FANUC Robot series

R-30*i*B Plus/R-30*i*B Mate Plus/R-30*i*B Mini Plus CONTROLLER

Force Sensor

OPERATOR'S MANUAL

B-83934EN/02

• Original Instructions

Thank you very much for purchasing FANUC Robot.
Before using the Robot, be sure to read the "FANUC Robot SAFETY HANDBOOK (B-80687EN)" and understand the content.

The products in this manual are controlled based on Japan's “Foreign Exchange and Foreign Trade Law". The export from Japan may be subject to an export license by the government of Japan. Further, re-export to another country may be subject to the license of the government of the country from where the product is re-exported. Furthermore, the product may also be controlled by re-export regulations of the United States government.
Should you wish to export or re-export these products, please contact FANUC for advice.

In this manual, we endeavor to include all pertinent matters. There are, however, a very large number of operations that must not or cannot be performed, and if the manual contained them all, it would be enormous in volume. It is, therefore, requested to assume that any operations that are not explicitly described as being possible are "not possible".

SAFETY PRECAUTIONS

This chapter describes the precautions which must be followed to enable the safe use of the robot. Before using the robot, be sure to read this chapter thoroughly.

For detailed functions of the robot operation, read the relevant operator's manual to understand fully its specification.

For the safety of the operator and the system, follow all safety precautions when operating a robot and its peripheral equipment installed in a work cell.
For safe use of FANUC robots, you must read and follow the instructions in “FANUC Robot series SAFETY HANDBOOK (**B-80687EN)**”.

1 PERSONNEL

Personnel can be classified as follows.

Operator:
- Turns the robot controller power ON/OFF
- Starts the robot program from operator panel

Programmer or Teaching operator:
- Operates the robot
- Teaches the robot inside the safeguarded space

Maintenance technician:
- Operates the robot
- Teaches the robot inside the safeguarded space
- Performs maintenance (repair, adjustment, replacement)

- The operator is not allowed to work in the safeguarded space.
- The programmer or teaching operator and maintenance technician are allowed to work in the safeguarded space. Works carried out in the safeguarded space include transportation, installation, teaching, adjustment, and maintenance.
- To work inside the safeguarded space, the person must be trained on proper robot operation.

Table 1 (a) lists the work outside the safeguarded space. In this table, the symbol “O” means the work allowed to be carried out by the specified personnel.

Table 1 (a) List of work outside the Safeguarded Space

	Operator	Programmer or Teaching operator	Maintenance technician
Turn power ON/OFF to Robot controller	O	O	O
Select operating mode (AUTO/T1/T2)		O	O
Select remote/local mode		O	O
Select robot program with teach pendant		O	O
Select robot program with external device		O	O
Start robot program with operator’s panel	O	O	O
Start robot program with teach pendant		O	O
Reset alarm with operator’s panel		O	O
Reset alarm with teach pendant		O	O
Set data on teach pendant		O	O
Teaching with teach pendant		O	O
Emergency stop with operator’s panel	O	O	O
Emergency stop with teach pendant	O	O	O
Operator’s panel maintenance			O
Teach pendant maintenance			O

During robot operation, programming and maintenance, the operator, programmer, teaching operator and maintenance technician take care of their safety using at least the following safety protectors.

- Use clothes, uniform, overall adequate for the work
- Safety shoes
- Helmet

2 DEFINITION OF SAFETY NOTATIONS

To ensure the safety of users and prevent damage to the machine, this manual indicates each precaution on safety with "**WARNING**" or "**CAUTION**" according to its severity. Supplementary information is indicated by "**NOTE**". Read the contents of each **"WARNING**", "**CAUTION**" and "**NOTE**" before using the robot.

Symbol	Definitions
⚠WARNING	Used if hazard resulting in the death or serious injury of the user will be expected to occur if he or she fails to follow the approved procedure.
⚠CAUTION	Used if a hazard resulting in the minor or moderate injury of the user, or equipment damage may be expected to occur if he or she fails to follow the approved procedure.
NOTE	Used if a supplementary explanation not related to any of WARNING and CAUTION is to be indicated.

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Introduction

1 PREFACE

This chapter describes the outline of this manual, overview of the FANUC Robot series Force sensor, and safety precautions which should be noted before using the force sensor.

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1.1 OVERVIEW

This manual "FANUC Robot series Force sensor Operator’s Manual" describes how to operate a force sensor controlled by the R-30*i*B Plus/R-30*i*B Mate Plus/R-30*i*B Mini Plus controller.
In this manual, only the operations and the technique of programming for the force control functions are explained assuming that the installation and setup of the robot have been completed.
(Refer to the "OPERATOR’S MANUAL (Basic Operation) （B-83284EN） " for other operations common to FANUC Robots.)

Table 1.1 Contents of this manual

Introduction	Chapter 1	PREFACE	How to use this manual.
	Chapter 2	OVERVIEW OF FORCE SENSOR AND FORCE CONTROL	An outline of the force sensor and the force control functions.
	Chapter 3	INSTALLING FORCE SENSOR	How to attach a force sensor by using Force Sensor Installation Guide.
Basic Function Guide	Chapter 1	PROGRAMMING AND TEACHING OF FORCE CONTROL INSTRUCTIONS	Operations, teaching, and setup of the force control functions with the force sensor.
	Chapter 2	FORCE SENSOR STATUS SCREEN	How to check the status of the force sensor, the execution history of the force control functions, and the graphical display of the force data log.
	Chapter 3	FORCE SENSOR UTILITIES SCREEN	Descript the screen of force sensor utilities.
Auxiliary Function Guide	Chapter 1	TOOL WEIGHT AND CENTER OF GRAVITY CALCULATION FUNCTION	How to use the function of Weight and Gravity Center Calculation.
	Chapter 2	TP PROGRAM AUTO GENERATION FUNCTION	How to use the function of TP Program Auto Generation.
	Chapter 3	WORKPIECE MASS MEASUREMENT FUNCTION	How to measure workpiece’s mass while robot moves.
	Chapter 4	FORCE SENSOR 4D GRAPHIC FUNCTION	How to check recorded force data log with 4D graphics function.
Maintenance Guide	Chapter 1	TROUBLESHOOTING	How to handle alarms as they are raised.

APPENDIX	Appendix A	FORCE CONTROL MENU MAP	Types of screens and hierarchical configuration of these screens.
	Appendix B	ALARM CODES OF FORCE CONTROL	Types of alarms, how to check alarms, and how to recover from alarms.
	Appendix C	FORCE SENSOR ATTACHMENT SETTING FUNCTION	How to setup the attachment type of force sensor.
	Appendix D	SYSTEM FILES OF FORCE SENSOR/FORCE CONTROL	Description about the force sensor / force control system files.
	Appendix E	FORCE DATA DISPLAY FUNCTION (PC)	Description of the function for displaying force data on a PC application.
	Appendix F	NON-FANUC FORCE SENSORS	Description of how to connect force sensors from manufacturers other than FANUC.

1.2 RELATED MANUALS

The following manuals are available for using the force sensor.

Table 1.2 Related manuals

R-30*i*B Plus R-30*i*B Mate Plus CONTROLLER	OPERATOR'S MANUAL (Basic Operation) B-83284EN	Topics: Robot functions, operations, programing, interfaces, alarms Use: Application design, Robot operation, teaching, system design
	Force Sensor OPERATOR'S MANUAL (this manual) B-83934EN	Topics: Force sensor functions, operations, programming, alarms Use: Teaching, installation
	Force Control Deburring Package OPERATOR'S MANUAL B-83934EN-1	Topics: Force Control Deburring Package functions, operations, programming, alarms Use: Teaching, installation
Mechanical Unit	Sensor Mechanical Unit/Control Unit OPERATOR'S MANUAL B-83984EN	Topics: Connection of the sensors, robots and controllers, maintenance of the sensors, design of the adapter for tool Use: Connection of the sensors, maintenance

2 OVERVIEW OF FORCE SENSOR AND FORCE CONTROL

The force control functions perform advanced operations such as machine part assembly and polishing with a constant force by using the force sensor. The mass of the workpiece can also be measured while the robot is operating.
This chapter describes an overview of the force sensor configurations and the force control functions.

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2.1 FORCE SENSOR OVERVIEW

OVERVIEW

There are two types of force sensors: 6-axis force sensor and 3-axis force sensor. The 6-axis force sensor can detect the force and moment (6 elements) applied to it from the external sources and it can be used for all functions that are described in this manual. The 3-axis force sensor detects 3 elements of force and moment and can be applicable to some of the functions.
For CRX, there are functions that can be used with just the internal sensor, without the need of a force sensor.
For details, refer to "Basic Functions Guide: 1.3 FORCE CONTROL INSTRUCTIONS"

2.1.1 System Configuration

A Force Sensor system is usually composed of a FANUC Robot, robot controller and a force sensor. Peripheral equipments and external control equipments may also be added to the system to meet the application requirements .
There are two types of force sensor configurations.

- Hand mount sensor (Force Sensor is attached to a robot wrist.)
- Fixed mount sensor (Force Sensor is attached to a working table.)

The system configurations for the above two attachment types are shown below.

Hand mount sensor

This is the standard configuration.

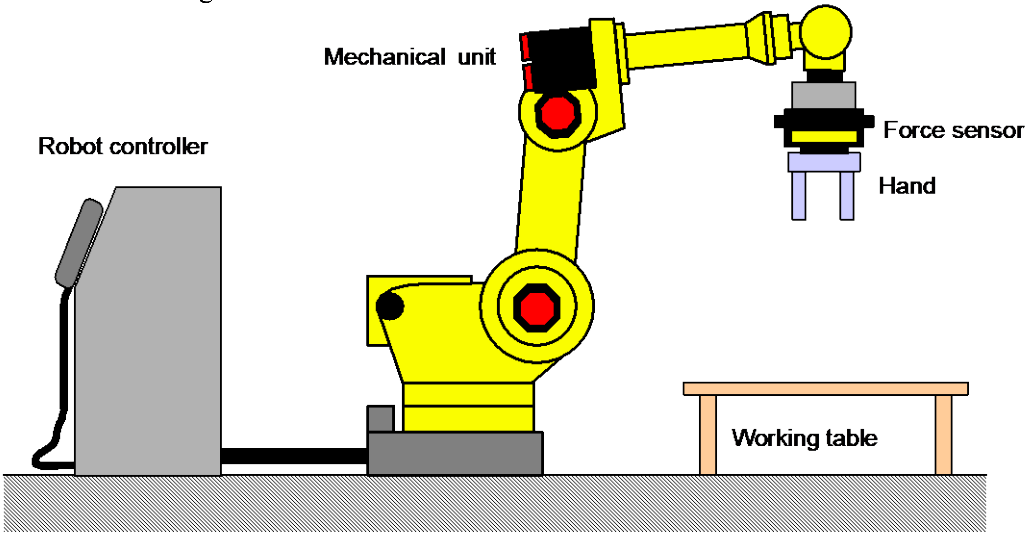


Fig.2.1.1(a) Standard configuration (hand mount sensor)

Fixed mount sensor

Fixed configuration is useful especially when downsizing the robot wrist is needed. This configuration requires an initial setting of the sensor frame.

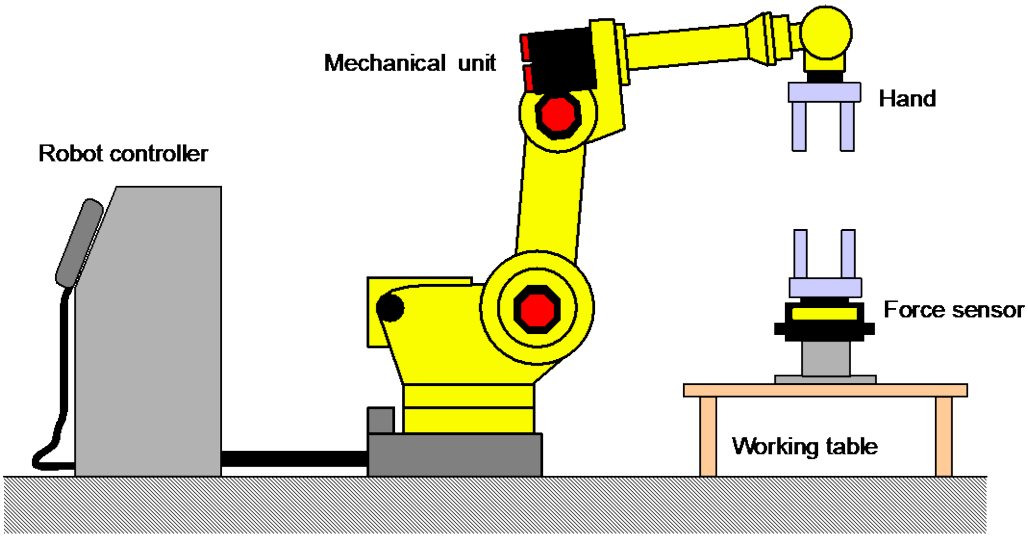


Fig.2.1.1(b) Fixed configuration (fixed mount sensor)

2.1.2 Types of Standard Adapters

For some series of force sensors, there are two types of standard adapters.

- Standard adapter (torque wrench needed)
- Standard adapter (torque wrench not needed)

Standard adapter (torque wrench needed)

For a standard adapter (torque wrench needed), the force sensor is shipped in a state where it is attached to this adapter. No special settings are required.
If this adapter is later used to attach the force sensor to a robot for which the force sensor is not attached before shipping, a torque wrench is needed.

Fig.2.1.2(a) FS-250*i*A's Standard adapter (torque wrench needed)

Standard adapter (torque wrench not needed)

For a standard adapter (torque wrench not needed), the force sensor is shipped in a state where it is integrated with this adapter. A torque wrench is not needed to attach the adapter to the robot.
However, the attachment type should be set.
(Refer to "APPENDIX: C FORCE SENSOR ATTACHMENT SETTING FUNCTION".)

Fig.2.1.2(b) FS-250*i*A's Standard adapter (torque wrench not needed)

2.1.3 Setting of Force Sensor Attachment

The setting is not usually needed, but in the following cases the setting of force sensor is necessary.
(Refer to "APPENDIX: C FORCE SENSOR ATTACHMENT SETTING FUNCTION".)

(1) The attachment type is 'HAND', if either of the following condition is met.
- A standard adapter (torque wrench not needed) is attached.
- The position of force sensor is changed from the robot wrist to some other position on the tool. (For instance, force sensor is attached to the tip of the tool)

(2) The attachment type is 'FIXED', if the sensor is mounted on a remote fixture.

2.2 FUNCTIONS ENABLED BY FORCE CONTROL

Overview

This section describes operations available with the force sensor and conditions under which those operations are possible.

2.2.1 Force Control Functions

Force control enables the robot to perform the following operations:

- Precise fitting of machine parts
- Gear teeth engagement
- Push under constant force
- Alignment of flat surface of one workpiece with a flat surface of another workpiece
- Material Removal including grinding, trimming, sanding, polishing, deburring, deflashing, cutting etc.

These functions are classified according to the application types such as constant push, and shaft insertion. For each application, optimum setting can be made.
(Refer to "Basic Function Guide: 1.3 FORCE CONTROL INSTRUCTIONS".)

2.2.2 Conditions for enabling Force Control

The force control is enabled under the following conditions.

(1) Insertion tolerance

- H7 / g7 or G7 / h7 class insertion is possible.
  For example, for a workpiece with a diameter of 10 mm, a clearance of approximately 12 µm is necessary.
- Press-fitting is not available with a clearance of zero or less.

(2) Positioning error at the start of force control

- Basically, the positioning error must not exceed the amount by which the part is chamfered. Fig. 2.2.2 shows an example in which a shaft part is inserted into a hole. If position error Δ < chamfer C, the part can be inserted into the hole.

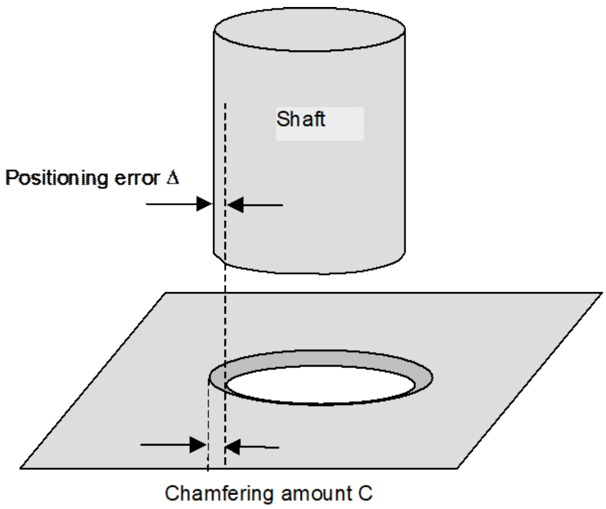


Fig. 2.2.2 Application example of the force control function

- The hole search function can be used to find the center of the hole even if Δ > C. However, an additional time is required for such search operation.
  (Refer to "Basic Function Guide: 1.5.4 Search Function" or "Basic Function Guide: 1.5.4.5 Hole Search".)

2.3 TYPES OF FORCE CONTROL INSTRUCTIONS

Overview

This section describes the types of force control instructions.

2.3.1 Instructions for Programming

The force control software provides force control instructions for controlling the robot motion with force control.

2.3.1.1 Instructions related to force control

There are nine types of force control instructions. 'FORCE CTRL ' is used to perform operation under force control. In addition, there are special instructions for operations such as force sensor diagnosis and automatic gain tuning, which are used as necessary.

Table 2.3.1.1 Instructions related to force control

Instruction	Description
FORCE CTRL	Instruction for executing force control. There are 12 force control functions in total. Select an appropriate function according to the workpiece and the type of application. After selecting a function, set the basic parameters such as a force value and velocity value using the force schedule data. (Refer to "Basic Function Guide: 1.3 FORCE CONTROL INSTRUCTIONS" and "Basic Function Guide: 1.5 SCHEDULE DATA".)
SENSOR DIAGNOSIS	This instruction checks whether the force sensor has a problem. (Refer to "Basic Function Guide: 1.10.1 Force Sensor Diagnosis Instructions".)
GET DIAG DATA	This instruction checks whether the force sensor has a problem. (Refer to "Basic Function Guide: 1.10.1 Force Sensor Diagnosis Instructions".)
AUTO TUNING ON/OFF	This instruction is used to automatically tune the gain that decides force control responsiveness. (Refer to "Basic Function Guide: 1.10.2 Force Control Gain Auto Tuning Instruction".)
TRQ ERROR ON/OFF	When a hand with a very large offset is used, a torque error may occur. This instruction corrects such errors. (Refer to "Basic Function Guide: 1.10.3 Torque Error Acquisition Instructions".)
END COND ON/OFF	This instruction automatically measures the depth by which the workpiece is inserted. (Refer to "Basic Function Guide: 1.10.4 End Condition Acquisition Instructions".)

2.3.1.2 Force control instruction [FORCE CTRL]

The "FORCE CTRL" instruction consists of the following two lines.

Force control instruction
FORCE CTRL[i] ← Schedule data number
ErrorLBL[j] ← Label number

Example 1 : FORCE CTRL[1]
: ErrorLBL[0]

2.3.2 Schedule Numbers and Error Label Numbers

The force control can be performed by specifying the schedule number and error label number.
For overview information about the schedule number and label number, refer to Table 2.3.2.
(Refer to "Basic Function Guide: 1.3 FORCE CONTROL INSTRUCTIONS".)

Table 2.3.2 Force Control Instruction Configuration

Item	Description
Schedule Number	A schedule is a data set designed to perform a specific force control function. Specify a set of schedule data used for each force control instruction with the schedule number. The available schedule numbers range from 1 to 30. The 12 executable functions specified in the schedule data are as follows. (Refer to "Basic Function Guide: 1.3 FORCE CONTROL INSTRUCTIONS" and "Basic Function Guide: 1.5 SCHEDULE DATA".) • Constant Push. • Face Match • Shaft Insert • Groove Insert • Square Insert • Search • Phase Search • Hole Search • Clutch Search • Contouring • Contouring End • Threading * With the 3-axis force sensor, available function is limited to 'Constant Push' or 'Contouring' or ' Contouring End'. * When the CRX internal sensor is used, the only functions that can be used for force control are: "Constant Push", "Face Match", "Phase Search", "Contouring", and "Contouring End".
Error Label Number	When execution ends with an error, Error Label Number can be used for error handling operations such as retry the operation, release the workpiece or ABORT the program.

2.3.2.1 Schedule setup for the force control

Schedule data provides the various parameters for the robot motion with force control. The threshold of force to detect contact with an object, the velocity to approach the object, the desired reaction force and velocity when fitting, the depth of insertion, pushing period after fitting, and so on are specified in the schedule data.
(Refer to "Basic Function Guide: 1.5 "SCHEDULE DATA".)

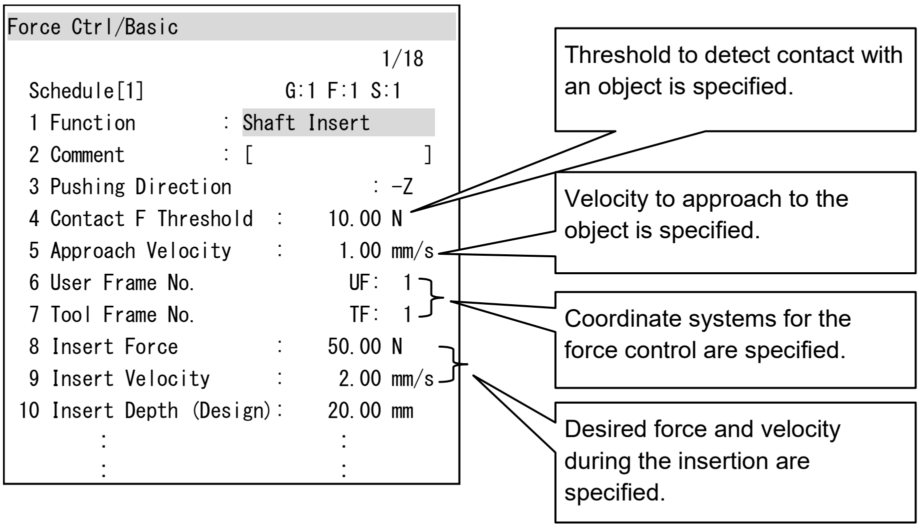


Fig. 2.3.2.1 Schedule setup for the force control

2.4 MASS MEASUREMENT BY FORCE SENSOR

The mass of workpiece can be measured while robot moves. It detects mass during handling so it does not increase cycle time. It is effective to check how many workpieces robot holds or to inspect the workpiece's mass.
(Refer to "Auxiliary Function Guide: 3 WORKPIECE MASS MEASUREMENT FUNCTION".)

Fig. 2.4 shows a diagram of mass measurement while moving with a force sensor.

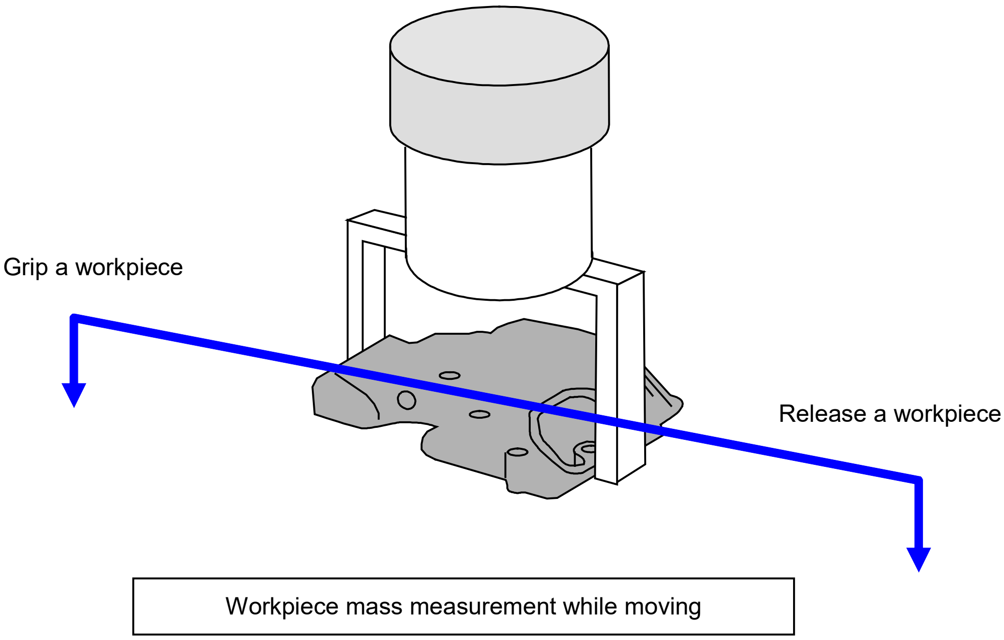


Fig.2.4 Other Application of force sensor

3 INSTALLING FORCE SENSOR

This chapter describes installation of the force sensor using the "Force Sensor Installation Guide".
Even users who are new to the force sensor can easily install and configure the force sensor following the on-screen instructions.

◇ **CONTENTS**

> ⚠ **WARNING**
> 1 Running force control with the sensor frame set incorrectly may apply excessive force. Note that, for example, if the sensor frame is set in the wrong x direction or y direction by 180 degrees, force will increase at an incredible rate, which may cause property damage or bodily injury.
> 2 When you install the force sensor or touch the force sensor with your fingers to check, make sure that emergency stop is enabled on the robot.

> **NOTE**
> 1 When the force sensor was installed at the factory and the force sensor is used without changing the original installation position, it is not necessary to use the "Force Sensor Install Guide". Skip over this chapter.
> 2 When the force sensor was not installed at the factory, a faulty force sensor is replaced, or the force sensor is installed in a special location, this setting is required.
> (When the force sensor is installed in a special location, the force sensor installation setting function can also be used. Also refer to "Appendix: C FORCE SENSOR ATTACHMENT SETTING FUNCTION".

3.1 OVERVIEW OF THE FORCE SENSOR INSTALL GUIDE

Install and set up the force sensor using the "Force Sensor Install Guide".
To display the [Home] screen of the "Force Sensor Install Guide", perform the following procedure.

Procedure for Displaying the Force Sensor Installation Guide Home Screen

1 Press the [Select Screen] key on the Teach Pendant for the robot controller.
Menu will appear.
2 Select [Utility] → [Force Sensor] from the menu.
The [Force Sensor Menu] screen will appear.
3 Move the cursor to the [Force Sensor Install Guide] and press F5 [DETAIL].
The [Home] screen of the "Force Sensor Install Guide" will appear.

3

3.1.1 Home Screen

Overview

On the [Home] screen, all the items necessary for setting the force sensor and the completed state of the setting are displayed.
When the setting of each item has been completed, [DONE] appears to the right of the item. Once all the items have been set to [DONE], the setting necessary for installing the force sensor is completed.

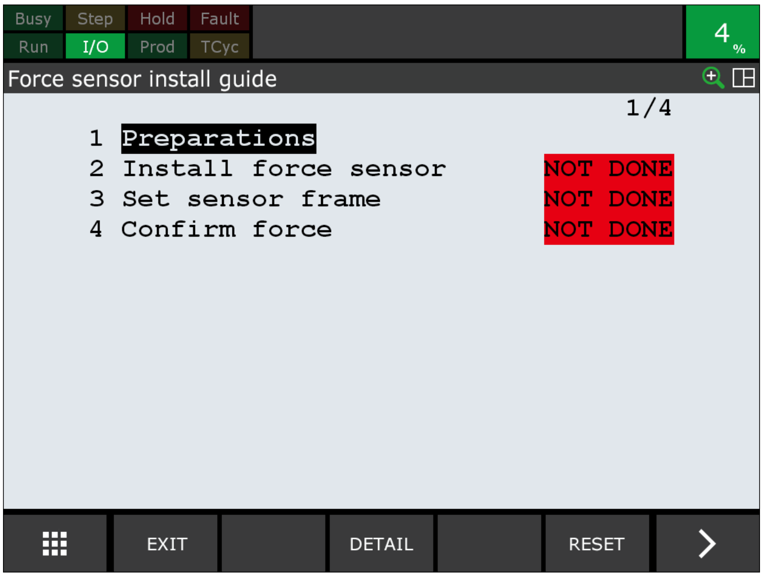


Fig. 3.1.1 [Home] Screen

Table 3.1.1 (a) [Home] Screen

Item	Description
[Preparations]	To switch to the [Preparations] screen, perform the following procedure. • Move the cursor to [Preparations] and press F3 [DETAIL]. The [Preparation] screen will appear. (Refer to "Introduction: 3.1.2 Preparations Screen")
[Install force sensor]	When installation of the force sensor has been completed, [DONE] is displayed. When installation of the force sensor has not been completed, [NOT DONE] is displayed. To switch to the [Install force sensor] screen, perform the following procedure. • Move the cursor to [Install force sensor] and press F3 [DETAIL]. The [Install force sensor] screen will appear. (Refer to "Introduction: 3.2.1 Force Sensor Installation Setting Screen")
[Set sensor frame]	When the setting of the force sensor frame has been completed, [DONE] is displayed. When the setting of the force sensor frame has not been completed, [NOT DONE] is displayed. To switch to the [Set sensor frame] screen, perform the following procedure. • Move the cursor to [Set sensor frame] and press F3 [DETAIL]. The [Set sensor frame] screen will appear. (Refer to "Introduction: 3.3 Setting Sensor Frame")
[Confirm force]	When confirmation of force has been completed, [DONE] is displayed. When confirmation of force has not been completed, [NOT DONE] is displayed. To switch to the [Confirm force] screen, perform the following procedure. • Move the cursor to [Confirm force] and press F3 [DETAIL]. The [Confirm force] screen will appear. (Refer to "Introduction: 3.4 Confirm Force")

NOTE
1. When the upper items on the screen have not been completed, the lower items cannot be set. Configure the setting of the items in order from top to bottom.
2. When a restart of the controller has not been completed, the [Set sensor frame] screen for each sensor type won't appear.
3. The TP screen may be displayed on Screen 2 or Screen 3, however, on-screen operation from the second and third screens is not enabled. Perform on-screen operation only from the first screen.

Function Keys

Function keys used on the [Home] screen are as follows:

Table 3.1.1 (b) Function Keys

Key	Display name	Description
F1	EXIT	Exits the [Home] screen and returns to the previous screen.
F3	DETAIL	Displays the Advanced Settings screen for the item to which the cursor has been moved.
F5	RESET	Resets the [DONE] state of the item to which cursor has been moved. Clicking [YES] will change the display to [Not Done].

NOTE
When F5 [RESET] is pressed, settings won't be changed. Only the screen display will change to [NOT DONE].

3.1.2 Preparations Screen

Overview

On the [Preparations] screen, software options, hardware, and the status of mastering are displayed.

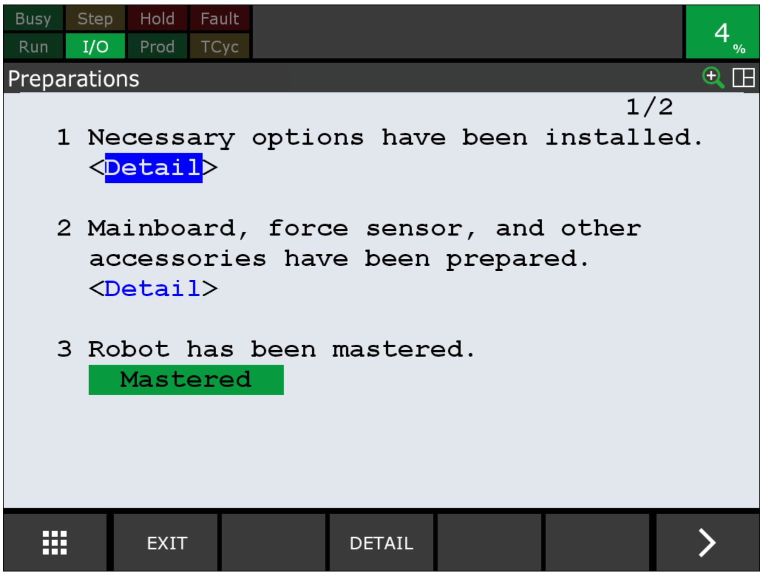


Fig. 3.1.2 [Preparations] Screen

Table 3.1.2 (a) [Preparations] Screen

Item	Description
[Confirm options necessary for force control]	To switch to the [Options] screen, perform the following procedure. • Move the cursor to [DETAIL] and press F3 [DETAIL]. The [Options] screen will appear. (Refer to "Introduction: 3.1.3 Options Screen")
[Main board, force sensor, and other accessories have been prepared.]	To switch to the [Confirmation item] screen, perform the following procedure. • Move the cursor to [DETAIL] and press F3 [DETAIL]. The [Confirmation item] screen will appear. (Refer to "Introduction: 3.1.4 Confirmation Item Screen")
[Robot has been mastered.]	When mastering has been completed, [DONE] will be displayed under the item. When mastering has not been completed, [NOT DONE] and [Mastering is necessary] will be displayed. (Refer to "OPERATOR'S MANUAL (Basic Operation)" (B-83284EN).)

Function Keys

Function keys used on the [Preparations] screen are as follows:

Table 3.1.2 (b) Function Keys

Key	Display name	Description
F1	EXIT	Exits the [Preparations] screen and returns to the previous screen.
F3	DETAIL	Displays the Advanced Settings screen for the item to which the cursor has been moved.

3.1.3 Options Screen

Overview

From the [Options] screen, you can verify whether necessary options are installed.

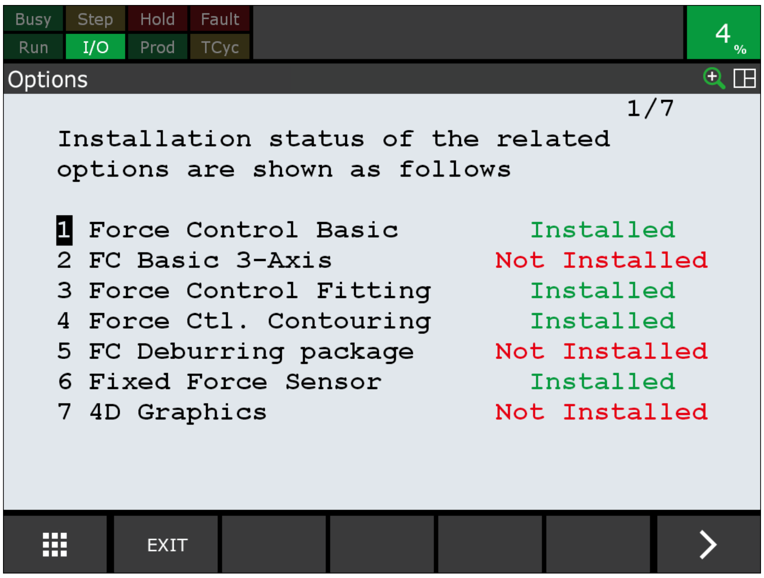


Fig. 3.1.3 [Options] Screen

Table 3.1.3 (a) [Options] Screen

Item	Description
[Force Control Basic]	It is necessary when a 6-axis force sensor is used. For the 6-axis force sensor, each function of "Constant Push" and "Face Match" can be used. If the function is installed, "Installed" is displayed to the right of the item. If the function is not installed, "Not Installed" is displayed. (Refer to "Basic Function Guide: 1.5.2 Constant Push / Face Match".)
[FC Basic 3-Axis]	It is necessary when a 3-axis force sensor is used. For the 3-axis force sensor, the "Constant Push" function can be used. If the function is installed, "Installed" is displayed to the right of the item. If the function is not installed, "Not Installed" is displayed.
[Force Control Fitting]	It is necessary when each function of "Shaft Insert", "Groove Insert", "Square Insert", "Search", "Phase Search", "Hole Search" or "Threading" is used. If the function is installed, "Installed" is displayed to the right of the item. If the function is not installed, "Not Installed" is displayed. (Refer to "Basic Function Guide: 1.5.3 Shaft Insert / Groove Insert / Square Insert".)
[Force Ctl. Contouring]	It is necessary when "Contouring" and "Contouring end" functions are used on a 6-axis or 3-axis force sensor. If the function is installed, "Installed" is displayed to the right of the item. If the function is not installed, "Not Installed" is displayed. (Refer to "Basic Function Guide: 1.5.5 Contouring Function".)
[FC Deburring package]	It is necessary when the "Deburring track automatic generation" function is installed. If the function is installed, "Installed" is displayed to the right of the item. If the function is not installed, "Not Installed" is displayed. (Refer to "R-30*i*B Plus Controller Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1).)
[Fixed Force Sensor]	It is necessary when the force sensor is installed and fixed. If the function is installed, "Installed" is displayed to the right of the item. If the function is not installed, "Not Installed" is displayed.
[4D Graphics]	It is necessary when the "4D Graphics" function is used. If the function is installed, "Installed" is displayed to the right of the item. If the function is not installed, "Not Installed" is displayed. (Refer to "Auxiliary Function Guide: 4 FORCE SENSOR 4D GRAPHIC FUNCTION".)

Function Keys

Function keys used on the [Options] screen are as follows:

Table 3.1.3 (b) Function Keys

Key	Display name	Description
F1	EXIT	Exits the [Options] screen and returns to the previous screen.

> **NOTE**
> 1 When the 3-axis force sensor is used, install the [FC Basic 3-Axis] option. (Verify that the display shows [FC Basic 3-Axis] is "Installed".)
> 2 When the fixed installation type force sensor is used, install the "Fixed Force Sensor (J843)" option. (Verify that the display shows [Fixed Force Sensor] is "Installed".)

3.1.4 Confirmation Item Screen

Overview

On the [Confirmation item] screen, information on sensor type, sensor adapter, pins, bolts, cables, torque wrench, and force sensor calibration data is displayed.

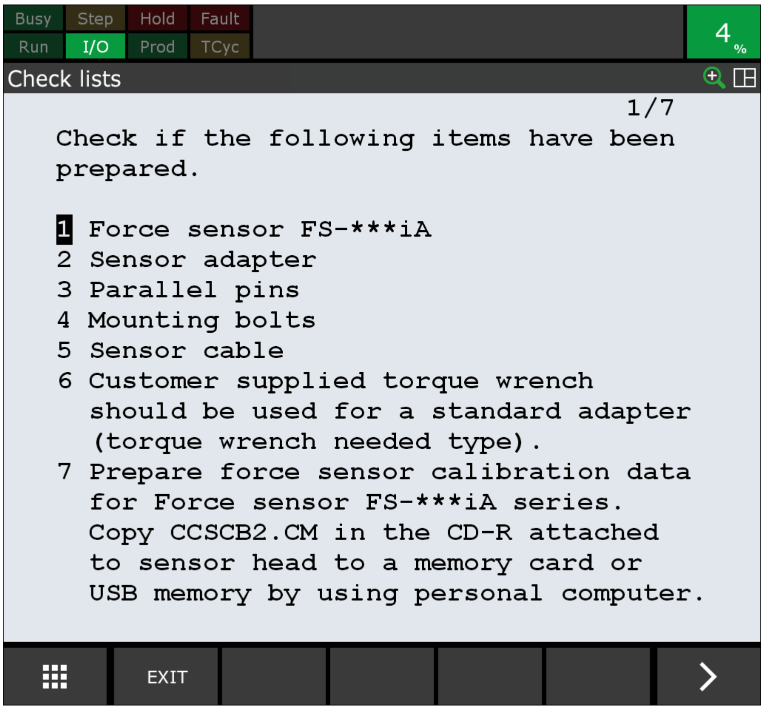


Fig. 3.1.4 [Confirmation item] Screen

Table 3.1.4 (a) [Confirmation item] Screen

Item	Description
[Force sensor type]	Verify that the force sensor type is the FS-****i*A series.
[Sensor adapter] [Parallel pins] [Mounting bolts]	A complete set of sensor adapter, parallel pins, and mounting bolts comes with the product. Make sure all items are included.
[Sensor cable]	Check to make sure the sensor cable is correct for the robot type and force sensor type.
[Customer supplied torque wrench should be used for a standard adapter (torque wrench needed type).]	When a torque wrench needed standard adapter is used, the torque wrench should be supplied by the customer in advance.
[Prepare force sensor calibration data for FS-****i*A series. Copy CCSCB2.CM in the CD-R attached to the sensor head to a memory card or USB memory by using a personal computer.]	Prepare force sensor calibration data for FS-****i*A series. Copy CCSCB2.CM in the CD-R attached to the sensor head to a memory card or USB memory by using a personal computer.

Function Keys

Function keys used on the [Confirmation item] screen are as follows:

Table 3.1.4 (b) Function Keys

Key	Display name	Description
F1	EXIT	Exits the [Confirmation item] screen and returns to the previous screen.

3.2 INSTALLING FORCE SENSOR

This section describes force sensor installation procedure.
The force sensor installation procedure can be classified into the following types.

(1) Hand type force sensor
- Standard adapter & torque wrench needed type
- Standard adapter & torque wrench not needed type
- Custom adapter & torque wrench needed type
- Custom adapter & torque wrench not needed type

(2) Fixed force sensor
- Torque wrench needed type
- Torque wrench not needed type

The procedure for installing the force sensor and screen vary, depending on the installation type. However, the procedure is common through to displaying the [Force sensor installation] screen.
(Refer to [Force sensor installation] in "Introduction: 3.1.1 Home Screen".)

3.2.1 Force Sensor Installation Setting Screen

Overview

On the [Force sensor installation setting] screen, items necessary for installing the force sensor and the completed state of the setting are displayed.
When the setting of each item has been completed, [DONE] appears to the right of the item. Once all the items have been set to [DONE], [Force sensor installation] on the [Home] screen is set to [DONE].
(Refer to "Introduction: 3.1.1 Home Screen".)
The [Force sensor installation] is common to the hand type and fixed type.

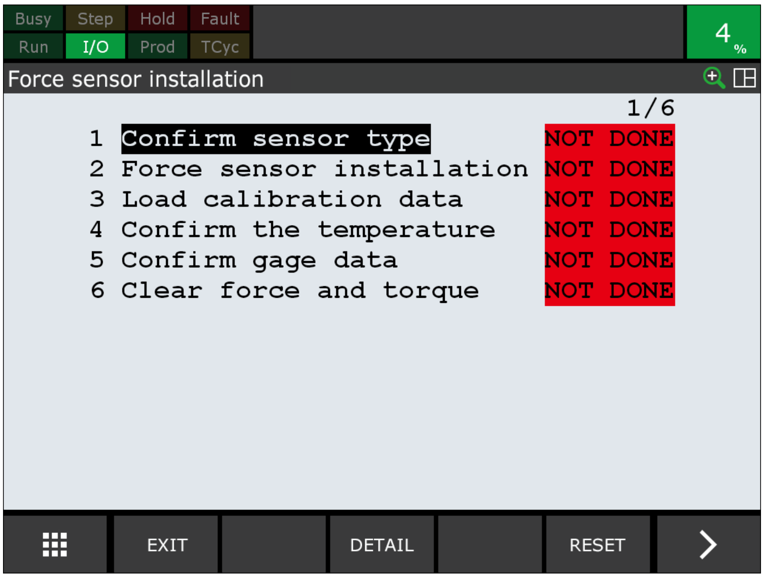


Fig. 3.2.1 [Force Sensor Installation Setting] Screen

Table 3.2.1 (a) [Force Sensor Installation Setting] Screen

Item	Description
[Select installation type]	When selection of the force sensor installation type has been completed, [DONE] is displayed. When selection of the force sensor installation type has not been completed, [NOT DONE] is displayed. To switch to the screen for selecting the installation type, perform the following procedure. • Move the cursor to [Select installation type] and press the F3 [DETAIL] key. Either [Select installation type] screen or [Select adapter type] screen will appear. (The screen varies depending on the force sensor type and options.) (Refer to "Introduction: 3.2.2.1 Selecting Force Sensor (Hand Type)" and "Introduction: 3.2.3.1 Selecting Sensor Type (Fixed Type)".)
[Installation method]	When installation of the force sensor has been completed, [DONE] is displayed. When installation of the force sensor has not been completed, [NOT DONE] is displayed. To switch to the force sensor installation method screen, perform the following procedure. • Move the cursor to [Installation method] and press the F3 [DETAIL] key. The [Force sensor installation position] screen or the [Confirmation item] screen will appear. (The screen varies depending on the force sensor type.) (Refer to "Introduction, 3.2.2.2 Installing Force Sensor (Hand Type)" and "Introduction, 3.2.3.2 Installing Force Sensor (Fixed Type)".)
[Load calibration data]	When loading of calibration data has been completed, [DONE] is displayed. When loading of calibration data has not been completed, [NOT DONE] is displayed. To switch to the [Load calibration data] screen, perform the following procedure. • Move the cursor to [Load calibration data] and press the F3 [DETAIL] key. The [Load calibration data] will appear. (Refer to "Introduction, 3.2.2.3 Loading Calibration Data".)
[Confirm the temperature]	When confirmation of the internal temperature has been completed, [DONE] is displayed. When confirmation of the internal temperature has not been completed, [NOT DONE] is displayed. To switch to the [Confirm sensor temperature] screen according to the sensor type, perform the following procedure. • Move the cursor to [Confirm the temperature] and press the F3 [DETAIL] key. The [Confirm sensor temperature] screen according to the sensor type will appear. (Refer to "Introduction: 3.2.2.4 Confirming the Temperature".)
[Confirm gage data]	When confirmation of gage data has been completed, [DONE] is displayed. When confirmation of gage data has not been completed, [NOT DONE] is displayed. To switch to the [Confirm gage data] screen, perform the following procedure. • Move the cursor to [Confirm gage data] and press the F3 [DETAIL] key. The [Confirm gage data] screen will appear. (Refer to "Introduction: 3.2.2.5 Confirming Gage Data".)
[Clear force and torque]	When clearing of force and torque values has been completed, [DONE] is displayed. When clearing of force and torque values has not been completed, [NOT DONE] is displayed. To switch to the [Reset force value] screen, perform the following procedure. • Move the cursor to [Clear force and torque] and press the F3 [DETAIL] key. The [Reset force value] screen will appear. (Refer to "Introduction: 3.2.2.6 Clear Force and Torque".)

Function Keys

Function keys used on the [Force sensor installation setting] screen are as follows:

Table 3.2.1 (b) Function Keys

Key	Display name	Description
F1	EXIT	Exits the [Home] screen and returns to the previous screen.
F3	DETAIL	Displays the Advanced Settings screen for the item to which the cursor has been moved.
F5	RESET	Resets the [DONE] state of the item to which cursor has been moved. Clicking [YES] will change the display to [Not Done].

NOTE
When F5 [RESET] is pressed, settings won't be changed. Only the screen display will change to [NOT DONE].

3.2.2 Installing Force Sensor (Hand Type)

This section describes installation of hand type force sensor.

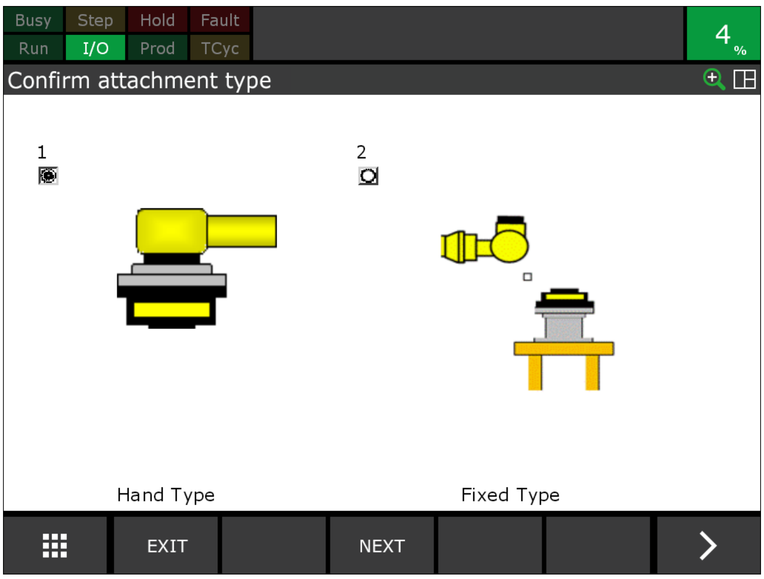
3.2.2.1 Selecting force sensor (hand type)

Overview

Select the hand type sensor type.
When selection of the sensor type has been completed, [DONE] is displayed in [Select installation type] on the [Force sensor installation setting] screen.

Procedure for Selecting Sensor Type (Hand Type)

1 The [Force Sensor Installation Setting] screen is displayed.
(Refer to [Force sensor installation] in " Introduction: 3.1.1 Home Screen".)
2 Move the cursor to [Select installation type] and press the F3 [DETAIL] key.
When the "Fixed force sensor (J843)" option is installed, the [Select installation type] screen will appear.
When the "Fixed force sensor (J843)" option is not installed, the [Select adapter type] screen will appear. There is no procedure for the [Select installation type] screen. Skip over steps 3 and 4.
* Options that have been installed can be confirmed on the [Options] screen.
(Refer to "Introduction: 3.1.3 Options Screen".)

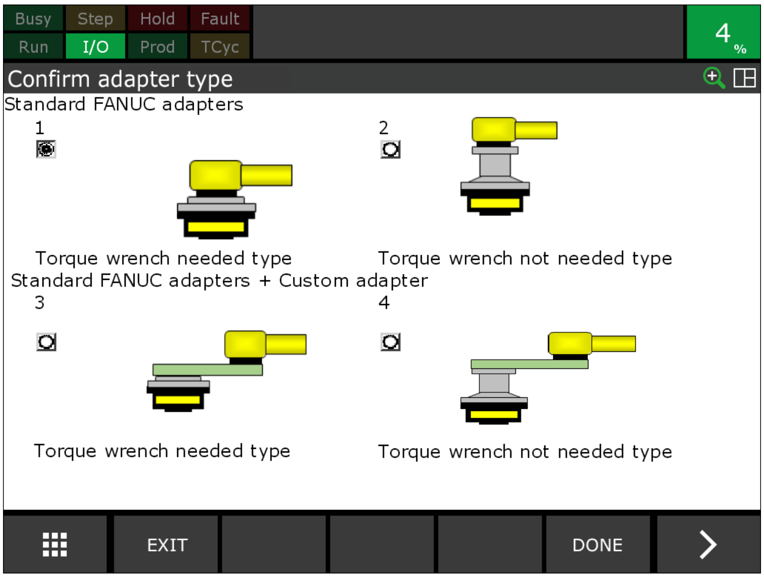


3 Check [Hand Type].

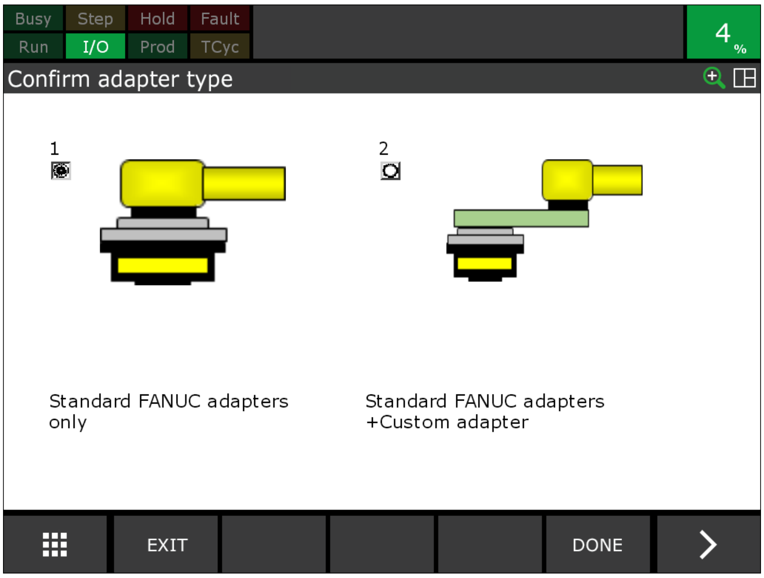
4 Press F3 [NEXT].
The [Select adapter type] screen will appear.

5 Check the adapter to be used.
The [Select adapter type] screen varies depending on the force sensor type.

The following is the screen when force sensor is "FS-250*i*A".



The following is the screen when force sensor is other than "FS-250*i*A".



6 Press F5 [DONE].

3.2.2.2 Installing force sensor (hand type)

Overview

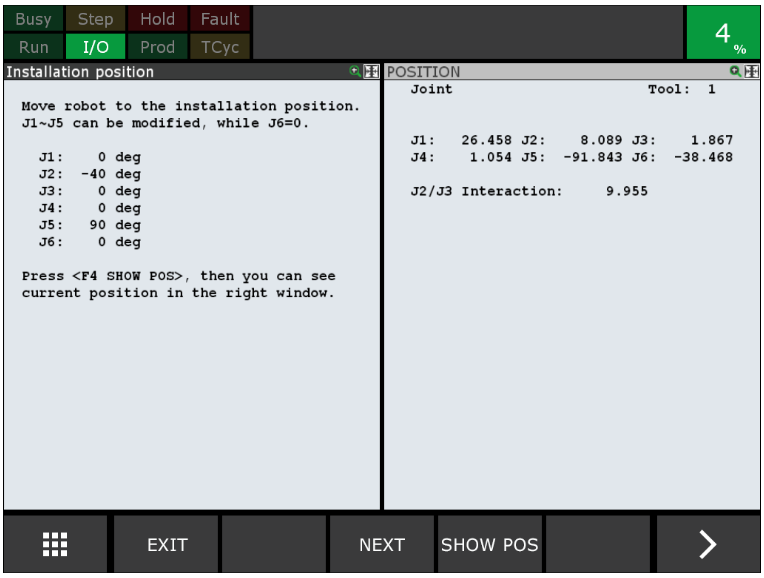
Install the hand type force sensor following the on-screen instructions.
The setting screen is displayed in the horizontal 2-split windows.
The right window is automatically displayed.
Recommended robot position for installing the force sensor is displayed in the left window. Move the robot to the position suitable for installing the force sensor while checking the screen.
When installation of the sensor type has been completed, [DONE] is displayed in [Installation method] on the [Force sensor installation setting] screen.

> ⚠ **WARNING**
> After moving the robot to the recommended position, make sure that emergency stop is enabled on the robot and install the force sensor.

Procedure for Installing Force Sensor (Hand Type)

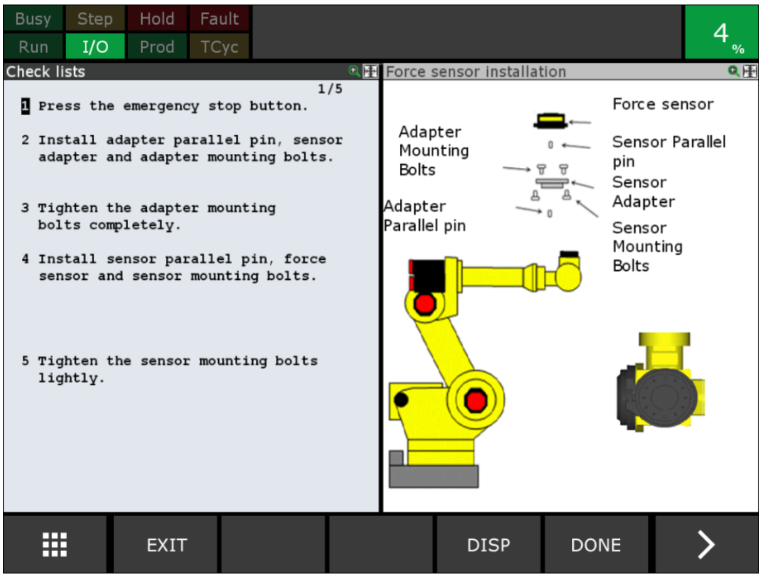
1 The [Force Sensor Installation Setting] screen is displayed.
(Refer to [Force sensor installation] in "Introduction: 3.1.1 Home Screen".)

2 Move the cursor to [Installation method] and press the F3 [DETAIL] key.
The [Force sensor installation position] screen and the [Current position] screen are displayed in two windows.
* When F4 [Current position] is pressed, the [Current position display] screen is displayed again in the right window.

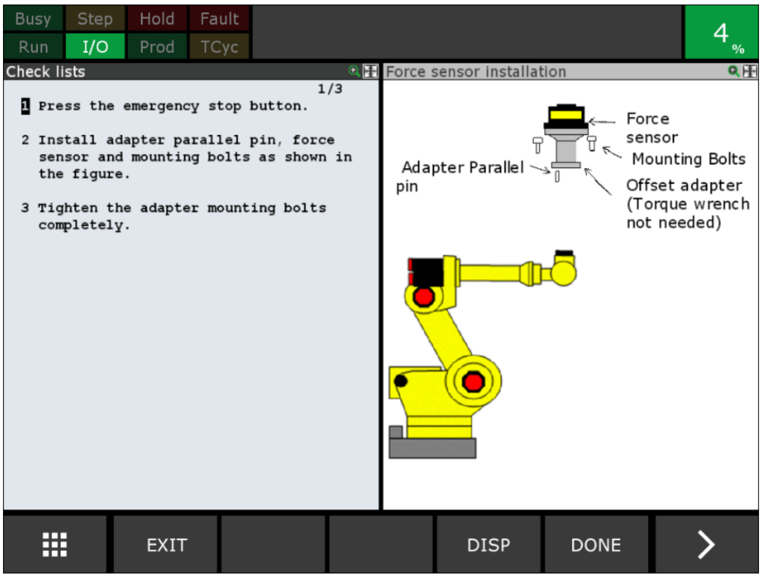


3 Press F3 [NEXT].
The [Confirmation item] screen and the [Force sensor installation] screen are displayed in two windows.

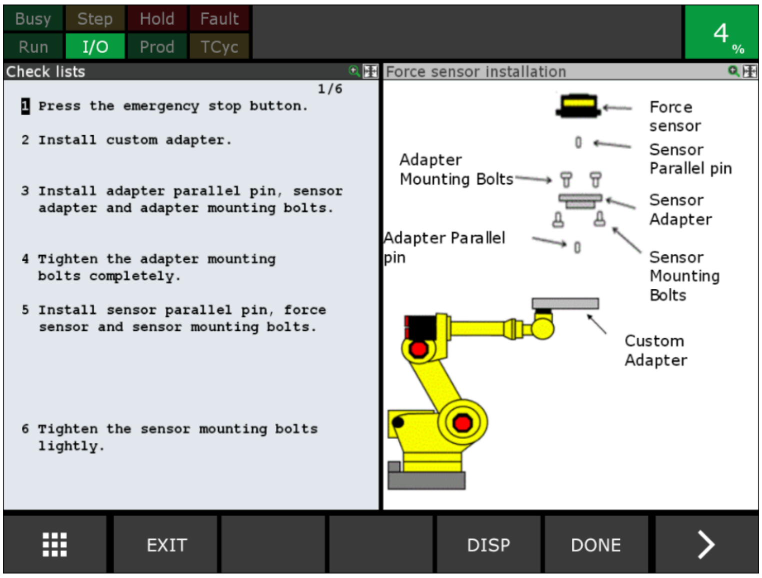
The [Confirmation item] screen and the [Force sensor installation] screen vary depending on the force sensor type.
The following is the standard adapter & torque wrench needed type screen.



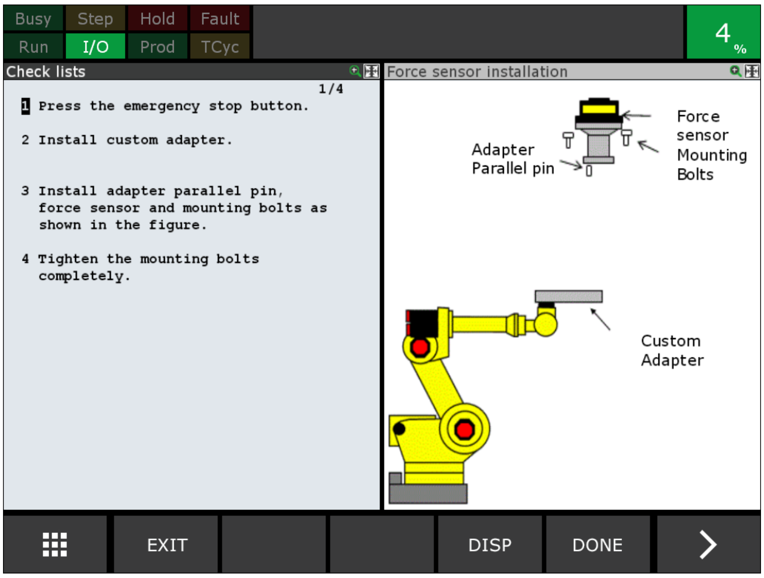
The following is the standard adapter & torque wrench not needed type screen.



The following is the custom adapter & torque wrench needed type screen.



The following is the custom adapter & torque wrench not needed type



4 Move the robot to the position suitable for installing the force sensor by following the procedure for confirmation items in the left window.
   * When F4 [DISPLAY] is pressed, the [Force sensor installation] screen is displayed again in the right window.

5 Press F5 [DONE].

3.2.2.3 Loading calibration data

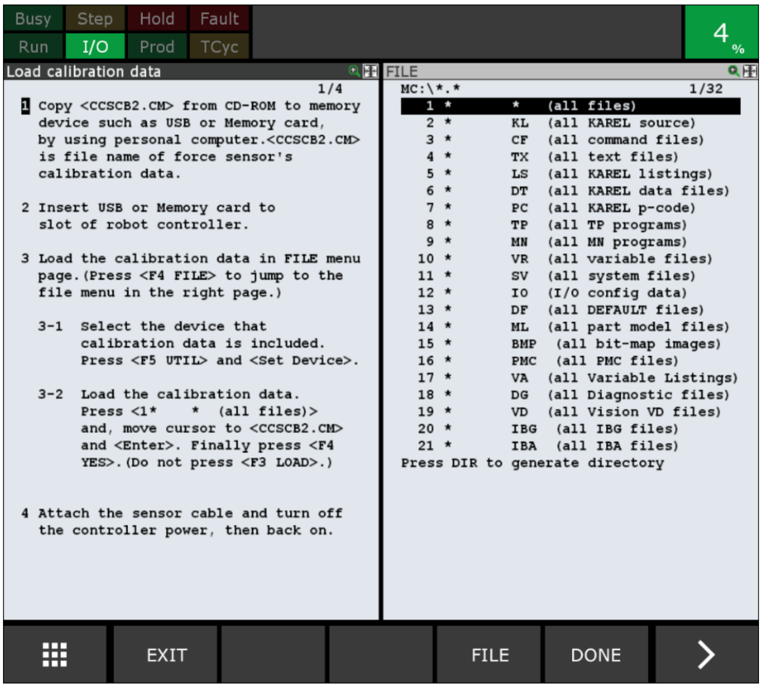
Overview

Load calibration data.
The setting screen is displayed in the horizontal 2-split windows.
The right window is automatically displayed.
The calibration data loading method is displayed in the left window.
When loading of calibration data has been completed, [DONE] is displayed in [Load calibration data] on the [Force sensor installation setting] screen.

> **NOTE**
> The procedure and screen for loading force sensor are common to the hand type and fixed type.

Procedure for Loading Calibration Data

1 The [Force Sensor Installation Setting] screen is displayed.
(Refer to [Force sensor installation] in "Introduction: 3.1.1 Home Screen".)
2 Move the cursor to [Load calibration data] and press the F3 [DETAIL] key.
The [Load calibration data] screen and the [File] screen are displayed in two windows.



3 Press F4 [File].
The file menu page is displayed again in the right window.
4 Press F5 [DONE].

3.2.2.4 Confirming the temperature

Overview

Confirm the internal temperature of the force sensor.
The confirmation screen is displayed in the horizontal 2-split windows.
The right window is automatically displayed.
The method for confirming the internal temperature of the force sensor is displayed in the left window.
When confirmation of the internal temperature has been completed, [DONE] is displayed in [Confirm temperature] on the [Force sensor installation setting] screen.

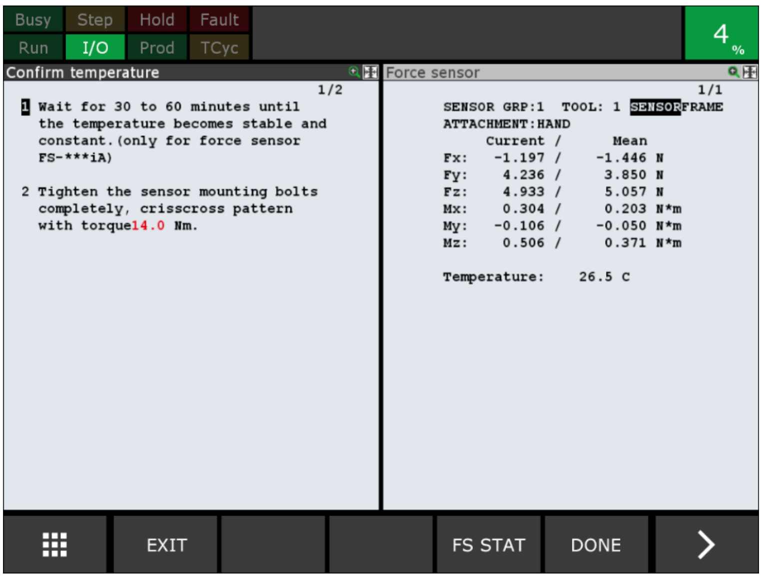
> **NOTE**
> Procedure and screen for confirming the internal temperature are common to the hand type and fixed type.

Procedure for Confirming Temperature

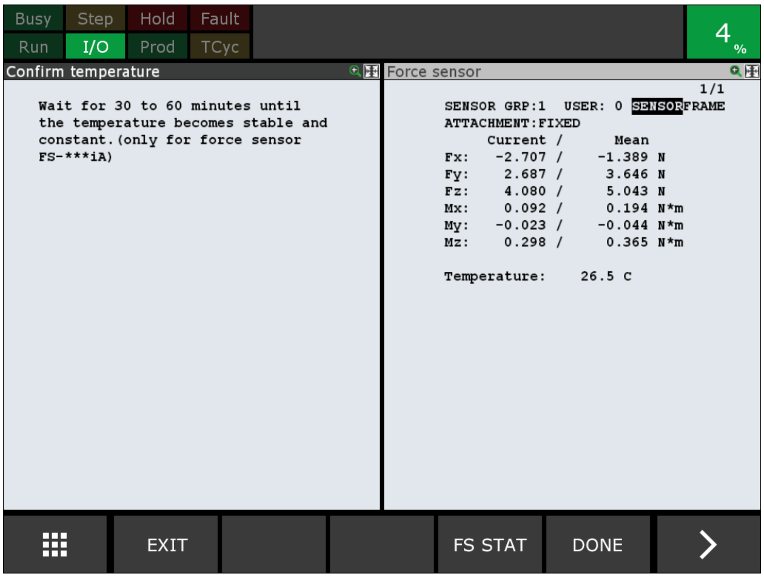
1 The [Force Sensor Installation Setting] screen is displayed.
(Refer to [Force sensor installation] in "Introduction: 3.1.1 Home Screen".)
2 Move the cursor to [Confirm temperature] and press the F3 [DETAIL] key.
The [Confirm temperature] screen and the [Force sensor] screen are displayed in two windows.
Bolt tightening torque based on the force sensor type is automatically displayed.

> **NOTE**
> When the force sensor type is FS-15*i*A, FS-40*i*A, FS-100*i*A, or FS-250*i*A, torque values are as follows:
> - FS-15*i*A : 7.0 Nm
> - FS-40*i*A : 4.5 Nm
> - FS-100*i*A : 13.0 Nm
> - FS-250*i*A : 14.0 Nm

The [Confirm sensor temperature] screen differs between "Torque wrench needed type" and "Torque wrench not needed type".
The following is the torque wrench needed type screen.



The following is the torque wrench not needed type screen.



3 Press F4 [FORCE STATUS].
The force sensor [Status display] screen is displayed again in the right window.
4 Press F5 [DONE].

3.2.2.5 Confirming gage data

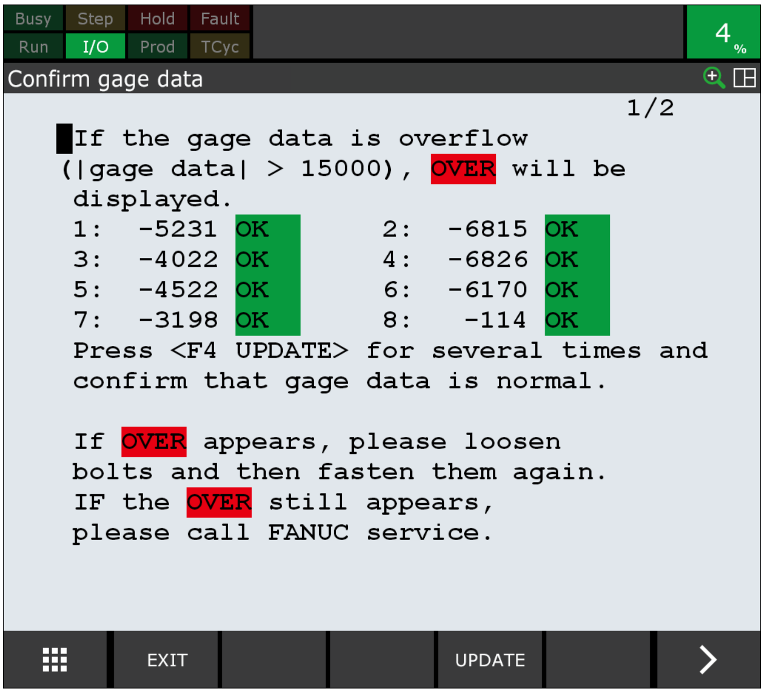
Overview

Confirm gage data.
The function for confirming gage data outputs force sensor gage data.
When confirmation of gage data has been completed, [DONE] is displayed in [Confirm gage data] on the [Force sensor installation setting] screen.

NOTE
The procedure and screen for confirming gage data are common to the hand type and fixed type.

Procedure for Confirming Gage Data

1 The [Force Sensor Installation Setting] screen is displayed.
(Refer to [Force sensor installation] in "Introduction: 3.1.1 Home Screen".)
2 Move the cursor to [Confirm gage data] and press the F3 [DETAIL] key.
The [Confirm gage data] screen will appear.



3 Press F4 [UPDATE].
The current gage data is acquired.
Verify that "OK" is displayed for all the items on the screen.
4 Press F1 [EXIT].

> **NOTE**
> When "OK" is displayed for all the items on the screen, pressing F1 [EXIT] will complete the procedure for confirming gage data.
> When even one "OVER" is displayed for the items on the screen, pressing F1 [EXIT] will not complete the procedure for confirming gage data.

3.2.2.6 Clear force and torque

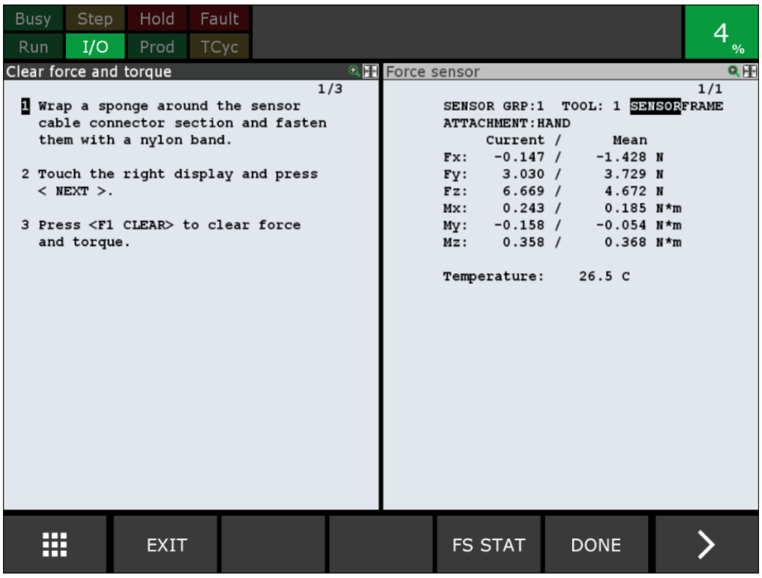
Overview

Clear force and torque values.
Set to clear force and torque values.
The setting screen is displayed in the horizontal 2-split windows.
The right window is automatically displayed.
A way to clear force and torque values is displayed in the left window.
When clearing of force and torque values has been completed, [DONE] is displayed in [Clear force and torque] on the [Force sensor installation setting] screen.

> **NOTE**
> The procedure and screen for clearing force and torque values are common to the hand type and fixed type.

Procedure for Clearing Force and Torque Values

1 The [Force Sensor Installation Setting] screen is displayed.
(Refer to [Force sensor installation] in "Introduction: 3.1.1 Home Screen".)
2 Move the cursor to [Clear force and torque] and press the F3 [DETAIL] key.
The [Reset force value] screen and the [Force sensor] screen will appear.



3 Press F4 [FORCE STATUS].
The force sensor [Status display] screen is displayed again in the right window.
* The [Status display] screen displayed in step 3 is the same as the [Force sensor] screen in step 2.

> **NOTE**
> When the [Reset force value] screen on the left is touched, F4 [FORCE STATUS] is displayed.
> When F4 [FORCE STATUS] is not displayed, touch the title bar on the [Reset force value] screen.

4 Press F5 [DONE].

3.2.3 Installing Force Sensor (Fixed Type)

This section describes installation of fixed type force sensor.

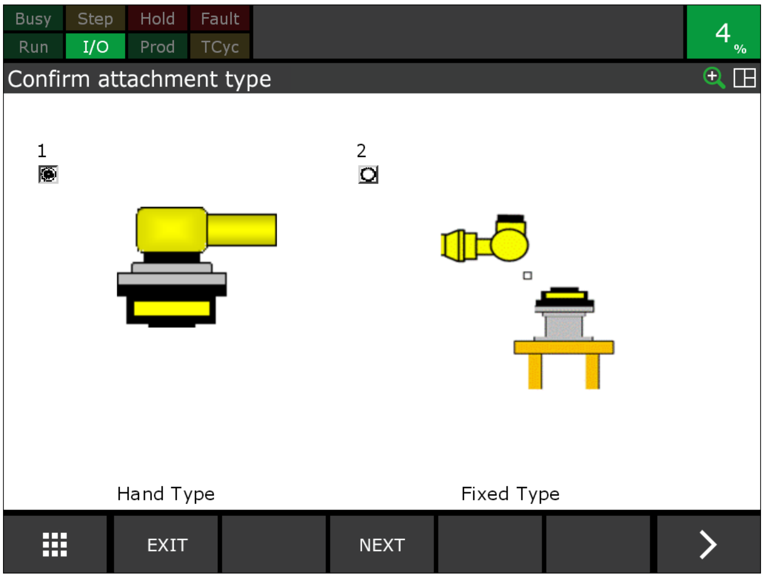
3.2.3.1 Selecting sensor type (fixed type)

Overview

Select the fixed type as a sensor type.
When selection of the sensor type has been completed, [DONE] is displayed in [Select installation type] on the [Force sensor installation setting] screen.

Procedure for Selecting Sensor Type (Fixed Type)

1 The [Force Sensor Installation Setting] screen is displayed.
(Refer to [Force sensor installation] in "Introduction: 3.1.1 Home Screen".)
2 Move the cursor to [Select installation type] and press the F3 [DETAIL] key.
When the "Fixed force sensor (J843)" option is installed, the [Select installation type] screen will appear.

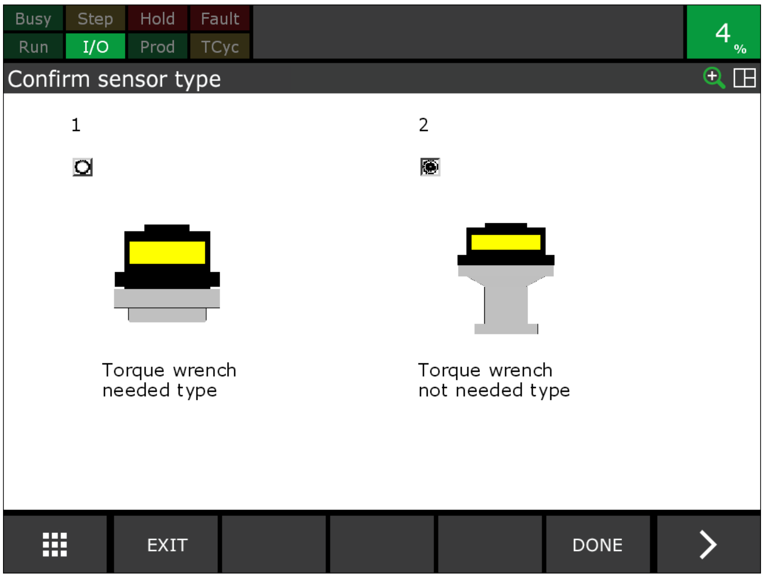


NOTE

When the fixed installation type force sensor is used, install the "Fixed Force Sensor (J843)" option.
Options that have been installed can be confirmed on the [Options] screen.
(Refer to "Introduction: 3.1.3 Options Screen".)

3 Check [Fixed Type].
4 Press F3 [NEXT].

When the force sensor is "FS-250*i*A", the [Confirm sensor type] screen will appear.



NOTE

When the force sensor is other than "FS-250*i*A", "torque wrench not needed type" does not exist, so the [Confirm sensor type] screen will not appear.
Press F3 [NEXT] to return to the [Force Sensor Installation Setting] screen.
Skip over steps 5 and 6.

5 Check the adapter to be used.

6 Press F5 [DONE].

3.2.3.2 Installing force sensor (fixed type)

Overview

Install the fixed type force sensor following the on-screen instructions.
The setting screen is displayed in the horizontal 2-split windows.
The right window is automatically displayed.
The recommended way of installing and fixing the force sensor is displayed in the left window. Fix the force sensor in place while checking the screen.
When installation of the sensor type has been completed, [DONE] is displayed in [Installation method] on the [Force sensor installation setting] screen.

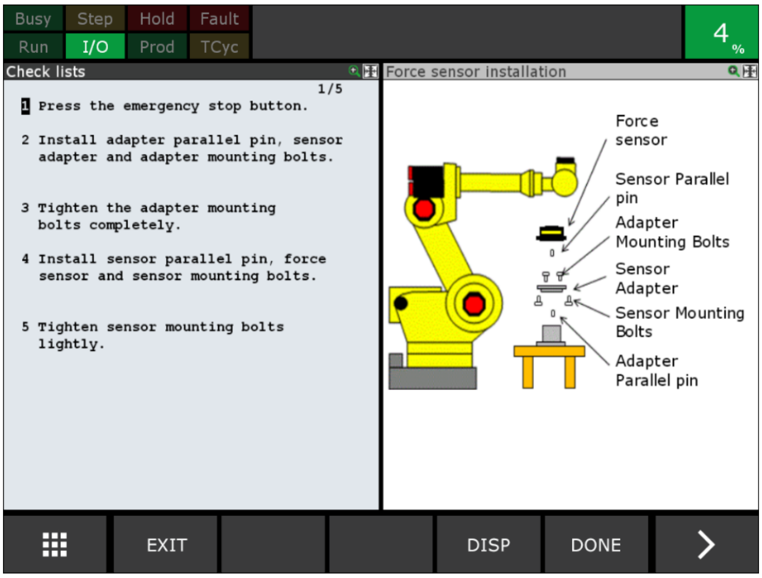
> ⚠ **WARNING**
> When you install the force sensor, make sure that emergency stop is enabled on the robot.

Procedure for Installing Force Sensor (Fixed Type)

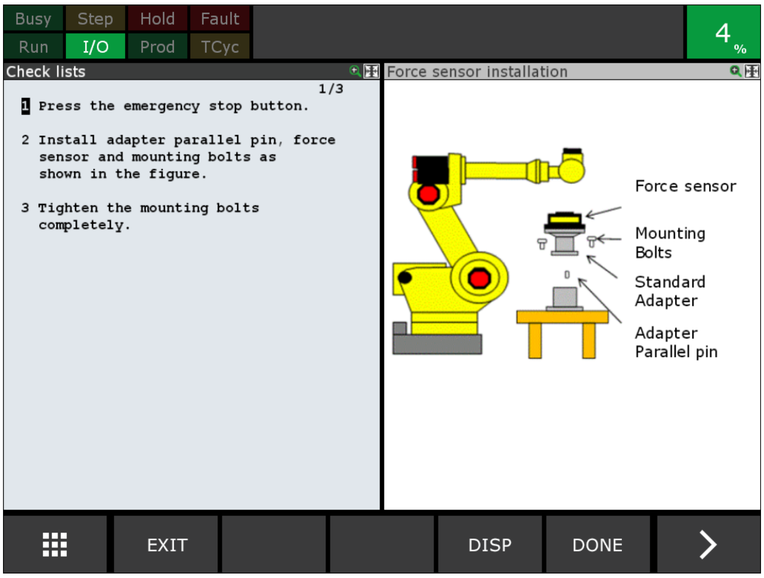
1 The [Force Sensor Installation Setting] screen is displayed.
(Refer to [Force sensor installation] in "Introduction: 3.1.1 Home Screen".)

2 Move the cursor to [Installation method] and press the F3 [DETAIL] key.
The [Confirmation item] screen and the [Force sensor installation] screen are displayed in two windows.

The [Confirmation item] screen differs between "Torque wrench needed type" and "Torque wrench not needed type".
The following is the torque wrench needed type screen.



The following is the torque wrench not needed type screen.



3 Install the force sensor by following the procedure for confirmation items in the left window.
 * When F4 [DISPLAY] is pressed, the [Force sensor installation] screen is displayed again in the right window.

4 Press F5 [DONE].

3.2.3.3 Loading calibration data

The procedure and screen for loading force sensor are common to the hand type and fixed type.
(Refer to "Introduction: 3.2.2.3 Loading Calibration Data".)

3.2.3.4 Confirming the temperature

Procedure and screen for confirming the internal temperature are common to the hand type and fixed type.
(Refer to "Introduction: 3.2.2.4 Confirming the Temperature".)

3.2.3.5 Confirming gage data

The procedure and screen for confirming gage data are common to the hand type and fixed type.
(Refer to "Introduction: 3.2.2.5 Confirming Gage Data".)

3.2.3.6 Clear force and torque

The procedure and screen for clearing force and torque values are common to the hand type and fixed type.
(Refer to "Introduction: 3.2.2.6 Clear Force and Torque".)

3.3 SETTING SENSOR FRAME

This section describes sensor frame setting procedure.
The sensor frame setting procedure can be classified into the following installation types.
(1) Hand type force sensor
 - Standard adapter type
 - Custom adapter
(2) Fixed force sensor

The procedure and screen for setting sensor vision frame vary, depending on the installation type. However, the procedure is common through to displaying the [Sensor vision frame set] screen.
(Refer to [Set sensor frame] in "Introduction: 3.1.1 Home Screen".)

> ⚠ **WARNING**
> Running force control with the sensor frame set incorrectly may apply excessive force. Note that, for example, if the sensor frame is set in the wrong x direction or y direction by 180 degrees, force will increase at an incredible rate, which may cause property damage or bodily injury.

3

3.3.1 Setting Sensor Frame (Hand Type)

Overview

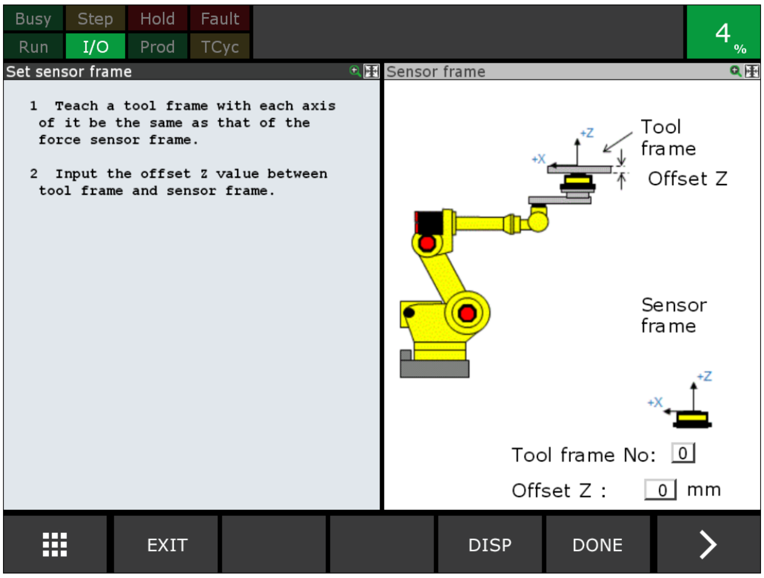
Select the hand type sensor frame.
When the setting of sensor frame has been completed, [DONE] is displayed in [Set sensor frame] on the [Home] screen.

> **NOTE**
> 1 For the hand type force sensor (standard adapter type), it is not necessary to set sensor frame, as default is automatically set. Reactivate the robot controller only.
> 2 For the hand type force sensor (custom adapter type), it is necessary to set sensor frame.

The following is the procedure for setting sensor frame for the hand type force sensor (custom adapter type).
The setting screen is displayed in the horizontal 2-split windows.
The right window is automatically displayed.
The sensor frame setting method is displayed in the left window.
Temporarily use tool frame to set sensor frame.

Procedure for Setting Sensor Frame (Hand Type/Custom Adapter Type)

1 The [Set sensor frame] screen will appear.
(Refer to [Set sensor frame] in "Introduction: 3.1.1 Home Screen".)



2 Enter tool frame number in [Tool frame number] in the right window.

* Enter value below a settable frame number. In the default setting, a maximum value that can be entered is "10".

3 Enter offset value in [Offset value] in the right window.
The offset value can be entered without limitation.

* When F4 [DISPLAY] is pressed, the [Sensor frame] screen is displayed again in the right window.

4 Press F5 [DONE].

> **NOTE**
> When you enter a value greater than the settable frame number in [Tool frame number] and press [DONE], the message "The frame number is not appropriate" will appear at the bottom of the left window.
> Example: If a maximum value of the frame number is default setting, when you enter frame number greater than "11" in [Tool frame number] and press [DONE], the message "The frame number is not appropriate" will appear at the bottom of the left window.

3.3.2 Setting Sensor Frame (Fixed Type)

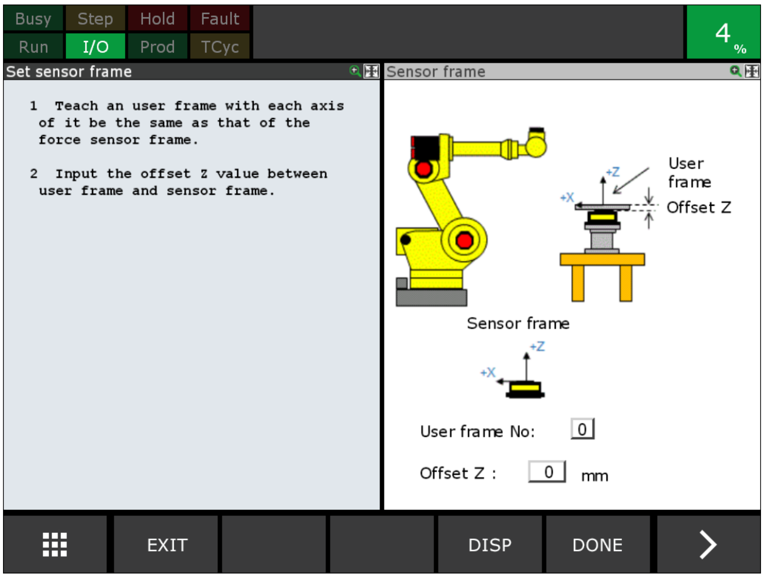
Overview

Set the fixed type sensor frame.
When the setting of sensor frame has been completed, [DONE] is displayed in [Vision Frame Set] on the [Home] screen.

The following is the procedure for setting sensor frame for the fixed type force sensor.
The setting screen is displayed in the horizontal 2-split windows.
The right window is automatically displayed.
The sensor frame setting method is displayed in the left window.
Temporarily use user frame to set sensor frame.

Setting Sensor Frame (Fixed Type)

1 The [Set sensor frame] screen will appear.
(Refer to [Set sensor frame] in "Introduction: 3.1.1 Home Screen".)



2 Enter user frame number in [User frame number] in the right window.

* Enter value below a settable frame number. In the default setting, a maximum value that can be entered is "9".

3 Enter offset value in [Offset value] in the right window.
The offset value can be entered without limitation.
* When F4 [DISPLAY] is pressed, the [Sensor frame] screen is displayed again in the right window.

4 Press F5 [DONE].

NOTE
When you enter value a greater than the settable frame number in [Tool frame number] and press [DONE], the message "The frame number is not appropriate" will appear at the bottom of the left window.
Example: If a maximum value of the frame number is default setting, when you enter frame number greater than "10" in [User frame number] and press [DONE], the message "The frame number is not appropriate" will appear at the bottom of the left window.

3.4 CONFIRM FORCE

This section describes the procedure for confirming force.
The procedure for confirming force can be classified into the following types.
(1) Hand type force sensor
(2) Fixed force sensor

The procedure for confirming force sensor and screen vary, depending on the installation type. However, the procedure is common through to displaying the [Confirm force] screen.
(Refer to [Confirm force] in "Introduction: 3.1.1 Home Screen".)

⚠ WARNING
When you touch and check the force sensor, make sure that emergency stop is enabled on the robot.

3.4.1 Confirming Force (Hand Type)

Overview

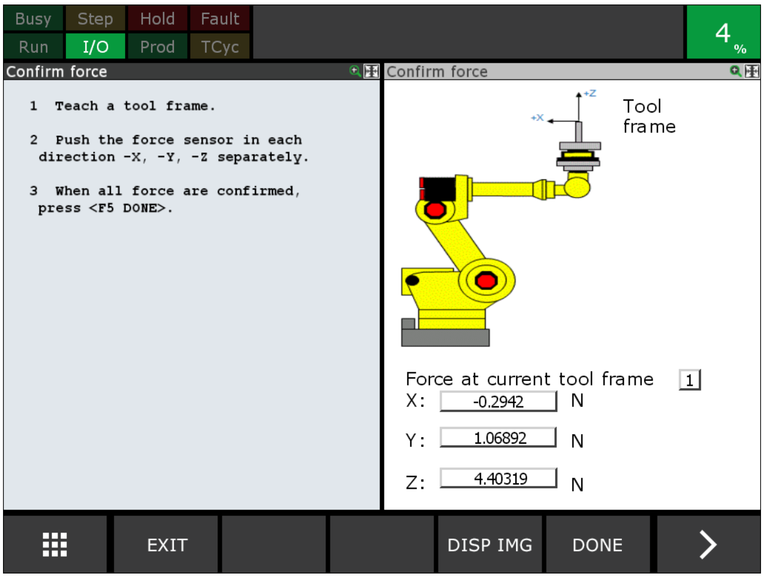
Confirm force of the hand type.
When confirmation of force has been completed, [DONE] is displayed in [Confirm force] on the [Home] screen.

The following is the procedure for confirming force for the hand type force sensor.
The confirmation screen is displayed in the horizontal 2-split windows.
The right window is automatically displayed.
The method for confirming force is displayed in the left window.

NOTE
Before confirming force, reactivate the robot controller.

Procedure for Confirming Force (Hand Type)

1 The [Confirm force] screen is displayed.
(Refer to [Confirm force] in "Introduction: 3.1.1 Home Screen".)
* When F4 [DISPLAY] is pressed, the [Confirm force] screen is displayed again in the right window.



2 Check the currently selected tool frame number and force sensor value in the selected tool frame in the right window ([Confirm force] screen).
3 Make sure the direction of force is correct by applying force to the force sensor.
4 Press F5 [DONE].

3.4.2 Confirming Force (Fixed Type)

Overview

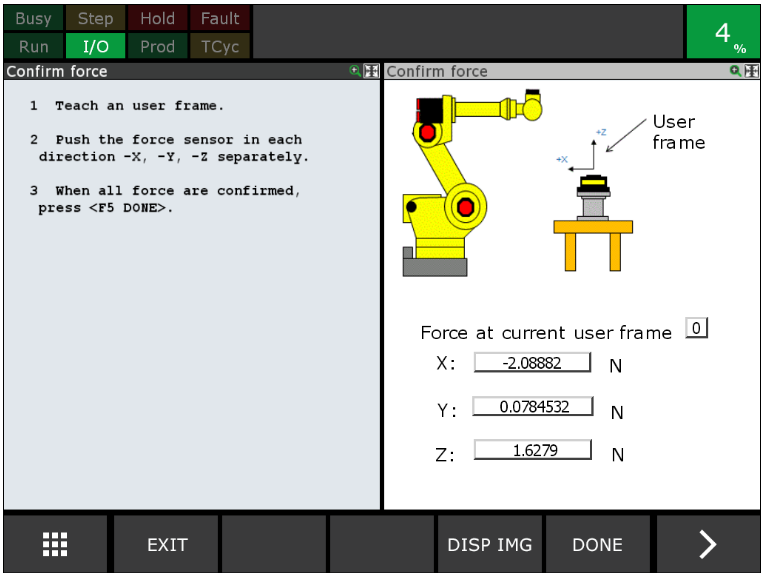
Confirm force for the fixed type.
When confirmation of force has been completed, [DONE] is displayed in [Confirm force] on the [Home] screen.

The following is the procedure for confirming force for the fixed type force sensor.
The setting screen is displayed in the horizontal 2-split windows.
The right window is automatically displayed.
The method for confirming force is displayed in the left window.

> **NOTE**
> Before confirming force, reactivate the robot controller.

Procedure for Confirming Force (Fixed Type)

1 The [Confirm force] screen is displayed.
(Refer to [Confirm force] in "Introduction: 3.1.1 Home Screen".)
* When F4 [DISPLAY] is pressed, the [Confirm force] screen is displayed again in the right window.



2 Check the currently selected user frame number and force sensor value in the selected user frame in the right window ([Confirm force] screen).
3 Make sure the direction of force is correct by applying force to the force sensor.
4 Press F5 [DONE].

Basic Functions Guide

1 PROGRAMMING AND TEACHING OF FORCE CONTROL INSTRUCTIONS

This chapter explains how to teach and operate the force control functions.
All the force control operations are performed using the teach pendant programs.

In addition to the robot motion and logic instructions, the force control instructions are programmed for the desired production operation. The basic and the performance data in the force schedule are used to operate the robot during the execution of the force control instruction. The basic data defines the application requirements that must be set before executing the force control instruction. The performance data is set by default and could be adjusted if necessary to improve the robot performance.
(For details on the basic data and performance data, refer to "Basic Function Guide: 1.5 SCHEDULE DATA".)

CONTENTS

1.1 NOTES / RESTRICTIONS

- Collision detection is disabled during the force control operation. The function is enabled again once the execution of the force control instruction is completed.
- Brake control is disabled during the force control operation. Brake control is enabled again once the execution of the force control instruction is completed.
- While executing a force control instruction other than the contouring function, the robot operates at the velocity set in the force control parameters regardless of the override value.
- The Force control instruction cannot be restarted after a temporary stop, nor can it be executed backwards.

> ⚠**CAUTION**
> Design a hand with adequate gripping force so that the workpiece does not slip or move during force control.

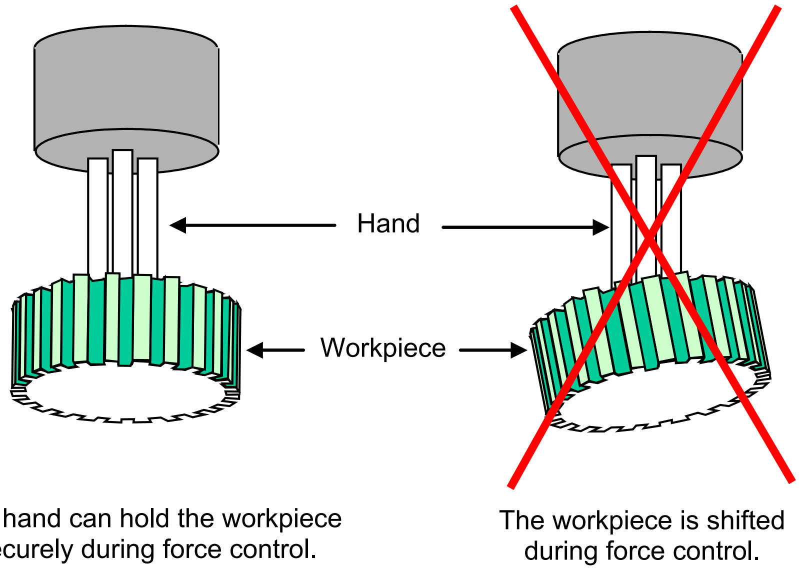


Fig. 1.1 Sample hand design

- If force sensor attachment and sensor frame settings are required, do so accurately.
  (For information on the conditions requiring settings, refer to "Introduction: 2 FORCE SENSOR OVERVIEW". For information on the configuration method, refer to "APPENDIX: C FORCE SENSOR ATTACHMENT SETTING FUNCTION".)

> ⚠**CAUTION**
> Force control instructions can only be run if mastering has been performed for the robot. The force sensor value is also not displayed on the Force sensor current value screen.
> If the mastering data is not accurate, the force control function may not operate correctly, causing the robot may move in the wrong direction.

1.2 TEACHING PROCEDURE

Overview

This section describes the procedure for performing teaching for force control.
Sensor Frame setup is necessary in the following cases.
(Refer to "APPENDIX: C FORCE SENSOR ATTACHMENT SETTING FUNCTION" for further details.)

(1) The attachment type is “HAND”, and either of the following condition is met – Standard Configuration
- Standard adapter plate is used.
- Offset adapter plate is used (For instance, force sensor is attached to the tip of the tool)

(2) The attachment type is “FIXED” – Fixed Configuration

The teaching procedure for force control

1 Perform teaching for the tool frame and user frame to use for force control.
- Tool frame settings:
  Specify the tool frame with the workpiece to be inserted or pushed mounted to the robot hand. Set the origin point of the tool frame to the tool’s center point, which is located on the center axis of the workpiece.
- User frame settings:
  Specify the user frame to the surface of the workpiece to be inserted. Ensure that one of the user frame axes matches the insertion direction.

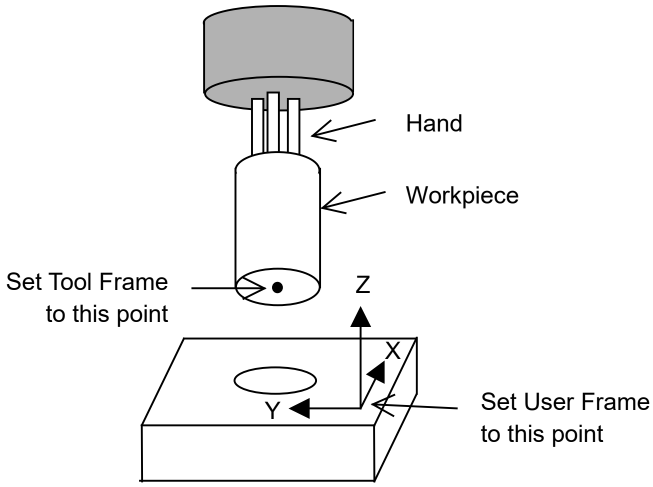


Fig. 1.2 (a) Set the user frame and tool frame

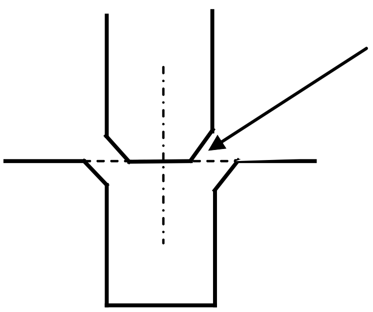
2 Select the above tool frame and user frame, create a robot operation program as indicated below, and perform teaching for the approach point (the point where the robot switches from regular position control to force control).

```
TEST
                                        1/3
   1:J P[1] 100% CNT50
   2:L P[2:Approach pos] 100mm/sec
    :   FINE
[End]
```

Fig. 1.2 (b) Create a TP program with an approach point

The method for teaching the approach point differs according to the function of the force control statement. Refer to Fig. 1.2 (c) to Fig. 1.2 (e) to perform accurate teaching.
(Refer to "Basic Function Guide: 1.3 FORCE CONTROL INSTRUCTIONS".)

For “Shaft Insert”, “Groove Insert”, “Square Insert”, “Threading”



Teach an approach point so that the height of the end face of the workpiece to be inserted matches the height of the plane of the object workpiece.
The position error between the workpiece and hole should be as small as possible.

Fig. 1.2 (c) Teaching the Approach Point
(for Shaft Insert, Groove Insert, Square Insert, and Threading)

For “Constant Push”, “Face Match”, “Search”
“Phase Search”, “Hole Search”

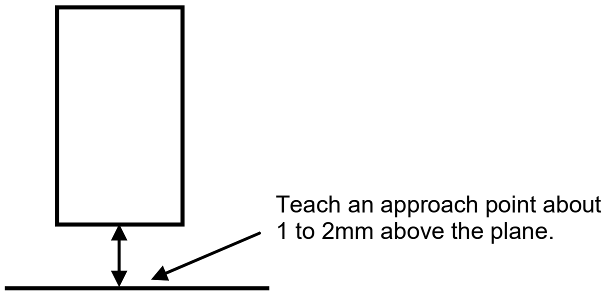


Fig. 1.2 (d) Teach an approach point
(For Constant Push, Face Match, Search, Phase Search, Hole Search)

For “Clutch Search”

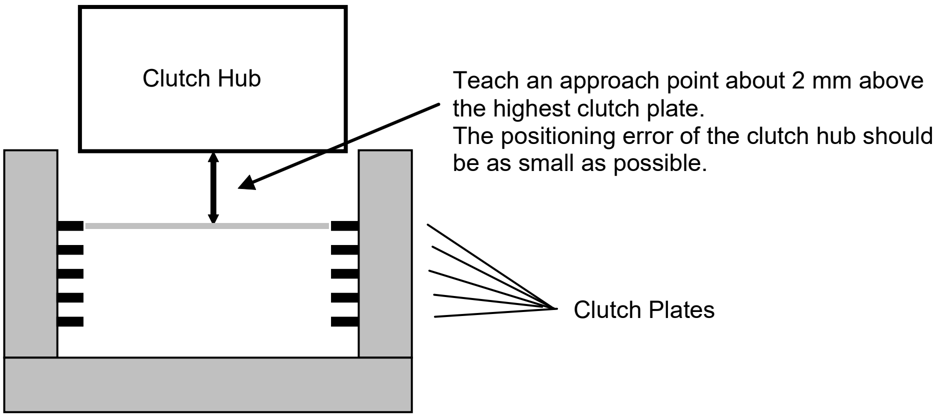


Fig. 1.2 (e) Teach an approach point (For “Clutch Search”)

3 Insert a force control statement after the approach point, as indicated in the example program below. (For details on the force control instructions, refer to "Basic Function Guide: 1.3 FORCE CONTROL INSTRUCTIONS".)

```
TEST
                                    1/3
   1:J   P[1] 100% CNT50
   2:L   P[2:Approach Point] 100mm/sec
     :   FINE
   3:    FORCE CTRL[1]
     :   ErrorLBL[0]
 [End]
```

Fig. 1.2 (f) Add a force control instruction to the TP program

4 Specify the Basic data of the Schedule data.
The parameters to be set vary depending on the force control instruction.
(Refer to "Basic Data Screen" for the corresponding section in "Basic Function Guide: 1.5.2 Constant Push / Face Match" to "Basic Function Guide: 1.5.5 Contouring Function".)

5 Insert an Auto tuning instruction to the program and then perform Force control gain automatic tuning. (For automatic tuning of Force control gain, refer to "Basic Function Guide 1.10.2 Force Control Gain Auto Tuning Instruction").

6 Confirm that the automatic adjustment statement was executed without an error, and delete the automatic adjustment statement from the program.

7 Execute the force control instruction and adjust basic data of the force schedule.
8 When necessary, specify the performance data of the force schedule

1.3 FORCE CONTROL INSTRUCTIONS

Overview

Force control statements have functions categorized by application.
Select the function that is most appropriate for the operation to perform.
(For details on each function, refer to the corresponding item in "Basic Function Guide: 1.5 SCHEDULE DATA".

NOTE
When using a 3-axis force sensor, only the 'Constant Push', 'Contouring', and 'Contouring end' functions of force control can be used.
When using a 6-axis force sensor, all functions are supported.

Table 1.3 (a) Types of force control functions

Function	Description
Unused	Schedule data is not used. Force control cannot be performed using an Unused schedule. (Refer to "Basic Function Guide: 1.5.1 Unused".)
Constant Push	This function is used to gently bring the robot hand into contact with the workpiece, for instance, for contact evaluation, temporary placement, and the arrangement of components along a particular guide. (Refer to "Basic Function Guide: 1.5.2 Constant Push / Face Match".) This function can also be used with a 3-axis force sensor. For CRX, this function can also be used with the internal sensor.
Face Match	This function is used to match the face of a workpiece held by the robot hand to the face of an object, such as inserting a workpiece into the chuck of a machine tool. (Refer to "Basic Function Guide: 1.5.2 Constant Push / Face Match".)
Shaft Insert	This function inserts a cylindrical mechanical component such as a shaft or a positioning pin. (Refer to "Basic Function Guide: 1.5.3 Shaft Insert / Groove Insert / Square Insert".)
Groove Insert	This function inserts a quadrangular prism workpiece into a groove. (Refer to "Basic Function Guide: 1.5.3 Shaft Insert / Groove Insert / Square Insert".)
Square Insert	This function inserts a quadrangular prism workpiece into a rectangular hole. (Refer to "Basic Function Guide: 1.5.3 Shaft Insert / Groove Insert / Square Insert".)
Search	This function absorbs the initial position and attitude errors that are present before the start of force control. Errors can be absorbed in five directions (two translation directions plus three rotation directions) except the insertion direction. (Refer to "Basic Function Guide: 1.5.4 Search Function".)

Function	Description
Phase Search	This function performs phase matching of teeth, such as the key shaft insertion and the gear engagement. (Refer to "Basic Function Guide: 1.5.4 Search Function".) This function is similar to the 'Phase Match Ins.' function but differs in the following: • When the torque is sensed during phase matching, "Phase Search" causes an inversion in the search direction. "Phase Search" performs phase matching by slightly changing the rotation velocity and torque so as not to damage the workpiece. • With 'Phase Search', only phase alignment is performed. To continue performing insertion, continuously execute 'Shaft Insert'. (For successive execution, refer to "Basic Function Guide: 1.7 SUCCESSIVE EXECUTION OF FORCE CONTROL INSTRUCTIONS (CUSTOMIZATION FUNCTION)".) For CRX, this function can also be used with the internal sensor. However, the rotation axis used in Phase Search must match J6.
Hole Search	This function performs a search operation on the plane perpendicular to the insertion direction. For shaft insertion, for example, the positioning error at the start of force control needs to be within the chamfer amount. The hole search function enables insertion even when there is a positioning error larger than the chamfer amount. For the successive execution, refer to "Basic Function Guide: 1.7 SUCCESSIVE EXECUTION OF FORCE CONTROL INSTRUCTIONS (CUSTOMIZATION FUNCTION)". (Refer to "Basic Function Guide: 1.5.4 Search Function".)
Clutch Search	This function is used to assemble a clutch for the automatic transmission of an automobile. The function performs phase matching around the insertion axis and searches for a position on a plane perpendicular to the insertion axis at the same time. This function is similar to 'Clutch Insert' but differs in the way for searching for a position on a plane. This function allows insertion when a larger initial positioning error than that permitted in "Clutch Insert" is present. (Refer to "Basic Function Guide: 1.5.4 Search Function".)
Contouring∗	This function traces the surface of a workpiece with applying a specified force. Used with a sander, this function can perform grinding. (Refer to "Basic Function Guide: 1.5.5, Contouring Function".) This function can also be used with a 3-axis force sensor. For CRX, this function can also be used with the internal sensor.
Contouring End∗	This instruction ends Contouring being executed. (Refer to "Basic Function Guide: 1.5.5, Contouring Function".) This function can also be used with a 3-axis force sensor. For CRX, this function can also be used with the internal sensor.
Threading	This instruction fastens screws with robot wrist or extended axis. Tightening torque is checked by force sensor. (Refer to "Basic Function Guide: 1.5.6, Threading".)

∗ This function can be used with a 3-axis force sensor.

The software options required for each function are indicated below.

Table 1.3 (b) Options

Force sensor	Function	Options			
		Force Control Basic A05B-2600-J876	**FC Basic 3-Axis** A05B-2600-J8744	**Force Control Fitting** A05B-2600-J877	**Force Ctl. Contouring** A05B-2600-J835
6-axis force sensor	Constant Push	√	–	–	–
	Face Match	√	–	–	–
	Shaft Insert	√	–	√	–
	Groove Insert	√	–	√	–
	Square Insert	√	–	√	–
	Search	√	–	√	–
	Phase Search	√	–	√	–
	Hole Search	√	–	√	–
	Clutch Search	√	–	√	–
	Contouring	√	–	–	√
	Contouring End	√	–	–	√
	Threading	√	–	√	–
3-axis force sensor	Constant Push	–	√	–	–
	Contouring	–	√	–	√
	Contouring End	–	√	–	√
CRX internal sensor	Constant Push	No options are required. (Standard function)			
	Face Match				
	Phase Search				
	Contouring				
	Contouring End				

Example of Using the Force Control Function

A schematic diagram indicating an example of applying force control is indicated below.

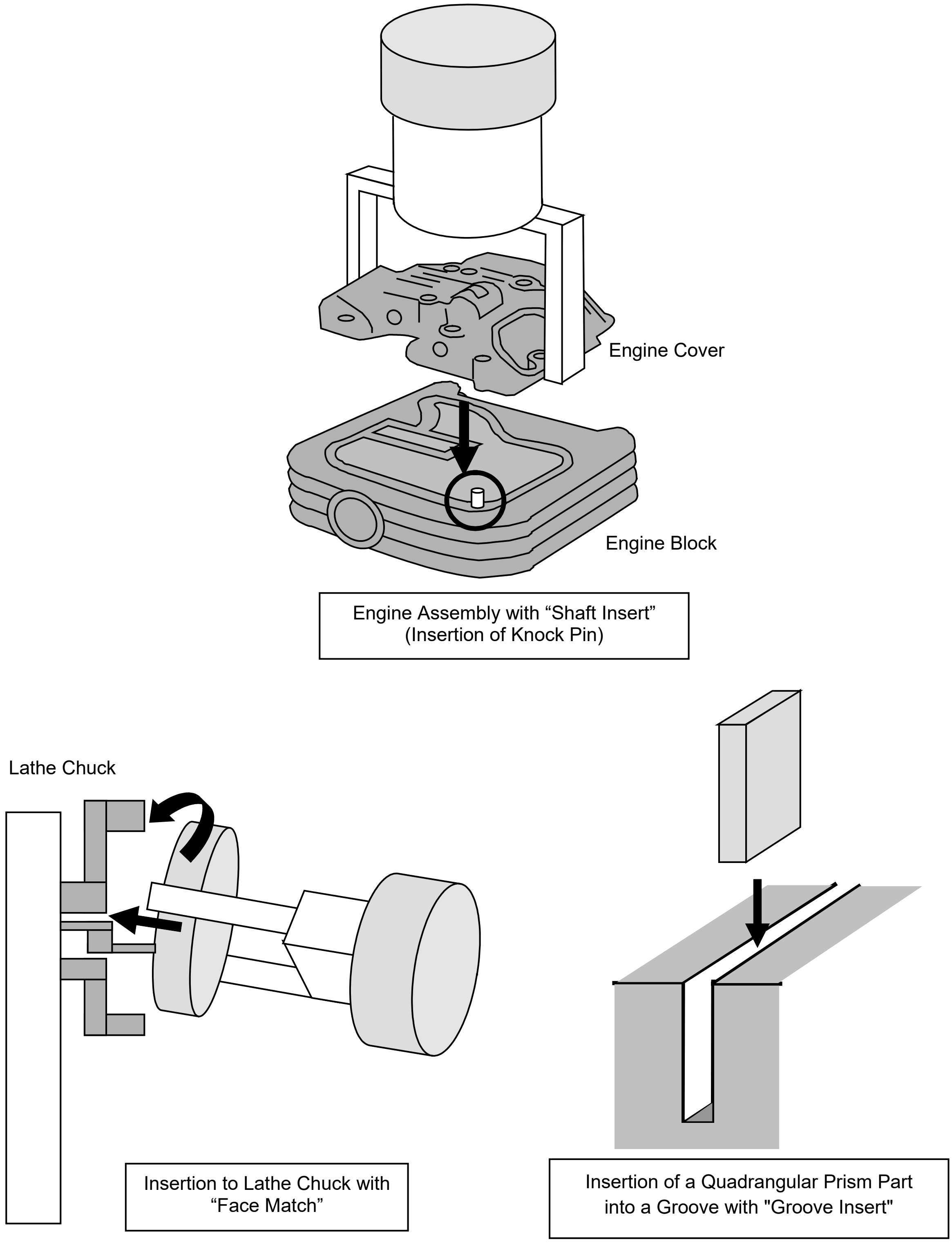
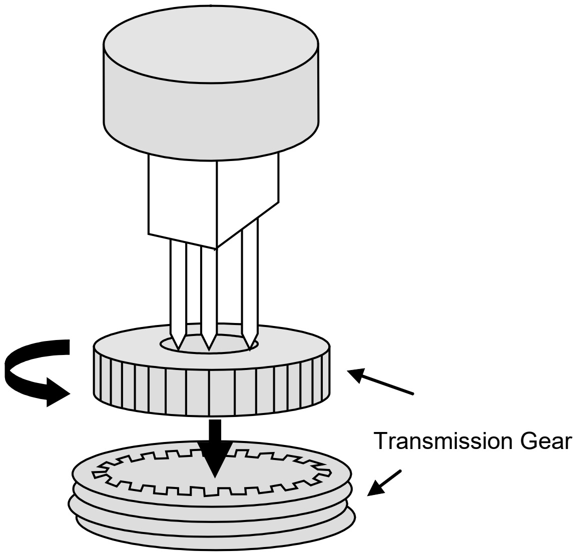
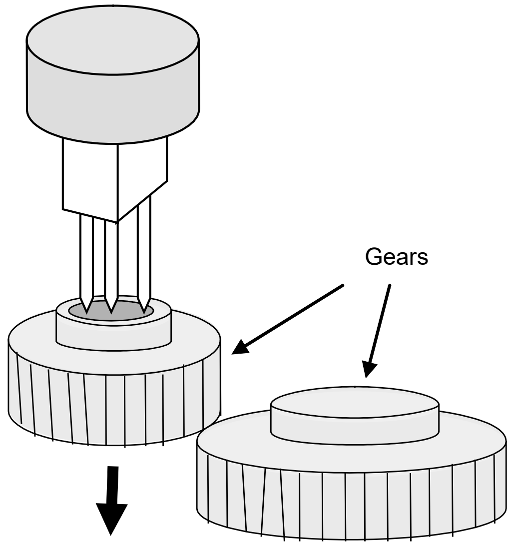


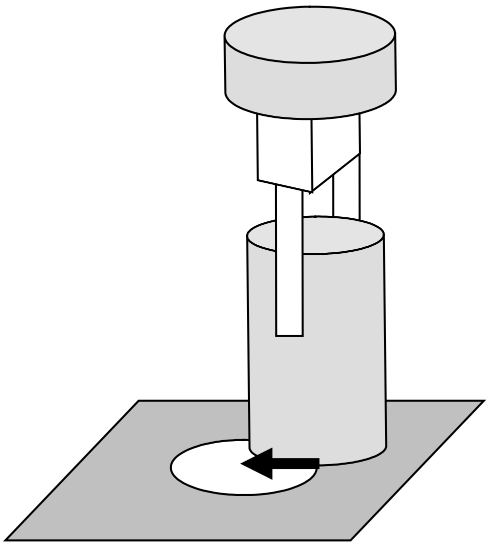
Fig. 1.3 (a) Example of Applying the Force Control Function (1/3)



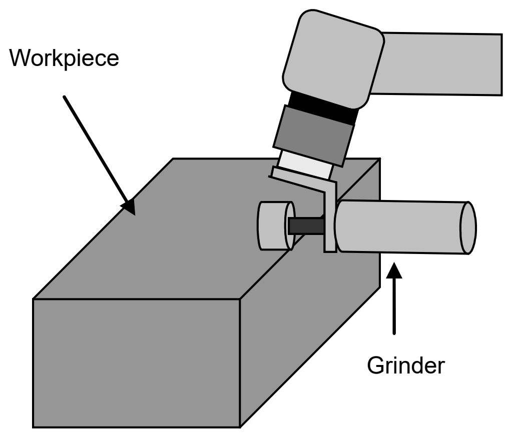
Transmission Assembly with
"Clutch Search"



“Phase Matching of Gear Parts with
"Phase Search"

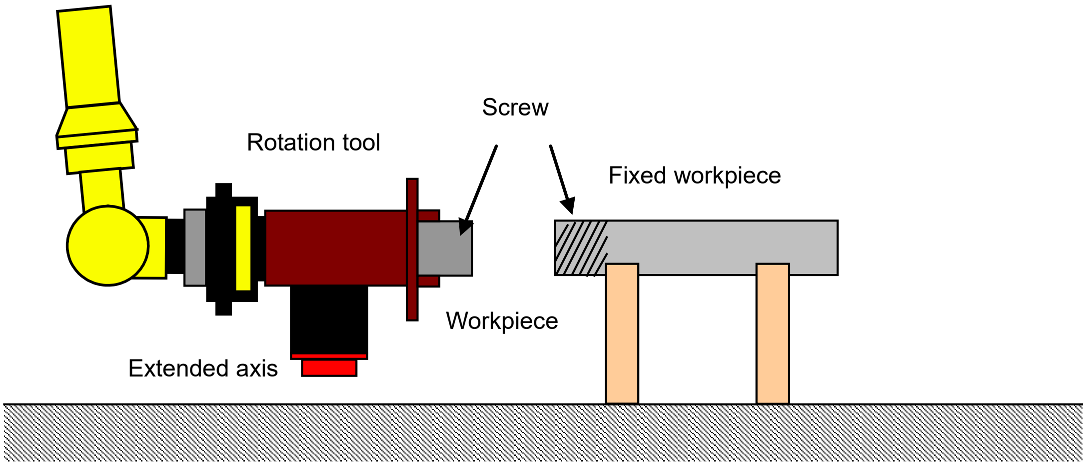


Search for Insertion Hole Position with
"Hole Search"



Grinding the surface of workpiece with
"Contouring"

Fig. 1.3 (b) Example of Applying the Force Control Function (2/3)



“Threading” : Extended axis is used for threading with tightening torque

Fig. 1.3 (c) Example of Applying the Force Control Function (3/3)

Selecting a Statement Relating to Force Control

1 Display the TP program training screen.
2 Press F1 [INST].
The menu ([Force control instructions.] screen) is displayed.

```
TEST
                                   1/1
[End]

[INST] |  |  |  | [EDCMD] | >
  F1     F2   F3   F4   F5
```

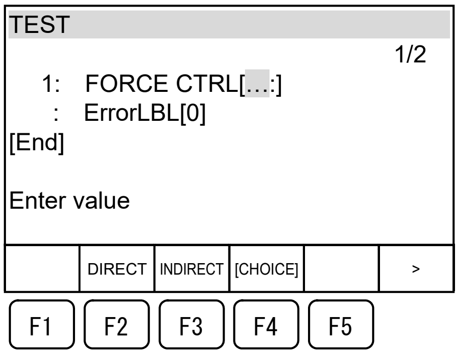
```
Instruction 1/4
 1 Registers
 2 I/O
 3 Force Control
 4 IF/SELECT
 5 WAIT
 6 JMP/LBL
 7 CALL
 8 ---next page---
```

3 Select 'Force Control'.
The menu is displayed.

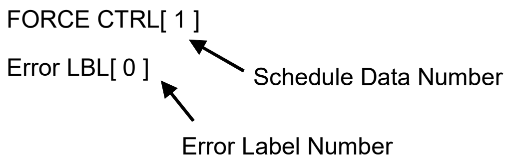
```
FORCE statement 1/2
 1 FORCE CTRL
 2 SENSOR DIAGNOSIS
 3 GET DIAG DATA
 4 AUTO TUNING ON
 5 AUTO TUNING OFF
 6 TRQ ERROR ON
 7 TRQ ERROR OFF
 8 ---next page---
```

```
FORCE statement 2/2
 1 END COND ON
 2 END COND OFF
 3
 4
 5
 6
 7
8 ---next page---
```

4 Select 'FORCE CTRL'.
A force control statement is added to the TP program.



Instruction



This is the instruction that performs the Force control. It is necessary to specify 'Schedule Data Number' and 'Error Label Number', explained as follows, for this instruction.

Schedule Data Number

It is necessary to set Schedule data referred by the 'FORCE CTRL' instruction. Schedule data number to which the 'FORCE CTRL' instruction refers is shown here. Refer to "Basic Function Guide: 1.5 SCHEDULE DATA" for details of Schedule data.

Error Label Number

In the 'FORCE CTRL' instruction, it is possible to jump to the 'LBL' instruction specified by this Error Label Number when an error occurs while executing this instruction. The recovery procedure of the error can be programmed beforehand by using this function. However, when 0 is set, the program is stopped according to the occurring error.

Selecting force control functions

The force control functions in Table 1.3 (a) are selected on the schedule data settings screen.
(Refer to "Basic Function Guide: 1.5 SCHEDULE DATA".)

In the example below, when an error occurs during force control, the hand lets go, the failed workpiece is released, and the operation resumes on the next workpiece.

```
TEST
                                   1/21
  1:   LBL[1]
  2:L P[1:approach pos] 100mm/sec
   :   FINE
  3:   FORCE CTRL[1]
   :   ErrorLBL[2]
              :
              :

  9:   ! Force control error occurs
 10:   LBL[2]
 11:   ! Open hand
 12:   DO[1]=OFF
 13:   ! Go back to approach pos
 14:L P[1:approach pos] 100mm/sec
   :   FINE
 15:   ! Remove failed workpiece
 16:   DO[11]=ON
 17:   ! Wait for next workpiece
 18:   WAIT DI[21]=ON
 19:   ! Restart Force control
 20:   JMP LBL[1]
[End]
```

Schedule Data Number is 1.
Error Label Number is specified to 2.

If Force control error occurs, Jump here.

Fig. 1.3 (d) Example of error recovery

The program can also be set to retry when an error occurs.
(Refer to "Basic Function Guide: 1.4 SAMPLE PROGRAM".) For information on the retry function, refer to "Basic Function Guide: 1.7.2 Retry".

1.4 SAMPLE PROGRAM

The example below shows the program that is set to retry when an error occurs.
(Refer to "Basic Function Guide: 1.7.2 Retry".)

```
SAMPLE
                                  1/60
   1:   LBL[1]
   2:   UFRAME_NUM = 0
   3:   UTOOL_NUM = 2
   4:   !OPEN HAND
   5:   DO[1]=OFF
   6:J P[1] 50% CNT100
   7:L P[2] 500mm/sec CNT100
   8:J P[3] 50mm/sec FINE
   9:   ! Grasp work
  10:   DO[1]=ON
              :        :
              :        :
  11    LBL[2]
  12:   !INSERTION
  13:   UFRAME_NUM = 1
  14:   UTOOL_NUM = 3
  15:L P[4:APPROACH POINT] 100mm/sec
     :   FINE
  16:   FORCE CTRL[1]
     :   ERROR LBL[3]
  17:   !SUCCESS
  18:   !OPEN HAND
  19:   DO[1]=OFF
  20:L P[5] 100mm/sec    FINE

  21:   JMP LBL[1]
              :        :
              :        :
  22:   !Force control ERROR
  23:   LBL[3]
  24:   !MOVE AWAY ERROR PARTS
  25:   FORCE CTRL[2]
     :   ERROR LBL[4]
  26:   JMP LBL[2]
              :        :
              :        :
  28:   LBL[4]
  52:   USER ALARM
              :        :
              :        :
[END]
```

Handles the workpiece.

The handled workpiece is fitted into another workpiece by the force control.

If force control insertion is successful, control returns to the beginning to the program to repeat processing.

Error processing if force control insertion fails
Firstly, pulls out the workpiece by using another force control instruction, and then performs retry operation.
For retry operation, refer to "Basic Function Guide: 1.7.2 Retry".

If a failure occurs while the workpiece is being pulled out, an alarm is issued.

Fig. 1.4 Sample program

1.5 SCHEDULE DATA

Overview

Data that specifies the operation condition of a force control instruction is referred to as schedule data. The detailed data must be specified on the schedule data screen.

> **NOTE**
> When using a 3-axis force sensor, only the "Constant Push", "Contouring", and "Contouring end" functions of force control can be used.
> When using a 6-axis force sensor, all functions are supported.

Displaying the Schedule Data Details Screen

1 Press the [DATA] key on the teach pendant of the robot controller.
2 Press F1 [TYPE].
The menu is displayed.
3 Select [Force Control] from the menu, and press the [ENTER] key on the teach pendant of the robot controller.
The [Schedule data list] screen is displayed.
* There are two [Schedule data list] screens; "LIST1" and "LIST2".
Press F5 [LIST1] or F5 [LIST2] to switch between the screens.

List1

```
Force Ctrl/Schdl
      Force Ctrl/Schedule List1           1/30
  No.  Function                Comment
   1 Unused               [                    ]
   2 Unused               [                    ]
   3 Constant Push        [                    ]
   4 Constant Push        [                    ]
   5 Face Match           [                    ]
   6 Face Match           [                    ]
   7 Shaft Insert         [                    ]
   8 Groove Insert        [                    ]
   9 Search               [                    ]
  10 Phase Search         [                    ]

[TYPE]  GROUP  DETAIL  COPY  LIST2  >
  F1     F2     F3     F4     F5
```

List2

```
Force Ctrl/Schdl
      Force Ctrl/Schedule List2     1/30
  No.  Function          UF    TF    Parent
   1 Unused             U: *  T: *  P:  *
   2 Unused             U: *  T: *  P:  *
   3 Constant Push      U: 0  T: 1  P:  0
   4 Constant Push      U: 0  T: 1  P:  0
   5 Face Match         U: 0  T: 1  P:  0
   6 Face Match         U: 0  T: 1  P:  0
   7 Shaft Insert       U: 0  T: 1  P:  0
   8 Groove Insert      U: 0  T: 1  P:  0
   9 Search             U: 0  T: 1  P:  0
  10 Phase Search       U: 0  T: 1  P:  0

[TYPE]  GROUP  DETAIL  COPY  LIST1  >
  F1     F2     F3     F4     F5
```

Table 1.5 (a) Schedule data list screen

List	Item	Description
LIST 1 / LIST 2	Function	Displays the name of the force control function. "Unused" is displayed if nothing has been set for the schedule, or the function name is displayed if a function is set. There are currently 13 types of force control functions, including "Unused". (Refer to "Basic Function Guide: 1.3 FORCE CONTROL INSTRUCTIONS".)
LIST 1	Comment	Displays the comment set on the detailed schedule data screen.
LIST 2	UF	Displays the user frame number set on the detailed schedule data screen.
	TF	Displays the tool frame number set on the detailed schedule data screen.
	Parent	Displays the parent schedule number for the customization function. (Refer to "Basic Function Guide: 1.7.4 Customization Function".)

Function keys

The function keys used on the [Schedule data list] screen are indicated below.

Table 1.5 (b) Function keys

Key	Item	Description
F1	TYPE	Allows you to change the display to a menu other than the force control menu.
F2	GROUP	Allows you to change motion groups.
F3	DETAIL	Displays the detailed schedule data screen.
Shift + F4	COPY	Copies the schedule data where the cursor currently is to the schedule data for another number. * Take care, as the destination schedule data is overwritten.
F5	LIST1	Switches to list 1 of the [Schedule data list] screen.
	LIST2	Switches to list 2 of the [Schedule data list] screen.

4 Move the cursor to the schedule to configure, and press F3 [DETAIL].
The detailed schedule data screen is displayed.

```
Force Ctrl/Basic
                                                          1/12
  Schedule[1]                          G:1 F:1 S:1
  1  Function                        : Constant Push
  2  Comment                         : [                ]
  3  Pushing Direction                     User: -Z
  4  Contact F Threshold             :       1.00 N
  5  Approach Velocity               :       1.00 mm/s
  6  User Frame No.                        UF:   0
  7  Tool Frame No.                        TF:   1
  8  Pushing Force                   :       5.00 N
  9  Approach Dist. Limit            :       5.00 mm
 10  Pushing Time                    :      20.00 sec
 11  F.Ctrl. Gain Auto Modify        :            OFF
        Prev. Result                 :      No Change
 12  Force Control Gain              :         Detail

 [TYPE]   GROUP   NUMBER   [CHOICE]   PERFORM   >
   F1      F2       F3        F4        F5
```

5 To change the function, move the cursor to [Function] and press F4 [CHOICE].
The menu ([Function selection] screen) is displayed.

6 Select a function from the menu ([Function selection] screen), and press the [ENTER] key on the teach pendant of the robot controller.
The "Change force control type?" message is displayed.

7 Press F4 [YES].
[Function] is changed.

> **NOTE**
> 1 The detailed data includes two types of data; basic data that must be set, and performance data that is set when specific operations need adjustment, etc.
> 2 The screen differs according to the force control function that is set.
> (For details on the screen for each force control function, refer to "Basic Function Guide: 1.5.1 Unused" to "Basic Function Guide: 1.5.6 Threading".)

Function keys

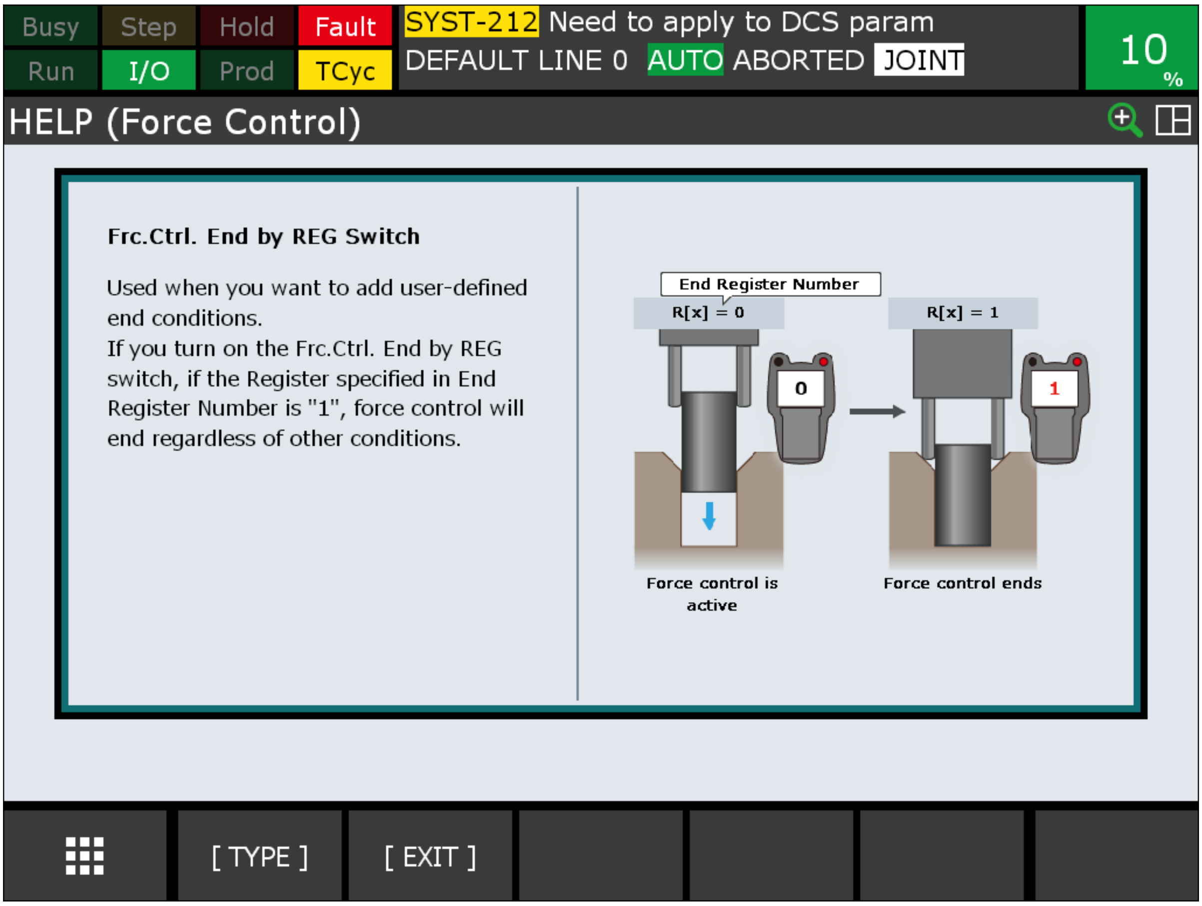
The function keys used on the detailed schedule data screen are indicated below.

Table 1.5 (c) Function keys

Key	Item	Description
F1	TYPE	Switches to a data screen other than the force control schedule data screen.
F2	GROUP	Switches the motion group.
	HELP	Displays a help screen that explains the meaning of a parameter.
F3	NUMBER	Switches to the screen for a different schedule data number.
F4	CHOICE	Displays the choices for the setting.
	YES	If pressing Shift + F4 [DEFAULT] displays the 'Set default data?' message, changes the setting.
	ON	Changes the setting to 'On'.
Shift + F4	DEFAULT	Returns all the settings of the selected schedule data to the default values.
F5	PERFORM	Switches to the [Performance Data Settings] screen.
	BASIC	Switches to the [Basic Data Settings] screen.
	NO	If pressing Shift + F4 [DEFAULT] displays the 'Set default data?' message, cancels changing the setting.
	OFF	Changes the setting to 'Off'.

Help Screen

To see the details of a parameter, place your cursor over the parameter and press F2 [HELP] to display a help screen. After the screen is displayed, press F2 [EXIT] to return to the original screen.



1.5.1 Unused

Overview

In the “Unused” menu, force control data cannot be specified, except for a comment and frame number. Schedule data that has never been used for force control is always indicated as “Unused”.

> **NOTE**
> Select 'Unused' to avoid unnecessary confusion when the schedule data is no longer used.

[Basic Data Settings] Screen

The [Basic Data Settings] screen (Unused) and its settings are indicated below.
Only comments and frame numbers can be entered.

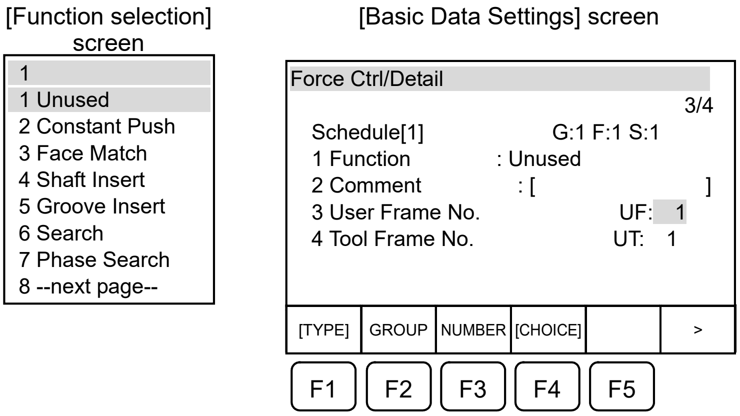


Fig. 1.5.1 Teaching “Unused” detailed data

Table 1.5.1 (a) [Basic data settings] Screen

Item	Description
Function	Select 'Unused' from the menu ([Function selection] screen). (For information on functions other than 'Unused', refer to "Basic Function Guide: 1.5.2 Constant Push / Face Match" to "Basic Function Guide: 1.5.6 Threading".)
Comment	Enter a comment for identifying the schedule data. Maximum number of characters: 16 characters.
User Frame No.	The user frame number.
Tool Frame No.	The tool frame number.
G F S	G represents a motion group number at the time of teaching. F represents a force control number. S represents a force sensor number. (These settings cannot be changed.) "Defaults : 1 1 1 "

Function keys

The function keys used on the [Basic Data Settings] screen (Unused) are indicated below.

Table 1.5.1 (b) Function keys

Key	Item	Description
F1	TYPE	Allows you to change the display to a menu other than the force control menu.
F2	GROUP	Allows you to change motion groups.
F3	NUMBER	Allows you to display the screen for another schedule number.
F4	CHOICE	Displays the choices for the setting.

1.5.2 Constant Push / Face Match

Overview

The 'Constant Push' function is suitable for all operations where the workpiece is pushed with a constant force.

In the 'Face Match' function menu, the settings for matching the face of the workpiece held in the robot hand with the face of the object, such as when a workpiece is inserted into the chuck of a machine tool, can be made.

Two types of setting screens are provided. The user must specify the settings on the [Basic data] screen, and enter those items on the [Performance data] screen as needed.

> **NOTE**
> 1 If the robot is a CRX robot and the software version is 7DF5/05 or later, "Constant Push" can also be used with the internal sensor. In this case, no external force sensor is necessary.
> 2 If the robot is a CRX robot and the software version is 7DF5/11 or later, "Face Match" can also be used with the internal sensor. In this case, no external force sensor is necessary. However, if the diameter of the matching face of the workpiece is small, the faces may not be matched completely with the internal sensor. (Use a diameter of 50 mm or more for good results.)
> 3 'Face Match' function have its own parameters. So there are some differences between 'Constant Push' and 'Face Match' in the performance screen.
> (Refer to [Performance Data] Screen.)
> 4 The 'Face Match' function cannot be used with a 3-axis force sensor.
> 5 If you use 3-axis force sensor, its own parameters are added in the [Basic Data Settings] screen of 'Constant Push'.
> (Refer to [Basic Data Settings] screen.)
> 6 The screens are different for robots that support “parameter auto tuning” and for robots that do not.

[Function selection] screen

1
1 Unused
2 Constant Push
3 Face Match
4 Shaft Insert
5 Groove Insert
6 Search
7 Phase Search
8 --next page--

[Basic Data Settings] screen

For robots "parameter auto tuning" is supported

Force Ctrl/Basic	
	1/12
Schedule[1]	G:1 F:1 S:1
1 Function	: Constant Push
2 Sensor	: Integrated Sensor
3 Comment	: [ ]
4 User Frame No.	UF: 0
5 Tool Frame No.	TF: 1
6 Pushing Direction	User: -Z
7 Approach Dist. Limit	: 20.00 mm
8 Pushing Time	: 20.00 sec
9 Pushing Force	: 15.00 N
10 Max Force Limit	: 50.00 N
11 Param. Auto Tune	: --------

[TYPE] GROUP NUMBER [CHOICE] PERFORM >

F1 F2 F3 F4 F5

[Basic Data Settings] screen

For robots "parameter auto tuning" is not supported

Force Ctrl/Basic	
	1/12
Schedule[1]	G:1 F:1 S:1
1 Function	: Constant Push
2 Comment	: [ ]
3 Pushing Direction	User: -Z
4 Contact F Threshold	: 10.00 N
5 Approach Velocity	: 1.00 mm/s
6 User Frame No.	UF: 1
7 Tool Frame No.	TF: 1
8 Pushing Force	: 10.00 N
9 Approach Dist. Limit	: 5.00 mm
10 Pushing Time	: 20.00 sec
11 F.Ctrl. Gain Auto Modify	: OFF
Prev. Result	: No Change
12 Force Control Gain	: Detail

[TYPE] GROUP NUMBER [CHOICE] PERFORM >

F1 F2 F3 F4 F5

[ParameterAuto Tune] screen

Force Ctrl/Basic	
	1/5
Schedule[1]	G:1 F:1 S:1
1 Function	: Constant Push
2 Comment	: [ ]
Param. Auto Tune	: -----
3 Approach Velocity	: 1.00 mm/s
4 Contact F Threshold	: 10.00 N
5 Pushing Impedance	: [Master Freq.]

[TYPE] GROUP NUMBER [CHOICE] PERFORM >

F1 F2 F3 F4 F5

[Force Ctrl/Gain] screen

Force Ctrl/Gain	
1/1	
Schedule[1]	G:1 F:1 S:1
Function	: Constant Push
1 Pushing Impedance	: [Master Freq.]

[TYPE] GROUP NUMBER [CHOICE] >

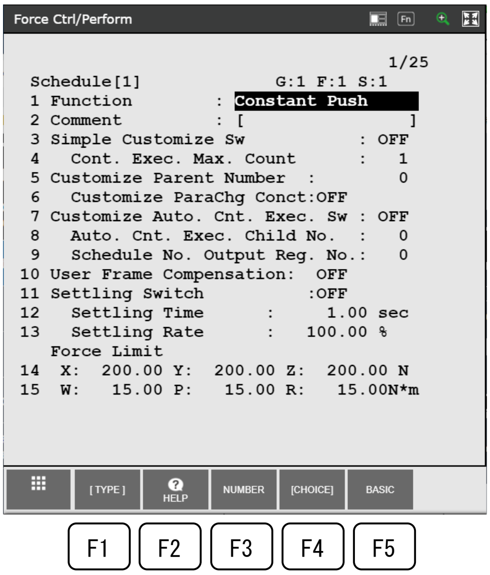
F1 F2 F3 F4 F5

Setting for 3-Axis Sensor

....	
11 3-Axis FS ContactP. Position	: TOOL
12 Setting Method	: Frame
13 [-]Pos. Reg. No.	: 0
14 [-]Distance	: 0.0 mm
....	

Fig. 1.5.2 (a) Teaching "Constant Push" detailed data (1/2)

［Performance Data Settings］ Screen（1/2）



［Performance Data Settings］ Screen（2/2）

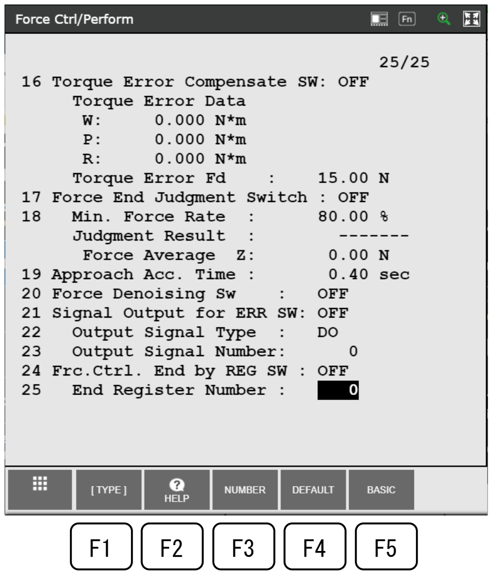


Fig. 1.5.2 (b) Teaching "Constant Push" detailed data (2/2)

[Function selection] screen

```
                        1
 1 Unused
 2 Constant Push
 3 Face Match
 4 Shaft Insert
 5 Groove Insert
 6 Search
 7 Phase Search
 8 --next page--
```

[Basic Data Settings] screen
For robots “parameter auto tuning” is supported

```
Force Ctrl/Basic
                                          1/12
  Schedule[1]                  G:1 F:1 S:1
  1 Function            : Face Match
  2 Sensor              : Ext. Force Sensor
  3 Comment             : [                 ]
  4 User Frame No.               UF:   1
  5 Tool Frame No.               TF:   1
  6 Pushing Direction          User: -Z
  7 Approach Dist. Limit   :     5.00 mm
  8 Pushing Force          :    10.00 N
  9 Max Force Limit        :    30.00 N
 10 Param. Auto Tune           : --------
[TYPE]  GROUP  NUMBER  [CHOICE]  PERFORM  >
 F1      F2      F3      F4        F5
```

[ParameterAuto Tune] screen

```
Force Ctrl/Auto Tune
                                          1/16
  Schedule[1]                  G:1 F:1 S:1
  1 Function            : Face Match
  2 Comment             : [                 ]
  3 Param. Auto Tune    :
  4 Approach Velocity   :      1.00 mm/s
  5 Contact F Threshold  :    10.00 N
  6 Pushing Impedance    : [Master Freq.]
  7 Check Orientation Change  :  ON
  8    Change MAX Limit   :   10.00 deg
  9    Pushing Time       :   20.00 sec
 10 Force End Judgment Switch : OFF
 11      Min. Force Rate    :   80.00 %
         Judgment Result   :        -------
           Force Average   Z:       0.00 N
 12 Torque End Judgment Switch: OFF
 13      Max. Torque       :    0.50 N*m
         Judgment Result   :      -------
           Torque Average W:    0.00 N*m
                          P:    0.00 N*m
 14 Vel. End Judgment Switch   : OFF
 15      Max. Velocity     :    0.30 mm/s
         Judgment Result   :        -------
           Vel. Average    Z:   0.00 mm/s
 16 Fast Ins. Switch       :         ON
 17      Fast Ins. Multiplier :    1.00
 18      Fast Ins. Acc. Time:      0.40 sec
 19 Approach Acc. Time     :      0.70 sec
[TYPE]  GROUP  NUMBER  [CHOICE]  [TYPE]  >
 F1      F2      F3      F4        F5
```

[Basic Data Settings] screen
For robots “parameter auto tuning” is not supported

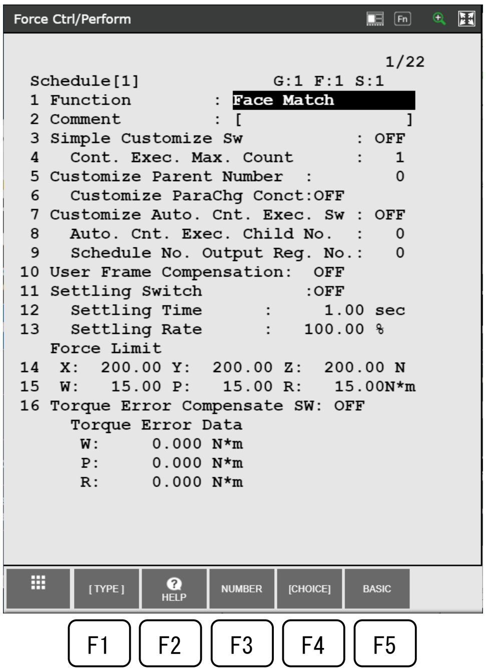
```
Force Ctrl/Basic
                                          1/12
  Schedule[1]                  G:1 F:1 S:1
  1 Function            : Face Match
  2 Comment             : [                 ]
  3 Pushing Direction          User: -Z
  4 Contact F Threshold   :     10.00 N
  5 Approach Velocity     :      1.00 mm/s
  6 User Frame No.               UF:   1
  7 Tool Frame No.               TF:   1
  8 Pushing Force         :     10.00 N
  9 Approach Dist. Limit  :      5.00 mm
 10 Check Orientation Change    : ON
 11     Change MAX Limit    :   10.00 deg
 12 Pushing Time          :     20.00 sec
 13 F.Ctrl. Gain Auto Modify  :      OFF
        Prev. Result      :    No Change
 14 Force Control Gain    :          Detail
[TYPE]  GROUP  NUMBER  [CHOICE]  PERFORM  >
 F1      F2      F3      F4        F5
```

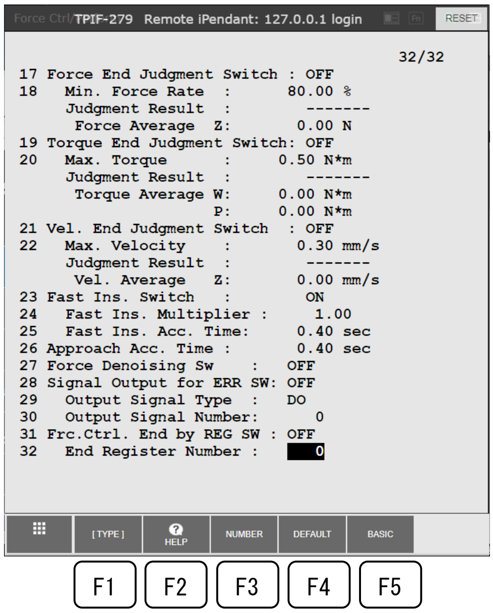
[Force Ctrl/Gain] screen

```
Force Ctrl/Gain
  Schedule[1]                  G:1 F:1 S:1
    Function            : Face Match
  1 Pushing Impedance    : [Master Freq. ]
[TYPE]  GROUP  NUMBER  [CHOICE]           >
 F1      F2      F3      F4        F5
```

Fig. 1.5.2 (c) Teaching "Face Match" detailed data (1/2)

［Performance Data Settings］ Screen（1/2） ［Performance Data Settings］ Screen（2/2）





(*) Parameters from No.17 to 26 are not displayed for robots that support “parameter auto tuning”.

Fig. 1.5.2 (d) Teaching "Face Match" detailed data (2/2)

Adjusting the Parameters of the Constant Push / Face Match Function

1 Display the [Basic Data Settings] screen for the 'Constant Push' function and 'Face Match' function.
2 Configure 'Pushing Direction', 'UFrame Number', and 'UTool Number'.
3 If the function supports parameter auto tuning, execute "Parameter Auto Tuning".
(For details, refer to "Basic Functions Guide: 1.10 FORCE CONTROL PARAMETER AUTO TUNING".)
If the function does not support parameter auto tuning, execute [F.Ctrl. Gain Auto Modify].
(Refer to "Basic Function Guide: 1.11.2 Force Control Gain Auto Tuning Instruction".)
4 Configure the other parameters on the [Basic Data Settings] screen.
5 Configure the parameters on the [Performance Data Settings] screen, as required.

NOTE

For the outline of force control instruction programming, refer to "Basic Function Guide: 1.1 NOTES/RESTRICTIONS", and "Basic Function Guide: 1.2 TEACHING PROCEDURE".

The procedure for tuning other parameters after completion of automatic force control gain adjustment is shown below.
(If "Parameter Auto Tuning" was executed, the following procedure is unnecessary.)

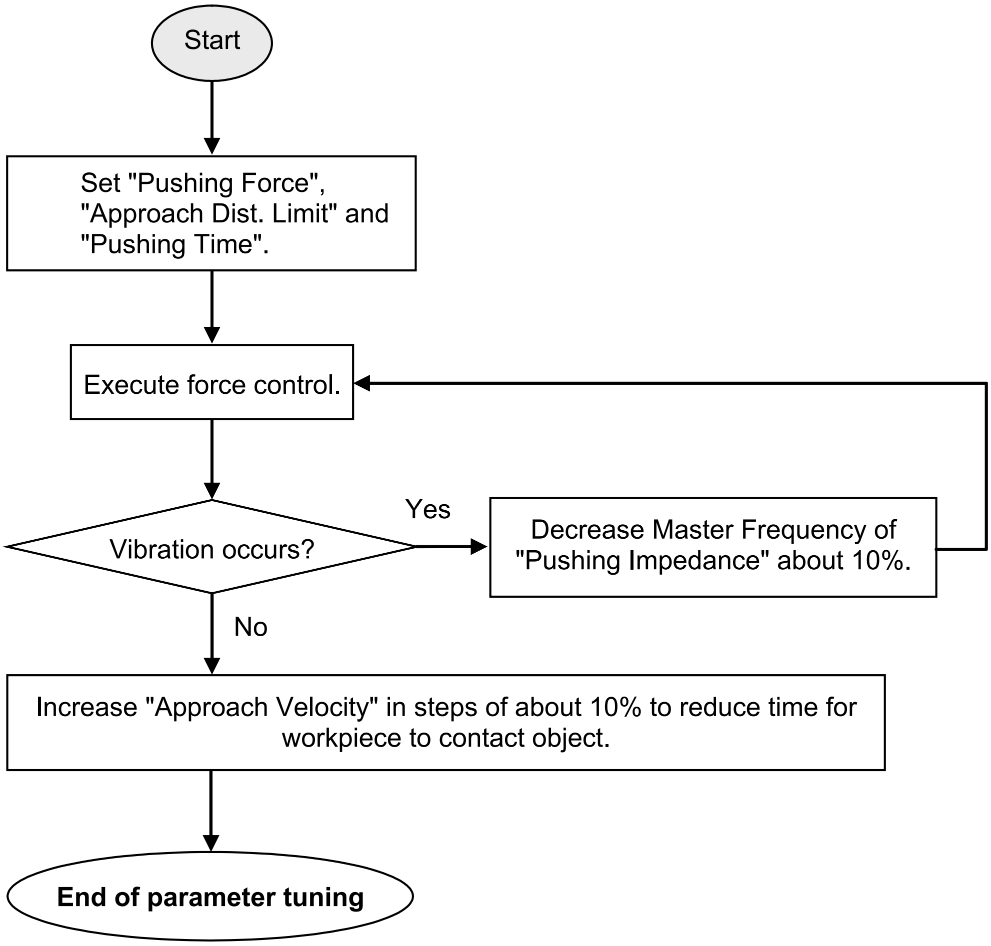


Fig. 1.5.2 (e) Adjusting Other Parameters

[Basic Data settings] screen

Parameters shown in this section must be set.

Table 1.5.2 (a) [Basic Data settings] Screen

Item	Description
Function	Select the function to set from the menu ([Function selection] screen). Select 'Constant Push' or 'Face Match'
Sensor Type	Select the type of sensor being used. For the CRX series, select either "External Force Sensor" or "Internal Sensor". A force sensor is unnecessary if "Internal Sensor" is selected. For robots other than the CRX series, "External Force Sensor" is automatically selected and cannot be changed. "Default : External Force Sensor"
Comment	Enter a comment for identifying the schedule data. Maximum number of characters: 16 characters.
User Frame Number	Enter the number of the user frame to use when pushing. (Enter the user frame number that was set in "Basic Functions Guide: 1.2 TEACHING PROCEDURE".) "Default : UF:0"
Tool Frame Number	Enter the number of the tool frame to use when pushing. (Enter the user tool number that was set in "Basic Functions Guide: 1.2 TEACHING PROCEDURE".) "Default : TF:1"
Pushing Direction	Enter the direction to push using the user frame that is set. "Default : -Z" If the Function is 'Constant Push', [TOOL] or [USER] is displayed before the [Pushing Direction] setting.
	Tool: The "User Frame Compensation" in the "Performance data" is set to "TOOL FRAME". In this case, the position of the user coordinate system is internally compensated to the position of the tool coordinate system designated by "Tool Frame No." at the beginning of the force control. (Refer to 1.8 "USER FRAME COMPENSATION".)
	User: The "User Frame Compensation" in the "Performance data" is set to other than "TOOL FRAME". (Refer to 1.8 "USER FRAME COMPENSATION".)
Approach Dist. Limit	Enter the distance that the workpiece can move during force control. An alarm occurs if contact is not made with the target after the workpiece has moved the amount set here. "Default : 5.00 mm"
Approach Velocity	Enter the target operation velocity until contact is made with the target. "Default : 1.00 mm/s" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
Contact F Threshold	Enter the threshold value for determining whether contact has been made with the target. "Default : 10.00 N" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen. **⚠ CAUTION** The cycle time may get worse if this value is too high, because the actual pushing operation starts after contact is made.
Pushing Force	Enter the target pushing force for the actual pushing operation. "Default : 30.00 N"

Item	Description
Check Orientation Change Switch	A switch that is used to check the Orient change during Face Match. This can be set to "ON" or "OFF". If this is set to "ON", the amount of change in the orientation during Face Match will be checked against the teaching orientation. "Default : ON" **NOTE** This parameter can be used with 'Face Match'. For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
Change MAX Limit	If [Enable Orientation Change Switch] is set to "ON", enter the upper limit of the amount of change in the orientation from the teaching orientation to allow. An alarm occurs if the change in orientation exceeds this value. "Default : 10.00 deg" **NOTE** This parameter can be used with 'Face Match'. For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
Pushing Time	Enter the length of time to perform 'Constant Push' or 'Face Match'. When this length of time elapses after contact, 'Constant Push' or 'Face Match' ends. "Default : 20.00 sec" **NOTE** In case of Face Match and for robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
Max Force Limit	Perform adjustment so that this value is not exceeded during parameter auto tuning. Set a value greater than [Pushing Force]. **NOTE** This parameter is displayed only for robots that support parameter auto tuning.
Param. Auto Tune	Display the status of and execute parameter auto tuning. '----', 'DONE', 'STOPPED', or 'FAILURE' is displayed as the status of automatic adjustment. If you press Shift+F2, auto tuning is executed. If you press F3, the auto tuned parameters are displayed. "Default : ----" **NOTE** This parameter is displayed only for robots that support parameter auto tuning.
G F S	G represents a motion group number at the time of teaching. F represents a force control number. S represents a force sensor number. (These settings cannot be changed.) "Defaults : 1 1 1 "

Table 1.5.2 (b) [Basic Data Settings] Screen
(“Constant Push” when using a 6-axis force sensor or ”Face Match” with robots that do not support “parameter auto tuning”)

Item	Description
F.Ctrl. Gain Auto Modify	This item is the switch used for automatic force control gain tuning. (Refer to 1.11.2, "Force Control Gain Auto Tuning Instruction".) "Default : OFF"
Prev. Result	Displays the previous result for [F.Ctrl. Gain Auto Modify]. "Default : No Change"
Force Control Gain	Perform the operation below to switch to the [Force Control Gain] screen. • Set this parameter manually. Move the cursor to this line then press the ENTER key. The screen display switches to the [Force Control Gain] detail screen. (For the parameters that can be set on this screen, refer to 1.6 "FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".)

The following settings on the [Basic Data Settings] screen are only for a 3-axis force sensor.
(For a detailed description using a schematic design, refer to "Basic Function Guide: 1.9 3-AXIS FORCE SENSOR SETTING".)

Table 1.5.2 (c) [Basic Data settings] Screen
(For “Constant Push” when using a 3-axis force sensor)

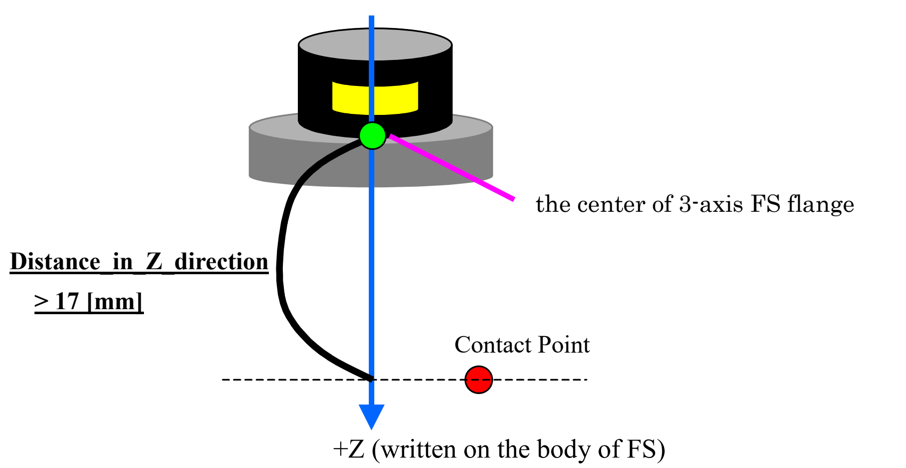
<table>
<tr><th>Item</th><th colspan="2">Description</th></tr>
<tr><td rowspan="3">3-Axis FS ContactP.
Position</td><td colspan="2">This parameter specifies whether to move a contact point with a robot motion or to fix the contact point in space for the 3-axis force sensor.
The 3-axis force sensor detects Fz, Mx, My. The force control for 3-axis force sensor estimates Fx, Fy, Mz at the contact point.
This parameter sets whether the contact point is on the mechanical interface coordinate system or on the world coordinate system. In other words, this parameter sets whether the positional relationship between a robot wrist flange and the contact point is fixed or the positional relationship between the world coordinate and the contact point is fixed.
Select [TOOL] or [USER].</td></tr>
<tr><td>TOOL</td><td>Move a contact point with a robot motion, as an origin of a tool coordinate system, on the world coordinate system.
Set the value that is given by after-mentioned parameter on the mechanical interface coordinate to the contact point.</td></tr>
<tr><td>USER</td><td>Fix a contact point, as an origin of a user coordinate system, on the world coordinate system.
Set the value that is given by after-mentioned parameter on the world coordinate system to the contact point.</td></tr>
<tr><td rowspan="2">Setting Method
(3-Axis ContactP.
Position)
(Fig 1.5.2(d))</td><td colspan="2">This parameter specifies the setting method for the position of a contact point for the 3-axis force sensor.
The setting value of the coordinate system and the position register described following are the values that are set at the beginning of the force control, as is the case with other parameters of the schedule data.
Select [TOOL], [Pos. Reg.], or [PushDirShift].
⚠ **CAUTION**
When specifying the method for determining the position to use as the contact point in [Setting Method] for the 3-axis force sensor function, the distance between the contact point and the flange center point of the 3-axis force sensor in the Z direction (this direction is indicated on the force sensor unit) must be greater than 17 mm. Take care when the robot operations cause this distance to vary.</td></tr>
<tr><td colspan="2">

Fig. 1.5.2 (d) Distance between the contact point and the flange center point of the 3-axis force sensor in the Z direction</td></tr>
</table>

Item	Description	
Setting Method (3-Axis ContactP. Position) (Fig 1.5.2(d))	Frame	• If "3-Axis FS ContactP. Position" is "TOOL" : A contact point is set to an origin of a tool coordinate system designated by "Tool Frame No." in the "Basic data". • If "3-Axis FS ContactP. Position" is "USER" : A contact point is set to an origin of a user coordinate system designated by "User Frame No." in the "Basic data". In this case, if "User Frame Compensation" in the "Performance data" is valid, the compensated user coordinate system is used as the user coordinate system.
	Pos. Reg	The position of a contact point is set to the values of X, Y, Z that are set to the position register, designated by after-mentioned "Pos. Reg. No.", at the beginning of the force control. • If "3-Axis FS ContactP. Position" is "TOOL" : The position of a contact point is set to the values of the position register on the mechanical interface coordinate system. • If "3-Axis FS ContactP. Position" is "USER" : The position of a contact point is set to the values of the position register on the world coordinate system.
	PushDirShift	• If "3-Axis FS ContactP. Position" is "TOOL" : A contact point is set to a point that an origin of the tool coordinate system designated by "Tool Frame No." is shifted by after-mentioned "Distance" in the direction designated by "Pushing Dir.". • If "3-Axis FS ContactP. Position" is "USER" : A contact point is set to a point that an origin of the user coordinate system designated by "User Frame No." is shifted by after-mentioned "Distance" in the direction designated by "Pushing Dir.".
Pos. Reg. No. (3-Axis ContactP. Position)	Enter the number of the position register to use when the position register is set as the above mentioned "Setting Method" with the 3-axis force sensor function.	
Distance (3-Axis ContactP. Position)	Enter the distance to use when the pushing direction shift is set as the above mentioned 'Setting Method' with the 3-axis force sensor function. "Unit : mm"	
F.Ctrl. Gain Auto Modify	This item is the switch used for automatic force control gain tuning. Set 'On' to execute auto adjustment of the force control gain. (Refer to 1.11.2, "Force Control Gain Auto Tuning Instruction".) "Default : OFF" **NOTE** This parameter is displayed only for robots that do not support parameter auto tuning.	
Prev. Result	Displays the previous result for [F.Ctrl. Gain Auto Modify]. "Default : No Change" **NOTE** This parameter is displayed only for robots that do not support parameter auto tuning.	
Force Control Gain	Perform the operation below to switch to the [Force Control Gain] screen. • Move the cursor to [DETAIL], and press the [ENTER] key on the teach pendant of the robot controller. The [Force Control Gain] screen is displayed. (For information on the parameters that can be set from the [Force Control Gain] screen, refer to "Basic Function Guide: 1.6 FORCE CONTROL GAIN (IMPEDANCE PARAMATERS)".)	

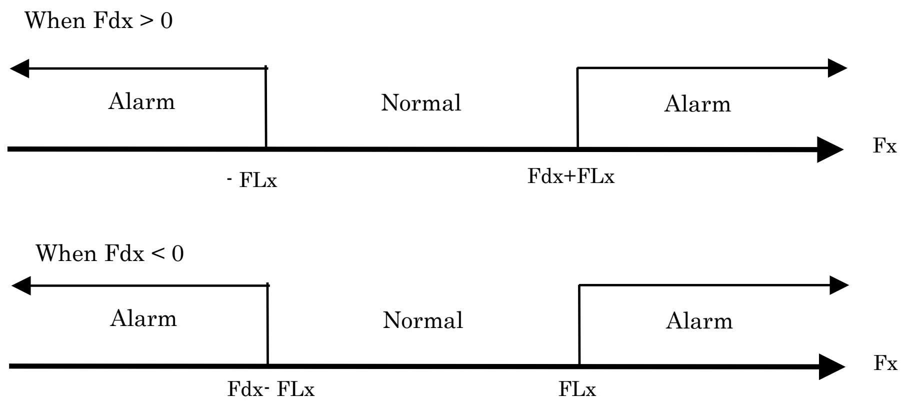
[Performance Data] Screen

Parameters shown in this section are for advanced users.

Table 1.5.2 (d) [Performance Data] Screen

Item	Description
Function	A desired function is selected from "Function selection screen". In this case, choose from "Constant Push" or "Face Match".
Comment	Enter a comment for identifying the schedule data. Maximum number of characters: 16 characters.
Simple Customize Sw	This switch is for force control continuous execution. This can be set to 'On' or 'Off'. If [Simple Customize Sw] is set to 'On', you can execute it after an arbitrary force control schedule. (Refer to "Basic Function Guide: 1.7.3 Simple Customization Function".) "Default: OFF"
Cont. Exec. Max. Count	Enter an integer for the number of times a force control schedule with the simple customization function enabled can be executed continuously. (Refer to "Basic Function Guide: 1.7.3 Simple Customization Function".) "Default : 1"
Customize Parent Number	Enter this when executing force control continuously. (Refer to "Basic Function Guide: 1.7.4 Customization Function".) "Default: 0"
Customize ParaChg Connection	This function is used when executing force control continuously. Select 'Both D', 'P2C', 'C2P', or 'Off'. (Refer to "Basic Function Guide: 1.7.4 Customization Function".) "Default: OFF"
Customize Auto. Cnt. Exec. Sw (Customize Auto. Cnt. Exec.)	This parameter specifies a switch for "Customize Auto. Cnt. Exec." function. This can be set to 'On' or 'Off'. "Customize Auto. Cnt. Exec." function enables to execute a series of the force control schedule data, which are combined with customization function, with a single force control instruction of the top parent schedule data. Set "Customize Auto. Cnt. Exec. Sw" to ON for all schedule data that are combined with "Customize Auto. Cnt. Exec." function. (Refer to "Basic Function Guide: 1.7.5 Customization Automatic Continuous Execution Function".) "Default: OFF"
Auto. Cnt. Exec. Child No. (Customize Auto. Cnt. Exec.)	Enter the number of the schedule data to execute next in 'Customization Auto Continuous Execution'. For schedule data with this parameter specified, set the number of this schedule data in [Customize Parent Number] on the [Performance Data Settings] screen. "Customize Auto. Cnt. Exec." function can link the schedule data up to 10. "Default: 0"
Schedule No. Output Reg. No. (Customize Auto. Cnt. Exec.)	Enter the number of the Numeric register that is used for 'Customization Auto Continuous Execution' function. When "Customize Auto. Cnt. Exec." function is executed, a running schedule data number is written to this Numeric register. If the series of the schedule data ends normally, 0 is written to this Numeric register. Only "Schedule No. Output Reg. No." of the top parent in the series of the schedule data is used. "Schedule No. Output Reg. No." of other than the top parent are not used. If "Schedule No. Output Reg. No." of the top parent equals to 0, this function does not output to the Numeric Register. When the series of the schedule data is executed, with the value that is output to the Numeric Register, it is possible to know whether all schedule data ends normally or if not, which schedule data fails. "Default: 0"

Item	Description
User Frame Compensation SW	This function uses *i*RVision to adjust the user frame set for the target surface. It is enabled when there is a possibility that the tilt of the target may change. Select 'Off', 'Pos. Reg.', or 'VISION REG'. If the "Function" is "Face Match", the User Frame Compensation must be used in combination with the OFFSET or VOFFSET instruction. If the "Function" is "Constant Push", compensates the user frame in combination with the OFFSET or VOFFSET instruction or compensates based on a tool coordinate system. If the "Function" is "Constant Push" and "User Frame Compensation" is set to "TOOL FRAME", the position of the user coordinate system is internally compensated to the position of the tool coordinate system designated by "Tool Frame No." at the beginning of the force control. With this function, the pushing direction can be set to the direction based on the tool coordinate system for "Constant Push". (Refer to 1.8, "USER FRAME COMPENSATION".) "Default : OFF"
Settling Switch	Settling involves reducing the pushing force after pushing is completed. Sets the switch used for settling to 'On' or 'Off'. If this is set to 'On', it activates if the workpiece vibrates due to a large shock when the hand is detached after pushing stops. "Default : OFF"
Settling Time	Enter the time until settling stops after it is started. "Default : 1.00 sec"
Settling Rate	Enter the settling ratio for the pushing force. The force is ultimately reduced to “Pushing Force” x “Settling Rate” / 100. If this “Settling Rate” is set to 100 %, settling is not performed. If this “Settling Rate” is set to 0 %, the force is reduced to 0. "Default : 100.00% "

Item	Description
Force Limit (Fig. 1.5.2 (e))	An alarm occurs if the force meets the conditions indicated in Figure 1.5.2 (e). Refer to "APPENDIX: B ALARM CODES OF FORCE CONTROL" and remove a cause of the alarm. Increase the values of this parameter after all measures are taken. Values are set for forces in the X, Y, and Z directions and moments in the W, P, and R directions. For example, for the force in the X direction, the following expressions are given: $Fx < -FLx$ or $Fx > Fdx + FLx$ (when $Fdx > 0$) $Fx > FLx$ or $Fx < Fdx - FLx$ (when $Fdx < 0$) Fx : Force generated during pushing or face matching (X direction) FLx : X component of the force limit Fdx : Target force in the X direction If the pushing direction is X or -X, Fdx is "Pushing Force". Otherwise, Fdx = 0. The same relationship holds for Y, Z, W, P, and R. "Defaults : X: 200.00 Y: 200.00 Z: 200.00 N W: 15.00 P: 15.00 R: 15.00 N*m" "Unit : N, N*m"  Fig. 1.5.2 (e) Force Limit and the occurrence of an alarm
Torque Error Compensate SW	This switch is used for torque error compensation. This can be set to 'On' or 'Off'. If this switch is turned ON, torque error compensation is performed, using Torque Error Data W, P, and R, and Torque Error Fd, indicated below. * Execute the torque error acquisition instruction before turning on this switch. (Refer to 1.11.3, "Torque Error Acquisition Instruction") "Default : OFF"
Torque Error Data	Displays the value estimated from the moment information of the force sensor when the robot is actually pushed with "Torque Error Fd" when "TRQ ERROR" is performed. W, P, and R are the values about the X-axis, Y-axis, and Z-axis, respectively, of the user frame used. If “Torque Error Compensate SW” is turned ON, these values are used to correct the torque error. (The values cannot be modified.) "Defaults : W : 0.000 N*m P : 0.000 N*m R : 0.000 N*m"
Torque Error Fd	Displays the value of the force actually exerted when "TRQ ERROR" is performed. If “Torque Error Compensate SW” is turned ON, this setting is used to correct the torque error. (This value cannot be modified.) "Default : 30.00 N"

Item	Description
Force End Judgment Switch	This item is the switch of the function for ending operation after checking whether a proper force has been generated. This can be set to 'On' or 'Off'. When this switch is turned ON in "Constant Push" or "Face Match", force control ends even within [Pushing Time] of [Basic data] if the result of force judgment is "SUCCESS". An alarm occurs if [Judgment Result] is not "SUCCESS" when [Pushing Time] elapses. (In Face Match, if two or more of [Force End Judgment Switch], [Torque End Judgment Switch], or [Vel. End Judgment Switch] are "ON", force control ends when the judgment of all functions that are on is "SUCCESS", even if [Pushing Time] has not elapsed.) "Default : OFF" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
Min. Force Rate	This value is used to judge whether an appropriate amount of force was generated. Enter a ratio. [Judgment Result] is "SUCCESS" if the magnitude of the force in [Pushing Direction] exceeds [Min. Force Rate] x [Pushing Force] / 100. If [Pushing Time] elapses while the above conditions are not met, [Judgment Result] is "FAILURE". "Default : 80.00 %" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
Judgment Result	This item displays [Judgment Result] at the end of "Constant Push" or "Face Match" for which [Force End Judgment Switch] is "ON". If the function has never been executed with [Force End Judgment Switch] set to "ON", "----" is displayed. "Default : -----" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
Force Average	This item displays the force magnitude of [Pushing Direction] at the end of "Constant Push" or "Face Match" for which [Force End Judgment Switch] is "ON". "Default : Z:0 N" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
Torque End Judgment Switch *	This item is the switch of the function for ending operation after checking whether the magnitude of generated torque has been decreased to a proper level. This can be set to 'On' or 'Off'. When this switch is "ON" in "Face Match", force control ends even within [Pushing Time] of [Basic data] if [Judgment Result] is "SUCCESS". An alarm occurs if [Judgment Result] is not "SUCCESS" when [Pushing Time] elapses. (In "Face Match", if two or more of [Force End Judgment Switch], [Torque End Judgment Switch], or [Vel. End Judgment Switch] are "ON", force control ends when the judgment of all functions set to On is "SUCCESS", even if [Pushing Time] has not elapsed.) "Default : OFF" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.

Item	Description
Max. Torque *	Enter the value to use to judge whether the magnitude of the generated torque is smaller than the appropriate value. If the magnitude of the torque about the axes other than the axis for [Pushing Direction] is less than or equal to [Max. Torque], [Judgment Result] is "SUCCESS". If [Pushing Time] elapses while the above conditions are not met, [Judgment Result] is "FAILURE". "Default : 0.50 N*m" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
Judgment Result *	This item displays [Judgment Result] at the end of "Constant Push" or "Face Match" for which [Torque End Judgment Switch] is "ON". If the function has never been executed with [Torque End Judgment Switch] set to "ON", "----" is displayed. "Default : -----" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
Torque Average *	This item displays the torque about the axes other than the axis for [Pushing Direction] at the end of "Face Match" for which [Torque End Judgment Switch] is set to "ON". (If the axis for [Pushing Direction] is Z, W for indicating rotation about the X-axis and P for indicating rotation about the Y-axis are displayed. Similarly, If the axis for “Pushing Direction” is X, P and R are displayed. If the axis for “Pushing Direction” is Y, W and R are displayed.) "Defaults : W：0.00 N*m P：0.00 N*m" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
Vel. End Judgment Switch *	This item is a switch of the function for ending operation after checking whether the velocity in the pushing direction has been decreased sufficiently. This can be set to 'On' or 'Off'. When this switch is "ON" in "Face Match", force control ends even within [Pushing Time] of [Basic data] if [Judgment Result] is "SUCCESS". An alarm occurs if [Judgment Result] is not "SUCCESS" when [Pushing Time] elapses. (In Face Match, if two or more of [Force End Judgment Switch], [Torque End Judgment Switch], or [Vel. End Judgment Switch] are "ON", force control ends when the judgment of all functions that are "ON" is "SUCCESS", even if [Pushing Time] has not elapsed.) "Default : OFF" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
Max. Velocity *	The value of this parameter is used for the pushing direction velocity judgment. If the magnitude of the velocity in the pushing direction is less than or equal to [Max. Velocity], [Judgment Result] is "SUCCESS". If [Pushing Time] elapses while the above conditions are not met, [Judgment Result] is "FAILURE". "Default : 0.30 mm/s" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.

<table>
<tr><th>Item</th><th>Description</th></tr>
<tr><td>Judgment Result *</td><td>This item displays [Judgment Result] at the end of "Constant Push" or "Face Match" for which [Vel. End Judgment Switch] is "ON".
If the function has never been executed with [Vel. End Judgment Switch] set to "ON", "----" is displayed.
"Default : -----"
NOTE
For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.</td></tr>
<tr><td>Vel. Average *</td><td>This item displays the velocity for [Pushing Direction] at the end of "Face Match" for which [Vel. End Judgment Switch] is set to "ON".
"Default : Z: 0.00 mm/s"
NOTE
For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.</td></tr>
<tr><td>Fast Ins. Switch *</td><td>This switch is for the function that accelerates the orientation correction operation.
This can be set to 'On' or 'Off'.
If it is 'On', the orientation correction operation is accelerated.
"Default : ON"
NOTE
For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.</td></tr>
<tr><td>Fast Ins. Multiplier *</td><td>Enter the speed of the orientation correction operation. If [Fast Ins. Switch] is "ON" and a value larger than the current value of [Fast Ins. Multiplier] is entered, the orientation correction operation becomes faster.
"Default : 1.00"
NOTE
For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
⚠ CAUTION
When increasing the [Fast Ins. Multiplier] value, increase it in increments of '0.50' for safety purposes.</td></tr>
<tr><td>Fast Ins. Acc. Time *</td><td>Enter the acceleration time of the orientation correction operation.
When 'Fast Ins. Switch' is set to 'On', if you enter a value smaller than the current value for [Fast Ins. Acc. Time], the orientation correction operation becomes faster.
"Default : 0.40 sec"
NOTE
For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
⚠ CAUTION
When decreasing the [Fast Ins. Multiplier] value, decrease it in increments of '0.10' for safety purposes.</td></tr>
<tr><td>Approach Acc. Time</td><td>Enter the time until the velocity reaches the [Approach Velocity] on the [Basic Data Settings] screen after the FORCE statement is started.
"Default : 0.40 sec"
NOTE
For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.</td></tr>
<tr><td>Force Denoising Sw</td><td>This parameter enables the "Force Denoising" function. This can be set to 'On' or 'Off'.
If it is 'On', heavy noise is removed from the force data.
This function is useful when:
• tool or work-piece is heavy
• using a tool such as a grinder and that has a big vibration
"Default : OFF"</td></tr>
</table>

Item	Description
Signal Output for ERR SW	This parameter enables the "Signal Output for ERR" function. This can be set to 'On' or 'Off'. If it is 'On', the specified signal is output when an error occurs during execution of force control. "Default : OFF"
Output Signal Type (Signal Output for ERR)	Select the type of signal to output when an error occurs during execution of force control with the error signal output function. Select 'DO', 'RO', or 'FLAG'. "Default : DO"
Output Signal Number (Signal Output for ERR)	Select the number of signal to output when an error occurs during execution of force control with the error signal output function. "Default : 0"
Frc.Ctrl. End by REG SW	This item is the switch of the function for ending operation when the condition specified in [End Register Number] is met. This can be set to 'On' or 'Off'. Normally, operation of "Constant Push" and "Face Match" ends when [Pushing Time] elapses. Also, operation ends earlier if one or more of [Force End Judgment Switch], [Torque End Judgment Switch], or [Vel. End Judgment Switch] is "ON", and the judgment result of all functions that are "ON" is "SUCCESS". If this switch is ON and a value of a Numeric Register whose number is designated by "End Register Number" becomes 1, the force control ends regardless of above conditions. "Default : OFF"
End Register Number	If "Frc.Ctrl. End by REG SW" is ON, • [End Register Number] is automatically set to '0' when the force control statement starts for the schedule to execute. • The force control statement for the schedule being executed exists when [End Register Number] changes to '1'. "Default : 0"
G F S	G represents a motion group number at the time of teaching. F represents a force control number. S represents a force sensor number. (These settings cannot be changed.) "Defaults : 1 1 1 "

* This parameter is used for 'Face Match'. It is not available for 'Constant Push'.

Function keys

The function keys used on the [Basic Data Settings] screen (Constant Push and Face Match) and [Performance Data Settings] screen (Constant Push and Face Match) are indicated below.

Table 1.5.2 (e) Function keys

Key	Item	Description
F1	TYPE	Allows you to change the display to a menu other than the force control menu.
F2	GROUP	Allows you to change motion groups.
	HELP	Display the help screen.
F3	NUMBER	Allows you to display the screen for another schedule number.
F4	CHOICE	Displays the choices for the setting.
	ON	Changes the setting to 'On'.
Shift + F4	DEFAULT	Allows you to set default data of the force control function.
F5	PERFORM / BASIC	Allows you to switch between the basic and performance screens.
	OFF	Changes the setting to 'Off'.

1.5.3 Shaft Insert / Groove Insert / Square Insert

Overview

In the “Shaft Insert” menu, the settings for inserting a cylindrical component are specified.
In the "Groove Insert" menu, the settings for inserting a workpiece into a groove can be made.
In the "Square Insert" menu, the settings for inserting a quadrangular prism workpiece into a rectangular hole can be made.
Two types of setting screens are provided. The user must specify the settings on the Basic data screen, and enter those items on the Performance data screen as needed.

NOTE

1. This function cannot be used with a 3-axis force sensor.
2. The screens are different for robots that support “parameter auto tuning” and for robots that do not.

[Function selection] screen

1
1 Unused
2 Constant Push
3 Face Match
4 Shaft Insert
5 Groove Insert
6 Search
7 Phase Search
8 --next page--

2
1 Hole Search
2 Clutch Search
3 Square Insert
4 Contouring
5 Contouring End
6 Threading
7
8 --next page--

[Basic Data Settings] screen For robots "parameter auto tuning" is supported

Force Ctrl/Basic		1/12
Schedule[1]		G:1 F:1 S:1
1 Function	:	Shaft Insert
2 Comment	:	[ ]
3 User Frame No.		UF: 1
4 Tool Frame No.		TF: 1
5 Insert Direction	:	-Z
6 Insert Depth (Design)	:	20.00 mm
7 Individual Diff. (+)	:	3.00 mm
8 Individual Diff. (-)	:	0.00 mm
9 Pushing Time	:	0.00 sec
10 Max Force Limit	:	30.00 N
11 Param. Auto Tune	:	--------

[TYPE]	GROUP	NUMBER	[CHOICE]	PERFORM	>
F1	F2	F3	F4	F5	

[Parameter Auto Tune] screen

Force Ctrl/Auto Tune		1/16
Schedule[1]		G:1 F:1 S:1
1 Function	:	Shaft Insert
2 Comment	:	[ ]
3 Param. Auto Tune	:	
4 Approach Velocity	:	1.00 mm/s
5 Insert Velocity	:	2.00 mm/s
6 Contact F Threshold	:	10.00 N
7 Insert Force	:	50.00 N
8 Insert Time Limit	:	20.00 sec
9 Insert Impedance	:	[Master Freq.]
10 Check Orientation Change	:	ON
11 Change MAX Limit	:	3.00 deg
12 Velocity Constant Switch	:	ON
13 Velocity Adjust Switch	:	ON
14 Adjustment Gain	:	2.0
15 Starting Rate	:	30.00 %
16 Ending Rate	:	100.00 %
17 Initial Insert Force	:	50.00 N
18 Init Force Keep Depth	:	0.00 mm
19 Insert F. Start Depth	:	0.00 mm
20 Fast Ins. Switch	:	ON
21 Fast Ins. Multiplier	:	2.00
22 Fast Ins. Acc. Time	:	0.40 sec
23 Approach Acc. Time	:	0.70 sec
24 Insert Acc. Time	:	0.70 sec

[TYPE]	GROUP	NUMBER	[CHOICE]	[TYPE]	>
F1	F2	F3	F4	F5	

[Basic Data Settings] screen For robots "parameter auto tuning" is not supported

Force Ctrl/Basic		1/18
Schedule[1]		G:1 F:1 S:1
1 Function	:	Shaft Insert
2 Comment	:	[ ]
3 Pushing Direction	:	-Z
4 Contact F Threshold	:	10.00 N
5 Approach Velocity	:	1.00 mm/s
6 User Frame No.		UF: 1
7 Tool Frame No.		TF: 1
8 Insert Force	:	50.00 N
9 Insert Velocity	:	2.00 mm/s
10 Insert Depth (Design)	:	20.00 mm
11 Individual Diff. (+)	:	3.00 mm
12 Individual Diff. (-)	:	0.00 mm
13 Pushing Time	:	0.00 sec
14 Check Orientation Change	:	ON
15 Change MAX Limit	:	3.00deg
16 Insert Time Limit	:	20.00sec
17 F.Ctrl. Gain Auto Modify	:	OFF
Prev. Result	:	No Change
18 Force Control Gain	:	Detail

[TYPE]	GROUP	NUMBER	[CHOICE]	PERFORM	>
F1	F2	F3	F4	F5	

(*) "Groove Insert" does not support "parameter auto tune function for all robots.

[Force Ctrl/Gain] screen

Force Ctrl/Gain		
1/1		
Schedule[1]		G:1 F:1 S:1
Function	:	Shaft Insert
1 Insert Impedance	:	[Master Freq.]

[TYPE]	GROUP	NUMBER	[CHOICE]		>
F1	F2	F3	F4	F5	

Fig. 1.5.3 (a) Teaching "Shaft Insert" "Groove Insert" and "Square Insert" Detailed Data (1/2)

[Performance Data Settings] Screen (1/2)

```
Force Ctrl/Perform
                                        1/39
 Schedule[1]                   G:1 F:1 S:1
 1 Function           : Shaft Insert
 2 Comment            : [                  ]
 3 Simple Customize Sw            : OFF
 4    Retry Sw                 :      OFF
 5    Cont. Exec. Max. Count      :   1
 6 Customize Parent Number   :        0
 7    Customize ParaChg Conct: OFF
 8 Customize Auto. Cnt. Exec. Sw : OFF
 9    Auto. Cnt. Exec. Child No.   :   0
10    Schedule No. Output Reg. No.:   0
11 User Frame Compensation:   OFF
12 Settling Switch              :   OFF
13    Settling Time         :      1.00 sec
14    Settling Rate         :    100.00 %
15 Initial Insert Force :          50.00 N
16 Velocity Adjust Switch      :  ON
17    Adjustment Gain       :     2.00
18    Starting Rate         :     30.00 %
19    Ending Rate           :     90.00 %
    Force Limit
20  X:   500.00 Y:   500.00 Z:   500.00 N
21  W:    50.00 P:    50.00 R:    50.00N*m
22 Ending Condition Switch     : OFF
       Insert Depth         :      0.00 mm
       Approach Length      :      0.00 mm
       Insert DIR
   [       0.000,      0.000,     -1.000]
23 Torque Error Compensate SW: OFF
       Torque Error Data
        W:       0.000 N*m
        P:       0.000 N*m
        R:       0.000 N*m
       Torque Error Fd      :     50.00 N

[TYPE]  HELP  NUMBER  [CHOICE]  BASIC  >
```

[Performance Data Settings] Screen (2/2)

```
Force Ctrl/Perform
                                        24/39
24 Init Force Keep Depth:      0.00 mm
25 Insert F. Start Depth   :       0.00 mm
26 Velocity Constant Switch   :   ON
27 Force End Judgment Switch : OFF
28     Min. Force Rate    :        80.00 %
       Judgment Result    :              -------
         Force Average    Z:        0.00 N
29 Torque End Judgment Switch:   OFF
30     Max. Torque        :        0.50 N*m
       Judgment Result    :              -------
         Torque Average W:         0.00 N*m
                        P:         0.00 N*m
31 Fast Ins. Switch     :           ON
32     Fast Ins. Multiplier :      2.00
33     Fast Ins. Acc. Time:        0.40 sec
34 Approach Acc. Time :            0.70 sec
35 Insert Acc. Time     :          0.70 sec
36 Force Denoising Sw       :     OFF
37 Signal Output for ERR SW:   OFF
38     Output Signal Type   :      DO
39     Output Signal Number:        0
40 Frc.Ctrl. End by REG SW : OFF
41     End Register Number :        0

[TYPE]  HELP  NUMBER  [CHOICE]  BASIC  >
  F1     F2     F3       F4       F5
```

(*) Parameters from No.15 to 19, from No.24 to 26 and from No.31 to 35 are not displayed for robots that support "parameter auto tuning".

Fig. 1.5.3 (b) Teaching "Shaft Insert" "Groove Insert" and "Square Insert" Detailed Data (2/2)

Adjusting the Parameters for the Shaft Insert, Groove Insert, and Square Insert Functions

1. Display the [Basic Data Settings] screen for the "Shaft Insert", "Groove Insert", and "Square Insert" functions.
2. Configure [Insert Direction], [UFrame Number], [UTool Number], and [Insert Depth (Design)].
3. If the function supports parameter auto tuning, execute "Parameter Auto Tuning".
   (For details, refer to "Basic Functions Guide: 1.10 FORCE CONTROL PARAMETER AUTO TUNING".)
   If the function does not support parameter auto tuning, execute [F.Ctrl. Gain Auto Modify].
   (Refer to "Basic Function Guide: 1.11.2 Force Control Gain Auto Tuning Instruction".)
4. Configure the other parameters on the [Basic Data Settings] screen.
5. Configure the parameters on the [Performance Data Settings] screen, as required.

NOTE

For the outline of force control instruction programming, refer to "Basic Function Guide: 1.1 NOTES/RESTRICTIONS", and "Basic Function Guide: 1.2 TEACHING PROCEDURE".

The procedure for tuning other parameters after completion of automatic force control gain adjustment is shown below.
(If "Parameter Auto Tuning" was executed, the following procedure is unnecessary.)

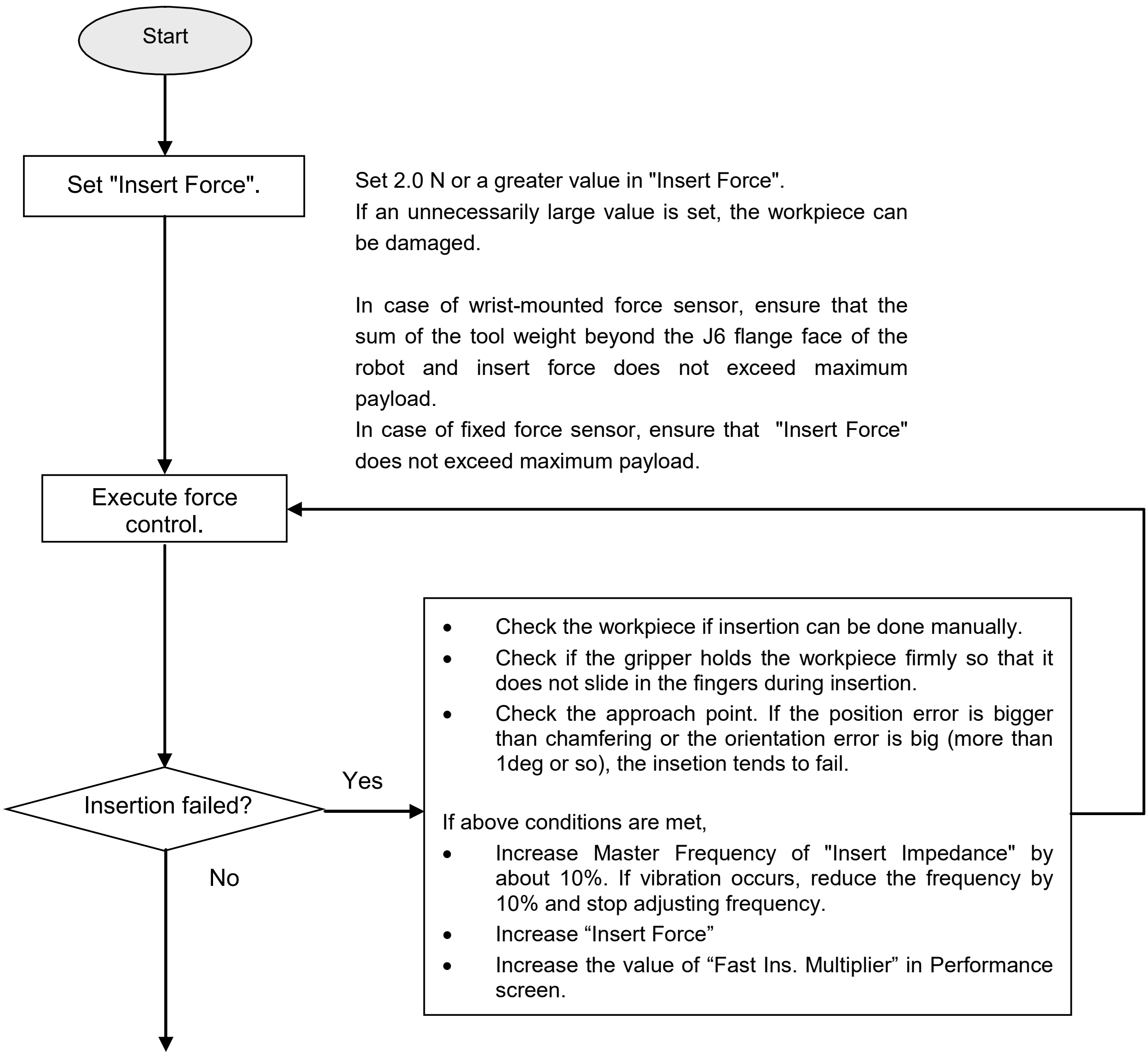


Fig. 1.5.3 (c) Adjusting Other Parameters (1/2)

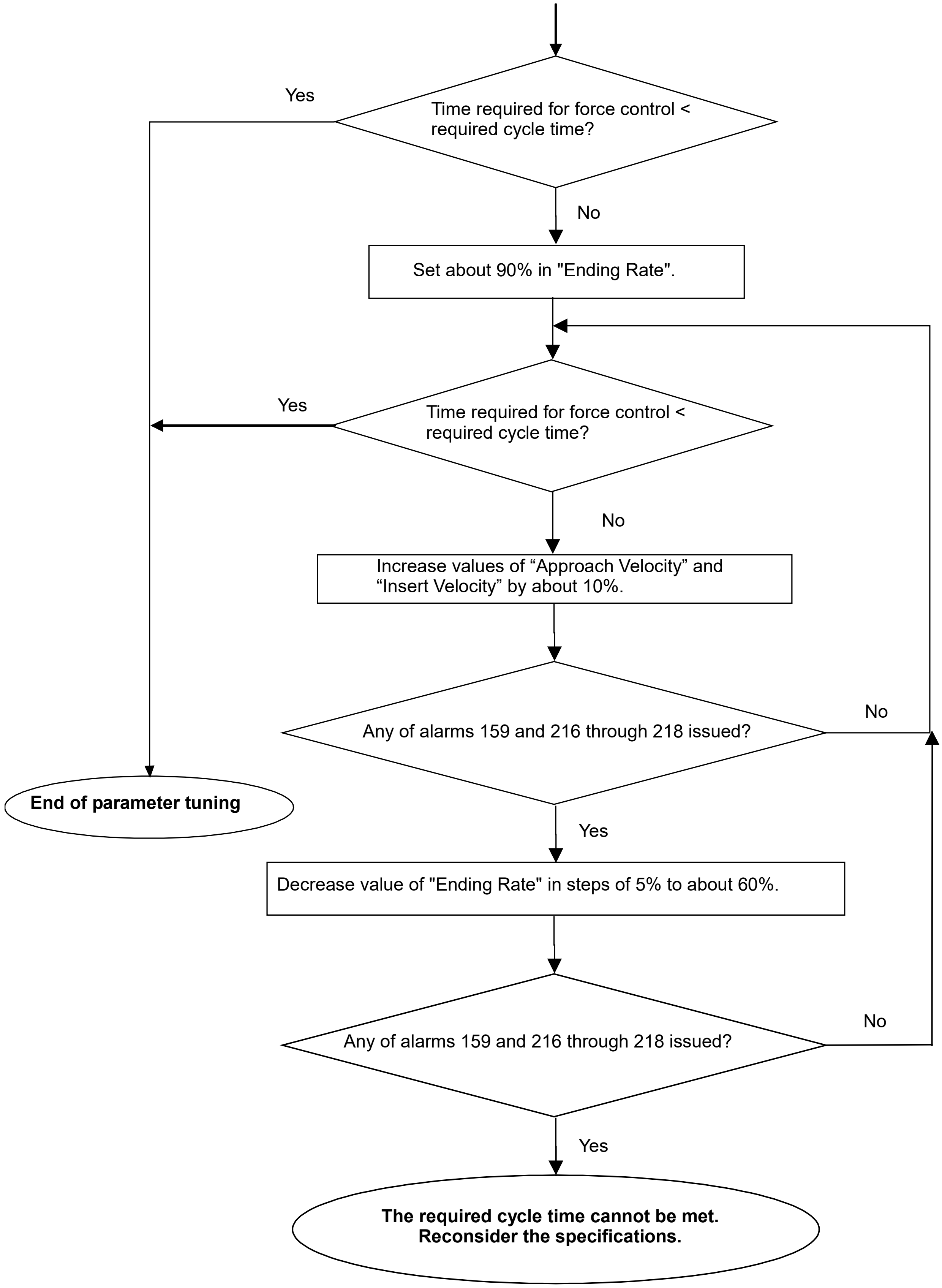


Fig. 1.5.3 (d) Adjusting Other Parameters (2/2)

[Basic data settings] screen

Parameters shown in this section must be set.

Table 1.5.3 (a) [Basic data settings] Screen

Item	Description
Function	A desired function is selected from "Function selection screen". In this case, choose from "Shaft Insert", "Groove Insert" or "Square Insert".
Comment	Enter a comment for identifying the schedule data. Maximum number of characters: 16 characters.
User Frame Number	Enter the number of the user frame to use when inserting. (Enter the user frame number that was set in "Basic Functions Guide: 1.2 TEACHING PROCEDURE".) "Default : UF:0"
Tool Frame Number	Enter the number of the tool frame to use when inserting. (Enter the user tool number that was set in "Basic Functions Guide: 1.2 TEACHING PROCEDURE".) "Default : TF:1"
Insert Direction	Enter the direction to insert using the user frame that is set. "Default :－Z"
Groove Direction *	Enter the longitudinal direction of the groove to insert the workpiece using the user frame that is set. "Default : Y"
Insert Depth (Design)	Enter depth to which the workpiece is inserted from the start of force control (approach point) to the end. "Default : 20.00 mm"
Individual Diff. (+)	If insertion proceeds past [Insert Depth (Design)] due to individual variations in a workpiece, enter the amount of margin to allow. An alarm occurs if insertion exceeds (Insert Depth (Design) - Individual Diff. (-) + this value). "Default : 3.00 mm"
Individual Diff. (-)	If insertion does not reach [Insert Depth (Design)] due to individual variations in a workpiece, enter the amount of margin to allow. If (Insert Depth (Design) - this value) is reached, insertion is determined to be successful. "Default : 0.00 mm"
Approach Velocity	Enter the target operation velocity until contact is made with the target. "Default : 1.00 mm/ s" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
Insert Velocity	Enter the target velocity for when actually performing the insertion operation. "Default : 2.00 mm/s" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
Contact F Threshold	Enter the threshold value for determining whether contact has been made with the target. "Default : 10.00 N" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen. **⚠ CAUTION** The cycle time may get worse if this value is too high, because the actual insertion operation starts after contact is made.

Item	Description
Insert Force	Enter the target inserting force for the actual insert operation. (To begin insertion with a small target force, refer to ［Init Force Keep Depth］ on the [Performance Data Settings] Screen.) "Default : 30.00 N" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen. ⚠ **CAUTION** Set a value "2.0" N or above for [Insert Force]. Setting a value higher than necessary may damage the work.
Pushing Time	This is the length of push time after the system assumes the insertion to have been successful. Enter the corresponding pushing time. "Default : 0.00 sec"
Check Orientation Change	This is the switch for checking how the orientation has been changed in insertion, in comparison with the orientation in teaching. This can be set to 'On' or 'Off'. Set 'On' to check how much the orientation has changed during insertion compared to the taught orientation. Usually, this switch is turned ON. "Default : ON" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
Change MAX Limit	If [Check Orientation Change] is set to 'On', enter the maximum orientation change to allow during insertion compared to the taught orientation. If the actual orientation change exceeds this “Change MAX Limit”, an alarm is issued. "Default : 3.00 deg" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
Insert Time MAX Limit	This is the maximum length of insertion time. Enter the maximum time. If insertion is not completed within this period after the workpiece comes in contact with the object, and the insertion begins, an alarm is issued. The pushing time after the system assumes the insertion to have been successful is excluded from the insertion time. (Refer to [Pushing Time].) "Default : 20.00 sec" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
F.Ctrl. Gain Auto Modify	This item is the switch used for automatic force control gain tuning. Set 'On' to execute auto adjustment of the force control gain. (Refer to "Basic Function Guide: 1.11.2 Force Control Gain Auto Tuning Instruction".) "Default : OFF" **NOTE** This is not displayed for robots that support parameter auto tuning.
Prev. Result	Displays the previous result for [F.Ctrl. Gain Auto Modify]. "Default : No Change" **NOTE** This is not displayed for robots that support parameter auto tuning.

Item	Description
Force Control Gain	Perform the operation below to switch to the [Force Control Gain] screen. • Move the cursor to this line then press the ENTER key. The screen display switches to the force control gain detail screen. (For the parameters that can be set on this screen, refer to "Basic Function Guide: 1.6 FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".) **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
Max Force Limit	Perform adjustment so that this value is not exceeded during parameter auto tuning. **NOTE** This parameter is displayed only for robots that support parameter auto tuning.
Param. Auto Tune	Display the status of and execute parameter auto tuning. '----', 'DONE', 'STOPPED', or 'FAILURE' is displayed as the status of automatic adjustment. If you press Shift+F2, auto tuning is executed. If you press F3, the auto tuned parameters are displayed. "Default : ----" **NOTE** This parameter is displayed only for robots that support parameter auto tuning.
G F S	G represents a motion group number at the time of teaching. F represents a force control number. S represents a force sensor number. (These settings cannot be changed.) "Defaults : G F S : 1 1 1"

* This parameter is used for 'Groove Insert'. It is not available for 'Shaft Insert' or 'Square Insert'.

[Performance Data Settings] Screen

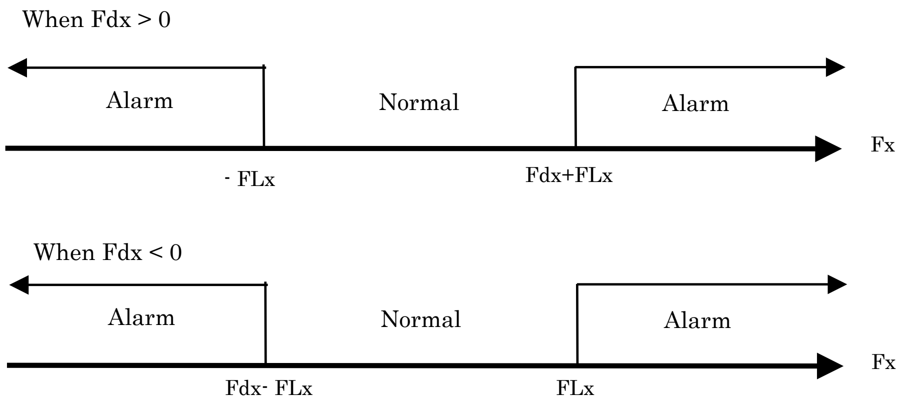
Parameters shown in this section are for advanced users.

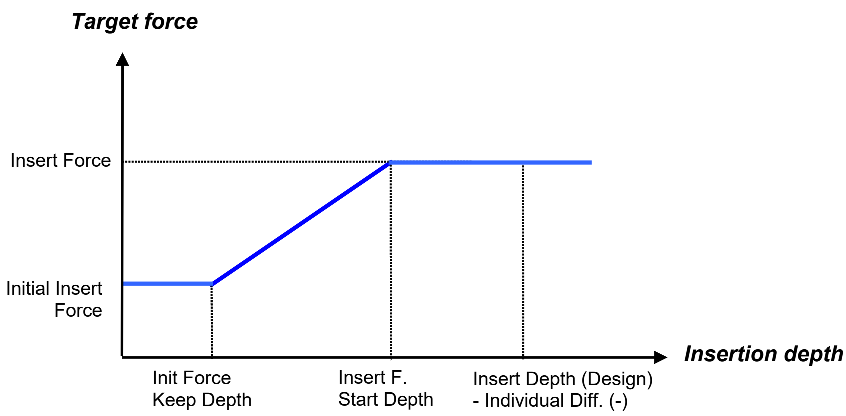
Table 1.5.3 (b) [Performance Data] Screen

Item	Description
Function	A desired function is selected from "Function selection screen". In this case, choose from "Shaft Insert", "Groove Insert" or "Square Insert".
Comment	Enter a comment for identifying the schedule data. Maximum number of characters: 16 characters.
Simple Customize Sw	This switch is for force control continuous execution. This can be set to 'On' or 'Off'. It enables to execute the schedule data being edited after any other schedule. (Refer to "Basic Function Guide: 1.7.3 Simple Customization Function".) "Default : OFF "
Retry Sw	This switch sets whether to use the force control schedule currently being executed for retrying the previously executed schedule. Select 'Off', 'ReturnPos1', or 'ReturnPos2'. If it is "OFF", the withdrawal distance is same as "Insert Depth (Design)" in Basic data setting screen. If it is "ReturnPos1", the robot withdraws a workpiece to a starting point of a previously executed schedule. If the previously executed schedule has a Parent schedule, it withdraws a workpiece to a starting point of the parent schedule. If it is "ReturnPos2", the robot withdraws a workpiece to a starting point of a previously executed schedule whether it has a parent or not. (Refer to "Basic Function Guide: 1.7.3 Simple Customization Function".) "Default : OFF "
Cont. Exec. Max. Count	Enter an integer for the number of times a force control schedule with the simple customization function enabled can be executed continuously. (Refer to "Basic Function Guide: 1.7.3 Simple Customization Function".) "Default : 1"
Customize Parent Number	Enter this when executing force control continuously. (Refer to "Basic Function Guide: 1.7.4 Customization Function".) "Default : 0"

Item	Description
Customize ParaChg Connection	This item is set when force control is executed successively. Select 'Both D', 'P2C', 'C2P', or 'Off'. (Refer to "Basic Function Guide: 1.7.4 Customization Function".) "Default : OFF"
Customize Auto. Cnt. Exec. Sw (Customize Auto. Cnt. Exec.)	This parameter specifies a switch for "Customize Auto. Cnt. Exec." function. This can be set to 'On' or 'Off'. "Customize Auto. Cnt. Exec." function enables to execute a series of the force control schedule data, which are combined with customization function, with a single force control instruction of the top parent schedule data. Set "Customize Auto. Cnt. Exec. Sw" to ON for all schedule data that are combined with "Customize Auto. Cnt. Exec." function. (Refer to "Basic Function Guide: 1.7.5 Customization Automatic Continuous Execution Function".) "Default : OFF"
Auto. Cnt. Exec. Child No. (Customize Auto. Cnt. Exec.)	Enter the number of the schedule data to execute next in 'Customization Auto Continuous Execution'. Set "Customize Parent Number" of the child, designated by "Auto. Cnt. Exec. Child No.", to this schedule data number. "Customize Auto. Cnt. Exec." function can link the schedule data up to 10. "Default : 0"
Schedule No. Output Reg. No. (Customize Auto. Cnt. Exec.)	Enter the number of the Numeric register that is used for 'Customization Auto Continuous Execution' function. When "Customize Auto. Cnt. Exec." function is executed, a running schedule data number is written to this Numeric register. If the series of the schedule data ends normally, 0 is written to this Numeric register. Only "Schedule No. Output Reg. No." of the top parent in the series of the schedule data is used. "Schedule No. Output Reg. No." of other than the top parent are not used. If "Schedule No. Output Reg. No." of the top parent equals to 0, this function does not output to the Numeric Register. When the series of the schedule data is executed, with the value that is output to the Numeric Register, it is possible to know whether all schedule data ends normally or if not, which schedule data fails. "Default : 0"
User Frame Compensation SW	This is the switch for correcting the user frame used for the workpiece to be pushed, using vision. This switch is useful if the workpiece to be pushed is not correctly positioned. Select 'Off', 'Pos. Reg.', or 'VISION REG'. The switch must be used in combination with the OFFSET or VOFFSET instruction. (Refer to "Basic Function Guide: 1.8, "USER FRAME COMPENSATION".) "Default : OFF"
Settling Switch	Settling involves reducing the pushing force after pushing is completed. Sets the switch used for settling to 'On' or 'Off'. If this is set to 'On', it activates if the workpiece vibrates due to a large shock when the hand is detached after pushing stops. "Default : OFF"
Settling Time	Enter the time until settling stops after it is started. "Default : 1.00 sec"
Settling Rate	Enter the settling ratio for the insertion force. The force is ultimately reduced to “Pushing Force” x “Settling Rate” / 100. If this “Settling Rate” is set to 100 %, settling is not performed. If this “Settling Rate” is set to 0 %, the force is reduced to 0. "Default : 100.00 %"

Item	Description
Initial Insert Force	Enter the target force when starting insertion. This setting is useful to begin insertion with a small force. As insertion proceeds, the target insertion force approaches “Insert Force” in "Basic data". (Refer to [Init Force Keep Depth] in the "Performance data".) "Default : 30.00 N" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
Velocity Switch	This is the switch for adjusting “Insert Velocity” in “Basic data” during insertion. This can be set to 'On' or 'Off'. This switch is useful when starting insertion slowly and then increasing the insertion velocity from a certain stage of insertion. However, if [Velocity Constant Switch] is set to 'On' on the [Performance Data Settings] screen, the restriction set in [Insert Velocity] on the [Basic Data Settings] screen is applied, regardless of the value in [Adjustment Gain]. "Default : ON" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
Adjustment Gain	Enter a numeric value for adjusting [Insert Velocity] on the [Basic Data Settings] screen. The value of [Insert Velocity] multiplied by [Adjustment Gain] is used as [Insert Velocity] during velocity adjustment. "Default : 2.00" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
Starting Rate	Enter the value (ratio) of the insertion depth where velocity adjustment starts. The velocity adjustment starts when insertion has reached the depth of the [Insert Depth (Design)] x [Starting Rate] / 100 on the [Basic Data Settings] screen. "Default : 30.00 %" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
Ending Rate	Enter the value (ratio) of the insertion depth where velocity adjustment ends. The velocity adjustment ends when insertion has reached the depth of the [Insert Depth (Design)] x [Ending Rate] / 100 on the [Basic Data Settings] screen. To prevent excessive force from being applied, the velocity command is set to 0 after insertion has reached this depth. "Default : 90.00 %" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.

Item	Description
Force Limit (Fig. 1.5.3 (e))	If generated force satisfies one of the expressions below, an alarm (FORC-216 - FORC-221) is issued. Refer to "APPENDIX: B ALARM CODES OF FORCE CONTROL" and remove a cause of the alarm. Increase the values of this parameter after all measures are taken. Values are set for forces in the X, Y, and Z directions and moments in the W, P, and R directions. For example, for the force in the X direction, the following expressions are given: $Fx < -FLx$ or $Fx > Fdx + FLx$ (when $Fdx > 0$) $Fx > FLx$ or $Fx < Fdx - FLx$ (when $Fdx < 0$) Fx : Force generated during phase matching (X direction) FLx : X component of the phase matching force limit Fdx : Target force in the X direction. If the insertion direction is X or –X, Fdx is "Insert Force". Otherwise, Fdx = 0. The same relationship holds for Y, Z, W, P, and R. "Defaults : X : 200.00 Y : 200.00 Z : 200.00 N W : 15.00 P : 15.00 R : 15.00 N*m" "Unit : N, N*m"  Fig. 1.5.3 (e) Force Limit and the occurrence of an alarm
Ending Condition Switch	This switch sets whether to use another condition for determining whether insertion is successful instead of the condition set on the [Basic Data Settings] screen. This can be set to 'On' or 'Off'. If [Ending Condition Switch] is turned ON, [Insert Depth] is used to judge whether insertion is successful instead of [Insert Depth (Design)] on the [Basic Data Settings] screen. [Insert DIR] is also used to judge whether insertion is successful instead of [Insert Direction] on the [Basic Data Settings] screen. Execute the end condition acquisition instruction before turning on this switch. (Refer to "Basic Function Guide: 1.11.4 End Condition Acquisition Instruction".) "Default : OFF"
Insert Depth	Displays the value set by 'Ending Condition Switch'. The depth of insertion is estimated from the actual insertion. If [Ending Condition Switch] is turned ON, [Insert Depth] is used to judge whether insertion is successful instead of [Insert Depth (Design)] on the [Basic Data Settings] screen. (This value cannot be modified.) "Default : 0.00 mm"
Approach Length	Displays the value set by 'Ending Condition Switch'. The length of approach is estimated from the actual insertion. If "Ending Condition Switch" is turned ON and if the actual approach length does not reach this "Approach Length", the system issues an alarm, assuming that a collision with an obstruction has occurred. (This value cannot be modified.) "Default : 0.00 mm"

Item	Description
Insert DIR	Displays the value set by 'Ending Condition Switch'. The direction of insertion is estimated from the current user frame through the actual insertion. If “Ending Condition Switch” is turned ON, this “Insert DIR”, instead of “Insert Direction” in “Basic data”, indicates the direction of insertion. (This value cannot be modified.) "Defaults : [0.000, 0.000, -1.000] "
Torque Error Compensate SW	This switch is used for torque error compensation. This can be set to 'On' or 'Off'. If this switch is turned ON, torque error compensation is performed, using Torque Error Data W, P, and R, and Torque Error Fd, indicated below. * Execute the torque error acquisition instruction before turning on this switch. (Refer to "Basic Function Guide: 1.11.3 Torque Error Acquisition Instruction") "Default : OFF"
Torque Error Data	Displays the value estimated from the moment information of the force sensor when the robot is actually pushed with "Torque Error Fd" when "TRQ ERROR" is performed. W, P, and R are the values about the X-axis, Y-axis, and Z-axis, respectively, of the user frame used. If “Torque Error Compensate SW” is turned ON, these values are used to correct the torque error. (This value cannot be modified.) "Defaults : W: 0.000 P: 0.000 R: 0.000 N*m"
Torque Error Fd	Displays the value of the force actually exerted when "TRQ ERROR" is performed. If “Torque Error Compensate SW” is turned ON, this setting is used to correct the torque error. (This value cannot be modified.) "Default : 30.00 N"
Init Force Keep Depth (Fig. 1.5.3 (f))	The target insertion force applied from when insertion begins until the insertion depth reaches this value is defined as [Initial Insert Force] on the [Performance Data Settings] screen. Enter the value of this depth. (However, if “Init Force Keep Depth” is set to a value greater than (“Insert Depth (Design)” - “Individual Diff. (-)”), “Initial Insert Force” is used up to the final depth as the target insertion force.) "Default : 0.00 mm"  Fig. 1.5.3 (f) Init Force Keep Depth **NOTE** If the function supports auto tuning, the auto tuning results screen is displayed.

Item	Description
Insert F. Start Depth	Change the target force so that the target insertion force turns to [Insert Force] on the [Basic Data Settings] screen, after insertion depth has passed [Init Force Keep Depth] over to this depth. Enter the value of this depth. (However, if “Insert F. Start Depth” is set to 0 or a value greater than (“Insert Depth (Design)” – “Individual Diff. (–)”), (“Insert Depth (Design)” – “Individual Diff. (–)”) is treated as “Insert F. Start Depth”. If “Insert F. Start Depth” is set to a value less than “Init Force Keep Depth”, the value of “Init Force Keep Depth” is treated as the value of “Insert F. Start Depth”.) "Default : 0.00 mm" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
Velocity Constant Switch	This item is the switch of the function for protecting against workpiece jamming during insertion by preventing the speed from increasing excessively, for example, even when reaction force disappears abruptly. This can be set to 'On' or 'Off'. If this switch is turned "ON" when "Shaft Insert", "Groove Insert", or "Square Insert" is performed, the speed during insertion can be controlled not to exceed [Insert Velocity] on the [Basic Data Setting] screen. (Even if “Velocity Adjust Switch” of the performance data is turned ON, control can be exercised so that “Insert Velocity” is not exceeded.) "Default : ON" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
Force End Judgment Switch	This item is the switch of the function for ending operation after checking whether a proper force has been generated. This can be set to 'On' or 'Off'. When [Force End Judgment Switch] is "ON", after the workpiece is inserted to the specified depth, force control ends if [Judgment Result] is "SUCCESS". An alarm occurs if [Judgment Result] is not "SUCCESS" when [Insert Time Limit] on the [Basic Data Settings] screen elapses. (When both [Force End Judgment Switch] and [Torque End Judgment Switch] are "ON", after the workpiece is inserted to the specified depth, force control ends if the judgment for both is "SUCCESS".) "Default : OFF"
Min. Force Rate	This value is used to judge whether an appropriate amount of force was generated. Enter a ratio. After the workpiece is inserted to the specified depth, [Judgment Result] is "SUCCESS" if the magnitude of the force in [Insert Direction] exceeds [Min. Force Rate] x [Insert Force] / 100. If [Insert Time Limit] elapses while the above conditions are not met, [Judgment Result] is "FAILURE". "Default : 80.00 %"
Judgment Result	This item displays the result of force judgment when "Shaft Insert", "Groove Insert", or "Square Insert" for which [Force End Judgment Switch] is set to "ON" ends. If the function has never been executed with [Force End Judgment Switch] set to "ON", "----" is displayed. "Default : -----"
Force Average	This item displays the force magnitude of [Insert Direction] at the end of "Shaft Insert", "Groove Insert", or "Square Insert" for which [Force End Judgment Switch] is "ON". "Default : Z : 0.00 N"

Item	Description
Torque End Judgment Switch	This item is the switch of the function for ending operation after checking whether the magnitude of generated torque has been decreased to a proper level. This can be set to 'On' or 'Off'. When [Torque End Judgment Switch] is "ON", after the workpiece is inserted to the specified depth, force control ends if [Judgment Result] is "SUCCESS". An alarm occurs if [Judgment Result] is not "SUCCESS" when [Insert Time Limit] on the [Basic Data Settings] screen elapses. (When both [Force End Judgment Switch] and [Torque End Judgment Switch] are "ON", after the workpiece is inserted to the specified depth, force control ends if the judgment for both is "SUCCESS".) "Default : OFF"
Max. Torque	Enter the value to use to judge whether the magnitude of the generated torque is smaller than the appropriate value. If the magnitude of the torque about the axes other than the axis for [Pushing Direction] is less than or equal to [Max. Torque] after the workpiece is inserted to the specified depth, [Judgment Result] is "SUCCESS". If [Insert Time Limit] elapses while the above conditions are not met, [Judgment Result] is "FAILURE". "Default : 0.50 N*m"
Judgment Result	This item displays the result of force judgment when "Shaft Insert", "Groove Insert", or "Square Insert" for which [Torque End Judgment Switch] is set to "ON" ends. If the function has never been executed with [Torque End Judgment Switch] set to "ON", "----" is displayed. "Default : -----"
Torque Average	This item displays the torque magnitude about axes other than the axis for [Insert Direction] at the end of "Shaft Insert", "Groove Insert", or "Square Insert" for which [Torque End Judgment Switch] is "ON". (If the axis for [Insert Direction] is Z, W for indicating rotation about the X-axis and P for indicating rotation about the Y-axis are displayed. If the axis for “Insert Direction” is Y, W and R are displayed.) "Defaults : W: 0.00 N*m P: 0.00 N*m"
Fast Ins. Switch	This switch is for the function that accelerates the orientation correction operation. This can be set to 'On' or 'Off'. If it is "On", the orientation correction operation is accelerated. "Default : ON" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
Fast Ins. Multiplier	Enter the speed of the orientation correction operation. If [Fast Ins. Switch] is "ON" and a value larger than the current value of [Fast Ins. Multiplier] is entered, the orientation correction operation becomes faster. "Default : 2.00" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen. **⚠ CAUTION** For the safety, increase this value in step of 0.50.

Item	Description
Fast Ins. Acc. Time	Enter the acceleration time of the orientation correction operation. If "Fast Ins. Switch" is "ON" and a value smaller than the current value of [Fast Ins. Acc. Time] is entered, the orientation correction operation becomes faster. **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen. "Default : 0.40 sec" ⚠ **CAUTION** For the safety, decrease this value in step of 0.10.
Approach Acc. Time	Enter the time until the velocity reaches the [Approach Velocity] on the [Basic Data Settings] screen after the FORCE statement is started. "Default : 0.40 sec" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
Insert Acc. Time	Enter the time until the velocity reaches the [Insert Velocity] on the [Basic Data Settings] screen after the force exceeds the [Contact F Threshold] on the [Basic Data Settings] screen. "Default : 0.40 sec" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
Force Denoising Sw	This parameter enables the "Force Denoising" function. This can be set to 'On' or 'Off'. This function removes the background big noise from force data. This function is useful when: • tool or work-piece is heavy • using a tool such as a grinder and that has a big vibration "Default : OFF"
Signal Output for ERR SW	This parameter enables the "Signal Output for ERR" function. This can be set to 'On' or 'Off'. If it is "On", the specified signal is output when an error occurs during execution of force control. "Default : OFF"
Output Signal Type (Signal Output for ERR)	Select the type of signal to output when an error occurs during execution of force control with the error signal output function. "DO", "RO", "FLAG" are available for the kind of a signal. "Default : DO"
Output Signal Number (Signal Output for ERR)	Select the number of signal to output when an error occurs during execution of force control with the error signal output function. "Default : 0"
Frc.Ctrl. End by REG SW	This item is the switch of the function for ending operation when the condition specified in [End Register Number] is met. This can be set to 'On' or 'Off'. Normally, the operation of "Shaft Insert", "Groove Insert", and "Square Insert" ends when the insertion depth reaches [Insert Depth (Design)]. Also when either or both [Force End Judgment Switch] and [Torque End Judgment Switch] are "ON", the insertion operation continues after the insertion depth reaches [Insert Depth (Design)] until the judgment result of all functions set to "ON" is "SUCCESS". If this switch is ON and a value of a Numeric Register whose number is designated by "End Register Number" becomes 1, the force control ends regardless of above conditions. "Default : OFF"

Item	Description
End Register Number	If "Frc.Ctrl. End by REG SW" is ON, • The value of the Numeric Register whose number is designated by this parameter automatically becomes 0 when a force control instruction with this schedule starts. • If the value of the Numeric Register whose number is designated by this parameter becomes 1, the force control instruction with this schedule ends. "Default : 0"
G F S	G represents a motion group number at the time of teaching. F represents a force control number. S represents a force sensor number. (These settings cannot be changed.) "Defaults : G F S : 1 1 1"

Function keys

The function keys indicated have the following functions:

Table 1.5.3 (c) Function keys

Key	Item	Description
F1	TYPE	Allows you to change the display to a menu other than the force control menu.
F2	GROUP	Allows you to change motion groups.
	HELP	Display the help screen.
F3	NUMBER	Allows you to display the screen for another schedule number.
F4	CHOICE	Displays the choices for the setting.
	ON	Changes the setting to 'On'.
Shift + F4	DEFAULT	Allows you to set default data of the force control function.
F5	PERFORM / BASIC	Allows you to switch between the basic and performance screens.
	OFF	Changes the setting to 'Off'.

1.5.4 Search Function

1.5.4.1 Outline of the search function

Overview

Typically, an insertion function requires that the positioning error of the approach position is less than the chamfer amount. In certain insertion applications, there may not be a chamfer or the position error may exceed the chamfer amount. Search function is designed to help in such application by minimizing the position and orientation error of the approach position prior to an insertion operation.

> **NOTE**
> This function cannot be used with a 3-axis force sensor.

Types of search functions

The search function can be used to search in a maximum of five directions other than the insertion direction. These five directions are the two translational directions and the three rotational directions. The following four functions are provided according to the direction to search in.

(1) "Search":
Enables searching in a maximum of five directions. The directions to be searched are set by the user in the parameters. It is the most versatile function and the number of search directions is limited in the "Phase Search," the "Hole Search" and the "Clutch Search" (described below). An example use of the search function can be seen in Fig. 1.5.4.1 (a), where phase matching needs to be performed while aligning the posture.
(See "1.5.4.3 Search" in the Basic Functions Manual.)

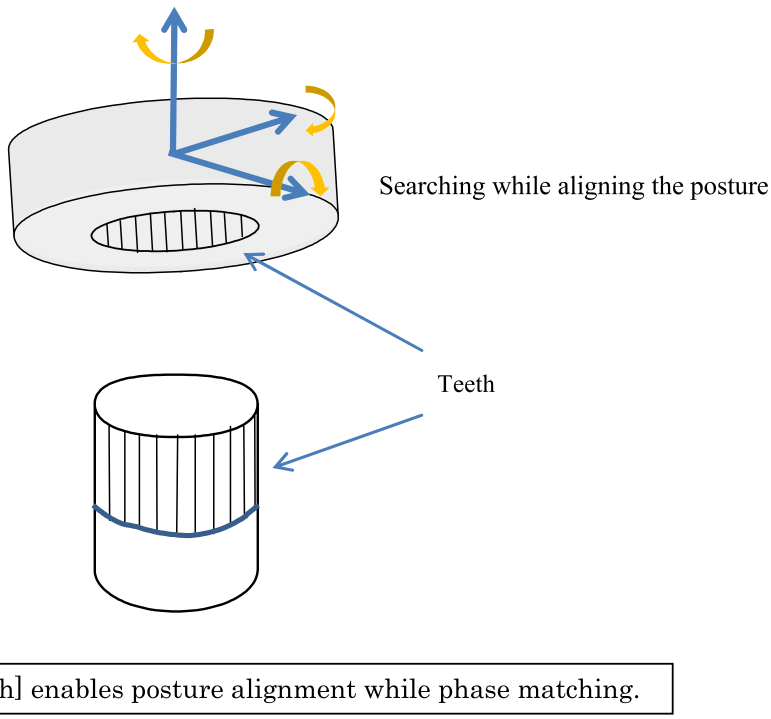


Fig. 1.5.4.1 (a) Search

(2) "Phase Search":
This function performs search operations in rotational direction around the insertion axis. This function can be used in an application where the teeth of two gears are mated with each other as shown in Fig. 1.5.4.1 (b).
(For details of parameters, refer to "Basic Function Guide: 1.5.4.4 Phase Search".)

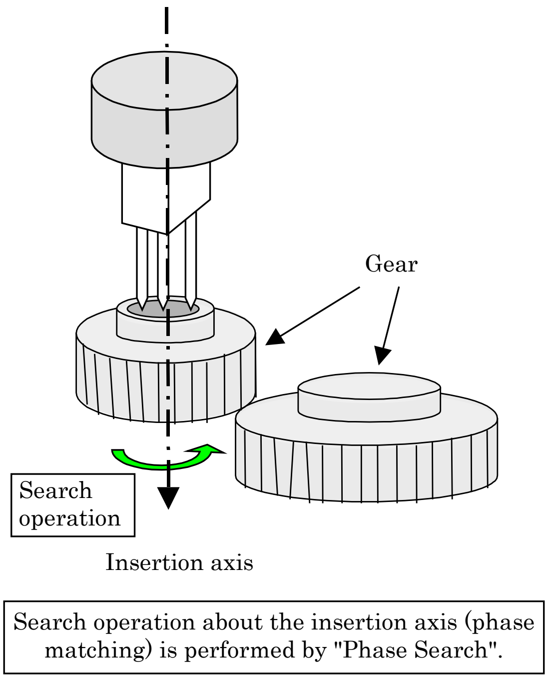


Fig. 1.5.4.1 (b) Phase Search

(3) "Hole Search":
This function searches for a hole position by making a movement in a plane perpendicular to the

insertion direction as shown in Fig. 1.5.4.1 (c).
(For details of parameters, refer to "Basic Function Guide: 1.5.4.5 Hole Search".)

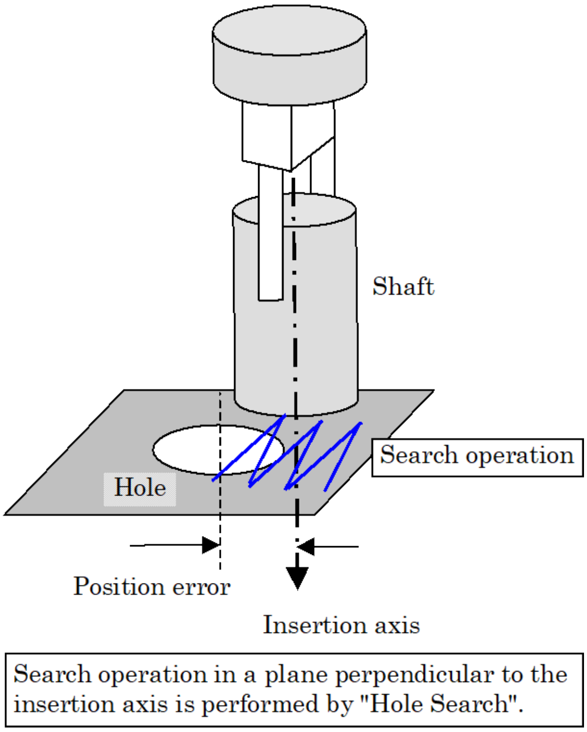


Fig. 1.5.4.1 (c) Position search in a plane

(4) "Clutch Search":
This function is used for clutch assembly. As shown in Fig. 1.5.4.1 (d), clutch search is used when a clutch hub with outer teeth is to be inserted into several clutch plates with inner teeth. The clutch plates are not fixed, so that the clutch plates move slightly (2 mm for example) in a plane perpendicular to the insertion axis. The initial phase of each tooth varies from one plate to another. "Clutch Search" performs search operation in the rotation direction about the insertion axis and in a plane perpendicular to the insertion axis at the same time.
(For details of parameters, refer to "Basic Function Guide: 1.5.4.6 Clutch Search".)

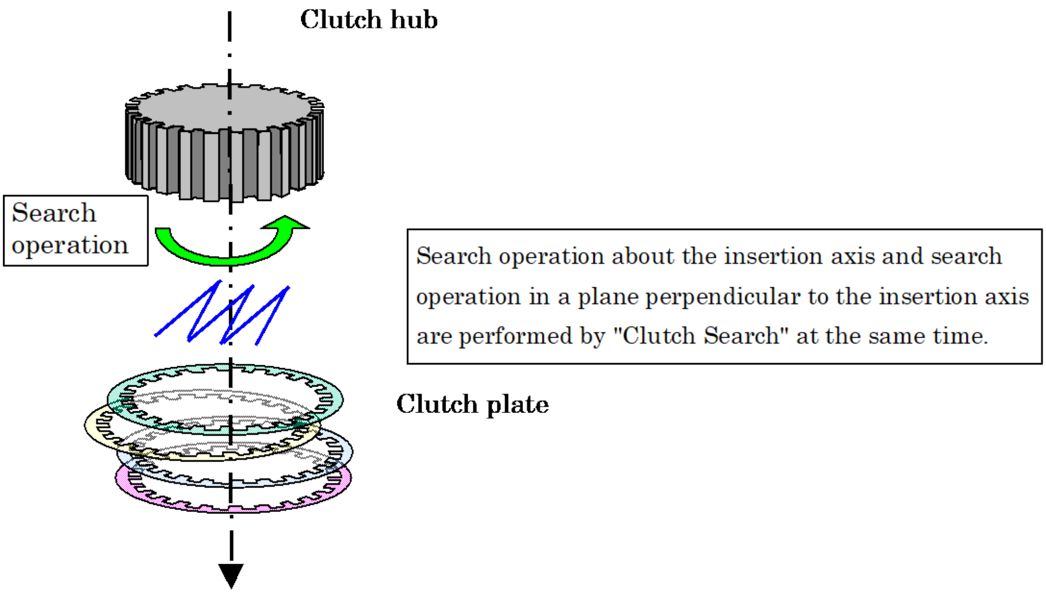


Fig. 1.5.4.1 (d) Clutch assembly (A phase search and position search in a plane are made simultaneously.)

1.5.4.2 Parameter tuning

Search range setting

When any of the four search functions are used, a search range needs to be set. This subsection describes how to set a search range.

Suppose that a workpiece is to be inserted into a hole as shown in Fig. 1.5.4.2 (a). Let G and C be as follows:

G: Gap between the workpiece and hole (clearance)

C: Chamfer amount of the hole (or workpiece),
Sum of the chamfer amounts of the hole and workpiece when both are chamfered

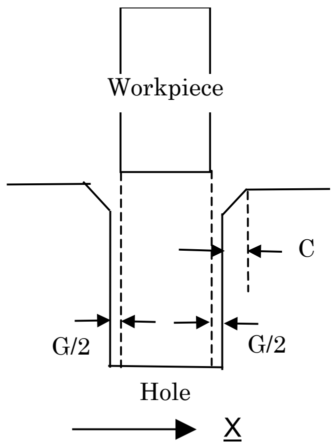


Fig. 1.5.4.2 (a) When inserting workpiece in a hole

Fig. 1.5.4.2 (b) shows that there is a positioning error in the X direction. If the error Er of the workpiece in the X direction does not exceed (C+G/2) before the start of exercising force control, the workpiece can be inserted without using the search function. If the error exceeds this value, the search function is required.

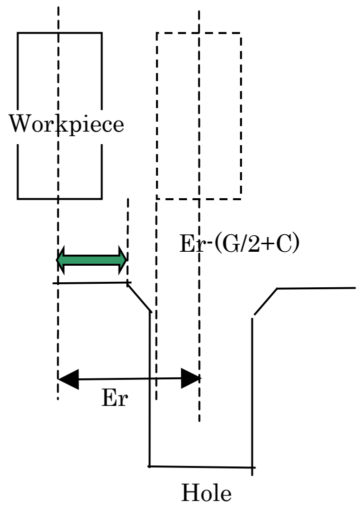


Fig. 1.5.4.2 (b) When inserting workpiece in a hole (when an error occurs in one direction)

In order to use the search function correctly, a sufficiently large range needs to be set.
If a too small range is set, search operation can fail more often. If a too large range is set, search operation takes an excessively long time.

In the example of Fig. 1.5.4.2 (b), the workpiece needs to move at least a distance of Er-(G/2+C) before the workpiece can be inserted.

Whether a plus or minus positioning error exists is unknown. So, a search range as long as 2×(Er-(G/2+C)) is required.

Accordingly, a search range with some margin added is:
$2\times(Er-(G/2+C))+\alpha$
When the value of α is large, the probability of success in search operation increases. If the value of α is unnecessarily large, search operation takes a long time.

The examples above indicate an initial positioning error in only one direction (X direction). Actually, an error in two directions (X and Y directions) can occur as shown in Fig. 1.5.4.2 (c). In such a case, a search range is to be set for each of the X and Y directions by using the method mentioned above.

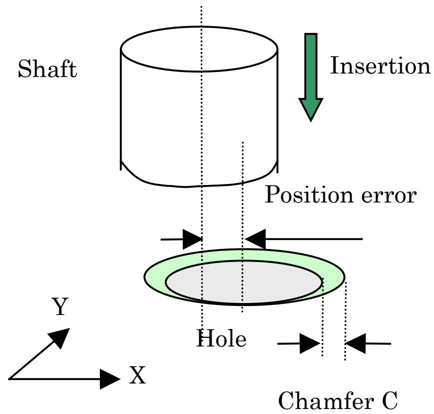


Fig. 1.5.4.2 (c) When inserting workpiece in a hole (when an error occurs in two directions)

When the search operation is simultaneously performed in multiple directions as in hole search in a plane, a search path is important as well as a search range. If a search range is searched finely, the probability of finding a target hole increases. If a search range is searched too finely, however, the search operation takes an excessively long time.

An example of search operation in the X and Y directions is given below.
Set a search range in the X and Y directions as shown in Fig. 1.5.4.2 (d).

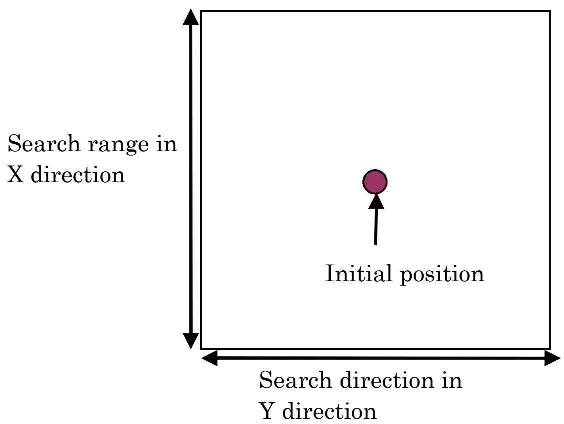


Fig. 1.5.4.2 (d) Search range

When the same search velocity is used in the X and Y directions, a search path lies on the orthogonal line as shown in Fig. 1.5.4.2 (e), so that the entire range cannot be searched.
Fig. 1.5.4.2 (f) shows a search path when the velocity in the X direction is 4 times greater than the velocity in the Y direction. Fig. 1.5.4.2 (g) shows a search path when the velocity in the X direction is 8 times greater than the velocity in the Y direction.

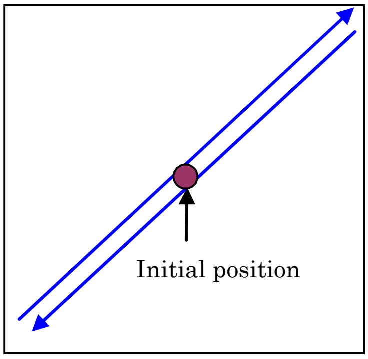


Fig. 1.5.4.2 (e) Search path (1/3)

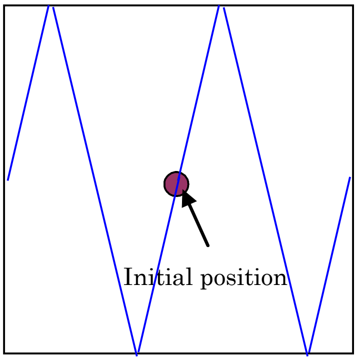


Fig. 1.5.4.2 (f) Search path (2/3)

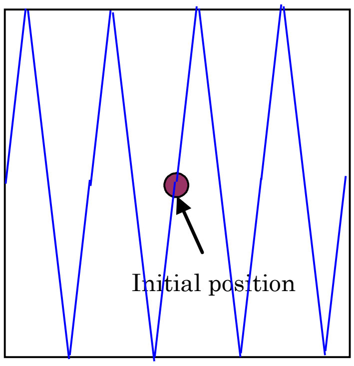


Fig. 1.5.4.2 (g) Search path (3/3)

As the ratio of the velocity in the X direction to the velocity in the Y direction or vice versa is greater, a finer search path is set, thus increasing the probability of success in search operation. If the velocity ratio is excessively increased, however, a longer search time results because of a reduced velocity in one direction. Set an appropriate velocity ratio according to the workpiece.

Target Force, Target Torque

Target force and target torque are the target values of the force (or torque) in a search direction. When the force (or torque) in a search direction reaches the specified value of a parameter, the velocity (or angular velocity) is reduced to 0 and the operation described below is performed.

(1) When the parameter "Reverse Switch" is set to ON (This switch is usually ON.)
Then jiggling starts. Jiggling causes very fine vibration in force (or torque). The frequency of vibration is specified in the parameter "Weaving Frequency", and jiggling lasts for the period of time specified in "Weaving Time". If "Search End Depth" is not reached even when "Weaving Time" has elapsed, the velocity is reversed and search operation restarts.
When the reverse number exceeds the "Retry Number", the alarm 420 occurs.

(2) When the parameter "Reverse Switch" is set to OFF
As with Item 1 , the velocity (or angular velocity) in that direction is reduced to 0, and jiggling starts. If "Search End Depth" is not reached even when "Retry Number" × "Weaving Time" has elapsed, alarm 420 is issued.

1.5.4.3 Search

Overview

The search function enables searching in a maximum of five directions.
There are four types of configuration screens; the [Basic Data Settings] screen and [Search Basic Param.] screen that must be configured by the user, and the [Performance Data Settings] screen and [Search Performance Param.] screen that are only configured when required.

[Function selection] screen

1
1 Unused
2 Constant Push
3 Face Match
4 Shaft Insert
5 Groove Insert
6 Search
7 Phase Search
8 --next page--

[Basic Data Settings] screen

(7DF5/05 or later)

```
Force Ctrl/Basic
                                        1/18
 Schedule[1]                 G:1 F:1 S:1
 1 Function            : Search
 2 Comment             : [                  ]
 3 User Frame No.             UF:   0
 4 Tool Frame No.             TF:   1
 5 Insert Direction          : -Z
 6 Search End Depth      :      5.00 mm
 7 Individual Diff. (+)  :      3.00 mm
 8 Individual Diff. (-)  :      0.00 mm
 9 Approach Velocity     :      1.00 mm/s
10 Search Insert Vel     :      0.00 mm/s
11 Contact F Threshold   :     10.00 N
12 Search Push Force     :     15.00 N
13 Search Basic Param.   :     Basic
14 Pushing Time          :      0.00 sec
15 Search Time Limit     :     20.00 sec
16 F.Ctrl. Gain Auto Modify :      OFF
       Prev. Result      :    No Change
17 Force Control Gain :            Detail

[TYPE] | GROUP | NUMBER | [CHOICE] | PERFORM | >
F1  F2  F3  F4  F5
```

[Basic Data Settings] screen

(7DF5/04 or earlier)

```
Force Ctrl/Basic
                                        1/18
 Schedule[1]                 G:1 F:1 S:1
 1 Function            : Search
 2 Comment             : [                  ]
 3 Insert Direction          : -Z
 4 Contact F Threshold   :     10.00 N
 5 Approach Velocity     :      1.00 mm/s
 6 User Frame No.             UF:   0
 7 Tool Frame No.             TF:   1
 8 Search End Depth      :      5.00 mm
 9 Search Push Force     :     50.00 N
10 Search Insert Vel     :      0.00 mm/s
11 Search Basic Param.   :     Basic
12 Individual Diff. (+)  :      3.00 mm
13 Individual Diff. (-)  :      0.00 mm
14 Pushing Time          :      0.00 sec
15 Search Time Limit     :     20.00 sec
16 F.Ctrl. Gain Auto Modify :      OFF
       Prev. Result      :    No Change
17 Force Control Gain :            Detail

[TYPE] | GROUP | NUMBER | [CHOICE] | PERFORM | >
F1  F2  F3  F4  F5
```

[Force Ctrl/Gain] screen

```
Force Ctrl/Gain
                                        1/1
 Schedule[1]                 G:1 F:1 S:1
   Function            : Search
 1 Search Impedance    : [Master Freq. ]

[TYPE] | GROUP | NUMBER | [CHOICE] |  | >
F1  F2  F3  F4  F5
```

Fig. 1.5.4.3 (a) "Search" screens (1/2)

[Performance Data Settings] Screen

```
Force Ctrl/Perform
                                      1/32
 Schedule[1]             G:1 F:1 S:1
 1 Function          : Search
 2 Comment           : [                 ]
 3 Simple Customize Sw          : OFF
 4   Cont. Exec. Max. Count    :   1
 5 Customize Parent Number  :       0
 6   Customize ParaChg Conct:OFF
 7 Customize Auto. Cnt. Exec. Sw : OFF
 8   Auto. Cnt. Exec. Child No.  :   0
 9   Schedule No. Output Reg. No.:   0
10 User Frame Compensation:   OFF
11 Search acc. time   :      0.100 sec
12 Decel. Depth Rate :       95.00 %
13 Search Performance Param.: Perform
14 Settling Switch            : OFF
15   Settling Time       :     1.00 sec
16   Settling Rate       :   100.00 %
17 Initial Push Force    :    50.00 N
   Force Limit
18  X:  500.00 Y:  500.00 Z:  500.00 N
19  W:   50.00 P:   50.00 R:   50.00N*m
20 Torque Error Compensate SW: OFF
     Torque Error Data
       W:      0.000 N*m
       P:      0.000 N*m
       R:      0.000 N*m
     Torque Error Fd     :    50.00 N
21 Velocity Constant Switch   : ON
22   Velocity Constant   :     5.00 mm/s
23 Force End Judgment Switch : OFF
24   Min. Force Rate   :       80.00 %
     Judgment Result   :       -------
       Force Average   Z:      0.00 N
25 Torque End Judgment Switch: OFF
26   Max. Torque       :       0.50 N*m
     Judgment Result   :       -------
       Torque Average W:       0.00 N*m
                      P:       0.00 N*m
27 Approach Acc. Time      :   0.70 sec
28 Search Acc. Time        :   0.70 sec
29 Force Denoising Sw     :    OFF
30 Signal Output for ERR SW: OFF
31   Output Signal Type  :   DO
32   Output Signal Number:        0
33 Frc.Ctrl. End by REG SW : OFF
34   End Register Number :        0
35 Push Force Change Switch : OFF
36   Push Force LowerLim.   :   0.00 N
37   Push Force Frequency   :   0.12 Hz
```

[Search Basic Param.] screen

```
Search/Basic
                                      1/16
 Search parameters Basic
    Search Valid Switch
 1   X: ON      Y: ON      Z: OFF
 2   W: OFF     P: OFF     R: OFF
    Force control Valid Switch
 3   X: ON      Y: ON      Z: ON
 4   W: OFF     P: OFF     R: OFF
    Velocity Order
 5   X: 1       Y: 2       Z: 0
 6   W: 0       P: 0       R: 0
    Target Velocity   [mm/s]
 7   X:     1.00 Y:     1.00 Z:     1.00
    Target Angular Velocity   [deg/s]
 8   W:     0.00 P:     0.00 R:     0.00
    Target Force   [N]
 9   X:    20.00 Y:    20.00 Z:    20.00
    Target Torque   [N*m]
10   W:     0.00 P:     0.00 R:     0.00
    Clearance & Chamfer   [mm]
11   X:     1.00 Y:     1.00 Z:     1.00
    Clearance   [deg]
12   W:     1.00 P:     1.00 R:     1.00
    Size of Search Range   [mm]
13   X:    10.00 Y:    10.00 Z:    10.00
    Size of Search Range   [deg]
14   W:    10.00 P:    10.00 R:    10.00
    Repeat Number
15   X:        1 Y:        1 Z:        1
16   W:        1 P:        1 R:        1

[TYPE] |      |      |  ON  |  OFF  |  >
  F1      F2     F3     F4     F5
```

[Search Performance Param.] screen

```
Search/Perform
                                      1/16
 Search parameters Performance
    Vel. Vib. Center
 1   X:     1.00 Y:     1.00 Z:     1.00
 2   W:     1.00 P:     1.00 R:     1.00
    Vel. Vib. Frequency   [Hz]
 3   X:     1.00 Y:     1.00 Z:     1.00
 4   W:     1.00 P:     1.00 R:     1.00
    Weaving Time   [sec]
 5   X:     1.00 Y:     1.00 Z:     1.00
 6   W:     1.00 P:     1.00 R:     1.00
    Weaving Frequency   [Hz]
 7   X:     1.00 Y:     1.00 Z:     1.00
 8   W:     1.00 P:     1.00 R:     1.00
    Reverse Switch
 9   X: ON      Y: ON      Z: ON
10   W: ON      P: ON      R: ON
    Retry Number
11   X:    10000 Y:    10000 Z:    10000
12   W:    10000 P:    10000 R:    10000
    Retry Magnification
13   X:     1.00 Y:     1.00 Z:     1.00
14   W:     1.00 P:     1.00 R:     1.00
    Search Range Margin   [mm]
15   X:     3.00 Y:     3.00 Z:     3.00
    Search Range Margin   [deg]
16   W:     3.00 P:     3.00 R:     3.00

[TYPE] |      |      |      |      |  >
  F1      F2     F3     F4     F5
```

Fig. 1.5.4.3 (b) "Search" screens (2/2)

Adjusting the Search Parameters

1. Display the [Basic Data Settings] screen for the search function.
2. Configure [Insert Direction], [UFrame Number], [UTool Number], and [Search End Depth].
3. Decide the direction to search in, and configure [Search Valid Switch] and [Force Control Valid Switch] on the [Search Basic Param.] screen.

Make sure to also set [Force Control Valid Switch] to 'On' for the direction that [Search Valid Switch] is set to 'On' for.

4 Configure [Velocity Order] for the direction that searching is valid for.

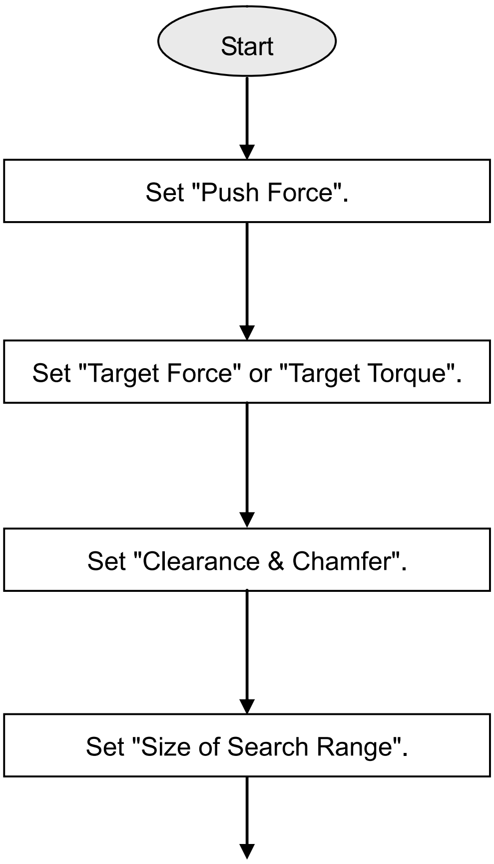
5 Execute [F.Ctrl. Gain Auto Modify].
(Refer to "Basic Function Guide: 1.11.2 Force Control Gain Auto Tuning Instruction".)

6 Configure the other parameters on the [Basic Data Settings] and [Search Basic Param.] screen.

7 Configure the parameters on the [Performance Data Settings] screen and [Search Performance Param.] screen, as required.

> **NOTE**
> For the outline of force control instruction programming, refer to "Basic Function Guide: 1.1 NOTES / RESTRICTIONS", and "Basic Function Guide: 1.2 TEACHING PROCEDURE".

The procedure for tuning other parameters after completion of automatic force control gain adjustment is shown below.



This parameter specifies a target pushing force during search operation. Set 2.0 N or a greater value in "Push Force".
If an unnecessarily large value is set, the workpiece can be damaged.
When the phase is not successful match, increase the value in step of 10%.

"Target Force" and "Target Torque" are displayed on the search parameters basic screen.
Determine a value according to the items of target force and target torque in Subsection 1.5.4.2, "Parameter tuning".
If an unnecessarily large value is set, the workpiece can be damaged.
When the phase is not successful match, increase the value in step of 10%.

"Clearance & Chamfer" is displayed on the search parameters basic screen.
Determine a value according to the setting items of search frequency, and clearance and chamfer amount in Subsection 1.5.4.2, "Parameter tuning".

"Size of Search Range" is displayed on the search parameters basic screen.
Determine a value according to the item of search range setting in "Basic Function Guide: 1.5.4.2 Parameter tuning".

Fig. 1.5.4.3 (c) Adjusting Other Parameters (1/2)

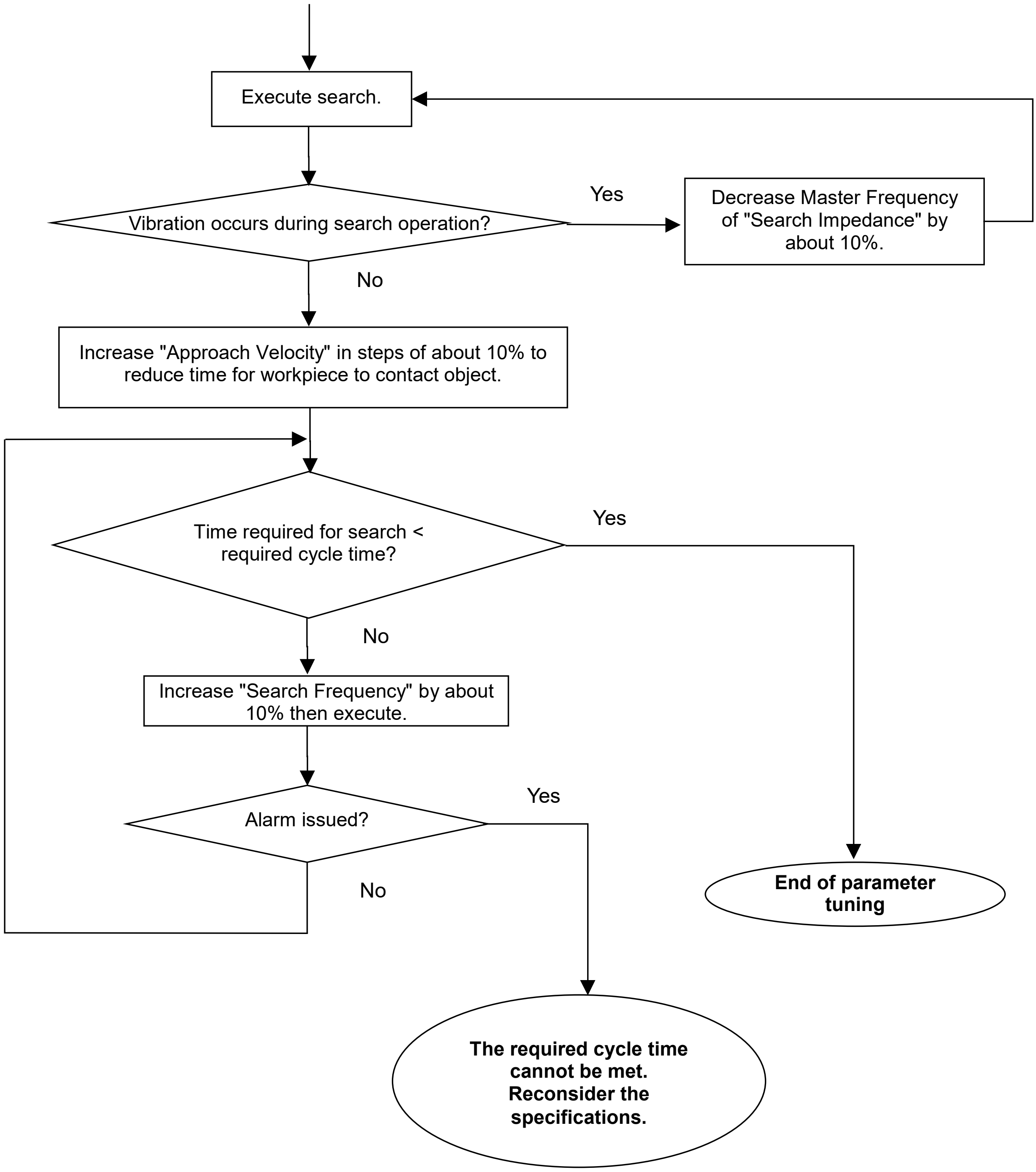


Fig. 1.5.4.3 (d) Adjusting Other Parameters (2/2)

[Basic data settings] screen

Parameters shown in this section must be set.

Table 1.5.4.3 (a) [Basic data settings] screen

Item	Description
Function	A desired function is selected from "Function selection screen". In this case, select "Search".
Comment	Enter a comment for identifying the schedule data. Maximum number of characters: 16 characters.

Item	Description
User Frame Number	Enter the number of the user frame to use when searching. (Enter the user frame number that was set in "Basic Functions Guide: 1.2 TEACHING PROCEDURE".) "Default : UF:0"
Tool Frame Number	Enter the number of the tool frame to use when searching. (Enter the user tool number that was set in "Basic Functions Guide: 1.2 TEACHING PROCEDURE".) "Default : TF:1"
Insert Direction	Enter the direction to insert using the user frame that is set. "Default : - Z"
Search End Depth	Enter the depth from the force control start (approach point) to where to end the search. "Default : 5.00 mm"
Individual Diff. (+)	If insertion proceeds past [Search End Depth] due to individual variations in a workpiece, enter the amount of margin to allow. An alarm occurs if insertion exceeds (Search End Depth - Individual Diff. (-) + this value). "Default : 3.00 mm"
Individual Diff. (-)	If insertion does not reach [Search End Depth] due to individual variations in a workpiece, enter the amount of margin to allow. If (Search End Depth - this value) is reached, insertion is determined to be successful. "Default : 0.00 mm"
Approach Velocity	Enter the target operation velocity until contact is made with the target. "Default : 1.00 mm/s"
Search Insert Vel	Enter the target velocity for inserting the workpiece when searching. "Default : 0.00 mm/s"
Contact F Threshold	Enter the threshold value for determining whether contact has been made with the target. "Default : 10.00 N" ⚠ **CAUTION** The cycle time may get worse if this value is too high, because the actual insertion operation starts after contact is made.
Push Force	Enter the target value for the force to push the workpiece to the insertion surface when searching. Increase the value if the workpiece is not inserted despite the position and phase being correct and decrease the value if the workpiece being inserted into is dragged along with the inserted work. "Default : 30.00 N" **NOTE** When changing [Search Push Force], change it by about 10% each time.
Search Basic Param.	Perform the following operation to switch to the [Search Basic Param.] screen for configuring the basic parameters for determining the search path. • Move the cursor to [Basic], and press the [ENTER] key on the teach pendant of the robot controller. The [Search Basic Param.] screen is displayed. (For information on the parameters that can be configured from [Search Basic Param.], refer to the settings on the [Search Basic Param.] screen.
Pushing Time	When search operation is assumed to be successful, pushing operation is performed in the insertion direction to absorb length differences in individual workpieces. Enter the corresponding pushing time. "Default : 0.00 sec"

Item	Description
Search Time MAX Limit	This search time means the period of time from the start of search operation after touching a workpiece target until search operation is assumed to be successful. Enter the maximum time. If "Search End Depth" is not reached within this period, an alarm is issued. This search time does not include a time for pushing operation after search operation is assumed to be successful. (Refer to [Pushing Time].) "Default : 20.00 sec"
F.Ctrl. Gain Auto Modify	This item is the switch used for automatic force control gain tuning. Set "On" to execute auto adjustment of the force control gain. (Refer to "Basic Function Guide: 1.11.2 Force Control Gain Auto Tuning Instruction".) "Default : OFF"
Prev. Result	Displays the previous result for [F.Ctrl. Gain Auto Modify]. "Default : No Change"
Force Control Gain	Perform the operation below to switch to the [Force Control Gain] screen. • Set this parameter manually. Move the cursor to this line then press the ENTER key. The screen display switches to the force control gain detail screen. (For the parameters that can be set on this screen, refer to "Basic Function Guide: 1.6 FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".)
G F S	G represents a motion group number at the time of teaching. F represents a force control number. S represents a force sensor number. (These settings cannot be changed.) "Defaults : G F S : 1 1 1"

[Search parameters basic] screen

The parameters on this screen must always be set when "Search" is used.
Each parameter for six directions (X, Y, Z, W, P, and R) is available.

Table 1.5.4.3 (b) [Search parameters basic] screen

Item	Description
Search Valid Switch	Set 'On' and 'Off' for whether to search in each direction. When this switch is set to ON, search in that direction. For example, when searching in X, Y, and Z direction, set ON for those directions and set OFF for the other directions of Z, P, and R. If the switch is set to ON for a direction, the "Force Control Valid switch" for the direction is also set to ON. If 'Off' is set, 'On' and 'Off' do not change for the [Force Control Valid Switch] of that direction. "Defaults : X : ON Y : ON Z : OFF W : OFF P : OFF R : OFF"
Force Control Valid Switch	Set 'On' and 'Off' for whether to search in each direction. Force control is exercised in those directions with this switch set to ON. No movement is made in those directions with this switch set to OFF. "Defaults : X : ON Y : ON Z : ON W : OFF P : OFF R : OFF"
Target Velocity / Target Angular Velocity	Target velocity (angular velocity) for operating a workpiece. "Defaults : X : 1.00 Y : 1.00 Z : 0.00" (Unit : mm/ s) "Default s: W : 0.00 P : 0.00 R : 0.00" (Unit : deg/ s)

Item	Description
Target Force / Target Torque	Enter the [Target Force] (target torque) for the search direction. If "Force 264 Error" or "Force 420 Error" occurs with little motion made, increase this value in steps of about 10% to 20%. If [Reverse Switch] is set to 'On' (default value) on the [Search Performance Data Settings] screen, the travel direction or rotate direction of the workpiece is automatically reversed when the force or torque reaches this value. If a position or phase match point is passed, decrease this value in steps of about 10% to 20%. (Refer to 'Target Force, Target Torque' in "Basic Function Guide: 1.5.4.2 Parameter tuning".) "Defaults : X : 20.00 Y : 20.00 Z : - 30.00" (Unit : N) "Defaults : W : 0.00 P : 0.00 R : 0.00" (Unit : N*m)
Size of Search Range	The range to search in each direction is determined and that size is entered to this parameter. (Refer to 'Search range setting' in "Basic Function Guide: 1.5.4.2 Parameter tuning".) "Defaults : X : 10.00 Y : 10.00 Z : 10.00" (Unit : mm) "Defaults : W : 10.00 P : 10.00 R : 10.00" (Unit : deg)

[Performance Data Settings] screen

Parameters shown in this section are for advanced users.

Table 1.5.4.3 (c) [Performance Data Settings] screen

Item	Description
Function	A desired function is selected from "Function selection screen". In this case, select "Search".
Comment	Enter a comment for identifying the schedule data. Maximum number of characters: 16 characters.
Simple Customize Sw	This switch is for force control continuous execution. This can be set to 'On' or 'Off'. It enables to execute the schedule data being edited after any other schedule. (Refer to "Basic Function Guide: 1.7.3 Simple Customization Function".) "Default : OFF"
Cont. Exec. Max. Count	Enter an integer for the number of times a force control schedule with the simple customization function enabled can be executed continuously. (Refer to "Basic Function Guide: 1.7.3 Simple Customization Function".) "Default : 1"
Customize Parent Number	Enter this when executing force control continuously. (Refer to "Basic Function Guide: 1.7.4 Customization Function".) "Default : 0"
Customize ParaChg Connection	This item is set when force control is executed successively. Select 'Both D', 'P2C', 'C2P', or 'Off'. (Refer to "Basic Function Guide: 1.7.4 Customization Function".) "Default : OFF"
Customize Auto. Cnt. Exec. Sw (Customize Auto. Cnt. Exec.)	This parameter specifies a switch for "Customize Auto. Cnt. Exec." Function. This can be set to 'On' or 'Off'. "Customize Auto. Cnt. Exec." function enables to execute a series of the force control schedule data, which are combined with customization function, with a single force control instruction of the top parent schedule data. Set "Customize Auto. Cnt. Exec. Sw" to ON for all schedule data that are combined with "Customize Auto. Cnt. Exec." function. (Refer to "Basic Function Guide: 1.7.5 Customization Automatic Continuous Execution Function".) "Default : OFF"

Item	Description
Auto. Cnt. Exec. Child No. (Customize Auto. Cnt. Exec.)	Enter the number of the schedule data to execute next in 'Customization Auto Continuous Execution'. Set "Customize Parent Number" of the child, designated by "Auto. Cnt. Exec. Child No.", to this schedule data number. "Customize Auto. Cnt. Exec." function can link the schedule data up to 10. "Default : 0"
Schedule No. Output Reg. No. (Customize Auto. Cnt. Exec.)	Enter the number of the Numeric register that is used for 'Customization Auto Continuous Execution' function. When "Customize Auto. Cnt. Exec." function is executed, a running schedule data number is written to this Numeric register. If the series of the schedule data ends normally, 0 is written to this Numeric register. Only "Schedule No. Output Reg. No." of the top parent in the series of the schedule data is used. "Schedule No. Output Reg. No." of other than the top parent are not used. If "Schedule No. Output Reg. No." of the top parent equals to 0, this function does not output to the Numeric Register. When the series of the schedule data is executed, with the value that is output to the Numeric Register, it is possible to know whether all schedule data ends normally or if not, which schedule data fails. "Default : 0"
User Frame Compensation SW	This is the switch for correcting the user frame used for the workpiece to be pushed, using vision. This switch is useful if the workpiece to be pushed is not correctly positioned. Select 'Off', 'Pos. Reg.', or 'VISION REG'. The switch must be used in combination with the OFFSET or VOFFSET instruction. (Refer to "Basic Function Guide: 1.8 USER FRAME COMPENSATION".) "Default : OFF"
Search acc. Time	Enter the constant during acceleration/deceleration of the search velocity. "Default : 0.100 sec"
Decel. Depth Rate	The angle velocity in the search direction reduced to the [Target Angular Velocity] x 0.1 on the [Basic Data Settings] screen, when insertion has reached the [Search End Depth] x [Decel. Depth Rate] / 100 on the [Basic Data Settings] screen. If the workpiece is damaged because it is moved forcibly or insertion stops despite the position and phase being correct, enter a value smaller than the current value. "Default : 95.00 %"
Search Performance Param.	[Search Performance Param.] are the parameters for determining the search path. Configure the parameters required for improving the search performance on the [Search Performance Param.] screen. Perform the following operation to switch to the [Search Performance Param.] screen. • Move the cursor to [PERFORM], and press the [Input] key on the teach pendant of the robot controller. The [Search Performance Param.] screen is displayed. (Refer to the [Search Performance Param.] screen.)
Settling Switch	Settling involves reducing the pushing force after pushing is completed. Sets the switch used for settling to 'On' or 'Off'. If this is set to 'On', it activates if the workpiece vibrates due to a large shock when the hand is detached after pushing stops. "Default : OFF"
Settling Time	Enter the time until settling stops after it is started. "Default : 1.00 sec"
Settling Rate	Enter the settling ratio for the pushing force. Finally, the force is "reduced" to ("Push Force") × ("setting rate")/100. When 100% is specified, settling operation is not practically performed. When 0% is specified, the force is reduced to 0. "Default : 100.00 %"

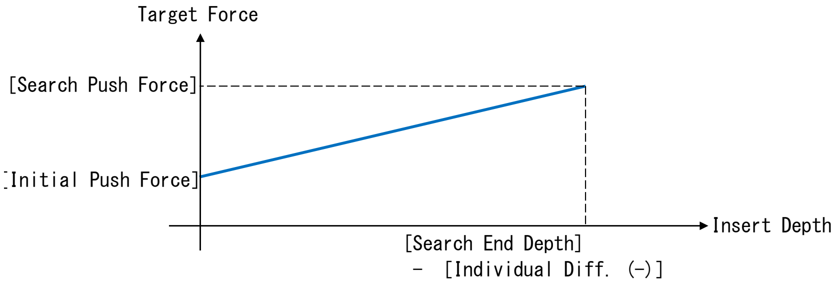
<table>
<tr><th>Item</th><th>Description</th></tr>
<tr><td>Initial Insert Force
(Fig. 1.5.4.3 (e))</td><td>Enter the target force when starting insertion.
This parameter is useful when a small force is initially used to insert a workpiece. As the workpiece is inserted, the target force during insertion approaches the basic data "Push Force".
This function is only enabled when performing an insertion operation.
"Default : 30.00 N"


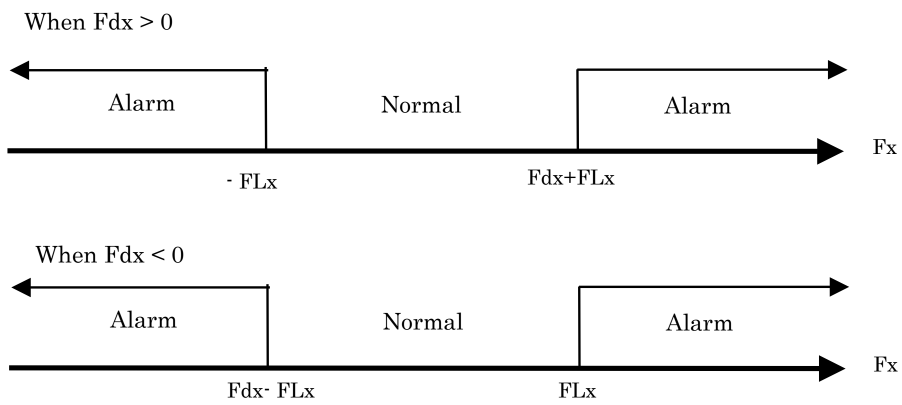
Fig. 1.5.4.3 (e) Init Force Keep Depth</td></tr>
<tr><td>Force Limit
(Fig. 1.5.4.3 (f))</td><td>An alarm occurs if the force exerted during the search meets the conditions indicated in Figure 1.5.4.3 (e). Refer to "APPENDIX: B ALARM CODES OF FORCE CONTROL" and remove a cause of the alarm.
Increase the values of this parameter after all measures are taken. Let FLx be an allowable force in the X direction, Fdx be a specified force in the X direction, and Fx be a detected force in the X direction.
For example, for the force in the X direction, an alarm is issued in the following cases:
$Fx < -FLx$ or $Fx > Fdx + FLx$ (when $Fdx > 0$)
$Fx > FLx$ or $Fx < Fdx - FLx$ (when $Fdx < 0$)
Fx : Detection force in the X direction
FLx : Force limit in the X direction
Fdx : Force instruction value in the X direction
The same relationship holds for Y, Z, W, P, and R.
"Defaults : X : 200.00 Y : 200.00 Z : 200.00 N
W : 15.00 P : 15.00 R : 15.00 N*m"


Fig. 1.5.4.3 (f) Force Limit and the occurrence of an alarm</td></tr>
<tr><td>Torque Error
Compensate SW</td><td>This switch is used for torque error compensation. This can be set to 'On' or 'Off'.

When this switch is set to ON, torque error compensation is performed using "Torque Error Data W", "Torque Error Data P", "Torque Error Data R", and "Torque Error Fd".
• Before setting this switch to ON, execute the torque error acquisition instruction. (Refer to "Basic Function Guide: 1.11.3 Torque Error Acquisition Instruction")
"Default : OFF"</td></tr>
</table>

Item	Description
Torque Error Data	Displays the value estimated from the moment information of the force sensor when the robot is actually pushed with "Torque Error Fd" when "TRQ ERROR" is performed. W, R, and P represent rotation about the X-axis, rotation about the Y-axis, and rotation about the Z-axis in the user frame (UF) used, respectively. When "Torque Error Compensate SW" is set to ON, torque error compensation is performed using these values. (The values cannot be modified.) "Defaults : W : 0.000 N*m P : 0.000 N*m R : 0.000 N*m"
Torque Error Fd	Displays the value of the force actually exerted when "TRQ ERROR" is performed. When "Torque Error Compensate SW" is set to ON, torque error compensation is performed using this value. (The value cannot be modified.) "Default : 30.00 N"
Velocity Constant Switch	This item is the switch of the function for protecting against workpiece jamming during insertion by preventing the speed from increasing excessively, for example, even when reaction force disappears abruptly. This can be set to 'On' or 'Off'. If this switch is set to "ON", the velocity along the "Insert Direction" during the search operation can be controlled as follows. • If "Search Insert Vel" on the "Basic Data Settings" screen is "0", the velocity is controlled so as not to exceed "Velocity Constant". • If "Search Insert Vel" on the "Basic Data Settings" screen is not "0", the velocity is controlled so as not to exceed "Search Insert Vel" regardless of the value of "Velocity Constant". If this switch is set to "OFF", the velocity is not limited. "Default : ON"
Velocity Constant	This parameter determines the maximum velocity along [Insert Direction] during the search operation. Refer to "Velocity Constant Switch" above as well. "Default : 5.00 mm/ s"
Force End Judgment Switch	This item is the switch of the function for ending force control operation after checking whether a proper force has been generated. This can be set to 'On' or 'Off'. When [Force End Judgment Switch] is "ON", after the workpiece is inserted to the specified depth, force control ends if [Judgment Result] is "SUCCESS". An alarm occurs if [Judgment Result] is not "SUCCESS" when [Search Time Limit] on the [Basic Data Settings] screen elapses. (When both [Force End Judgment Switch] and [Torque End Judgment Switch] are "ON", after the workpiece is inserted to the specified depth, force control ends if the judgment for both is "SUCCESS".) "Default : OFF"
Min. Force Rate	This value is used to judge whether an appropriate amount of force was generated. Enter a ratio. After the workpiece is inserted to the specified depth, [Judgment Result] is "SUCCESS" if the magnitude of the force in [Insert Direction] exceeds [Min. Force Rate] x [Search Push Force] / 100. If [Search Time Limit] elapses while the above conditions are not met, [Judgment Result] is "FAILURE". "Default : 80.00 %"
Judgment Result	This item displays [Judgment Result] at the end of "Search" for which [Force End Judgment Switch] is "ON". If the function has never been executed with [Force End Judgment Switch] set to "ON", "----" is displayed. "Default : -----"
Force Average	This item displays the force magnitude of [Insert Direction] at the end of "Search" for which [Force End Judgment Switch] is "ON". "Default : Z : 0.00 N"

Item	Description
Torque End Judgment Switch	This item is the switch of the function for ending force control operation after checking whether the magnitude of generated torque has been decreased to a proper level. This can be set to 'On' or 'Off'. When [Torque End Judgment Switch] is "ON", after the workpiece is inserted to the specified depth, force control ends if [Judgment Result] is "SUCCESS". An alarm occurs if [Judgment Result] is not "SUCCESS" when [Search Time Limit] on the [Basic Data Settings] screen elapses. (When both [Force End Judgment Switch] and [Torque End Judgment Switch] are "ON", after the workpiece is inserted to the specified depth, force control ends if the judgment for both is "SUCCESS".) "Default : OFF"
Max. Torque	Enter the value to use to judge whether the magnitude of the generated torque is smaller than the appropriate value. If the magnitude of the torque about the axes other than the axis for [Pushing Direction] is less than or equal to [Max. Torque] after the workpiece is inserted to the specified depth, [Judgment Result] is "SUCCESS". "Default : 0.50 N*m"
Judgment Result	This item displays [Judgment Result] at the end of "Search" for which [Torque End Judgment Switch] is "ON". If the function has never been executed with [Torque End Judgment Switch] set to "ON", "----" is displayed. "Default : -----"
Torque Average	This item displays the magnitude of torque about the axes other than the axis for [Insert Direction] at the end of "Search" for which [Torque End Judgment Switch] is set to "ON". (If the axis for [Insert Direction] is Z, W for indicating rotation about the X-axis and P for indicating rotation about the Y-axis are displayed. If the axis for "Insert Direction" is Y, W and R are displayed.) "Defaults : W : 0.00 N*m P : 0.00 N*m"
Approach Acc. Time	Enter the time until the velocity reaches the [Approach Velocity] on the [Basic Data Settings] screen after the FORCE statement is started. "Default : 0.40 sec"
Search Acc. Time	Enter the time until the velocity reaches the [Search Insert Vel] on the [Basic Data Settings] screen after the force exceeds the [Contact F Threshold] on the [Basic Data Settings] screen. "Default : 0.40 sec"
Force Denoising Sw	This parameter enables the "Force Denoising" function. This can be set to 'On' or 'Off'. This function removes the background big noise from force data. This function is useful when: • tool or work-piece is heavy • using a tool such as a grinder and that has a big vibration "Default : OFF"
Signal Output for ERR SW	This parameter enables the "Signal Output for ERR" function. This can be set to 'On' or 'Off'. If it is "On", the specified signal is output when an error occurs during execution of force control. "Default : OFF"
Output Signal Type (Signal Output for ERR)	Select the type of signal to output when an error occurs during execution of force control with the error signal output function. "DO", "RO", "FLAG" are available for the kind of a signal. "Default : DO"
Output Signal Number (Signal Output for ERR)	Select the number of signal to output when an error occurs during execution of force control with the error signal output function. "Default : 0"

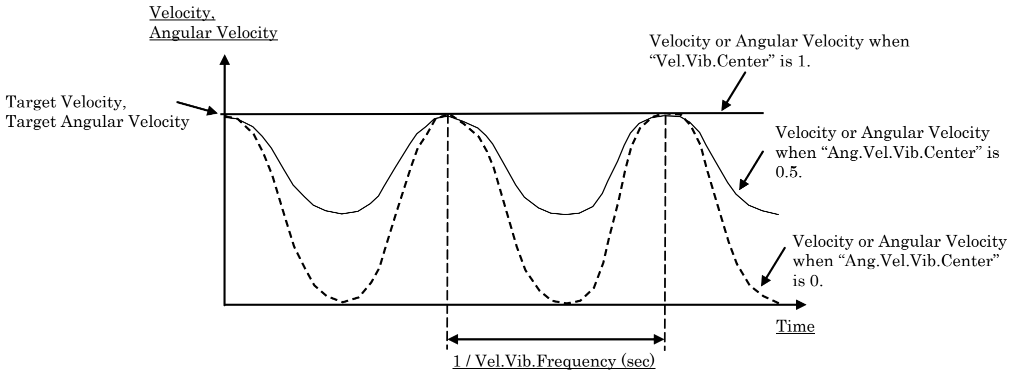
Item	Description
Frc.Ctrl. End by REG SW	This item is the switch of the function for ending operation when the condition specified in [End Register Number] is met. This can be set to 'On' or 'Off'. Normally, the operation of "Search" ends when the insertion depth reaches [Search End Depth]. Also when either or both [Force End Judgment Switch] and [Torque End Judgment Switch] are "ON", the insertion operation continues after the insertion depth reaches [Insert Depth (Design)] until the judgment result of all functions set to "ON" is "SUCCESS". "Default : OFF"
End Register Number	If "Frc.Ctrl. End by REG SW" is ON, • The value of the Numeric Register whose number is designated by this parameter automatically becomes 0 when a force control instruction with this schedule starts. • If the value of the Numeric Register whose number is designated by this parameter becomes 1, the force control instruction with this schedule ends. "Default : 0"
Pushing Force Change Switch	This item is the switch for enabling the function for varying the pushing force in the insertion direction at the set interval. This can be set to "ON" or "OFF". This function can increase the success rate in cases such as when a blockage occurs during insertion and stops motion, when co-rotation occurs with the workpiece, or when there is a loose part such as a clutch in the workpiece.
Pushing Force MIN Limit	When [Pushing Force Change Switch] is "ON", the pushing force changes in a sine wave from [Pushing Force MIN Limit] to [Search Push Force] on the [Basic Data Settings] screen.
Pushing Force Frequency	If [Pushing Force Change Switch] is "ON", the pushing force changes in a sine wave with the frequency in [Pushing Force Frequency].
G F S	G represents a motion group number at the time of teaching. F represents a force control number. S represents a force sensor number. (These settings cannot be changed.) "Defaults : G F S : 1 1 1"

[Search parameters performance] screen

Parameters shown in this section are for advanced users.
Each parameter on this screen is available for each of the six directions: X, Y, Z, W, P, and R.

Table 1.5.4.3 (d) [Search parameters performance] screen

Item	Description
Vel. Vib. Center	Set a value of 0 to 1 in this parameter to vibrate a target velocity (angular velocity) during search. Change the target velocity (angular velocity) during search operation according to the following expression: V = Vd { (1-C) cos(2 ft) + C} V : Target velocity (angular velocity) during search operation Vd : Target velocity (angular velocity) . Parameter on the search parameters basic screen C : Velocity vibration center f : Velocity vibration frequency t : Time When 0 is set, the velocity of "Target Velocity (Target Angular Velocity)" is the amplitude of velocity vibration, and vibration occurs without making any movement. When 1 is set, the amplitude is 0, and a constant velocity (angular velocity) operation is performed at "Target Velocity (Target Angular Velocity)". "Default: X : 1.00 Y : 1.00 Z : 1.00 W : 1.00 P : 1.00 R : 1.00" (for no vibration)

Item	Description
Vel. Vib. Frequency (Fig. 1.5.4.1 (g))	When a value less than 1 is set in "Vel. Vib. Center", the target velocity (angular velocity) vibrates at the frequency set in this parameter. Set a frequency from 0.1 Hz to 3 Hz. "Default: X : 1.00 Y : 1.00 Z : 1.00 W : 1.00 P : 1.00 R : 1.00" "Unit: Hz"  Fig. 1.5.4.3 (g) Vel. Vib. Frequency
Weaving Time	Weave operation finely vibrates force or torque at a location where a position or angular match is found during search. For the time specified in this parameter, weave operation is performed. "Default: X : 1.00 Y : 1.00 Z : 1.00 W : 1.00 P : 1.00 R : 1.00" "Unit: sec"
Weaving Frequency	Vibration frequency in weave operation. "Default: X : 1.00 Y : 1.00 Z : 1.00 W : 1.00 P : 1.00 R : 1.00" "Unit: Hz"
Reverse Switch	This switch specifies whether to reverse the search direction when the workpiece cannot be inserted even by weave operation or the upper search range limit is reached. If this switch is set to OFF, search operation ends when the upper search range limit is reached. If this switch is set to ON, search operation is continued by reversing the direction when the upper search range limit is reached. "Default: X : ON Y : ON Z : ON W : ON P : ON R : ON "
Retry Number	If the workpiece cannot be inserted even by weave operation or the upper search range limit is reached, and "Reverse Switch" is set to ON, reversing the direction is repeated as many times as specified in this parameter. When the number of reversions exceeds the value specified in this parameter, the "Force 420: Search Retry Limit" error occurs. If this error occurs frequently, increase the value specified in this parameter. "Default: X : 10000 Y : 10000 Z : 10000 W : 10000 P : 10000 R : 10000 "
Retry Magnification	If the workpiece cannot be inserted even by weave operation or the upper search range limit is reached, and "Reverse Switch" is set to ON, reversing the direction is repeated as many times as specified in "Retry Number". Each time the direction is reversed, "Target Force" or "Target Torque" multiplied by the magnification specified in this parameter is used as a new target force or target torque in search operation. If search is retried frequently, increase (or decrease) the value specified in this parameter by about 10% to 20%. "Default: X : 1.00 Y : 1.00 Z : 1.00 W : 1.00 P : 1.00 R : 1.00"

Item	Description
Search Range Margin	Search operation is performed in the range specified by the search basic data "Size of Search Range". An alarm is issued when the upper search range limit plus the value specified in this parameter is reached. When search operation is performed in the X, Y, or Z direction: When search operation is performed in the W, P, or R direction: "Default: X : 3.00 Y : 3.00 Z : 3.00" (Unit : mm) "Default: X : 3.00 Y : 3.00 Z : 3.00" (Unit : deg)

Function keys

The function keys indicated have the following functions:

Table 1.5.4.3 (e) Function keys

Key	Item	Description
F1	TYPE	Allows you to change the display to a menu other than the force control menu.
F2	GROUP	Allows you to change motion groups.
	HELP	Display the help screen.
F3	NUMBER	Allows you to display the screen for another schedule number.
F4	CHOICE	Displays the choices for the setting.
	ON	Changes the setting to 'On'.
Shift + F4	DEFAULT	Allows you to set default data of the force control function.
F5	PERFORM / BASIC	Allows you to switch between the basic and performance screens.
	OFF	Changes the setting to 'Off'.

1.5.4.4 Phase Search

Overview

The "Phase Search" function performs searching in the rotation direction around the insertion axis.
There are three types of configuration screens; the [Basic Data Settings] screen that must be configured by the user, and the [Performance Data Settings] screen and [PhaseM Performance Param.] screen that are only configured when required.

NOTE

1. If the robot is a CRX robot and the software version is 7DF5/08 or later, "Phase Search" can also be used with the internal sensor. In this case, no external force sensor is necessary. However, the rotation axis used in Phase Search must match wrist axis J6 of the robot.
2. The screens are different for robots that support “parameter auto tuning” and for robots that do not.
3. If the software version is 7DF5/07 or earlier, parameter “2 sensor” is not displayed in the [Basic Data Settings] screen.

[Function selection] screen

```
1
1 Unused
2 Constant Push
3 Face Match
4 Shaft Insert
5 Groove Insert
6 Search
7 Phase Search
8 --next page--
```

[Basic Data Settings] screen
For robots "parameter auto tuning" is supported

```
Force Ctrl/Basic
                                          11/11
 Schedule[1]                  G:1 F:1 S:1
 1 Function             : Phase Search
 2 Sensor               : Ext. Force Sensor
 3 Comment              : [                  ]
 4 User Frame No.                 UF:   0
 5 Tool Frame No.                 TF:   1
 6 Insert Direction               : -Z
 7 PhaseMatch End Depth :    5.00 mm
 8 Individual Diff. (+) :    3.00 mm
 9 Individual Diff. (-) :    0.00 mm
10 Max Force Limit      :   50.00 N
11 Param. Auto Tune     :   --------

[TYPE] | Execute | Result |  | PERFORM | >
  F1       F2       F3      F4     F5
```

[Parameter Auto Tune] screen

```
Force Ctrl/Auto Tune
                                          1/14
 Schedule[1]                  G:1 F:1 S:1
 1 Function             : Phase Search
 2 Comment              : [                  ]
 3 Param. Auto Tune     :        -------
 4 Approach Velocity    :      1.00 mm/s
 5 PhaseMatch Insert Vel:      2.00 mm/s
 6 Contact F Threshold  :     10.00 N
 7 PhaseMatch Push Force:     15.00 N
 8 PhaseMatch Ang. Vel  :      5.00 deg/s
 9 PhaseMatch Torque    :      1.00 N*m
10 PhaseMatch Ang. Limit :    30.00 deg
11 Pushing Time         :      0.00 sec
12 PhaseMatch Time Limit:     60.00 sec
13 Pushing Impedance    :  [Master Freq. ]
14 Initial Push Force   :     15.00 N

[TYPE] |  |  | [CHOICE] |  | >
  F1     F2   F3    F4     F5
```

[Basic Data Settings] Screen
For robots "parameter auto tuning" is not supported

```
Force Ctrl/Basic
                                          1/20
 Schedule[1]                  G:1 F:1 S:1
 1 Function             : Phase Search
 2 Sensor               : Ext. Force Sensor
 3 Comment              : [                  ]
 4 User Frame No.                 UF:   0
 5 Tool Frame No.                 TF:   1
 6 Insert Direction               : -Z
 7 PhaseMatch End Depth :    5.00 mm
 8 Individual Diff. (+) :    3.00 mm
 9 Individual Diff. (-) :    0.00 mm
10 Approach Velocity    :    1.00 mm/s
11 PhaseMatch Insert Vel:    0.00 mm/s
12 Contact F Threshold  :   10.00 N
13 PhaseMatch Push Force:   15.00 N
14 PhaseMatch Ang. Vel  :    1.00 deg/s
15 PhaseMatch Torque    :    1.00 N*m
16 PhaseMatch Ang. Limit:   10.00 deg
17 Pushing Time         :    0.00 sec
18 PhaseMatch Time Limit:   20.00 sec
19 F.Ctrl. Gain Auto Modify :     OFF
      Prev. Result      : No Change
20 Force Control Gain :          Detail

[TYPE] | GROUP | NUMBER | [CHOICE] | PERFORM | >
  F1      F2       F3        F4        F5
```

[Force Ctrl/Gain] screen

```
Force Ctrl/Gain
                                          1/1
 Schedule[1]                  G:1 F:1 S:1
   Function             : Phase Search
 1 Phase M Impedance    : [Master Freq. ]

[TYPE] | GROUP | NUMBER | [CHOICE] |  | >
  F1      F2       F3        F4      F5
```

Fig. 1.5.4.4 (a) "Phase Search" screens (1/2)

[Performance Data Settings] Screen (1/2)

```
Force Ctrl/Perform
                                        1/37
 Schedule[1]                 G:1 F:1 S:1
 1 Function           : Phase Search
 2 Comment            : [                  ]
 3 Simple Customize Sw             : OFF
 4    Cont. Exec. Max. Count       :    1
 5 Customize Parent Number   :          0
 6    Customize ParaChg Conct: OFF
 7 Customize Auto. Cnt. Exec. Sw : OFF
 8    Auto. Cnt. Exec. Child No.   :    0
 9    Schedule No. Output Reg. No.:    0
10 User Frame Compensation:   OFF
11 PhaseM acc. time    :        0.100 sec
12 Decel. Depth Rate   :        95.00 %
13 PhaseM Performance Param.: Perform
14 Settling Switch              : OFF
15    Settling Time        :     1.00 sec
16    Settling Rate        :   100.00 %
17 Initial Push Force      :    50.00 N
      Force Limit
18  X:   500.00 Y:   500.00 Z:   500.00 N
19  W:    50.00 P:    50.00 R:    50.00N*m
[TYPE] HELP NUMBER [CHOICE] BASIC >
F1 F2 F3 F4 F5
```

[Performance Data Settings] Screen (2/2)

```
Force Ctrl/Perform
                                       20/37
20 Torque Error Compensate SW:   OFF
      Torque Error Data
        W:      0.000 N*m
        P:      0.000 N*m
        R:      0.000 N*m
      Torque Error Fd     :     50.00 N
21 Velocity Constant Switch  :    ON
22    Velocity Constant   :      5.00 mm/s
23 Force End Judgment Switch : OFF
24    Min. Force Rate   :       80.00 %
      Judgment Result   :          -------
        Force Average   Z:       0.00 N
25 Approach Acc. Time       :   0.70 sec
26 PhaseMatch Acc. Time     :   0.70 sec
     PhaseMatch ForceControl Valid Switch
27     X: OFF             Y: OFF
28     W: OFF             P: OFF
29 Force Denoising Sw      :    OFF
30 Signal Output for ERR SW:   OFF
31    Output Signal Type   :     DO
32    Output Signal Number:        0
33 Frc.Ctrl. End by REG SW :   OFF
34    End Register Number :        0
35 Push Force Change Switch : OFF
36    Push Force LowerLim.   :    0.00 N
37    Push Force Frequency   :    0.12 Hz
[TYPE] HELP NUMBER [CHOICE] BASIC >
F1 F2 F3 F4 F5
```

[PhaseM Performance Param.] screen

```
Search/Perform
                                        1/8
 Search parameters Performance
  1 Ang.Vel.Vib. Center    :     1.00
  2 Ang.Vel.Vib. Freq.     :     1.00 Hz
  3 Weaving Time           :     1.00 sec
  4 Weaving Frequency      :     1.00 Hz
  5 Reverse Switch          : ON
  6 Retry Number           :   10000
  7 Retry Magnification    :    1.00
  8 Search Range Margin:        3.00 deg
[TYPE]                                 >
F1 F2 F3 F4 F5
```

Fig. 1.5.4.4 (b) "Phase Search" screens (2/2)

Adjusting the Phase Search Parameters

1. Display the [Basic Data Settings] screen for the 'Phase Search' function.
2. Configure "Insert Direction", "UFrame Number", "UTool Number", and "PhaseMatch End Depth".
3. If the function supports parameter auto tuning, execute "Parameter Auto Tuning". (For details, refer to "Basic Functions Guide: 1.10 FORCE CONTROL PARAMETER AUTO TUNING".)
   If the function does not support parameter auto tuning, execute [F.Ctrl. Gain Auto Modify].
   (Refer to "Basic Function Guide: 1.11.2 Force Control Gain Auto Tuning Instruction".)
4. Configure the other parameters on the [Basic Data Settings] screen.
5. Configure the parameters on the [Performance Data Settings] screen and [PhaseM Performance Param.] screen, as required.

> **NOTE**
> For the outline of force control instruction programming, refer to "Basic Function Guide: 1.1 NOTES / RESTRICTIONS", and "Basic Function Guide: 1.2 TEACHING PROCEDURE".

For details of each parameter, see the pages that follow.

The procedure for tuning other parameters after completion of automatic force control gain adjustment is shown below.

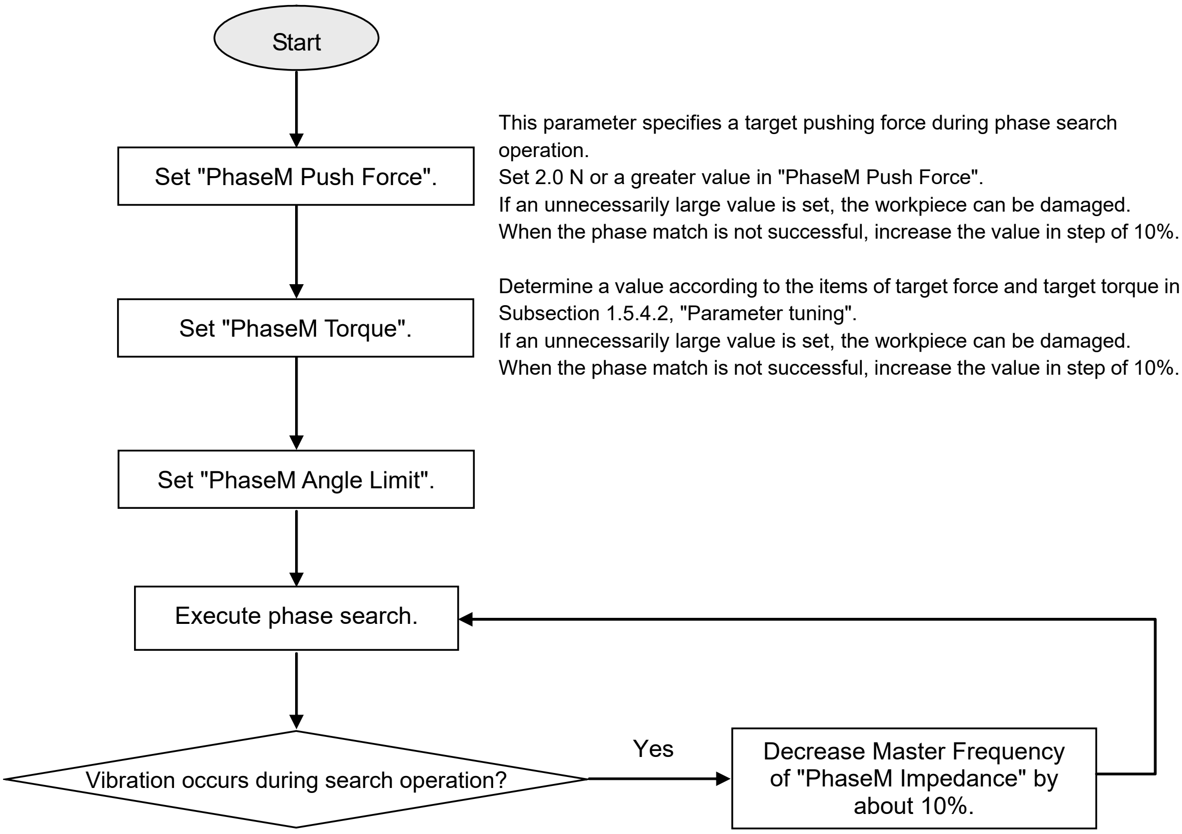


Fig. 1.5.4.4 (c) Adjusting Other Parameters (1/2)

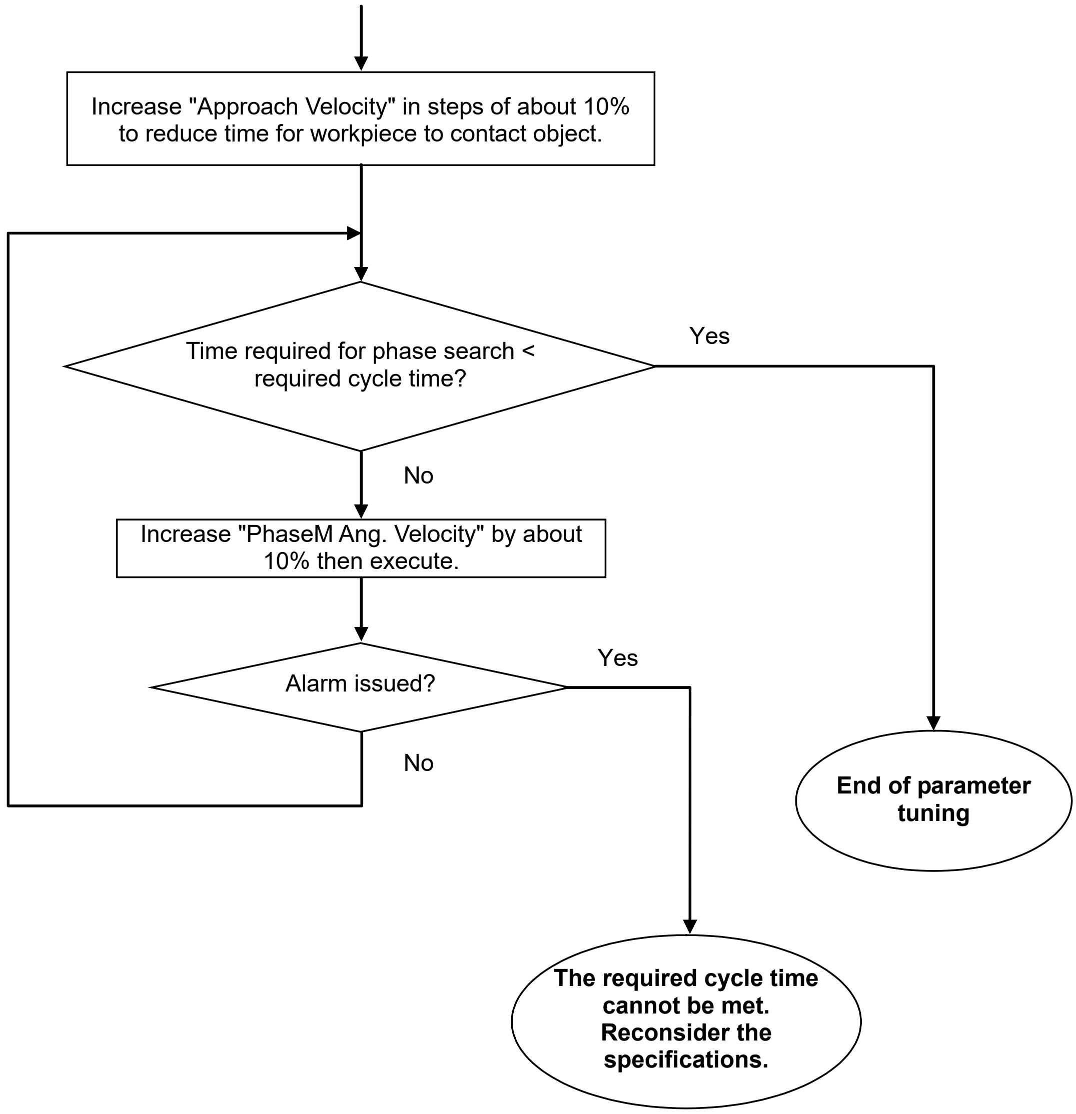


Fig. 1.5.4.4 (d) Adjusting Other Parameters (2/2)

[Basic data settings] screen

Parameters shown in this section must be set.

Table 1.5.4.4 (a) [Basic data settings] screen

Item	Description
Function	A desired function is selected from "Function selection screen". In this case, select "Phase search".
Sensor Type	Select the type of sensor being used. For the CRX series, select either "External Force Sensor" or "Internal Sensor". A force sensor is unnecessary if "Internal Sensor" is selected. For robots other than the CRX series, "External Force Sensor" is automatically selected and cannot be changed. "Default : External Force Sensor"
Comment	Enter a comment for identifying the schedule data. Maximum number of characters: 16 characters.
User Frame Number	Enter the number of the user frame to use when searching. (Enter the user frame number that was set in "Basic Functions Guide: 1.2 TEACHING PROCEDURE".) "Default : UF:0"

Item	Description
Tool Frame Number	Enter the number of the tool frame to use when searching. (Enter the user tool number that was set in "Basic Functions Guide: 1.2 TEACHING PROCEDURE".) "Default : TF:1"
Insert Direction	Enter the direction to insert using the user frame that is set. "Default : – Z"
PhaseMatch End Depth	Enter the value for when insertion proceeds to a certain point, phase matching is judged to be successful and phase matching ends. "Default : 5.00 mm"
Individual Diff. (+)	If insertion proceeds past [PhaseMatch End Depth] due to individual variations in a workpiece, enter the amount of margin to allow. An alarm occurs if insertion exceeds (PhaseMatch End Depth - Individual Diff. (-) + this value). "Default : 3.00 mm"
Individual Diff. (-)	If insertion does not reach [PhaseMatch End Depth] due to individual variations in a workpiece, enter the amount of margin to allow. If (PhaseMatch End Depth - this value) is reached, insertion is determined to be successful. "Default : 0.00 mm"
Approach Velocity	Enter the target operation velocity until contact is made with the target. "Default : 1.00 mm/ sec" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
PhaseMatch Insert Vel	Enter the target velocity for inserting the workpiece when performing phase matching. "Default : 0.00 mm/s for robots that do not support parameter auto tuning : 2.00 mm/s for robots that support parameter auto tuning" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
Contact F Threshold	Enter the threshold value for determining whether contact has been made with the target. "Default : 10.00 N" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen. ⚠ **CAUTION** The cycle time may get worse if this value is too high, because the actual insertion operation starts after contact is made.
PhaseMatch Push Force	Enter the target value for the force to push the workpiece to the insertion surface when performing phase matching. Increase the value if the workpiece is not inserted despite the phase being correct and decrease the value if the workpiece being inserted into is dragged along due to the phase matching rotation. "Default : 30.00 N" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen. **NOTE** When changing [PhaseMatch Push Force], change it by about 10% each time.

Item	Description
PhaseMatch Ang. Vel	Enter the target value for the rotation velocity during phase matching. Increase this value if search operation is successful but takes a longer time. Decrease this value if search operation fails. "Default : 1.00 deg/s for robots that do not support parameter auto tuning : 5.00 deg/s for robots that support parameter auto tuning" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
PhaseMatch Torque	Enter the target torque value when rotating the workpiece during phase matching. If "Reverse Switch" in the Phase Matching performance screen is ON (default) and the actual moment exceeds this value, the rotation direction of the workpiece is automatically reversed. If little rotation occurs, and "Force 264 Error" or "Force 420 Error" occurs, increase this value in steps of about 10% to 20%. If a phase match point is passed, decrease this value in steps of about 10% to 20%. (Determine a value according to the items of target force and target torque described in "Basic Function Guide: 1.5.4.2 Parameter tuning".) "Default : 1.00 N*m" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
PhaseMatch Ang. Limit	Enter the maximum value for the rotation range for performing phase matching. If the reverse switch on the phase matching performance screen is set to ON, phase matching is continued by reversing the direction when the upper angular range limit is reached. "Default : 10.00 deg for robots that do not support parameter auto tuning : 30.00 deg for robots that support parameter auto tuning" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
Pushing Time	When search operation is assumed to be successful, pushing operation is performed in the insertion direction to absorb length differences in individual workpieces. Enter the corresponding pushing time. "Default : 0.00 sec" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
PhaseMatch Time Limit	The phase matching time is the time until searching is judged to have succeeded after making contact with the target and starting the insertion operation. Enter the maximum time. If "PhaseMatch End Depth" is not reached within this period, an alarm is issued. This search time does not include a time for pushing operation after search operation is assumed to be successful ([Pushing Time]). (Refer to [Pushing Time].) "Default : 20.00 sec for robots that do not support parameter auto tuning : 60.00 deg for robots that support parameter auto tuning" **NOTE** For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.
F.Ctrl. Gain Auto Modify	This item is the switch used for automatic force control gain tuning. Set "On" to execute auto adjustment of the force control gain. (Refer to "Basic Function Guide: 1.11.2 Force Control Gain Auto Tuning Instruction".) "Default :OFF" **NOTE** This is not displayed for robots that support parameter auto tuning.

Item	Description
Prev. Result	Displays the previous result for [F.Ctrl. Gain Auto Modify]. "Default : No Change" **NOTE** This is not displayed for robots that support parameter auto tuning.
Force Control Gain	Perform the operation below to switch to the [Force Control Gain] screen. • Set this parameter manually. Move the cursor to this line then press the ENTER key. The screen display switches to the force control gain detail screen. (For the parameters that can be set on this screen, refer to "Basic Function Guide: 1.6 FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".) **NOTE** This is not displayed for robots that support parameter auto tuning.
Max Force Limit	Perform adjustment so that this value is not exceeded during parameter auto tuning. **NOTE** This parameter is displayed only for robots that support parameter auto tuning.
Param. Auto Tune	Display the status of and execute parameter auto tuning. '----', 'DONE', 'STOPPED', or 'FAILURE' is displayed as the status of automatic adjustment. If you press Shift+F2, auto tuning is executed. If you press F3, the auto tuned parameters are displayed. "Default : ----" **NOTE** This parameter is displayed only for robots that support parameter auto tuning.
G F S	G represents a motion group number at the time of teaching. F represents a force control number. S represents a force sensor number. (These settings cannot be changed.) "Defaults : G F S : 1 1 1"

[Performance data setting] screen

Parameters shown in this section are for advanced users.

Table 1.5.4.4 (b) [Performance data setting] screen

Item	Description
Function	A desired function is selected from "Function selection screen". In this case, select "Phase search".
Comment	Enter a comment for identifying the schedule data. Maximum number of characters: 16 characters.
Simple Customize Sw	This switch is for force control continuous execution. This can be set to 'On' or 'Off'. It enables to execute the schedule data being edited after any other schedule. (Refer to "Basic Function Guide: 1.7.3 Simple Customization Function".) "Default : OFF"
Cont. Exec. Max. Count	Enter an integer for the number of times a force control schedule with the simple customization function enabled can be executed continuously. (Refer to “Basic Function Guide: 1.7.3 Simple Customization Function".) "Default : 1"
Customize Parent Number	Enter this when executing force control continuously. (Refer to “Basic Function Guide: 1.7.4 Customization Function".) "Default : 0"
Customize ParaChg Connection	This item is set when force control is executed successively. Select 'Both D', 'P2C', 'C2P', or 'Off'. (Refer to “Basic Function Guide: 1.7.4 Customization Function".) "Default : OFF"

Item	Description
Customize Auto. Cnt. Exec. Sw (Customize Auto. Cnt. Exec.)	This parameter specifies a switch for "Customize Auto. Cnt. Exec." Function. This can be set to 'On' or 'Off'. "Customize Auto. Cnt. Exec." function enables to execute a series of the force control schedule data, which are combined with customization function, with a single force control instruction of the top parent schedule data. Set "Customize Auto. Cnt. Exec. Sw" to ON for all schedule data that are combined with "Customize Auto. Cnt. Exec." function. (Refer to “Basic Function Guide: 1.7.5 Customization Automatic Continuous Execution Function".) "Default : OFF"
Auto. Cnt. Exec. Child No. (Customize Auto. Cnt. Exec.)	Enter the number of the schedule data to execute next in "Customization Auto Continuous Execution". Set "Customize Parent Number" of the child, designated by "Auto. Cnt. Exec. Child No.", to this schedule data number. "Customize Auto. Cnt. Exec." function can link the schedule data up to 10. "Default : 0"
Schedule No. Output Reg. No. (Customize Auto. Cnt. Exec.)	Enter the number of the Numeric register that is used for 'Customization Auto Continuous Execution' function. When "Customize Auto. Cnt. Exec." function is executed, a running schedule data number is written to this Numeric register. If the series of the schedule data ends normally, 0 is written to this Numeric register. Only "Schedule No. Output Reg. No." of the top parent in the series of the schedule data is used. "Schedule No. Output Reg. No." of other than the top parent are not used. If "Schedule No. Output Reg. No." of the top parent equals to 0, this function does not output to the Numeric Register. When the series of the schedule data is executed, with the value that is output to the Numeric Register, it is possible to know whether all schedule data ends normally or if not, which schedule data fails. "Default : 0"
User Frame Compensation SW	This is a switch for correcting a user frame set on a workpiece target plane through vision. This parameter is useful when a workpiece target is not positioned correctly. Select 'Off', 'Pos. Reg.', or 'VISION REG'. The switch must be used in combination with the OFFSET or VOFFSET instruction. (Refer to "Basic Function Guide: 1.8 USER FRAME COMPENSATION".) "Default : OFF"
PhaseM acc. Time	Enter the constant during acceleration/deceleration of the PhaseMatch Ang. Vel. "Default : 0.100 sec"
Decel. Depth Rate	The phase matching angular velocity is reduced to the [PhaseMatch Ang. Vel] x 0.1 on the [Basic Data Settings] screen, when insertion has reached the [PhaseMatch End Depth] x [Decel. Depth Rate] / 100 on the [Basic Data Settings] screen. If an attempt to move the workpiece forcibly damages the workpiece or stops insertion even when a phase match is ensured, decrease this value. "Default : 95.00 %"
Phase Performance Param.	Configure the advanced parameters for phase matching on the [PhaseM Performance Param.] screen. Perform the following operation to switch to the [PhaseM Performance Param.] screen. • Move the cursor to [PERFORM], and press the [Input] key on the teach pendant of the robot controller. The [PhaseM Performance Param.] screen is displayed. (Refer to "[PhaseM Performance Param.] screen".)
Settling Switch	Settling involves reducing the pushing force after pushing is completed. Sets the switch used for settling to 'On' or 'Off'. If this is set to 'On', it activates if the workpiece vibrates due to a large shock when the hand is detached after pushing stops. "Default : OFF"

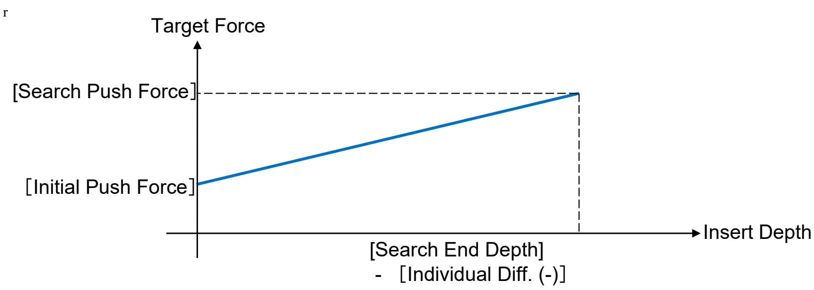
<table>
<tr><th>Item</th><th>Description</th></tr>
<tr><td>Settling Time</td><td>Enter the time until settling stops after it is started.
"Default : 1.00 sec"</td></tr>
<tr><td>Settling Rate</td><td>Enter the settling ratio for the pushing force.
The force is ultimately reduced to "PhaseMatch Push Force" x "Settling Rate" / 100. If this "Settling Rate" is set to 100 %, settling is not performed. If this "Settling Rate" is set to 0 %, the force is reduced to 0.
"Default : 100.00 %"</td></tr>
<tr><td>Initial Insert Force
(Fig. 1.5.4.4 (e))</td><td>Enter the target force when starting insertion.
This parameter is useful when a small force is initially used to insert a workpiece. As the workpiece is inserted, the target force during insertion approaches the basic data " PhaseMatch Push Force".
"Default : 30.00 N"


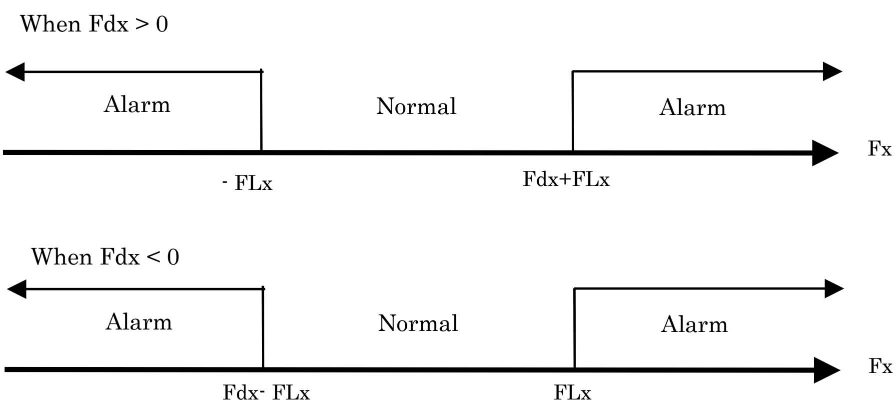
Fig. 1.5.4.4 (e) Init Force Keep Depth
NOTE
For robots that support parameter auto tuning, it is displayed in [Parameter auto tune] screen.</td></tr>
<tr><td>Force Limit
(Fig 1.5.4.4(f))</td><td>If force generated during search satisfies one of the expressions below, an alarm (FORC-216 - FORC-221) is issued. Refer to "APPENDIX: B ALARM CODES OF FORCE CONTROL" and remove a cause of the alarm. Increase the values of this parameter after all measures are taken. Let FLx be an allowable force in the X direction, Fdx be a specified force in the X direction, and Fx be a detected force in the X direction.
Then, an alarm is issued in the following cases:
$Fx < -FLx$ or $Fx > Fdx + FLx$ (when $Fdx > 0$)
$Fx > FLx$ or $Fx < Fdx - FLx$ (when $Fdx < 0$)
Fx : Detection force in the X direction
FLx : Force limit in the X direction
Fdx : Force instruction value in the X direction
The same relationship holds for Y, Z, W, P, and R.
"Defaults : X : 200.00 Y : 200.00 Z : 200.00 N
W : 15.00 P : 15.00 R : 15.00 N*m"


Fig. 1.5.4.4 (f) Force Limit and the occurrence of an alarm</td></tr>
</table>

Item	Description
Torque Error Compensate SW	This switch is used for torque error compensation. This can be set to 'On' or 'Off'. If this switch is turned ON, torque error compensation is performed, using Torque Error Data W, P, and R, and Torque Error Fd, indicated below. * Execute the torque error acquisition instruction before turning on this switch. (Refer to "Basic Function Guide: 1.11.3 Torque Error Acquisition Instruction") "Default : OFF"
Torque Error Data	Displays the value estimated from the moment information of the force sensor when the robot is actually pushed with "Torque Error Fd" when "TRQ ERROR" is performed. W, R, and P represent rotation about the X-axis, rotation about the Y-axis, and rotation about the Z-axis in the user frame (UF) used, respectively. When "Torque Error Compensate SW" is set to ON, torque error compensation is performed using these values. (The values cannot be modified.) "Defaults : W : 0.000 N*m P : 0.000 N*m R : 0.000 N*m"
Torque Error Fd	Displays the value of the force actually exerted when "TRQ ERROR" is performed. If “Torque Error Compensate SW” is turned ON, this setting is used to correct the torque error. (This value cannot be modified.) "Default : 30.00 N"
Velocity Constant Switch	This item is the switch of the function for protecting against workpiece jamming during insertion by preventing the speed from increasing excessively, for example, even when reaction force disappears abruptly. This can be set to 'On' or 'Off'. If this switch is set to "ON", the velocity along the "Insert Direction" during the phase search operation can be controlled as follows. • If "PhaseMatch Insert Vel" on the "Basic Data Settings" screen is "0", the velocity is controlled so as not to exceed "Velocity Constant". • If "PhaseMatch Insert Vel" on the "Basic Data Settings" screen is not "0", the velocity is controlled so as not to exceed "PhaseMatch Insert Vel" regardless of the value of "Velocity Constant". If this switch is set to "OFF", the velocity is not controlled. "Default : ON"
Velocity Constant	This parameter determines the maximum velocity along [Insert Direction] during the phase search operation. Refer to "Velocity Constant Switch" above as well. "Default : 5.00 mm/ sec"
Force End Judgment Switch	This item is the switch of the function for ending force control operation after checking whether a proper force has been generated. This can be set to 'On' or 'Off'. When [Force End Judgment Switch] is "ON", after the workpiece is inserted to the specified depth, force control ends if [Judgment Result] is "SUCCESS". An alarm occurs if [Judgment Result] is not "SUCCESS" when [PhaseMatch Time Limit] on the [Basic Data Settings] screen elapses. "Default : OFF"
Min. Force Rate	This value is used to judge whether an appropriate amount of force was generated. Enter a ratio. After the workpiece is inserted to the specified depth, [Judgment Result] is "SUCCESS" if the magnitude of the force in [Insert Direction] exceeds [Min. Force Rate] x [Search Push Force] / 100. If [PhaseMatch Time Limit] elapses while the above conditions are not met, [Judgment Result] is "FAILURE". "Default : 80.00 %"
Judgment Result	This item displays [Judgment Result] at the end of "Phase Search" for which [Force End Judgment Switch] is "ON". If the function has never been executed with [Force End Judgment Switch] set to "ON", "----" is displayed. "Default : -----"

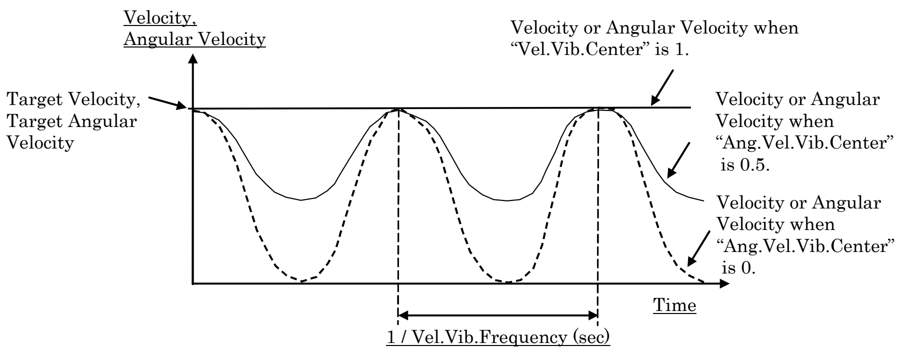
Item	Description
Force Average	This item displays the force magnitude of [Insert Direction] at the end of "Phase Search" for which [Force End Judgment Switch] is "ON". "Default : Z：0.00 N"
Approach Acc. Time	Enter the time until the velocity reaches the [Approach Velocity] on the [Basic Data Settings] screen after the FORCE statement is started. "Default : 0.40 sec"
PhaseMatch Acc. Time	Enter the time until the velocity reaches the [PhaseMatch Insert Vel] on the [Basic Data Settings] screen after the force exceeds the [Contact F Threshold] on the [Basic Data Settings] screen. "Default : 0.40 sec"
PhaseMatch ForceControl Valid Switch	This parameter is a switch for performing force control in the translational directions during phase matching. This can be set to 'On' or 'Off'. Force control is exercised in those directions with this switch set to ON. No movement is made in those directions with this switch set to OFF. "Defaults : X : OFF Y : OFF W : : OFF P : OFF" **NOTE** For robots that support parameter auto tuning, default values of X and Y are 'ON'.
Force Denoising Sw	This parameter enables the "Force Denoising" function. This can be set to 'On' or 'Off'. If it is "On", heavy noise is removed from the force data. This function is useful when: • tool or work-piece is heavy • using a tool such as a grinder and that has a big vibration "Default : OFF"
Signal Output for ERR SW	This parameter enables the "Signal Output for ERR" function. This can be set to 'On' or 'Off'. If it is "On", the specified signal is output when an error occurs during execution of force control. "Default : OFF"
Output Signal Type (Signal Output for ERR)	Select the type of signal to output when an error occurs during execution of force control with the error signal output function. "DO", "RO", "FLAG" are available for the kind of a signal. "Default : DO"
Output Signal Number (Signal Output for ERR)	Select the number of signal to output when an error occurs during execution of force control with the error signal output function. "Default : 0"
Frc.Ctrl. End by REG SW	This item is the switch of the function for ending operation when the condition specified in [End Register Number] is met. This can be set to 'On' or 'Off'. Normally, the operation of "Phase Search" ends when the insertion depth reaches [PhaseMatch End Depth]. Also, the insertion operation continues until [Judgment Result] is "SUCCESS" when [Force End Judgment Switch] is "ON". If this switch is ON and a value of a Numeric Register whose number is designated by "End Register Number" becomes 1, the force control ends regardless of above conditions. "Default : OFF"
End Register Number	If "Frc.Ctrl. End by REG SW" is ON, • The value of the Numeric Register whose number is designated by this parameter automatically becomes 0 when a force control instruction with this schedule starts. • If the value of the Numeric Register whose number is designated by this parameter becomes 1, the force control instruction with this schedule ends. "Default : 0"

Item	Description
Pushing Force Change Switch	This item is the switch for enabling the function for varying the pushing force in the insertion direction at the set interval. This can be set to "ON" or "OFF". This function can increase the success rate in cases such as when a blockage occurs during insertion and stops motion, when co-rotation occurs with the workpiece, or when there is a loose part such as a clutch in the workpiece.
Pushing Force MIN Limit	When [Pushing Force Change Switch] is "ON", the pushing force changes in a sine wave from [Pushing Force MIN Limit] to [Search Push Force] on the [Basic Data Settings] screen.
Pushing Force Frequency	If [Pushing Force Change Switch] is "ON", the pushing force changes in a sine wave with the frequency in [Pushing Force Frequency].
G F S	G represents a motion group number at the time of teaching. F represents a force control number. S represents a force sensor number. (These settings cannot be changed.) "Defaults : G F S : 1 1 1"

[Phase Matching performance] screen

Each parameter on this screen is available for each of the directions of rotation about an insertion axis.

Table 1.5.4.4 (c) [Phase Matching performance] screen

Item	Description
Ang. Vel. Vib. Center	Enter the value from 0 to 1 to vibrate the target angular velocity during search operation. Change the target angular velocity during search operation according to the following expression: $V = Vd * \{ (1 - C) * \cos(2\pi ft) + C \}$ V : Target velocity (angular velocity) during search operation Vd : Target velocity (angular velocity). Parameter on the search parameters basic screen C : Velocity vibration center f : Velocity vibration frequency t : Time When 0 is set, "PhaseMatch Ang. Vel" is the amplitude of velocity vibration, and vibration occurs without making any movement. When 1 is set, the amplitude is 0, and a constant angular velocity operation is performed at "PhaseMatch Ang. Vel". "Default : 1.00" (for no vibration)
Ang. Vel. Vib. Freq. (Fig. 1.5.4.4 (g))	When a value less than 1 is set in "Ang. Vel. Vib. Center", the target angular velocity vibrates at the frequency set in this parameter. Set a frequency from 0.1 Hz to 3 Hz. "Default : 1.00 Hz"  Fig. 1.5.4.4 (g) [Ang. Vel. Vib. Freq.]
Weaving Time	Weave operation finely vibrates moment at a location where an angular match is found during search. Weaving is only performed for the time entered in this parameter. "Default : 1.00 sec"

Item	Description
Weaving Frequency	Enter the vibration frequency for the weaving operation. "Default : 1.00 Hz"
Reverse Switch	This switch specifies whether to reverse the search direction when the workpiece cannot be inserted even by weave operation or the upper search range limit is reached. This can be set to 'On' or 'Off'. If this switch is set to OFF, search operation ends when the upper search range limit is reached. If this switch is set to ON, search operation is continued by reversing the direction when the upper search range limit is reached. "Default : ON"
Retry Number	Enter the number of times to repeat reversal when insertion cannot be performed after weaving or [Reverse Switch] is set to On and the search range limit is reached. When the number of reversions exceeds the value specified in this parameter, the "Force 420: Search Retry Limit" error occurs. If this error occurs frequently, increase the value specified in this parameter. "Default : 10000"
Retry Magnification	When insertion cannot be performed after weaving or "Reverse Switch" is set to "On" and the search range limit is reached, reversing the direction is repeated as many times as specified in "Retry Number". Each time the direction is reversed, "PhaseM Torque" multiplied by the magnification specified in this parameter is used as a new target torque in search operation. If search is retried frequently, increase (or decrease) the value specified in this parameter by about 10% to 20%. "Default : 1.00"
Search Range Margin	Search operation is performed in the range specified by the search basic data "Size of Search Range". An alarm is issued when the upper search range limit plus the value specified in this parameter is reached. Enter the range value to use as the margin. "Default : 3.00 deg"

Function keys

The function keys indicated have the following functions:

Table 1.5.4.4 (d) Function keys

Key	Item	Description
F1	TYPE	Allows you to change the display to a menu other than the force control menu.
F2	GROUP	Allows you to change motion groups.
	HELP	Display the help screen.
F3	NUMBER	Allows you to display the screen for another schedule number.
F4	CHOICE	Displays the choices for the setting.
	ON	Changes the setting to 'On'.
Shift + F4	DEFAULT	Allows you to set default data of the force control function.
F5	PERFORM / BASIC	Allows you to switch between the basic and performance screens.
	OFF	Changes the setting to 'Off'.

1.5.4.5 Hole Search

Overview

The "Hole Search" function searches for the hole position by searching a perpendicular flat surface in the insertion direction.

There are four types of configuration screens; the [Basic Data Settings] screen and [Search Basic Param.] screen that must be configured by the user, and the [Performance Data Settings] screen and [Search Performance Param.] screen that are only configured when required.

[Function selection] screen

```
1
1 Unused
2 Constant Push
3 Face Match
4 Shaft Insert
5 Groove Insert
6 Search
7 Phase Search
8 --next page--
```

```
2
1 Hole Search
2 Clutch Search
3 Square Insert
4 Contouring
5 Contouring End
6 Threading
7
8 --next page--
```

[Basic Data Settings] screen

```
Force Ctrl/Basic
                                         1/18
 Schedule[1]                  G:1 F:1 S:1
 1 Function              : Hole Search
 2 Comment               : [                ]
 3 Insert Direction             : -Z
 4 Contact F Threshold   :     10.00 N
 5 Approach Velocity     :      1.00 mm/s
 6 User Frame No.                UF:   1
 7 Tool Frame No.                TF:   1
 8 Search End Depth      :      5.00 mm
 9 Search Push Force     :     50.00 N
10 Search Insert Vel     :      0.00 mm/s
11 Search frequency      :      1.00 Hz
12 Search Basic Param.   :     Basic
13 Individual Diff. (+) :      3.00 mm
14 Individual Diff. (-) :      0.00 mm
15 Pushing Time          :      0.00 sec
16 Search Time Limit     :     20.00 sec
17 F.Ctrl. Gain Auto Modify :       OFF
       Prev. Result      : No Change
18 Force Control Gain :             Detail

[TYPE]  GROUP  NUMBER  [CHOICE]  PERFORM  >
  F1     F2     F3       F4       F5
```

[Force Ctrl/Gain] screen

```
Force Ctrl/Gain
                                          1/1
 Schedule[1]                  G:1 F:1 S:1
   Function            : Hole Search
 1 Search Impedance    : [Master Freq. ]

[TYPE]  GROUP  NUMBER  [CHOICE]           >
  F1     F2     F3       F4       F5
```

[Performance Data Settings] Screen

```
Force Ctrl/Perform
                                          1/32
 Schedule[1]                  G:1 F:1 S:1
 1 Function              : Hole Search
 2 Comment               : [                ]
 3 Simple Customize Sw              : OFF
 4    Cont. Exec. Max. Count       :    1
 5 Customize Parent Number   :          0
 6    Customize ParaChg Conct:OFF
 7 Customize Auto. Cnt. Exec. Sw : OFF
 8    Auto. Cnt. Exec. Child No.   :    0
 9    Schedule No. Output Reg. No.:    0
10 User Frame Compensation:   OFF
11 Search acc. time   :        0.100 sec
12 Decel. Depth Rate :         95.00 %
13 Search Performance Param.: Perform
14 Settling Switch              : OFF
15    Settling Time         :     1.00 sec
16    Settling Rate         :   100.00 %
17 Initial Push Force    :    50.00 N
     Force Limit
18   X:   500.00 Y:   500.00 Z:   500.00 N
19   W:    50.00 P:    50.00 R:    50.00N*m
20 Torque Error Compensate SW: OFF
        Torque Error Data
          W:       0.000 N*m
          P:       0.000 N*m
          R:       0.000 N*m
        Torque Error Fd      :     50.00 N
21 Velocity Constant Switch    : ON
22    Velocity Constant   :        5.00 mm/s
23 Force End Judgment Switch : OFF
24    Min. Force Rate   :         80.00 %
        Judgment Result   :          -------
          Force Average   Z:        0.00 N
25 Approach Acc. Time        :    0.70 sec
26 Search Acc. Time          :    0.70 sec
27 Force Denoising Sw      :    OFF
28 Signal Output for ERR SW:    OFF
29    Output Signal Type   :     DO
30    Output Signal Number:          0
31 Frc.Ctrl. End by REG SW :    OFF
32    End Register Number :          0
33 Push Force Change Switch : OFF
34    Push Force LowerLim.   :    0.00 N
35    Push Force Frequency   :    0.12 Hz

[TYPE]  HELP  NUMBER  [CHOICE]  BASIC  >
```

Fig. 1.5.4.5 (a) "Hole Search" screens (1/2)

[Search Basic Param.] screen

Search/Basic
1/6
Search parameters Basic
Velocity Order
1 X: 1 Y: 2
Target Velocity [mm/s]
2 X: 1.00 Y: 1.00
Target Force [N]
3 X: 20.00 Y: 20.00
Clearance & Chamfer [mm]
4 X: 1.00 Y: 1.00
Size of Search Range [mm]
5 X: 10.00 Y: 10.00
Repeat Number
6 X: 1 Y: 1

[TYPE]					>

F1 F2 F3 F4 F5

[Search Performance Param.] screen

Search/Perform
1/8
Search parameters Performance
Vel. Vib. Center
1 X: 1.00 Y: 1.00
Vel. Vib. Frequency [Hz]
2 X: 1.00 Y: 1.00
Weaving Time [sec]
3 X: 1.00 Y: 1.00
Weaving Frequency [Hz]
4 X: 1.00 Y: 1.00
Reverse Switch
5 X:ON Y:ON
Retry Number
6 X: 10000 Y: 10000
Retry Magnification
7 X: 1.00 Y: 1.00
Search Range Margin [mm]
8 X: 3.00 Y: 3.00

[TYPE]					>

F1 F2 F3 F4 F5

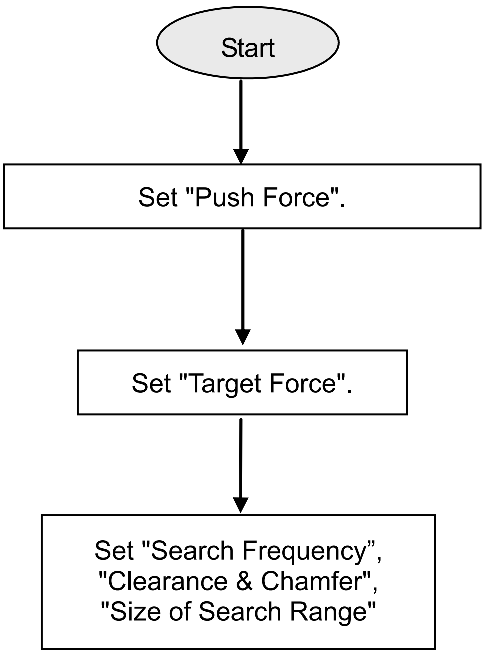
Fig. 1.5.4.5 (b) "Hole Search" screens(2/2)

Adjusting the Hole Search Parameters

1 Display the [Basic Data Settings] screen for the "Hole Search" function.
2 Configure "Insert Direction", "UFrame Number", "UTool Number", and "Search End Depth".
3 Configure [Velocity Order] for the two directions to search in.
4 Execute [F.Ctrl. Gain Auto Modify].
(Refer to "Basic Function Guide: 1.11.2 Force Control Gain Auto Tuning Instruction".)
5 Configure the other parameters on the [Basic Data Settings] and [Search Basic Param.] screen.
6 Configure the parameters on the [Performance Data Settings] screen and [Search Performance Param.] screen, as required.

NOTE
For the outline of force control instruction programming, refer to "Basic Function Guide: 1.1 NOTES / RESTRICTIONS", and "Basic Function Guide: 1.2 TEACHING PROCEDURE".

For details of each parameter, see the pages that follow.
The procedure for tuning other parameters after completion of automatic force control gain adjustment is shown below.



This parameter specifies a target pushing force during search operation.
Set 2.0 N or a greater value in "Push Force".
If an unnecessarily large value is set, the workpiece can be damaged.
When the phase is not successful match, increase the value in step of 10%.

"Target Force" is displayed on the search parameters basic screen.
Determine a value according to the items of target force and target torque in Subsection 1.5.4.2, "Parameter tuning".
If an unnecessarily large value is set, the workpiece can be damaged.
When the phase is not successful match, increase the value in step of 10%.

"Search Frequency" is displayed on the basic data setting screen.
"Clearance & Chamfer" and "Size of Search Range" are displayed on the search parameters basic screen.
These parameters decide the velocity of search directions. "Target Velocity" on the search parameters basic screen are automatically set.

If the value of above parameter is changed, the value of "Target Velocity" is also changed.
Refer to Subsection 1.5.4.2, "Parameter tuning" for more detail.

Fig. 1.5.4.5 (c) Adjusting Other Parameters (1/ 2)

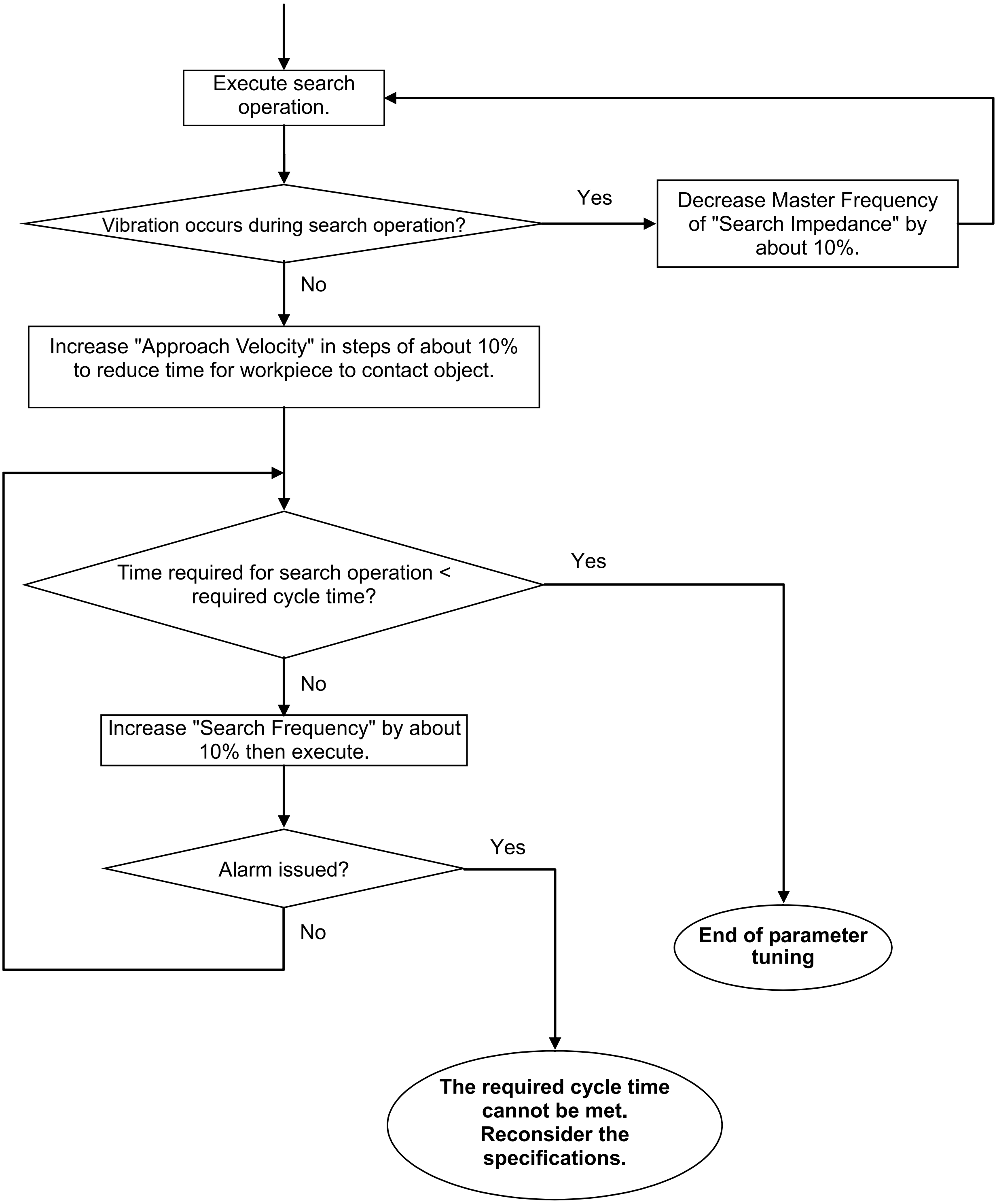


Fig. 1.5.4.5 (d) Adjusting Other Parameters (2/2)

[Basic data settings] screen

Parameters shown in this section must be set.

Table 1.5.4.5 (a) [Basic data settings] screen

Item	Description
Function	A desired function is selected from "Function selection screen". In this case, select "Hole Search".
Comment	Enter a comment for identifying the schedule data. Maximum number of characters: 16 characters.
User Frame Number	Enter the number of the user frame to use when searching. (Enter the user frame number that was set in "Basic Functions Guide: 1.2 TEACHING PROCEDURE".) "Default : UF:0"
Tool Frame Number	Enter the number of the tool frame to use when searching. (Enter the user tool number that was set in "Basic Functions Guide: 1.2 TEACHING PROCEDURE".) "Default : TF:1"
Insert Direction	Enter the direction to insert using the user frame that is set. "Default : –Z"
Search End Depth	Enter the depth from the force control start (approach point) to where to end the search. "Default : 5.00 mm"
Individual Diff. (+)	If insertion proceeds past [Search End Depth] due to individual variations in a workpiece, enter the amount of margin to allow. An alarm occurs if insertion exceeds (Search End Depth - Individual Diff. (-) + this value). "Default : 3.00 mm"
Individual Diff. (-)	If insertion does not reach [Search End Depth] due to individual variations in a workpiece, enter the amount of margin to allow. If (Search End Depth - this value) is reached, insertion is determined to be successful. "Default : 0.00 mm"
Approach Velocity	Enter the threshold value for determining whether contact has been made with the target. "Default : 1.00 mm/ s"
Search Insert Vel	Enter the target velocity for inserting the workpiece when searching. "Default : 0.00 mm/s"
Contact F Threshold	Enter the threshold value for determining whether contact has been made with the target. "Default : 10.00 N" ⚠ **CAUTION** The cycle time may get worse if this value is too high, because the actual insertion operation starts after contact is made.
Push Force	Enter the target value for the force to push the workpiece to the insertion surface when searching. Increase the value if the workpiece is not inserted despite the phase being correct and decrease the value if the workpiece being inserted into is dragged along due to the phase matching rotation. "Default : 30.00 N" **NOTE** When changing [Search Push Force], change it by about 10% each time.
Search Basic Param.	Perform the following operation to switch to the [Search Basic Param.] screen for configuring the basic parameters for determining the search path. • Move the cursor to [Basic], and press the [ENTER] key on the teach pendant of the robot controller. The [Search Basic Param.] screen is displayed. (Refer to the description of the [Search parameters basic] screen.)

Item	Description
Pushing Time	When search operation is assumed to be successful, pushing operation is performed in the insertion direction to absorb length differences in individual workpieces. Enter the corresponding pushing time. "Default : 0.00 sec"
Search Time MAX Limit	This search time means the period of time after touching a workpiece target until search operation is assumed to be successful. Enter the maximum time. If "Search End Depth" is not reached within this period, an alarm is issued. This search time does not include time for pushing operation after search operation is assumed to be successful ([Pushing Time]). (Refer to [Pushing Time].) "Default : 20.00 sec"
F.Ctrl. Gain Auto Modify	This item is the switch used for automatic force control gain tuning. Set "On" to execute auto adjustment of the force control gain. (Refer to "Basic Function Guide: 1.11.2 Force Control Gain Auto Tuning Instruction".) "Default : OFF"
Prev. Result	Displays the previous result for [F.Ctrl. Gain Auto Modify]. "Default : No Change"
Force Control Gain	This item switches the screen display to the screen for force control gain setting. • Move the cursor to this line then press the [ENTER] key. The screen display switches to the force control gain detail screen. (For the parameters that can be set on this screen, refer to "Basic Function Guide: 1.6 FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".)
G F S	G represents a motion group number at the time of teaching. F represents a force control number. S represents a force sensor number. (These settings cannot be changed.) "Defaults : G F S : 1 1 1"

[Search parameters basic] screen

The parameters on this screen must always be set when "Hole Search" is used.
Each parameter for two directions is available.

Table 1.5.4.5 (b) [Search parameters basic] screen

Item	Description
Target Velocity	Target velocity for operating workpiece. "Defaults : X : 1.00 Y : 1.00" ("Unit : mm/ s")
Target Force	Enter the "Target Force" of the search direction. If "Force 264 Error" or "Force 420 Error" occurs with little motion made, increase this value in steps of about 10% to 20%. If "Reverse Switch" in the Search parameters performance screen is ON (default) and the actual force exceeds this value, the moving direction of the workpiece is automatically reversed. If a position or phase match point is passed, decrease this value in steps of about 10% to 20%. (Refer to 'Target Force, Target Torque' in "Basic Function Guide: 1.5.4.2 Parameter tuning".) "Defaults : X : 20.00 Y : 20.00" ("Unit : N")
Size of Search Range	The range to search in each direction is determined and that size is entered to this parameter. (Refer to 'Search range setting' in "Basic Function Guide: 1.5.4.2 Parameter tuning".) "Defaults : X : 10.00 Y : 10.00" ("Unit : mm")

[Performance Data settings] screen

The items to configure on the performance screen for "Hole Search" are the same as those on the [Performance Data Settings] screen for "Phase Search".
(Refer to the [Performance Data Settings] screen in "Basic Function Guide: 1.5.4.4 Phase Search".)

NOTE
Replace the "[PhaseM Performance Param.] screen" described on the [Performance Data Settings] screen for "Phase Search" with "[Search Performance Param.] screen"

[Search Performance Param.] screen

The [Search Performance Param.] screen enables more advanced parameters to be configured for the search direction.
On the search parameters performance screen, high-level parameters related to search directions can be specified.
The parameters are the same as those on the search parameters performance screen for "Search" and on the phase matching performance screen for "Phase Search".
(Refer to "Basic Function Guide: 1.5.4.3 Search" and "Basic Function Guide: 1.5.4.4 Phase Search".)

NOTE
The "Hole Search" function can only search in two directions on a flat surface. Therefore, only the parameters for those two directions are displayed on the screen.

Function keys

The function keys indicated have the following functions:

Table 1.5.4.5 (c) Function keys

Key	Item	Description
F1	TYPE	Allows you to change the display to a menu other than the force control menu.
F2	GROUP	Allows you to change motion groups.
	HELP	Display the help screen.
F3	NUMBER	Allows you to display the screen for another schedule number.
F4	CHOICE	Displays the choices for the setting.
	ON	Changes the setting to 'On'.
Shift + F4	DEFAULT	Allows you to set default data of the force control function.
F5	PERFORM / BASIC	Allows you to switch between the basic and performance screens.
	OFF	Changes the setting to 'Off'.

1.5.4.6 Clutch search

Overview

It is used for assembling the clutch, which is a part used in the automatic transmission of automobiles. This operation inserts multiple clutch plates with teeth on the inner side into a clutch hub with teeth on its outer circumference.

There are four types of configuration screens; the [Basic Data Settings] screen and [Search Basic Param.] screen that must be configured by the user, and the [Performance Data Settings] screen and [Search Performance Param.] screen that are only configured when required.

[Function selection] screen

```
1
1 Unused
2 Constant Push
3 Face Match
4 Shaft Insert
5 Groove Insert
6 Search
7 Phase Search
8 --next page--
```

```
2
1 Hole Search
2 Clutch Search
3 Square Insert
4 Contouring
5 Contouring End
6 Threading
7
8 --next page--
```

[Basic Data Settings] screen

```
Force Ctrl/Basic
                                        1/18
 Schedule[1]                 G:1 F:1 S:1
 1 Function              : Clutch Search
 2 Comment               : [               ]
 3 Insert Direction              : -Z
 4 Contact F Threshold   :     10.00 N
 5 Approach Velocity     :      1.00 mm/s
 6 User Frame No.                UF:   1
 7 Tool Frame No.                TF:   1
 8 Search End Depth      :      5.00 mm
 9 Search Push Force     :     50.00 N
10 Search Insert Vel     :      0.00 mm/s
11 Search frequency      :      1.00 Hz
12 Search Basic Param.   :      Basic
13 Individual Diff. (+) :       3.00 mm
14 Individual Diff. (-) :       0.00 mm
15 Pushing Time          :      0.00 sec
16 Search Time Limit     :     20.00 sec
17 F.Ctrl. Gain Auto Modify :         OFF
      Prev. Result       : No Change
18 Force Control Gain :               Detail

[TYPE]  GROUP  NUMBER  [CHOICE]  PERFORM  >
  F1     F2      F3       F4       F5
```

[Force Ctrl/Gain] screen

```
Force Ctrl/Gain
                                        1/1
 Schedule[1]                 G:1 F:1 S:1
    Function             : Clutch Search
 1 Search Impedance      : [Master Freq. ]

[TYPE]  GROUP  NUMBER  [CHOICE]           >
  F1     F2      F3       F4       F5
```

[Performance Data Settings] Screen

```
Force Ctrl/Perform
                                        1/32
 Schedule[1]                 G:1 F:1 S:1
 1 Function              : Clutch Search
 2 Comment               : [               ]
 3 Simple Customize Sw              : OFF
 4    Cont. Exec. Max. Count     :     1
 5 Customize Parent Number   :          0
 6    Customize ParaChg Conct:OFF
 7 Customize Auto. Cnt. Exec. Sw : OFF
 8    Auto. Cnt. Exec. Child No.   :   0
 9    Schedule No. Output Reg. No.:    0
10 User Frame Compensation:   OFF
11 Search acc. time   :        0.100 sec
12 Decel. Depth Rate :         95.00 %
13 Search Performance Param.: Perform
14 Settling Switch                : OFF
15    Settling Time        :     1.00 sec
16    Settling Rate        :   100.00 %
17 Initial Push Force    :    50.00 N
    Force Limit
18  X:   500.00 Y:   500.00 Z:   500.00 N
19  W:     50.00 P:     50.00 R:     50.00N*m
20 Torque Error Compensate SW: OFF
      Torque Error Data
       W:        0.000 N*m
       P:        0.000 N*m
       R:        0.000 N*m
      Torque Error Fd       :      50.00 N
21 Velocity Constant Switch   : ON
22    Velocity Constant   :        5.00 mm/s
23 Force End Judgment Switch : OFF
24    Min. Force Rate   :          80.00 %
      Judgment Result   :            -------
       Force Average    Z:          0.00 N
25 Approach Acc. Time        :    0.70 sec
26 Search Acc. Time          :    0.70 sec
27 Force Denoising Sw        :    OFF
28 Signal Output for ERR SW:   OFF
29    Output Signal Type    :      DO
30    Output Signal Number:          0
31 Frc.Ctrl. End by REG SW :   OFF
32    End Register Number :          0
33 Push Force Change Switch : OFF
34    Push Force LowerLim.   :    0.00 N
35    Push Force Frequency   :    0.12 Hz

[TYPE]  HELP  NUMBER  [CHOICE]  BASIC  >
```

Fig. 1.5.4.6 (a) "Clutch Search" screens (1/2)

[Search Basic Param.] screen

```
Search/Basic
                                   1/10
Search parameters Basic
   Velocity Order
 1  X: 2   Y: 3   R: 1
   Target Velocity   [mm/s]
 2  X:    1.00   Y:    1.00
   Target Angular Velocity   [deg/s]
 3  R:    1.00
   Target Force   [N]
 4  X:   20.00   Y:   20.00
   Target Torque   [Nm]
 5  R:    1.00
   Clearance & Chamfer   [mm]
 6  X:    1.00   Y:    1.00
   Clearance   [deg]
 7  R:    1.00
   Size of Search Range   [mm]
 8  X:   10.00   Y:   10.00
   Size of Search Range   [deg]
 9  R:   10.00
   Repeat Number
10  X:       1   Y:       1   R:       1

[TYPE] |    |    |    |    | >
  F1     F2   F3   F4   F5
```

[Search Performance Param.] screen

```
Search/Perform
                                   1/15
Search parameters Performance
   Vel. Vib. Center
 1  X:    1.00   Y:    1.00
 2  R:    1.00
   Vel. Vib. Frequency   [Hz]
 3  X:    1.00   Y:    1.00
 4  R:    1.00
   Weaving Time   [sec]
 5  X:    1.00   Y:    1.00
 6  R:    1.00
   Weaving Frequency   [Hz]
 7  X:    1.00   Y:    1.00
 8  R:    1.00
   Reverse Switch
 9  X:ON      Y:ON      R:ON
   Retry Number
10  X:   10000   Y:   10000
11  R:   10000
   Retry Magnification
12  X:    1.00   Y:    1.00
13  R:    1.00
   Search Range Margin   [mm]
14  X:    3.00   Y:    3.00
   Search Range Margin   [deg]
15  R:    3.00

[TYPE] |    |    |    |    | >
  F1     F2   F3   F4   F5
```

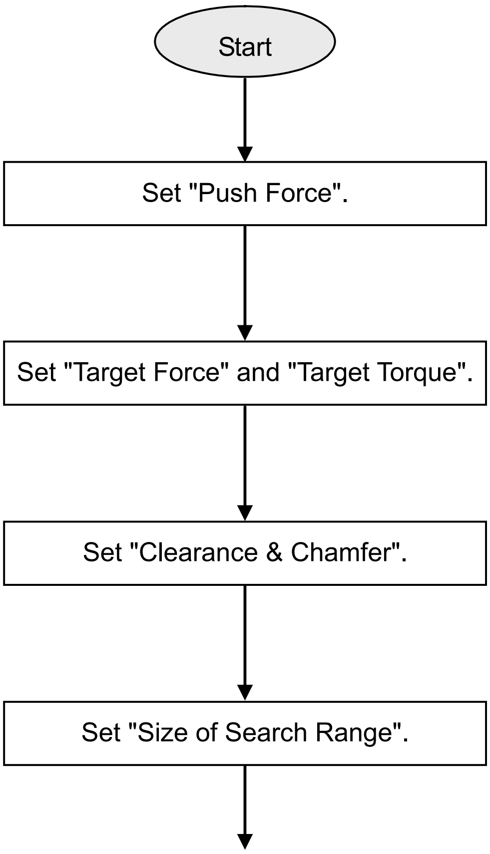
Fig. 1.5.4.6 (b) "Clutch Search" screens (2/2)

Adjusting the Clutch Search Parameters

1 Display the [Basic Data Settings] screen for the "Clutch Search" function
2 Configure "Insert Direction", "UFrame Number", "UTool Number", and "Search End Depth".
3 Configure [Velocity Order] for the three directions to search in.
4 Execute [F.Ctrl. Gain Auto Modify].
(Refer to "Basic Function Guide: 1.11.2 Force Control Gain Auto Tuning Instruction".)
5 Configure the other parameters on the [Basic Data Settings] and [Search Basic Param.] screen.
6 Configure the parameters on the [Performance Data Settings] screen and [Search Performance Param.] screen, as required.

> **NOTE**
> For the outline of force control instruction programming, refer to "Basic Function Guide: 1.1 NOTES / RESTRICTIONS", and "Basic Function Guide: 1.2 TEACHING PROCEDURE".

For details of each parameter, see the pages that follow.
The procedure for tuning other parameters after completion of automatic force control gain adjustment is shown below.



This parameter specifies a target pushing force during search operation.
Set 2.0 N or a greater value in "Push Force".
If an unnecessarily large value is set, the workpiece can be damaged.
When the phase is not successful match, increase the value in step of 10%.

"Target Force" and "Target Torque" are displayed on the search parameters basic screen.
Determine a value according to the items of target force and target torque in Subsection 1.5.4.2, "Parameter tuning".
If an unnecessarily large value is set, the workpiece can be damaged.
When the phase is not successful match, increase the value in step of 10%.

"Clearance & Chamfer" is displayed on the search parameters basic screen.
Determine a value according to the setting items of search frequency, and clearance and chamfer amount in Subsection 1.5.4.2, "Parameter tuning".

"Size of Search Range" is displayed on the search parameters basic screen.
Determine a value according to the item of search range setting in Subsection 1.5.4.2, "Parameter tuning".

Fig. 1.5.4.6 (c) Adjusting Other Parameters (1/ 2)

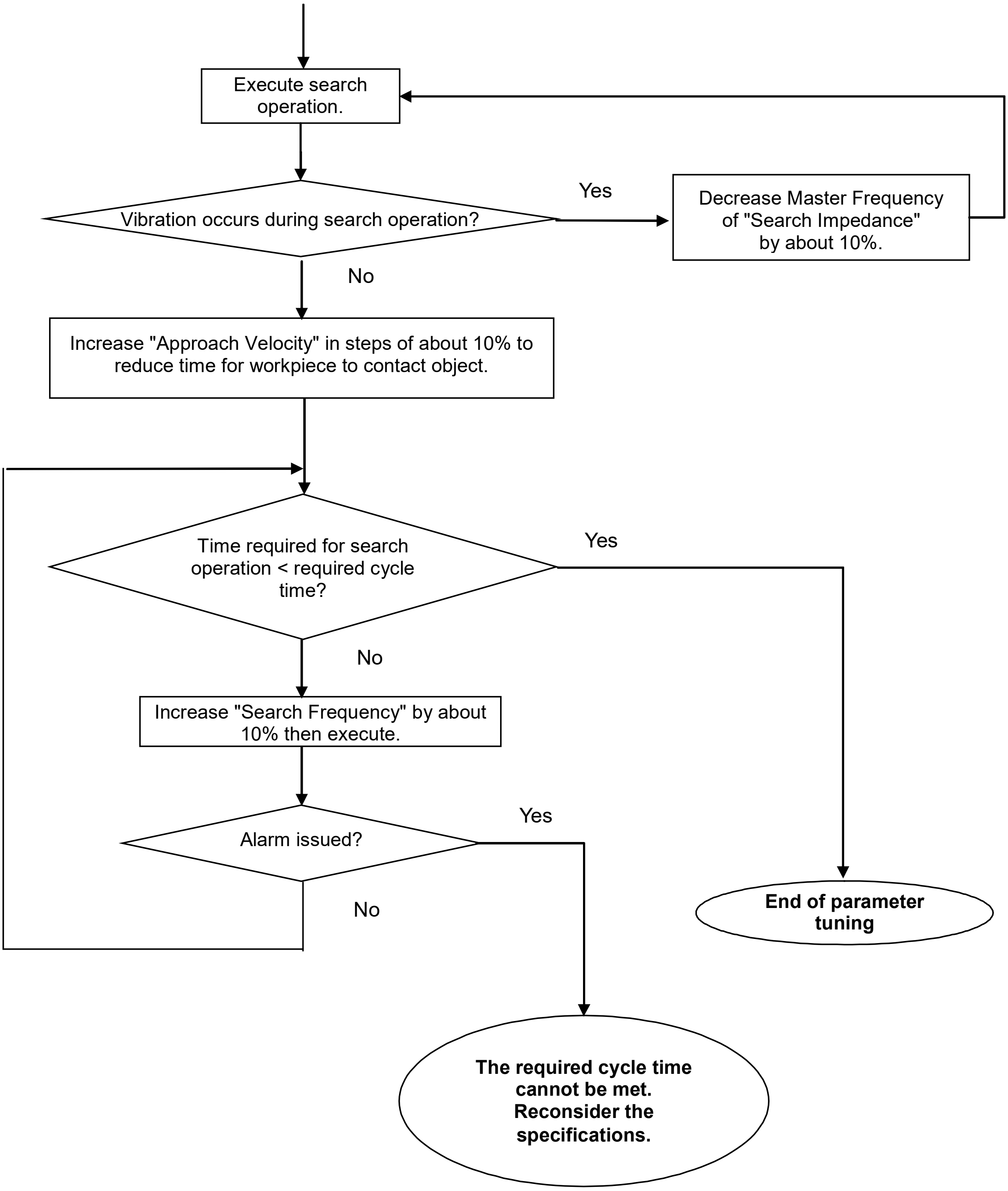


Fig. 1.5.4.6 (d) Adjusting Other Parameters (2/2)

[Basic data settings] screen

Parameters shown in this section must be set.

Table 1.5.4.6 (a) [Basic data settings] screen

Item	Description
Function	A desired function is selected from "Function selection screen". In this case, select "Clutch Search".
Comment	Enter a comment for identifying the schedule data. Maximum number of characters: 16 characters.
User Frame Number	Enter the number of the user frame to use when searching. (Enter the user frame number that was set in "Basic Functions Guide: 1.2 TEACHING PROCEDURE".) "Default : UF:0"
Tool Frame Number	Enter the number of the tool frame to use when searching. (Enter the user tool number that was set in "Basic Functions Guide: 1.2 TEACHING PROCEDURE".) "Default : TF:1"
Insert Direction	Enter the direction to insert using the user frame that is set. "Default : –Z"
Search End Depth	Enter the depth from the force control start (approach point) to where to end the search. "Default : 5.00 mm"
Individual Diff. (+)	If insertion proceeds past [Search End Depth] due to individual variations in a workpiece, enter the amount of margin to allow. An alarm occurs if insertion exceeds (Search End Depth - Individual Diff. (-) + this value). "Default : 3.00 mm"
Individual Diff. (-)	If insertion does not reach [Search End Depth] due to individual variations in a workpiece, enter the amount of margin to allow. If (Search End Depth - this value) is reached, insertion is determined to be successful. "Default : 0.00 mm"
Approach Velocity	Enter the target operation velocity until contact is made with the target. "Default : 1.00 mm/ s"
Search Insert Vel	Enter the target velocity for inserting the workpiece during insertion. "Default : 0.00 mm/s"
Contact F Threshold	Enter the threshold value for determining whether contact has been made with the target. "Default : 10.00 N" ⚠ **CAUTION** The cycle time may get worse if this value is too high, because the actual insertion operation starts after contact is made.
Push Force	Enter the target value for the force to push the workpiece to the insertion surface during insertion. Increase the value if the workpiece is not inserted despite the phase being correct and decrease the value if the workpiece being inserted into is dragged along due to the phase matching rotation. "Default : 30.00 N" **NOTE** When changing [Search Push Force], change it by about 10% each time.
Search Basic Param.	This parameter is used to switch to a screen for setting basic parameters for search path determination. • Move the cursor to [Basic], and press the [ENTER] key on the teach pendant of the robot controller. The [Search Basic Param.] screen is displayed. (Refer to the description of the [Search parameters basic] screen.)

Item	Description
Pushing Time	When search operation is assumed to be successful, pushing operation is performed in the insertion direction to absorb length differences in individual workpieces. Enter the corresponding pushing time. "Default : 0.00 sec"
Search Time MAX Limit	This search time means the period of time from the start of search operation after touching a workpiece target until search operation is assumed to be successful. Enter the maximum time. If [Search End Depth] is not reached within this period, an alarm is issued. This search time does not include a time for pushing operation after search operation is assumed to be successful ([Pushing Time]). (Refer to [Pushing Time].) "Default : 20.00 sec"
F.Ctrl. Gain Auto Modify	This item is the switch used for automatic force control gain tuning. Set "On" to execute auto adjustment of the force control gain. (Refer to "Basic Function Guide: 1.11.2 Force Control Gain Auto Tuning Instruction".) "Default : OFF"
Prev. Result	Displays the previous result for [F.Ctrl. Gain Auto Modify]. "Default : No Change"
Force Control Gain	This item switches the screen display to the screen for force control gain setting. • Move the cursor to this line then press the ENTER key. The screen display switches to the [Force control gain detail] screen. (For the parameters that can be set on this screen, refer to "Basic Function Guide: 1.6 FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".)
G F S	G represents a motion group number at the time of teaching. F represents a force control number. S represents a force sensor number. (These settings cannot be changed.) "Defaults : G F S : 1 1 1"

[Search Basic Param.] screen

The parameters on this screen must always be set when "Clutch Search" is used.
Each parameter for three directions (the rotation direction about an insertion axis, and the two directions on a plane perpendicular to the insertion axis.) is available.

Table 1.5.4.6 (b) [Search Basic Param.] screen

Item	Description
Target Velocity / Target Angular Velocity	Target velocity (angular velocity) for operating a workpiece. "Defaults : X : 1.00 Y : 1.00" ("Unit : mm/ s") (When search operation is performed in the X, Y, or Z direction.) "Default : R : 1.00" ("Unit : deg/ s") (When search operation is performed in the W, P, or R direction.)
Target Force / Target Torque	Enter the [Target Force] (target torque) for the search direction. If "Force 264 Error" or "Force 420 Error" occurs with little motion made, increase this value in steps of about 10% to 20%. If "Reverse Switch" in the Search parameters performance screen is ON (default) and the actual force or moment exceeds this value, the moving direction or rotation direction of the workpiece is automatically reversed. If a position or phase match point is passed, decrease this value in steps of about 10% to 20%. (Refer to 'Target Force, Target Torque' in "Basic Function Guide: 1.5.4.2 Parameter tuning".) "Defaults : X : 20.00 Y : 20.00" ("Unit : N") "Default : R : 1.00" ("Unit : N*m")

Item	Description
Size of Search Range	The range to search in each direction is determined and that size is entered to this parameter. (Refer to 'Search range setting' in "Basic Function Guide: 1.5.4.2 Parameter tuning".) "Defaults : X : 10.00 Y : 10.00" ("Unit : mm") (When search operation is performed in the X, Y, or Z direction.) "Default : R : 10.00" ("Unit : deg") (When search operation is performed in the W, P, or R direction.)

[Performance Data Settings] Screen

The items to configure on the [Performance Data Settings] screen for "Clutch Search" are the same as those on the [Performance Data Settings] screen for "Phase Search".
(Refer to the [Performance Data Settings] screen in "Basic Function Guide: 1.5.4.4 Phase Search".)

NOTE
Replace the "[PhaseM Performance Param.] screen" described on the [Performance Data Settings] screen for "Phase Search" with "[Search Performance Param.] screen"

[Search Performance Param.] screen

The [Search Performance Param.] screen enables more advanced parameters to be configured for the search direction.
On the search parameters performance screen, high-level parameters related to search directions can be specified.
The parameters are the same as those on the search parameters performance screen for "Search" and on the phase matching performance screen for "Phase Search".
(Refer to "Basic Function Guide: 1.5.4.3 Search" and "Basic Function Guide: 1.5.4.4 Phase Search".)

NOTE
The "Clutch Search" function only searches in three directions; the rotation around the insertion axis and the two directions on the perpendicular flat surface of the insertion axis. Therefore, only the parameters for those three directions are displayed on the screen.

Function keys

The function keys indicated have the following functions:

Table 1.5.4.6 (c) Function keys

Key	Item	Description
F1	TYPE	Allows you to change the display to a menu other than the force control menu.
F2	GROUP	Allows you to change motion groups.
	HELP	Display the help screen.
F3	NUMBER	Allows you to display the screen for another schedule number.
F4	CHOICE	Displays the choices for the setting.
	ON	Changes the setting to 'On'.
Shift + F4	DEFAULT	Allows you to set default data of the force control function.
F5	PERFORM / BASIC	Allows you to switch between the basic and performance screens.
	OFF	Changes the setting to 'Off'.

1.5.5 Contouring Function

1.5.5.1 Overview of the contouring function

Contouring Function traces the surface of a workpiece while applying a target force.
Used with a tool such as a grinder, this function can perform polishing and grinding.
In general, if the workpiece to be machined is heavy or large, the workpiece is secured onto a table and a grinder is attached to the robot. If the workpiece to be machined is small compared with a tool, the tool is secured onto a table, and the robot holds the workpiece. In either case, the operation is performed while a set force is applied.

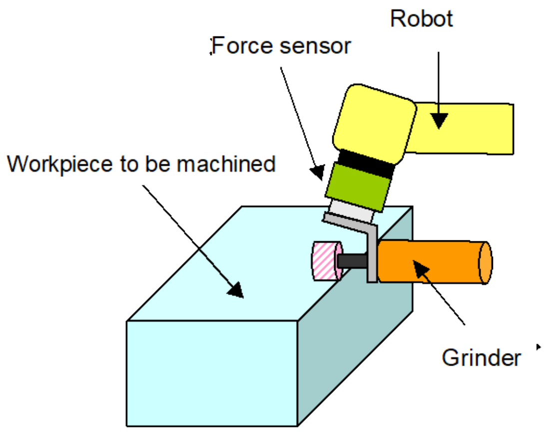


Fig. 1.5.5.1 (a) Example of Surface Grinding (with Tool Held by Robot)

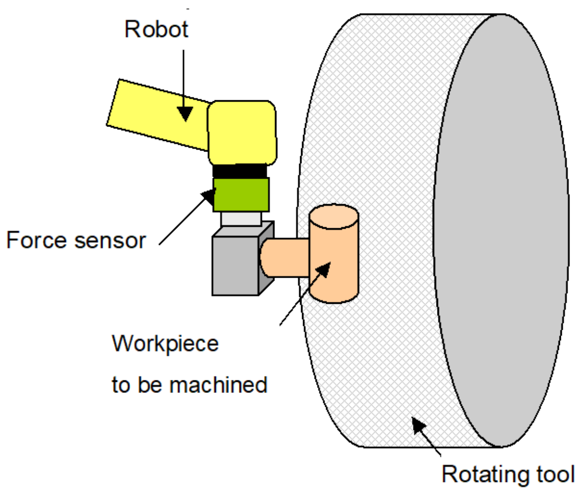


Fig. 1.5.5.1 (b) Example of Buffing (with Workpiece Held by Robot)

1.5.5.2 Teaching of the Contouring Function

Teach point setting

When the Contouring Function is used, an approximate path is determined by teaching points with ordinary motion statements.
Teach points where the traveling direction is reversed or the posture of the robot changes extensively, in addition to a contouring start point and contouring end point. Fig. 1.5.5.2 (a) shows an example where the posture of the robot changes halfway, and Fig. 1.5.5.2 (b) shows an example where the traveling direction is reversed.

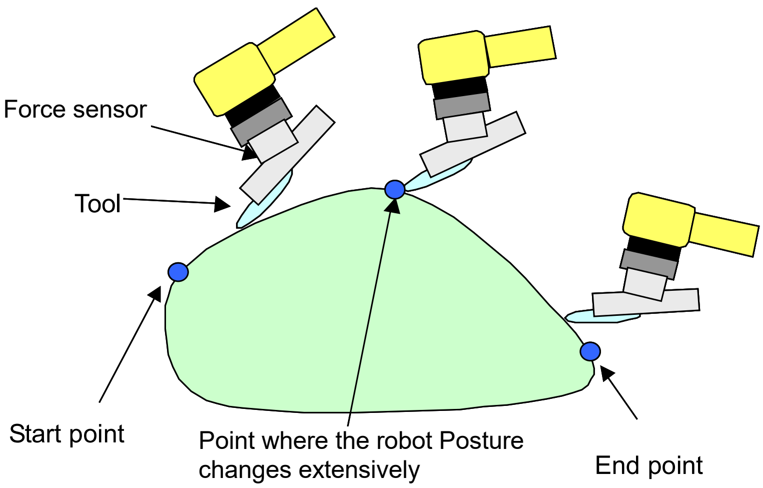


Fig. 1.5.5.2 (a) Setting of teaching points where posture of robot changes

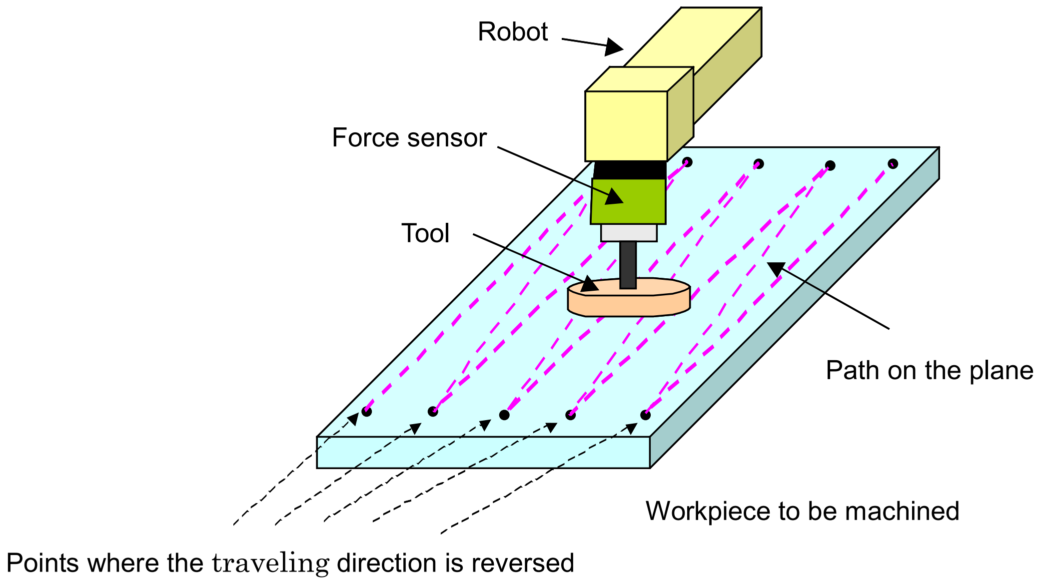


Fig. 1.5.5.2 (b) Setting of teaching points where traveling direction is reversed

When teaching points, consider the following two items:

- Control frame during contouring
- Posture at teach points

A detailed description is as follows.

Control frame during contouring

First determine whether to perform contouring operation in the tool frame or user frame.
If the pushing direction does not change during the contouring operation, select the user frame.
If the pushing direction changes during the contouring operation, select the tool frame.

If the pushing direction does not change (select the user frame)

If the pushing direction does not change (for example, when polishing the workpiece while pushing it in the same direction as a fixed grinder and buff), select the user frame.

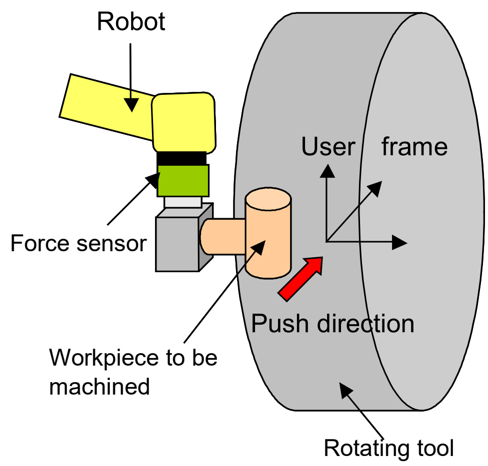


Fig. 1.5.5.2 (c) Control based on user frame

If the pushing direction changes (select the tool frame)

Select tool frame for applications where the pushing direction changes frequently.
Set the frame so that one of the X, Y, or Z axes of the frame to use matches the pushing direction.

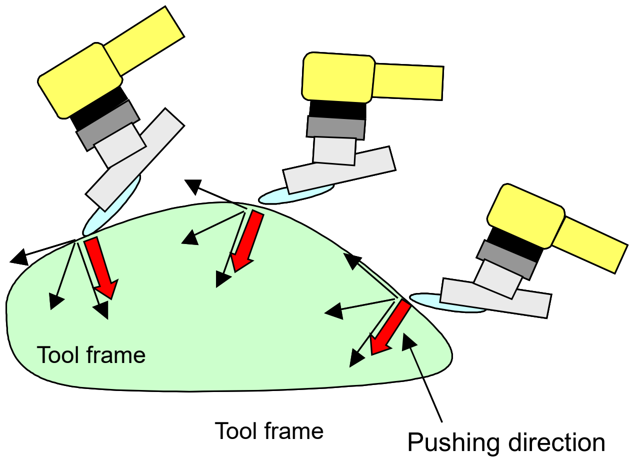


Fig. 1.5.5.2 (d) Control based on tool frame

Posture at teach points

In polishing or grinding, it is important that the tool and workpiece contact each other at the same posture. In the example of Fig. 1.5.5.2 (e), set the teaching point so that $\theta 1$ and $\theta 2$ match whenever possible.

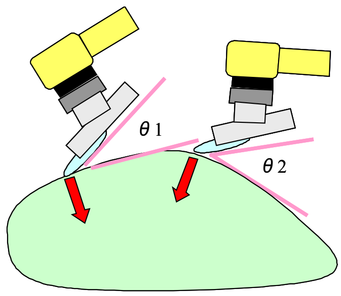


Fig. 1.5.5.2 (e) Posture at teach points

Example of teaching point

Set each teach point so that the tool center point (TCP) is about 1 mm off the surface of the workpiece to be machined (Fig. 1.5.5.2 (f)). Even though each teach point is off the surface of the workpiece, the tool will contact the workpiece when using the contouring function.

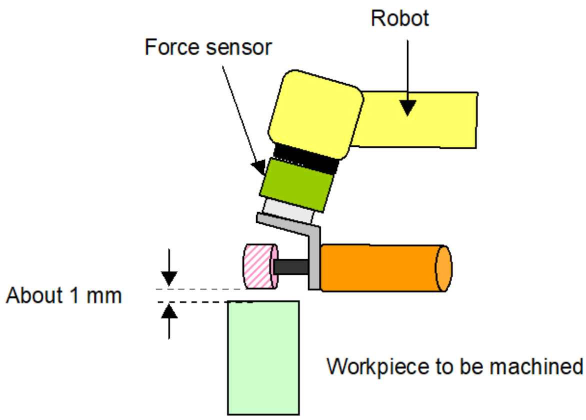


Fig. 1.5.5.2 (f) Example of teach point setting

⚠CAUTION

If teaching point is taught so that the tool center point (TCP) contacts the surface of the workpiece, the actual pushing force becomes larger than the set value.

If a workpiece has complicated shapes, many points need to be set. To improve the performance of the contouring function, all the points need to be set as precisely as possible.
To reduce time and effort in teaching points, a function is available, that sets points precisely and automatically by tracing the surface of the workpiece slowly with less teaching points.
(Refer to "Auxiliary Function Guide: 2 TP PROGRAM AUTO GENERATION FUNCTION".)

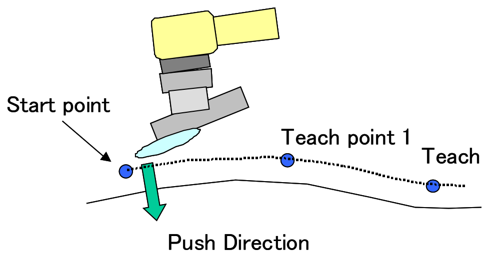


Fig. 1.5.5.2 (g) Good example

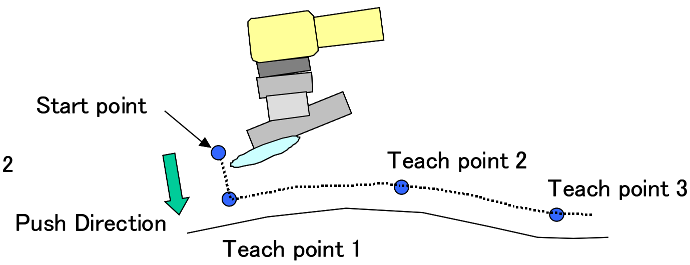


Fig. 1.5.5.2 (h) Bad example

⚠CAUTION

As indicated in Figure 1.5.5.2 (g), set each training point and the contouring start point so they are at the same distance from the workpiece surface as possible. Do not set the direction from the contouring start point to the next training point to be the same or near the pushing direction as indicated in Figure 1.5.5.2 (h), as this will apply excessive force when contact is made.

Contact after starting contouring function

There are 2 methods to approach and contact from a starting point.
With the first method, the robot starts it's traveling and pushing direction motion simultaneously, as shown in Fig 1.5.5.2(i).
With the second method, the robot starts it's pushing direction motion first and moves in the traveling direction after detecting contact with the part, as shown in Fig. 1.5.5.2 (j).
(Refer to Performance Screen Item "Motion Start" in "Basic Function Guide: 1.5.5.6 Parameters")
These two methods are used for different tools attached to the tip.

In the first method shown in Fig. 1.5.5.2 (i), it takes time for the tool to make contact with the surface of the workpiece. The Non-contact distance (d) is defined as the contour starting point to the point where the tool makes contact with the workpiece surface. The distance from the starting point to the workpiece surface is defined as (h). The approach velocity (Va), and (V) is defined as the traveling direction speed.
(Refer to "Basic Function Guide: 1.5.5.6 Parameters")
As the values of (h) and (V) are increased, (d) becomes longer. As the value of (Va) is increased, (d) becomes shorter. If (Va) is increased too much, it can cause a spike in force and remove more material at the beginning of the force control. Determine the position of a start point, considering non-contact distance (d).
After the tool contacts the workpiece surface, the robot moves while maintaining the set force.
Use this method when using tools that cut a large amount of material (such as a super hard cutter or grinder) for deburring or grinding, etc.

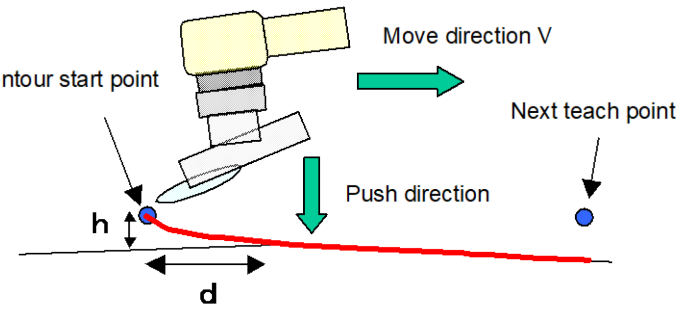


Fig. 1.5.5.2 (i) Move in the pushing direction and in the traveling direction at the same time from the starting point

With the second method, the robot starts it's pushing direction motion first and continues the pushing direction until the tool makes contact with the part, as shown in Fig. 1.5.5.2 (j). After detecting contact with the part the robot starts its motion in the traveling direction, while maintaining the programmed force. The second method is called after contact.
When applying a tool with a weak cutting force (such as a buff) or a tool that does not cut at all (such as roller), use the method that starts moving after making contact, as indicated in Figure 1.5.5.2 (j).

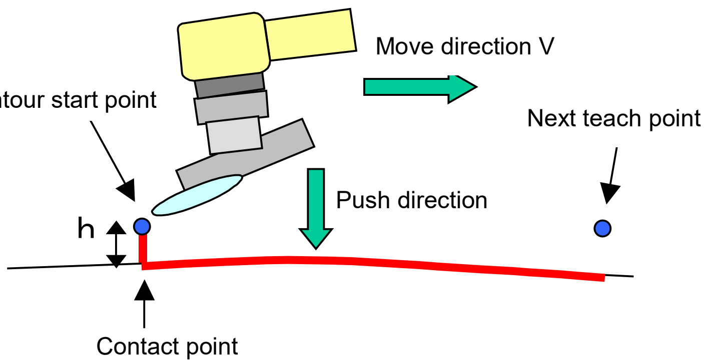


Fig. 1.5.5.2 (j) Move in the pushing direction first and after detecting a contact move in the traveling direction also

> ⚠**CAUTION**
> If you use the method that starts moving after making contact as indicated in Figure 1.5.5.2 (j) with a tool that cuts a large amount of material (such as a super hard cutter or grinder) for deburring or grinding, etc., the tool may cut the workpiece the instant contact is made and make a hole in the work.

End point of contouring function

The robot stops instantly when the contouring finishes. If a tool that cuts a large amount of material (such as a super hard cutter or grinder) for deburring or grinding is used, it may make a hole on the workpiece. To avoid this problem, add one teaching point that is away from a surface of the workpiece by about 3mm before force control instruction (Contouring End).
Termination type of previous teaching point of "Contouring End" instruction should be "FINE" instead of "CNT".

Automatically Changing the Pushing Direction

The pushing direction can be automatically changed according to the taught path during execution of a single force control statement (contouring function).
For a circular path, etc., the robot can be pushed towards the center of the circle or away from the center of the circle. This enables the robot to move in a circular path without greatly rotating the robot wrist.
With a rectangular path, the pushing direction can be automatically changed for each side. This eliminates the need for switching the force control statement for each side.

However, this function can only be used for paths within a flat surface.
(Refer to the [Pushing Dir Auto Chg] item in Table 1.5.5.6 (e).)

Changing the Pushing Force

The pushing force can be changed during execution of a single force control statement (contouring function).
This enables to switch the pushing force according to the area that the robot is pushing without stopping the robot.
(Refer to "Basic Operations Guide: 1.5.5.7 Other functions in the contouring function".)

1.5.5.3 Gravity compensation for the force sensor

In addition to force exerted between tool and workpiece, the force sensor also detects the effects of gravity on the tool. As the posture of robot changes during contouring, the gravity acting on the force sensor also changes. Gravity compensation for the force sensor compensates for this varying force by gravity to find real force exerted between the tool and workpiece If gravity compensation is not performed, incorrect push force can occur. A force greater than the set value may be applied or the tool may move away from the workpiece, resulting in degraded polishing or grinding performance.

Be sure to perform gravity compensation by attaching tool at the top of the force sensor when the tool is to be held by the robot as shown in Fig. 1.5.5.1 (a) or by holding a workpiece with a hand attached at the top of the force sensor if the workpiece is to be held by the robot as shown in Fig. 1.5.5.1 (b).

In order to make gravity compensation valid, the weight and center of mass of the tool or workpiece at the top of the force sensor is required. The function which can calculate those values automatically is available.
(In order to perform this function, refer to "Auxiliary Function Guide: 1 TOOL WEIGHT AND CENTER OF GRAVITY CALCULATION FUNCTION".)

NOTE

It compensates gravity only while force control is active. It does not affect the motion performance outside of force control.

1.5.5.4 Program

With Contouring Function, "Contouring" and "Contouring End" of the schedule data are used.
After the point where contouring operation is started, place "Contouring". After the point where contouring operation is ended, place "Contouring End".
When the "Contouring" and "Contouring End" functions are used, no jump can be made to a set error label number even if an error occurs during execution.

```
TEST

   1:J @P[1:START] 100% FINE
   2:   FORCE CTRL[1:CONTOURING]
    :   ErrorLBL[0]
   3:C @P[2]
    :     P[3] 50mm/sec CNT100
   4:J @P[4:END] 50msec FINE
   5:   FORCE CTRL[2:CONTOURING END]
    :   ErrorLBL[0]

[END]
```

Fig. 1.5.5.4 Example of program

In the example above, a contouring operation starts at position 1 of the program, passes near position 2 and position 3, and then ends near position 4. During contouring, the tool or workpiece moves, with both contacting each other, along the path, so that the path is slightly apart from the teach points.
(For information on setting the pushing force during contouring, etc., refer to "Basic Function Guide: 1.5.5.6 Parameters".)

1.5.5.5 Notes on the contouring function

If an alarm is issued or an emergency button is pressed during contouring operation, the processing described below is performed. At this time, the Contouring Function does not stop peripheral devices such as grinder. Ensure that those operations are performed by the system.

When an error occurs during contouring operation:

1. Contouring operation stops and the robot stops.
2. The message "FORC-279 Contouring aborted" is displayed on the TP.
3. If an alarm reset is made after correcting the cause of the error, operation is performed under normal position control. To resume contouring operation, re-execute "Contouring" instruction.

When an emergency button is pressed during contouring operation:

1. The contouring operation stops and the robot stops.
2. The messages "FORC-211 Servo error occurred" and "FORC-279 Contouring aborted" are displayed on the TP.
3. If an alarm reset is made, operation is performed under normal position control. To resume the contouring operation, re-execute "Contouring" instruction.

When a temporary stop (hold) is performed during contouring operation:

1. The robot stops.
2. After restart, the contouring operation is continued.
3. If the program is executed starting with another line after a temporary stop, the contouring operation stops and the message "FORC-279 Contouring aborted" is displayed on the TP.

When jog feed is executed during contouring operation

1. The contouring operation stops.
2. The message "FORC-279 Contouring aborted" is displayed on the TP.
3. Execute jog feed. To resume the contouring operation, re-execute "Contouring" instruction.

When backward execution is used during contouring operation

1. The contouring operation stops.
2. The message "FORC-279 Contouring aborted" is displayed on the TP.
3. Subsequent operations are performed under normal position control. To resume the contouring operation, re-execute "Contouring" instruction.

1.5.5.6 Parameters

Overview

The parameters for "Contouring" are indicated below.
Only in the case of using 3-axis force sensor, its own parameters are added in the basic screen. The parameters displayed on the basic screen must be set at all times.

> **NOTE**
> 1 If the robot is a CRX robot and the software version is 7DF5/05 or later, "Contouring" can also be used with the internal sensor. In this case, no external force sensor is necessary.

[Function selection] screen

```
1
1 Unused
2 Constant Push
3 Face Match
4 Shaft Insert
5 Groove Insert
6 Search
7 Phase Search
8 --next page--
```

```
2
1 Hole Search
2 Clutch Search
3 Square Insert
4 Contouring
5 Contouring End
6 Threading
7
8 --next page--
```

[Basic Data Settings] screen

```
Force Ctrl/Basic
                                        1/11
  Schedule[1]                 G:1 F:1 S:1
  1 Function             : Contouring
  2 Comment              : [              ]
  3 Pushing Dir.              Tool: -Z
  4 Contact F Threshold  :    10.00 N
  5 Approach Velocity    :     1.00 mm/s
  6 Control Frame        : Tool Frame
  7 User Frame No.             UF:   1
  8 Tool Frame No.             TF:   1
  9 Contouring Force     :    50.00 N
 10 Push Dist. Limit     :    50.00 mm
 11 Force Control Gain :          Detail
[TYPE]  GROUP  NUMBER  [SELECT]  PERFORM  >
  F1     F2     F3      F4        F5
```

Setting for 3-Axis Sensor

```
........
11 3-Axis FS ContactP. Position : TOOL
12     Setting Method      : Frame
13     [-]Pos. Reg. No.    :          0
14     [-]Distance         :     0.0 mm
........
```

[Force Ctrl/Gain] screen

```
Force Ctrl/Gain
                                        1/1
  Schedule[1]                 G:1 F:1 S:1
     Function            : Contouring
  1 Contour Impedance    : [Master Freq. ]

 [ TYPE ] GROUP   NUMBER   [CHOICE]
[TYPE]  GROUP  NUMBER  [SELECT]           >
  F1     F2     F3      F4        F5
```

[Performance Data Settings] Screen (1/2)

```
Force Ctrl/Perform
                                        1/53
  Schedule[1]                 G:1 F:1 S:1
  1 Function             : Contouring
  2 Comment              : [              ]
  3 Simple Customize Sw          : OFF
  4    Cont. Exec. Max. Count     :    1
  5 Customize Parent Number  :         0
  6    Customize ParaChg Conct:OFF
  7 User Frame Compensation:   OFF
     Force Limit
  8   X:   500.00 Y:   500.00 Z:   500.00 N
  9   W:    50.00 P:    50.00 R:    50.00N*m
     Force Change Limit
 10   X:   200.00 Y:   200.00 Z:   200.00 N
 11 Pushing Dir. Velocity:       0.00 mm/s
 12 Motion Start          : before contact
 13 Chk Overload Chg Trav Vel Sw: OFF
 14    Monitoring Force     :   travel
 15    Min. Force           :     2.00 N
 16    Max. Force           :     8.00 N
 17    Min. Speed Rate      :     1.00 %
 18 Overload F. Detect Sw.:    OFF
 19    Output Num.Reg. No. :           0
 20    Monitoring Force     :   travel
 21    OvrF.Judgment Thres.:   30.00 N
 22 Deact.PushDirMotion Sw:    OFF
 23    Input Num.Reg. No.   :          0
 24 Change Push. Force Sw.:    OFF
 25    Min. Speed           :     2.0 mm/s
 26    Max. Speed           :    50.0 mm/s
 27 Pushing Dir Auto Chg: OFF
 28 Chk Push Chg Trav Vel Sw    : OFF
 29    Min. Force Rate        :    5.0 %
 30    Max. Force Rate        :   70.0 %
 31    Min. Speed Rate        :   1.00 %
[TYPE]  GROUP  NUMBER  [SELECT]  Basic    >
  F1     F2     F3      F4        F5
```

Fig. 1.5.5.6 (a) Screen for "Contouring"(1/2)

[Performance Data Settings] Screen (2/2)

```
Force Ctrl/Perform
                                        33/53
 33 Monit Min Push F Sw     :   OFF
 34     Min. Force Rate     :        10.0 %
 35     Monit Time          :        1.0 sec
 36 Monit Push Dir Depth Sw:  OFF
 37     Monit Motion Input Reg No :      0
 38     Monit Motion Output Reg No:      0
 39     End Depth           :        2.0 mm
 40     Max Depth Per Path  :        0.5 mm
 41     Max Repeat Count    :            10
 42     Monit Domain Rate   :        80.0 %
 43 Force Denoising Sw      :   OFF
 44 Signal Output for ERR SW: OFF
 45     Output Signal Type  :   DO
 46     Output Signal Number:        0
 47 2 Direction Push        :   OFF
 48     Pushing Direction 2          : -Z
 49     Contouring Force 2 :     10.00 N
 50     Approach Velocuty 2:       0.00 mm/s
 51     Pushing Dir. Vel. 2:     0.00 mm/s
        Push Dist. Limit Individual
 52       X:OFF       Y:OFF       Z:OFF
 53       X:    10.0 Y:     10.0 Z:    10.0 mm
 54 Face Match              OFF:     Setting
 55 Auto.Follow             OFF:     Setting
 56 TPProgramAuto.Gen.Sw. :   OFF
 57     TPProgramAuto.Gen.Param.No. :     0
 58     Pos.Acquisition.Cond: Aftr.Aprch.

[TYPE] | GROUP | NUMBER | [SELECT] | Basic | >
  F1      F2      F3        F4       F5
```

[Contour/FaceMatch] screen

```
Contour/FaceMatch
                                        1/9
  Schedule[1]                 G:1 F:1 S:1
  1 Function              : Contouring
  2 Comment               : [                  ]
  3 Face Match Sw.           :   OFF
  4     FaceMatchDir:       W: OFF   P: OFF
        Dist.Of ContactP. from Axis:
  5                 W:    0.0   P:    0.0   mm
        FaceMatch Max Rotation Velocity:
  6                 W:   1.0    P:   1.0 deg/s
        AftrCntct FaceMtch UpperLim Time:
  7                                    20.0 sec
  8     Orientation Chg. Chk. Sw: ON
  9      Orient.Chg. UpperLim:     30.0 deg

[TYPE] | GROUP | NUMBER | [SELECT] | Basic | >
  F1      F2      F3        F4       F5
```

[Contour/AutoFollow] screen

```
Contour/AutoFollow
                                        1/14
  Schedule[1]                 G:1 F:1 S:1
  1 Function              : Contouring
  2 Comment               : [                  ]
  3 Auto.Follow Sw.       : OFF
  4     Travel.Dir. to Push.Dir.: LeftDir
        Move UpperLim.         :
  5       1: Dist.From Strt.CtP:    100.0 mm
  6       2: Total Move Dist.:      100.0 mm
  7       3: Total Move Time :       20.0 sec
  8     End Pos. Designate   : None
  9       Pos.Reg. No.         :             0
 10       In Position Thres. :       0.0 mm
 11     Aprch.Dir.Ang InptNumReg No.:     0
 12     NrmlEnd for MoveUpperLim:   None
 13     End by Num.Reg         :   OFF
 14       End Num.Reg. No.     :             0

[TYPE] | GROUP | NUMBER | [SELECT] | Basic | >
  F1      F2      F3        F4       F5
```

Fig. 1.5.5.6 (b) Screen for "Contouring"(2/2)

Adjusting the Parameters for the Contouring Function

1 Display the [Basic Data Settings] screen for the "Contouring" function.
2 Select [Control Frame].
Select "Tool frame" or "User Frame".
3 Configure [UTool Number], [UFrame Number], [Pushing Direction], [Pushing Force], [Contact F Threshold], [Approach Velocity], and [Push Dist. Limit].
4 Configure [Force Control Gain].
(Refer to "Basic Function Guide: 1.6 FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".)
5 Configure the other parameters on the [Basic Data Settings] screen.
6 Configure the parameters on the [Performance Data Settings] screen, as required.

NOTE
1 Force control gain auto adjustment cannot be executed for the "Contouring" function. Configure it manually.
2 For the outline of force control instruction programming, refer to "Basic Function Guide: 1.1 NOTES / RESTRICTIONS", and "Basic Function Guide: 1.2 TEACHING PROCEDURE".

[Basic Data Settings] screen

Parameters shown in this section must be set.

Table 1.5.5.6 (a) [Basic Data Settings] screen

Item	Description
Function	A desired function is selected from "Function selection screen". In this case, select " Contouring ".
Sensor Type	Select the type of sensor being used. For the CRX series, select either "External Force Sensor" or "Internal Sensor". A force sensor is unnecessary if "Internal Sensor" is selected. For robots other than the CRX series, "External Force Sensor" is automatically selected and cannot be changed. "Default : External Force Sensor"
Comment	Enter a comment for identifying the schedule data. Maximum number of characters: 16 characters.
User Frame Number	Enter the number of the user frame to use when contouring. (Enter the user frame number that was set in "Basic Functions Guide: 1.2 TEACHING PROCEDURE".) "Default : UF:0"
Tool Frame Number	Enter the number of the tool frame to use when contouring. (Enter the user tool number that was set in "Basic Functions Guide: 1.2 TEACHING PROCEDURE".) "Default : TF:1"
Control Frame	Select whether to perform pushing with the tool frame or user frame from "Tool Frame", "User Frame", or "User Frame FIXED". In a case such as grinding a secured workpiece that is always being pushed in the same direction with a fixed grinder or buffer, select "User Frame". For applications where the pushing direction sometimes changes rapidly, select "Tool Frame". In cases such as remote TCP, where the workpiece is pushed while its orientation is changed so that it remains in contact with a fixed point on the tool, select "User Frame FIXED". "Default : Tool Frame"

<table>
<tr><th>Item</th><th colspan="2">Description</th></tr>
<tr><td rowspan="4">Pushing Direction</td><td colspan="2">Enter the direction to push using the user frame that is set.
"Default : −Z"
[AutoChg], [TOOL] or [USER] is displayed before the [Pushing Direction] setting.</td></tr>
<tr><td>AutoChg</td><td>[Pushing Dir Auto Chg] is set to [TRUE] on the [Performance Data Settings] screen.</td></tr>
<tr><td>Tool</td><td>[Control Frame] is set to [Tool Frame] on the [Basic Data Settings] screen.</td></tr>
<tr><td>User</td><td>[Control Frame] is set to [User Frame] on the [Basic Data Settings] screen.</td></tr>
<tr><td>Push Dist. Limit</td><td colspan="2">Enter the distance that the workpiece can move during contouring.
The robot also moves in the pushing direction a little away from the trained path during contouring.
The robot stops due to an alarm if the workpiece moves more than the value set here.
"Default : 50.00 mm"</td></tr>
<tr><td>Approach Velocity</td><td colspan="2">Enter the target operation velocity until contact is made with the target.
"Default : 1.00 mm/s"
⚠ CAUTION
Increasing the value in [Approach Velocity] reduces the time it takes until contact is made, but a larger force than the set value will be applied the instant that contact is made, which may cut too much material.</td></tr>
<tr><td>Contact F Threshold</td><td colspan="2">Enter the threshold value for determining whether contact has been made with the target.
Actual contouring operation starts after a contact is made. Enter a value equal to or less than [Pushing Force].
"Default : 10.00 N"</td></tr>
<tr><td>Contouring Force</td><td colspan="2">Enter the target pushing force for the actual pushing operation.
The target pushing force is changed if "the function of changing target pushing force during a contouring".
(Refer to "Basic Function Guide: 1.5.5.7 Other functions of the contouring function".)
"Default : 30.00 N"</td></tr>
<tr><td>[G F S]</td><td colspan="2">G represents a motion group number at the time of teaching. F represents a force control number. S represents a force sensor number.
(These settings cannot be changed.)
"Defaults : G F S : 1 1 1"</td></tr>
</table>

Table 1.5.5.6 (b) [Basic data settings] screen (In the case of 6-axis force sensor)

Item	Description
Force Control Gain	Perform the operation below to switch to the [Force Control Gain] screen. • Move the cursor to this line then press the [ENTER] key. The screen display switches to the force control gain detail screen. Configure the parameters on the [Force Control Gain] screen manually. (For the parameters that can be set on this screen, refer to "Basic Function Guide: 1.6 FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".)

The following parameters from "3-Axis FS ContactP. Position (3-axis FS)" to "Distance (3-Axis ContactP. Position) (3-axis FS)" are specific to 3-axis force sensor.
(Refer to "Basic Function Guide: 1.9 3-AXIS FORCE SENSOR SETTING".)

Table 1.5.5.6 (c) [Basic data settings] screen (In the case of 3-axis force sensor)

<table>
<tr><th>Item</th><th colspan="2">Description</th></tr>
<tr><td rowspan="3">3-Axis FS ContactP.
Position</td><td colspan="2">With the 3-axis sensor function, set whether to move the position used as the contact point together with the robot or to fix it in space.
The 3-axis force sensor detects Fz, Mx, My. The force control for 3-axis force sensor estimates Fx, Fy, Mz with the contact point at that a tool contacts with a work.
This parameter sets whether the contact point is on the mechanical interface coordinate system or on the world coordinate system. In other words, this parameter sets whether the positional relationship between a robot wrist flange and the contact point is fixed or the positional relationship between the world coordinate and the contact point is fixed.
Select [TOOL] or [USER].</td></tr>
<tr><td>TOOL</td><td>Move a contact point with a robot motion, as an origin of a tool coordinate system, on the world coordinate system.
Set the value that is given by after-mentioned parameter on the mechanical interface coordinate to the contact point.</td></tr>
<tr><td>USER</td><td>Fix a contact point, as an origin of a user coordinate system, on the world coordinate system.
Set the value that is given by after-mentioned parameter on the world coordinate system to the contact point.</td></tr>
<tr><td>Setting Method
(3-Axis ContactP.
Position)
(Fig. 1.5.5.6 (c))</td><td colspan="2">This parameter specifies the setting method for the position of a contact point for the 3-axis force sensor.
The setting value of the coordinate system and the position register described following are the values that are set at the beginning of the force control, as is the case with other parameters of the schedule data.
Select [TOOL], [Pos. Reg.], or [PushDirShift].

⚠ **CAUTION**
When specifying the method for determining the position to use as the contact point in [Setting Method] for the 3-axis force sensor function, The distance between the contact point and the flange center point of the 3-axis force sensor in the Z direction (this direction is indicated on the force sensor unit) must be greater than 17 mm. Take care when the robot operations cause this distance to vary.

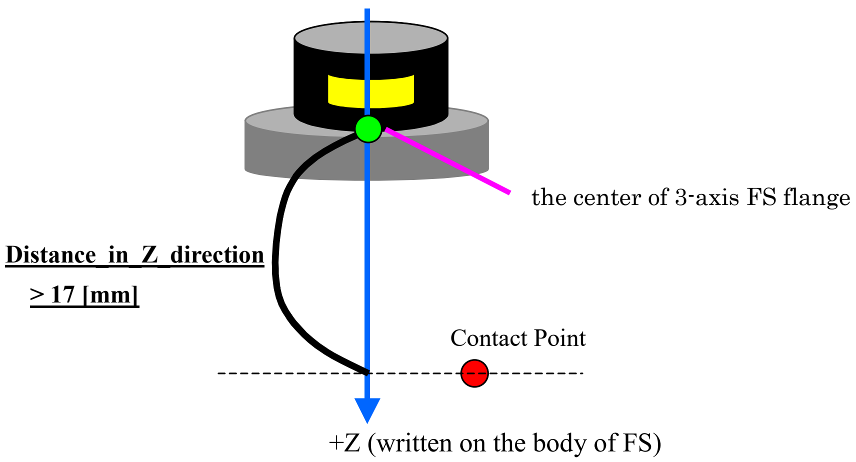


Fig. 1.5.5.6 (c) Distance between the contact point and the flange center point of the 3-axis force sensor in the Z direction</td></tr>
</table>

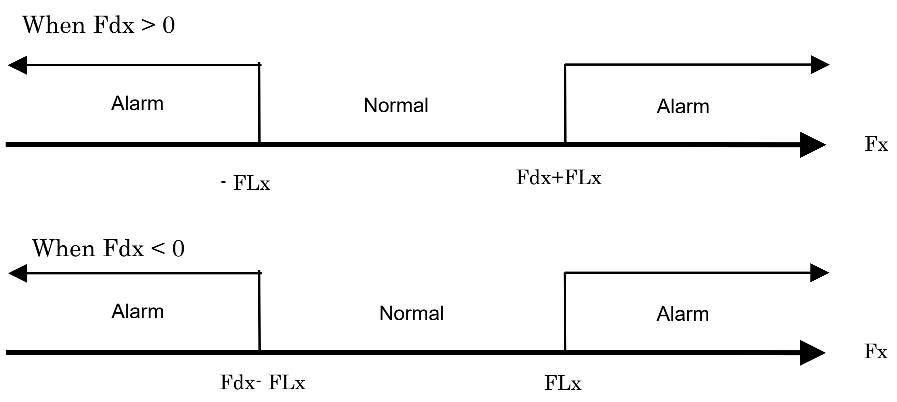
Item	Description	
Setting Method (3-Axis ContactP. Position) (Fig. 1.5.5.6 (c))	Frame	• If "3-Axis FS ContactP. Position" is "TOOL" : A contact point is set to an origin of a tool coordinate system designated by "Tool Frame No." in the "Basic data". • If "3-Axis FS ContactP. Position" is "USER" : A contact point is set to an origin of a user coordinate system designated by "User Frame No." in the "Basic data". In this case, if "User Frame Compensation" in the "Performance data" is valid, the compensated user coordinate system is used as the user coordinate system.
	Pos. Reg.	The position of a contact point is set to the values of X, Y, Z that are set to the position register, designated by after-mentioned "Pos. Reg. No.", at the beginning of the force control. • If "3-Axis FS ContactP. Position" is "TOOL" : The position of a contact point is set to the values of the position register on the mechanical interface coordinate system. • If "3-Axis FS ContactP. Position" is "USER" : The position of a contact point is set to the values of the position register on the world coordinate system.
	PushDirShift	• If "3-Axis FS ContactP. Position" is "TOOL" : A contact point is set to a point that an origin of the tool coordinate system designated by "Tool Frame No." is shifted by after-mentioned "Distance" in the direction designated by "Pushing Dir." or in the direction which is changed automatically by the "Pushing Dir Auto Chg" function. • If "3-Axis FS ContactP. Position" is "USER" : A contact point is set to a point that an origin of the user coordinate system designated by "User Frame No." is shifted by after-mentioned "Distance" in the direction designated by "Pushing Dir." or in the direction which is changed automatically by the "Pushing Dir Auto Chg" function.
Pos. Reg. No. (3-Axis ContactP. Position)	Enter the number of the position register to use when the position register is set as the above mentioned "Setting Method" with the 3-axis force sensor function.	
Distance (3-Axis ContactP. Position)	Enter the distance to use when the pushing direction shift is set as the above mentioned "Setting Method" with the 3-axis force sensor function. "Unit : mm"	
Force Control Gain	Perform the operation below to switch to the [Force Control Gain] screen. • Move the cursor to this line then press the [ENTER] key. The screen display switches to the force control gain detail screen. (For the parameters that can be set on this screen, refer to "Basic Function Guide: 1.6 FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".)	

[Performance data setting] screen

Parameters shown in this section are for advanced users.

Table 1.5.5.6 (d) [Performance data setting] screen (1/3)

Item	Description
Function	A desired function is selected from "Function selection screen". In this case, select "Contouring".
Comment	Enter a comment for identifying the schedule data. Maximum number of characters: 16 characters.
Simple Customize Sw	This switch is for force control continuous execution. This can be set to 'On' or 'Off'. It enables to execute the schedule data being edited after any other schedule. (Refer to "Basic Function Guide: 1.7.3 Simple Customization Function".) "Default : OFF"

Item	Description
Cont. Exec. Max. Count	Enter an integer for the number of times a force control schedule with the simple customization function enabled can be executed continuously. (Refer to "Basic Function Guide: 1.7.3 Simple Customization Function".) "Default : 1"
Customize Parent Number	Enter this when executing force control continuously. (Refer to "Basic Function Guide: 1.7.4 Customization Function".) "Default : 0"
Customize ParaChg Connection	This item is set when force control is executed successively. Select 'Both D', 'P2C', 'C2P', or 'Off'. (Refer to "Basic Function Guide: 1.7.4 Customization Function".) "Default : OFF"
User Frame Compensation SW	This parameter is the switch for correcting the user frame set for the workpiece, using vision. This switch is useful if the workpiece cannot be correctly positioned. Select 'Off', 'Pos. Reg.', or 'VISION REG'. The switch must be used in combination with the OFFSET or VOFFSET instruction. (Refer to "Basic Function Guide: 1.8 USER FRAME COMPENSATION".) "Default : OFF"
Force Limit (Fig. 1.5.5.6 (d))	When a generated force satisfies the expressions below, an alarm(FORC-216 - FORC-221) is issued. Refer to "APPENDIX: B ALARM CODES OF FORCE CONTROL" and remove a cause of the alarm. Increase the values of this parameter after all measures are taken. Set a force in each of the three directions, X, Y, and Z. In addition, set a moment in each of the three directions, W, P, and R. For example, the expressions for the X direction are: $Fx < -FLx$ or $Fx > Fdx + FLx$ (when $Fdx > 0$) $Fx > FLx$ or $Fx < Fdx - FLx$ (when $Fdx < 0$) Fx : Force generated during push or face match operation. (in the X direction) FLx : X component of "Force Limit". Fdx : Target force in the X direction. When the push direction is "X" or " – X," Fdx is "Contouring Force". In other cases, Fdx= 0. The same relationships apply to Y, Z, W, P, and R. "Defaults : X : 200.00 Y : 200.00 Z : 200.00 N W : 15.00 P : 15.00 R : 15.00 N*m"  Fig. 1.5.5.6 (d) Force Limit and the occurrence of an alarm
Force Change Limit	Enter the allowed force change for the X, Y, and Z directions. When a change of generated force in X, Y, Z direction exceeds this value, an alarm is issued. Large vibrations from a grinding tool or a nut runner or oscillation of the robot with a very big force control gain could be a reason of the alarm. Remove the cause of the alarm first. If it can't be removed, increase the value of this parameter. "Defaults : X : 100.00 Y : 100.00 Z : 100.00 N"

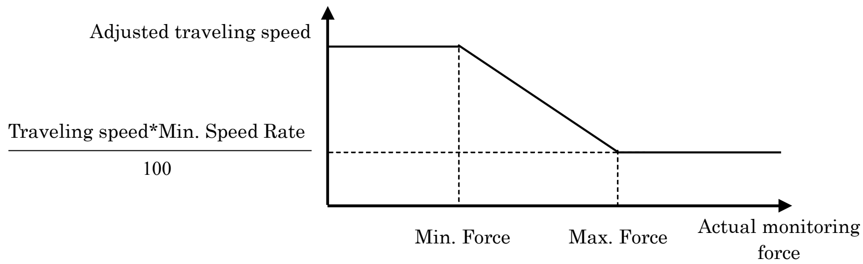
<table>
<tr><th>Item</th><th>Description</th></tr>
<tr><td>Pushing Dir. Velocity</td><td>The velocity command for the pushing direction. Normally enter "0".
Enter a value between about "1" mm/s to "10" mm/s if the workpiece and tool separate during contouring due to the curvature of the work.
"Default : 0.00 mm/ s"</td></tr>
<tr><td>Motion Start</td><td>Select the start operation for contouring.
Select "before contact" to start before making contact or "after contact" to start after making contact.
(Refer to 'Contact after starting contouring function' in "Basic Function Guide: 1.5.5.2 Teaching of the Contouring Function".)
"Default : before contact "</td></tr>
<tr><td>Chk Overload Chg Trav Vel Sw
(Fig. 1.5.5.6 (e))</td><td>This parameter is a switch for the "Chk Overload Chg Trav Vel" function that changes a moving velocity depending on generated force. This can be set to 'On' or 'Off'.
This " Chk Overload Chg Trav Vel" function can prevent overload on a tool or a workpiece by reducing the traveling speed depending on force. And this function reduces the speed only when it is needed, so a total cycle time of a system can be shortened.
The adjusted traveling speed is calculated from "Min. Force", "Max. Force", "Min. Speed Rate" and actual monitoring force.
"Default : OFF"


Fig. 1.5.5.6 (e) Calculation of the velocity command of [Chk Overload Chg Trav Vel Sw]</td></tr>
<tr><td>Monitoring Force
(Chk Overload Chg Trav Vel)</td><td>Select the type of force to monitor with the Chk Overload Chg Trav Vel function.
• "Resultant": Monitors the resultant force applied from the X, Y, and Z directions.
• "X", "Y", and "Z": Monitors the force applied from the X, Y, and Z directions in "Control Frame".
• "Travel": Monitors the force applied from the travel direction.
"Default : travel"</td></tr>
<tr><td>Min. Force
(Chk Overload Chg Trav Vel)</td><td>Enter the minimum value for the force to monitor with the Chk Overload Chg Trav Vel function.
When the force to monitor is less than this value, the general velocity is not adjusted.
“Default : 2.00 N"</td></tr>
<tr><td>Max. Force
(Chk Overload Chg Trav Vel)</td><td>Enter the maximum value for the force to monitor with the Chk Overload Chg Trav Vel function.
When the force to monitor is equal to or less than this value, the general velocity is reduced based on the ratio set in [Min. Speed Rate] (overload check progress velocity adjustment).
When monitoring force is greater than or equal to "Min. Force" and less than "Max. Force", the "Chk Overload Chg Trav Vel" function changes the moving velocity depending on monitoring force.
"Default : 8.00 N"</td></tr>
</table>

Item	Description
Min. Speed Rate (Chk Overload Chg Trav Vel)	This parameter specifies a proportion to determine a minimum speed when the "Chk Overload Chg Trav Vel" function is enabled. The minimum speed is determined by the multiplication of original speed and "Min. Speed Rate" / 100. Enter a number between "0.001" and "100" for this value. * This value must be between 0.001 and 100, otherwise this function does not work. "Default : 1.00 %"
Overload F. Detect Sw.	This parameter is a switch for the "Overload F. Detect" function, which detects excessive force by comparing generated force to a threshold value and changes a Numeric Register value depending on the result continuously. This can be set to 'On' or 'Off'. The "Overload F. Detect" function can be used with the High Speed Skip Function during a contouring. And other instructions can be executed when the High Speed Skip Function detects excessive force by monitoring the Numeric Register. "Default : OFF"
Output Num.Reg. No. (Overload F. Detect)	Enter the register number to output this value to with the overload force detection function. The output values of the Numeric Register mean as follows: • 1 : Excessive force is detected. • 0 : Excessive force is not detected. "Default : 0"
Monitoring Force (Overload F. Detect)	Select the type of force to monitor with the overload force detection function. The choices of this parameter mean as follows: • "resultant" : Resultant Force. (Sum of force in X, Y, Z direction on "Control Frame".) • "X, Y, Z" : Force in X, Y, Z direction on "Control Frame". • "travel" : Force in traveling direction. "Default : travel "
OvrF.Judgment Thres (Overload F. Detect) (Fig. 1.5.5.6 (f))	Enter the threshold value for judging that the force is too high with the overload force detection function. If generated force is larger than or equal to this value, the generated force is judged to be excessive force and the "Overload F. Detect" function output 1 to the designated Numeric Register. Otherwise output is 0. • As an application of the "Overload F. Detect" function, a sample TP Program is shown in Fig. 1.5.5.6 (f). The TP Program makes it possible by using the "Overload F. Detect" function and the High Speed Skip Function to move as quickly as possible while avoiding an obstacle whose maximum size is known beforehand, after detecting a collision with the obstacle. (In this TP Program, after-mentioned "Deact. Push Dir Motion" function is also used to stop activating pushing motion by force control while avoiding the obstacle.) "Default : 30.00 N"
Deact.PushDirMotion Sw	This parameter is a switch for temporarily deactivating the pushing motion by force control according to the values of the Numeric Register during executing the contouring function. This can be set to 'On' or 'Off'. "Default : OFF"
Input Num.Reg. No. (Deact. Push. Dir. Motion)	Enter the register number to disable with the deactivate push direction motion function. The input values of the Numeric Register mean as follows: • 1 : deactivate pushing motion by force control. • Otherwise : do not deactivate pushing motion by force control. "Default : 0"
Change Push. Force Sw.	This parameter is a switch for adjusting the pushing force according to the traveling velocity. This can be set to 'On' or 'Off'. This "Change Push. Force" function reduces desired pushing force when the traveling velocity is small. "Default : OFF"

Item	Description
Min. Speed (Change Push. Force)	When the traveling velocity is smaller than this value, the "Change Push. Force" function reduces pushing force as small as possible. Enter the threshold value. "Default : 2.0 mm/ s"

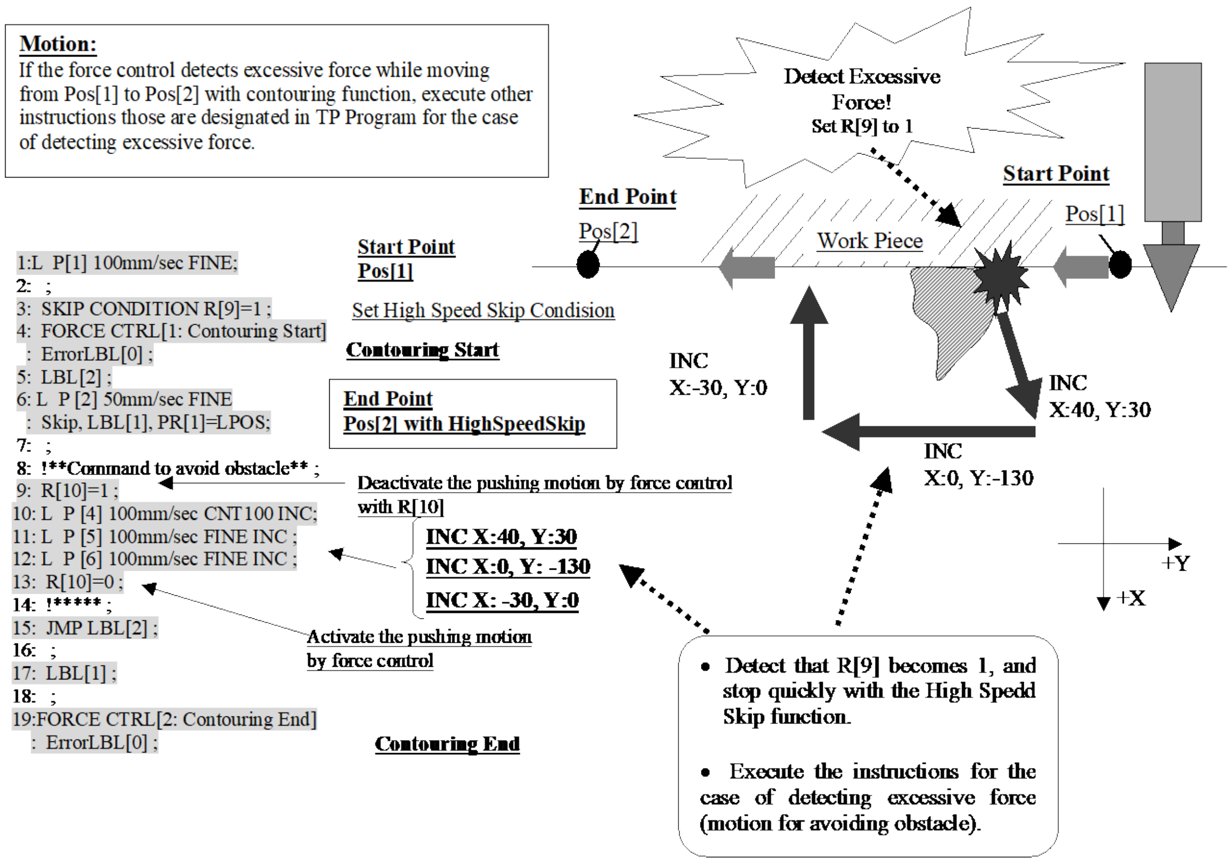
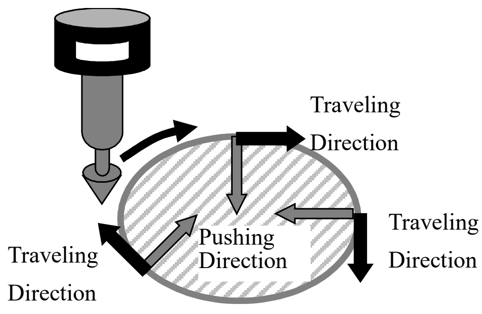
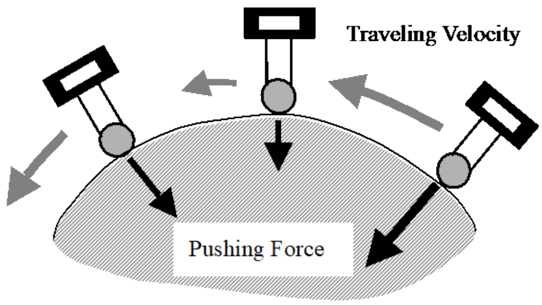
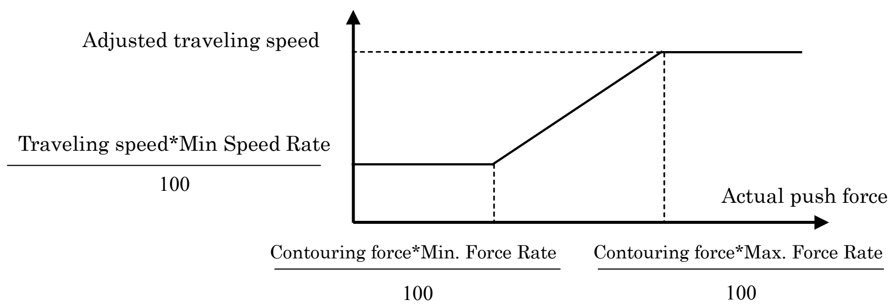
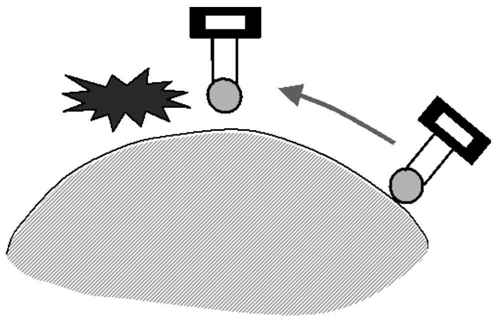


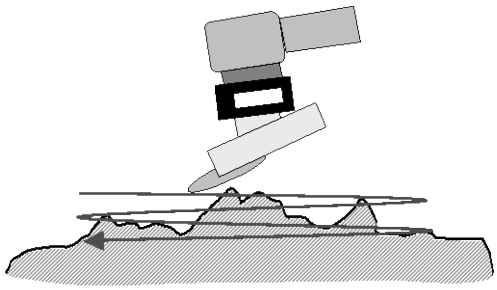
Fig. 1.5.5.6 (f) Example TP Program using the "Overload F. Detect" function and the High Speed Skip Function

Table 1.5.5.6 (e) [Performance data setting] screen (2/3)

Item	Description
Max. Speed (Change Push. Force)	When the traveling velocity is greater than or equal to this value, the "Change Push. Force" function does not reduce pushing force. Enter the threshold value. When the traveling velocity is greater than or equal to "Min. Speed" and less than "Max. Speed", the "Change Push. Force" function reduces the desired pushing force depending on the traveling velocity. "Default : 50.0 mm/ s"
Pushing Dir Auto Chg (Fig. 1.5.5.6 (g))	This parameter enables the "Pushing Dir Auto Chg" function. This function automatically changes the pushing direction according to the travel direction. Select "Off" or "UserFrame X-Y". The "Pushing Dir Auto Chg" function changes the pushing direction in response to the motion of the origin of "Tool Frame" maintaining the same relationship between the pushing direction and the traveling direction same as at the beginning of the path. The pushing direction at this time is perpendicular to the taught traveling direction. When using this function, the force data from the "Force Data Log Function" is read as follows: (Refer to "Basic Function Guide: 2.3 FORCE DATA LOG FUNCTION".) • When "Pushing Direction" is set to ±X: Fx : Force in a pushing direction, Fy : Force in a traveling direction, Fz : Force in the Z direction of "User Frame". • When "Pushing Direction" is set to ±Y: Fx : Force in a traveling direction, Fy : Force in a pushing direction, Fz : Force in the Z direction of "User Frame". * When using this function, the X,Y,Z directions of "Force Limit" set in the "Performance data" and the "Chk Overload Chg Trav Vel" function and "Overload F. Detect" function are based on "User Frame". "Default : OFF" **⚠ CAUTION** [Pushing Dir Auto Chg] internally changes the pushing direction. Take care, as the pushing direction will differ from the [Pushing Direction] setting on the [Basic Data Settings] screen while [Pushing Dir Auto Chg] is operating.  Fig. 1.5.5.6 (g) [Pushing Dir Auto Chg]

Item	Description
Chk Push Chg Trav Vel Sw (Fig. 1.5.5.6 (h), Fig. 1.5.5.6 (i))	This parameter enables the "Chk Push Chg Trav Vel" function. This function reduces the moving velocity in response to a generated force in the pushing direction when the force in a pushing direction is less than the target force. Select "Off", "Dir 1", "Dir 2", or "Dir 1&2". The "Dir 1" setting is for pushing in [Pushing Direction] on the [Basic Data Settings] screen, and "Dir 2" is the pushing direction set in [2 Direction Pushing], which is explained later. For details, refer to [2 Direction Pushing]. This "Chk Push Chg Trav Vel" function checks the pushing direction force and maintains contact between the tool and work-piece. The adjusted velocity command is calculated by the "Min. Force Rate", "Max. Force Rate", "Min. Speed Rate", and the actual push force. (Refer to "Fig. 1.5.5.6 (j)".) "Default : OFF"
	 Fig. 1.5.5.6 (h) [Chk Push Chg Trav Vel Sw]  Fig. 1.5.5.6 (i) Calculation of the adjusted velocity command
Min. Force Rate (Chk Push Chg Trav Vel)	When the generated force in a pushing direction is less than target force × "Min. Force Rate" / 100, the "Chk Push Chg Trav Vel" function reduces the traveling velocity to a value determined by "Min. Speed Rate"(Chk Push Chg Trav Vel) (described below). Enter the ratio. "Default : 5.0 %"
Max. Force Rate (Chk Push Chg Trav Vel)	When the generated force in a pushing direction is greater than or equal to target force × "Min. Force Rate" / 100 and less than target force × "Max. Force Rate" / 100, the "Chk Push Chg Trav Vel" function reduces the traveling velocity to a value determined by "Min. Force Rate" and "Max. Force Rate" and "Min. Speed Rate" (described below). Enter the ratio. When generated force in a pushing direction is greater than or equal to target force × "Max. Force Rate" / 100, the "Chk Push Chg Trav Vel" function does not reduce the traveling velocity. "Default : 70.0 %"
Min. Speed Rate (Chk Push Chg Trav Vel)	This parameter specifies a proportion to determine a minimum speed when the "Chk Push Chg Trav Vel " function is enabled. The minimum speed is determined by the multiplication of original speed and "Min. Speed Rate" / 100. This value must be between 0.001 and 100, otherwise this function does not work. "Default : 1.00 %"

Item	Description
Monit Min Push F Sw (Fig. 1.5.5.6 (j))	This parameter enables the "Monit Min Push F" function. This function monitors the generated force in a pushing direction and check whether the generated force in the pushing direction is small or not. Select "Off", "Dir 1", "Dir 2", or "Dir 1&2". When the generated force in a pushing direction is less than a value determined by "Min. Force Rate"(Monit Min Push F) (described below) for a period in a row, designated by "Monit Time" (described below), the "Monit Min Push F" function issues an alarm and stops the robot. This "Monit Min Push F" function can stop the robot when a tool and a work-piece are not in contact or the generated force in a pushing direction is small after the tool and the work-piece come to be in contact. "Default : OFF"
	 Fig. 1.5.5.6 (j) [Monit Min Push F Sw]
Min. Force Rate (Monit Min Push F)	"Monit Min Push F" function compares generated force in a pushing direction with target force × "Min. Force Rate" / 100. Enter the minimum ratio for the force. "Default : 10.0 %"
Monit Time (Monit Min Push F)	When generated force is less than target force × "Min. Force Rate" / 100 for "Monit Time" [sec] in a row, "Monit Min Push F" function issues an alarm and stops the robot. Enter the time. "Default : 1.0 sec"
Monit Push Dir Depth Sw (Fig. 1.5.5.6 (k), Fig. 1.5.5.6 (l), Fig. 1.5.5.6 (m))	This parameter enables the "Monit Push Dir Depth" function. This function monitors the depth in a push direction while contouring and tries not to exceed the designated depth (end depth) by checking whether TCP reaches the designated depth (end depth) or not. This can be set to 'On' or 'Off'. The "Monit Push Dir Depth" function is mainly designed for applications that grind a work-piece to designated depth with a grinder. For example; rough grinding of a casting burr or weld grinding. The monitoring depth function has "Start", "Continue" and "End" actions. By setting a value of a designated "Numeric Register", these actions are switched and the judging depth process is executed and the result is output to a designated "Numeric Register". How to use: • Set parameters for "Contouring". • Make a TP Program with an appropriate path that is parallel to a target surface of a work-piece after deburring and insert a setting of a "Numeric Register" designated by "Monit Motion Input Reg No" and a process according to a value of another "Numeric Register" designated by "Monit Motion Output Reg No" in the TP Program. (Refer to also example TP Programs described in Fig. 1.5.5.6 (l), Fig. 1.5.5.6 (m).) "Default : OFF"

Item	Description	
Monit Push Dir Depth Sw (Fig. 1.5.5.6 (k), Fig. 1.5.5.6 (l), Fig. 1.5.5.6 (m))	 Fig. 1.5.5.6 (k) [Monit Push Dir Depth Sw]	
	"Start", "Continue" and "End" actions of the monitoring depth action	With a value of a designated "Numeric Register", the "Start" or "Continue" or "End" action of the monitoring depth action is selected. The "Numeric Register" number for setting the monitoring depth action is designated by "Monit Motion Input Reg No". Setting the value of the "Numeric Register" designated by "Monit Motion Input Reg No" means the following: • 1: "Start" :Start or restart the monitoring depth action. • 2: "Continue": Judge depth and continue the monitoring depth action. • 3: "End :End the monitoring depth action. To start or restart from "Continue", set the "Numeric Register" to equal 1. To continue the monitoring depth action and output the result of the judging depth process, set the "Numeric Register" to equal 2. To end the monitoring depth action and output the result of the judging depth process, set the "Numeric Register" to equal 3. When executing "Contouring End" or aborting "Contouring", the monitoring depth action ends also.
	Judging the depth process	The judging depth process judges whether TCP reaches a depth designated by "End Depth" or not during a period between "Start" and, "Continue" or "End". The depth in this function is defined as a distance in a pushing direction and is measured from the taught point in the path. When a proportion of a domain, where TCP reaches "End Depth", to a domain of the taught path in a TP Program is greater than or equal to "Monit Domain Rate", the judgment result is OK. Otherwise the judgment result is NG. "Monit Motion Output Reg No" designates the number of a "Numeric Register" to which outputs the results of the judging depth process. The output value to the "Numeric Register" specified by "Monit Motion Output Reg No" means as follows: • 1 : The result is OK • 2 : The result is NG

Item	Description	
Monit Push Dir Depth Sw (Fig. 1.5.5.6 (k), Fig. 1.5.5.6 (l), Fig. 1.5.5.6 (m))	The monitoring depth action	The "Monit Push Dir Depth" function prevents that a position of TCP in a pushing direction exceeds a designated depth. There are two kinds of actions for preventing that a position of TCP in a pushing direction exceeds a designated depth. One is to prevent from exceeding "Max Depth Per Path", another is to prevent from exceeding "End Depth". "Max Depth Per Path" is a limit depth for one path action. The one path action is an action between "Start" and, "Continue" or "End". "Max Depth Per Path" is compared to a depth that is from the latest path. If "Start" is a restart of "Continue", the depth is based on the shallowest point in the latest path. "End Depth" is a limit depth for the monitoring depth action. "Max Depth Per Path" must be set to be less than "End Depth". When a depth reaches "Max Depth Per Path" or "End Depth", the "Monit Push Dir Depth" function tries not to proceed in a pushing direction any more in the monitoring depth action. If the force in a direction opposite to a pushing direction is greater than or equal to target force, this function moves TCP to the direction opposite to the pushing direction. When "Continue" is designated after "Start", the repeat counter is incremented. If the repeat counter reaches "Max Repeat Count", this function issues an error and stops the robot. If "Max Repeat Count" is set to 0, this function does not check the repeat counter described above. If the monitoring depth action is set to "Start" from "Continue", the monitoring depth action restarts.
Monit Motion Input Reg No (Monit Push Dir Depth)	This parameter specifies the number of a Numeric Register that is for setting the monitoring depth action of "Monit Push Dir Depth" function. Enter the register specified in [Monit Motion Input Reg No] according to the depth monitoring operation, as indicated below. • 1 : "Start" : Start or restart the monitoring depth action. • 2 : "Continue": Judge depth and continue the monitoring depth action. • 3 : "End" : End the monitoring depth action. The value of the "Numeric Register" specified with "Monit Motion Input Reg No" is initialized with 0 at the execution of "Contouring" of "Force Control" instruction. "Default : 0"	
	This parameter specifies the number of a Numeric Register to which outputs the results of the judging depth process of "Monit Push Dir Depth" function. The output value to the "Numeric Register" specified by "Monit Motion Output Reg No" means the following: • 1 : The result is OK • 2 : The result is NG The value of the "Numeric Register" specified with "Monit Motion Output Reg No" is initialized with 0 at the execution of "Contouring" of "Force Control" instruction. "Default : 0"	
End Depth (Monit Push Dir Depth)	Enter the depth that should not be exceeded while performing depth monitoring with the monitor push direction depth function. "Default : 2.0 mm"	
Max Depth Per Path (Monit Push Dir Depth)	Enter the depth that should not be exceeded with a single operation while performing depth monitoring with the monitor push direction depth function. A single operation refers to the operation from "Start" to "Continue" or "End". [Max Depth Per Path] uses the shallowest position of the last operation as the reference value if the operation is after "Continue". Enter a value that does not exceed [End Depth] for [Max Depth Per Path]. "Default : 0.5 mm"	

Item	Description
Max Repeat Count (Monit Push Dir Depth)	This parameter specifies a maximum value of a repeat counter for the "Monit Push Dir Depth" function. The repeat counter is incremented every time the monitoring depth action is switched to "Start" from "Continue". "Default : 10"
Monit Domain Rate (Monit Push Dir Depth)	The judging depth process of the "Monit Push Dir Depth" function uses this rate. When a proportion of a domain, where TCP reaches "End Depth", to a domain of the taught path in a TP Program is greater than or equal to "Monit Domain Rate", the judgment result is OK. Otherwise the judgment result is NG. Enter the threshold value ratio. "Default : 80.0 %"
Force Denoising Sw	This parameter enables the "Force Denoising" function. This function removes the background big noise from force data. This function is useful when: • tool or work-piece is heavy. • using a tool such as a grinder and that has a big vibration. "Default : OFF"

NOTE

1 The following restrictions apply to [Pushing Dir Auto Chg].
- The designated work-piece plane is on the X – Y plane of a "User Frame".
- The "Control Frame" in "Basic data" is set to "User Frame".
- The "Pushing Direction" in "Basic data" is set to either ±X or ±Y.
- At the beginning of contouring, the pushing direction is not parallel to the traveling direction.
- Changing target pushing force before or during a contouring is prohibited.
- Changing a target pushing direction before or during a contouring is prohibited.
- The following functions cannot be used together:
  - "Successive Execution of Force Control Instructions (Customization Function) ".
- Restarting contouring from a pause is prohibited when using this function with the following functions:
  - "Chk Push Chg Trav Vel" function
  - "Monit Push Dir Depth" function

2 The following restrictions apply to [Chk Push Chg Trav Vel Sw].
- This function is effective once the workpiece makes contact to the object (the contact means that generated force exceeds "Contact F Threshold"). The moving velocity does not change before contact.
- The following functions cannot be used together:
  - "Deact.PushDirMotion" function
  - "Change Push. Force" function
  - "Monit Push Dir Depth" function

3 The following restrictions apply to [Monit Min Push F Sw].
- This function is effective once the workpiece makes contact to the object (the contact means that generated force exceeds "Contact F Threshold"). The force in a pushing direction is not monitored before contact.
- The following functions cannot be used together:
  - "Deact. Push. Dir. Motion" function
  - "Change Push. Force" function
  - "Monit Push Dir Depth" function

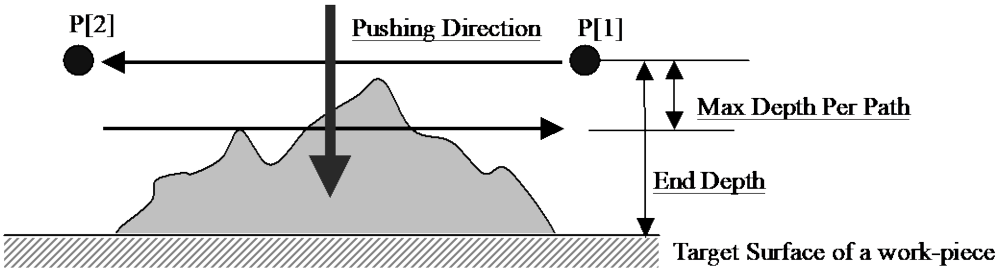
4 The following restrictions apply to [Monit Push Dir Depth Sw].

- Paths of a TP Program should be parallel to last target paths, that is, a target surface of a work-piece after deburring.
- A pushing direction must be perpendicular to the paths of a TP Program.
- A TP Program that fails to fulfill the conditions described above is such as the following:
    - During the monitoring depth action, a robot moves in a direction that includes a direction opposite to a pushing direction, with the High Speed Skip Function and incremental motion, and avoids an obstacle. After avoiding the obstacle, the robot moves in a direction that includes a pushing direction.
- If "Monit Push Dir Depth Sw" is ON and even if "Start" is not designated, if "Motion Start" is "after contact" and TCP moves and exceeds "End Depth" in pushing direction without contact, this function issues an alarm and stops the robot.
- The following functions cannot be used together:
    - "Deact. Push. Dir. Motion" function
    - "Successive Execution of Force Control Instructions (Customization Function) "
    - "Chk Push Chg Trav Vel" function
    - "Monit Min Push F" function
    - "2 Direction Push"

As an application of the "Monit Push Dir Depth" function, example TP Programs are shown in Fig. 1.5.5.6 (l), Fig. 1.5.5.6 (m).

Motion:

Grind to a target surface of a work-piece with a reciprocating motion based on taught points, "Max Depth Per Path" and "End Depth"



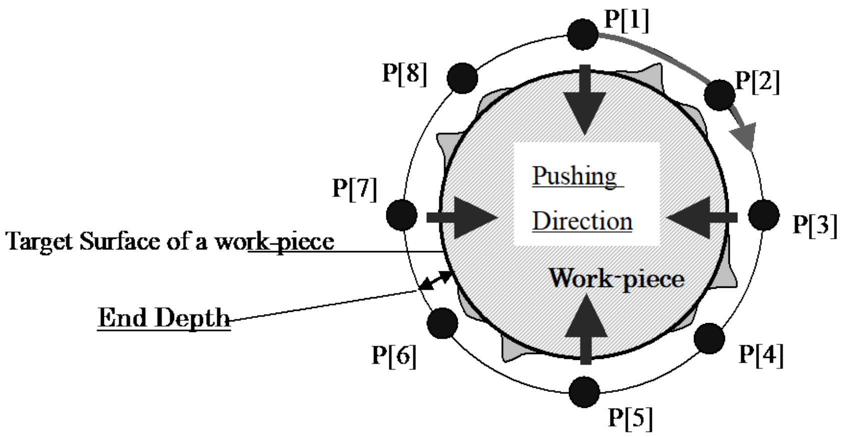
Monit Motion Input Reg No: 1
Monit Motion Output Reg No: 2

```
 9: L P[1] 500mm/sec FINE ;
10:   !***Start Contouring***;
11:   FORCE CTRL[1: Start Contouring] : ErrorLBL[0] ;// Start Contouring
12:   !***Move from P[1] to P[2]***;
13:   LBL[1] ;
14:   R[1:Motion Input]=1 ;                 // Start the monitoring depth action
15:L P[2] 50mm/sec FINE ;
16:   R [2:Result Output]=0 ;               // Set R[ ], to which result is output, to 0
17:   R[1: Motion Input]=2 ;                // Judge depth and output the result and
                                            // continue the monitoring depth action.
                                            // Increment the repeat counter
18:   WAIT R[2:Result Output]<>0 ;          // Wait until the result is output to R[ ]
19:   IF R[2:Result Output]=1,JMP LBL[2]    // If the result is OK, finish "Contouring"
20:   !*** Move from P[2] to P[1]***;
21:   R[1:Motion Input]=1 ;                 // Start the monitoring depth action
22:L P[1] 50mm/sec FINE ;
23:   R[2:Result Output]=0 ;                // Set R[ ], to which result is output, to 0
24:   R[1:Motion Input]=2 ;                 // Judge depth and output the result and
                                            // continue the monitoring depth action.
                                            // Increment the repeat counter
25:   WAIT R[2:Result Output]<>0 ;          // Wait until the result is output to R[ ]
26:   IF R[2:Result Output]=1,JMP LBL[2] ;  // If the result is OK, finish "Contouring"
27:   IF R[2:Result Output]=2,JMP LBL[1] ;  // If the result is NG, repeat again
28:   !*** End Contouring ***;
29:   LBL[2] ;
30:   FORCE CTRL[2: Contouring End] : ErrorLBL[0] ;// Contouring End
```

Fig. 1.5.5.6 (l) Example TP Program 1 of "Monit Push Dir Depth" function: Grind with reciprocating motion

Motion:

Grind to a target surface of a work-piece with a going around motion based on taught points, "Max Depth Per Path" and "End Depth"



Monit Motion Input Reg No : 1
Monit Motion Output Reg No : 2

```
15:L P[1] 100mm/sec FINE ;
16:     !*** Start Contouring ***;
17:   FORCE CTRL[1: Start Contouring] : ErrorLBL[0] ;// Start Contouring
18:     !*** Go around a work-piece from P[1] to P[1]***;
19:   LBL[1] ;
20:   R[1: Monit Input]=1 ;                  // Start the monitoring depth action
21:C P[2]
   :   P[3] 50mm/sec CNT100 ;
22:C P[4]
   :   P[5] 50mm/sec CNT100 ;
22:C P[6]
   :   P[7] 50mm/sec CNT100 ;
22:C P[8]
   :   P[1] 50mm/sec FINE ;
23:   R[2: Result Output]=0 ;                // Set R[ ], to which result is output, to 0
24:   R[1: Monit Input]=2 ;                  // Judge depth and output the result and
                                             // continue the monitoring depth action.
                                             // Increment the repeat counter
25:   WAIT R[2: Result Output]<>0 ;          // Wait until the result is output to R[ ]
26:   IF R[2: Result Output]=1,JMP LBL[2] ;  // If the result is OK, finish "Contouring"
27:   JMP LBL[1] ;
28:   !*** End Contouring ***;
29:   LBL[2] ;
30:   FORCE CTRL[2: Contouring End] : ErrorLBL[0] ;// Contouring End
```

Fig. 1.5.5.6 (m) Example TP Program 2 of "Monit Push Dir Depth" function: Grind with going around motion

Table 1.5.5.6 (f) [Performance data setting] screen (3/3)

Item	Description
Signal Output for ERR SW	This parameter enables the "Signal Output for ERR" function. This can be set to 'On' or 'Off'. If it is "On", the specified signal is output when an error occurs during execution of force control. "Default : OFF"
Output Signal Type (Signal Output for ERR)	Select the type of signal to output when an error occurs during execution of force control with the error signal output function. "DO", "RO", "FLAG" are available for the kind of a signal. "Default : DO"
Output Signal Number (Signal Output for ERR)	Select the number of signal to output when an error occurs during execution of force control with the error signal output function. "Default : 0"
2 Direction Push	This switch is for the function that pushes in the second direction, which differs from [Pushing Direction] on the [Basic Data Settings] screen. If a setting of other function of contouring function uses the second direction, enable this function and set parameters of this function. "Default : OFF"
Pushing Direction 2 (2 Direction Push)	This parameter specifies a direction as the second pushing direction in which the "2 Direction Push" function pushes. Select an axis value that differs from [Pushing Direction] on the [Basic Data Settings] screen. Select [+X], [-X], [+Y], [-Y], [+Z], or [-Z]. If "Pushing Dir Auto Chg" in "Performance data" is valid, • set "Pushing Direction 2" to ±Z. • the pushing direction designated by "Pushing Direction 2" is not changed automatically while contouring. "Default : − Z"
Contouring Force 2 (2 Direction Push)	Enter the target pushing force when performing the pushing operation in the second pushing direction. The target pushing force is changed if "the function of changing target pushing force during a contouring" is used. (Refer to "Basic Function Guide: 1.5.5.7 Other functions of the contouring function".) "Default : 10.00 N"
Approach Velocity 2 (2 Direction Push)	Enter the target operation velocity for the second direction until contact is made with the target. "Default : 0.00 mm/ s" ⚠ **CAUTION** Increasing the value in [Approach Velocity 2] reduces the time it takes until contact is made, but a large force than the set value will be applied the instant that contact is made, which may cut too much material.
Pushing Dir. Vel. 2 (2 Direction Push)	This parameter specifies speed in the second pushing direction after a contact is made. Usually, 0.00 may be specified. Normally enter "0.00". Enter a value between about "1" mm/s to "10" mm/s if the workpiece and tool separate during contouring. "Default : 0.00 mm/ s"
Push Dist. Limit Individual (2 Direction Push)	"2 Direction Push" function monitors whether the deviation from the taught path in X, Y, Z direction of the used control frame is within upper limit individually. During a contouring, the path that robot moves actually is different from the taught path. Switch monitoring of the offset distance between "On" and "Off". If it is "On", enter the maximum allowed value when monitoring for each direction. If the deviation exceeds the upper limit in the direction that the monitoring is valid, the robot stops with an alarm. "Defaults : X : OFF, Y : OFF, Z : OFF" ("Default of Monitoring Sw") "Defaults : X : 10.0, Y : 10.0, Z : 10.0" ("Unit : mm")

Item	Description
Face Match	Perform the operation below to switch to the [Contour/FaceMatch] screen. • Move the cursor to [Setting], and press the [Input] key on the teach pendant of the robot controller. The [Contour/FaceMatch] screen is displayed. The following is displayed after configuring the face match function for "Contouring" on the [Contour/FaceMatch] screen. • OFF : The "Face Match" function of "Contouring" is disabled. • ON : The "Face Match" function of "Contouring" is enabled. • [Face Match] is not displayed for robots other than the LRMate200iD series, M-10iA series, M-10iD series, CR-7iA series, CR-14iA/L, CR-15iA, CR-35iA, CRX series, M-20iA series, M-20iB series, M-20iD series, M-710iC/20L, and the 3-axis force sensor. (Refer to the description of [Contour/FaceMatch] screen below.)
Auto.Follow	Perform the operation below to switch to the [Contour/AutoFollow] screen. • Move the cursor to [Setting], and press the [Input] key on the teach pendant of the robot controller. The [Contour/AutoFollow] screen is displayed. The following is displayed after configuring the auto contouring function for "Contouring" on the [Contour/AutoFollow] screen. • OFF : The "Auto.Follow" function of "Contouring" is disabled. • ON : The "Auto.Follow" function of "Contouring" is enabled. • [Auto Follow] is not displayed for robots other than the LRMate200iD series, M-10iA series, M-10iD series, CR-7iA series, CR-14iA/L, CR-15iA, and CRX series. (Refer to the description of [Contour/AutoFollow] screen below.)
TPProgramAuto.Gen.Sw.	This item is a switch of the function for automatically generating a TP Program after the execution of contouring. This can be set to 'On' or 'Off'. In contrast to the "TP Program auto generation" function, to be executed with KAREL, as described in "Auxiliary Function Guide: 2 TP PROGRAM AUTO GENERATION FUNCTION", this function is called the "contouring TP Program auto generation" function. (Refer to "Auxiliary Function Guide: 2 TP PROGRAM AUTO GENERATION FUNCTION".) When "TPProgramAuto.Gen.Sw." is "ON", a TP Program is generated if contouring operation is ended after contact during the contouring operation (after the generated force exceeds "Contact F Threshold"). No TP Program is generated if contouring operation is ended before contact. A TP Program is generated if contouring operation is ended after contact, regardless of whether the operation ends normally or abnormally. Perform the operation below to switch to the screen for configuring the "TP Program auto generation" function. • Move the cursor to [TPProgramAuto.Gen.Sw.], and press F2 [Group]. The screen for configuring the "TP Program auto generation" function is displayed. "Default : OFF" ⚠ **CAUTION** When moving the robot using a TP program generated with [TPProgramAuto.Gen.Sw.], the path that is moved may differ from the actual path that the robot takes. Make sure to confirm the position of the generated TP program before execution.

Item	Description
TPProgramAuto.Gen. Param.No (TP Program Auto Generation)	Enter the number of the TP program auto generate parameter used by the "TP Program auto generation" function for "Contouring" for generating a TP program. The contouring TP Program auto generation function generates a TP Program in accordance with the parameter that is set in TPProgramAuto.Gen.Param.No. specified with this parameter. Perform the operation below to switch to the screen for configuring the "TP Program auto generation" function. • Move the cursor to [TPProgramAuto.Gen.Param.No.], and press F6 [SET]. The screen for configuring the "TP Program auto generation" function is displayed. "Default : 0"
Pos.Acquisition.Cond (TP Program Auto Generation)	Select the conditions for retrieving the position used as the basis for generating the TP program by the "TP Program auto generation" function for "Contouring". The TP program is generated as indicated below. • "Aftr.Aprch." : Positions during contouring after approach are acquired. Based on these positions, a TP Program is generated. • "Contact" : When a force exceeds "Contact F Threshold" during a contouring, the positions are acquired. Based on these positions, a TP Program is generated. • "All" : All positions during contouring are acquired. Based on these positions, a TP Program is generated. If "Auto.Follow Sw." is "ON", and the setting is "Aftr.Aprch.", the positions at the time of contact after approach are acquired. Perform the operation below to switch to the screen for configuring the "TP Program auto generation" function. • Move the cursor to [Pos.Acquisition.Cond] and press F2 [GROUP]. The screen for configuring the "TP Program Auto Generate" function is displayed. "Default : Aftr.Aprch."
G F S	G represents a motion group number at the time of teaching. F represents a force control number. S represents a force sensor number. (These settings cannot be changed.) "Defaults : G F S : 1 1 1"

NOTE

1 The following restrictions apply to [2 Direction Push].
- If "Pushing Dir Auto Chg" in "Performance data" is valid,
  - set "Pushing Direction 2" to ±Z
  - a pushing direction designated by "Pushing Direction 2" is not changed automatically while contouring
- The following functions cannot be used together:
  - "Monit Push Dir Depth" function
  - Changing a target pushing direction before or during a contouring is prohibited.
    (Refer to "Basic Function Guide: 1.5.5.7 (2), "The function of changing a target pushing direction during a contouring".)

2 The following restrictions apply to [TPProgramAuto.Gen.Sw.].
- A TP Program is generated based on the parameter specified with "TPProgramAuto.Gen.Param.No.".
  Set also the parameter specified with "TPProgramAuto.Gen.Param.No.".
  (Refer to "Auxiliary Function Guide: 2, "TP PROGRAM AUTO GENERATION FUNCTION".)
- A TP Program is generated with the user frame and the tool frame that are set in "User Frame No." and "Tool Frame No." in the Basic data.
- When a TP Program is generated, the parameter settings and the acquired positions are output with the specified "DT File" name that is set in the parameter specified with "TPProgramAuto.Gen.Param.No.".
- Velocity adjustment cannot be performed while executing "Auto Contouring".
  (For other cautions when generating a TP program using the "TP Program auto generation" function, refer to "Auxiliary Function Guide: 2 TP PROGRAM AUTO GENERATION FUNCTION".)
- The positions acquired with the "contouring TP Program auto generation" function cannot be used with the "TP Program auto generation" function.
- The "contouring TP Program auto generation" function does not support the following items of the "TP Program auto generation" function:
  - "Auxiliary Function Guide: 2.3 REGENERATING TP PROGRAM WITH MODIFIED PARAMETERS"
- During the execution of the force control instruction "Contouring", do not change the parameter specified with "TPProgramAuto.Gen.Param.No.".

[Contour/FaceMatch] screen

The settings on the [Contour/FaceMatch] screen are indicated below.

NOTE

The [Contour/FaceMatch] screen is not displayed for robots other than the LRMate200iD series, M-10iA series, M-10iD series, CR-7iA series, CR-14iA/L, CR-15iA, CR-35iA, CRX series, M-20iA series, M-20iB series, M-20iD series, M-710iC/20L, and the 3-axis force sensor.

Table 1.5.5.6 (g) [Contour/ FaceMatch] screen

Item	Description
Function	A desired function is selected from "Function selection screen". Select this to change the function to another function.

Item	Description
Comment	Enter a comment for identifying the schedule data. Maximum number of characters: 16 characters.
Face Match Sw.	This item is a switch of the function for performing face match in the specified direction when the contouring function is executed. This can be set to 'On' or 'Off'. When this switch is "ON", face match operation is performed in the specified direction. "Default : OFF"
FaceMatchDir	This switch is for the function that performs face matching in each direction when the contouring function is executing. This can be set to 'On' or 'Off'. The directions that can be set are displayed. Face matching is executed for each direction if "On" is set. Face matching is not executed if "Off" is set. "Defaults : W : OFF, P : OFF"
Dist.Of ContactP. from Axis	Enter the maximum expected length from the rotary axis to the contact area for each face matching direction. In [Dist.Of ContactP. from Axis], enter the maximum length for each direction from the area where the objects to perform face matching for are first expected to make contact to each rotary axis. By setting "Dist.Of ContactP. from Axis" appropriately, it may be possible to perform face match operation faster and more stably. "Defaults : W : 0.00, P : 0.00 mm"
FaceMatch Max Rotation Velocity	Enter the maximum rotation speed (deg/sec) for each face matching direction. The rotation velocity during face match operation is adjusted by using this value as an upper limit. If "FaceMatch Max Rotation Velocity" is large, the impact at the time of contact may be large, and the posture may vary frequently during face match operation. In such a case, adjust the value of "FaceMatch Max Rotation Velocity" according to the situation. "Defaults : W : 1.0, P : 1.0 deg/ s"
AftrCntct FaceMtch UpperLim Time	If [Motion Start] is set to [after contact] on the [Performance Data Settings] screen, enter the maximum time for face matching after contact is made (after the force exceeds [Contact F Threshold]). The contouring operation is started even within the upper limit time specified here, when face match is completed. An example of use is to set "Motion Start" to "after contact" and "AftrCntct FaceMtch UpperLim Time" to an appropriate value, execute the force control "Contouring" instruction, and immediately after that, execute force control "Contouring end". In this way, only face match operation can be executed. "Default : 20.0 sec"
Orientation Chg. Chk. Sw	This item is a switch of the function for checking for posture changes against the teach posture during a contouring. This can be set to 'On' or 'Off'. When the item is "ON", a check is made for posture changes. When a check is made for posture changes, an alarm is issued and the contouring operation is stopped when the posture changes beyond the value that is set in "Orient.Chg. UpperLim" against the teach posture during the contouring operation. "Default : ON"
Orient.Chg. UpperLim (Orientation Chg. Chk.)	Enter the maximum value to allow when checking the orientation change. When "Orientation Chg. Chk. Sw" is "ON", an alarm is issued and the contouring operation is stopped if the posture changes beyond this upper limit value [deg] against the teach posture during the contouring operation. Set a value greater than the posture movement amount to be moved with face match. "Default : 30.0 deg"
G F S	G represents a motion group number at the time of teaching. F represents a force control number. S represents a force sensor number. "Defaults : G F S : 1 1 1"

NOTE

1 The following restrictions apply to [Face Match Sw.].
- As with other contouring functions, set the mass and the center of gravity of

the object mounted to the force sensor, and enable the "gravity compensation" function.

- Set "Pushing Dir. Velocity" in the Performance data to such a large value that does not cause the robot to oscillate (about 10 to 20 mm/sec). By setting "Pushing Dir. Velocity" in the Performance data to such a large value that does not cause the robot to oscillate, it may be possible to perform face match operation faster and more stably.
- The posture does not change until contact is judged to have been made based on "Contact F Threshold" in the Basic data.
- TCP, which is the origin of the tool frame specified with "Tool Frame No." in the Basic data, becomes the rotation center point of face match operation. Set the tool frame number and the tool frame so that the rotation center point can be the point described below. There are cases in which TCP needs only to be on a plane containing the portion subject to face match.
  - Point where the moment around the rotation center point is balanced when face match is performed.
  - Geometric center point of the portion subject to face match.
- If wishing to adjust force control operation in each rotation direction, adjust "Indivi-Freq.", "FaceMatch Max Rotation Velocity", and other items in "Force Control Gain" in the Basic data.
- As with other force control functions, do not start force control in the contact state. To start force control in the contact state, use the function concurrently with the "Simple Customize" function or the "Customize" function in the Performance data.
- Prohibition on concurrent use : It is prohibited to use this function concurrently with the following robots, force sensors, and functions.
  - Robots other than the LRMate200iD series, M-10iA series, M-10iD series, CR-7iA series, CR-14iA/L, CR-15iA, CR-35iA, CRX series, M-20iA series, M-20iB series, M-20iD series, M-710iC/20L, and the 3-axis force sensor
  - 3-axis force sensor (FS-15*i*Ae)
  - Basic data:
    "Control Frame", set to "User Frm Fixed"
  - Performance data:
    "Change Push. Force Sw."
    "Pushing Dir Auto Chg"
    "Monit Push Dir Depth Sw"
    "Auto.Follow Sw."
    "The function of changing a target pushing direction during a contouring"
    "The function of changing a contact point during a contouring
    (In the case of 3-axis force sensor)"

2 The following face matching directions can be set for [FaceMatchDir].
- If "Pushing Dir." in the Basic data is ±X : "P", "R"
- If "Pushing Dir." in the Basic data is ±Y : "W", "R"
- If "Pushing Dir." in the Basic data is ±Z : "W", "P".

3 The following directions for face matching can be set for [Dist.Of ContactP. from Axis].
- If "Pushing Dir." in the Basic data is ±X:"P", "R"
- If "Pushing Dir." in the Basic data is ±Y:"W", "R"
- If "Pushing Dir." in the Basic data is ±Z:"W", "P"

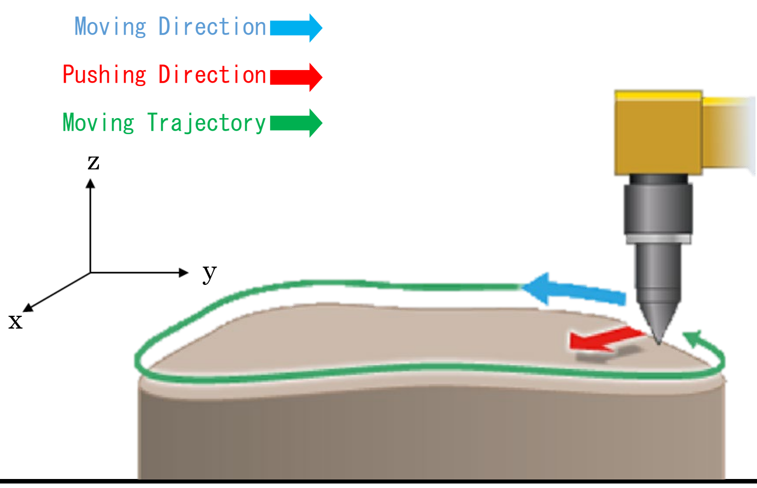
[Contour/AutoFollow] screen

The settings on the [Contour/AutoFollow] screen are indicated below.

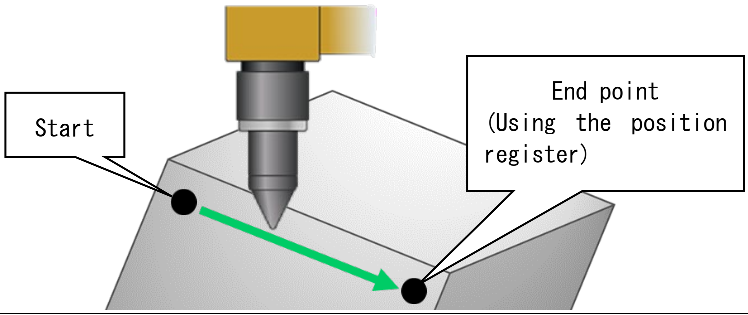
> ⚠**CAUTION**
> When setting or executing the [Auto.Follow Sw.], pay attention to the following points.
> - During the execution of the "Auto.Follow" function, the robot follows automatically a shape of a workpiece and guide member, etc. Be sure to use this function by paying attention to the movement and operation of the robot while checking the situation around the robot system.
> - As with other force control functions, do not start force control in the contact state. To start force control in the contact state, use the function concurrently with the "Simple Customize" function.

> **NOTE**
> The [Contour/AutoFollow] screen is not displayed for robots other than the LRMate200iD series, M-10iA series, M-10iD series, CR-7iA series, CR-14iA/L, CR-15iA, and CRX series.

Table 1.5.5.6 (h) [Contour/ AutoFollow] screen

Item	Description
Function	A desired function is selected from "Function selection screen". Select this to change the function to another function.
Comment	Enter a comment for identifying the schedule data. Maximum number of characters: 16 characters.
Auto.Follow Sw.	This item is a switch of the function for automatic contouring. Select "Off" or "UserFrame X-Y". When this switch is "UserFrame X – Y", the function is enabled, so that another object such as a workpiece is automatically contoured on the X – Y plane where the +Z direction is set to be an upward direction. When the "Contouring" force control statement is executed, the robot moves in the approach direction and automatically performs pushing, moving away, and contouring on other target after contact is made (when the force exceeds [Contact F Threshold]). By using this function concurrently with "contouring TP Program auto generation", a shape of a workpiece and guide member, etc. can be automatically contoured, and a TP Program for moving along the shape can be generated. "Default : OFF" 

Item	Description
Travel.Dir. to Push.Dir.	This parameter sets the relation of the traveling direction to the pushing direction. Switch between "LeftDir" and "RightDir". • "LeftDir" : The left direction in relation to the approach direction and the pushing direction, i.e., the direction resulting from rotating by +90 [deg] about the +Z axis in relation to the approach direction and the pushing direction on the preset user frame is regarded as the traveling direction. • "RightDir" : The right direction in relation to the approach direction and the pushing direction, i.e., the direction resulting from rotating by -90 [deg] about the +Z axis in relation to the approach direction and the pushing direction on the preset user frame is regarded as the traveling direction. "Default : LeftDir "
Move UpperLim.	Enter the three types of limits in [Move UpperLim]. If one of the three upper limits is reached during a contouring, the operation is assumed to end abnormally, and is stopped after an alarm is issued. As for the upper limit specified with "NrmlEnd for MoveUpperLim", described later, the operation ends normally if the upper limit is reached.
Dist.From Strt.CtP (Move UpperLim.)	This is the first upper limit of Move UpperLim. Enter the maximum distance (mm) from the position where contact is judged to have been made (where the force exceeds [Contact F Threshold]). "Default : 100.0 mm"
Total Move Dist. (Move UpperLim.)	This is the second upper limit of Move UpperLim. Enter the maximum total move distance (mm) along the contouring object with the position where contact is judged to have been made (where the force exceeds [Contact F Threshold]) as the start position. An example of use is to set "NrmlEnd for MoveUpperLim" so that a normal end occurs if this upper limit is reached. In this way, the robot can be moved along a shape of a workpiece by the specified distance and be ended. "Default : 100.0 mm"
Total Move Time (Move UpperLim.)	This is the third upper limit of Move UpperLim. Enter the maximum elapsed time (sec) from the time where contact is judged to have been made (when the force exceeds [Contact F Threshold]). "Default : 20.0 sec"
End Pos. Designate	Set this item to end the force control instruction "Contouring" normally when the position during contouring operation reaches a designated position. Select "None", "Around", or "Pos.Reg.". • "None" : The position where the operation ends normally is not designated. • "Around" : The operation ends normally when the robot moves away from the position where the first contact is judged to have been made (the generated force exceeds "Contact F Threshold") and returns to the position where the first contact is made. • "Pos.Reg." : The operation ends normally when the X and Y position during contouring operation reaches the position that is set in the position register designated with "Pos.Reg. No.", described later. If the Z position is different, auto following is performed up to the Z position of the end position while changing linearly. "Default : None

<table>
<tr><th>Item</th><th>Description</th></tr>
<tr><td>Pos.Reg. No.
(End Pos. Designate)</td><td>When [End Pos. Designate] is set to [Pos.Reg.], enter the position register number to use for exiting when the position set in the specified position register is reached.
Enter the position to use for exiting in the specified position register.
Enter the position of the user frame or tool frame specified in [UFrame Number] or [UTool Number] on the [Basic Data Settings] screen in the specified position register.
"Default : 0"
NOTE
When the force control instruction "Contouring" is executed, the end position is set based on the values that are set for the X and Y of the designated position register. If the value set for "Z" in the specified position register is different from the starting position "Z" value, it is adjusted linearly during auto following so that the operation ends at the value set for "Z" in the specified position register. Even if the value of the designated position register is changed after the execution of the force control instruction "Contouring", the change is not reflected.

</td></tr>
<tr><td>In Position Thres.
(End Pos. Designate)</td><td>If something other than [None] is selected for [End Pos. Designate], enter the threshold value for judging whether the specified position has been reached.
If the setting is 0 mm, a value of about 2 mm is internally used as the threshold value. When the robot moves away by the value of "In Position Thres." after approaching the designated position, the force control instruction "Contouring" is ended.
"Default : 0.0 mm"
NOTE
If the specified value is small, it may happen that the robot is not regarded as having entered the preset range during movement, so that the instruction is not ended even if the robot appears to have reached around the designated position.</td></tr>
<tr><td>Aprch.Dir.Ang
InptNumReg No.</td><td>Enter the register number to use when setting the approach direction to move in when "Auto Contouring" is started.
If the setting is 0, "Pushing Dir." in the Basic data is the approach direction. When the force control instruction "Contouring" is executed, the approach direction is set with the value that is set in the designated Numeric Register. In the designated Numeric Register, set the angle [deg] from the +X direction about the +Z-axis.
"Default : 0"</td></tr>
</table>

Item	Description
NrmlEnd for MoveUpperLim	This item is the setting for assuming that the operation ends normally, not abnormally, if the movement upper limit is reached. Select the first ([Dist.From Strt.CtP]), second ([Total Move Dist.]), or third ([Total Move Time]) motion limit as the limit to reach for exiting without an error. • "None" : The operation is assumed to end abnormally if any of the movement upper limits is reached. • "1" : If the first movement upper limit is reached, and the distance from the first contact position to the position during contouring operation exceeds the upper limit value, the operation is assumed to end normally, not abnormally. • "2" : If the second movement upper limit is reached, and the total movement distance along the object to contour, with the first contact position as the start position, exceeds the upper limit value, the operation is assumed to end normally, not abnormally. • "3" : If the third movement upper limit is reached, and the time that passes from the time of the first contact (the generated force exceeds "Contact F Threshold") exceeds the upper limit value, the operation is assumed to end normally, not abnormally. • "1, 2" : If the movement upper limit reached during contouring operation is the first or second movement upper limit, the operation is assumed to end normally, not abnormally. • "2, 3" : If the movement upper limit reached during contouring operation is the second or third movement upper limit, the operation is assumed to end normally, not abnormally. • "1, 3" : If the movement upper limit reached during contouring operation is the first or third movement upper limit, the operation is assumed to end normally, not abnormally. • "1, 2, 3: : If any one of the movement upper limits is reached during contouring operation, the operation is assumed to end normally, not abnormally. "Default : None "
End by Num.Reg	This item is a switch for the function that ends the force control instruction "Contouring" normally, by using a Numeric Register. This can be set to 'On' or 'Off'. If "Auto.Follow Sw." is "ON" and "End by Num.Reg" is also "ON", the force control instruction "Contouring" can be ended normally by using a Numeric Register. When the force control instruction "Contouring" is started, the designated Numeric Register is set to a value of 0. Then, if the designated Numeric Register is set to a value of 1, the force control instruction "Contouring" is ended normally. "Default : OFF"
End Num.Reg. No. (End by Num.Reg)	Enter the register number to use when exiting the "Contouring" force control statement without an error. "Default : 0"
G F S	G represents a motion group number at the time of teaching. F represents a force control number. S represents a force sensor number. (These settings cannot be changed.) "Defaults : G F S : 1 1 1"

NOTE

1 The following restrictions apply to [Contour/AutoFollow].
- If "Approach Velocity" in the Basic data is set to a value greater than 10 mm/sec, it is internally set to 10 mm/sec.
- When "Aprch.Dir.Ang InptNumReg No." is 0, set "Pushing Dir." in the Basic data to ±X and ±Y.
- Depending on the shape of the object to contour or the object mounted to the force sensor, contouring may not be performed properly.

- Items to set :
  Set the following items.
  - Basic data :
    "Pushing Dir." (if not using "Aprch.Dir.Ang InptNumReg No.")
    "Approach Velocity". If "Approach Velocity" is 0 mm/sec, the internal value is used.
    Set "Control Frame" to "user frame".
    "User Frame No."
    "Tool Frame No."
    "Force Control Gain". Set it with "Master Frequency", so that the X and Y values of "Indivi-Freq." become the same.
  - Performance data :
    "Force Limit"
    "Force Change Limit"
    [Auto Contouring] Settings

* The Auto.Follow function has multiple functions that are prohibited from being used concurrently with it. It is preferable to create a new schedule data and set only the necessary items.

- Functions that can be used concurrently with this function :
  It is possible to use this function concurrently with the following functions.

- Performance data :
  "Simple Customize Sw"
  "Force Denoising Sw"
  "Signal Output for ERR SW"
  "TPProgramAuto.Gen.Sw."

- Functions prohibited from concurrent use :
  It is prohibited to use this function concurrently with the following robots and functions.
  - Robots other than the LRMate200iD series, M-10iA series, M-10iD series, CR-7iA series, CR-14iA/L, CR-15iA, and CRX series.
  - Basic data :
    "Control Frame", set to "Tool Frame" or "User Frm Fixed"
  - Performance data :
    "Customize Parent Number", set to a value other than 0
    "User Frame Compensation"
    "Chk Overload Chg Trav Vel Sw"
    "Overload F. Detect Sw."
    "Deact.PushDirMotion Sw"
    "Change Push. Force Sw."
    "Pushing Dir Auto Chg"
    "Chk Push Chg Trav Vel Sw"
    "Monit Min Push F Sw"
    "Monit Push Dir Depth Sw"
    "2 Direction Push"
    "Face Match"
  - "The function of changing target pushing force during a contouring"
  - "The function of changing a target pushing direction during a contouring"
  - "The function of changing a contact point during a contouring (In the case of 3-axis force sensor)"
  - "The function of changing the force control gain during contouring"

- Settings ignored :
  The following function settings are not reflected.
  - Basic data :
    "Contact F Threshold"
    "Contouring Force"
    "Push Dist. Limit"
  - Performance data :
    "Pushing Dir. Velocity"
    "Motion Start"
- If an operation such as the following is performed, it ends abnormally.
  - If not in AUTO mode, releasing the SHIFT button or releasing the deadman switch during contouring operation.
  - Pressing the HOLD button during contouring.
- If "TPProgramAuto.Gen.Sw." is "ON", even if an abnormal end such as the ones below occurs, a TP Program is generated even after contact (after the generated force exceeds "Contact F Threshold"), provided that contact is judged to have been made.
- If the following operations are performed, they end normally.
  - Operation that ends at the end position designated with "End Pos. Designate".
  - Operation that reaches the upper limit for the item that is set in Move UpperLim. and for which the upper limit is specified with "NrmlEnd for MoveUpperLim".
  - Operation for which the "End by Num.Reg" is "ON" and the designated Numeric Register is turned ON during a contouring.

2 The following restrictions apply to [Aprch.Dir.Ang InptNumReg No.].
- When "Aprch.Dir.Ang InptNumReg No." is 0, set "Pushing Dir." in the Basic data to ±X and ±Y.
- The Numeric Register value must be – 360 or greater and 360 or less.
- Even if the value of the designated Numeric Register is changed after the execution of the force control instruction "Contouring", the change is not reflected.

Function keys

The function keys indicated have the following functions:

Table 1.5.5.6 (i) Function keys

Key	Item	Description
F1	TYPE	Allows you to change the display to a menu other than the force control menu.
F2	GROUP	Allows you to change motion groups.
	HELP	Display the help screen.
F3	NUMBER	Allows you to display the screen for another schedule number.
F4	CHOICE	Displays the choices for the setting.
	ON	Changes the setting to 'On'.
Shift + F4	DEFAULT	Allows you to set default data of the force control function.
F5	PERFORM / BASIC	Allows you to switch between the basic and performance screens.
	OFF	Changes the setting to 'Off'.
F6	SET	Allows you to display the screen for configuring the "TP Program auto generation" function.

Parameters for "Contouring End"

The screen for "Contouring End" is shown below. However, no information other than a comment needs to be set.

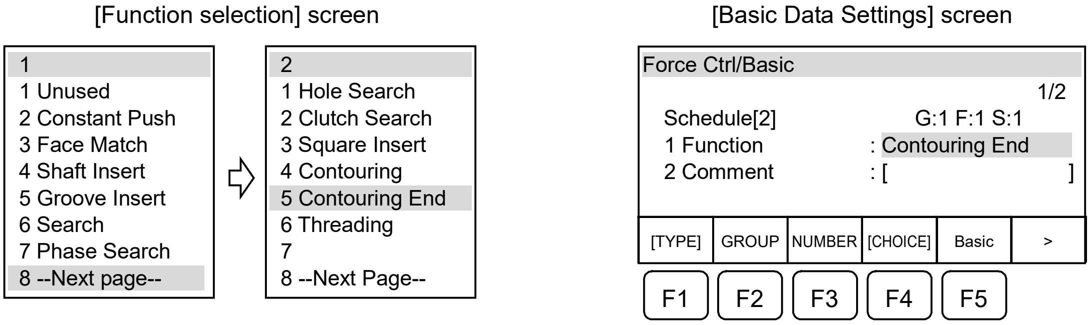


Fig. 1.5.5.6 (n) Screen for "Contouring End"

Function keys

The function keys indicated have the following functions:

Table 1.5.5.6 (j) Function keys

Key	Item	Description
F1	TYPE	Allows you to change the display to a menu other than the force control menu.
F2	GROUP	Allows you to change motion groups.
F3	NUMBER	Allows you to display the screen for another schedule number.
F4	CHOICE	Displays the choices for the setting.

1.5.5.7 Other functions of the contouring function

The following functions are explained in this part.

(1) The function of changing target pushing force during a contouring
(2) The function of changing a target pushing direction during a contouring
(3) The function of changing a contact point during a contouring (In the case of 3-axis force sensor)
(4) The function of changing the force control gain during contouring
(5) The function of returning the pushing force, pushing direction, contact point, and force control gain to their settings in the Basic data

(1) The function of changing target pushing force during a contouring

This function enables to change contouring force during a contouring.
Normally, the target pushing force is determined according to [Pushing Force] on the [Basic Data Settings] screen and [Pushing Force 2] on the [Performance Data Settings] screen, and does not change while that schedule is being executed. This function enables the target pushing force to be changed during an operation.
When target force needs to be changed during the contouring, this function is useful.

How to change pushing force

- Insert a call of the KAREL program FCNCHPFN into a TP Program. By executing the KAREL Program, target pushing force can be changed during a contouring.

- The FCNCHPF can be executed before the start of a "Contouring" instruction. But to prevent unexpected change, the FCNCHPF should be executed during contouring.
  When the FCNCHPF is executed before the start of a "Contouring" instruction, the change of target pushing force is applied after the "Contouring" instruction starts. However, if multiple KAREL Programs of FCNCHPF, and after-mentioned FCNCHCFR, FCNCH3CTP and FCNCHOFF are executed before the "Contouring" instruction, only the last executed KAREL Program before the "Contouring" instruction has effect.
  (For information on FCNCHCFR, see "The function of changing a target pushing direction during a contouring". For information on FCNCH3CTP, see "The function of changing a contact point during a contouring (In the case of 3-axis force sensor)". For information on FCNCHOFF, see "The function of returning the pushing force, pushing direction, contact point, and force control gain to their settings in the Basic data".

> **NOTE**
> 1 In order to prevent unexpected changes, execute FCNCHPF during contouring rather than before executing the "Contouring" statement, unless necessary. (The FCNCHPFN, FCNCHCFR, FCNCH3CTP, and FCNCHOFF executed during contouring are reflected when executed.
> 2 The FCNCHPFN setting is automatically reset when the "Contouring" statement exits or when the "Contouring end" statement is executed. (The basic data settings are restored.) Executing FCNCHOFF before the FORCE statement is safe because it prevents unexpected changes. (For information on FCNCHOFF, see "The function of returning the pushing force, pushing direction, contact point, and force control gain to their settings in the Basic data ".)

Arguments of FCNCHPFN (ARG1, ARG2)

The settings of ARG1 are as follows.
Select to restore or change target-pushing force.

Table 1.5.5.7 (a) Changing the Pushing Force with Argument 1 and 2

Setting of ARG1	Description
If ARG1 equals to 0	Restore the target pushing force to settings of the "Contouring Force" in a "Basic data" and the "Contouring Force 2" in a "Performance data". If ARG1 equals to 0, ARG2 is not need to be set.
If ARG1 equals to 1	Change a target pushing force to a designated value in "Pushing Direction" in a "Basic data".
If ARG1 equals to 2	Change a target pushing force to a designated value in "Pushing Direction 2" in a "Performance data". If ARG1 equals to 2, "2 Direction Push" in a "Performance data" must be valid.

Specify the pushing force with ARG2 when changing the target pushing force. The ARG2 unit is N.

> **NOTE**
> 1 ARG1, ARG2 can take Numeric Register.
> 2 The ARG2 unit is N.

Example Setting of FCNCHPFN Arguments

An example of configuring the FCNCHPFN arguments is indicated below.

Table 1.5.5.7 (b) Example Setting of FCNCHPFN Arguments

Example Setting	Description
In case of restoring a setting to a setting of a "Basic data".	FCNCHPFN (0)
In case of changing target pushing force to 30 N.	FCNCHPFN (1, 30)
In case of changing target pushing force to 30 N. ("2 Direction Push" in a "Performance data" is valid.)	FCNCHPFN (2, 30)

Example TP Program

An example TP program for changing the pushing force during motion is indicated below.
The FCNCHPFN is called at the Motion instruction in the 4th line. Target pushing force in the direction designated by "Pushing Direction" in the "Basic data" is changed to 30 N at P[3] independent of the "Contouring Force" of the "Basic data".

```
 1:L   P[1: Start] 50mm/sec FINE
 2:   FORCE CTRL[1: Contouring Start]
   :   ErrorLBL[0]
 3:L   P[2] 100mm/sec CNT100
 4:L   P[3] 100mm/sec CNT100
   :   TB       .20sec,
   :   CALL FCNCHPFN (1,30)
 5:L   P[4:END] 100mm/sec FINE
 6:   FORCE CTRL[2: Contouring End]
   :   ErrorLBL[0]
```

Fig. 1.5.5.7 (a) Example TP Program: Changing target pushing force

> **NOTE**
> The Time Before function is used in the 4th line in this example. When a moving velocity is large, an instantaneous stop occurs at P[3] sometimes without the Time Before function.

(2) The function of changing a target pushing direction during a contouring

This function enables to change a target pushing direction during a contouring by rotating and changing a control frame internally for force control.
In the explanation below, Pd represents the “Pushing direction” (±X or ±Y or ±Z value) set in the "Basic data" and Cf represents the "Control Frame" setting in the "Basic data". (the value is a "Tool Frame" or an "User Frame").
Normally setting the "Control Frame Cf" and the "Pushing Direction Pd" determines a target pushing direction during contouring and the target pushing direction cannot be changed during force control of the "schedule data". With this function, rotating and changing the control frame and calculating a new target pushing direction can change the target pushing direction.

> **NOTE**
> 1 The pushing direction that can be changed with this function is the direction specified in [Pushing Direction] on the [Basic Data Settings] screen.
> 2 The following functions cannot be used together:
> - 2 Direction Push
> - Successive Execution Of Force Control Instructions
>   (Refer to "Basic Function Guide: 1.7 SUCCESSIVE EXECUTION OF FORCE CONTROL INSTRUCTIONS (CUSTOMIZATION FUNCTION)".)

How to change a pushing direction

- Insert a call of the KAREL program FCNCHCFR into a TP Program. By executing the KAREL Program, a target pushing direction can be changed during contouring.
- The FCNCHCFR can be executed before the start of a "Contouring" instruction. But to prevent unexpected change, the FCNCHCFR should be executed during contouring.
  When the FCNCHCFR is executed before the start of a "Contouring" instruction, the change of a target pushing direction is applied after the start of the "Contouring" instruction. However, if multiple KAREL Programs of FCNCHPFN, FCNCHCFR, and after-mentioned FCNCH3CTP, FCNCHOFF are executed before the "Contouring" instruction, only the last executed KAREL Program before the "Contouring" instruction has effect.
  (For information on FCNCH3CTP, see "The function of changing a contact point during a contouring (In the case of 3-axis force sensor)". For information on FCNCHOFF, see "The function of returning the pushing force, pushing direction, contact point, and force control gain to their settings in the Basic data".

NOTE

1 In order to prevent unexpected changes, execute FCNCHCFR during contouring rather than before executing the "Contouring" statement, unless necessary. (The FCNCHPFN, FCNCHCFR, FCNCH3CTP, and FCNCHOFF executed during contouring are reflected when executed.

2 The pushing direction set with FCNCHCFR is reset automatically at the end process of "Contouring" instruction or "Contouring End" (the pushing direction returns to what is set in the "Basic data"). For the sake of safety it is recommended to execute after-mentioned FCNCHOFF before the "Contouring" instruction to prevent an unexpected change.
(For information on FCNCHOFF, see "The function of returning the pushing force, pushing direction, contact point, and force control gain to their settings in the Basic data ".)

Arguments of FCNCHCFR(ARG1, ARG2, ARG3)

- ARG1, ARG2:
  Setting for rotating a control frame. Which control frame to rotate is determined by ARG3.
- ARG3:
  Determine whether to use the "Control Frame Cf" or another frame as the control frame. Which control frame to rotate is also determined by this value.
- The methods for rotating the control frame to change a target pushing direction are three types of the following.
  - Moving the control frame the specified angle based on [Tool Frame] on the [Basic Data Settings] screen
  - Moving the control frame the specified angle based on [User Frame] on the [Basic Data Settings] screen
  - Rotate the control frame to orient a target pushing direction to the designated direction

  ARG1 determines the method to rotate the control frame.
  ARG2 determines to which direction or how much rotate the control frame.

The settings of ARG1, ARG2, and ARG3 are described in detail in Table 1.5.5.7 (c), Table 1.5.5.7 (d).

Table 1.5.5.7 (c) The rotating method of the control frame by ARG1 and ARG2 settings

Setting of ARG1	Description
If ARG1 equals to 0	• Restore a rotated and changed control frame to a setting of a "Basic data". (The type of the control frame, "Tool Frame" or "User Frame", is restored to the setting of the "Basic data") • ARG2 and ARG3 don't matter and are not necessary to be set.
If ARG1 equals to 1	• Rotate a control frame by designated W, P, and R degrees in a "Tool Frame" of a "Basic data". • Set a position register number to ARG2. And set angles of W, P, and R [deg] for rotating the control frame to the position register. Settings of X, Y, and Z don't matter and are not necessary to be set. • With ARG3 the control frame can be changed from "Control Frame Cf" of the "Basic data" to another frame and that changed control frame is rotated with the settings of ARG1 and ARG2.
If ARG1 equals to 2	• Rotate a control frame by designated W, P, and R degrees in a "User Frame" of a "Basic data". • Set a position register number to ARG2. And set angles of W, P, and R [deg] for rotating the control frame to the position register. Settings of X, Y, and Z don't matter and are not necessary to be set. • With ARG3 the control frame can be changed from "Control Frame Cf" of the "Basic data" to another frame and that changed control frame is rotated with the settings of ARG1 and ARG2.
If ARG1 equals to 3	• Rotate a control frame to match the target pushing direction with a direction of a designated vector defined on a coordinate system that is parallel to the world coordinate system and whose origin is TCP. • Set a position register number to ARG2. And set a vector that indicates a target pushing direction to the position register. The position register is set by values that indicate a target direction defined on a coordinate system that is parallel to the world coordinate system and whose origin is TCP (that is designated by "Tool Frame"). • The unit [mm] of X, Y, and Z shown in position register is irrelevant and magnitude of the vector is arbitrary. For example, to change a target pushing direction to a direction that is parallel to the X direction of the world coordinate system, set (1, 0, 0) to (X, Y, Z). Settings of W, P, and R don't matter and are not necessary to be set. • With ARG3 the control frame can be changed from "Control Frame Cf" of the "Basic data" to another frame and that changed control frame is rotated with the settings of ARG1 and ARG2.

Table 1.5.5.7 (d) The changing method of the control frame by ARG3 setting

Setting of ARG3	Description
If ARG3 equals to none or 0	Set a control frame to a "Control Frame Cf" of a "Basic data".
If ARG3 equals to 1	Set a control frame to a "Tool Frame" of a "Basic data" despite the setting of the "Control Frame Cf" of the "Basic data".
If ARG3 equals to 2	Set a control frame to a "User Frame" of a "Basic data" despite the setting of the "Control Frame Cf" of the "Basic data".

NOTE

1 ARG1, ARG2 and ARG3 can take Numeric Register.
2 Note that if argument 3 is omitted or set to "0", the control frame is set to the "Control Frame Cf" specified on the [Basic Data Settings] screen.

Example Setting of FCNCHCFR Arguments

An example of configuring the FCNCHCFR arguments is indicated below.

Table 1.5.5.7 (e) Example Setting of FCNCHCFR Arguments

Example Setting	Description
In case of restoring a setting (type and rotation) to a setting of a "Basic data".	FCNCHCFR(0)
In case of not changing a control frame and rotating a target pushing direction, that is determined by a "Control Frame Cf" and a "Pushing Direction Pd" of a "Basic data", (W1, P1, R1) degrees in a "Tool Frame" of the "Basic data".	• Set (W, P, R) of a position register PRN to (W1, P1, R1). • Set the arguments of the KAREL to FCNCHCFR(1, PRN).
In case of not changing a control frame and rotating a target pushing direction, that is determined by a "Control Frame Cf" and a "Pushing Direction Pd" of a "Basic data", (W1, P1, R1) degrees in a "User Frame" of the "Basic data".	• Set (W, P, R) of a position register PRN to (W1, P1, R1). • Set the arguments of the KAREL to FCNCHCFR(2, PRN).
In case of not changing a control frame and setting a target pushing direction to a direction that is parallel to the – Y of the world coordinate system.	• Set (X, Y, Z) of a position register PRN to (0, -1, 0). • Set the arguments of the KAREL to FCNCHCFR(3, PRN).
In case of changing a control frame that is set to a "Tool Frame" of a "Basic data" to a "User frame" of the "Basic data" and setting a target pushing direction to a direction which is determined by the "User Frame" and a "Pushing Direction Pd" of the "Basic data".	• Set (W, P, R) of a position register PRN to (0, 0, 0). • Set the arguments of the KAREL to FCNCHCFR(2, PRN, 2).

Example TP Program

An example TP Program that changes a target pushing direction during a contouring is shown in Fig. 1.5.5.7 (b). The FCNCHCFR is called at the Motion instruction in the 4th line. The target pushing direction is changed to the designated direction with PR[10] at P[3].

```
1:L   P[1:start] 50mm/sec FINE
2:   FORCE CTRL[1: Contouring Start]
  :   ErrorLBL[0]
3:L   P[2] 100mm/sec CNT100
4:L   P[3] 100mm/sec CNT100
  :   TB      .20sec,
  :   CALL FCNCHCFR(1,10,0)
5:L   P[4:end] 100mm/sec FINE
6:   FORCE CTRL[2: Contouring End]
  :   ErrorLBL[0]
```

Fig. 1.5.5.7 (b) Example TP Program: Changing a target pushing direction

> **NOTE**
> The Time Before function is used in the 4th line in this example. When a moving velocity is large, an instantaneous stop occurs at P[3] sometimes without the Time Before function.

(3) The function of changing a contact point during a contouring (In the case of 3-axis force sensor)

This function enables to change a contact point, which is used for force control with 3-axis force sensor, during a contouring.

Normally setting the "Setting Method" and "3-Axis FS ContactP. Position" in a "Basic data" determines a contact point and the contact point cannot be changed during force control of the "schedule data". This function can change the contact point.

> **NOTE**
> This function changes parameters set by "Setting Method" in "Basic data" and cannot change a parameter set by "3-Axis FS ContactP. Position" in a "Basic data".

How to change a contact point

- Insert a call of the KAREL program FCNCH3CTP into a TP Program. By executing the KAREL Program, a contact point can be changed during contouring.
- The FCNCH3CTP can be executed before the start of a "Contouring" instruction. But to prevent unexpected change, the FCNCH3CTP should be executed during contouring.
  When the FCNCH3CTP is executed before the start of a "Contouring" instruction, the change of a contact point is applied after the start of the "Contouring" instruction. However, if multiple KAREL Programs of FCNCHPFN, FCNCHCFR, FCNCH3CTP and after-mentioned FCNCHOFF are executed before the "Contouring" instruction, only the last executed KAREL Program before the "Contouring" instruction has effect.
  (For information on FCNCHOFF, see "The function of returning the pushing force, pushing direction, contact point, and force control gain to their settings in the Basic data ".)

> **NOTE**
> 1 In order to prevent unexpected changes, execute FCNCH3CTP during contouring rather than before executing the "Contouring" statement, unless necessary. (The FCNCHPFN, FCNCHCFR, FCNCH3CTP, and FCNCHOFF executed during contouring are reflected when executed.
> 2 The contact point set with FCNCH3CTP is reset automatically at the end process of "Contouring" instruction or "Contouring End" (the contact point returns to what is set in the "Basic data"). For the sake of safety it is recommended to execute after-mentioned FCNCHOFF before the "Contouring" instruction to prevent an unexpected change.
> (For information on FCNCHOFF, see "The function of returning the pushing force, pushing direction, contact point, and force control gain to their settings in the Basic data".)

Arguments of FCNCH3CTP (ARG1, ARG2)

The settings of ARG1 are as follows.
Setting for a setting method for a contact point.

Table 1.5.5.7 (f) Changing the Contact Point with Argument 1

Setting of ARG1	Description
If ARG1 equals to 0	Restore a setting method for a contact point to a setting in the "Basic data". In this case, ARG2 is not needed. If the "Setting Method" in the "Basic data" is "Pos. Reg.", the values that are set to the position register at the beginning of the force control is applied. This is the same with FCNCHOFF.
If ARG1 equals to 1	Change a setting method for a contact point to set with a position register designated by ARG2 and set the contact point with the values of the position register. If "Setting Method" in a "Basic data" is set to "Pos. Reg." and want to reflect a change of the value of the position register, FCNCH3CTP can reflect the change.
If ARG1 equals to 2	Change a setting method for a contact point to set with "PushDirShift". If "Setting Method" in a "Basic data" is set to "PushDirShift" and want to change the value of the distance of the "PushDirShift", FCNCH3CTP can change the value.

The settings of ARG2 are as follows.

Table 1.5.5.7 (g) Changing the Contact Point with Argument 2

Setting of ARG1	Description
If ARG1 equals to 0	ARG2 is not need to be set.
If ARG1 equals to 1	ARG2 specifies the position register number.
If ARG1 equals to 2	ARG2 specifies the distance that a contact point is shifted in a pushing direction and set ARG2 greater than 0. In this case, a unit of ARG2 is mm.

> **NOTE**
> ARG1, ARG2 can take Numeric Register.

Example Setting of FCNCH3CTP Arguments

An example of configuring the FCNCH3CTP arguments is indicated below.

Table 1.5.5.7 (h) Example Setting of FCNCH3CTP Arguments

Example Setting	Description
In case of restoring a setting method to a setting of the "Basic data".	FCNCH3CTP(0)
In case of setting a setting method to "Pos. Reg." and setting the position register number to 10.	FCNCH3CTP(1, 10)
In case of setting a setting method to "PushDirShift" and setting the distance to 30 mm.	FCNCH3CTP(2, 30)

Example TP Program

An example TP Program that changes a setting of a contact point is shown in Fig. 1.5.5.7 (c). The FCNCH3CTP is called at the Motion instruction in the 4th line. The contact point is changed to the position that is based on the coordinate system (the mechanical interface coordinate system or the world coordinate system) designated by "3-Axis FS ContactP. Position" in the "Basic data" with PR[10] at P[3].

```
1:L   P[1:start] 50mm/sec FINE
2:   FORCE CTRL[1: Contouring Start]
  :   ErrorLBL[0]
3:L   P[2] 100mm/sec CNT100
4:L   P[3] 100mm/sec CNT100
  :   TB       .20sec,
  :   CALL FCNCH3CTP(1,10)
5:L   P[4:end] 100mm/sec FINE
6:   FORCE CTRL[2: Contouring End]
  :   ErrorLBL[0]
```

Fig. 1.5.5.7 (c) Example TP Program: Changing a contact point

> **NOTE**
> The Time Before function is used in the 4th line in this example. When a moving velocity is large, an instantaneous stop occurs at P[3] sometimes without the Time Before function.

(4) The function of changing the force control gain during contouring

This function can be used to change the force control gain after contact (after the generated force exceeds "Contact F Threshold") contouring operation. This function changes the parameter corresponding to "Force Control Gain" in the Basic data. (For information on force control gain, refer to "Basic Function Guide: 1.6 FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".)

Usually, the force control gain during contouring operation is set with "Force Control Gain" in the Basic data, and remains unchanged while the schedule data is being executed. By using this function, the force control gain can be changed in the middle of contouring operation. If the force control gain is changed with this function before contact, the changed value is applied after contact. If the force control gain is changed with this function after contact, the changed value is immediately applied.

> **NOTE**
> This function cannot be used in conjunction with the following functions.
> - Customization function
>   (Refer to "Basic Function Guide: 1.7 SUCCESSIVE EXECUTION OF FORCE CONTROL INSTRUCTIONS (CUSTOMIZATION FUNCTION)".)

Changing the force control gain

- Insert a call of the KAREL program FCNCHFCG into a TP Program. By executing the KAREL program, the force control gain can be changed during contouring.
- If FCNCHFCG is executed before the execution of the "Contouring" instruction, the settings are reflected after the start of "Contouring". (If two or more of FCNCHPFN, FCNCHCFR, FCNCH3CTP, FCNCHFCG, and FCNCHOFF are executed before the start of the "Contouring" instruction, only the settings of the last executed one are reflected.) To prevent unexpected changes, execute FCNCHFCG during contouring, not before the execution of the "Contouring" instruction, unless doing so is necessary. (If FCNCHPFN, FCNCHCFR, FCNCH3CTP, FCNCHFCG, and FCNCHOFF are executed during contouring, the settings are reflected each time they are executed.)
  (For information on FCNCHOFF, see "The function of returning the pushing force, pushing direction, contact point, and force control gain to their settings in the Basic data".)

> **NOTE**
> 1 In order to prevent unexpected changes, execute FCNCHPF during contouring rather than before executing the "Contouring" statement, unless necessary. (The FCNCHPFN, FCNCHCFR, FCNCH3CTP, FCNCHFCG, and FCNCHOFF executed during contouring are reflected when executed.
> 2 The settings of FCNCHFCG are automatically reset at the end of the "Contouring" instruction or during the execution of the "Contouring end" instruction (restore to the settings in the Basic data). For safety, it is recommended to execute FCNCHOFF, described later, before the force control instruction to prevent unexpected changes.
> (For information on FCNCHOFF, see "The function of returning the pushing force, pushing direction, contact point, and force control gain to their settings in the Basic data ".)

FCNCHFCG (ARG1, ARG2, ARG3, and ARG4)

In ARG1, set the method of changing the force control gain. The settings of ARG1 are as follows.

Table 1.5.5.7 (i) Changing the Force Control Gain with Argument 1

Setting of ARG1	Description
If ARG1 equals to 0	Restore the force control gain to the setting of "Force Control Gain" in the Basic data. In this case, ARG2 and the subsequent arguments need not be set. FCNCHOFF also restore the force control gain to the setting of "Force Control Gain" in the Basic data, but in this case, all values that are changed with FCNCHPFN, FCNCHCFR, and FCNCH3CTP are restored to the settings in the schedule data. If ARG1 is 0, ARG2 and the subsequent arguments are not necessary.
If ARG1 equals to 1	Change the force control gain with "Master Frequency". (For an explanation of "Individual Frequency", refer to "Basic Function Guide: 1.6 FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".) If ARG1 is 1, ARG2 is necessary.

Setting of ARG1	Description
If ARG1 equals to 2	Change the force control gain with "Individual Frequency". (For an explanation of "Individual Frequency", refer to "Basic Function Guide: 1.6 FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".) If ARG1 is 2, ARG2, ARG3, and ARG4 are necessary.

NOTE
Numeric Registers can be used for the arguments.

The settings for arguments 1 to 4 are indicated below.

Table 1.5.5.7 (j) Changing the Force Control Gain with Arguments 1 to 4

Changing operation	Argument	Description
Restoring the gain to the original setting	ARG1 = 0 FCNCHFCG(0)	Restore the control gain to the setting of "Force Control Gain" in the Basic data. ARG1: 0
Changing "Master Frequency"	ARG1 = 1 FCNCHFCG (1, ARG2 [Hz])	Change the force control gain with "Master Frequency". ARG1: 1 ARG2: Master Frequency value [Hz] The value of ARG2 must be greater than 0.
Changing Indivi-Freq."	ARG1 = 2 FCNCHFCG (2, ARG2[Hz], ARG3[Hz], ARG4[Hz])	Change the force control gain with "Individual Frequency". ARG1: 2 ARG2: Indivi-Freq.X value [Hz] ARG3: Indivi-Freq.Y value [Hz] ARG4: Indivi-Freq.Z value [Hz] The values of ARG2, ARG3, and ARG4 must be greater than 0.

NOTE
1 Be sure not to set the post-change force control gain to a large value.
2 Before executing FCNCHFCG, check whether the arguments are appropriate.

Examples of setting FCNCHFCG arguments

An example of configuring the FCNCHFCG arguments is indicated below.

Table 1.5.5.7 (k) Examples of setting FCNCHFCG arguments

Example Setting	Description
Restoring the force control gain to the setting of "Force Control Gain" in the Basic data.	FCNCHFCG(0)
Changing the force control gain to the value of 0.1 [Hz] with "Master Frequency".	FCNCHFCG(1, 0.1)
Changing the force control gain with "Individual Frequency" as follows: X:0.1[Hz], Y:0.2[Hz], Z:0.3[Hz].	FCNCHFCG(2, 0.1, 0.2, 0.3)

TP Program example

This is a TP Program example that changes the force control gain during contouring operation. FCNCHFCG is called when the Motion instruction in the fourth line is executed. At P[3], the force control gain is changed to a value of 0.1 [Hz] with "Master Frequency", regardless of the value of "Force Control Gain" in the Basic data.

```
1:L @P[1:start] 50mm/sec FINE
2:   FORCE CTRL[1:Contour start] ErrorLBL[0]
3:L   P[2] 100mm/sec CNT100
4:L   P[3] 100mm/sec CNT100
  :   TB       .20sec,
  :   CALL FCNCHFCG (1,0.1)
5:L   P[4:end] 100mm/sec FINE
6:   FORCE CTRL [2:Contour end] ErrorLBL [0]
```

Fig. 1.5.5.7 (d) TP Program example changing the force control gain

> **NOTE**
> In this example, a Time Before instruction is used in the fourth line. Without the Time Before instruction, the program may stop momentarily at teach position [3] if the operation velocity is high.

(5) The function of restoring the pushing force, pushing direction, contact point, and force control gain to their settings in the Basic data

This function can be used to return the target pushing force, pushing direction, contact point, and force control gain, which have been changed during contouring in the above-mentioned KAREL programs, FCNCHPFN, FCNCHCFR, FCNCH3CTP, and FCNCHFCG, to their settings in the Basic data. This is useful if it is desired that, after any of the pushing force, pushing direction, contact point, and force control gain are changed during contouring, they be restored to their settings in the Basic data with a single instruction.

Execution method

- Insert a call of the KAREL program FCNCHOFF into a TP Program. By executing the KAREL program during contouring, the pushing force, pushing direction, contact point, and force control gain can be restored to their settings in the Basic data.
- If one of FCNCHPFN, FCNCHCFR, FCNCH3CTP, FCNCHFCG, and FCNCHOFF is executed before the execution of the "Contouring" instruction, the settings of the program are reflected after the start of "Contouring".

> **NOTE**
> 1 If two or more of FCNCHPFN, FCNCHCFR, FCNCH3CTP, FCNCHFCG, and FCNCHOFF are executed before the start of the "Contouring" instruction, only the settings of the last executed one are reflected.
> 2 To prevent unexpected changes, execute FCNCHOFF before the "Contouring" instruction. In this way, the settings are all reset (restore to those in the Basic data), thereby preventing unexpected changes.

Example TP Program

A TP Program example that restores the pushing force, pushing direction, contact point, and force control gain, changed during movement, to their settings in the Basic data is shown in Fig. 1.5.5.7 (e).
The settings are restored at P[4].

```
 1:L   P[1:start] 50mm/sec FINE
 2:   FORCE CTRL[1: Contouring Start]
   :   ErrorLBL[0]
 3:L   P[2] 100mm/sec CNT100
 4:L   P[3] 100mm/sec CNT100
 5:   CALL FCNCHPF(1,3)
 6:   CALL FCNCHCFR(1,10,0)
 7:L   P[4] 100mm/sec CNT100
 8:   CALL FCNCHOFF
 9:L   P[5:end] 100mm/sec FINE
10:   FORCE CTRL[2: Contouring End]
   :   ErrorLBL[0]
```

Fig. 1.5.5.7 (e) TP Program example restoring the changed pushing force, pushing direction, contact point, and force control gain to their settings in the Basic data

1.5.6 Threading

Overview

The "Threading" function is used to perform threading by rotating one of two workpieces and, at the same time, performing pushing operation on the other workpiece. Threading is stopped where the torque in the rotation direction reaches the preset value, so that torque-managed threading can be performed. This function offers two choices: Performing threading by rotating a workpiece centered on TCP with the robot alone; and performing threading by rotating a workpiece by using an auxiliary axis.

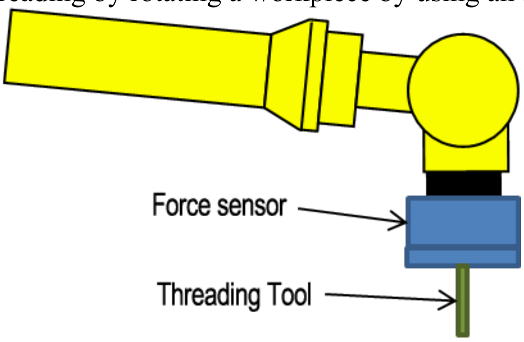


Fig. 1.5.6 (a) When rotating the workpiece centered on the TCP and threading using a robot only

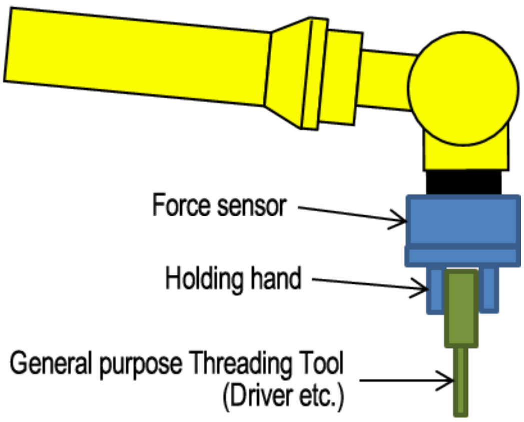


Fig. 1.5.6 (b) When rotating the workpiece using an auxiliary axis

If an auxiliary axis is used, a choice can be made between mounting an auxiliary axis to a hand and rotating the pick workpiece and fixing an auxiliary axis to the pedestal and rotating a stationary workpiece.

There are two types of configuration screens; the [Basic Data Settings] screen that must be configured by the user, and the [Performance Data Settings] screen that is only configured when required.

NOTE

1 This function cannot be used with a 3-axis force sensor.

2 When performing threading with the robot alone and the rotation axis of threading does not correspond to J6 of a robot, the rotation velocity for threading is limited to 5 deg/s or less for safety. Under the following conditions, threading can be performed at a maximum of 200 deg/s. For details about the configuration, refer to the [Rotation Velocity] item on the [Basic Data Settings] screen.
   - The center of rotation of the screw (TCP) is on J6.
   - The degree of the angle between the insertion direction and the J6 axis is 3 degrees or less.

Constraints on using auxiliary axis

The following constraints are imposed on the use of an auxiliary axis.

- Each auxiliary axis must have a sufficient rated torque for the target torque.
- The rotary workpiece and the auxiliary axis must be able to rotate unlimitedly without interference.
- The center of the thread is on the rotation axis of the auxiliary axis.
- The included auxiliary axis option (J518) exists, and the auxiliary axis is set appropriately to the same group as the robot.
- The continuous turn option (J613) exists, and the continuous turn setting is made appropriately.
- The type of auxiliary axis must be "Auxiliary Rotary Axis".

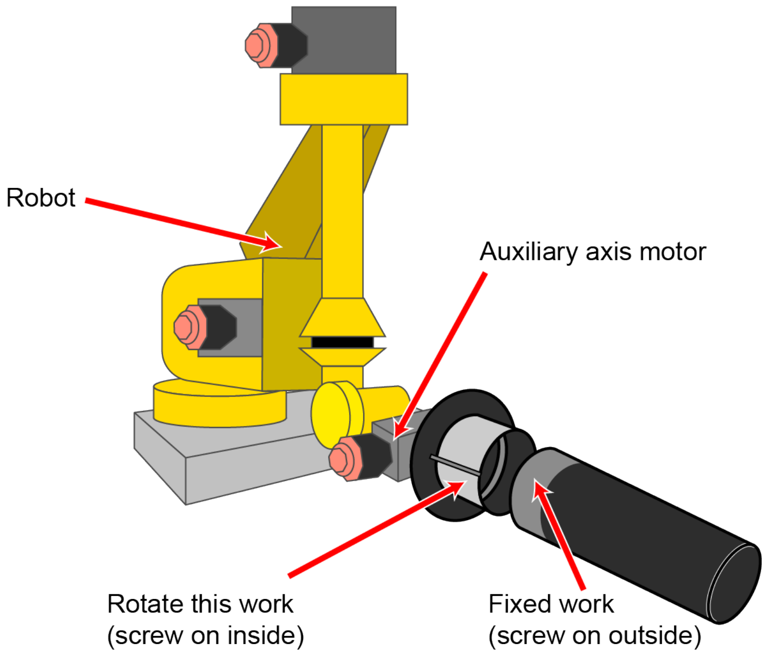


Fig. 1.5.6 (c) Workpiece to rotate and auxiliary axis can be rotated without limit or interference

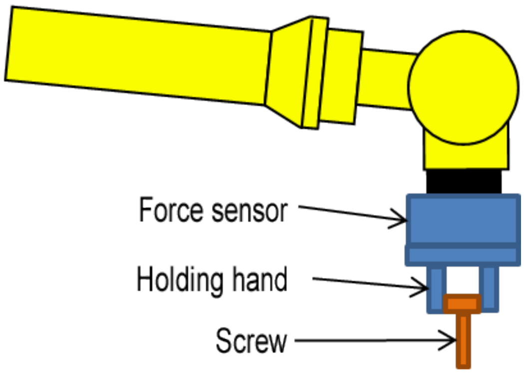


Fig. 1.5.6 (d) The screw area is in the center of the rotary axis of the auxiliary axis

1.5.6.1 Parameter

Overview

The parameters for "Threading" are indicated below.
Make sure to configure the parameters on the [Basic Data Settings] screen.

[Function selection] screen

```
1
1 Unused
2 Constant Push
3 Face Match
4 Shaft Insert
5 Groove Insert
6 Search
7 Phase Search
8 --next page--
```

```
2
1 Hole Search
2 Clutch Search
3 Square Insert
4 Contouring
5 Contouring End
6 Threading
7
8 --next page--
```

[Basic Data Settings] screen

```
Force Ctrl/Basic
                                          1/20
  Schedule[1]                 G:1 F:1 S:1
  1 Function              : Threading
  2 Comment               : [                  ]
  3 Rotation Mechanism    : Robot
  4 Insert Direction      : -Z
  5 Screw Helix Dir.      : Right Handed
  6 Rotate Direction      : Tighten
  7 Contact F Threshold   :    10.00 N
  8 Approach Velocity     :     1.00 mm/s
  9 User Frame No.             UF:  0
 10 Tool Frame No.             TF:  1
 11 Target Torque         :     1.00 N*m
      Last Torque         :     0.00 N*m
 12 Rotation Velocity     :     1.00 deg/s
 13 Rotation Ang. Limit   :     0.00 deg
 14 Insert Force          :    10.00 N
 15 Insert Velocity       :     2.00 mm/s
 16 Minimum depth         :    20.00 mm
 17 Maximum depth         :    30.00 mm
 18 Rotation Time Limit   :    20.00 sec
 19 F.Ctrl. Gain Auto Modify :       OFF
        Prev. Result      : No Change
 20 Force Control Gain    :        Detail
[TYPE] | GROUP | NUMBER | [SELECT] | PERFORM | >
  F1      F2      F3        F4         F5
```

[Force Ctrl/Gain] screen

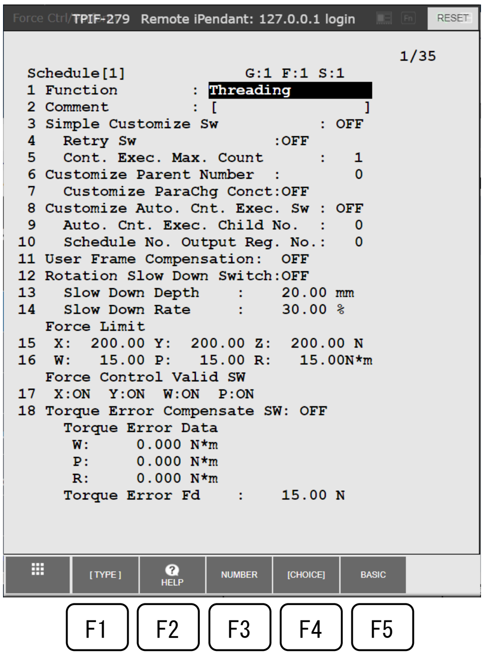
```
Force Ctrl/Gain
                                          1/2
  Schedule[1]                 G:1 F:1 S:1
    Function              : Threading
  1 Insert Impedance      : [Master Freq. ]
[TYPE] | GROUP | NUMBER | [SELECT] |  | >
  F1      F2      F3        F4      F5
```

[Performance Data Settings] Screen

```
Force Ctrl/Perform
                                          1/35
  Schedule[1]                 G:1 F:1 S:1
  1 Function              : Threading
  2 Comment               : [                  ]
  3 Simple Customize Sw          :   OFF
  4   Retry Sw                   :   OFF
  5   Cont. Exec. Max. Count     :     1
  6 Customize Parent Number      :     0
  7   Customize ParaChg Conct    : OFF
  8 Customize Auto. Cnt. Exec. Sw : OFF
  9   Auto. Cnt. Exec. Child No.  :   0
 10   Schedule No. Output Reg. No.:   0
 11 User Frame Compensation :  OFF
 12 Rotation Slow Down Switch: OFF
 13   Slow Down Depth     :   20.00 mm
 14   Slow Down Rate      :   30.00 %
    Force Limit
 15   X:  200.00 Y:  200.00 Z :  200.00 N
 16   W:   15.00 P:   15.00 R:   15.00N*m
    Force Control Valid Sw
 17   X:ON   Y:ON   W:ON   P:ON
 18 Torque Error Compensate SW: OFF
       Torque Error Data
        W:      0.000 N*m
        P:      0.000 N*m
        R:      0.000 N*m
       Torque Error Fd    :   50.00 N
 19 Velocity Constant Switch  : ON
 20 Force End Judgment Switch : OFF
 21   Min. Force Rate   :     80.00 %
       Judgment Result  :       -------
        Force Average   Z:     0.00 N
 22 Fast Ins. Switch    :       ON
 23   Fast Ins. Multiplier :    2.00
 24   Fast Ins. Acc. Time:      0.40 sec
 25 Approach Acc. Time :        0.70 sec
 26 Rotation Acc. Time :        0.70 sec
 27 Force Denoising Sw   :     OFF
 28 Signal Output for ERR SW:  OFF
 29   Output Signal Type  :    DO
 30   Output Signal Number:       0
 31 Frc.Ctrl. End by REG SW  : OFF
 32   End Register Number :       0
[TYPE] | GROUP | NUMBER | [SELECT] | Basic | >
  F1      F2      F3        F4       F5
```

Fig. 1.5.6.1 (a) Teaching “Threading” detailed data (1/2)

［Performance Data Settings］ Screen（1/2）



［Performance Data Settings］ Screen（2/2）

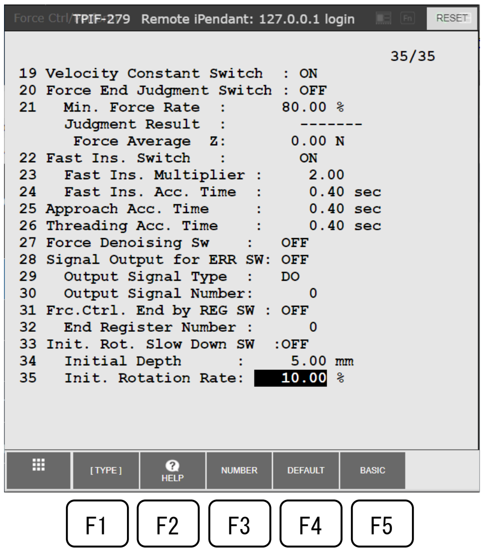


Fig. 1.5.6.1 (b) Teaching "Threading" detailed data (2/2)

Adjusting the Parameters for the "Threading" Function

1 Display the [Basic Data Settings] screen for the "Threading" function.
2 Configure [Rotation Mechanism], [Insert Direction], [Screw Helix Dir.], and [Rotate Direction].
3 Configure "UFrame Number" and "UTool Number".
4 Configure [Target Torque], [Rotation Velocity], [Midepth], and [Maximum depth].
5 Execute [F.Ctrl. Gain Auto Modify].
(Refer to "Basic Function Guide: 1.11.2 Force Control Gain Auto Tuning Instruction".)
6 Adjust the parameters on the [Performance Data Settings] screen, as required.

> **NOTE**
> For the outline of force control instruction programming, refer to "Basic Function Guide: 1.1 NOTES / RESTRICTIONS", and "Basic Function Guide: 1.2 TEACHING PROCEDURE".

The procedure for tuning other parameters after the completion of automatic force control gain adjustment is shown below.

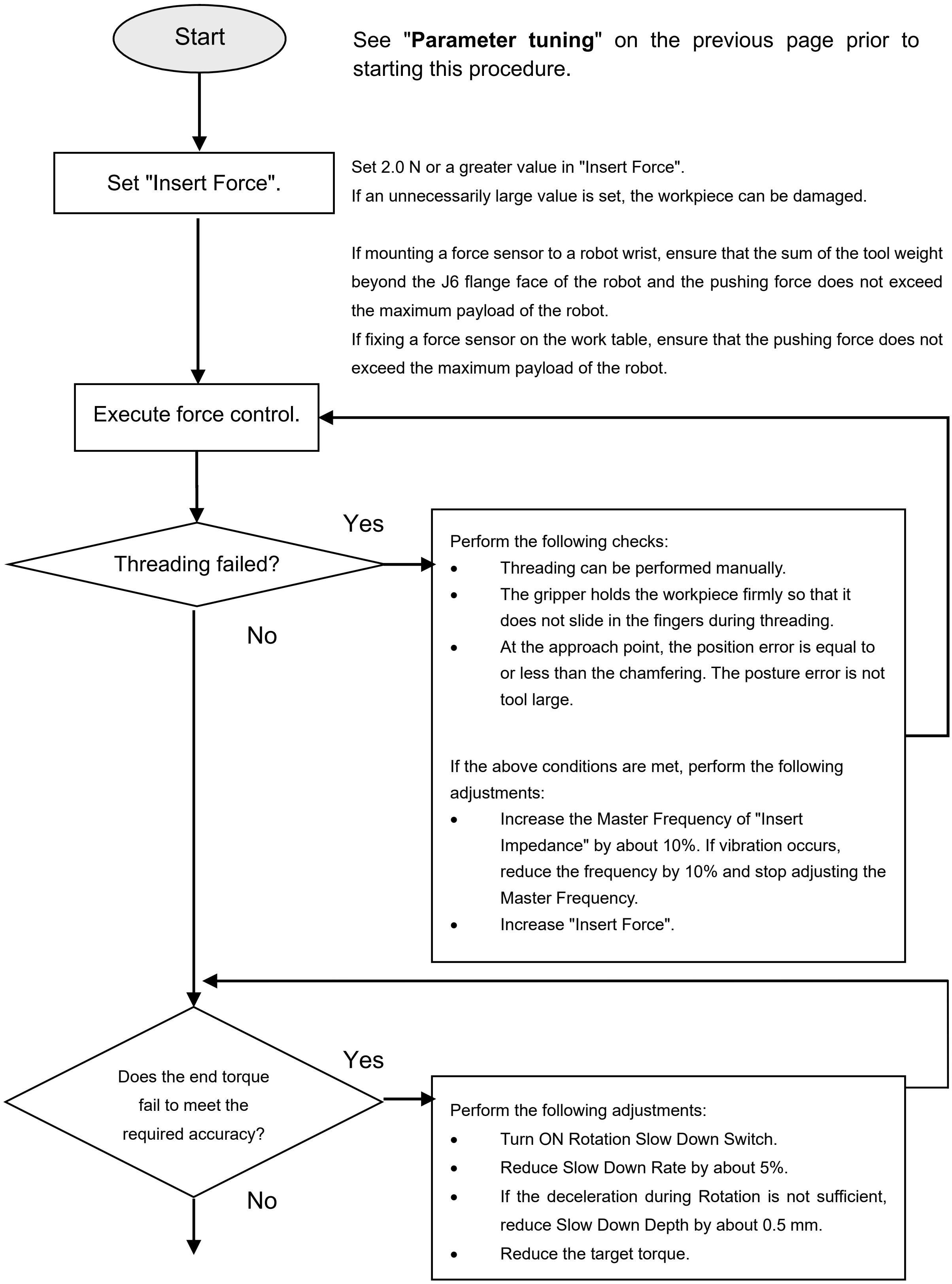


Fig. 1.5.6.1 (c) Adjusting Other Parameters (1/2)

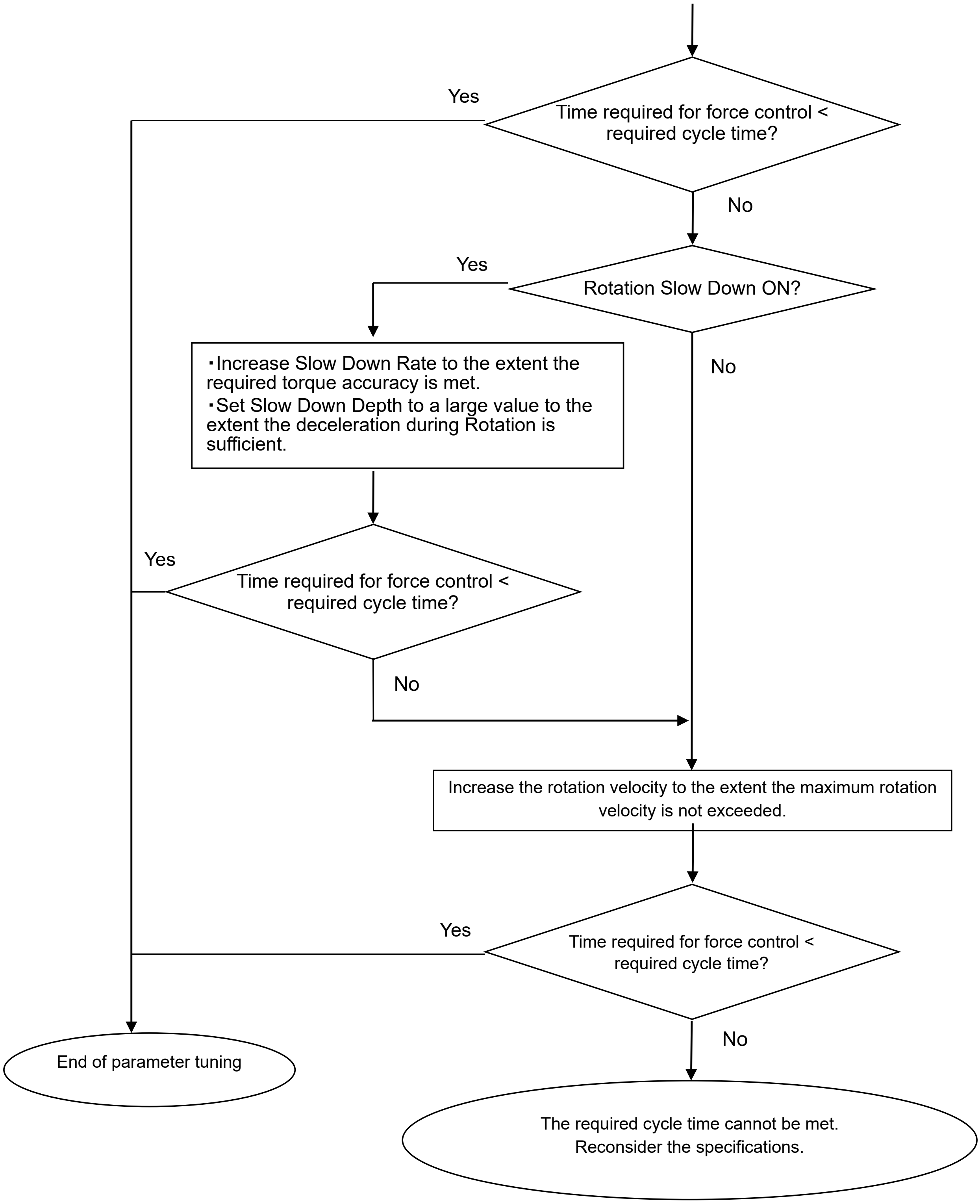


Fig. 1.5.6.1 (d) Adjusting Other Parameters (2/2)

[Basic data settings] screen

The settings on the [Basic Data Settings] screen (Threading) are indicated below.

Table 1.5.6.1 (a) [Basic data settings] screen

Item	Description
Function	A desired function is selected from "Function selection screen". In this case, select "Threading".
Comment	Enter a comment for identifying the schedule data. Maximum number of characters: 16 characters.
Rotation Mechanism	Select the mechanism for rotating the workpiece. If not using auxiliary axis, select "Robot". If using auxiliary axis, select from "J7-Axis", "J8-Axis", and "J9-Axis". "Default : Robot "
User Frame Number	Enter the number of the user frame to use when tightening or removing the screw. (Enter the user frame number that was set in "Basic Functions Guide: 1.2 TEACHING PROCEDURE".) "Default : UF:0"
Tool Frame Number	Enter the number of the tool frame to use when tightening or removing the screw. (Enter the user tool number that was set in "Basic Functions Guide: 1.2 TEACHING PROCEDURE".) "Default : TF:1"
Insert Direction	Enter the direction to insert using the user frame. Select [+X], [-X], [+Y], [-Y], [+Z], or [-Z]. "Default : – Z"
Screw Helix Dir.	Select "Right Handed" or "Left Handed" for the screw to thread. This is used to determine the rotate direction. "Default : Right Handed "
Rotate Direction	Select "Tighten" or "Loosen" to specify the direction to turn the screw. This is used to determine the rotation direction and judge the operation mode. If "Loosen" is selected, extraction mode is assumed. "Default : Tighten"
Target Torque	This is the torque value used for the judgment of the end of force control. The direction is decided from [Insert Direction], [Screw Helix Dir.], and [Rotate Direction], so enter them as absolute values. "Default : 1.00 N*m"
Last Torque	This is the end-time torque used when this schedule was executed last. This is not a setting parameter, so the cursor does not stop here. "Default : 0.00 N*m"
Minimum depth	If this depth is not reached at the end of force control, an alarm is issued. Enter the value. In extraction mode, force control ends normally if this depth is reached. "Default : 20.00 mm"
Maximum depth	If the torque does not reach the target value even after this depth is exceeded, an alarm is issued. Enter the value. "Default : 30.00 mm"
Approach Velocity	Enter the target operation velocity until contact is made with the target. "Default : 1.00 mm/s"
Insert Velocity	Enter the target velocity for the pushing direction. Set it to a value several mm/s greater than the traveling velocity calculated from the rotation velocity and the thread pitch. "Default : 2.00 mm/s"
Contact F Threshold	Enter the threshold value for determining whether contact has been made with the target. "Default : 10.00 N"
Insert Force	Enter the target pushing force for the pushing direction. "Default : 30.00 N"

Item	Description
Rotation Velocity	Enter the absolute value of the target velocity in the rotate direction. If not using auxiliary axis, enter it in deg/s. If using auxiliary axis, enter it in rpm. The direction is determined by [Insert Direction], [Screw Helix Dir.], and [Rotate Direction]. "Default : 1.00 deg/ s" **NOTE** About the upper input limit when not using the auxiliary axis If the center of rotation is not on the J6 axis, only a value of 5 deg/s or lower can be set because the rotation axis and the J6 axis will not match. If the center of rotation is on the J6 axis, a value of up to 200 deg/s can be set. However, if threading is performed at a velocity of 5 deg/s or greater and the angle between the insertion direction and the J6 axis is 3 degrees or more, an alarm will occur. If the angle exceeds 3 degrees at the start of threading: FORCE-498 Invalid rotation velocity If the angle exceeds 3 degrees during threading: FORCE-265 Change in angle is too large
Rotation Ang. Limit	Enter the maximum value when an auxiliary axis is not used. When an operation is performed by the angle that is set here from the start of rotation, the operation stops with an alarm. If requiring to set an operation range due to possible interference with hands and other peripheral devices, set an appropriate value. If this item is unnecessary, set it to 0. The default is 0. "Default : 0.00 deg" **NOTE** This item cannot be set if an auxiliary axis is used. (If it is set, the cursor will not stop.) Also, no item number will be assigned, causing the subsequent numbers to be moved forward by one.
Threading Time Limit	If force control is not ended even after this time has passed, an alarm is issued. Enter the maximum time. "Default : 20.00 sec"
F.Ctrl. Gain Auto Modify	This is the switch used in automatic force control gain adjustment. Set "On" to execute auto adjustment of the force control gain. (Refer to "Basic Function Guide: 1.10.2 Force Control Gain Auto Tuning Instruction".) "Default : OFF"
Prev. Result	Displays the previous result for [F.Ctrl. Gain Auto Modify]. "Default : No Change"
Force Control Gain	Perform the operation below to switch to the [Force Control Gain] screen. • Move the cursor to this line and then press the "ENTER" key, and the screen display switches to the [Force Ctrl/Gain] screen. (For the parameters that can be set on this screen, refer to "Basic Function Guide: 1.6 FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".)
G F S	G represents a motion group number at the time of teaching. F represents a force control number. S represents a force sensor number. (These settings cannot be changed.) "Defaults : G F S : 1 1 1"

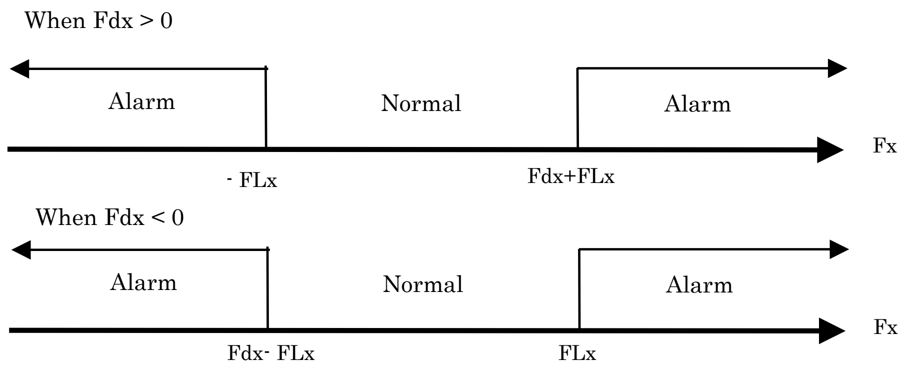
[Performance data setting] screen

The settings on the [Performance Data Settings] screen (Threading) are indicated below.

Table 1.5.6.1 (b) [Performance data setting] screen

Item	Description
Function	A desired function is selected from "Function selection screen". In this case, select "Threading".
Comment	Enter a comment for identifying the schedule data. Maximum number of characters: 16 characters.
Simple Customize Sw	This switch is for force control continuous execution. This can be set to 'On' or 'Off'. When this switch is set to ON, force control can be executed after any force control schedule. (Refer to "Basic Function Guide: 1.7.3 Simple Customization Function".) "Default : OFF"
Retry Sw	This switch sets whether to use the force control schedule currently being executed for retrying the previously executed schedule. Select "Off", "ReturnPos1", or "ReturnPos2". If the item is "OFF", the robot moves by the distance specified in "Minimum depth" on the Basic screen. If it is "ReturnPos1", the robot returns to the starting point of a previously executed schedule. If the previously executed schedule has a parent schedule established for it, the robot returns to the starting point of the parent schedule. If it is "ReturnPos2", the robot returns to the starting point of a previously executed schedule regardless of whether it has a parent schedule established for it. (Refer to "Basic Function Guide: 1.7.3 Simple Customization Function".) "Default : OFF"
Cont. Exec. Max. Count	Enter an integer for the number of times a force control schedule with the simple customization function enabled can be executed continuously. (Refer to "Basic Function Guide: 1.7.3 Simple Customization Function".) "Default : 1"
Customize Parent Number	Enter this when executing force control continuously. (Refer to "Basic Function Guide: 1.7.4 Customization Function".) "Default : 0"
Customize ParaChg Conct	Set this item to execute force control successively. Select 'Both D', 'P2C', 'C2P', or 'Off'. (Refer to "Basic Function Guide: 1.7.4 Customization Function".) "Default : OFF"
Customize Auto. Cnt. Exec. Sw (Customize Auto. Cnt. Exec.)	This item is a switch of the function for automatically executing successively a series of force control schedule data combined together with the customization function merely by specifying the parent number at the top. This can be set to 'On' or 'Off'. Set this item to "ON" for all schedule data subject to Customize Auto. Cnt. Exec., whether it be a parent or a child. (Refer to "Basic Function Guide: 1.7.5 Customization Automatic Continuous Execution Function".) "Default : OFF"
Auto. Cnt. Exec. Child No. (Customize Auto. Cnt. Exec.)	Enter the number of the schedule data to execute next in "Customization Auto Continuous Execution". For the schedule data specified with this parameter, specify the number of this schedule data in [Customize Parent Number] in the Performance data. [Customize Auto. Cnt. Exec.] can combine together up to ten sets of force control schedule data. "Default : 0"

Item	Description
Schedule No. Output Reg. No. (Customize Auto. Cnt. Exec.)	Enter the number of the Numeric register that is used for 'Customization Auto Continuous Execution' function. When "Customize Auto. Cnt. Exec." function is executed, a running schedule data number is written to this Numeric register. If the series of the schedule data ends normally, 0 is written to this Numeric register. For the value of "Schedule No. Output Reg. No.", only the value of the parent at the top of the series of force control schedule data combined together with the customization function is used. The value of a child is not used even it is set. If the value of "Schedule No. Output Reg. No." of the parent at the top is 0, no value is output to the Numeric Register. If force control with Customize Auto. Cnt. Exec. results in a failure, the number of the schedule data that fails can be determined by checking the value that is set in the Numeric Register specified here. "Default : 0"
User Frame Compensation	This is the switch for correcting the user frame that is set for the workpiece object face, using *i*RVision. This is useful if the slope of the workpiece object may vary. Select 'Off', 'Pos. Reg.', or 'VISION REG'. This item must be used concurrently with the OFFSET or VOFFSET instruction. (Refer to "Basic Function Guide: 1.8 USER FRAME COMPENSATION".) "Default : OFF"
Rotation Slow Down Switch	This item is a switch of the function for decelerating when the depth specified with Slow Down Depth is reached. This can be set to 'On' or 'Off'. "Default : OFF"
Slow Down Depth	If [Rotation Slow Down Switch] is set to "On", enter the depth to start slowing down at. "Default : 20.00 mm"
Slow Down Rate	If [Rotation Slow Down Switch] is set to "On", enter the ratio for slowing down. After Slow Down Depth, the rotation velocity multiplied by this rate is regarded as the target value. "Default : 30.00 %"

Item	Description
Force Limit (Fig. 1.5.6.1 (g))	If the generated force satisfies one of the expressions below, an alarm (FORC-216 - FORC-221) is issued. Refer to "APPENDIX: B ALARM CODES FOR FORCE CONTROL" first to remove the cause of the alarm. If the alarm persists even after all possible measures are taken, increase the values of this parameter. Set the values of the forces in the three directions, X, Y, and Z, as well as the moments in the three directions, W, P, and R. For example, for the force in the X direction, the following expressions are given: Fx < – FLx or Fx > Fdx + FLx (when Fdx > 0) Fx > FLx or Fx < Fdx – FLx (when Fdx < 0) Fx : Force generated during insertion (X direction) FLx : X component of the force limit Fdx : Target force in the X direction If the insertion direction is "X" or " – X", Fdx is "Insert Force"; otherwise, Fdx = 0. The same relationship holds for Y, Z, W, P, and R. "Defaults : X : 200.00 Y : 200.00 Z : 200.00 N W : 15.00 P : 15.00 R : 15.00 N*m" "Unit: N, N*m"  Fig. 1.5.6.1 (g) Force Limit and the occurrence of an alarm
Threading Force Control Valid SW	This switch sets whether to perform force control in a direction other than the pushing direction or rotation direction during threading. This can be set to 'On' or 'Off'. If the item is ON, force control is enabled; if OFF, force control is disabled. If force control is enabled in the X, Y, and Z directions, threading can be performed while correcting the position error. If it is enabled in the W, P, and R directions, threading can be performed while correcting the posture error. "Defaults : X : ON Y : ON W : ON P : ON"
Torque Error Compensate SW	This switch is used for torque error compensation. This can be set to 'On' or 'Off'. If this switch is turned "ON", torque error compensation is performed, using "Torque Error Data W", "Torque Error Data P", "Torque Error Data R", and "Torque Error Fd" indicated below. * Execute the torque error acquisition instruction before turning ON this switch. (Refer to "Basic Function Guide: 1.11.3 Torque Error Acquisition Instruction") "Default : OFF"
Torque Error Data	Displays the value estimated from the moment information of the force sensor when the robot is actually pushed with "Torque Error Fd" when "TRQ ERROR" is performed. W, P, and R represent rotation about the X-axis, Y-axis, and Z-axis of the user frame (UF) used, respectively. If "Torque Error Compensate SW" is turned "ON", these values are used to correct the torque error. (This value cannot be modified.) "Defaults : W : 0.00 P : 0.00 R : 0.00 N*m"
Torque Error Fd	Displays the value of the force actually exerted when "TRQ ERROR" is performed. If "Torque Error Compensate SW" is turned "ON", this setting is used to correct the torque error. (This value cannot be modified.) "Default : 30.00 N"

Item	Description
Velocity Constant Switch	This item is a switch of the function for preventing the velocity from increasing excessively even when, for example, the reaction force disappears abruptly. This can be set to 'On' or 'Off'. When this switch is turned "ON", the velocity during threading can be prevented from exceeding "Insert Velocity" in the Basic data. "Default : ON"
Force End Judgment Switch	This item is a switch of the function for ending operation after checking whether a proper force has been generated. This can be set to 'On' or 'Off'. When [Force End Judgment Switch] is "ON", after the target torque is reached, force control ends if [Judgment Result] is "SUCCESS". An alarm occurs if [Judgment Result] is not "SUCCESS" when "Rotation Time Limit" on the [Basic Data Settings] screen elapses. "Default : OFF"
Min. Force Rate	This value is used to judge whether an appropriate amount of force was generated. Enter a ratio. [Judgment Result] is "SUCCESS" if the magnitude of the force in [Pushing Direction] exceeds [Min. Force Rate] x [Pushing Force] / 100. If [Rotation Time Limit] elapses while the above conditions are not met, [Judgment Result] is "FAILURE". "Default : 80.00 %"
Judgement Result	This item displays [Judgment Result] at the end of "Threading" for which [Force End Judgment Switch] is "ON". If the function has never been executed with [Force End Judgment Switch] set to "ON", "----" is displayed. "Default : -----"
Force Average	This item displays the force magnitude of [Pushing Direction] at the end of "Threading" for which [Force End Judgment Switch] is "ON". "Default : Z : 0.00 N"
Fast Ins. Switch	This item is a switch of the function for speeding up posture correction operation. This can be set to 'On' or 'Off'. If it is "On", the orientation correction operation is accelerated. "Default : ON"
Fast Ins. Multiplier	Enter the speed of the orientation correction operation. If [Fast Ins. Switch] is "ON" and a value larger than the current value of [Fast Ins. Multiplier] is entered, the orientation correction operation becomes faster. "Default : 2.00" ⚠ **CAUTION** For safety, increase this value in steps of about 0.50.
Fast Ins. Acc. Time	Enter the acceleration time of the orientation correction operation. If "Fast Ins. Switch" is ON, posture adjustment operation becomes faster by decreasing this value. "Default : 0.40 sec" ⚠ **CAUTION** For safety, decrease this value in steps of about 0.10.
Approach Acc. Time	Enter the time until the velocity reaches the [Approach Velocity] on the [Basic Data Settings] screen after the FORCE statement is started. "Default : 0.40 sec"
Threading Pushing Time	Enter the time until the velocity in [Pushing Direction] reaches the [Insert Velocity] on the [Basic Data Settings] screen after the force in [Pushing Direction] exceeds the [Contact F Threshold] on the [Basic Data Settings] screen. "Default : 0.40 sec"

Item	Description
Force Denoising Sw	This item is a switch of the function for removing large noise from force data. This can be set to 'On' or 'Off'. If it is "On", heavy noise is removed from the force data. This function is useful when: • tool or workpiece is heavy • using a tool such as a grinder and that has a big vibration "Default : OFF" ⚠ **CAUTION** If [Force Denoising Sw] is set to "On" for the threading function, the force data may be delayed and the tightening torque may exceed the target value due to momentum.
Signal Output for ERR SW	This item is a switch of the function for outputting a designated signal when an alarm is issued during force control. This can be set to 'On' or 'Off'. If it is "On", the specified signal is output when an error occurs during execution of force control. "Default : OFF"
Output Signal Type (Signal Output for ERR)	Select the type of signal to output when an error occurs during execution of force control with the error signal output function. The type of signal that can be specified are DO, RO, and FLAG. "Default : DO"
Output Signal Number (Signal Output for ERR)	Select the number of signal to output when an error occurs during execution of force control with the error signal output function. "Default : 0"
Frc.Ctrl. End by REG SW	This is the switch for monitoring a Numeric Register value during force control and ending force control when the Numeric Register value changes, in addition to usual ending conditions. This can be set to 'On' or 'Off'. Set "On" to add user-defined conditions to the exit conditions. "Default : OFF"
End Register Number	If "Frc.Ctrl. End by REG SW" is ON, • The value of the Numeric Register whose number is designated by this parameter automatically becomes 0 when a force control instruction with this schedule starts. • If the value of the Numeric Register whose number is designated by this parameter becomes 1, the force control instruction with this schedule ends. "Default : 0"
Init. Rot. Slow Down SW	This switch sets the function for slowing down the initial rotation speed. This can be set to 'On' or 'Off'. "Default : OFF"
Initial Depth	Enter the threshold value of the depth for stopping initial slow down. "Default : 5.00 mm"
Init. Rotation Rate	Enter the ratio for initial slow down. "Default : 10.00 %"
G F S	G represents a motion group number at the time of teaching. F represents a force control number. S represents a force sensor number. (These settings cannot be changed.) "Defaults : 1 1 1"

Function keys

The function keys indicated have the following functions:

Table 1.5.6.1 (c) Function keys

Key	Item	Description
F1	TYPE	Allows you to change the display to a menu other than the force control menu.
F2	GROUP	Allows you to change motion groups.
	HELP	Display the help screen.
F3	NUMBER	Allows you to display the screen for another schedule number.
F4	CHOICE	Displays the choices for the setting.
	ON	Changes the setting to 'On'.
Shift + F4	DEFAULT	Allows you to set default data of the force control function.
F5	PERFORM / BASIC	Allows you to switch between the basic and performance screens.
	OFF	Changes the setting to 'Off'.

1.6 FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)

Overview

The force control gain is a parameter that determines the response speed of force control. Increasing the value improves response speed, but the robot may vibrate if the value is too high.
Adjust the force control gain if vibrations become pronounced during force control or if operations are sluggish during force control.
When the force control function is set to something other than "Contouring", this value is not normally used if force control gain auto adjustment is complete.
(Refer to "Basic Function Guide: 1.11.2 Force Control Gain Auto Tuning Instruction".)
When the force control function is set to 'Contouring', make sure to set a value manually because auto adjustment cannot be performed.
There are two types of [Impedance detail] screen, depending on the 'XX Impedance' setting; the 'Indivi-Freq.' screen and 'Master Frequency' screen.

Tuning the Force Control Gain

1 Move the cursor to [Force Control Gain :Detail] on the [Basic Data Settings] screen for each function, and press the [ENTER] key on the teach pendant of the robot controller.
The [Force Ctrl/Gain] screen is displayed.
(Refer to "Basic Function Guide: 1.5 SCHEDULE DATA".)

2 Move the cursor to [XX Impedance] on the [Force Ctrl/Gain] screen, and press F4 [CHOICE].
The menu is displayed.

3 Select the target impedance from 'Indivi-Freq.' or 'Master Freq.', and press the [ENTER] key on the teach pendant of the robot controller.
The following [Impedance detail] screen is displayed.
- [Impedance detail] screen for 'Indivi-Freq.'
- [Impedance detail] screen for 'Master Freq.'

4 Adjust the force control gain.
- For the [Impedance detail] screen for 'Indivi-Freq.'

```
Impedance detail
                                                    1/6
    Input Individual Frequency (Hz)
     1                     X:      0.007
     2                     Y:      0.007
     3                     Z:      0.007
     4                     W:      0.005
     5                     P:      0.005
     6                     R:      0.005

 [TYPE]  |        |        |        |        |   >
  F1        F2       F3       F4       F5
```

Table 1.6 (a) 'Individual Frequency' Screen

Item	Description
Individual Frequency	This parameter determines the response speed of force control. Unlike the master frequency, the response can be changed on a direction-by-direction basis. Enter a value. As the direction value of "Frequency" increases, the responsiveness of force control increases, but the vibration may also increase. As the value of "Frequency" decreases, the vibration decreases, but the response in force control also decreases, resulting in sluggish operation. "Unit : Hz"

- For the [Impedance detail] screen for 'Master Frequency'

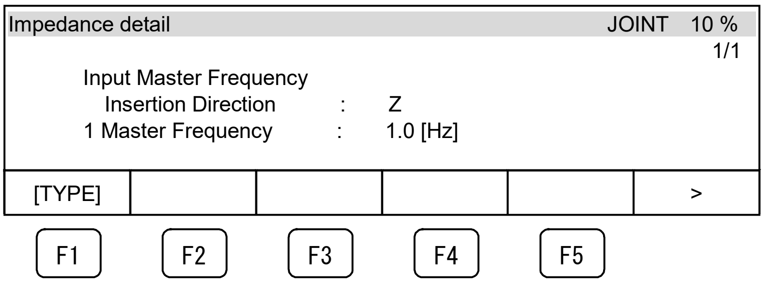


Table 1.6 (b) 'Master Frequency' Screen

Item	Description
Insertion Direction	This indicates the direction in which insertion is performed. This value cannot be changed.
Master Frequency	This parameter determines the response speed of force control. In particular, the parameter for determining the response speed in the insertion direction is called the [Master Frequency]. Enter a value. As the value of "Master Frequency" increases, the responsiveness of force control increases, but the vibration may also increase. As the value of "Master Frequency" decreases, the vibration decreases, but the responsiveness of force control also decreases, resulting in sluggish operation. If you change the value for [Master Frequency], the frequency of the five directions other than the insertion direction also changes by the same ratio. If the force control function is set to "Contouring", the default value is set according to the robot, as indicated below. For the LR Mate 200*i*D, M-10*i*A, or M-20*i*A: About 0.500 Hz For the M-710*i*C, R-1000*i*A, R-2000*i*B, or R-2000*i*C: About 0.100 Hz Observe whether the robot does not vibrate during force control and increase it by about same value. "Unit : Hz"

1.7 SUCCESSIVE EXECUTION OF FORCE CONTROL INSTRUCTIONS (CUSTOMIZATION FUNCTION)

There are 13 types of 'FORCE CTRL' instructions in total as mentioned in '1.3 FORCE CTRL Instruction'. While a single force control instruction may be used to operate the robot, multiple force control instructions may also be executed successively to allow the robot to perform complicated assembly work and, in case of an insertion failure, retry operation.
(Refer to "Basic Function Guide: 1.7.1 Combination of Force Control Operations", "Basic Function Guide: 1.7.2 Retry".)
The user can combine force control instructions freely for execution, so that this function is referred to as the customization function.
There are three types of the customizing function.

(1) Simple Customization Function :
If this function is valid for a force schedule, it can be executed after any other force schedule. The initial force sensor values which are acquired as basis when the previous schedule is executed are also used for this schedule.
(Refer to "Basic Function Guide: 1.7.3 Simple Customization Function".)

(2) Customization Function:
It enables to successively execute more than one force schedules by setting parent-child relationship. The initial force sensor values which are acquired as basis when the parent schedule is executed are also used for all child schedules. If the “Force Control Gain” of a schedule is changed, it can be automatically copied to the gain of its parent or child schedule.
(Refer to "Basic Function Guide: 1.7.4 Customization Function".)

(3) Customization Auto Continuous Execution Function :
It enables automatic continuous execution of several schedules by setting parent-child relationship. Teach only a force control instruction which corresponds to a parent schedule in TP program, then child schedules are automatically executed one after another. Several schedules are combined and executed as if they are ONE schedule.
(Refer to "Basic Function Guide: 1.7.5 Customization Automatic Continuous Execution Function".)

1.7.1 Combination of Force Control Operations

This section describes how to perform complicated assembly by continuously executing multiple FORCE statements.
In this example, the following continuous operation is performed.
(1) Insert a gear into a shaft. Continue insertion until the gear touches another gear.
(2) Once the gear touches the other gear, perform rotation for phase matching.
Such a combination of operations can be enabled by executing force control instructions successively.

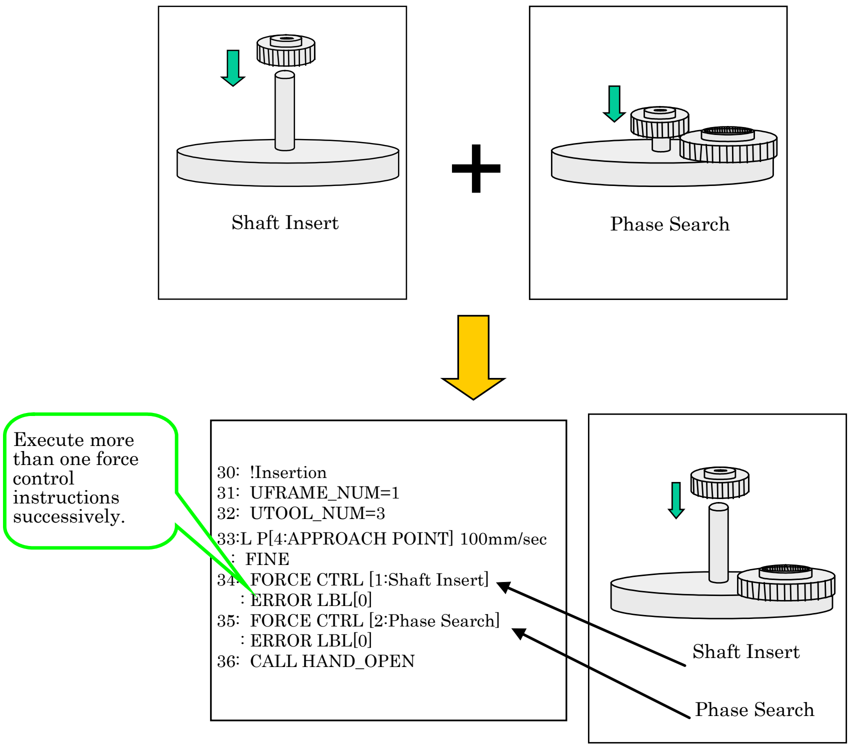


Fig. 1.7.1 Combination of force control operations

1.7.2 Retry

This section describes the retry operation when insertion fails.
In this example, extraction is performed by continuously executing FORCE statements in the opposite direction if a failure occurs during force control. Such retry operation can improve the percentage of success.

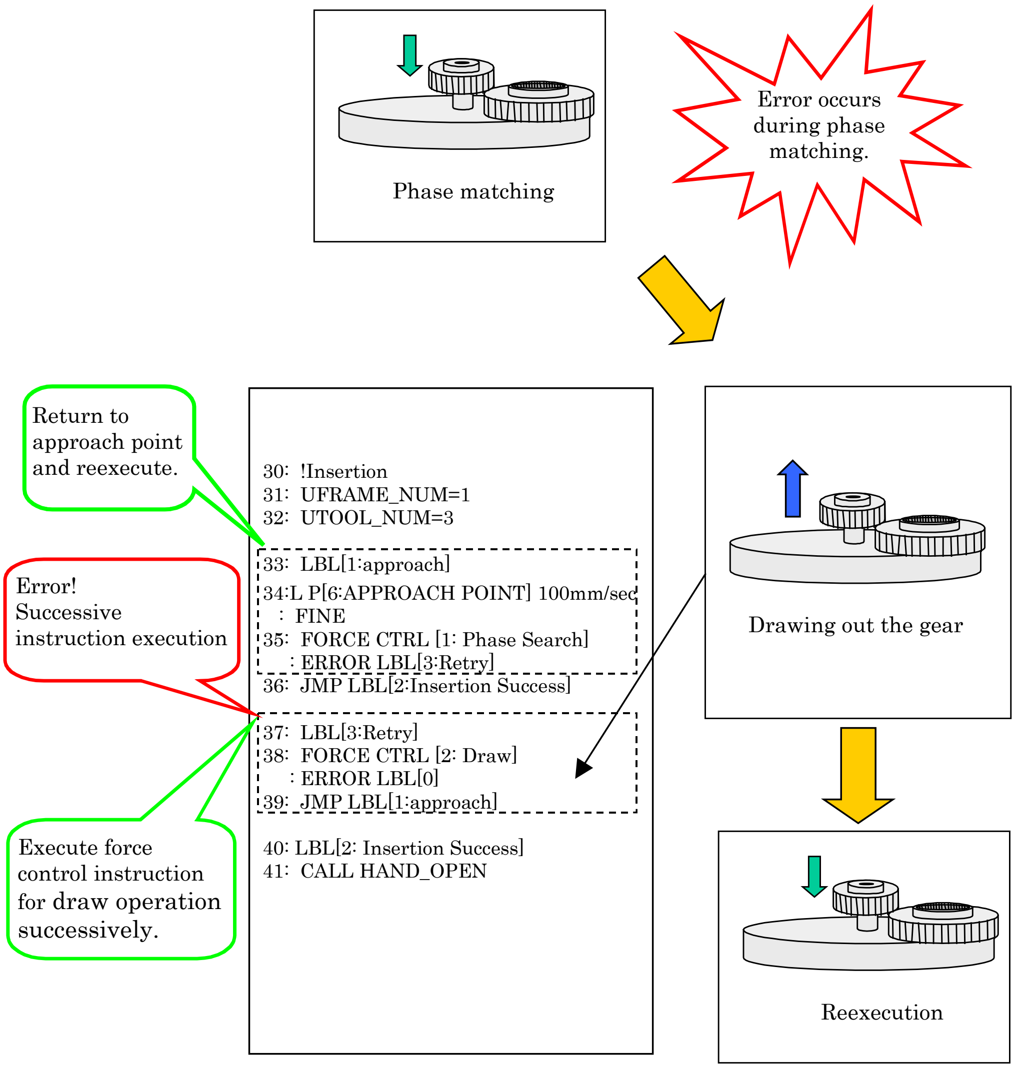


Fig. 1.7.2 Retry

1.7.3 Simple Customization Function

A force control schedule with this function enabled can be executed after an arbitrary force control schedule.
The following sections describe the compound operation explained in '1.7.1 Combination of Force Control Operations' and the method for retrying explained in '1.7.2 Retry'. Only [Shaft Insert], [Groove Insert], [Square Insert] can be used for a Retry.
(Refer to "Basic Function Guide: 1.7.1 Combination of Force Control Operations", "Basic Function Guide: 1.7.2 Retry".)

1.7.3.1 Combination of force control operations by simple customization function

Sample program

In this example, compound operations using the simple customization function are described using the following sample program.
Simple customization is used to execute FORCE statements for three schedules in the order [Shaft Insert] -> [Phase Search] -> [Shaft Insert].

```
          :                    :
30:   !Insertion
31:   UFRAME_NUM = 1
32:   UTOOL_NUM = 3
33:L P[6:approach] 100mm/sec
   :   FINE

34:   FORCE CTRL[1:Shaft Insert]
   :   ErrorLBL[0]
35:   FORCE CTRL[2:Phase Search]
   :   ErrorLBL[0]
36:   FORCE CTRL[3:Shaft Insert]
   :   ErrorLBL[0]

37:   CALL HAND_OPEN
38: L P [7] 100mm/sec FINE
[End]
```

Fig.1.7.3.1 (a) Example TP Program

The simple customization function is disabled for the first FORCE statement ([Shaft Insert] for schedule 1), and parameters are set as with a standalone schedule.

```
Force Ctrl/Perform

 Schedule[1]                G:1 F:1 S:1
1  Function               : Shaft Insert
2  Comment                : [ Shaft Insert ]
3  Simple Customize Sw            : OFF
4     Retry Sw                 :    OFF
5     Cont. Exec. Max. Count    :      1
6  Customize Parent Number  :        0
```

Fig. 1.7.3.1 (b) Example configuration for schedule data (schedule 1)

For a second (Phase Search , schedule 2) and a third force control instruction (Shaft Insert , schedule 3), "Simple Customization" are valid. Set following parameters in Performance data setting screen.

```
Force Ctrl/Perform

 Schedule[2]                G:1 F:1 S:1
1  Function               : Phase Search
2  Comment                : [Phase Search ]
3  Simple Customize Sw            :  ON
4     Cont. Exec. Max. Count    :      1
5  Customize Parent Number  :        0
```

Fig. 1.7.3.1 (c) Example configuration for schedule data (schedule 2)

```
Force Ctrl/Perform

 Schedule[3]              G:1 F:1 S:1
1  Function              : Shaft Insert
2  Comment               : [ Shaft Insert ]
3  Simple Customize Sw          : ON
4     Retry Sw              :    OFF
5     Cont. Exec. Max. Count    :     2
6  Customize Parent Number  :        0
```

Fig. 1.7.3.1 (d) Example configuration for schedule data (schedule 3)

Table 1.7.3.1 Performance data setting screen

Item	Description
Simple Customize Sw	When the schedule data being edited is used after other schedule and make combined motion, turn on this switch. If it is ON, the initial force sensor values which are acquired as basis when the previous schedule is executed are also used for this schedule. "Default : OFF"
Retry Sw*	When the schedule data being edited is used after other schedule not as a retry but as a general combined motion, select OFF. "Default : OFF"
Cont. Exec. Max. Count	It designates how many force schedules with "Simple Customize Sw" ON can be executed successively. In the program which is shown in Fig.1.7.3.1 (b), if the simple customization is invalid for schedule 1 and valid for schedule 2 and 3, it should be 1 or bigger for schedule 2 and 2 or bigger for schedule 3. "Default : 1"

* It exists only for [Shaft Insert], [Groove Insert], [Square Insert].

> ⚠ **CAUTION**
> Take care, as the actual pushing force will be higher than the set value if a statement is executed immediately after the previous schedule when [Simple Customize Sw] is set to 'OFF'.

> **NOTE**
> 1 [Simple Customize Sw] cannot be set to 'On' if [Customize Parent Number] is set to a value other than '0' (customizing and simple customizing cannot be used for the same schedule at the same time). The message 'Customize and Simple Customize are Prohibit Cmb.' is displayed on the bottom of the screen.
> (Refer to "Basic Function Guide: 1.7.4 Customization Function".)
> 2 [Customize Auto. Cnt. Exec. Sw] and [Simple Customize Sw] can both be set to 'On' (customizing auto continuous execution and simple customizing can be used for the same schedule at the same time).
> (Refer to "Basic Function Guide: 1.7.5 Customization Automatic Continuous Execution Function".)
> However, [Retry Sw] must be set to 'OFF'. If it is not set to 'OFF', the message 'Ctm. Auto Cnt. and Retry are Prohibit Cmb.' is displayed on the bottom of the screen.

1.7.3.2 Retry by simple customization function

Sample program

In this example, the retry operation is described using the following sample program.
In this example, FORCE statements are executed in the order [Shaft Insert] -> [Phase Search] -> [Shaft Insert] as with " Basic Function Guide: 1.7.3.1 Combination of Force Control Operations by Simple Customization Function".

```
          :                 :
 30:   !Insertion
 31:   UFRAME_NUM = 1
 32:   UTOOL_NUM = 3

 33:   LBL[1:approach pos]
 34:L P[6:approach] 100mm/sec
   :   FINE
 35:   FORCE CTRL[1:Shaft Insert]
   :   ErrorLBL[2]
 36:   FORCE CTRL[2:Phase Search]
   :   ErrorLBL[2]
 37:   FORCE CTRL[3:Shaft Insert]
   :   ErrorLBL[2]
 38:   JMP LBL[3:Insert Success]

 39:   LBL[2:retry]
 40:   FORCE CTRL[4:Withdraw]
   :   ErrorLBL[0]
 41:   JMP LBL[1: approach pos]

 42:   LBL[3: Insert Success]
[End]
```

Fig. 1.7.3.2 (a) Example TP Program

If an error occurs during one of these FORCE statements, extraction is automatically performed by executing the force control schedule for retrying (schedule 4).
The types of force control schedules that can be retried are [Shaft Insert], [Groove Insert], and [Square Insert].
The parameters on the [Basic Data Settings] screen and [Performance Data Settings] screen for schedule 4 are configured as follows for retrying.

```
Force Ctrl/Perform

 Schedule[4]              G:1 F:1 S:1
1  Function             : Shaft Insert
2  Comment              : [ Withdraw ]
3  Simple Customize Sw           :   ON
4    Retry Sw               :  ReturnPos1
5    Cont. Exec. Max. Count      :    3
6  Customize Parent Number  :         0
```

Fig. 1.7.3.2 (b) Example configuration for schedule data (schedule 4)

Table 1.7.3.2 (a) Basic data setting screen

Item	Description
Insert Direction	The [Insert Direction] of the schedule data being edited has to be opposite of that of previously executed schedule. For example, if the insertion direction of previously executed schedule is '+Z', set '–Z' here. When the [customization function] or [customization automatic continuous execution function] is valid for previously executed schedule, the [Insert Direction] of all schedules that are connected with parent-child relationship have to be same and opposite of the schedule data being edited. (Refer to "Basic Function Guide: 1.7.4 Customization Function", "Basic Function Guide: 1.7.5 Customization Automatic Continuous Execution Function".) "Default : –Z"

Item	Description
User Frame No.	The [User Frame No.] of the schedule data being edited has to be same as that of previously executed schedule. For example, if the User Frame number of previously executed schedule is 3 , set 3 here. When the [customization function] or [customization automatic continuous execution function] is valid for previously executed schedule, the [User Frame No.] of all schedules that are connected with parent-child relationship and of the schedule data being edited have to be same. (Refer to "Basic Function Guide: 1.7.4 Customization Function", "Basic Function Guide: 1.7.5 Customization Automatic Continuous Execution Function".) "Default : UF : 0"
Tool Frame No.	The [Tool Frame No.] of the schedule data being edited has to be same as that of previously executed schedule. For example, if the Tool Frame number of previously executed schedule is 2 , set 2 here. When the [customization function] or [customization automatic continuous execution function] is valid for previously executed schedule, the [User Frame No.] of all schedules that are connected with parent-child relationship and of the schedule data being edited have to be same. (Refer to "Basic Function Guide: 1.7.4 Customization Function", "Basic Function Guide: 1.7.5 Customization Automatic Continuous Execution Function".) "Default : TF : 1"

Table 1.7.3.2 (b) Performance data setting screen

<table>
<tr><th>Item</th><th colspan="2">Description</th></tr>
<tr><td>Simple Customize Sw</td><td colspan="2">When the schedule data being edited is used as a retry for other schedule, turn on this switch. If it is ON, the initial force sensor values which are acquired as basis when the previous schedule is executed are also used for this schedule.
"Default : OFF"</td></tr>
<tr><td rowspan="2">Retry Sw*</td><td colspan="2">When the schedule data being edited is used as a retry for other schedule, select 'ReturnPos1' or "'ReturnPos2'.
It is possible to make a retry with this parameter 'OFF'. In this case, the withdrawal distance is same as [Insert Depth (Design)] in Basic data setting screen.
"Default : OFF"</td></tr>
<tr><td>If it is 'ReturnPos1'</td><td>A withdrawal distance is decided by the setting of previously executed force schedule and how far the workpiece was inserted by it. The value of [Insert Depth (Design)] of the schedule data being edited is neglected.
• If a previously executed force schedule does not have a Parent Schedule, the robot withdraws a workpiece to a starting point of previous schedule.
(Refer to "Basic Function Guide: 1.7.4 Customization Function".)
• If a previously executed force schedule has a Parent Schedule, the robot withdraws a workpiece to a starting point of previous schedule's greatest parent schedule. Take an example in Fig.1.7.3.2 (a), if the schedule 1 is a parent of schedule 2 and the schedule 2 is a parent of schedule 3 and when the schedule 3 failed, the robot withdraws a workpiece to a starting point of schedule 1.
(Refer to "Basic Function Guide: 1.7.4 Customization Function".)
• If "Customize Auto. Cnt. Exec. Sw" of a previous force schedule is ON, the robot withdraws a workpiece to a starting point of it.
(Refer to "Basic Function Guide: 1.7.5 Customization Automatic Continuous Execution Function".)</td></tr>
</table>

Item	Description	
Retry Sw*	If it is 'ReturnPos2'	A withdrawal distance is decided by the setting of previously executed force schedule and how far the workpiece was inserted by it. The value of 'Insert Depth (Design)' of the schedule data being edited is neglected. • If a previously executed force schedule does not have a Parent Schedule, the robot withdraws a workpiece to a starting point of previous schedule. (Refer to "Basic Function Guide: 1.7.4 Customization Function".) • If a previously executed force schedule has a Parent Schedule, the robot withdraws a workpiece to a starting point of previous schedule. It does not go back to a starting point of previous schedule's parent schedule. Take an example in Fig. 1.7.3.2 (a), if the schedule 1 is a parent of schedule 2 and the schedule 2 is a parent of schedule 3 and when the schedule 3 failed, the robot withdraws a workpiece to a starting point of schedule 3 (not schedule 1). (Refer to "Basic Function Guide: 1.7.4 Customization Function".) • If [Customize Auto. Cnt. Exec. Sw] of a previous force schedule is ON, the robot withdraws a workpiece to a starting point of it. (Refer to "Basic Function Guide: 1.7.5 Customization Automatic Continuous Execution Function".)
Cont. Exec. Max. Count	It designates how many force schedules with [Simple Customize Sw] ON can be executed successively. In the program which is shown in Fig. 1.7.3.2 (a), if the simple customization is invalid for schedule 1 and valid for schedule 2, 3 and 4, it should be 1 or bigger for schedule 2 and 2 or bigger for schedule 3 and 3 or bigger for schedule 4. "Default : 1"	

* It exists only for [Shaft Insert], [Groove Insert], [Square Insert].

> ⚠ **CAUTION**
> It may not be possible to perform extraction if a statement is executed immediately after the previous schedule when [Simple Customize Sw] is set to "OFF".

> **NOTE**
> 1 [Simple Customize Sw] cannot be set to 'ON' if [Customize Parent Number] is set to a value other than '0' (customizing and simple customizing cannot be used for the same schedule at the same time). The message 'Customize and Simple Customize are Prohibit Cmb.' is displayed on the bottom of the screen.
> (Refer to "Basic Function Guide: 1.7.4 Customization Function".)
> 2 The Function of a previously executed force schedule or the schedules which are connected with parent-child relationship have to be other than 'Contour' or 'Contour End' in case of retry. Or the alarm will be issued.

1.7.3.3 Extracting an inserted workpiece

Sample program

This section shows an example of how to grasp and extract a workpiece that was previously inserted. For example, a workpiece might be inserted into a jig for finishing by a machine tool and then be extracted after finishing. It might not be possible to cleanly extract the workpiece with a simple FORCE statement because the operation for grasping it applies a certain amount of force.
In this case, the FORCE statements [Shaft Insert (for obtaining the standard force value)] → [Shaft Insert (for extraction)] should be executed in that order.

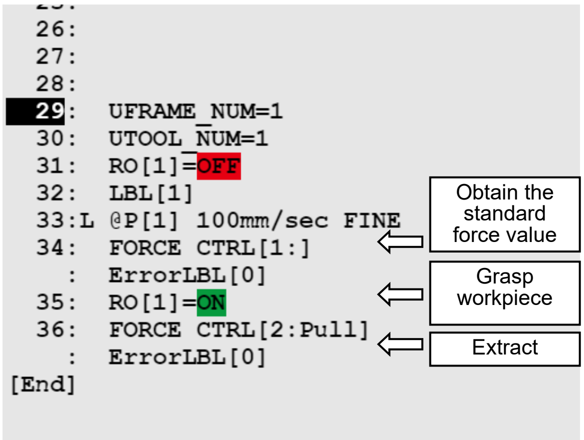


Fig. 1.7.3.3 (a) TP Program example

In the example above, use position [1] as the position for grasping, and make sure that the hand does not come into contact with the workpiece or surrounding devices to avoid applying force to the force sensor. At this position, the FORCE statement of Schedule No. 1 is executed. This FORCE statement is necessary to obtain the basis value of the force sensor. To finish in a short amount of time, settings are made as follow, for example. (Insert Depth (Design) is 0 mm, Approach Velocity and Insert Force are as small as possible)

```
Force Ctrl/Basic

 Schedule[1]                G:1 F:1 S:1
 1 Function            : Shaft Insert
 2 Comment             : [                 ]
 3 User Frame No.              UF:   0
 4 Tool Frame No.              TF:   1
 5 Insert Direction                : -Z
 6 Insert Depth (Design):     20.00 mm
 7 Individual Diff. (+) :      3.00 mm
 8 Individual Diff. (-) :      0.00 mm
 9 Approach Velocity    :      1.00 mm/s
10 Insert Velocity      :      0.00 mm/s
```

Fig. 1.7.3.3 (b) Schedule data setting example (Schedule No. 1)

After the workpiece is grasped, the FORCE statement of Schedule No. 2 is executed. Extraction is performed with this FORCE statement, but because the basis value of the force sensor obtained with Schedule No. 1 is used, the Simple Customize Sw on the [Performance Data Settings] screen is set. Refer to tables 1.7.3.3 (a) and 1.7.3.3 (b).

```
Force Ctrl/Perform

 Schedule[2]                 G:1 F:1 S:1
 1 Function          : Shaft Insert
 2 Comment           : [Pull                ]
 3 Simple Customize Sw              : ON
 4   Retry Sw                :OFF
 5   Cont. Exec. Max. Count      :    1
 6 Customize Parent Number   :        0
```

Fig. 1.7.3.3 (c) Schedule data setting example (Schedule No. 2)

Table 1.7.3.3 (a) [Basic Data Settings] screen

Item	Description
Insert Direction	Set [Insert Direction] as the direction for extraction. "Default : -Z"
User Frame Number	[User Frame Number] in the schedule data being edited is the same as [User Frame Number] in the previously executed schedule (for obtaining the basis value of the force sensor). For example, if [User Frame Number] in the previously executed schedule is "3", set "3" here. "Default : UF:0"
Tool Frame Number	[Tool Frame Number] in the schedule data being edited is the same as [Tool Frame Number] in the previously executed schedule (for obtaining the basis value of the force sensor). For example, if [Tool Frame Number] in the previously executed schedule is "2", set "2" here. "Default : TF:1"

Table 1.7.3.3 (b) [Performance Data Settings] screen

Item	Description
Simple Customize Sw	Set this switch to "ON". When it is "ON", [Default Force Sensor] of the previously executed sensor is used as the basis value.
Retry Sw *	Set to "OFF". The distance to move is the value set for [Insert Depth (Design)] on the [Basic Data Settings] screen.

※ It saved only in [Shaft Insert], [Groove Insert], and [Square Insert].

⚠ CAUTION

It may not be possible to perform extraction if a statement is executed when [Simple Customize Sw] is set to "OFF".

NOTE

1. [Simple Customize Sw] cannot be set to "ON" when [Customize Parent Number] is a value other than "0". (Customizing and Simple Customizing cannot be used at the same time in the same schedule.) "Customize and Simple Customize are Prohibit Cmb." is displayed at the bottom of the screen.
(Refer to "Basic Functions Guide"1.7.4 Customization Function".)
2. The schedule data to execute first must be something other "Contouring" or "Contouring end". If the schedule data to execute first or schedule data in a parent-child relationship to it is "Contouring" or "Contouring end" and you try to execute a retry with Simple Customize, an alarm occurs.

1.7.4 Customization Function

Parent/child relationships can be set for multiple FORCE statements and used in compound operations and retries. This is similar to the simple customization function, but with this function the order for executing the force control schedules is clearly defined. Also, when the force control gain value is changed for a single schedule, it can also be changed for the other schedules with a parent/child relationship.
(Refer to "Basic Function Guide: 1.7.1 Combination of Force Control Operations", "Basic Function Guide: 1.7.2 Retry", "Basic Function Guide: 1.7.3 Simple Customization Function".)

1.7.4.1 Specifying the parent-child relationship

Overview

When more than one force control instructions are successively executed, the former instruction is called 'Parent' schedule and the latter instruction is called 'Child' schedule. The Parent - Child relationship is set by specifying parent's schedule number to the parameter [Customize Parent Number] on the performance screen of the child schedule. By default, this parameter is set to 0, that indicates that the force control operation is executed independently or that in successive execution, the schedule data is for the force control instruction to be executed first.

Sample program

In this example, the following sample program (continuous executing of three FORCE statements) is used. The schedule number of the first force control instruction is 1, the second one's schedule number is 2, the last one's schedule number is 3, respectively.

```
30:   !Insertion
31:   UFRAME_NUM=1
32:   UTOOL_NUM=3
33:L P[6:APPROACH POINT] 100mm/sec
    :   FINE
34:   FORCE CTRL [1: Shaft Insert]
      : ERROR LBL[0]
35:   FORCE CTRL [2: Phase Search]
      : ERROR LBL[0]
36:   FORCE CTRL [3: Shaft Insert]
      : ERROR LBL[0]

37:   CALL HAND_OPEN
38:L P[7] 100mm/sec :   FINE
```

Fig. 1.7.4.1 (a) Example TP Program

[Customize Parent Number] is set to '0' because there is no parent for schedule data 1.

```
Force Ctrl/Perform

 Schedule[1]                G:1 F:1 S:1
1  Function              : Shaft Insert
2  Comment               : [ Shaft Insert ]
3  Simple Customize Sw            : OFF
4     Retry Sw                  :    OFF
5     Cont. Exec. Max. Count      :     1
6  Customize Parent Number  :         0
```

Fig. 1.7.4.1 (b) Example schedule data settings (schedule 1)

Since schedule data 2 will be the parent of schedule data 1, specify "1" for [Customize Parent Number] as indicated below.

```
Force Ctrl/Perform

 Schedule[2]                G:1 F:1 S:1
1  Function              : Phase Search
2  Comment               : [Phase Search ]
3  Simple Customize Sw            : OFF
4     Cont. Exec. Max. Count      :     1
5  Customize Parent Number  :         1
```

Fig. 1.7.4.1 (c) Example schedule data settings (schedule 2)

Also, since schedule data 3 will be the parent of schedule data 2, specify "2" for [Customize Parent Number] as indicated below.

```
Force Ctrl/Perform

 Schedule[3]                G:1 F:1 S:1
1  Function              : Shaft Insert
2  Comment               : [ Shaft Insert ]
3  Simple Customize Sw          : OFF
4    Retry Sw                   :   OFF
5    Cont. Exec. Max. Count     :     1
6  Customize Parent Number  :       2
```

Fig. 1.7.4.1 (d) Example schedule data settings (schedule 3)

Table 1.7.4.1 Performance data setting screen

Item	Description
Customize Parent Number	When the schedule data being edited is to be used as child data of another schedule data, the parent schedule data number is specified. When this setting is made, the impedance parameters are copied from the parent to child or vice versa according to [Customize PareChg Connection] described below. By default, 0 is set, meaning independent execution. "Default : 0"
Customize ParaChg Conct	If schedule data has a parent-child relationship, the impedance parameters are copied when: • Impedance data has been modified. • [Customize Parent Number] mentioned above has been set. The copy direction between the parent and child is specified by this parameter. One of the following four directions can be selected: (a) BothD: When modification to the parent or child schedule data is made, parameter data is copied to the other. (b) P2C : Parameter data is copied from the parent to child schedule data. (c) C2P : Parameter data is copied from the child to parent schedule data. (d) OFF : Even when impedance parameters are modified, copy is not taken. "Default : OFF"

1.7.4.2 Combination of force control operations by customization function

Whenever force control instructions are executed successively, the parent-child relationship must always be specified as described in "Basic Function Guide: 1.7.4.1 Specifying the Parent-Child Relationship".

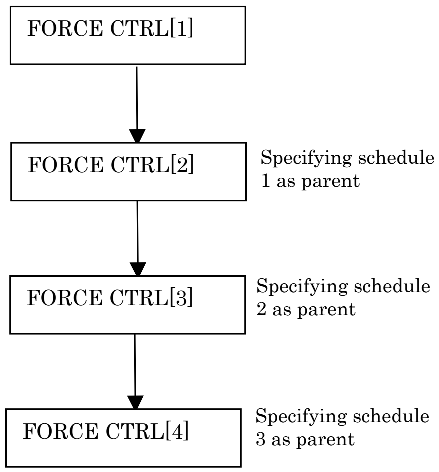
> ⚠ **CAUTION**
> That if multiple force control instructions are successively executed without specifying the parent-child relationship, the actual pushing force may become greater than the set value when a second or subsequent force control instruction is executed.

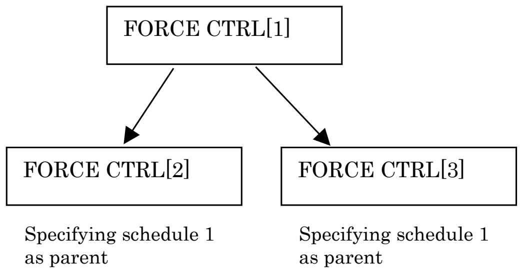
1.7.4.3 Retry by customization function

When child schedule data uses the same user frame and tool frame as the parent schedule data and specifies the insertion direction opposite to that specified by the parent schedule data, the child schedule data is regarded as schedule data for retry operation. (Example: The insertion direction of the parent schedule is –Z, and the insertion direction of the child schedule is +Z.) However, contouring function has no child schedule for retry operation.

1.7.4.4 Notes and restrictions

(a) A single set of schedule data can have up to two sets of child schedule data including one for retry operation and the other for operation other than the retry operation. However, contouring function can have only one child schedule for other than retry operation.
(b) Schedule data for retry operation cannot have its child schedule data.





In the example above, schedule 2 and schedule 3 specify schedule 1 as the parent.
Two or more schedules for insertion cannot be possessed as child schedules. However, one schedule may be possessed for insertion operation, and another schedule may be possessed for retry operation.
Successive execution is enabled if schedule 2 or schedule 3 is schedule data for retry, operation of schedule 1.
Successive execution is disabled if both schedule 2 or schedule 3 is schedule data for insertion operation of schedule 1.
Successive execution is also disabled if schedule 2 and schedule 3 are both for retry operation of schedule 1.

Fig. 1.7.4.4 (a) Example for successive execution of force control instructions (1/2)

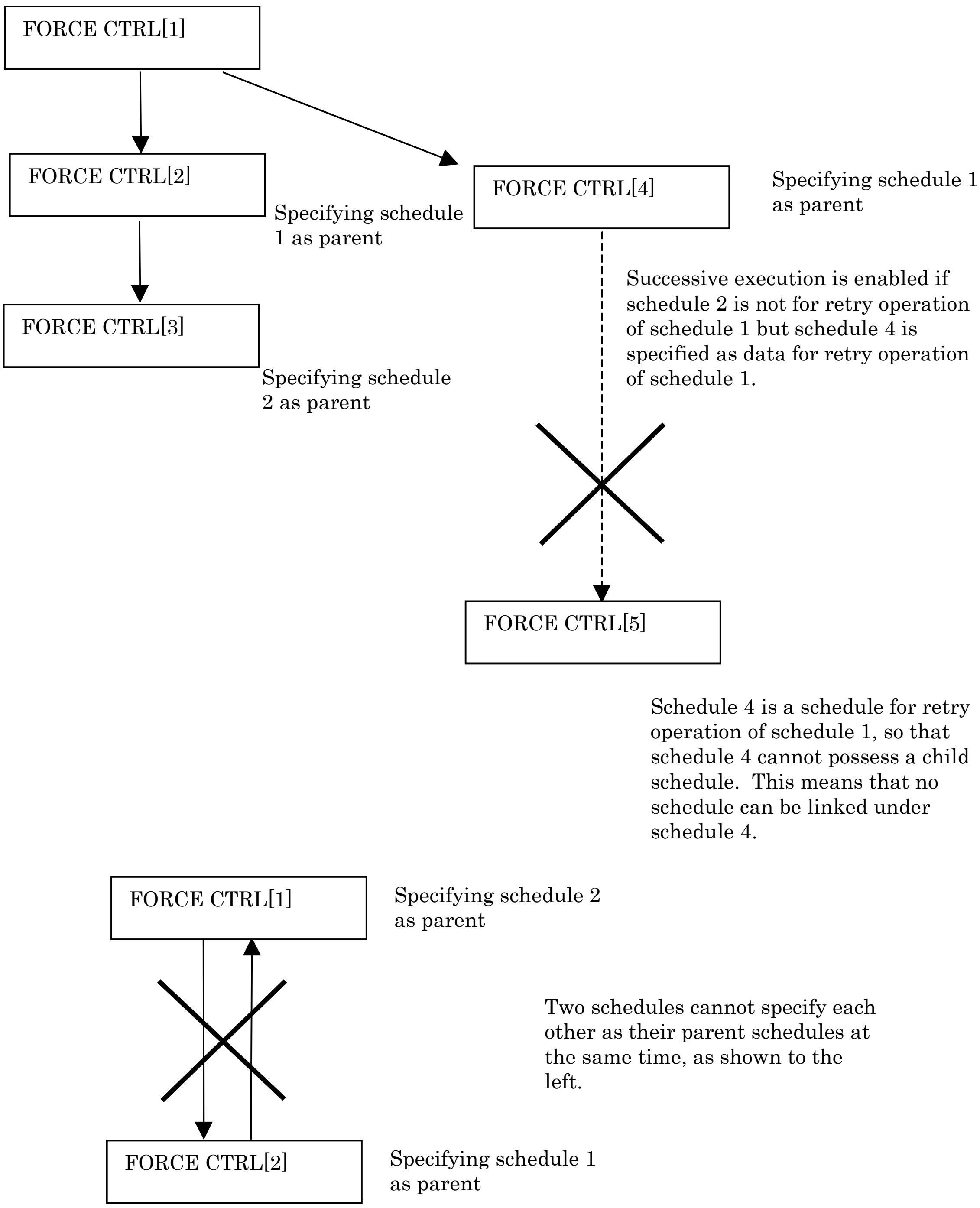


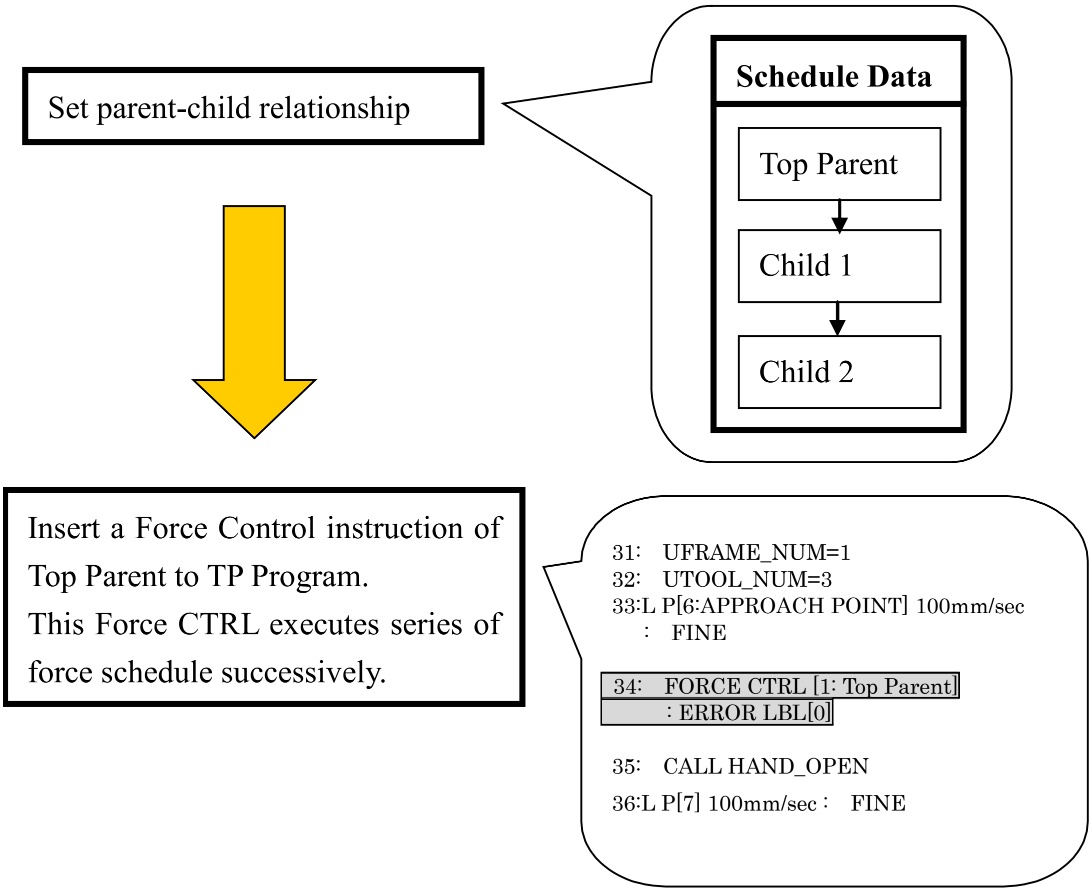
Fig. 1.7.4.4 (b) Example for successive execution of force control instructions (2/2)

1.7.5 Customization automatic continuous execution function

Overview

'Customize Auto. Cnt. Exec.' function enables to execute a series of the force control schedule data, which are combined with customization function, with a single force control instruction of the top parent schedule data.

Series of force schedules that are connected by Parent-Child relationship are executed as if they are 'One' new schedule.
With the customization function, the schedule data is linked by specifying the parent in 'Customize Parent Number'. However, with the customization auto continuous execution function, the schedule data is linked by specifying parent/child relationships.
With the customization function, it is necessary to insert all the parent/child FORCE statements to execute in the TP program. However, with the customization auto continuous execution function, only the FORCE statement for the top parent is inserted in the TP program. In other words, the force control set in the schedule data can be automatically executed continuously from the parent to the child.
With the customization function, it takes some time (about 0.3 seconds) to link from parent to child when executing continuous FORCE statements. However, with the customization auto continuous execution function, this time is not taken.
(Refer to "Basic Function Guide: 1.7.4 Customization Function")



⚠ CAUTION

1. When executing "Customize Auto. Cnt. Exec." function, following functions must be set to invalid.
   - 'Torque Error Acquisition'
   - 'End Condition Acquisition'
   - 'Force Control Gain Auto Tuning'
2. Make sure that the parameters relating to the following frame settings are the same in the series of schedule data when using the customization auto continuous execution function.
   - 'User Frame No.'
   - 'Tool Frame No.'
   - 'User Frame Compensation'
3. The types of the force control function that can be linked with [Customize Auto. Cnt. Exec.] function are [Constant Push], [Face Match], [Shaft Insert], [Square Insert], [Groove Insert], [Search], [Hole Search], [Clutch Search], [Phase Search], [Threading]. Other functions cannot use 'Customize Auto. Cnt. Exec.'.
4. 'Customize Auto. Cnt. Exec.' function can link the schedule data up to 10. In other words, up to 9 schedule data can follow the top parent schedule data.

Sample program

In this example, the customization auto continuous execution function is described using the following sample program.

Take an example program in which three schedule data are automatically and successively executed with a single force control instruction by "Customize Auto. Cnt. Exec." function as an example. This TP program executes the series of the schedule data in the order of schedule data 1, schedule data 2, schedule data3. The force control instruction of the top parent schedule data (schedule data 1) is inserted into the TP Program.

```
30:
31:  UFRAME_NUM=1
32:  UTOOL_NUM=3
33:L P[6:APPROACH POINT] 100mm/sec
   :  FINE

34:  FORCE CTRL [1: Top Parent]
     : ERROR LBL[0]

35:  CALL HAND_OPEN
36:L P[7] 100mm/sec :  FINE
```

Fig. 1.7.5 (a) Example TP Program

NOTE

1. It is impossible to execute a force control instruction as the child with the Customization Function after the force control instruction that is the top parent of 'Customize Auto. Cnt. Exec.' function in TP Program. (Customization Function cannot have 2 children that are not regarded as that for the retry operation.)
2. When an error occurs while executing the series of the schedule data, jump to the 'LBL' instruction specified by the Error Label Number of the force control instruction of the top parent schedule data irrespective of the running schedule data number.

Set the [Customize Auto. Cnt. Exec. Sw] to 'On' for the schedule data 1, 2, and 3 to use for the customization auto continuous execution function.
Set [Customize Parent Number] to '0' because there is no parent for schedule data 1.
Set [Auto. Cnt. Exec. Child No.] to '2' to make schedule data 2 the child of schedule data 1.
Only "Schedule No. Output Reg. No. " of the schedule data 1 is set because the value of the top parent is applied and the value of others are not used.

```
Force Ctrl/Perform
                                          1/39
 Schedule[1]                   G:1 F:1 S:1
 1 Function               : Shaft Insert
 2 Comment                : [Top Parent       ]
 3 Simple Customize Sw          :    OFF
 4    Retry Sw            :OFF
 5    Cont. Exec. Max. Count     :    1
 6 Customize Parent Number  :         0    <- '0' when there is no parent
 7 Customize ParaChg Conct:OFF
 8 Customize Auto. Cnt. Exec. Sw : ON
 9    Auto. Cnt. Exec. Child No.   :   2    <- '2' when schedule data 2 is a child
 10   Schedule No. Output Reg. No.:    5
```

Fig. 1.7.5 (b) Example Schedule Data (Schedule data 1)

Since schedule data 2 will be the parent of schedule data 1, set [Customize Parent Number] to '1'.
Set [Auto. Cnt. Exec. Child No.] to '3' to make schedule data 3 the child of schedule data 2.

```
Force Ctrl/Perform
                                          1/32
 Schedule[2]                   G:1 F:1 S:1
 1 Function               : Phase Search
 2 Comment                : [Child 1          ]
 3 Simple Customize Sw          :    OFF
 4    Cont. Exec. Max. Count          : 1
 5 Customize Parent Number          :    1    <- '1' when schedule data 1 is a parent
 6    Customize ParaChg Conct:OFF
 7 Customize Auto. Cnt. Exec. Sw : ON
 8    Auto. Cnt. Exec. Child No.   :   3    <- '3' when schedule data 3 is a child
 9    Schedule No. Output Reg. No.:    0
```

Fig. 1.7.5 (c) Example Schedule Data (Schedule data 2)

Since schedule data 3 will be the parent of schedule data 2, set [Customize Parent Number] to '2'.
Set [Auto. Cnt. Exec. Child No.] to '0' because schedule data 3 does not have a child.

```
Force Ctrl/Perform
                                          1/39
 Schedule[3]                    G:1 F:1 S:1
 1 Function              : Shaft Insert
 2 Comment               : [Child 2        ]
 3 Simple Customize Sw          :    OFF
 4    Retry Sw           :OFF
 5    Cont. Exec. Max. Count     :    1
 6 Customize Parent Number  :          2    ← '2' when schedule data 2 is a parent
 7 Customize ParaChg Conct:OFF
 8 Customize Auto. Cnt. Exec. Sw : ON
 9    Auto. Cnt. Exec. Child No.  :    0    ← '0' when there is no child
10    Schedule No. Output Reg. No.:   0
```

Fig. 1.7.5 (d) Example Schedule Data (Schedule data 3)

Set the parameters related to the customization auto continuous execution function as indicated below.

Table 1.7.5 Performance data setting screen

Item	Description
Customize Parent Number	Specify the parent schedule data number.
Customize Auto. Cnt. Exec. Sw	Set all schedule data to 'On' for the customization auto continuous execution function, regardless of the parent/child relationships. In schedule data with [Customize Auto. Cnt. Exec. Sw] enabled, schedule data that is normally deemed to be child schedule data for retrying is deemed to be child schedule data not for retrying.
Auto. Cnt. Exec. Child No.	Specify the child schedule data number. Enter '0' to not specify a child number. Set the number of the above schedule data with child specified in [Customize Parent Number] for the performance data of the schedule data specified in [Auto. Cnt. Exec. Child No.]. In other words, make the child specified by the parent in [Auto. Cnt. Exec. Parent No.] match the parent specified by the child in [Auto. Cnt. Exec. Child No.].
Schedule No. Output Reg. No.	[Customize Auto. Cnt. Exec.] function can output the running schedule data number to a Numeric Register. If the series of the schedule data ends normally, this function outputs 0 to the Numeric Register. When the series of the schedule data is executed, this function enables to know whether the force control of the last child schedule data ends normally or if not, which schedule data fails. It is possible to program the TP that responds to the schedule data number that fails in the middle of the series of the schedule data. If the [Schedule No. Output Reg. No.] of the top parent of the series of the schedule data equals to 0, this function does not output the value to the Numeric Register.

NOTE

1 For the following settings, the settings of the top parent in the series of schedule data are used, and the settings of the children linked with that parent are ignored.
- [Schedule No. Output Reg. No.]
- [Gravity Compensation Switch]
- [Force Denoising Sw]
- [Signal Output for ERR SW]
- [Frc.Ctrl. End by REG SW], [End Register Number]

2 The following settings of the series of schedule data follow the settings of each schedule.
- Data of "Torque Error Compensate"
- Data of "Ending Condition"
- "Contact F Threshold"
- Setting of "Force End Judgment" and "Torque End Judgment"

3 In the series of the schedule data, the setting of the pushing direction such as "Insert Direction" or "Pushing Direction" can be different.

4 While executing a series of the schedule data and when force exceeds "Contact F Threshold" of the running schedule data, all the schedule data that follow is executed as after a contact.
If a schedule data starts as before a contact and the schedule data ends without exceeding "Contact F Threshold" of the schedule data, the next child of the schedule data starts as before a contact.

5 "Change MAX Limit" for "Check Orientation Change" checks the orientation change from the orientation at the start of its schedule data.

6 Search range of search function is based on the position at the start of its schedule data.

7 Execution histories of force control instructions in the case of "Customize Auto. Cnt. Exec." Function.
- The result of the schedule data that is executed in the series of the "Customize Auto. Cnt. Exec." function is displayed.
(If a schedule data fails, the results of the schedule data that leads from the failed schedule data are not displayed. If the series of the schedule data ends normally, the results of all the schedule data are displayed.)
- "Time" (Start time and data) of other than the top parent schedule data is same as the time of the top parent schedule data. Data of execution histories except the "Time" are the result of each schedule data in the series of the schedule data.

1.8 USER FRAME COMPENSATION

Overview

The force control instructions other than 'Contouring' designate the moving direction with the axes (X,Y or Z) of the User frame in the schedule. The 'Contouring' function pushes to the axes (X,Y or Z) of User frame or Tool frame in the schedule.
This function enables to offset the User frame in the schedule with the result of *i*RVision. For example, it facilitates the precise fitting by offsetting the moving direction based on the results of *i*RVision.
This function also enables to change the moving direction such as the pushing direction and the insert direction by compensating the user coordinate system internally without changing the setting value of the user coordinate system designated by 'User Frame No.'.

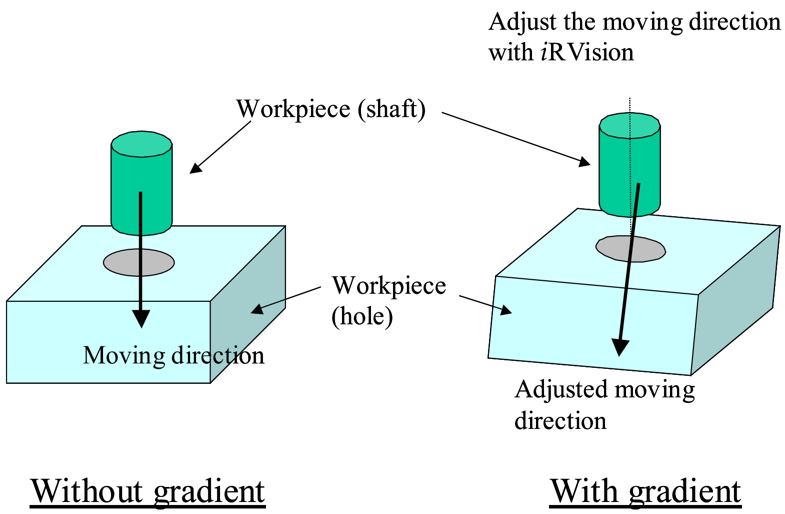


Fig. 1.8 (a) Adjustment of moving direction by user frame compensation

Using User Frame Compensation

There are two methods for using user frame compensation; using position compensation condition statements, and using vision compensation condition statements. In addition, there is method (3) for [Constant Push]. The method (3) compensates based on a tool coordinate system.

method 1 Using an Offset Condition Statement

The travel direction is adjusted according to the specified position register.

1 Specify the position register number to use for compensation in a position compensation condition statement.
An example TP program is indicated below.

```
TEST
                                        1/4
  1: UFRAME_NUM=1
  2: OFFSET CONDITION PR[1]
  3: L P[1:approach point] 100mm/sec
   :   FINE Offset
  4:   FORCE CTRL[1]
   :   ERROR LBL[0]
 [END]
```

Use PosReg 1 for Offset Compensation

Force Control instruction

2 Store the offset detected with *i*RVision in the position register.
(Refer to the "*i*RVision OPERATOR'S MANUAL (Reference) (B-83914EN)".)
3 Set [User Frame Compensation] to 'POS REG.' in the FORCE statement.

```
Force Ctrl/Perform
                                      11/39
 Schedule[1]            G:1 F:1 S:1
 1 Function        : Shaft Insert
 2 Comment         : [                ]
 3 Simple Customize Sw           : OFF
 4   Retry Sw                :OFF
 5   Cont. Exec. Max. Count      :   1
 6 Customize Parent Number  :        0
 7   Customize ParaChg Conct:OFF
 8 Customize Auto. Cnt. Exec. Sw : OFF
 9   Auto. Cnt. Exec. Child No.  :   0
10   Schedule No. Output Reg. No.:   0
11 User Frame Compensation:  POS REG
12 Settling Switch           :OFF
13   Settling Time      :     1.00 sec
```

method 2 Using a Vision Compensation Condition Statement

Adjust the travel direction according to the specified vision register.
(For information on using vision to set the offset for the position register and vision register, see the "*i*RVision OPERATOR'S MANUAL (Reference) (B-83914EN)".)

1 Specify the vision register number to use for compensation in a vision compensation condition statement.
An example TP program is indicated below.

```
TEST
                                   1/4
   1: UFRAME_NUM=1
   2: VOFFSET CONDITION VR[1]   <-- Use VR[1] for offset compensation
   3: L[1:approach point] 100mm/sec
    :   FINE VOFFSET
   4:   FORCE CTRL[1]           <-- Force Control instruction
    :   ERROR LBL[0]
 [END]
```

2 Store the offset detected with *i*RVision in the vision register.
(Refer to "*i*RVision OPERATOR'S MANUAL (Reference)" (B-83914EN) etc, for detailed information.)

3 Set [User Frame Compensation] to 'VISION REG' in the FORCE statement.

```
Force Ctrl/Perform
                                      11/39
 Schedule[1]            G:1 F:1 S:1
 1 Function        : Shaft Insert
 2 Comment         : [                ]
 3 Simple Customize Sw           : OFF
 4   Retry Sw                :OFF
 5   Cont. Exec. Max. Count      :   1
 6 Customize Parent Number  :        0
 7   Customize ParaChg Conct:OFF
 8 Customize Auto. Cnt. Exec. Sw : OFF
 9   Auto. Cnt. Exec. Child No.  :   0
10   Schedule No. Output Reg. No.:   0
11 User Frame Compensation:  VISION REG
12 Settling Switch           :OFF
13   Settling Time      :     1.00 sec
```

> ⚠ **CAUTION**
> 1 The *i*RVision option is required to use vision compensation conditions.
> 2 Enable vision compensation condition statements. Select [SET] -> [General] from the [TYPE] key. Enable "VOFFSET".
> 3 Set Vision Register's type as 'Fixed Frame Offset'.

method 3 Using a Tool Coordinate System (In the case of [Constant Push])

By selecting [TOOL FRAME], the position/posture of the user frame becomes the same as the tool frame specified in [UTool Number] in the basic data when force control is started. This enables the pushing direction of the 'Constant Push' function to be based on the tool frame.
When [User Frame Compensation] is set to 'TOOL FRAME' in the 'Constant Push' function, [TOOL] is displayed for [Pushing Direction] in the basic data, and 'USER' is displayed if [User Frame Compensation] is set to something other than [TOOL FRAME].

1 Set [User Frame Compensation] to [TOOL FRAME] in Performance screen of force control schedule.

```
Force Ctrl/Perform
                                    1/23
 Schedule[1]            G:1 F:1 S:1
 1 Function        : Constant Push
 2 Comment         : [                ]
 3 Simple Customize Sw           : OFF
 4   Cont. Exec. Max. Count      :   1
 5 Customize Parent Number  :        0
 6   Customize ParaChg Conct:OFF
 7 Customize Auto. Cnt. Exec. Sw : OFF
 8   Auto. Cnt. Exec. Child No.  :   0
 9   Schedule No. Output Reg. No.:   0
10 User Frame Compensation:  TOOL FRAME
11 Settling Switch          :OFF
12   Settling Time      :     1.00 sec
13   Settling Rate      :   100.00 %
```

1.9 3-AXIS FORCE SENSOR SETTING

Overview

FANUC 3-Axis Force Sensor detects Fz(force in Z), Mx(moment around X), My(moment around Y). To estimate Fx(force in X), Fy(force in Y), Mz(moment around Z), it is necessary to set "3-Axis FS ContactP. Position" and teach a robot so that a workpiece and a tooling always make a contact at this position during force control.
"Contact Position" can be set as a point that moves with a robot wrist like an origin of Tool Frame or fixed point such as an origin of User Frame.

> ⚠ **CAUTION**
> If the actual contact position is away from '3-Axis FS ContactP. Position', the estimation error of Fx, Fy, Mz will get big and it may deteriorate the force control performance.

The 3-Axis Force Sensor can be used only for 'Contant Push' and 'Contour'. The "Basic data setting screen"s of these functions have following parameters.

- 3-Axis FS ContactP. Position
- Setting Method (3-Axis ContactP. Position)
- Pos. Reg. No. (3-Axis ContactP. Position)

- Distance (3-Axis ContactP. Position)
  (There are explanations for these parameters in "Basic Function Guide: 1.5.2, Constant Push / Face Match" for 'Contant Push' and in "Basic Function Guide: 1.5.7.6 Parameter" for 'Contour'. Conceptual diagrams for them are given in this section for better understanding.)

> **NOTE**
> Refer to Fig. 1.9 (a) and Fig. 1.9 (b) first.

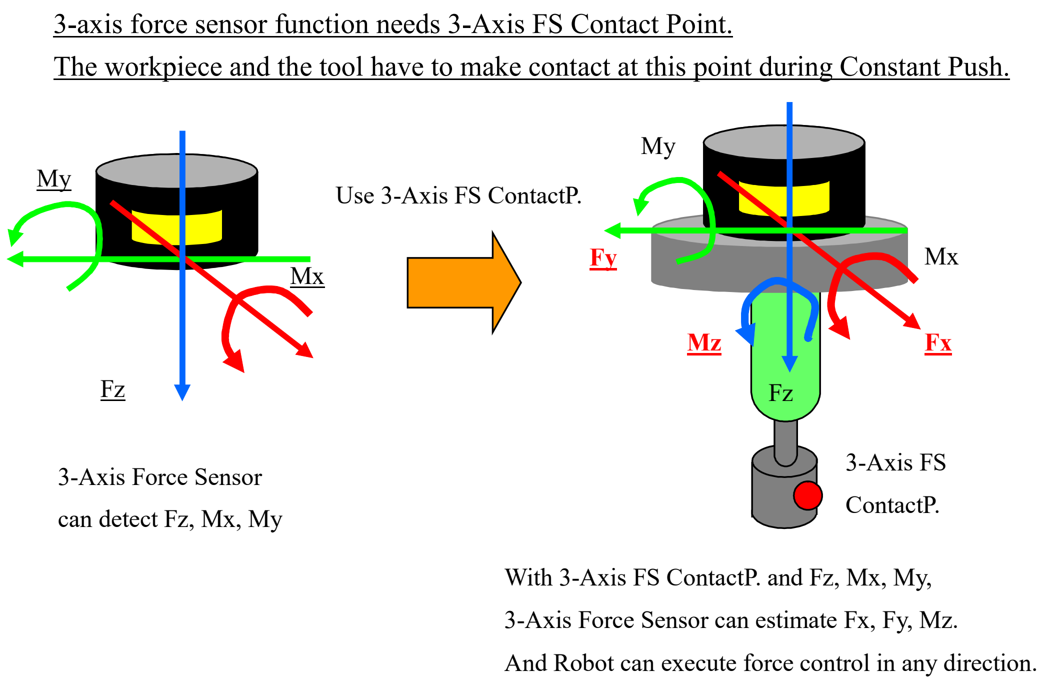
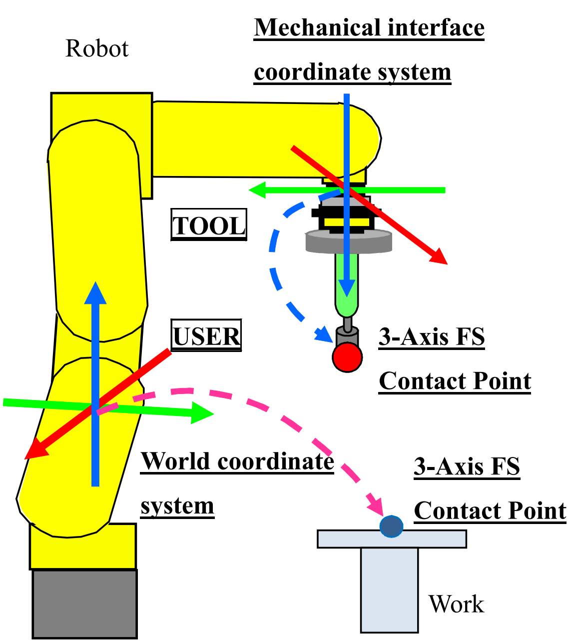


Fig. 1.9 (a) 3-Axis FS ContactP. Position

Designating a position of the 3-Axis FS Contact Point TOOL or USER



"TOOL":

The position of the 3-Axis FS Contact Point is given on the mechanical interface coordinate system.
If the contact point moves with a robot wrist, select it.

"USER" :

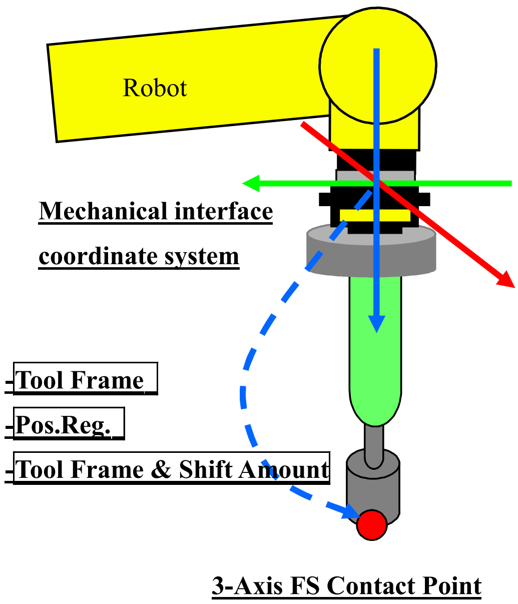
The position of the 3-Axis FS Contact Point is given on the world coordinate system.
If the contact point is fixed on the world coordinate system (floor), select it.

Fig. 1.9 (b) Setting of "3-Axis FS ContactP. Position"

If the contact point is fixed to the robot wrist (it moves with the robot wrist like an origin of Tool Frame), refer to Fig. 1.9 (c), Fig. 1.9 (e), Fig. 1.9 (f) and Fig. 1.9 (g). In case of 'Contant Push', Fig. 1.9 (g) is unrelated.
If the contact point is fixed to a floor, refer to Fig. 1.9 (d), Fig. 1.9 (h) and Fig. 1.9 (i).

The notion of setting "TOOL" to "3-Axis FS ContactP. Position"

The position of the 3-Axis FS Contact Point is given on the mechanical interface coordinate system.



"Setting Method" is "Frame"

The positional relationship between the mechanical interface coordinate system and the contact point is given by Tool Frame (designated in basic data).

"Setting Method" is "Pos.Reg."

The positional relationship between the mechanical interface coordinate system and the contact point is given by Positional Register.

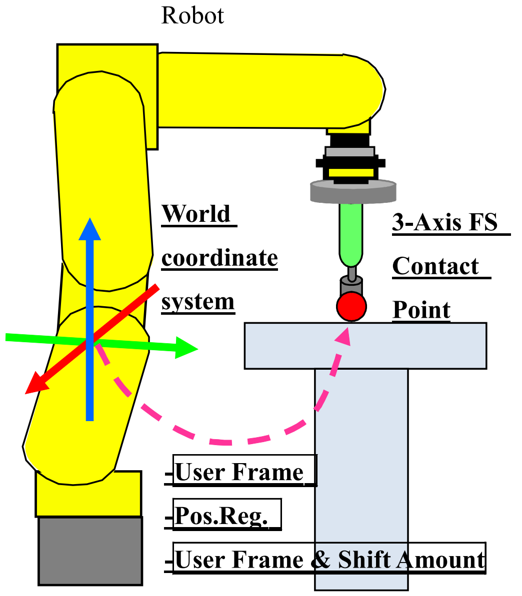
"Setting Method" is "Push Dir Shift"

The positional relationship between the mechanical interface coordinate system and the contact point is given by Tool Frame and a shift amount in the pushing direction.

Fig. 1.9 (c) If "3-Axis FS ContactP. Position" is TOOL

The notion of setting "USER" to "3-Axis FS ContactP. Position"

The position of the 3-Axis FS Contact Point is given on the world coordinate system.



"Setting Method" is "Frame"

The positional relationship between the world coordinate system and the contact point is given by UF (designated in basic data).

"Setting Method" is "Pos.Reg."

The positional relationship between the world coordinate system and the contact point is given by Positional Register.

"Setting Method" is "Push Dir Shift"

The positional relationship between the world coordinate system and the contact point is given by User Frame and a shift amount in the pushing direction.

Fig. 1.9 (d) If "3-Axis FS ContactP. Position" is USER

Example 3-axis Force Sensor Settings

Example 3-axis force sensor settings are indicated below.

Example 1 of setting TOOL to "3-Axis FS ContactP. Position" "Setting Method" is "Frame" or "Pos.Reg."

The position of Contact point is represented by the mechanical interface coordinate system.

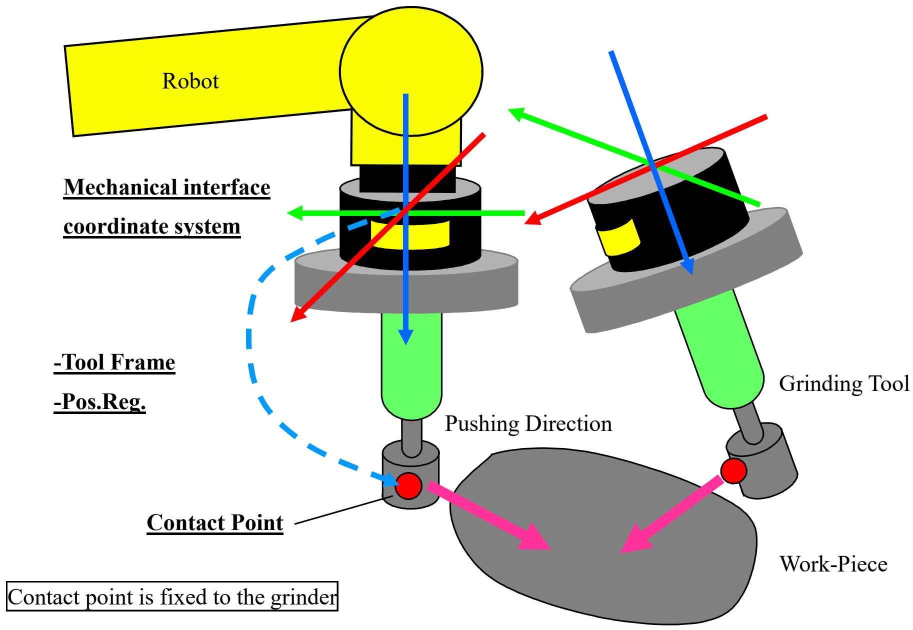


Fig. 1.9 (e) Example 1 of setting TOOL to "3-Axis FS ContactP. Position"

Example 2 of setting TOOL to "3-Axis FS ContactP. Position"   “Setting Method” is “Push. Dir. Shift”

The position of Contact point is represented by the mechanical interface coordinate system.

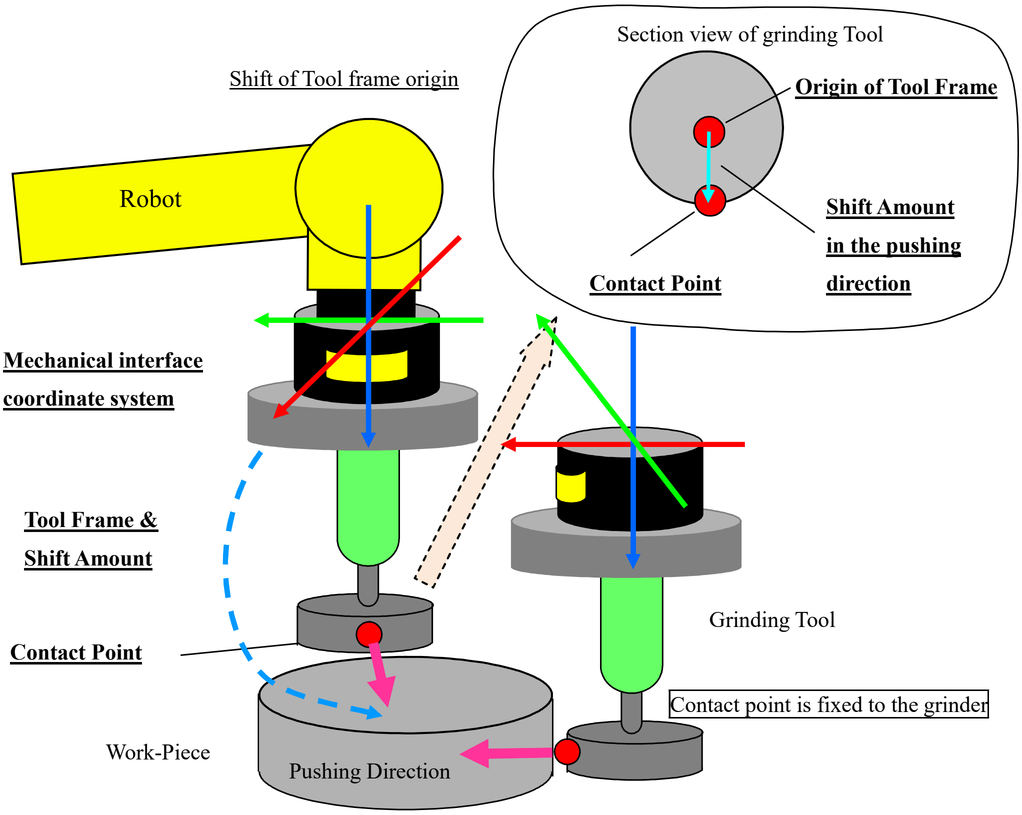


Fig. 1.9 (f)   Example 2 of setting TOOL to "3-Axis FS ContactP. Position"

Example 3 of setting TOOL to "3-Axis FS ContactP. Position" “Setting Method” is “Push. Dir. Shift”
Force control function is “Contour” and “Pushing Dir Auto Chg” is ON.

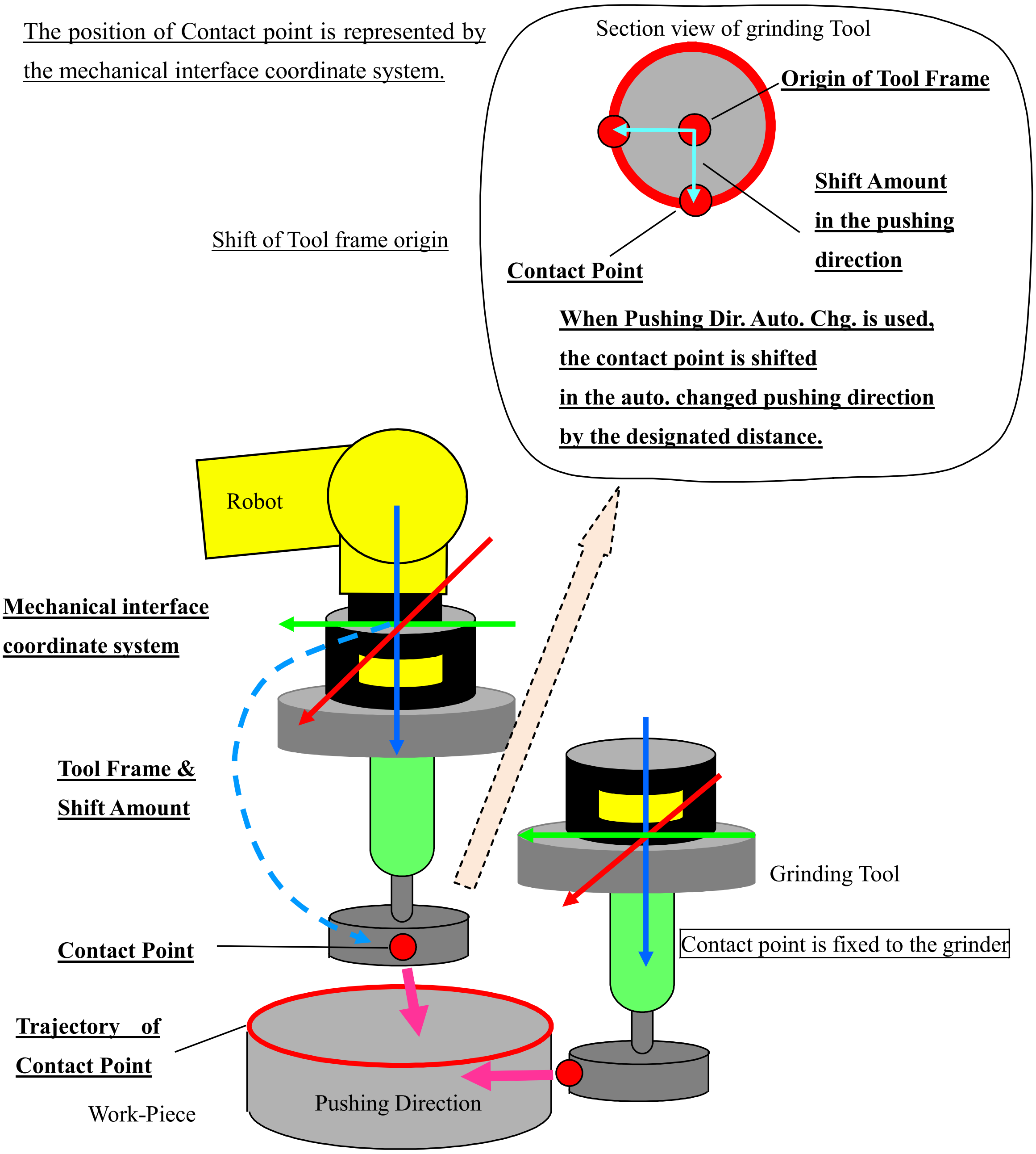


Fig. 1.9 (g) Example 3 of setting TOOL to "3-Axis FS ContactP. Position"

Example 1 of setting USER to "3-Axis FS ContactP. Position" "Setting Method" is "Frame"

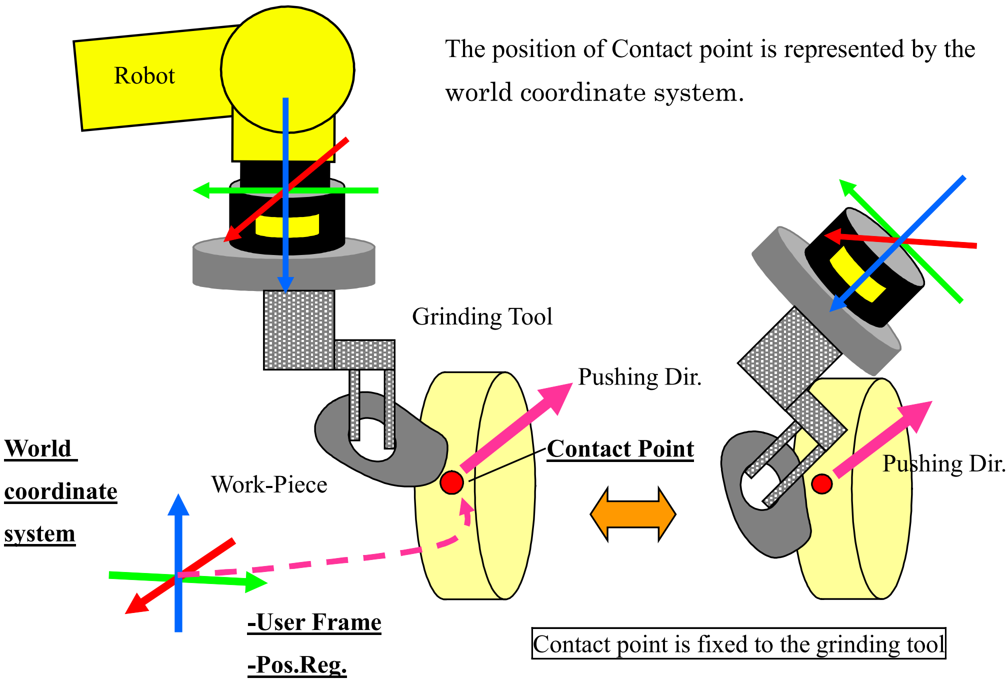


Fig. 1.9 (h) Example 1 of setting USER to "3-Axis FS ContactP. Position"

Example 2 of setting UJSER to "3-Axis FS ContactP. Position" "Setting Method" is "Push.

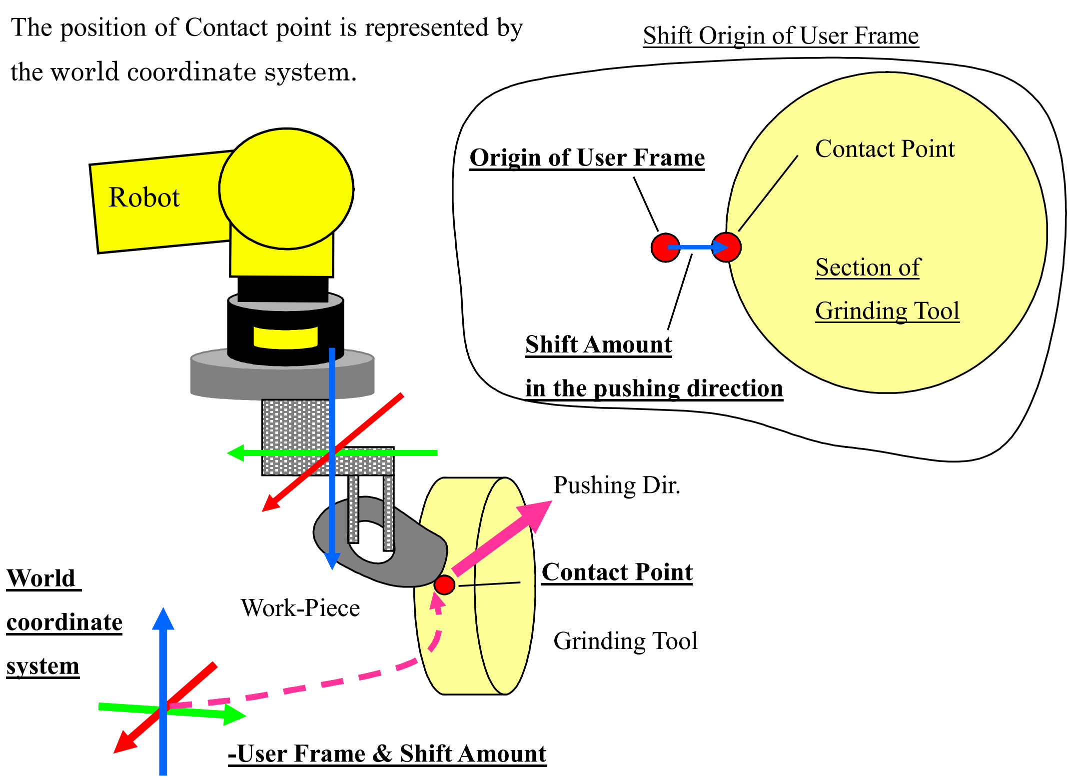


Fig. 1.9 (i) Example 2 of setting USER to "3-Axis FS ContactP. Position"

1.10 FORCE CONTROL PARAMETER AUTO TUNING

Overview

This function automatically adjusts certain force-control parameters (Force Control Gain, Approach Velocity, etc.) by executing a FORCE statement multiple times. The appropriate force-control parameters vary based on factors such as the type of robot, the hand, and workpiece, but with this function the appropriate force-control parameters can be determined according to the use conditions.

Notes and restrictions

- This function is available with the 7DF5 series 05 edition software and later on certain robots, such as CRX, and functions. When this function is available, the parameter [Parameter Auto Tuning] appears on the [Basic Data Settings] screen. Refer to Fig. 1.10 (a).
- If [Parameter Auto Tuning] is not displayed, use Force Control Gain Auto Tuning. For information about Force Control Gain Auto Tuning, refer to "Basic Functions Guide: 1.11.2 Force Control Gain Auto Tuning Instruction ".
- If [Parameter Auto Tuning] is displayed, Force Control Gain Auto Tuning is not available.
- When auto tuning starts, this function automatically adjusts the parameters based on the workpiece, the hand, and the robot position/orientation. Therefore, you should test the operation on several individual workpieces after auto tuning completes. Also, when the hand or the robot position/orientation is changed, perform auto tuning again, or test the parameters after the change to ensure they do not cause problems.
- For Face Match, Shaft Insert, or Square Insert, the parameters are adjusted based on the orientation error that was modified with force control from the first auto tuning. Therefore, you should execute auto tuning from a state with the largest error assumed in the system. If the orientation error will be larger than that used for auto tuning, you should test with that orientation error to ensure there are no problems.
- The parameters adjusted with auto tuning can be manually changed later, but you should always test the parameters after changing them to ensure there are no problems.
- This function is not available with a 3-axis force sensor.
- This function is not available with User Frame Compensation.
- This function is not available with the Customize function. However, it can be executed with the parent schedule.
- This function can be executed only from the first window.
- This function can be executed in AUTO/T1/T2 modes. If this function is executed in T1/T2 modes, you must grip the dead-man's switch and hold down the [SHIFT] key while auto tuning is operating.

Tuning screen

This screen is displayed by moving the cursor to [Parameter Auto Tuning] and pressing the F2 [EXEC] and F3 [RESULT CO] keys. This screen is when FORCE statement is "Constant Push".

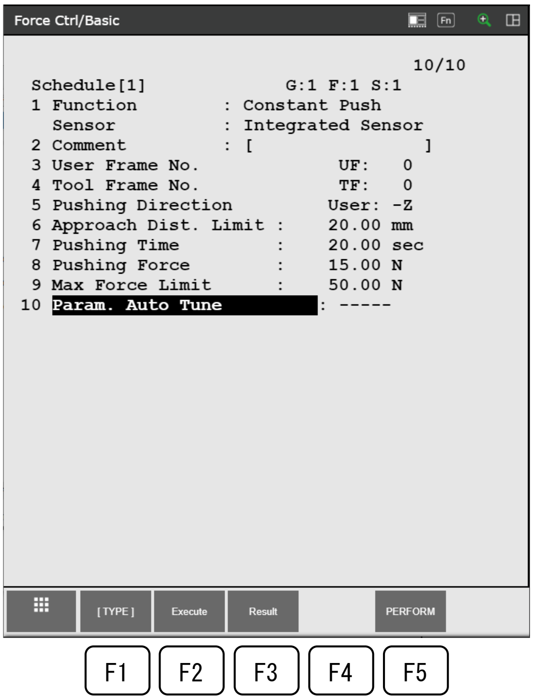


Fig. 1.10 (a) Auto Tuning screen

Key	Display	Description
F2	EXEC	Press this key together with [SHIFT] to start the auto tuning operation.
F3	RESULT CO	Displays a screen with the parameters that were adjusted with auto tuning.

> ⚠ **WARNING**
> For safety reasons, the F2 [EXEC] key must be pressed together with the [SHIFT] key.

Operation

When this function is executed, the robot returns repeatedly a set number of times to the position/orientation at the time the FORCE statement was executed and auto tuning started. The FORCE statement is executed based on the setting values on the basic data screen of the open schedule number, so be sure to set all the items on the basic data screen before executing auto tuning.

⚠ **CAUTION**

- Before executing auto tuning, move the robot to the position/orientation where the FORCE statement will be executed.
- During auto tuning, visually check the robot operation, and be ready to stop operation immediately if it looks like nearby objects might interfere with the operation. For Face Match, Shaft Insert, and Square Insert, be particularly careful because the robot will operate in the following manner.
  - The orientation error is modified during the first force control.
  - The second and subsequent force controls are executed by applying the same magnitude of orientation error as the first force control, but in different directions.
- The override can be changed during auto tuning, but the override should be set so that HOLD stop or emergency stop can be performed on the robot before anything interferes.

Operation Procedure

An overview of the operation of this procedure is given below.

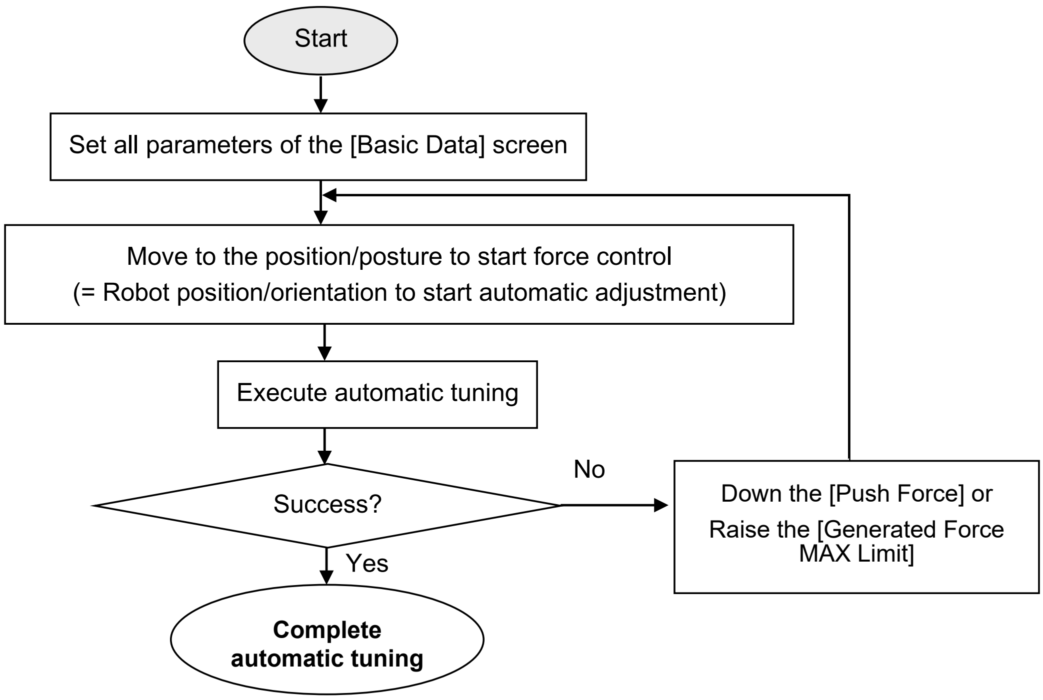
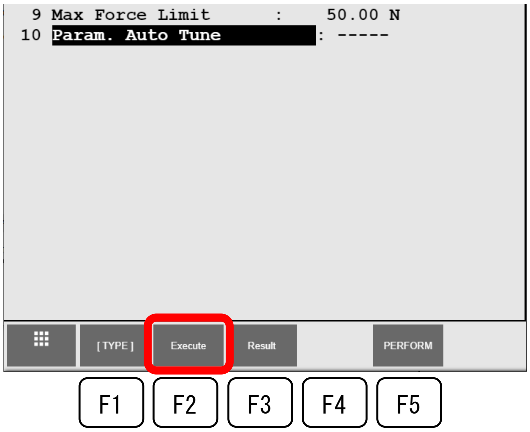


Fig. 1.10 (b) Auto Tuning operation procedure

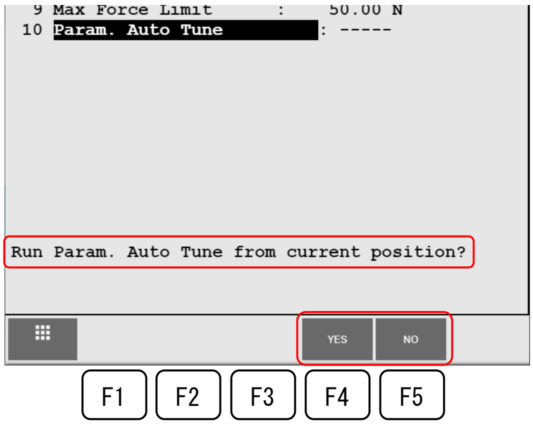
Below is a detailed explanation of the operation procedure.

1. Set all the parameters on the Basic Data screen. (Refer to Fig. 1.10 (a).)
2. Move the robot to the position/orientation for starting auto tuning. For this position, use the same position/orientation as for executing the FORCE statement.
3. If there is alarm, clear it.

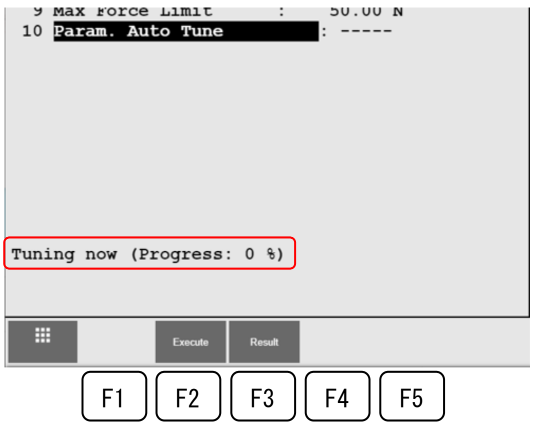
4. Press the [SHIFT] key together with the F2 [EXEC] key.



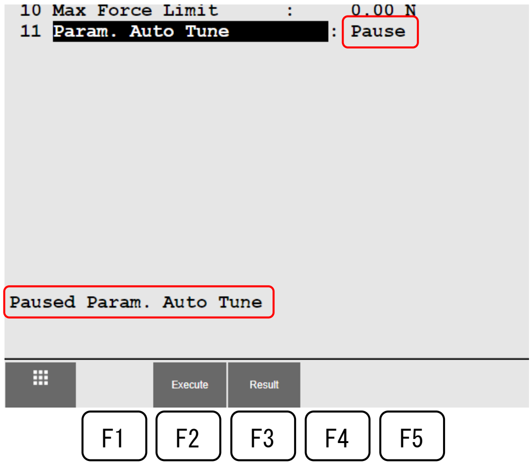
5. When a message for confirming the start of auto tuning is displayed, press the F4 [YES] key. To cancel execution, press the F5 [NO] key. Also, if auto tuning cannot be started, a message explaining the cause is displayed. Resolve the cause and execute the operation again.



6. During auto tuning, force control (Constant Push, etc.) operation and returning to the original position are repeated. The progress is displayed as below until auto tuning finishes. Also, override will be changed automatically when auto tuning starts, but override can be changed during execution.



7. If the HOLD key or the emergency stop button is pressed or an alarm occurs during auto tuning, the following message is displayed, and auto tuning will be stopped. To execute auto tuning again, return to step 3.



NOTE

1 If auto tuning stops unintentionally, check the alarm history and take the appropriate measures.

2 If the message "EXEC-105 (~CC_ATTUNE, 1) execution cannot start" is displayed, select "EXIT PROGRAM" from the sub menu to exit the currently executing program and execute it again.

3 In T1/T2 modes, if you release the [SHIFT] key during auto tuning, auto setting will be stopped, but in AUTO mode, auto tuning will not stop unless you press the HOLD key or the emergency stop button.

4 If auto tuning is stopped, the results of auto tuning up to that point will not be applied.

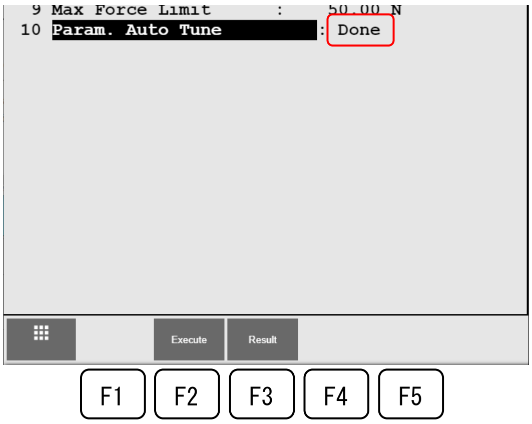
8. If an appropriate parameter is not found with auto tuning, auto tuning will result in failure, and the following message is displayed.

NOTE

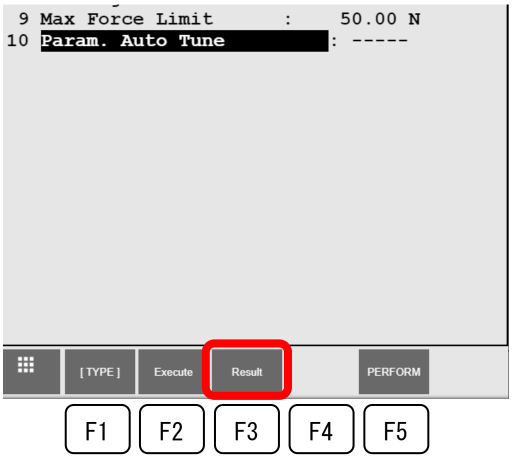
If parameter auto tuning fails, check the alarm message that was issued and take the following actions.

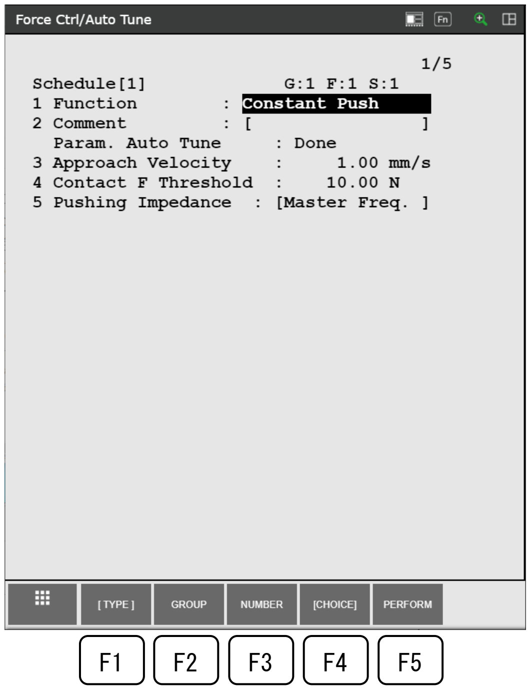
- "FORC-518 Auto tune: Reduce orientation error": For Shaft Insert and Square Insert, auto tuning failed because insertion was unsuccessful even after automatically raising the insertion force. The alarm occurred because the orientation error was too large. Reduce the orientation error and execute auto tuning again.
- "FORC-519 Auto tune: Adjustment not possible with this hand": This alarm occurs when adjustment cannot be performed due to a tendency to vibrate during force control. Auto tuning is not possible with the current hand. Change to a light, short hand and execute auto tuning, or adjust the parameters manually.
- "FORC-520 Auto tune: Adjustment not possible at this position": Auto tuning failed because an excessive force was generated during force control. The generated force exceeded "Generated Force MAX Limit", or if the contact stop function is enabled, the contact stop threshold was about to be exceeded. Either raise "Generated Force MAX Limit", or execute auto tuning again at a different robot position or orientation.

9. When auto tuning completes, the following message is displayed. The time to complete the last executed force control is displayed as the cycle time.



10. Press the F3 [RESULT CO] key, and check the adjusted parameters. This completes auto tuning.





1.11 OTHER INSTRUCTIONS RELATED TO FORCE CONTROL

Overview

This section describes statements related to force control.
The following eight statements related to force control are available.

- Force sensor diagnosis statement
- Diagnosis data read statement
- Force control gain auto adjustment on statement
- Force control gain auto adjustment off statement
- Torque error retrieval on statement
- Torque error retrieval off statement
- Exit condition on statement
- Exit condition off statement

See the subsequent sections for details on each statement.

Selecting a Force Control Related Statement

1 Press F1 [INST] on the [TP Program Training] screen.
The [Force control instructions.] screen is displayed.

2 Select [Force Control].

```
Instruction 1/4
  1 Registers
  2 I/O
  3 Force Control
  4 IF/SELECT
  5 WAIT
  6 JMP/LBL
  7 CALL
  8 ---next page---
```

A menu such as the following is displayed.

3 Select the required statement from the list of nine statement types.

```
FORCE statement 1/2          FORCE statement 2/2
 1 FORCE CTRL                 1 END COND ON
 2 SENSOR DIAGNOSIS           2 END COND OFF
 3 GET DIAG DATA              3
 4 AUTO TUNING ON             4
 5 AUTO TUNING OFF            5
 6 TRQ ERROR ON               6
 7 TRQ ERROR OFF              7
 8 ---next page---           8 ---next page---
```

The program below is displayed when [AUTO TUNING ON] is selected.

```
TEST
                                   1/2
   1:  AUTO TUNING ON

[End]



                       [CHOISE]
```

See the subsequent sections for details on each statement type.
(For information on [SENSOR DIAGNOSIS] and [GET DIAG DATA], refer to "Basic Function Guide: 1.11.1 Force Sensor Diagnosis Instructions". For information on [AUTO TUNING ON] and [AUTO TUNING OFF], refer to "Basic Function Guide: 1.11.2 Force Control Gain Auto Tuning Instruction".) For information on [TRQ ERROR ON] and [TRQ ERROR OFF], refer to "Basic Function Guide: 1.11.3 Torque Error Acquisition Instruction".) For information on [END COND ON] and [END COND OFF], refer to "Basic Function Guide: 1.11.4 End Condition Acquisition Instruction".)

1.11.1 Force Sensor Diagnosis Instructions

Overview

The force sensor diagnosis statement is a function for diagnosing whether a problem has occurred with the 6-axis sensor due to a collision that occurred due to an operational mistake, etc. during training. The 'SENSOR DIAGNOSIS' and 'GET DIAG DATA' statements are used as indicated in Figure 1.11.1.1(a), 1.11.1.1(b).

> **NOTE**
> This function does not need to be used for the 3-axis force sensor because it has its own diagnosis function. Diagnosis is not performed if this function is executed, but force sensor data is retrieved and the values can be checked in Figure 1.11.1.2.

Instruction

GET DIAG DATA

When using force sensor for the first time, it is recommended that the user execute the GET DIAG DATA instruction to acquire sensor data at a taught robot position. This instruction acquires the force sensor data needed for 'SENSOR DIAGNOSIS'. It must be executed before executing 'SENSOR DIAGNOSIS'. If it is executed repeatedly, 'FORC-026 Init data has been set' is displayed. In general, execute this instruction once at the beginning. If tool is changed, re-execute this instruction.

SENSOR DIAGNOSIS

To check the force sensor status after a collision or repeated use, move the robot to the same taught position, and execute 'SENSOR DIAGNOSIS' instruction. This instruction compares the force sensor data acquired by executing the 'GET DIAG DATA' instruction with the current data to determine if the force sensor is operating properly. According to the result of the diagnosis, the robot will display 'FORC-016 Diagnosis normal end' message if the sensor is normal or 'FORC-015 Force sensor error exceed limit' message if the sensor is abnormal.
For 3-Axis Force sensor, the diagnosis is not done but force values are recorded. The message 'FORC-017 Diag. data has been set' is displayed.

1.11.1.1 How to execute Force Sensor Diagnosis Instructions

To perform a diagnosis on the force sensor, move the robot to the same position and execute a 'SENSOR DIAGNOSIS' statement.
Execute the GET DIAG DATA instruction to acquire sensor data at a taught robot position. Be sure that the force sensor, tool or workpiece don't contact to anything. Or the diagnosis result will not be accurate.

```
DIAG                                JOINT   10 %
                                             1/2
   1: J P[1] 30% FINE
   2:     GET DIAGNOSIS DATA
[End]
```

Get Diagnosis Data at this position.

At first, "GET DIAGNOSIS DATA"

Fig. 1.11.1.1 (a) Specifying force sensor diagnosis

To check force sensor state, execute the following program:

```
DIAG                                JOINT   10 %
                                             1/2
   1: J P[1] 30% FINE
   2:     SENSOR DIAGNOSIS
[End]
```

Move to the same position as above.

Execute SENSOR DIAGNOSIS to diagnose.

When execution terminates normally, "Diagnosis normal end" is issued.
When execution terminates abnormally, "Force sensor error exceed limit" is issued.

Fig. 1.11.1.1 (b) Specifying force sensor diagnosis instruction

1.11.1.2 Display results of force sensor diagnosis instructions

Overview

The force sensor data, etc. retrieved in the previous section can be accessed on the [Force Sensor Diagnosis Results] screen.
(Refer to "Basic Function Guide: 1.11.1.1 How to execute Force Sensor Diagnosis Instructions".)

Displaying the Results of Force Sensor Diagnosis

1 Press the [MENU] key on the teach pendant of the robot controller.
The menu is displayed.
2 Select [UTILITIES] from the menu.
The [UTILITIES] screen is displayed.
(Refer to "Basic Function Guide: 3 FORCE SENSOR UTILITIES SCREEN".)

3 Move the cursor to [Force Sensor Diagnosis Results], and press F3 [DETAIL] or the [ENTER] key on the teach pendant of the robot controller.
A screen such as the following is displayed.

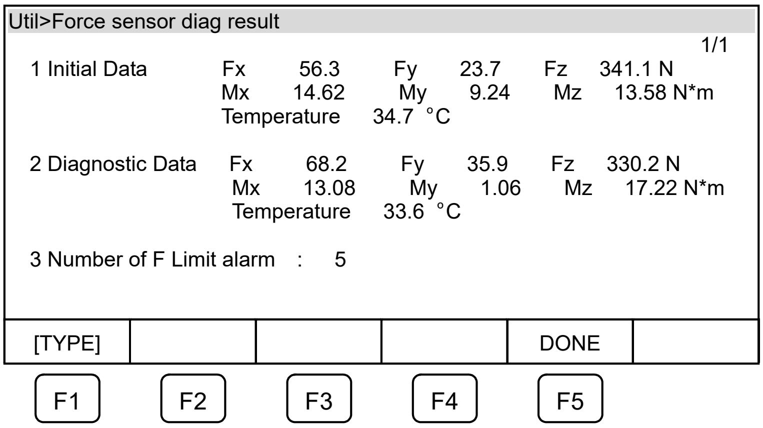


Table 1.11.1.2 Force Sensor Diagnosis Results screen

Item	Description
Initial Data	Force values (Fx, Fy, Fz, unit : N), Moment values (Mx, My, Mz, unit : N*m) and temperature(unit : degree Celsius) when'GET DIAG DATA' was executed are shown. "Unit : N/N*m" (Fx、Fy、Fz、Mx、My、Mz) "Unit :°C"
Diagnostic Data	Force values (Fx, Fy, Fz, unit : N), Moment values (Mx, My, Mz, unit : N*m) and temperature(unit : degree Celsius) when 'SENSOR DIAGNOSIS' was executed are shown. If the values are different from above 'Initial data' by a big margin, for example, the rated force/moment of the force sensor. Consult FANUC. "Unit : N/N*m" (Fx、Fy、Fz、Mx、My、Mz) "Unit : °C"
Number of F Limit alarm	The number of "FORC-159 F/S sensor limit overflow" occurred. If the message 'Diagnosis normal end' is displayed when a force sensor diagnosis statement is executed, the force sensor can be used. If the message 'Force sensor error exceed limit' is displayed, replace the sensor head.

1.11.2 Force Control Gain Auto Tuning Instruction

Overview

Force control gain is the parameter that defines the response speed of the robot during force control. Robot responsiveness also depends on the workpieces, the posture of robot, and the rigidity of the tool. Force control gain parameters for each workpiece must be set to a suitable value to improve the response of the robot. Force control gain auto tuning is recommended for the initial setting of the force control gain. A force control gain value acquired by automatic tuning instructions may not be optimal. In order to find the optimal value, it is often necessary to use this function to execute auto adjustment and then perform final adjustment manually.

> ⚠ **WARNING**
> During automatic force control gain tuning (force control instruction after 'AUTO TUNING ON' instruction), periodic motion of about 1 mm and 1 deg occurs. Execute such a force control instruction at a place that does not cause interference with surroundings.

> ⚠ **CAUTION**
> Automatic tuning is disabled with 'Contouring' and 'Contouring End'.

Instruction

AUTO TUNING ON
AUTO TUNING OFF

In the force control gain auto tuning procedure, 'FORCE CTRL' instruction can be executed between 'AUTO TUNING ON' instruction and 'AUTO TUNING OFF' instruction.
An actual procedure is described as the following Force Control Gain Auto Tuning Procedure.

Force Control Gain Auto Tuning Procedure

1 Perform training for force control.
(Refer to "Basic Function Guide: 1.2 TEACHING PROCEDURE".)

```
TEST                                JOINT   10 %
                                            1/3
   1:J P[1] 100% CNT50
   2:L P[2:Approach pos] 100mm/sec
     :   FINE
   3:   FORCE CTRL[1]
     :   ErrorLBL[0]
 [End]
```

2 Turn on [F.Ctrl Gain Auto Modify] of the target schedule.

```
Force Ctrl/Basic
                                                        1/12
  Schedule[1]                     G:1 F:1 S:1
  1 Function                      : Constant Push
  2 Comment                       : [                    ]
  3 Pushing Direction                  User: -Z
  4 Contact F Threshold           :       10.00 N
  5 Approach Velocity             :        1.00 mm/s
  6 User Frame No.                          UF:   1
  7 Tool Frame No.                          TF:   1
  8 Pushing Force                 :         10.00 N
  9 Approach Dist. Limit          :          5.00 mm
 10 Pushing Time                  :         20.00 sec
 11 F.Ctrl. Gain Auto Modify      :          OFF
        Prev. Result              :      No Change
 12 Force Control Gain            :      Detail

 [TYPE]   GROUP   NUMBER    ON     OFF     >
  F1       F2      F3       F4     F5
```

Turn on this item

3 Insert 'AUTO TUNING ON', 'AUTO TUNING OFF', 'PAUSE' instructions before and after 'FORCE CTRL' instruction respectively.

```
TEST                          JOINT   10 %
                                        1/6
  1:J P[1] 100% CNT50
  2:L P[2:Approach pos] 100mm/sec
    :  FINE
  3:  AUTO TUNING ON
  4:  FORCE CTRL[1]
    :  ErrorLBL[0]
  5:  AUTO TUNING OFF
  6 :  PAUSE
[End]
```

Add these instructions

4 Execute the program above. In this case, periodic motion of about ±1 mm and ±1 deg occurs at the place where force control instruction is executed. Execute the program at a place that does not cause interference with surroundings.

> **NOTE**
> Step 1 to 4 is completed if “FORCE CTRL” instruction ends without any alarms and the program pauses on line 5. (Go to Step 5.) If “FORCE CTRL” instruction stops with the alarm concerning Force control gain auto tuning on line 5, execute the program again by correcting the schedule data referring to "Appendix: B ALARM CODES OF FORCE CONTROL". (Go to Step 4.)

5 Confirm the tuned parameters with the following procedures.

(1) Delete the instructions added at Step 3 from the program.

(2) Execute the program. Stability during force control execution is monitored, and if it is unstable, force control gain is decreased to make execution stable.

(3) Repeat program execution until the previous result of the schedule data becomes stable and 'No Change' is displayed. However, "F.Ctrl Gain Auto Modify" is turned off when force control is finished. So if you need to do tuning one more, please turn "F.Ctrl Gain Auto Modify" on.

```
TEST                          JOINT   10 %
                                        1/3
  1:J P[1] 100% CNT50
  2:L P[2:Approach pos] 100mm/sec
    :  FINE
  3:  FORCE CTRL[1]
    :  ErrorLBL[0]
[End]
```

Delete instructions added at step3.

```
Force Ctrl/Basic
                                                   1/12
  Schedule[1]            G:1 F:1 S:1
  1 Function                    : Constant Push
  2 Comment                     : [                ]
  3 Pushing Direction             User: -Z
  4 Contact F Threshold         :   10.00 N
  5 Approach Velocity           :    1.00 mm/s
  6 User Frame No.                  UF:   1
  7 Tool Frame No.                  TF:   1
  8 Pushing Force               :   10.00 N
  9 Approach Dist. Limit        :    5.00 mm
 10 Pushing Time                :   20.00 sec
 11 F.Ctrl. Gain Auto Modify    :     OFF
        Prev. Result            :   No Change
 12 Force Control Gain          :   Detail

 [TYPE]    GROUP    NUMBER    [SELECT]    PERFORM    >
  F1        F2        F3        F4          F5
```

This switch is turned off automatically when force control is finished.
If you need to do tuning again, please turn this switch on.

Execute repeatedly until 「Prev. Result」 of the schedule data is successively set as 「No Change」.

The operation is completed when smooth insertion is confirmed.

6 When the response of the force control is slow or vibrating, do the following:
 (1) Change 'Insert Impedance' or 'Pushing Impedance' parameters in the basic screen. (Refer to "Basic Function Guide: 1.6 FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".)
 (2) Execute force control gain auto tuning again. Go back to Step 2.

1.11.3 Torque Error Acquisition Instruction

Overview

The force control function calculates torque around the tool center point (TCP). When the TCP has offset from the central axis of force sensor because of the shape of the tool, this calculation might not always be performed appropriately, due to a TCP setting error. If the torque is inaccurate, the performance of the 'Face Match', 'Shaft Insert' may be deteriorated. This function acquires parameters necessary for accurate compensation in such a case. Torque error acquisition can be performed for any 'FORCE CTRL' instruction. Specifically, this function acquires and sets the values of 'Torque Error Data W, P, and R' and 'Torque Error Pushing force Fd' in the performance data, which is described later.

Preparation

This function needs a special jig having the same TCP as that in actual insertion or pressing. Robot pushes at a center point of the jig in the same orientation as actual insertion or pressing. By this operation, torque error can be acquired.

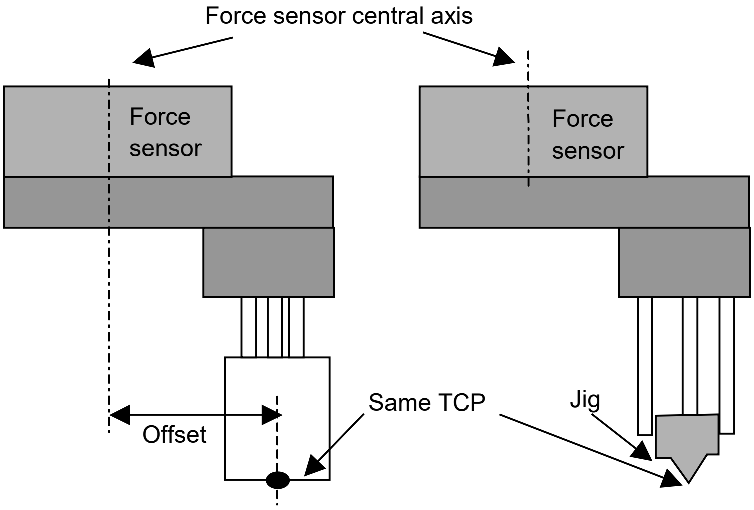


Fig. 1.11.3 Preparation for torque error acquisition

Instruction

TORQUE ERROR ON

TORQUE ERROR OFF

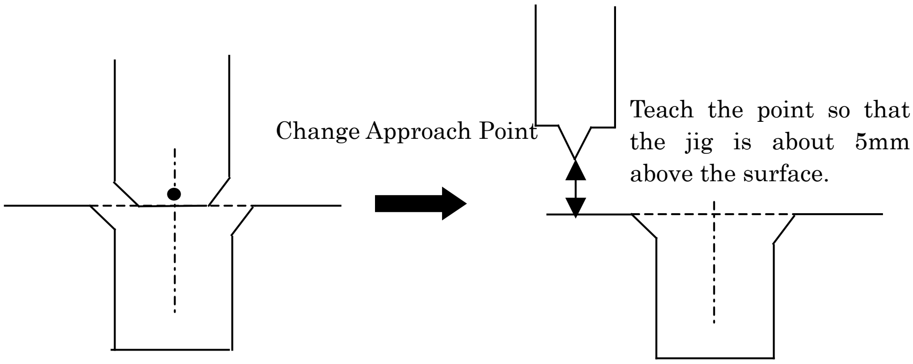
Torque error acquisition is performed for any FORCE CTRL instruction executed between 'TORQUE ERROR ON' instruction and 'TORQUE ERROR OFF' instruction. An actual procedure is described in the following.

Torque Error Acquisition Procedure

1 Teach the program.
(Refer to "Basic Function Guide: 1.2 TEACHING PROCEDURE".)

```
TEST                              JOINT   10 %
                                          1/3
   1:J P[1] 100% CNT50
   2:L P[2:Approach pos] 100mm/sec
      :   FINE
   3:   FORCE CTRL[1]
      :   ErrorLBL[0]
 [End]
```

2 Mount the jig described in 'Preparation'.
* If the function name is 'Shaft Insert', 'Groove Insert', 'Phase Match Ins.', 'Square Insert', 'Search', 'Hole Search', or 'Clutch Search', copy the program to another program and change the approach point to a location near the location to insert.
* In case that function is 'Constant Push' or 'Face Match', use the program as it is and don’t need to change the approach point.



3 Insert 'TORQUE ERROR ON' and 'TORQUE ERROR OFF' instructions before and after the 'FORCE CTRL' instruction, respectively.

```
TEST                              JOINT   10 %
                                           1/6
   1:J P[1] 100% CNT50
   2:L P[2:Approach pos] 100mm/sec
     :  FINE
   3:  TORQUE ERROR ON
   4:  FORCE CTRL[1]
     :  ErrorLBL[0]
   5:  TORQUE ERROR OFF
[End]
```

Add these instructions

4 Execute the program created in Steps 1-3.
Torque error acquisition is completed if 'FORCE CTRL' instruction ends without any alarms and the program completes. (Go to Step 5.)

NOTE

If 'FORCE CTRL' instruction stops with an alarm on line 5, execute the program again by correcting the schedule data referring to "Appendix: B ALARM CODES OF FORCE CONTROL". (Go to Step 4.)

5 In case that function is 'Constant Push' or 'Face Match', delete the instructions added at Step 3 from the program. Otherwise use the original program without modifications.

```
TEST                              JOINT   10 %
                                           1/3
   1:J P[1] 100% CNT50
   2:L P[2:Approach pos] 100mm/sec
     :  FINE
   3:  FORCE CTRL[1]
     :  ErrorLBL[0]
[End]
```

Delete instructions added at step 3.

Using the Obtained Torque Error

1 Press the [DATA] key on the teach pendant of the robot controller.
2 Press F1 [TYPE].
The menu is displayed.
3 Select [Force Ctrl] from the menu, and press the [ENTER] key on the teach pendant of the robot controller.
The [Schedule data list] screen is displayed.
4 Move the cursor to the configured schedule, and press F3 [DETAIL].
The [Basic Data Settings] screen is displayed for the schedule data.
5 Press F5 [PERFORM].
The [Performance Data Settings] screen is displayed for the schedule data.
(Refer to "Basic Function Guide: 1.5 SCHEDULE DATA".)
The retrieved torque values are displayed in [W], [P], and [R] in [Torque Error Data].
* [W], [P], and [R] display the moments around the X-axis, Y-axis, and Z-axis of each user frame (UF).
6 Set [Torque Error Compensate SW] to "On" on the [Performance Data Settings] screen.
The torque error is adjusted the next time force control is executed, and values are automatically displayed in [Torque Error Data W], [Torque Error Data P], [Torque Error Data R], and [Torque Error Fd].

1.11.4 End Condition Acquisition Instruction

Overview

End condition is criterion for judging whether operation by force control function is complete. This data usually needs to be set on the [Performance Data Settings] screen of the schedule data. (Refer to " Basic Function Guide: 1.5 SCHEDULE DATA".) Exit condition retrieval is a function for automatically retrieving exit condition data via the actual process when the exit condition settings and actual process do not match. More specifically, the 'Insert Depth', 'Approach Depth', and 'Insertion Direction' values mentioned later in this document are retrieved and set for the performance data.

Instruction

END CONDITION ON
END CONDITION OFF

End condition acquisition is performed for any 'FORCE CTRL' instruction executed between 'END CONDITION ON' instruction and 'END CONDITION OFF' instruction. An actual procedure is described in the following.

End Condition Acquisition Procedure

1 Perform training for force control.
(Refer to "Basic Function Guide: 1.2 TEACHING PROCEDURE".)

```
TEST                          JOINT   10 %
                                       1/3
  1:J P[1] 100% CNT50
  2:L P[2:Approach pos] 100mm/sec
     :  FINE
  3:   FORCE CTRL[1]
     :  ErrorLBL[0]
 [End]
```

2 Insert each 'END CONDITION ON' and 'END CONDITION OFF' instruction before and after 'FORCE CTRL' instruction.

```
TEST                              JOINT   10 %
                                          1/6
   1:J P[1] 100% CNT50
   2:L P[2:Approach pos] 100mm/sec
     :  FINE
   3:  END CONDITION ON       <--+
   4:  FORCE CTRL[1]             |-- Add these instructions
     :  ErrorLBL[0]              |
   5:  END CONDITION OFF      <--+
[End]
```

3 Execute the program created in Steps 1-2.
Exit condition retrieval finishes if the FORCE statement finished without an error.

> **NOTE**
> If the 'FORCE CTRL' instruction stops with an alarm on line 5, execute the program again by correcting the schedule data referring to "APPENDIX: B ALARM CODES OF FORCE CONTROL". (Go to Step 3.)

4 Delete the statement added in step 2 from the programs.

```
TEST                              JOINT   10 %
                                          1/3
   1:J P[1] 100% CNT50
   2:L P[2:Approach pos] 100mm/sec
     :  FINE
   3:  FORCE CTRL[1]
     :  ErrorLBL[0]
[End]
```

Delete instructions added at step 2

Procedure for using the acquired end conditions

1 Press the [DATA] key on the teach pendant of the robot controller.
2 Press F1 [TYPE].
The menu is displayed.
3 Select [Force Ctrl] from the menu, and press the [ENTER] key on the teach pendant of the robot controller.
The [Schedule data list] screen is displayed.
4 Move the cursor to the configured schedule, and press F3 [DETAIL].
The [Basic Data Settings] screen is displayed for the schedule data.
5 Press F5 [PERFORM].
The [Performance Data Settings] screen is displayed for the schedule data.
(Refer to "Basic Function Guide: 1.5 SCHEDULE DATA".)
[Insert Depth] indicates the depth of actual insertion. [Approach Length] indicates the depth until the workpiece touches the work object. [Insert DIR] indicates the direction of actual insertion in a vector form in the user frame.
6 Set the [Ending Condition Switch] on the [Performance Data Settings] Screen to 'ON'. In the next and subsequent execution, the value indicated in [Insert Depth] is assumed to be the design value of depth. Insertion is performed in the direction indicated in [Insert DIR].

2 FORCE SENSOR STATUS SCREEN

On the Force sensor status screen, current values and attachment type of the force sensor, execution histories of force control instructions, force and moment values during force control can be checked.

CONTENTS

2.1 FORCE SENSOR CURRENT VALUE SCREEN

Overview

On this screen, the attatchment type, current values and inside temperature of the force sensor can be checked.
There are two force sensor attachment types: hand mount and fixed mount. Screens differ depending on the attachment type.
(Refer to "Introduction: 2.1 FORCE SENSOR OVERVIEW".)

Procedure for displaying the force sensor current value screen

1. Press the [MENU] key on the teach pendant of the robot controller.
   The menu is displayed.
2. Select [NEXTPAGE] -> [Status] from the menu.
3. Press F1 [TYPE].
   The menu is displayed.
4. Select [Force Sensor].
   The force sensor current value screen is displayed.

   There are two force sensor attachment types: hand mount and fixed mount.

   - Force sensor current value screen

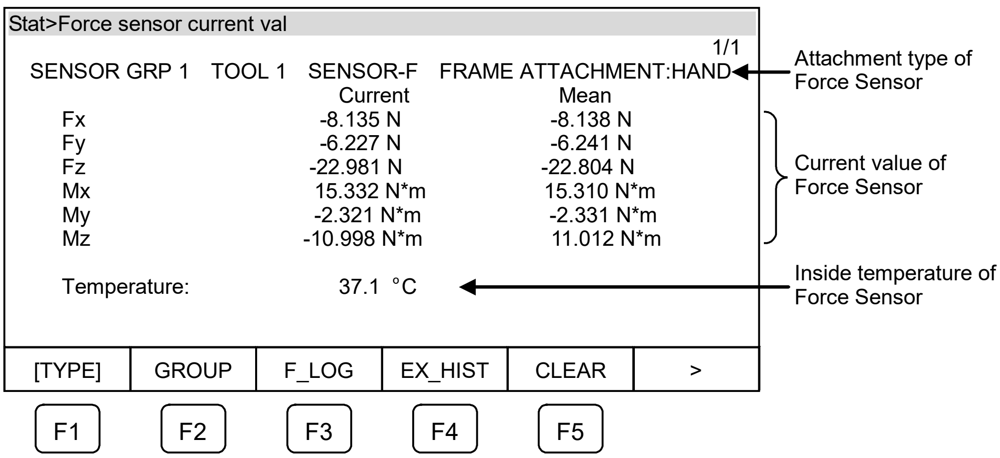


Table 2.1 (a) Force sensor current value screen

Item	Description
SENSOR GRP	Fixed at '1'.
FRAME	Displays 'SENSOR FRAME'.
ATTACHMENT	Displays the force sensor attachment type. For the hand mount type, 'HAND' is displayed.
Current	Displays the current values for the force sensor. 'Unit : N, N*m'
Mean	Displays the average values for approximately one minute for the force sensor. 'Unit : N, N*m'
Temperature	Displays the temperature within the force sensor.

* The unit of Fx, Fy, Fz is N and the unit of Mx, My, Mz is N*m.

- Current value screen of fixed force sensor

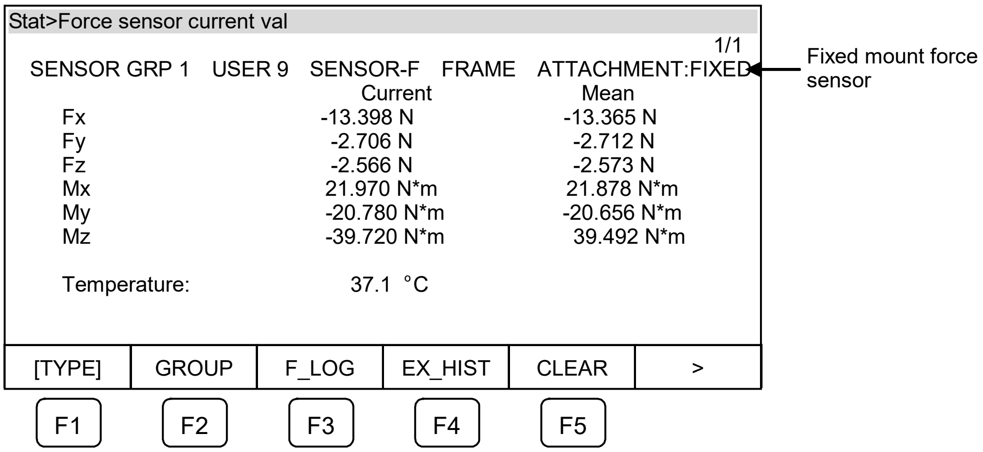


Table 2.1 (b) Current value screen of fixed force sensor

Item	Description
SENSOR GRP	Fixed at '1'.
FRAME	Displays 'SENSOR FRAME'.
ATTACHMENT	Displays the force sensor attachment type. For the fixed mount type, 'FIXED' is displayed.
Current	Displays the current values for the force sensor. 'Unit : N, N*m'
Mean	Displays the average values for approximately one minute for the force sensor. 'Unit : N, N*m'
Temperature	Displays the temperature within the force sensor.

* The unit of Fx, Fy, Fz is N and the unit of Mx, My, Mz is N*m.

Function Keys

The function keys indicated have the following functions.

Table 2.1 (c) Function Keys

Key	Label	Description
F1	TYPE	Switches the [Force sensor status] screen to other status screen
F2	GROUP	Switches force sensor groups
F3	F_LOG	Display the [Force Data Log] screen. (Refer to "Basic Function Guide: 2.3 FORCE DATA LOG FUNCTION".)
F4	EX_HIST	Displays execution histories of the force control instructions. (Refer to "Basic Function Guide: 2.2 EXECUTION HISTORIES OF FORCE CONTROL INSTRUCTIONS".)
F5	CLEAR	All force values become zero.

2.2 EXECUTION HISTORIES OF FORCE CONTROL INSTRUCTIONS

Overview

Execution history screen displays the execution time of the force control instruction, the arrival depth, orientation change, generated force and moment during the force control operation.

There are two kinds of execution histories.

- Execution histories of all force control instructions.
  (Refer to "Basic Function Guide: 2.2.1 All Execution Histories".)
- Execution histories of force control instructions with alarms.
  (Refer to "Basic Function Guide: 2.2.2 Execution Histories with Alarms".)

2.2.1 All Execution Histories

2.2.1.1 List screen of all execution histories

Procedure for displaying [Force Ctrl Ex-hist list (all)]

1 Display the force sensor current value screen.
(Refer to "Basic Function Guide: 2.1 FORCE SENSOR CURRENT VALUE SCREEN".)

2 Press F4 [EX_HIST].
The [Force Ctrl Ex-hist list (all)] screen is displayed.

Stat>Force hist all

				Total 20
No.	Program name	Schedule	Function	Time
1	SAMPLE3	3	Phase Search	5-22 15:30:21
2	SAMPLE1	1	Constant Push	5-22 15:11:15
3	A0000	2	Unused	5-22 14:32:31
4	A0000	5	Unused	5-21 12:10:42
5		0		
6		0		
7		0		
8		0		
9		0		
10		0		

[TYPE]	ALARM	F_LOG	CUR_VAL	DETAIL	>
F1	F2	F3	F4	F5	

NOTE
1 Each row corresponds to a force control instruction.
2 The past twenty execution histories of the force control instructions are displayed in the order of their execution (Line 1 shows the execution of the last force control instruction.).

Table 2.2.1.1 (a) List screen of all execution histories

Item	Description
Program name	Displays the names of the TP programs that contain the executed force control instructions.
Schedule	Displays the force control schedule numbers.
Time	Displays time when force control instructions were executed. The top row contains the last executed force control instruction and the bottom row contains the oldest force control instruction.

Function Keys

The function keys indicated have the following functions.

Table 2.2.1.1 (b) Function Keys

Key	Label	Description
F1	TYPE	Switches the [Force sensor status] screen to other status screen
F2	ALARM	Only displays the execution histories with alarms. (Refer to "Basic Function Guide: 2.2.2 Execution Histories with Alarms".)
F3	F_LOG	Displays the [Force Data Log] screen. (Refer to "Basic Function Guide: 2.3 FORCE DATA LOG FUNCTION".)
F4	CUR_VAL	Switches to the [Force sensor current value] Screen. (Refer to "Basic Function Guide: 2.1 FORCE SENSOR CURRENT VALUE SCREEN".)
F5	DETAIL	Displays the detail information of the selected execution history. (Refer to "Basic Function Guide: 2.2.1.2 Detail screen of all execution histories".)

2.2.1.2 Detail screen of all execution histories

Procedure for displaying [Force Ctrl Ex-hist list (all)] screen

1 Display the [Force Ctrl Ex-hist list (all)] screen.
(Refer to "Basic Function Guide: 2.2.1.1 List screen of all execution histories".)
2 Move the cursor over a row to see the detail for and press F5 [DETAIL].
The [Force Ctrl Ex-hist hist [1] (all)] screen is displayed.

```
Stat>Force hist all
                                                         Total 17
    HIST 1    all
     1      Time              2017- 4-23   13:49:52
     2      Program name      SAMPLE3
     3      Schedule          3
     4      Function          Phase Search
     5      Alarm No           1: 0    2: 0    3: 0
                              4: 0    5: 0
     6      Arrival depth     5.002   mm
     7      Working time      5.300   sec
     8      Orient chang      0.005   deg
            End Force        (Axial dir      / Amd the axis)
     9      X               (      0.080 /          0.8000)
    10      Y               (      0.020 /          0.0700)
    11      Z               (      0.100 /         -1.0100)
            Generative force         MIN   /    MAX
    12      X dir [N]               -1.081 /    2.148
    13      Y dir [N]               -0.129 /    3.015
    14      Z dir [N]               -0.260 /    1.189
    15      X arnd [N*m]            -0.008 /    4.003
    16      Y arnd [N*m]             0.000 /    0.117
    17      Z arnd [N*m]            -2.001 /    0.008
 [TYPE]   NUMBER   F_LOG   CUR_VAL   LIST
   F1       F2       F3       F4      F5
```

Table 2.2.1.2 (a) Detail screen of all execution histories

Item	Description
Time	Start time and date of force control instruction.
Program name	TP program name.
Schedule	Schedule data number.
Function	Function name of executed schedule.
Alarm No	The number of occurred alarm. (This item displays the previous five records.) (Refer to "APPENDIX: B ALARM CODES OF FORCE CONTROL".)
Arrival depth	Distance that the robot moves in the specified direction during the force control. 'Unit : mm'
Working time	Working time of the force control instruction. 'Unit : sec'
Orient change	Orientation change around TCP during the force control. 'Unit : deg'
End Force	Force (three elements in X, Y, Z directions of the user frame which is used during the force control, unit: N) and moment (three elements in around X, Y, Z directions of the above user frame, unit: N∗m) when force control ends. 'Unit : N, N*m'
Generated force	Maximum and Minimum values of Generated force (three elements in X, Y, Z directions of the user frame which is used during the force control, unit: N) and moment (three elements in around X, Y, Z directions of the above user frame, unit: N) during the force control. If the values are much bigger than push force, the workpiece may have collided during insertion or vibration occurred. 'Unit : N, N*m'

Function Keys

The function keys indicated have the following functions.

Table 2.2.1.2 (b) Function Keys

Key	Label	Description
F1	TYPE	Switches the [Force sensor status] screen to other status screen.
F2	NUMBER	Switches to the [Force Ctrl Ex-hist hist [1] (all)] screen for a different history number. Enter a history number in the displayed menu.
F3	F_LOG	Displays the [Force Data Log] screen. (Refer to "Basic Function Guide: 2.3 FORCE DATA LOG FUNCTION".)
F4	CUR_VAL	Switches to" Force sensor current value" screen. (Refer to "Basic Function Guide: 2.1 FORCE SENSOR CURRENT VALUE SCREEN".)
F5	LIST	Display the [Force Ctrl Ex-hist list (all)] screen. (Refer to "Basic Function Guide: 2.2.1.1 List screen of all execution histories".)

2.2.2 Execution Histories with Alarms

2.2.2.1 List screen of execution histories with alarms

Procedure for displaying the [Force Ctrl Ex-hist list (alarm)] screen

1 Display the [Force Ctrl Ex-hist list (all)] screen.
(Refer to "Basic Function Guide: 2.2.1.1 List screen of all execution histories".)
2 Press F2 [ALARM].
The [Force Ctrl Ex-hist list (alarm)] screen is displayed.

Stat>Force hist alarm

				Total 40
No.	Program name	Schedule	Function	Time
1	SAMPLE1	1	Phase Search	5-22 15:11:13
2	A0000	5	Constant Push	5-22 14:32:31
3		0		
4		0		
5		0		
6		0		
7		0		
8		0		
9		0		
10		0		

[TYPE]	ALL	F_LOG	CUR_VAL	DETAIL	
F1	F2	F3	F4	F5	

Table 2.2.2.1 (a) List screen of execution histories with alarms

Item	Description
Alarm occurred	Displayed if an alarm has occurred for any of the histories.
No.	Each row corresponds to a force control instruction. The past 40 force control instructions are logged. The top row contains the last executed force control instruction and the bottom row contains the oldest force control instruction.
Program name	Displays the names of the TP programs that contain the executed force control instructions.
Schedule	Displays the force control schedule numbers.
Time	Displays time when force control instructions were executed.

Function Keys

The function keys indicated have the following functions.

Table 2.2.2.1 (b) Function Keys

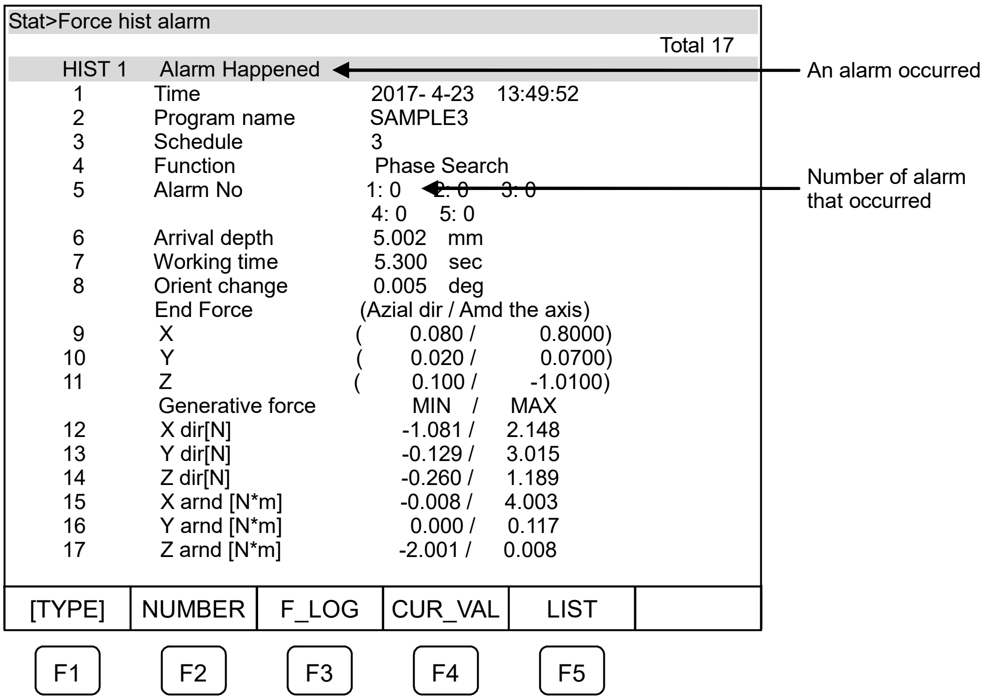
Key	Label	Description
F1	TYPE	Switches the [Force sensor status] screen to other status screen
F2	ALL	Switches to the list screen of all execution histories. (Refer to "Basic Function Guide: 2.2.1.1 List screen of all execution histories ".)
F3	F_LOG	Displays the [Force Data Log] screen. (Refer to "Basic Function Guide: 2.3 FORCE DATA LOG FUNCTION".)
F4	CUR_VAL	Switches to the [Force sensor current value] screen. (Refer to "Basic Function Guide: 2.1 FORCE SENSOR CURRENT VALUE SCREEN".)
F5	DETAIL	Displays the detail information of the selected execution history with alarm. (Refer to "Basic Function Guide: 2.2.2.2 Detail screen of execution histories with alarms".)

2

2.2.2.2 Detail screen of execution histories with alarms

Procedure for displaying the [Force Ctrl Ex-hist hist [1] (alarm)] screen

1 Display the [Force Ctrl Ex-hist list (alarm)] screen.
(Refer to "Basic Function Guide: 2.2.2.1 List screen of execution histories with alarms".)
2 Press F5 [DETAIL].
The [Force Ctrl Ex-hist hist [1] (alarm)] screen is displayed.



3 Press the [PREV] key on the teach pendant of the robot controller.
This returns to the [Force Ctrl Ex-hist list (alarm)] screen.
(Refer to "Basic Function Guide: 2.2.2.1 List screen of execution histories with alarms".)

Table 2.2.2.2 (a) Detail screen of the execution history with alarm

Item	Description
Time	Start time and date of force control instruction.
Program name	TP program name.
Schedule	Schedule data number.
Function	Function name of executed schedule.
Alarm No	The number of occurred alarm. (This item displays the previous five records.) (Refer to "APPENDIX: B ALARM CODES OF FORCE CONTROL".)
Arrival depth	Distance that the robot moves in the specified direction until an alarm occurs. 'Unit : mm'
Working time	Working time of the force control instruction until an alarm occurs. 'Unit : sec'
Orient change	Orientation change around TCP until an alarm occurs. 'Unit : deg'
End Force	Force (three elements in X, Y, Z directions of the user frame which is used during the force control, unit: N) and moment (three elements in around X, Y, Z directions of the above user frame, unit: N∗m) when alarm occurs. 'Unit : N, N*m'

Item	Description
Generated force	Maximum and Minimum values of Generated force (three elements in X, Y, Z directions of the user frame which is used during the force control, unit: N) and moment (three elements in around X, Y, Z directions of the above user frame, unit: N) during the force control. If the values are much bigger than push force, the workpiece may have collided during insertion or vibration occurred. 'Unit : N, N*m'

NOTE

The causes of alarms may be concluded according to the information on this screen.
For instance, the arrival depth is 5.002 mm and the working time is 20.3 sec. Suppose that the "Insert Depth" in this schedule data is set to be 10 mm, and "Insert Time MAX Limit" is set to be 20 sec. The cause of the alarm is that the working time exceeded the "Insert Time MAX Limit" before the robot reached the defined "Insert depth".

Function Keys

The function keys indicated have the following functions.

Table 2.2.2.2 (b) Function Keys

Key	Label	Description
F1	TYPE	Switches the [Force sensor status] screen to other status screen
F2	NUMBER	Switches to the [Force Ctrl Ex-hist hist [1] (alarm)] screen for a different history number. Enter a history number in the displayed menu.
F3	F_LOG	Displays the [Force Data Log] screen. (Refer to "Basic Function Guide: 2.3 FORCE DATA LOG FUNCTION".)
F4	CUR_VAL	Switches to the [Force sensor current value] screen. (Refer to "Basic Function Guide: 2.1 FORCE SENSOR CURRENT VALUE SCREEN".)
F5	LIST	Displays the list information of the selected execution history with alarm. (Refer to "Basic Function Guide: 2.2.2.1 List screen of execution histories with alarms ".)

2.3 FORCE DATA LOG FUNCTION

Overview

The Force data log function records the force data to a dat file during the force control operation. The force data can be graphically displayed on the *i*Pendant after the force control operation.
Making the following selections displays the Force data log screen.

The following operations are available on the “Force Data Log” screen, besides displaying the force and moment.

- Selecting the force data log file to be displayed.
  (Refer to "Basic Function Guide: 2.3.1 Selecting Force Data File".)
- Enabling/disabling Force data log function.
  (Refer to "Basic Function Guide: 2.3.2 Enabling/disabling Force Data Log Function".)
- Selecting device to save the force data log file.
  (Refer to "Basic Function Guide: 2.3.3 Selecting a Device to Save Force Data Log File".)
- Setting sampling interval of force data log.
  (Refer to "Basic Function Guide: 2.3.4 Setting the Sampling Interval of the Force Data Log".)

Procedure for displaying the [Force Data Log] screen

1 Display the force sensor current value screen.
(Refer to "Basic Function Guide: 2.1 FORCE SENSOR CURRENT VALUE SCREEN".)

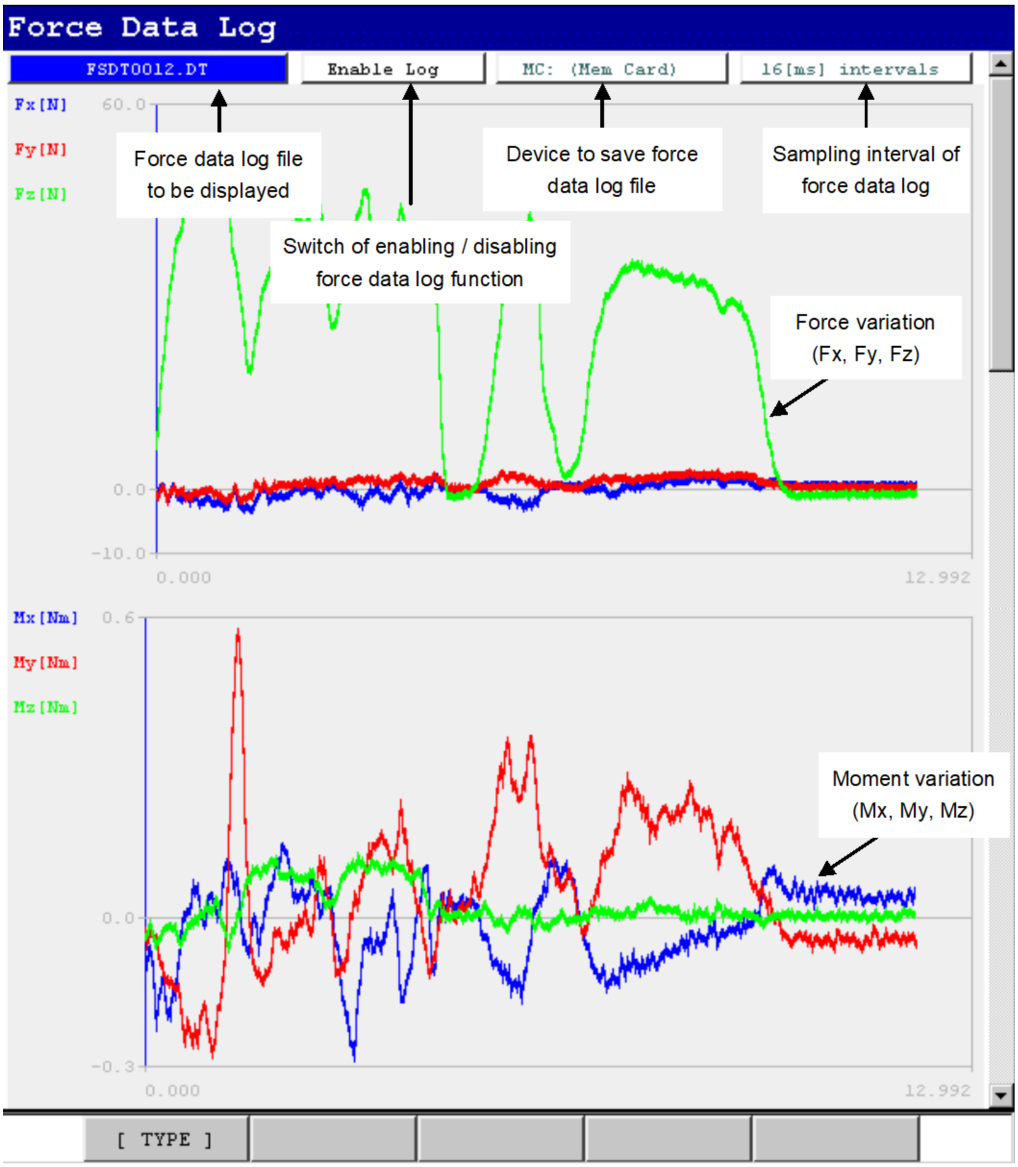
```
Stat>Force sensor current val

 SENSOR GRP 1   TOOL 1   SENSOR-F   FRAME   ATTACHMENT:HAND
                           Current              Mean
    Fx                    -8.135 N            -8.138 N
    Fy                    -6.227 N            -6.241 N
    Fz                   -22.981 N           -22.804 N
    Mx                     1.533 N*m           1.531 N*m
    My                    -0.232 N*m          -0.233 N*m
    Mz                    -1.099 N*m          -1.012 N*m

    Temperature            37.1  °C

 [TYPE]   GROUP   F_LOG   EX_HIST   CLEAR   >
   F1      F2      F3       F4       F5
```

2 Press F → F3[F_LOG].
The [Force Sensor Log] screen is displayed.
* Press the function key '→' to switch to display F3 [F_LOG].
* Typically, the graph of the moment elements Mx, My, Mz is invisible. Press the arrow key '↓' continuously to scroll up the screen and display the graph.



NOTE

1 The force data graph shows the variations from the reference data obtained at the beginning of the force control.
The upper graph shows the Fx, Fy, and Fz components of the force over time (horizontal axis).
The lower graph shows the Mx, My, and Mz components of the moment over time (horizontal axis).

2 If the force control is other than 'Contour', the directions X, Y, Z are the axes of User frame which is designated in the schedule.
In case of 'Contour', the directions X, Y, Z are the axes of User frame or Tool frame depending on the [Control frame] of the schedule.
If the [Pushing Dir Auto Chg] is 'UserFrame X-Y', Fx or Fy is the force in the pushing direction which is automatically changed. For example, if the [Pushing Direction] is ±X, the Fx is a force in pushing direction and the Fy is a force in the direction perpendicular to the pushing direction.

3 Press the [PREV] key on the teach pendant of the robot controller.
This returns to the force sensor current value screen.
(Refer to "Basic Function Guide: 2.1 FORCE SENSOR CURRENT VALUE SCREEN".)

Table 2.3 (a) Force Data Log screen

Item	Description
Data file name	Switches the menu to a different data file.
Enable/Disable Log	Switches the data log function to be enabled/disabled.
Device name	Switches the menu to a different device. Select from 'MC: (Mem Card)', 'UD1: (USB memory)', 'RD: (RAM Disk)', or 'FR: (FROM Disk)'.
Sampling interval	Changes the sampling interval. Enter a numerical value from the displayed numerical value entry menu.

* The unit of Fx, Fy, Fz is N and the unit of Mx, My, Mz is N*m.

Function Keys

The function keys indicated have the following functions.

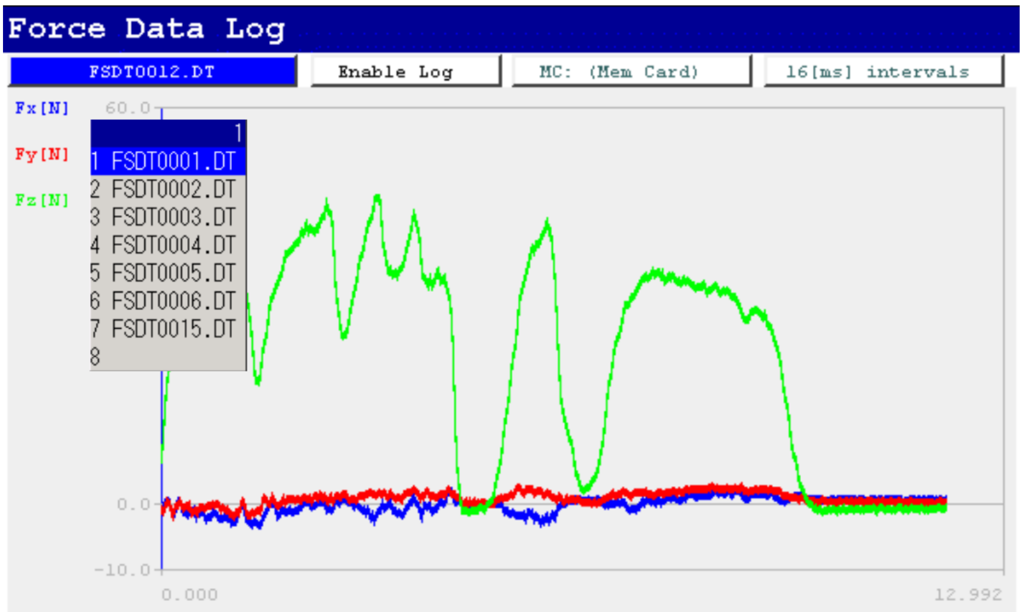
Table 2.3 (b) Function Keys

Key	Label	Description
F1	TYPE	Switches the [Force sensor status] screen to other status screen

2.3.1 Selecting Force Data File

Procedure for selecting a force data file

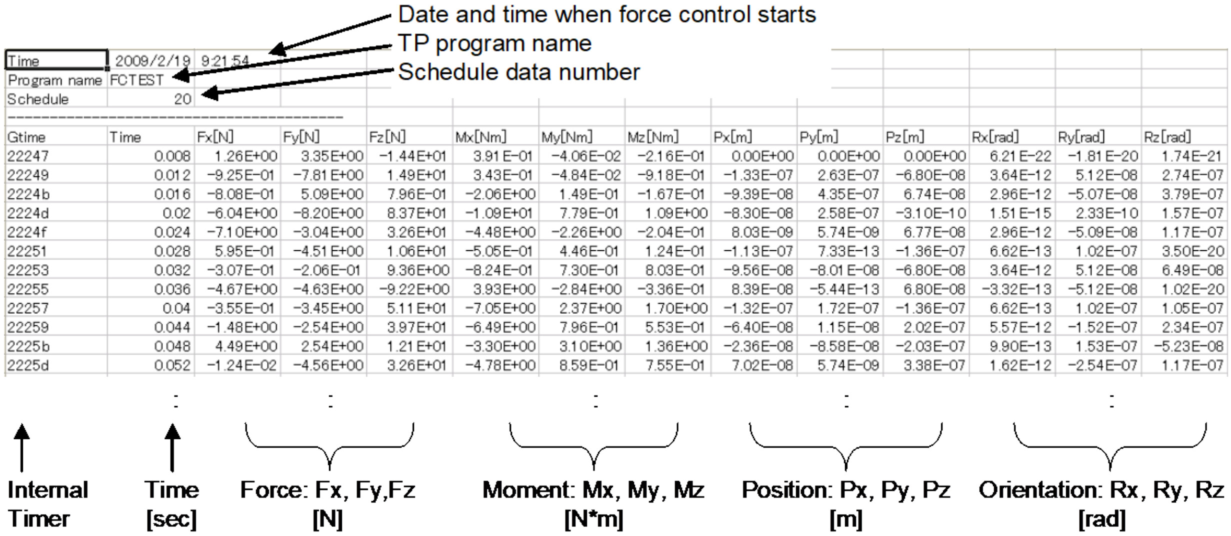
1 Display the [Force Data Log] screen.
(Refer to "Basic Function Guide: 2.3 FORCE DATA LOG FUNCTION".)
2 Click the data file name.
The force data file menu is displayed.
3 Select a file to display and click [YES].
The graph shows the logged force data.



NOTE

1. The file name is combined with 'FSDT' + four-digit number + '.DT'. The four-digit number is among 0001~9999 and increases successively and automatically according to the order the log file is recorded. If the four-digit number exceeds 9999, it returns to 0001 and override the old log file.
2. If the sampling interval is too short or the working time of the force control is too long, the force data are graphically displayed with part of them thinned out.

4 The detail of the graph may be checked by copying the force data log file to PC and opening it with a diagram calculation software or data analysis software.
The following shows a force data log file opened by Microsoft Excel.



Time	2009/2/19	9:21:54
Program name	FCTEST	
Schedule	20	

Gtime	Time	Fx[N]	Fy[N]	Fz[N]	Mx[Nm]	My[Nm]	Mz[Nm]	Px[m]	Py[m]	Pz[m]	Rx[rad]	Ry[rad]	Rz[rad]
22247	0.008	1.26E+00	3.35E+00	-1.44E+01	3.91E-01	-4.06E-02	-2.16E-01	0.00E+00	0.00E+00	0.00E+00	6.21E-22	-1.81E-20	1.74E-21
22249	0.012	-9.25E-01	-7.81E+00	1.49E+01	3.43E-01	-4.84E-02	-9.18E-01	-1.33E-07	2.63E-07	-6.80E-08	3.64E-12	5.12E-08	2.74E-07
2224b	0.016	-8.08E-01	5.09E+00	7.96E-01	-2.06E+00	1.49E-01	-1.67E-01	-9.39E-08	4.35E-07	6.74E-08	2.96E-12	-5.07E-08	3.79E-07
2224d	0.02	-6.04E+00	-8.20E+00	8.37E+01	-1.09E+01	7.79E-01	1.09E+00	-8.30E-08	2.58E-07	-3.10E-10	1.51E-15	2.33E-10	1.57E-07
2224f	0.024	-7.10E+00	-3.04E+00	3.26E+01	-4.48E+00	-2.26E+00	-2.04E-01	8.03E-09	5.74E-09	6.77E-08	2.96E-12	-5.09E-08	1.17E-07
22251	0.028	5.95E-01	-4.51E+00	1.06E+01	-5.05E-01	4.46E-01	1.24E-01	-1.13E-07	7.33E-13	-1.36E-07	6.62E-13	1.02E-07	3.50E-20
22253	0.032	-3.07E-01	-2.06E-01	9.36E+00	-8.24E-01	7.30E-01	8.03E-01	-9.56E-08	-8.01E-08	-6.80E-08	3.64E-12	5.12E-08	6.49E-08
22255	0.036	-4.67E+00	-4.63E+00	-9.22E+00	3.93E+00	-2.84E+00	-3.36E-01	8.39E-08	-5.44E-13	6.80E-08	-3.32E-13	-5.12E-08	1.02E-20
22257	0.04	-3.55E-01	-3.45E+00	5.11E+01	-7.05E+00	2.37E+00	1.70E+00	-1.32E-07	1.72E-07	-1.36E-07	6.62E-13	1.02E-07	1.05E-07
22259	0.044	-1.48E+00	-2.54E+00	3.97E+01	-6.49E+00	7.96E-01	5.53E-01	-6.40E-08	1.15E-08	2.02E-07	5.57E-12	-1.52E-07	2.34E-07
2225b	0.048	4.49E+00	2.54E+00	1.21E+01	-3.30E+00	3.10E+00	1.36E+00	-2.36E-08	-8.58E-08	-2.03E-07	9.90E-13	1.53E-07	-5.23E-08
2225d	0.052	-1.24E-02	-4.56E+00	3.26E+01	-4.78E+00	8.59E-01	7.55E-01	7.02E-08	5.74E-09	3.38E-07	1.62E-12	-2.54E-07	1.17E-07

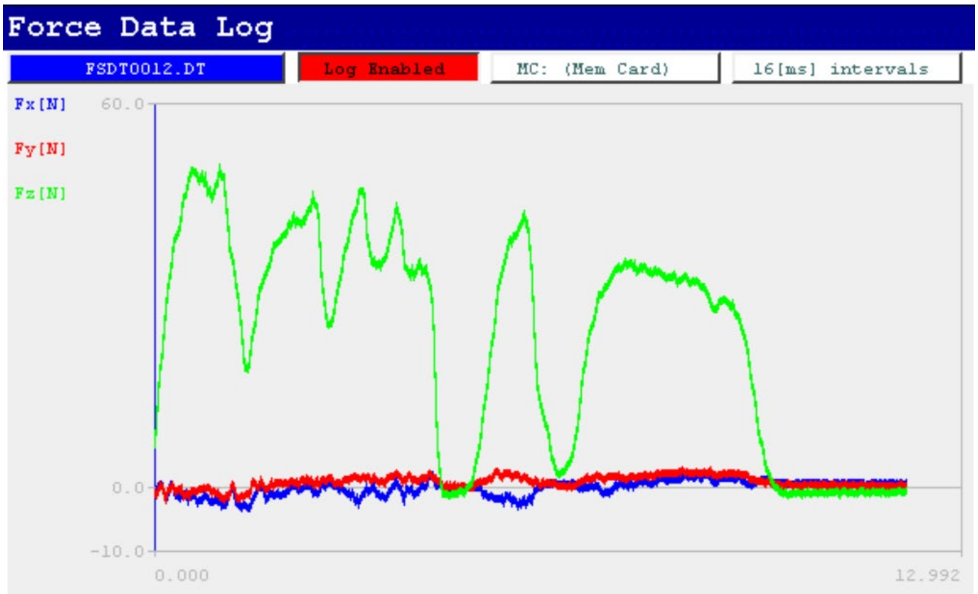
NOTE

1. The force data log file is a text file punctuated by tabulator.
2. The force, moment, and orientation data in this file are difference values from those at force control start point.
3. As for position data, they are difference values from those at force control start point for software version 7DC2/07 and before, they are values in the World frame for software version 7DC2/08 and later.

2.3.2 Enabling/disabling Force Data Log Function

Procedure for enabling/disabling the force data log function

1. Display the [Force Data Log] screen.
   (Refer to "Basic Function Guide: 2.3 FORCE DATA LOG FUNCTION".)
2. Perform the following operations to enable/disable the data log function.
   - If [Enable Log] is displayed, click [Enable Log].
     The button on the screen changes to 'Log Enabled'. In this state, if a force control instruction is executed, the force data under the force control are logged.
   - If [Log Enabled] is displayed, click [Log Enabled].
     The button on the screen changes to 'Enable Log'. In this state, even if a force control instruction is executed, no force data under the force control is logged.



NOTE
The execution time of force control instruction is longer when data logging is enabled. It is recommended that this function is used only during the setup operation.

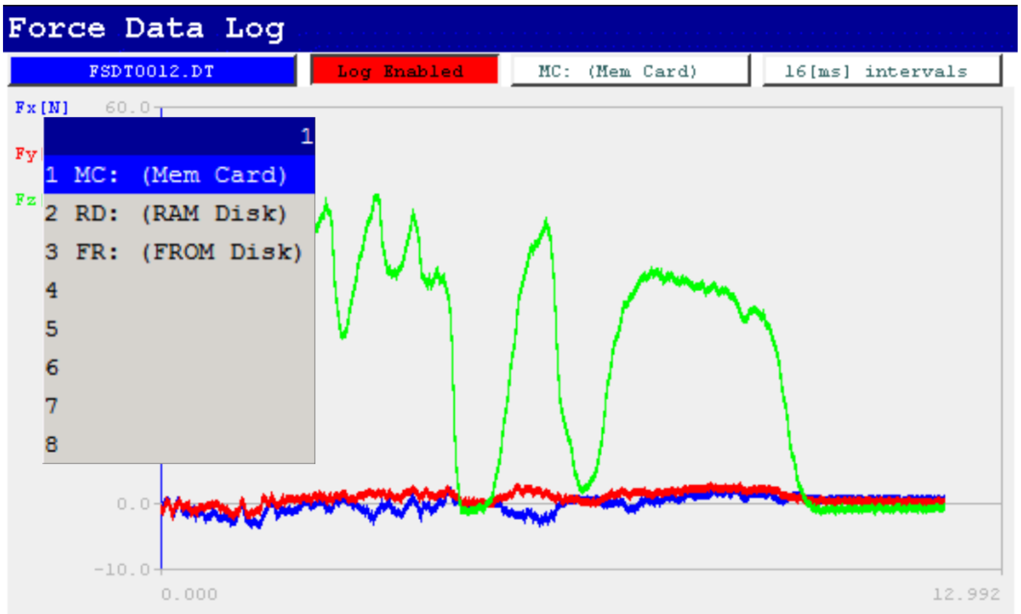
2.3.3 Selecting a Device to Save Force Data Log File

Procedure for selecting a device to store the force data file in.

1 Display the [Force Data Log] screen.
(Refer to "Basic Function Guide: 2.3 FORCE DATA LOG FUNCTION".)

2 Click the device name.
The menu is displayed.

3 Select a device name to save the force data file in and press the [ENTER] key on the teach pendant of the robot controller.
The button on the screen changes to the destination device name.
* The force data file can be saved to device 'MC: (Mem Card)', 'UD1: (USB memory)', 'RD: (RAM Disk)' or 'FR: (FROM Disk)'.



NOTE

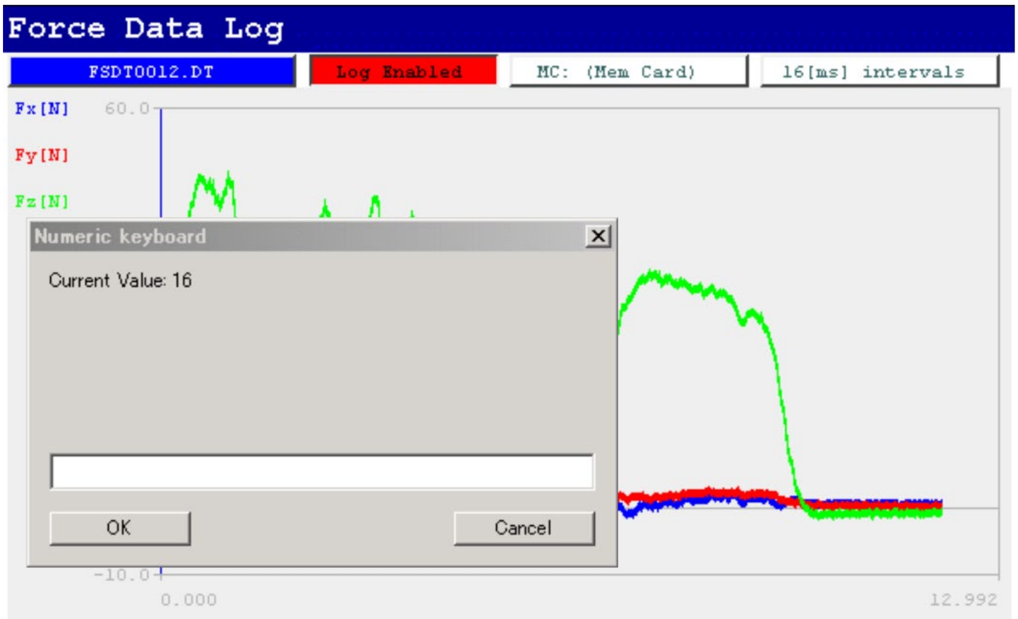
1 The force data log files are placed in the directory 'FSDT1' in the specified device. The file name is combined with 'FSDT' + four-digit number + '.DT'. The four-digit number is among 0001~9999 and increases successively and automatically according to the order the log file is recorded. If the four-digit number exceeds 9999, it returns to 0001 and override the old log file.

2 It is recommended to select 'MC: (Mem Card)' or 'UD1: memory' for a device to save the force data file in because they provide a higher processing speed. Make sure to provide a memory card or USB memory designated by Fanuc in advance.

2.3.4 Setting the Sampling Interval of the Force Data Log

Procedure for setting the force data sampling interval

1 Display the [Force Data Log] screen.
(Refer to "Basic Function Guide: 2.3 FORCE DATA LOG FUNCTION".)
2 Click the sampling interval. The numeric value entry menu is displayed.
* By default, [16[ms] intervals] is displayed.
3 Enter an integer and press "Enter" to sets the sampling interval of the force data log.
* The unit is ms.



4 Click the EXIT.
Set the sampling interval of the force data log.

NOTE
There is a size limitation for the force data log during the execution of one force control instruction. Increase the sampling interval to enable force data log for long time.

3 FORCE SENSOR UTILITIES SCREEN

This chapter describes the utility functions of the force sensor.

CONTENTS

3.1 OUTLINES OF FORCE SENSOR UTILITIES SCREEN

OVERVIEW

On the [Force sensor utilities] screen, the screen of 'Workpiece Mass Measurement Function', 'Tool Weight and COG Calculation Function', 'Force Sensor Attachment Function', 'TP Program Auto Generation Function', 'Deburring Path Auto Generation Function', 'Force Sensor Diagnosis Results Function', '4D Graphic' or 'Force Sensor Installation Guide' can be displayed. This section explains how to operate [Force sensor utilities] screen.
To open the [Force sensor utilities] screen, select the following.

Procedure for displaying a force sensor utility screen

1 Press the [MENU] key on the teach pendant of the robot controller.
The menu is displayed.

2 Select [UTILITIES] -> [Force Sensor].
The [UTILITIES Force Sensor] screen is displayed.

```
UTILITIES Force Sensor
                                                    Total 8
     1    Workpiece Mass Measurement
     2    Tool Weight and COG Calculation
     3    Force Sensor Attachment
     4    TP Program Auto Generation
     5    Deburring Path Auto Generation
     6    Force Sensor Diagnosis Results
     7    4D graphic
     8    Force Sensor Installation Guide

 [TYPE]  |        | DETAIL |        |        |
   F1       F2       F3       F4       F5
```

3 Move the cursor over the item to set and press F3 [DETAIL].
The force sensor utility screen for the selected item is displayed.

Table 3.1 (a) shows the overview of each function on the force sensor utilities screen.
Refer to section of each function for detail.

Table 3.1 (a) Items in force sensor utilities screen

Item	Description
Workpiece Mass Measurement	Open the parameter setting screen of Mass Measurement function. Refer to "Auxiliary Function Guide: 3 WORKPIECE MASS MEASUREMENT FUNCTION".
Tool Weight and COG Calculation	Open the Menu screen of Tool Weight and Center of Gravity Calculation function. Refer to "Auxiliary Function Guide: 1 TOOL WEIGHT AND CENTER OF GRAVITY CALCULATION FUNCTION".
Force Sensor Attachment	Execute the setting program of force sensor attachment. Refer to "Appendix: C FORCE SENSOR ATTACHMENT SETTING FUNCTION".
TP Program Auto Generation	Open the list of parameter setting screen for TP Program Auto Generation Function. Refer to "Auxiliary Function Guide: 2 TP PROGRAM AUTO GENERATION FUNCTION".
Deburring Path Auto Generation	This function intends to quickly and automatically generate deburring path to remove burrs on machined surface of castings. Designate deburr lines on ROBOGUIDE and *i*RVision Camera or 3D laser vision sensor detects real workpiece's edge lines, then, the robot program for the deburr tool to contour the edge line will be generated. Software option 'Force Control Deburring Package' (J840) is necessary to use this function. Refer to "R-30*i*B Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934-1EN).
Force Sensor Diagnosis Results	Open the results of force sensor diagnosis. Refer to "Basic Function Guide: 1.10.1 Force Sensor Diagnosis Instructions".
4D graphic	Open the parameter setting screen of 4D Graphic. Refer to "Auxiliary Function Guide: 4 FORCE SENSOR 4D GRAPHIC FUNCTION".
Force Sensor Installation Guide	Displays the [Home] screen of the Force Sensor Installation Guide. Refer to "Introduction: 3 INSTALLING FORCE SENSOR".

Function keys

The function keys have the following functions.

Table 3.1 (b) Function keys

Key	Item	Description
F1	TYPE	Allows you to change the display to a menu other than the force sensor utilities.
F3	DETAIL	Allows you to display the screen of each function.

Auxiliary Functions Guide

1 TOOL WEIGHT AND CENTER OF GRAVITY CALCULATION FUNCTION

For the gravity compensation during the force control, this program finds the weight and gravity center of the tool or workpiece attached to a force sensor.

CONTENTS

> ⚠ **CAUTION**
> The F4 [Prev] key is disabled when [SHIFT] key is pressed.

> **NOTE**
> 1 When using the contouring function, be sure to execute this program.
> 2 It can be useful for other functions such as “Face Match “ if the orientation change is larger than, for example, 5deg.

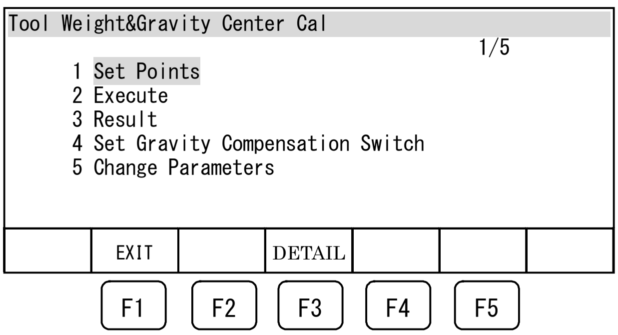
1.1 MENU SCREEN

Overview

The menu screen of weight and gravity center calcuration function is opened from the force sensor utilities screen.
(Refer to "Basic Function Guide: 3 FORCE SENSOR UTILITIES SCREEN".)

Procedure for displaying the [Tool Weight & Gravity Center Cal] screen

1 Press the [MENU] key on the teach pendant of the robot controller.
The menu is displayed.
2 Select [UTILITIES]->[Force Sensor].
The [UTILITIES Force Sensor] screen is displayed.
(Refer to "Basic Function Guide: 3 FORCE SENSOR UTILITIES SCREEN".)
3 Move the cursor over [Tool Weight and COG Calculation] and press F3 [DETAIL].
The [Tool Weight & Gravity Center Cal] screen is displayed.



4 Move the cursor over a row to display and press F3 [DETAIL].
The detailed setting screen for the individual item is displayed.

Table 1.1 (a) Items in "Menu" screen

Item	Description
Set Points	Use the following procedure to switch to the [Set Points] screen. • Click [Set Points]. The [Set Points] screen is displayed. (Refer to "Auxiliary Function Guide: 1.2 TEACHING POSITIONS")
Execute	Use the following procedure to calculate the tool weight and center of gravity. • Click [Execute]. • Click [YES]. Three teaching points are used to perform measurements for calculating the tool weight and center of gravity. The execution result screen is displayed. (Refer to "Auxiliary Function Guide: 1.3 CALCULATING THE WEIGHT AND GRAVITY CENTER OF THE TOOL")
Result	Use the following procedure to switch to the result list screen. • Click [Result]. The result list screen is displayed. (Refer to "Auxiliary Function Guide: 1.4 CALCULATION RESULTS")
Set Gravity Compensation Switch	Use the following procedure to switch to the [Set Gravity Compensation Switch] screen. • Click [Set Gravity Compensation Switch]. The [Set Gravity Compensation Switch] screen is displayed. (Refer to "Auxiliary Function Guide: 1.5 SETTING THE GRAVITY COMPENSATION SWITCH")
Change Parameters	Use the following procedure to switch to the [Change Parameters] screen. • Click [Change Parameters]. The [Change Parameters] screen is displayed. (Refer to "Auxiliary Function Guide: 1.6 PARAMETER MODIFICATION")

Function Keys

The function keys indicated have the following functions.

Table 1.1 (b) Function keys

Key	Items	Description
F1	EXIT	Allows you to go back the force sensor utilities screen.
F3	DETAIL	Displays the detailed setting screen for the item on which the cursor is placed. * If the cursor is placed on [Execute], the tool weight and center of gravity are calculated.

1.2 TEACHING POSITIONS

To teach measurement positions, three teaching points are required.
Set the teaching points in the [Set Points] screen and its detailed screen.

1.2.1 Set Points Screen

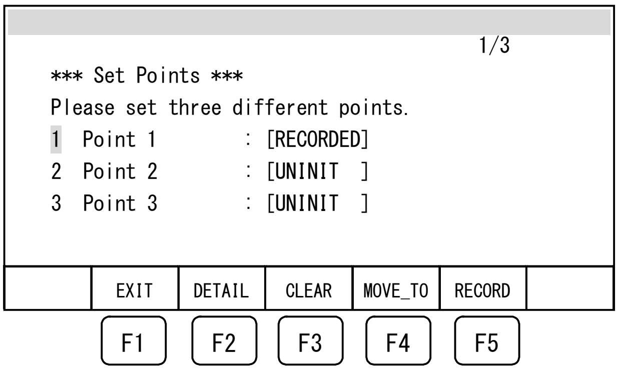
Overview

In the [Set Points] screen, the current position can be saved in the format of axes.
It is also possible to see whether each of the three teaching points is [UNINIT] or [RECORDED].
Display the [Set Points] screen from the [Tool Weight & Gravity Center Cal] screen.
(Refer to "Auxiliary Function Guide: 1.1 MENU SCREEN")

Procedure for displaying/setting the [Set Points] screen

1 Display the [Tool Weight & Gravity Center Cal] screen.
(Refer to "Auxiliary Function Guide: 1.1 MENU SCREEN")

2 Click [Set Points].
The [Set Points] screen is displayed.
- For a position which is not taught yet, “UNINIT” is displayed.
- For an already taught position, “RECORDED” is displayed.



3 To save the current position in the format of axes, move the cursor over the target point ([Approach point 1], [Approach point 2], or [Approach point 3]) and press Shift+F5 [RECORD].
The display changes from [UNINIT] to [RECORDED].

Function Keys

The function keys indicated have the following functions.

Table 1.2.1 Function keys

Key	Label	Description
F1	EXIT	Pressing F1 (EXIT) or [Prev] returns the screen display to the “Menu” screen.
F2	DETAIL	Displays the detail screen for position X where the cursor is currently placed.
Shift+F3	CLEAR	Deletes the data of position X where the cursor is currently placed, and displays “UNINIT”
Shift+F4	MOVE_TO	Press F2 [MOVE_TO] while the cursor is placed over an item marked as [RECORDED] to move the robot to the recorded position (taught in [Approach point 1], [Approach point 2], or [Approach point 3]). If F2 [MOVE_TO] is pressed while the cursor is placed over an item marked as [UNINIT], an error message 'Please set the point!' is displayed in the error message display area at the top of the screen.
Shift+F5	RECORD	The current position is saved and the display changes from “UNINIT” to “RECORDED”.

1.2.2 Set Points Detail Screen

Overview

In the [Detail] screen, the details of teaching points can be checked.
Also, the teaching points can be set by manually entering values.
(Refer to "Auxiliary Function Guide: 1.2.1 Set Points Screen")

> **NOTE**
> It is necessary to teach three positions from the suggested list .If three positions are selected improperly, the weight and gravity center of the tool or workpiece cannot be calculated. The orientation should vary as greatly as possible to change the force and moment applied to the force sensor.

Procedure for displaying/setting the [DETAIL] screen

1. Display the [Set Points] screen.
   (Refer to "Auxiliary Function Guide: 1.2.1 Set Points Screen")
2. Move the cursor over the target teaching point ([Approach point 1], [Approach point 2], or [Approach point 3]) and press F3[DETAIL].
   The [Detail] screen is displayed.

> **NOTE**
> 1 The unit of each axis is “deg” for a rotation axis.
> 2 The unit of each axis is “mm” for a linear axis.

Below is an example of the [Detail] screen when the point is marked as [RECORDED].
The [Detail] screen displays a value in the specified axis format for J1 to J6 of position X selected on the “Set Points” screen.

```
                                              1/6
  *** Set Points ***
  Point         1
    1    J1 :       0.000   deg
    2    J2 :       0.000   deg
    3    J3 :       0.000   deg
    4    J4 :       0.000   deg
    5    J5 :     -90.000   deg
    6    J6 :       0.000   deg

        EXIT
       [F1]   [F2]   [F3]   [F4]   [F5]
```

If the point is not taught, no value is set for this point and all axes display asterisks (*).

```
                                              1/6
  *** Set Points ***
  Point         1
    1    J1 : **********   deg
    2    J2 : **********   deg
    3    J3 : **********   deg
    4    J4 : **********   deg
    5    J5 : **********   deg
    6    J6 : **********   deg

        EXIT
       [F1]   [F2]   [F3]   [F4]   [F5]
```

3 To set the teaching point, click the name of an item to set.
The numeric value entry screen is displayed.

4 Teach three teaching points.
The recommended teaching orientations are shown in Table 1.2.2 (a).

- First select orientations 1 to 3 and perform teaching.
- If there is an orientation in orientations 1 to 3 that does not reach, select orientation 4 or 5, and perform teaching.

Table 1.2.2 (a) Recommended teaching orientations

Position Number	Joint (Unit: deg)						Orientation of robot flange
	J1	J2	J3	J4	J5	J6	
1	0	0	0	0	-90	0	–Z axis in world frame coordinate (Downward)
2	0	0	0	0	0	0	+X axis in world frame coordinate (Forward)
3	0	0	0	0	90	0	+Z axis in world frame coordinate (Upward)
4	0	0	0	90	-90	0	–Y axis in world frame coordinate (Horizontally)
5	0	0	0	-90	-90	0	+Y axis in world frame coordinate (Horizontally)

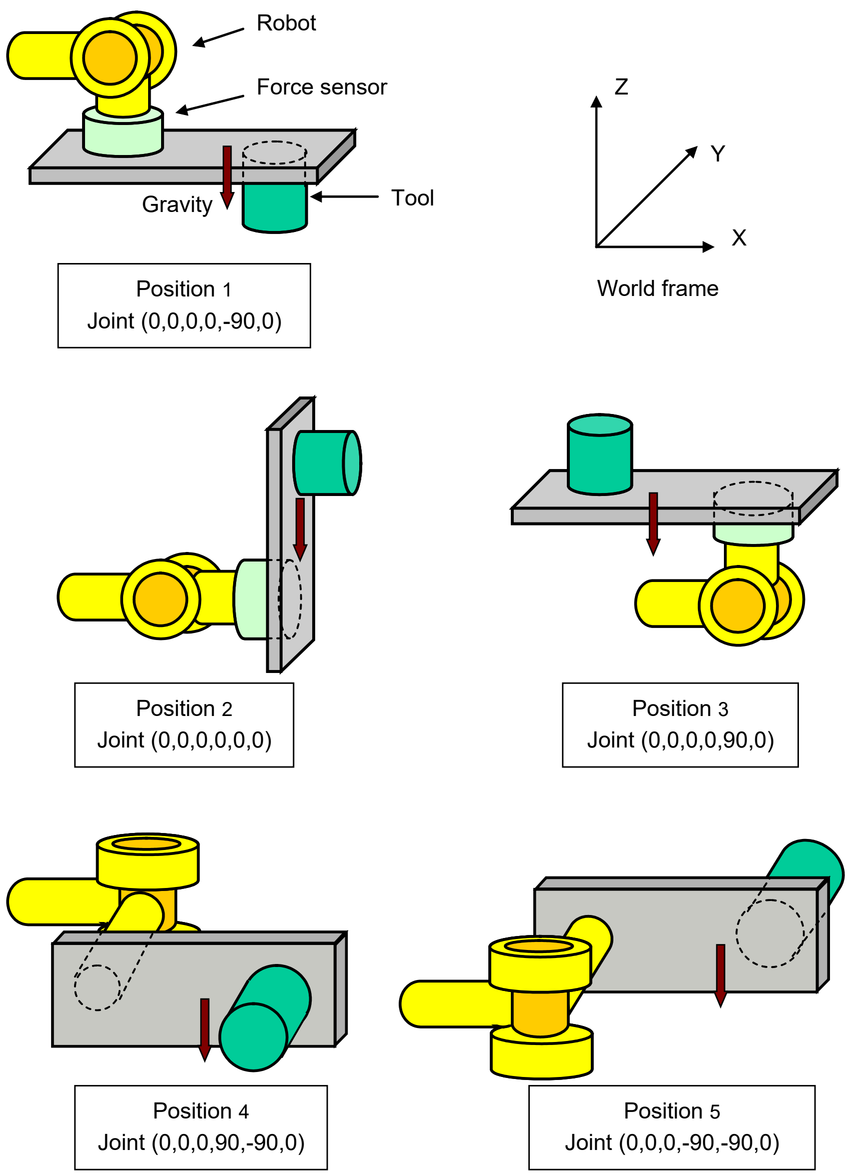


Fig. 1.2.2 Set the points

> **NOTE**
> It is necessary that the gravity of the tool applied to the force sensor differs at three points. If the orientation change between two positions is around Z axis in the world frame coordinate, the gravity of the tool applied to the sensor does not change. Make sure the orientation changes are around X or Y axis in world frame coordinate by following the sample positions mentioned above.

5 If values are already set for all of J1 to J6, press F1 [EXIT] key to store those values, return to the “Set Points” screen and change the status to “RECORDED”.

> **NOTE**
> 1 The values set here are saved even after the controller is restarted.
> 2 If a value entered for any of the joints is not within the allowable range , the previous value is retained, and the top line of the screen displays “Value Limit Error”.

Function Keys

The function keys indicated have the following functions.

Table 1.2.2 (b) Function Keys

Key	Label	Description
F1	EXIT	If values are already set for all of J1 to J6, press F1(EXIT) or [Prev] key to store those values, return to the “Set Points” screen and change the status to “RECORDED”. The values set here are saved even after the controller is restarted. If a value entered for any of the joints is not within the allowable range , the previous value is retained, and the top line of the screen displays “Value Limit Error”

1.3 CALCULATING THE WEIGHT AND GRAVITY CENTER OF THE TOOL

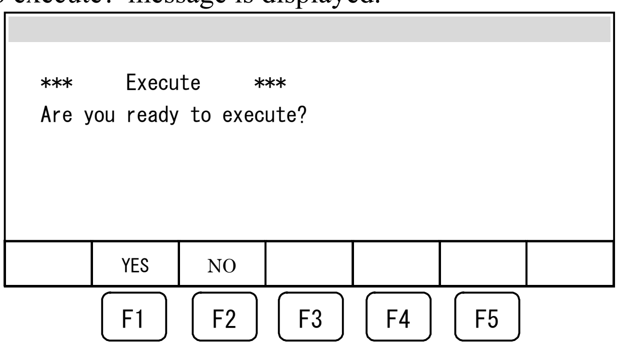
Overview

Three teaching points are used to perform measurements for calculating the tool weight and center of gravity.

Procedure for calculating the tool weight and center of gravity

1 Display the [Tool Weight & Gravity Center Cal] screen.
(Refer to "Auxiliary Function Guide: 1.1 MENU SCREEN")

2 Move the cursor over [Execute] and press F3 [DETAIL].
The 'Are you ready to execute?' message is displayed.



3 Press F1 [YES].
Three teaching points are used to perform measurements for calculating the tool weight and center of gravity.
The robot moves sequentially to the three points set in "Auxiliary Function Guide: 1.2 TEACHING POSITIONS", and then the force sensor data at three points are recorded. After moving to point 3, the weight and gravity center of the tool are calculated.
(Refer to "Auxiliary Function Guide: 1.2 TEACHING POSITIONS")
* If F2[NO] is pressed, the screen returns to the [Tool Weight&Gravity Center Cal] screen.

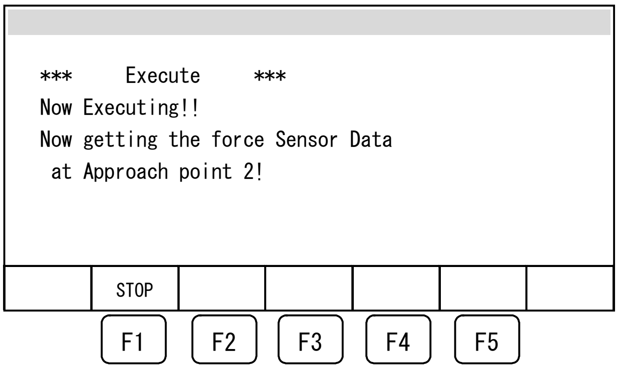
⚠ CAUTION

1 Pay attention to the robot's movement for the override is automatically set to 10 %.
2 During the execution of this program, the robot moves to three points sequentially. Make sure that nothing interferes the robot's movement.

NOTE

Put the robot controller in T1/T2 mode and set the ON/OFF switch to [ON] on the teach pendant.

If the force sensor data at position X (X is 1, 2 or 3) are being obtained, "Now getting the force Sensor Data at approach point X" is displayed under "Now executing!!".



When the calculation finishes normally, the calculation result is displayed.

1.3.1 Confirming Calculation Results

In the execution result screen, the calculation result can be checked and saved.

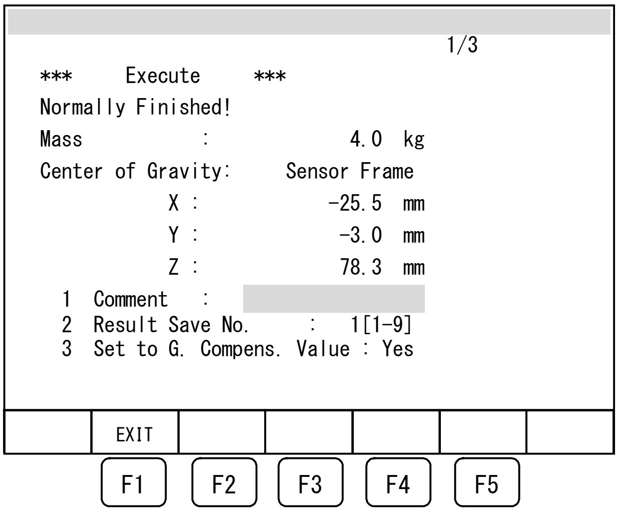


Fig. 1.3.1 Calculation Results

Table 1.3.1 (a) Execution result screen

Item	Description
Comment	Click [Comment] to display the numeric value entry screen. Enter a comment.
Result Save No. [1～9]	Enter the calculation result save number as a numeric value from '1' to '9'. Up to 9 results of calculation can be preserved. By specifying a number, the corresponding result of calculation can be used later. (To check the result of calculation corresponding to another number, refer to "Auxiliary Function Guide: 1.4 CALCULATION RESULTS".)
Set G. Compens. Value	Select [Yes] or [No] to determine whether to set to the gravity compensation value. If “Yes” is specified in “Set to G. Compens. Value” at this time, the weight and gravity center data corresponding to the specified number is used for force control from now on. (To use the weight and gravity center data corresponding to another number, refer to "Auxiliary Function Guide: 1.4 CALCULATION RESULTS".)

Function Keys

The function keys indicated have the following functions.

Table 1.3.1 (b) Function Keys

Key	Label	Description
F1	EXIT	Pressing F1(EXIT) or [Prev] key saves the result of calculation to the number specified in “2 Result Save No.” and returns the screen display to the “Menu” screen.

1.3.2 Error Display when Execution Starts

When [YES] is clicked to start calculating the tool weight and center of gravity, the following error message may display.

(1) “Switch is turning OFF. Please Turn ON.”

If the ON/OFF switch on teach pendant is set to OFF, the error message “Switch is turning OFF. Please Turn ON.” is displayed on the top line of the screen. Set the ON/OFF switch to [ON].

(2) “Please set all points!”

If all positions are not taught, the error message “Please set all points!” is displayed on the top line of the screen. Teach all positions.
(Refer to "Auxiliary Function Guide: 1.2.1 Set Points Screen")

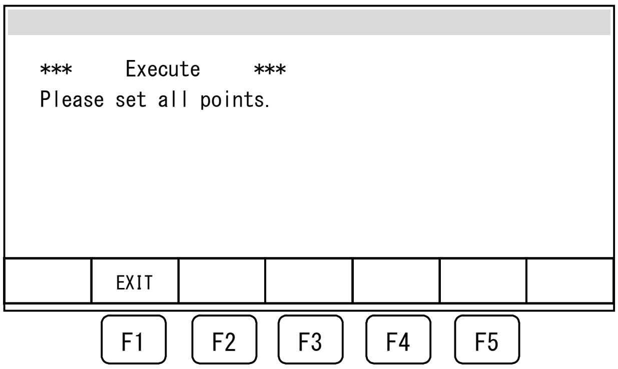


Fig. 1.3.2 (b) When there are positions not taught

(3) “Same points exist. Please shift it.”

If the same position is taught to more than one points, the error message “Same points exist. Please shift it.” is displayed on the top line of the screen. Teach different positions.
(Refer to "Auxiliary Function Guide: 1.2.2 Set Points Detail Screen")

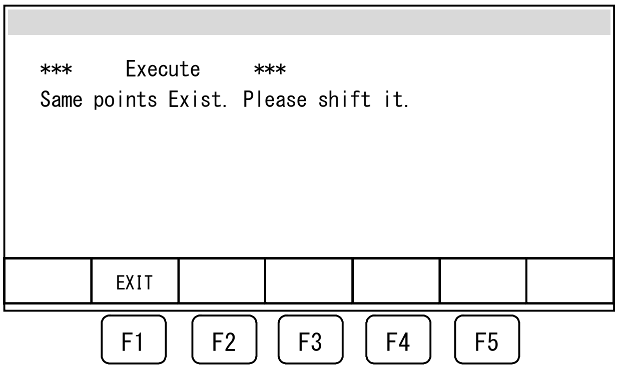


Fig. 1.3.2 (c) When the same position is taught to more than one points

(4) “Position change not enough. Please shift it.”

If the orientation changes among three positions are not enough, the error message “Position change not enough. Please shift it.” is displayed on the screen. Change the orientation as greatly as possible.

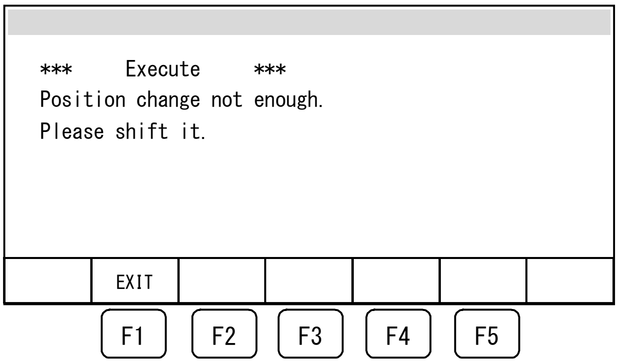


Fig. 1.3.2 (d) When the orientation change is not enough

In this situation, the following error message is displayed on the top line of the screen. Take action according to the remedy indicated in the right-hand column.

Table 1.3.2 Error messages displayed when the orientation changes are not enough

Error Message	Cause and remedy
P1&P2 position change not enough.	Orientation change between Position 1 and Position 2 is too small. Make sure the orientation change between the two points is greater than the parameter “Position Change Th.”. Refer to "Auxiliary Function Guide: 1.6 PARAMETER MODIFICATION".
P2&P3 position change not enough.	Orientation change between Position 2 and Position 3 is too small. Make sure the orientation change between the two points is greater than the parameter “Position Change Th.”. Refer to "Auxiliary Function Guide: 1.6 PARAMETER MODIFICATION".
P1&P3 position change not enough.	Orientation change between Position 1 and Position 3 is too small. Make sure the orientation change between the two points is greater than the parameter “Position Change Th.”. Refer to "Auxiliary Function Guide: 1.6 PARAMETER MODIFICATION".

1.3.3 Calculation Error

If a calculation error occurs, the corresponding error message is displayed as indicated below.

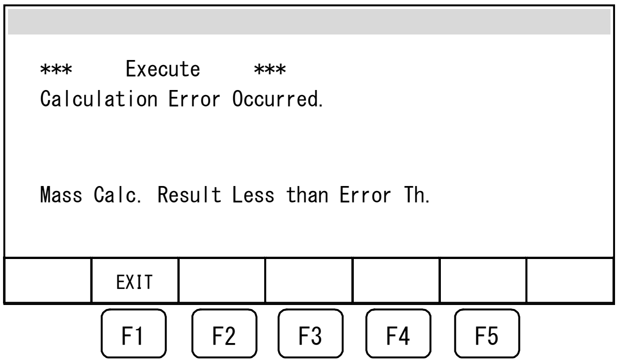


Fig. 1.3.3 When the calculation error occurs

Take action according to the remedy indicated in the right-hand column.

Table 1.3.3 Error messages displayed when the calculation result has an error

Error message	Cause and remedy
Mass Calc. Result Less than Error Th.	The mass calculation result is less than the parameter “Mass Error Threshold”. Reduce the “Mass Error Threshold”. Refer to "Auxiliary Function Guide: 1.6 PARAMETER MODIFICATION".
No Force Change.	The output force from the force sensor at each teach point does not differ. Check the setting of the force sensor and the tool. Make sure that the mass of the tool is not too small.
No Moment Change.	The output moment from the force sensor at each teach point does not differ. Check the setting of the force sensor and the tool. Make sure that the mass of the tool is not too small.
Mass Calc. Result is negative.	The mass calculation result is negative. Check the setting of the robot frame and the force sensor.
Other Error.	An error occurred for a cause other than the above.

1.4 CALCULATION RESULTS

Overview

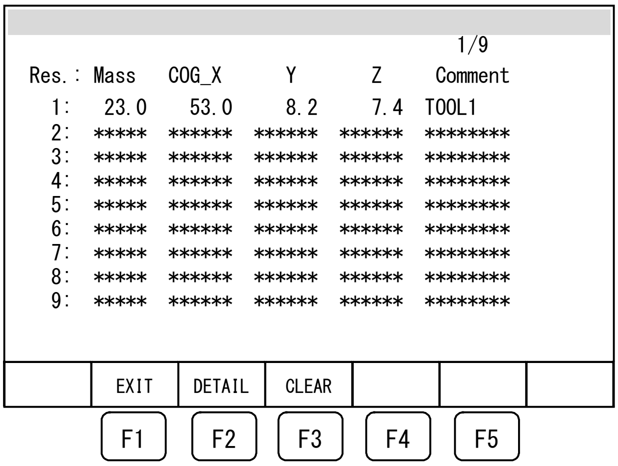
Select “Result” on the “Menu” screen to display the “Result” screen.

How to display the result list screen

1 Display the [Tool Weight & Gravity Center Cal] screen.
(Refer to "Auxiliary Function Guide: 1.1 MENU SCREEN")

2 Move the cursor over [Result] and press F3 [DETAIL].
The result list screen is displayed.

- * This screen shows the calculation results for the tool weight and gravity center measurements executed before.
- * For result items 1 to 9, weight and X, Y and Z value of gravity center are displayed.
- * For a data item with no values being set, asterisks (*) are indicated in each display field.
- * The result item with a (+) at its left side shows it is used for gravity compensation by the force sensor.



Function Keys

The function keys indicated have the following functions.

Table 1.4 Function Keys

Key	Label	Description
F1	EXIT	Pressing F1 (EXIT) or [Prev] key returns the screen display to the “Menu” screen.
F2	DETAIL	Displays the details of result X where the cursor is currently placed.
F3	CLEAR	Deletes the details of result X where the cursor is currently placed.

NOTE

If a program is running, the calculation result cannot be cleared and detail screen cannot be displayed.

1.4.1 Calculation Result Detail Screen

Overview

The detail screen displays a comment, weight, X, Y and Z value of gravity center, and whether to use the result for gravity compensation with force sensor.

NOTE
The unit of gravity is “mm”, and the unit of weight is “kg”.

Procedure for displaying the calculation result detail screen

1 Display the result list screen.
(Refer to "Auxiliary Function Guide: 1.4 CALCULATION RESULTS")
2 Move the cursor over the data to display and press F3 [DETAIL].
The [Detail] screen is displayed.
For data with values, a screen similar to the one below is displayed.

```
                                          1/6
 ***   Results   ***
 Result No.   :              1
   1 Comment  :          Tool1
   2 Mass     :          23.0  kg
   Center of Gravity :  Sensor Frame
   3       X :          -25.5  mm
   4       Y :           -3.0  mm
   5       Z :           78.3  mm
   6 Set to G. Compens. Value:Yes

        EXIT
      F1     F2     F3     F4     F5
```

When no value is set for an item other than the item of comment, asterisks (∗) are displayed in the display field.

```
                                          1/6
 ***   Results   ***
 Result No.   :              1
   1 Comment  :       ********
   2 Mass     :         *****  kg
   Center of Gravity :  Sensor Frame
   3       X :         ******  mm
   4       Y :         ******  mm
   5       Z :         ******  mm
   6 Set to G. Compens. Value:***

        EXIT
      F1     F2     F3     F4     F5
```

3 To enter of change values, click the name of an item.
The input screen for the individual item is displayed.

NOTE
1 Press [YES] on item “Set to G. Compens.Value”, to apply gravity compensation during the force control operation. Click [NO] not to use this result.
2 The gravity compensation switch must be set to ON in the force schedule to enable gravity compensation.
(Refer to "Auxiliary Function Guide: 1.5 SETTING THE GRAVITY COMPENSATION SWITCH")

4 Press F1 [EXIT].
The result list screen is displayed.

Function Keys

The function keys indicated have the following functions.

Table 1.4.1 Function Keys

Key	Label	Description
F1	EXIT	Pressing F1 (EXIT) or the [Prev] key displays the “Results” screen.

Setting Calculation Result from TP Program

The specified number of calculation result can also be set for gravity compensation from TP program with the following command. As it enables to switch the calculation result, it is useful when the tool is changed during operation.

```
1:   CALL SET_WCG(1)
```

“1” is the number of Calculation result (it can be 1 to 9) to be set.
If the specified calculation result is uninitialized, error message is displayed.

1.5 SETTING THE GRAVITY COMPENSATION SWITCH

Overview

The “Gravity Compensation Switch” has to be set in order to use the mass and the center of gravity that are calculated in "Auxiliary Function Guide: 1.4 CALCULATION RESULTS" and compensate for the effect of gravity.
This section describes the method of setting the gravity compensation switch for each schedule number.

Procedure for displaying the [Set Gravity Compensation Switch] screen

1 Display the [Tool Weight & Gravity Center Cal] screen.
(Refer to "Auxiliary Function Guide: 1.1 MENU SCREEN")
2 Move the cursor over [Set Gravity Compensation Switch] and press F3 [DETAIL].
The [Set Gravity Compensation Switch] screen is displayed.

```
                                            1/8
   *** Setting of G. Compes. Switch ***
   Setting of G. Compes. of each Schedule.
      1:  OFF   2:  OFF   3:  OFF   4:  OFF
      5:  OFF   6:  OFF   7:  OFF   8:  OFF
      9:  OFF  10:  OFF  11:  OFF  12:  OFF
     13:  OFF  14:  OFF  15:  OFF  16:  OFF
     17:  OFF  18:  OFF  19:  OFF  20:  OFF
     21:  OFF  22:  OFF  23:  OFF  24:  OFF
     25:  OFF  26:  OFF  27:  OFF  28:  OFF
     29:  OFF  30:  OFF  31:  OFF  32:  OFF

        EXIT     ON     OFF    ALL_ON  ALL_OFF
         F1      F2      F3      F4      F5
```

3 Click a schedule number to set.
Or press the numeric key corresponding to a schedule number to set on the teach pendant of the robot controller and press the [ENTER] key.
The selected schedule number is displayed in the first row.

```
                                         1/8
 *** Setting of G. Compes. Switch ***
 Setting of G. Compes. of each Schedule.
   21: OFF  22: OFF  23: OFF  24: OFF
   25: OFF  26: OFF  27: OFF  28: OFF
   29: OFF  30: OFF  31: OFF  32: OFF
   33: OFF  34: OFF  35: OFF  36: OFF
   37: OFF  38: OFF  39: OFF  40: OFF
   41: OFF  42: OFF  43: OFF  44: OFF
   45: OFF  46: OFF  47: OFF  48: OFF
   49: OFF  50: OFF

        EXIT    ON     OFF   ALL_ON  ALL_OFF
        F1      F2     F3    F4      F5
```

4 Press F2[On] or F3[Off].

NOTE

1 Pressing the [Next] key changes the F1 key to [RETURN]. Pressing the [Next] key again returns the screen display to the “Setting of G. Compens. Switch” screen.Press the F1 key [RETURN] to reset all gravity compensation switches to their previous states.
2 If a program is running, the Gravity Compensation Switch cannot be modified.

Function Keys

The function keys indicated have the following functions.

Table 1.5 Function Keys

Key	Label	Description
F1	EXIT	Pressing F1 (EXIT) or [Prev] key returns the screen display to the “Menu” screen.
F2	ON	Changes the setting of the schedule number on which the cursor is placed to ON.
F3	OFF	Changes the setting of the schedule number on which the cursor is placed to OFF.
F4	ALL_ON	Changes the settings of all schedule numbers to ON.
F5	ALL_OFF	Changes the settings of all schedule numbers to OFF.

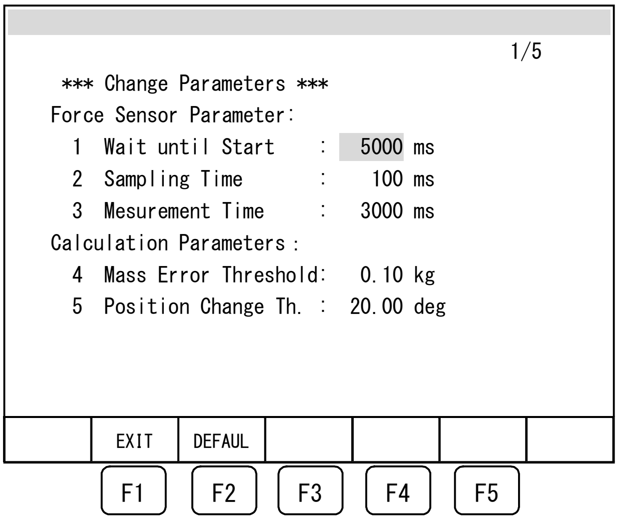
1.6 PARAMETER MODIFICATION

Overview

In the [Change Parameters] screen, the parameters for [Force Sensor Parameter] and [Calculation Parameters] can be modified.

Procedure for setting the [Change Parameters] screen

1 Display the [Tool Weight & Gravity Center Cal] screen.
(Refer to "Auxiliary Function Guide: 1.1 MENU SCREEN")
2 Move the cursor over [Change Parameters] and press F3 [DETAIL].
The [Change Parameters] screen is displayed.



3 Click an item to change and enter the parameter.

The setting items on the [Change Parameters] screen are as follow.

Table 1.6 (a) Change Parameters

Item		Description
Force Sensor Parameter	[Wait until Start]	Waiting time between moving to a position and starting to obtain force sensor data "Default : 5000 ms"
	[Sampling Time]	Sampling time of obtaining force sensor data "Default : 100 ms"
	[Measurement Time]	Total measurement time of obtaining force sensor data "Default : 3000 ms"
Calculation Parameters	[Mass Error Threshold]	The minimum mass of the tool that can be measured "Default : 0.1 kg"
	[Position change Th.]	Orientation change between every two points among three teach points mentioned in "Auxiliary Function Guide: 1.2 TEACHING POSITIONS" "Default : 20.0 deg"

Function Keys

The function keys indicated have the following functions.

Table 1.6 (b) Function Keys

Key	Label	Description
F1	EXIT	Pressing F1(EXIT) or [Prev] returns the screen display to the “Menu” screen.
F2	DEFAULT	Resets the parameter of the item on which the cursor is placed to its default.

2 TP PROGRAM AUTO GENERATION FUNCTION

It is time taking to teach a deburr path for a workpiece with complex shape. TP Program Auto Generation function saves time by tracing a rough path taught on the workpiece with the Contouring function under force control and generating a fine path for production operation. As shown in the following figure, the taught path of the workpiece has minimum positions compared to the fine path generated by this function.

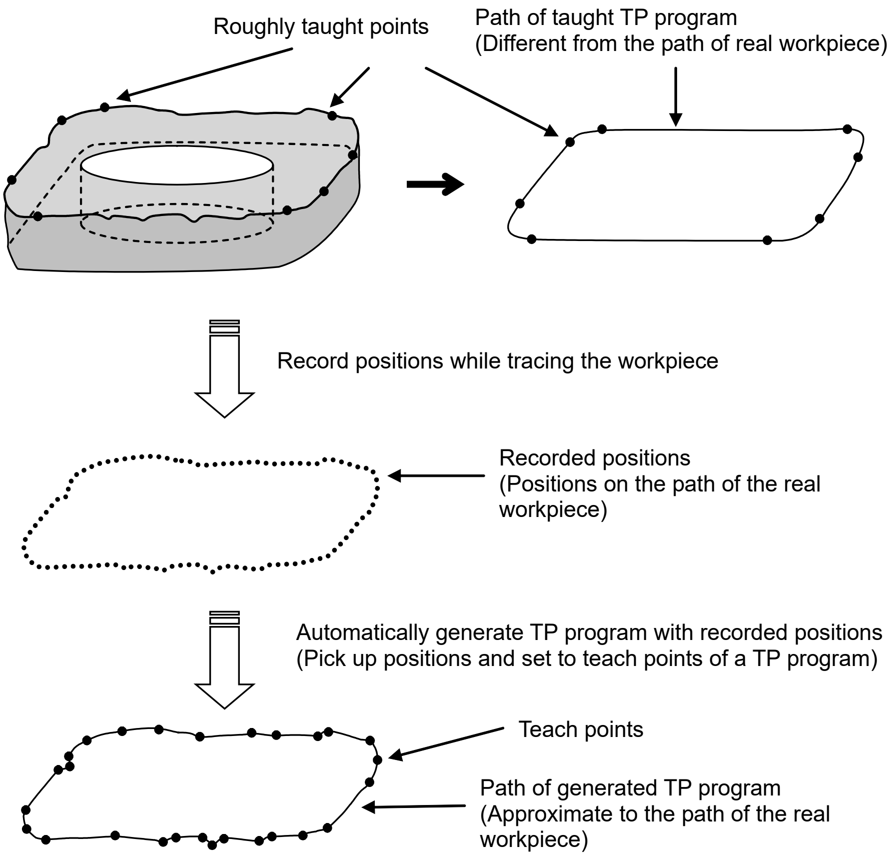


Fig. 2 (a) TP Program Auto Generation function

CONTENTS

> **NOTE**
> 1 The parameter setting cannot be modified if a program is being run.
> 2 The maximum number of recorded positions depends on the empty capacity of the robot controller.
> 3 Maximum number of teach points in the generated TP program is 2000.

How To Use This Function

(1) Set parameters of this function to generate a TP program. (Refer to "Auxiliary Function Guide: 2.2 parameter setting screen")
(2) Set parameters "TPProgramAuto.Gen.Sw.", "TPProgramAuto.Gen.Param.No." and "Pos.Acquisition.Cond " in [Performance Data Settings] screen of contour function. (Refer to "Basic Function Guide: "1.5.5.6 Parameters" of "1.5.5 Contouring Function"")
(3) After tracing the path of the real workpiece, generate a TP program automatically to reappear the path.

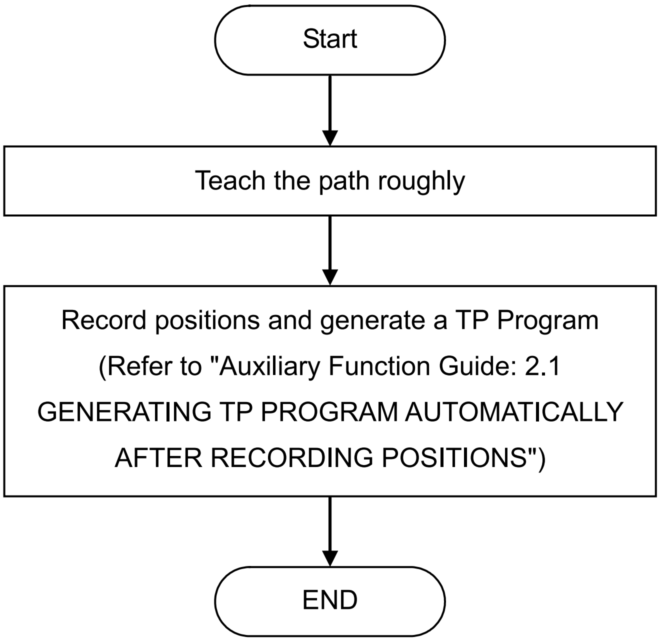


Fig. 2 (b) How to use the TP Program Auto Generation function

2.1 GENERATING TP PROGRAM AUTOMATICALLY AFTER RECORDING POSITIONS

Overview

Record the positions when tracing the path of a workpiece with the Contouring function under force control, after that generate a TP program fitting to the path.

> **NOTE**
> The tracing velocity when recording positions is suggested to be no greater than 5 mm/s, for the purpose of tracing the workpiece reliably.

Procedure for generating TP programs automatically after recording positions

1 Create a TP program called 'M_MAIN_01.TP'.
The following is a program example for 'M_MAIN_01.TP'.

```
M_MAIN_01.TP

 1:J   P[1] 30% FINE              ← Approach point of Contouring
 2:   FORCE CTRL[1:]              ← Contouring starts
  :   ErrorLBL[0] ;                  (Set schedule data number 1 to "Contouring")
 3:L   P[2] 50mm/sec CNT100
 4:L   P[3] 50mm/sec CNT100          Roughly taught path
 5:L   P[4] 50mm/sec CNT100
          …
 6:   FORCE CTRL[2:]              ← Contouring ends
  :   ErrorLBL[0] ;                  (Set schedule data number 2 to 2Contouring End")
 7:L   P[5] 50mm/sec FINE         ← Leave point fo contouring
 [END]
```

NOTE

In the program M_MAIN_01.TP, the path of a workpiece, on the basis of the roughly taught points, is traced with the Contouring function under force control, and the switch of starting and ending the position recording are also specified.

2 Open schedule data screen. ([DATA] key → F1 [TYPE] → [Force Control])
3 Select schedule data number (it is 1, in this example) that is used in M_MAIN_01.TP and press F3[Detail] key.
4 Press F5[PERFORM] key and move to [Performance Data Settings] screen.
5 Set ON to "TPProgramAuto.Gen.Sw." and set a parameter setting number to "TPProgramAuto.Gen.Param.No." Refer to "Auxiliary Function Guide: 2.2 parameter setting screen" for a parameter setting number.
6 Set "Pos.Acquisition.Cond ", if necessary.
7 Execute program M_MAIN_01.TP to start tracing the path and recording positions. A TP program, with the default name of M_PROG_01.TP, is generated after position recording finishes.

⚠ **CAUTION**

1 If the robot stops when recording positions, the program M_MAIN_01.TP must be terminated and executed from its first line for the next recording process.
2 When running generated subprogram, make sure that the robot does not interfere with any of the peripheral equipment as it moves to each teaching point.

2.2 PARAMETER SETTING SCREEN

The list of parameter setting screen is opened from the force sensor utilities screen. Refer to "Basic Function Guide: 3 FORCE SENSOR UTILITIES SCREEN".

.

2.2.1 List of parameter setting screen

Overview

To open the list of parameter setting screen, select the following.

Procedure for displaying the [TP Program Auto Gen / List] screen

1 Press the [MENU] key on the teach pendant of the robot controller.
The menu is displayed.
2 Select [UTILITIES]->[Force Sensor].
The [UTILITIES Force Sensor] screen is displayed.
(Refer to "Basic Function Guide: 3 FORCE SENSOR UTILITIES SCREEN".)
3 Move the cursor over [TP Program Auto Generation] and press F3 [DETAIL].
The [TP Program Auto Gen / List] screen is displayed.
Comments of 50 parameter settings are shown in this screen.

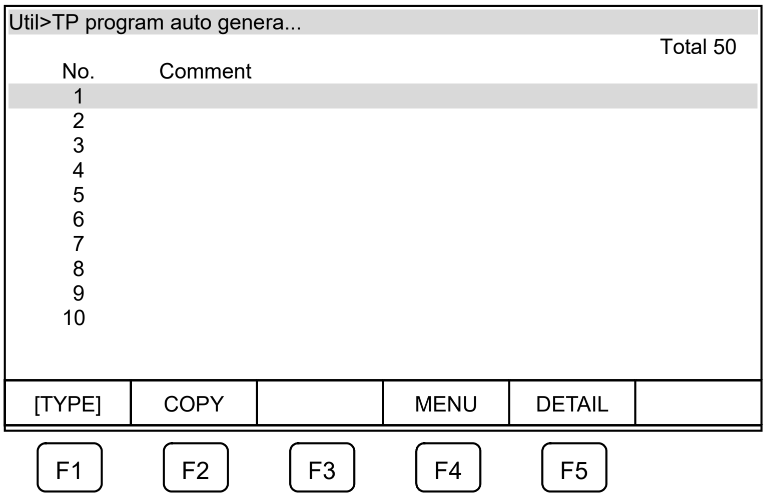


Fig. 2.2.1 List of parameter setting screen

Function keys

The function keys indicated have the following functions.

Table 2.2.1 Function keys

Key	Item	Description
F1	TYPE	Switches to a menu item other than the [TP Program Auto Gen / List] screen.
F2	COPY	To copy the parameter to another one. (TP program name will not be copied.)
F4	MENU	Displays the [UTILITIES Force Sensor] screen.
F5	DETAIL	To display the parameter setting screen.

2.2.2 Parameter setting detail screen

Overview

Display the [Parameter Setting] screen from the [TP Program Auto Gen / List] screen.
Parameters for TP Program Auto Generation and position recording can be modified in the “Parameter Setting” screen.

Procedure for displaying the [Parameter Setting] screen

1 Display the [TP Program Auto Gen / List] screen.
(Refer to "Auxiliary Function Guide: 2.2.1 List of parameter setting screen".)
2 Move the cursor over a parameter number to display and press F5 [DETAIL].
The [Parameter Setting] screen is displayed.

```
Util>TP p...>parameter setting
                                                    Total 12
  Recording Position
    1   Comment
    2   Interval                                     48 ms

  TP Program Generation
    3   Program Name             M_PROG_01
    4   Distance Threshold                           1.5 mm
    5   Angle Threshold                              3.0 deg
    6   Orient Change Thres                         10.0 deg
    7   General Velocity                              50 mm/s
    8   Cnt                                           85
    9   Use Circular Command                       FALSE
   10   Use Angular Velocity                       FALSE
   11   Angular Velocity                             100 deg/s

 [TYPE]  DEFAULT          EXIT   DONE
   F1      F2      F3      F4     F5
```

The setting items on the [Parameter Setting] screen are as follows.

Table 2.2.2 (a) Parameters for TP program auto generation

Item		Description
Recording Position	Comment	Comment of parameter setting.
	Interval	Sampling interval of position recording. "Default : 48 ms "
TP Program Generation	Program Name	Name of the generated TP program. "Default : M_PROG_** " ** is parameter setting number.
	Distance Threshold	Minimum distance between any two consecutive teach points in the generated TP program. By decreasing this value, the number of teach points in the circular part of the workpiece increases and the path of the TP program approaches to the shape of real workpiece. "Default : 1.5 mm " **NOTE** Set the parameter “Distance Threshold” to be no greater than the curvature radius of the workpiece’s corner.
	Angle Threshold	Minimum angle among any three consecutive teach points in the generated TP program. By decreasing this value, the number of teach points in the circular part of the workpiece increases and the path of the TP program approaches to the shape of real workpiece. "Default : 3.0 deg "
	Orient Change Thres.	Minimum orientation change between any two consecutive teach points in the generated TP program. By decreasing this value, the number of teach points in the circular part of the workpiece increases and the path of the TP program path approaches to the shape of real workpiece. "Default : 10.0 deg "
	General Velocity	Motion velocity in the generated TP program. "Default : 50 mm/s "
	Cnt	Cnt value of Linear command and Circular command. "Default : 85"

Item		Description
	Use Circular Command	Switch of whether to use circular command in the corner. (This program detects the corner automatically.) • FALSE : Use Linear command for all teach points. • TRUE : Use circular command in the corner. "Default : FALSE "
	Use Angular Velocity	Switch of whether to use angular velocity in the corner. (This program detects the corner automatically.) • FALSE : Do NOT use [Angular Velocity] in the corner. • TRUE : Use [Angular Velocity] in the corner. "Default : FALSE " **NOTE** If the parameter “Use Angular Velocity” is set TRUE, adjust the parameter “Rotation Velocity” on the basis of the curvature radius of the workpiece’s corner.
	Angular Velocity	Angular velocity in the corner. The parameter will be used only if the switch [Use Angular Velocity] is set TRUE and the robot orientation changes greatly in the corner. "Default : 100 deg/s "

Function keys

The function keys indicated have the following functions.

Table 2.2.2 (b) Function keys

Key	Item	Description
F1	TYPE	Switches to a menu item other than the [Parameter Setting] screen.
F2	DEFAULT	Reset all parameters to default values.
F4	EXIT	Returns to the [TP Program Auto Gen / List] screen.
F5	DONE	Displays the [UTILITIES Force Sensor] screen.

3 WORKPIECE MASS MEASUREMENT FUNCTION

This function measures the mass of a workpiece which is gripped or adsorbed by a robot with a force sensor. As the measurement is done while the robot is moving, it does not increase cycle time.
A workpiece can be judged as a defective piece if its mass is very different from a standard value. It can also check if a hand picked up more than prescribed number of workpieces by measuring weight or not.

CONTENTS

NOTE

- When measuring the mass of a workpiece, if the force sensor flange is horizontal and the gravity center of of the hand and the workpiece is on or close to the center axis of the force sensor (fig. 3 (a)), use "3.1 Workpiece Mass Measurement Function".
- When measuring the mass of a workpiece, if the force sensor flange is not horizontal or the gravity center of the hand and the workpiece is away from the center axis of the force sensor (fig. 3 (b)), use "3.2 Workpiece Mass Compensation Function".

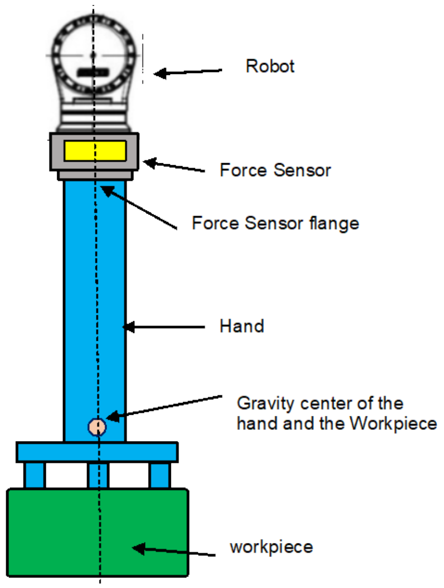


Fig. 3 (a) Workpiece mass measurement

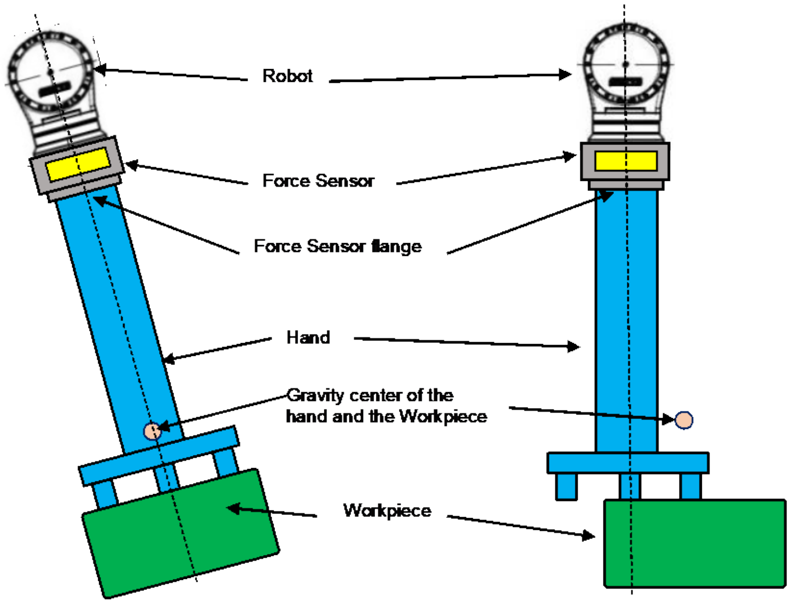


Fig. 3 (b) Workpiece mass compensation

3.1 Workpiece Mass Measurement Function

3.1.1 OVERVIEW AND HOW TO USE

Overview

The Workpiece Mass Measurement function consists of two steps.
A “Basis Measurement” step without a workpiece and a “Mass Measurement” step with the workpiece. It calculates the mass from a difference of these results.
As the mass is written to a designated register, defection judgment can be done in a TP program.
If “Basis Measurement” is done on the way to picking up a workpiece and “Mass Measurement” is executed after it is picked up, the cycle time will not increase.

> ⚠ **CAUTION**
> While measurement is being performed, move at a constant speed along a straight path. If measurement is performed while accelerating or moving along a curved path, the error in the obtained mass will increase.

How to use the workpiece mass measurement function

1 Press the [MENU] key on the teach pendant of the robot controller.
The menu is displayed.
2 Select [UTILITIES] ->[Force Sensor].
The [UTILITIES Force Sensor] screen is displayed.
(Refer to "Basic Function Guide: 3 FORCE SENSOR UTILITIES SCREEN".)
3 Move the cursor over [Workpiece Mass Measurement] and press F5 [DETAIL].
The [Setting for Mass Measurement] screen is displayed.
4 Set the parameters on the [Setting for Mass Measurement] screen.
(Refer to "Auxiliary Function Guide: 3.1.2 PARAMETER SETTING SCREEN".)
5 Create a TP program for mass measurement.
Teach the motions for the "Basis Measurement" and "Mass Measurement" and add the operation add instructions for measurement to operation statements.
* The path for measurement should be a linear trajectory.
(Refer to "Auxiliary Function Guide: 3.1.4 TP PROGRAM EXAMPLE".)
6 Execute “Basis Measurement” when the robot does not have a workpiece.

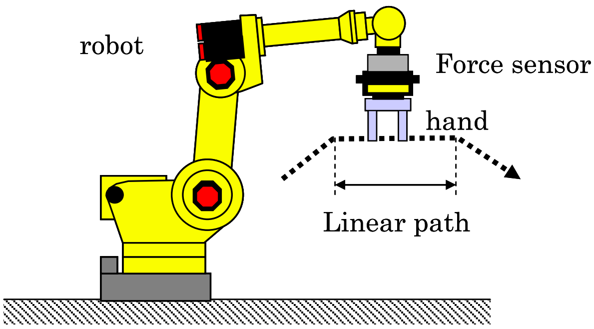


Fig. 3.1.1 (a) Basis measurement (without a workpiece)

7 Execute "Mass Measurement" when the robot has a workpiece.
The workpiece's mass is automatically calculated and it is written to a register which is designated in "Parameter Setting Screen".

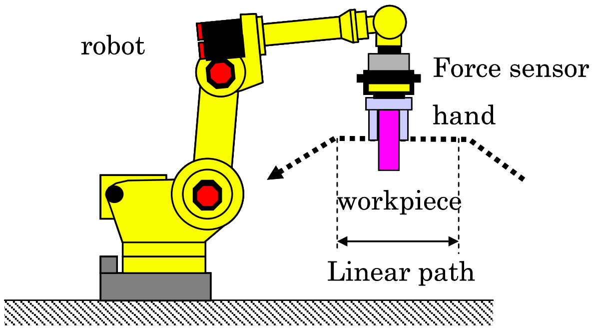


Fig. 3.1.1 (b) Mass measurement (with a workpiece)

> **NOTE**
> If the mass is not accurate, make a fine adjustment of operation statements. (Refer to "Auxiliary Function Guide: 3.1.3 RESULT DISPLAY SCREEN", and "Auxiliary Function Guide: 3.1.5 IF THE MASS IS NOT RIGHT".)

8 Press F3 [RESULT].
The [Result of Mass Measurement] screen is displayed.
The mass, measurement time, force amplitude, force standard deviation are displayed on "Result Display Screen".

> **⚠ CAUTION**
> 1 Execute not only "Mass Measurement" but also "Basis Measurement" for every workpiece. If the "Basis Measurement" is done once and it is used for all workpieces, the error of mass may be big.
> 2 The orientation of robot wrist has to be same for "Basis Measurement" and "Mass Measurement". Don't change the orientation while measurement.
> 3 In case of 3-axis force sensor, the Z direction of force sensor has to be correspondent to gravity direction. In case of 6-axis force sensor, any orientation is OK as long as it does not change during measurement.

3.1.2 PARAMETER SETTING SCREEN

Overview

The parameters must be specified on the "Parameter Setting" Screen.

Procedure for displaying the [Setting for Mass Measurement] screen

1 Press the [MENU] key on the teach pendant of the robot controller.
The menu is displayed.
2 Select [UTILITIES]->[Force Sensor].
The [UTILITIES Force Sensor] screen is displayed.
(Refer to "Basic Function Guide: 3 FORCE SENSOR UTILITIES SCREEN".)
3 Move the cursor over [Workpiece Mass Measurement] and press F3 [DETAIL].
The [Setting for Mass Measurement] screen is displayed.

```
Util>Set Workpiece Mass Meas.
                                                   Total 7
  1      Mass Measurement SW     :           ON
  2      Reg. No. Basis Measure  :           10
  3      Reg. No. Mass Measure   :           11
  4      Reg. No. Mass Result    :           15
  5      Max. Data Record Time   :         10.0 sec

 [TYPE]  |        | RESULT | MENU |        |
   F1        F2      F3      F4      F5
```

> **NOTE**
> If you already open the result screen of mass measurement, parameter setting screen can be opened by simply pressing F3 [MEAS.SET] key.

Table 3.1.2 (a) [Setting for Mass Measurement] screen

Item	Description
Mass Measurement SW	This parameter is a switch to enable “Mass Measurement” function. In order to change the following parameters “Reg. No. Basis Measure”, “Reg. No. Mass Measure”, “Reg. No. Mass Result”, this switch has to be [OFF]. Once it is set to [ON], the mass measurement will be executed depending on the values of “Reg. No. Basis Measure”, “Reg. No. Mass Measure” that are explained below. "Default : OFF"
Reg. No. Basis Measure	This parameter designates register number which determines the start/stop timing of “Basis Measurement”. As illustrated in section 3.4, the measurement starts when the value of the register becomes '1' and the measurement stops when it becomes '2'. This function automatically set it '3' after the completion of calculation of basis value. Make a TP program so that the “Basis Measurement” is done when the robot does not hold a workpiece. (Refer to "Auxiliary Function Guide: 3.1.4 TP PROGRAM EXAMPLE".) "Default : 0 "
Reg. No. Mass Measure	This parameter designates register number which determines the start/stop timing of “Mass Measurement”. As illustrated in section 3.4, the measurement starts when the value of the register becomes '1' and the measurement stops when it becomes '2'. This function automatically set it '3' after the completion of mass calculation. Make a TP program so that the “Mass Measurement” is done when the robot holds a workpiece. (Refer to "Auxiliary Function Guide: 3.1.4 TP PROGRAM EXAMPLE".) "Default : 0 "

Item	Description
Reg. No. Mass Result	This parameter designates register number to which a calculated mass is written. "Default : 0 "
Max. Data Record Time	Maximum time for the “Basis Measurement” and “Mass Measurement”. If the elapsed time since measurement started exceeds this value, the measurement is discontinued. In case of “Mass Measurement”, the mass is calculated from already acquired data and it is written to a register which is designated by “Reg.No.Mass Result”. "Default : 10 sec "

NOTE
If a program is running, the setting of “Mass Measurement SW” cannot be changed.

Function Keys

The function keys indicated have the following functions.

Table 3.1.2 (b) Function Keys

Key	Item	Description
F1	[TYPE]	Switches to a menu item other than the [Setting for Mass Measurement] screen.
F3	RESULT	Allows you to display the [Result Display] screen. (Refer to "Auxiliary Function Guide: 3.1.3 RESULT DISPLAY SCREEN".)
F4	MENU	Allows you to go back the [force sensor utilities] screen.

3.1.3 RESULT DISPLAY SCREEN

Overview

A calculated mass, measurement time, force amplitude, force standard deviation are displayed in "Result Display" Screen.

Procedure for displaying the [Result of Mass Measurement] screen

1 Display the [Setting for Mass Measurement] screen.
(Refer to "Auxiliary Function Guide: 3.1.2 PARAMETER SETTING SCREEN")
2 Press F3 [RESULT].
The [Result of Mass Measurement] screen is displayed.

Util>Set Workpiece Mass Meas.
Total 7

1	Calculated Mass	:		0.43 kg				
2	Basis Measure Time	:		1.24 sec				
3	Mass Measure Time	:		1.32 sec				
4	Basis Measure F amp.	: Fx:	0.5	Fy:	1.7	Fz:	2.0 N	
5	Mass Measure F amp.	: Fx:	0.9	Fy:	2.1	Fz:	2.9 N	
6	Basis Measure F STDEV	: Fx:	0.4	Fy:	0.3	Fz:	0.4 N	
7	Mass Measure F STDEV	: Fx:	0.2	Fy:	0.3	Fz:	0.3 N	

[TYPE]		MEAS.SET	MENU		

F1 F2 F3 F4 F5

3

Table 3.1.3 (a) Result display screen

Item	Description
Calculated Mass	Displays the workpiece mass calculated by performing the basis measurement and mass measurement. The value is same as the one written to a register that is designated by [Reg.No.Mass Result] in the [Parameter Setting Screen]. "Unit : kg"
Basis Measure Time	It is an actual time that force sensor data were collected during “Basis Measurement”. If it is too short (around 0.3sec or shorter), the calculated mass may include big error. Extend the length of a linear path or reduce the travel speed. "Unit : sec"
Mass Measure Time	It is an actual time that force sensor data were collected during “Mass Measurement”. If it is too short (around 0.3sec or shorter), the calculated mass may include big error. Extend the length of a linear path or reduce the travel speed. “Unit : sec”
Basis Measure F amp. (Force amplitude) (Fig. 3.1.3)	These are differences between maximum and minimum value of force data ([Fx], [Fy], [Fz]) during “Basis Measurement”. The smaller these values, the more accurate the calculated mass. If the force sensor is 3-axis type, only the value of [Fz] is written and values of [Fx], [Fy] are zero. "Unit : N"
Mass Measure F amp. (Force amplitude) (Fig. 3.1.3)	These are differences between maximum and minimum value of force data ([Fx], [Fy], [Fz]) during “Mass Measurement”. The smaller these values, the more accurate the calculated mass. If the force sensor is 3-axis type, only the value of [Fz] is written and values of [Fx], [Fy] are zero. "Unit : N"
Basis Measure F STDEV (Force standard deviation) (Fig. 3.1.3)	These are standard deviation of force data ([Fx], [Fy], [Fz]) during “Basis Measurement”. The smaller these values, the more accurate the calculated mass. If the force sensor is 3-axis type, only the value of [Fz] is written and values of [Fx], [Fy] are zero. "Unit : N"
Mass Measure F STDEV (Force standard deviation) (Fig. 3.1.3)	These are standard deviation of force data ([Fx], [Fy], [Fz]) during “Mass Measurement”. The smaller these values, the more accurate the calculated mass. If the force sensor is 3-axis type, only the value of [Fz] is written and values of [Fx], [Fy] are zero. "Unit : N"

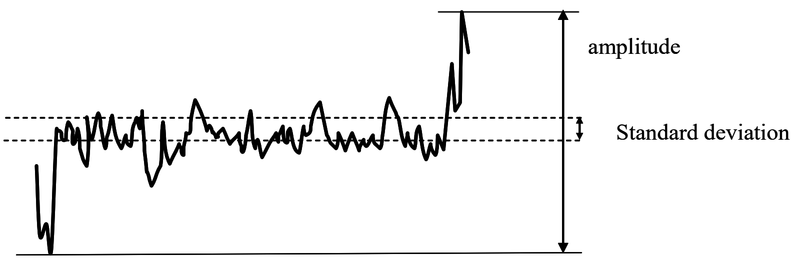


Fig. 3.1.3 amplitude and standard deviation

Function Keys

The function keys have the following functions.

Table 3.1.3 (b) Function Keys

Key	Item	Description
F1	[TYPE]	Switches to a menu item other than the [Setting for Mass Measurement] screen.
F3	MEAS.SET	Allows you to display the [Parameter Setting] screen (Refer to "Auxiliary Function Guide: 3.1.2 PARAMETER SETTING SCREEN".)
F4	MENU	Allows you to go back the [force sensor utilities] screen.

3.1.4 TP PROGRAM EXAMPLE

Overview

This section shows a TP program example.
Teach a linear path on a horizontal plane. The actual trajectory contains curves near the teaching points just as shown in Fig. 3.1.4 (a) and Fig. 3.1.4 (b). In this example, the operation add instructions (TIME BEFORE and TIME AFTER) are used to measure only in a linear trajectory.
(Refer to "R-30*i*B Plus CONTROLLER OPERATOR'S MANUAL (Basic Operation)" (B-83284EN) Chapter 9 for "TIME BEFORE instruction".)

Basis measurement	Move from Point 1 to Point 4 via Point 2 and Point 3 without a workpiece. Measure basis value between Point 2 and Point 3.

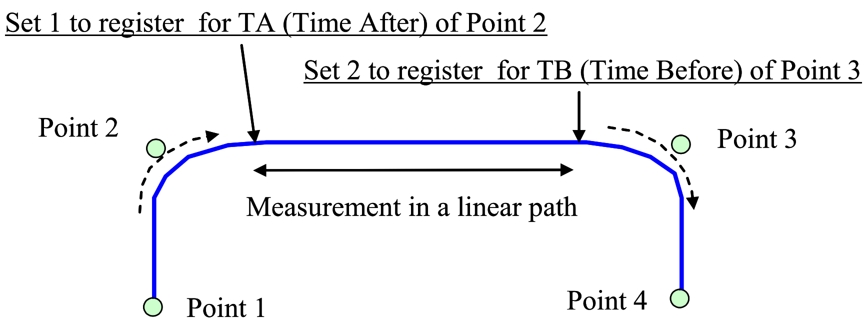


Fig. 3.1.4 (a) example of "Basis Measurement"

Mass measurement	Move from Point 4 to Point 1 via Point 3 and Point 2 with a workpiece. Measure mass between Point 3 and Point 2.

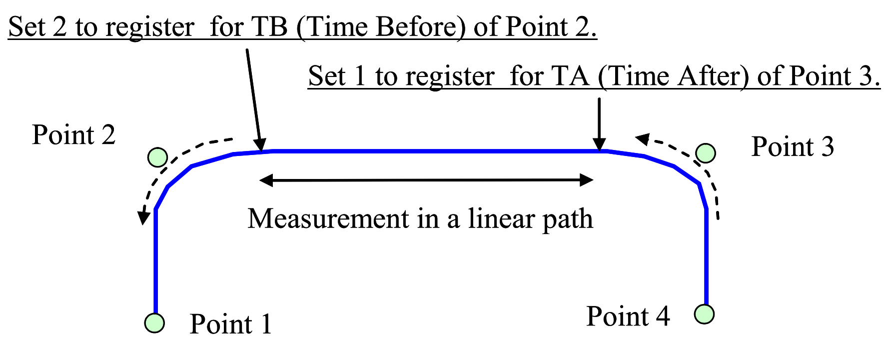


Fig. 3.1.4 (b) example of "Mass Measurement"

TP PROGRAM EXAMPLE

TP program example is shown below.

```
Set following parameters on "Parameter Setting Screen"
      Mass Measurement SW = ON
      Reg. No. Basis Measure = 1
      Reg. No. Mass Measure = 2
      Reg. No. Mass Result = 3


Main program

    ' Basis Measurement (without a workpiece)
   L   P[1] 500mm/sec FINE
   L   P[2] 300mm/sec CNT100                  ' Execute MEAS_ST 0.2sec after P[2]
      TA   .20sec, CALL   MEAS_ST(1)          ' R[1]=1
   L   P[3] 300mm/sec CNT100                  ' Execute MEAS_FN 0.2sec before P[3]
      TB   .20sec, CALL   MEAS_FN(1)          ' R[1]=2
   L   P[4] 500mm/sec FINE
   WAIT   R[1] = 3                   ' Wait until the basis is calculated

   'Grip or adsorb a workpiece

    ' Mass Measurement (with a workpiece)
   L   P [3] 300mm/sec CNT 100                ' Execute MEAS_ST 0.2sec after P[3]
      TA   .20sec, CALL   MEAS_ST(2)          ' R[2]=1
   L   P [2] 300mm/sec CNT 100                ' Execute MEAS_FN 0.2sec before P[2]
      TB   .20sec, CALL   MEAS_FN(2)          ' R[2]=2
   L   P [1] 500mm/sec FINE
   WAIT   R[2] = 3                   ' Wait until the mass is calculated
                                              ' It is written to R[3]

    'Check the value of mass
   IF   R[3] <R[5 : Min],JMP LBL[10]          ' Min. value of mass is written to R[5]
   IF   R[3] >R[6 : Max],JMP LBL[10]          ' Max. value of mass is written to R[6]
              . . . . .

   LBL[10 : WRONG MASS]                       ' Alarm if the mass is out of range
   UALM[1]


Sub program

MEAS_ST.TP                                    ' Start collecting data

   R[100]=AR[1]
   R[R[100]] = 1


MEAS_FN.TP                                    ' Finish collecting data

   R[100]=AR[1]
   R[R[100]] = 2
```

Fig. 3.1.4 (c) TP program example

3.1.5 IF THE MASS IS NOT RIGHT

If the acquired mass is different from the actual mass or the result is deviated for each measurement, check the following items.

(1) Check items for the workpiece, robot, and peripheral devices

- The workpiece and the robot are out of contact with surrounding objects when the robot is running.
- Force sensor cable is not under heavy load.

(2) Check items during the workpiece mass measurement

- The paths for measurement in "Basis Measurement" and "Mass Measurement" are linear and on horizontal plane.

- Perform the "Basis Measurement" and "Mass Measurement" for each workpiece.
  - * Not only “Mass Measurement” but also “Basis Measurement” are executed for every workpiece. If the “Basis Measurement” is done once and it is used for all workpieces, the error of mass may be big.
- The orientation of robot wrist is same for “Basis Measurement” and “Mass Measurement” and it does not change during measurement.
- In case of 3-axis force sensor, the Z direction of force sensor is correspondent to gravity direction.
  - * In case of 6-axis force sensor, any orientation is OK as long as it does not change during measurement.

(3) Check items on the [Result of Mass Measurement] screen

- “Basis Measure Time” and “Mass Measure Time” in “Result Display Screen” are not too small. If these values are around 0.3 sec or smaller, the mass may be calculated with a big error. Extend the length of a linear path or reduce the travel speed.
- “Basis Measure F amp.” and “Mass Measure F amp.” in “Result Display Screen” are not too big. These values show the difference between maximum and minimum value of force data (unit : N). If at least one of “F amp.” / 9.8 is (are) not negligibly big compared with a mass (unit : Kg), the force may have been measured not only in a linear path but also in an acceleration zone (Fig. 3.1.5 (a), Fig. 3.1.5 (b)).
  Take TP program as an example, extend the time (0.2sec) of the operation add instructions (TIME BEFORE and TIME AFTER). Note that the measuring zone will be short if the time is increased by a large margin.
  (Refer to " Auxiliary Function Guide: 3.1.4 TP PROGRAM EXAMPLE")

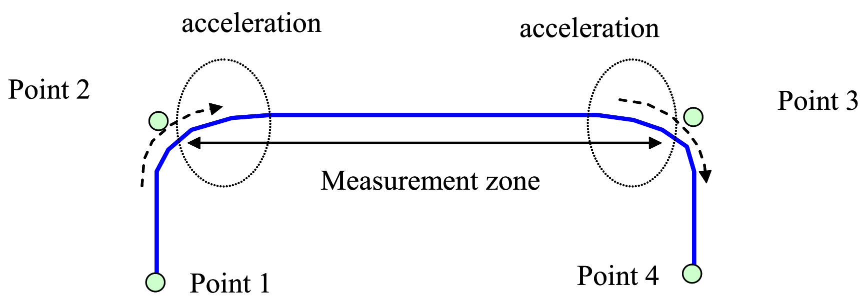


Fig. 3.1.5 (a) Measurement with accelerating zone

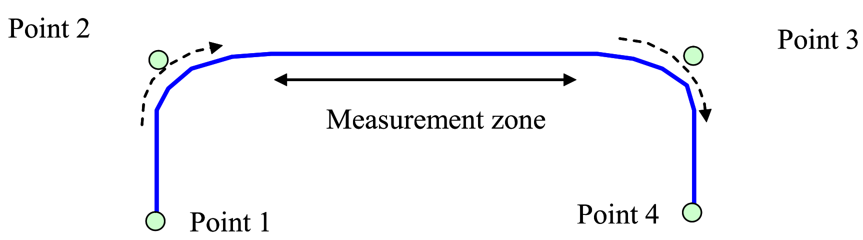


Fig. 3.1.5 (b) Measurement without accelerating zone

- “Basis Measure F STDEV” and “Mass Measure F STDEV” in “Result Display Screen” are not too big. If at least one of “STDEV” / 9.8 is(are) not negligibly big compared with a mass (unit : Kg), the robot may have been vibrated or the force may have been measured not only in a linear path but also in an acceleration zone.

3.2 Workpiece Mass Compensation Function

3.2.1 Overview and Usage Method

3

Overview

With the function explained in this section, the measured value of the workpiece mass is compensated to match with the actual hand and workpiece to obtain a more accurate workpiece mass in the following cases. (Fig. 3.2.1 (a))

- When measuring workpiece mass, the force sensor flange is not horizontal or the gravity center of the hand and the workpiece is away from the center axis of the force sensor.

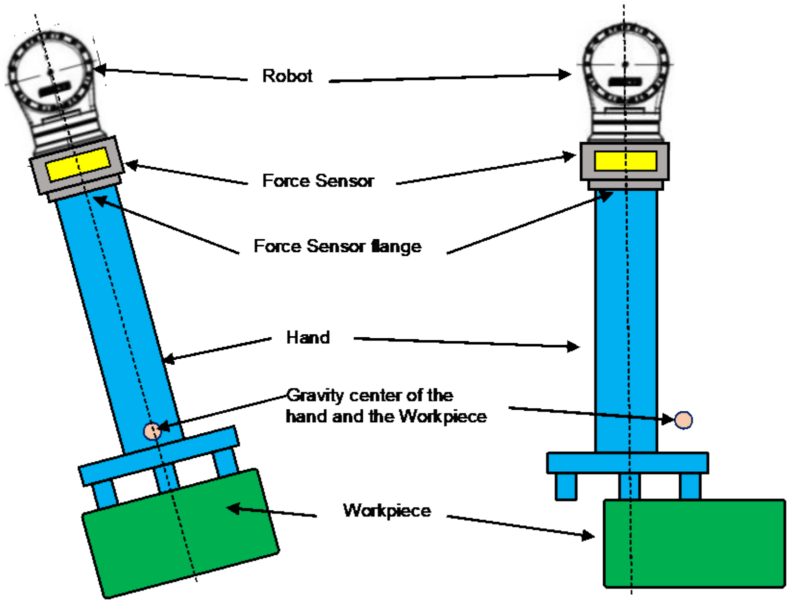


Fig. 3.2.1(a) Mass calibration

This function is supported in the following software versions.

- 7DF1/34 or later version
- 7DF3/15 or later version
- 7DF5/11 or later version

NOTE
- Check that the workpiece and robot will not make contact with surrounding items during operation.
- Check that an excessive load is not being applied to the force sensor cable.

How to use the Workpiece Mass Compensation function

This function is executed with the following two steps.
(1) Step that determines the calibration data → Refer to 3.2.2
(2) Step that determines the workpiece mass → Refer to 3.2.3

> **NOTE**
> There are two conditions for accurate mass compensation result.
> - The center of gravity of the hand should be on or close to the center axis of the force sensor. (Fig. 3.2.1 (b))
> - Prepare sample workpieces for mass measurement in step 3.2.2 "Getting the Calibration Data for Workpiece Mass Measurement" and its center of gravity should be on or close to the center axis of the force sensor. (Fig. 3.2.1 (b))

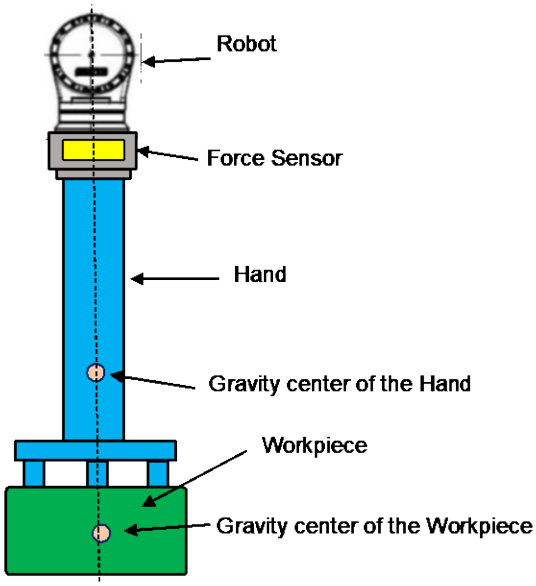


Fig. 3.2.1 (b) Mass Measurement

3.2.2 Getting the Calibration Data for Workpiece Mass Measurement

Before using this function to measure and calibrate the mass of the workpiece, it is necessary to get mass calibration data by moving the robot to several specified positions to get force values.

The detailed steps are described as follows.
(1) Get the accurate weight of the hand and the workpiece. (Unit: N) Refer to a drawing of the workpiece or measure with the scale.
(2) Copy the sample TP program "FS_CLB_HND.TP" to a new program (ex. "FS_CLB_HND1.TP").
(3) Open TP program "FS_CLB_HND1.TP" and change the argument "#" of the command "CALL FSSETHAND(#)" to the weight of the hand only. (Unit: N)
(4) Run TP program "FS_CLB_HND1.TP" to move the robot without loading a workpiece. (Fig. 3.2.2 (a))
   - ➢ It calls TP programs "FS_MOV_##DEG.TP" (## = 5,15,30,45) and "FS_GET_F.TP" to slowly move J4 of the robot from 0 to 45 degrees and J6 from -180 to 180 degrees to get force values.
   - ➢ If the hand oscillates, try to reduce the robot velocity or increase the wait time in TP program FS_GET_F.TP.

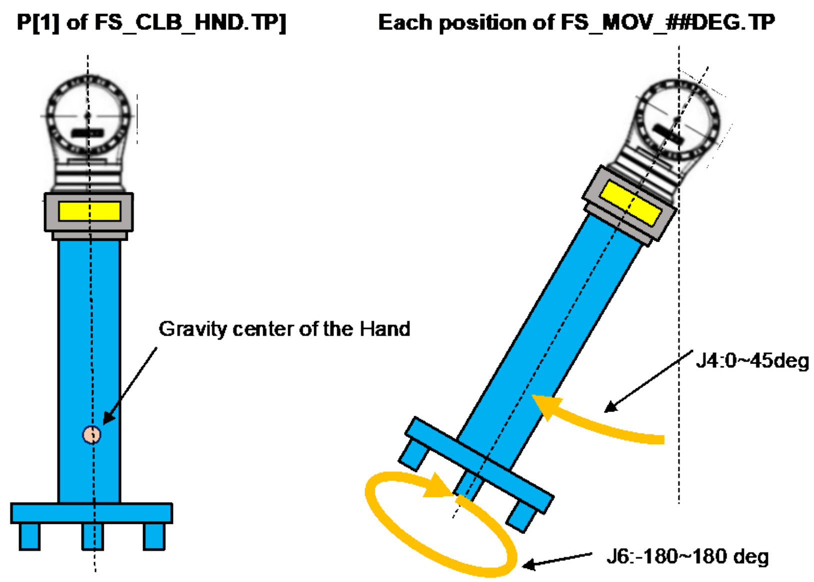


Fig. 3.2.2 (a) Get force values without loading a workpiece

(5) Copy the sample TP program "FS_CLB_WRK.TP" to a new program (ex. "FS_CLB_WRK1.TP").
(6) Open TP program "FS_CLB_WRK1.TP" and change the argument "#" of the command "CALL FSSETWORK(#)" in FS_CLB_WRK1.TP to the total gravity of hand and workpiece. (Unit: N)

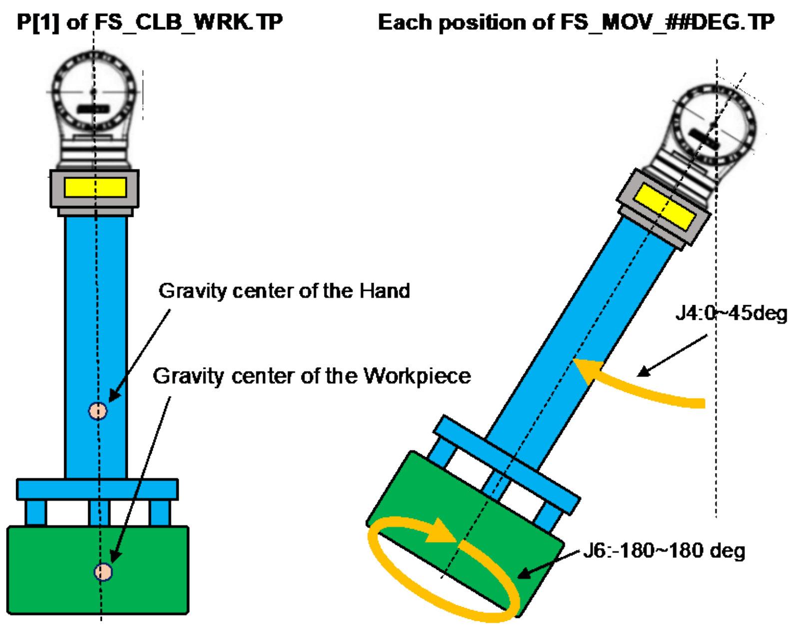


Fig. 3.2.2 (b) Get force values with a workpiece loaded

(7) Load the sample workpiece onto the hand, and make sure its center of gravity is just under the center of the force sensor when the robot is moved to P[1] in "FS_CLB_WRK1.TP". (Fig. 3.2.2 (b))
(8) Run FS_CLB_WRK1.TP to call "FS_MOV_##DEG.TP" (## = 5,15,30,45) and "FS_GET_F.TP" to slowly move J4 of the robot from 0 to 45 degrees and J6 from -180 to 180 degrees to get force data. (Fig. 3.2.2 (b))
   - ➢ Make sure there is enough moment change of Mx and My between J4=0deg and J4=45deg. (If not, the mass measurement result may not be accurate.)
   - ➢ If the hand or workpiece oscillates, reduce the robot velocity or increase the wait time in TP program FS_GET_F.TP.

➢ At the end of the FS_CLB_WRK1.TP, the mass calibration data will be calculated by the command “CALL FSSETCLB”and it is saved in the robot controller. It does not disappear even after the robot controller is powered off/on or the software version is updated.

NOTE
- Steps (1) to (8) should be executed once for each robot system with a real force sensor, sensor adapter, and hand installed.
- If the force sensor or the force sensor adapter are exchanged or reinstalled, steps (1) to (8) need to be executed again.

3.2.3 Workpiece Mass Measurement and Calibration

After getting the mass calibration data in 3.2.2, the mass of the workpiece can be measured and calibrated as follows.

- Getting the calibrated workpiece mass without stopping the robot → Refer to 3.2.3.1
- Getting the calibrated workpiece mass while the robot is stopped → Refer to 3.2.3.2

3.2.3.1 How to get the calibrated workpiece mass without stopping the robot

① Move robot near to the workpiece.
② Copy the sample TP program “FS_MEAS_WRK1.TP” to a new program (ex. “FS_MEAS_WRK10.TP”).
③ Open “FS_MEAS_WRK10.TP” and teach the current position to P[1] in the command “L P[1] 200mm/sec CNT30 TB .20sec, CALL FSGRVINIT”, and make sure that the robot moves linearly and that its velocity is constant at the moment the command “FSGRVINIT” is executed.
④ Load the workpiece and move up the robot.
⑤ Teach the current position to P[2] in the command “L P[2] 200mm/sec CNT30 TB .20sec, CALL FSGRVMEAS(#) ”, and make sure that the robot moves linearly and that its velocity is constant at the moment that the command “FSGRMEAS(#)” is executed.
⑥ P[2] and P[1] should have the same or nearly the same orientation.
⑦ Specify the register number “#” in the command “L P[2] 200mm/sec CNT30 TB .20sec,CALL FSGRVMEAS(#)”for outputting the calibrated mass.
⑧ Run “FS_MEAS_WRK10.TP” to get the calibrated workpiece mass and output it to the specified number register.

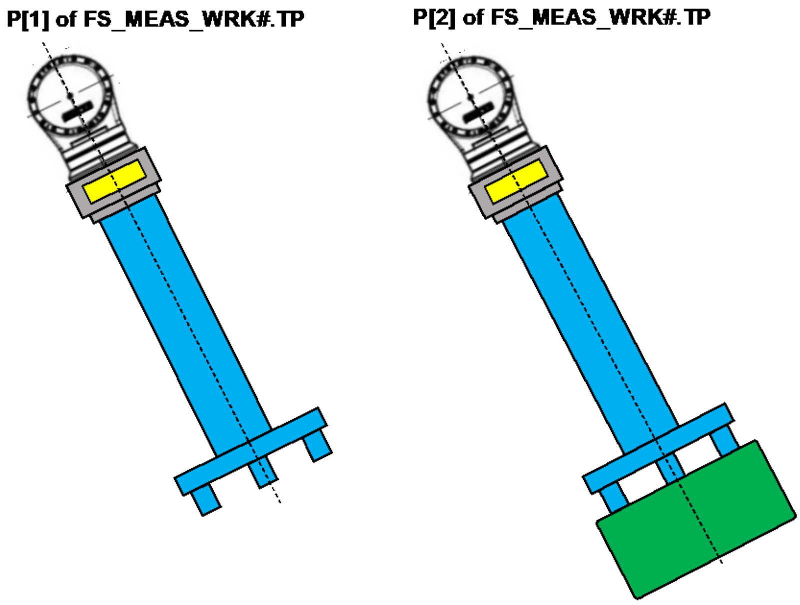


Fig. 3.2.3 Measuring workpiece mass

3.2.3.2 How to get the calibrated workpiece mass while the robot is stopped

① Move robot near to the workpiece.
② Copy the sample TP program “FS_MEAS_WRK2.TP” to a new program (ex. “FS_MEAS_WRK20.TP”).
③ Open “FS_MEAS_WRK20.TP” and teach the current position to P[1] in the command “L P[1] 200mm/sec FINE”.
④ Load the workpiece and move up the robot.
⑤ Teach the current position to P[2] in the command “L P [2] 200mm/sec FINE”.
⑥ P[2] and P[1] should have the same or nearly the same orientation.
⑦ Specify the register number “#” in the command “FSGRVMEAS(#)”for outputting the calibrated mass.
⑧ Run “FS_MEAS_WRK20.TP” to get the calibrated workpiece mass and output it to the specified number register.

3.2.4 Example of TP Programs and Karel Programs

3.2.4.1 Example of TP Programs

The following are example of TP programs.

FS_CLB_HND.TP:

Set the weight of the hand that was acquired beforehand and move the robot without workpiece to several locations and record force data.

```
1:  ! Set hand mass only,[N] ;
2:  CALL  FSSETHAND(constant) ;     ← Set the weight of the hand (parameter "constant", unit: N)
3:   ;
4:J  P[1] 10%  FINE    ; ← Move the robot, record force data
5:  WAIT  5.00(sec) ;
```

```
 6:  CALL  FS_GET_F    ;
 7:   ;
 8:  !J4_5deg ;
 9:  CALL  FS_MOV_5DEG    ;
10:   ;
11:  !J4_15deg ;
12: CALL  FS_MOV_15DEG    ;
13:   ;
14:  !J4_30deg ;
15: CALL  FS_MOV_30DEG    ;
16:   ;
17:  !J4_45deg ;
18: CALL  FS_MOV_45DEG    ;
19:   ;
20:J  P[1] 10% FINE    ;
21: WAIT  5.00(sec) ;
22: CALL  FS_GET_F    ;
```

FS_CLB_WRK.TP

Set the combined weight of the hand and workpiece that was acquired beforehand and move the robot to several locations and record force data. And then calculate the workpiece mass compensation.

```
 1:  ! Set hand+work mass [N] ;
 2:  CALL    FSSETWORK(constant) ;     ← Set the weight of the hand and workpiece (parameter "
constant ", unit: N)
 3:   ;
 4: J  P[1] 10%  FINE    ; ← Move the robot, record force data
 5:  WAIT  5.00(sec) ;
 6:  CALL  FS_GET_F    ;
 7:   ;
 8:  !J4_5deg ;
 9:  CALL  FS_MOV_5DEG    ;
10:   ;
11:  !J4_15deg ;
12: CALL  FS_MOV_15DEG    ;
13:   ;
14:  !J4_30deg ;
15: CALL  FS_MOV_30DEG    ;
16:   ;
17:  !J4_45deg ;
18: CALL  FS_MOV_45DEG    ;
19:   ;
20: J  P[1] 10%  FINE    ;
21:  WAIT  5.00(sec) ;
22: CALL  FS_GET_F    ;
23:   ;
24:  !Calc Calib data ;
25: CALL  FSSETCLB    ;    ← Calculate the calibration data and store it in the robot controller
```

FS_MOV_##DEG.TP: (##=5, 15, 30, 45)

Move the robot to J1–J3, J4, J6=0, J5=0 to 90deg, and then move to J4=5 to 45deg, J6=-180 to 180, and record force data.

Example FS_MOVE_45DEG.TP

```
  1:  !J4_45DEG ;
  2: J  P[1] 10%  FINE    ;
  3:  WAIT  5.00(sec) ;
  4:  CALL  FS_GET_F    ;
  5: J  P[2] 10%  FINE    ;
  6:  CALL  FS_GET_F    ;
  7: J  P[3] 10%  FINE    ;
  8:  CALL  FS_GET_F    ;
...
```

FS_GET_F.TP:

Record force data.

```
  1:  !Get force ;
  2:  WAIT  1.00(sec) ;
  3:  CALL  FSSETFRC    ;
```

FS_MEAS_WRK1.TP:

Measure the workpiece mass without stopping the robot.

1: ! Init Work Grv ;

2: L P[1] 200mm/sec CNT30 TB .20sec, CALL FSGRVINIT   ; ← Call FSGRVINIT 0.2 seconds in advance of arriving at P[1] to get the initial force value. ← P[1] is untaught

3:   ;

4: ! Load Workpiece here ;

5:   ;

6:   ;

7: ! Get Work Grv and output to Reg ;

8:L P[2] 200mm/sec CNT30 TB .20sec, CALL FSGRVMEAS(constant)   ; ← Call FSGRVMEAS 0.2 seconds in advance of arriving at P[2] to measure the mass and output the results to the register specified by "constant". (The value of P[2] is untaught)

FS_MEAS_WRK2.TP:

Measure the workpiece mass while the robot is stopped.

1: L P [1] 200mm/sec FINE   ; ← P[1] is untaught

2: ! Init Work Grv ;

3: CALL FSGRVINIT   ; ← Call FSGRVINIT at P[1] to get the initial force value.

4:   ;

5: ! Load Workpiece here ;

6:   ;

7:   ;

8: L P [2] 200mm/sec FINE   ; ← P[2] is untaught

9: ! Get Work Grv and output to Reg ;

10: CALL FSGRVMEAS(constant) ; ← Call FSGRVMEAS at P[2] to measure the mass and store the result in the register specified by "constant".

3.2.4.2 KAREL Programs

Examples and descriptions of KAREL programs (*.PC) that are used in TP programs in 3.2.4.1 are given in table 3.2.4.2.

Table 3.2.4.2 KAREL programs

Example	Description
CALL FSSETHAND(#)	Sets the weight of the hand. Parameter #: Hand weight, unit: N
CALL FSSETWORK(#)	Sets the combined weight of the hand and workpiece. Parameter #: Combined weight of the hand and workpiece, unit: N
CALL FSSETFRC	Gets force data.
CALL SSETCLB	Calculates the calibration coefficient and saves it in the robot controller.
CALL FSGRVINIT	Gets the initial weight of the hand.
CALL FSGRVMEAS(#)	Gets the workpiece mass and outputs it to the specified register. Parameter #: Calibrated workpiece mass (unit: N) and the register number for output
CALL FSSETPRM(#1,#2)	Changes a parameter and measures the workpiece mass. The first argument “#1” is the parameter index and second argument “#2” is the parameter value. ➢ If the first argument “#1” is “1”, then the second argument “#2” is the measuring time of KAREL FSGRVINIT and FSGRVMEAS. (Unit: second) ➢ If the first argument “#1” is “2”, then the second argument “#2” is the tolerance value of the total angle change of W and P during mass measurement. (Unit: degree)

4 FORCE SENSOR 4D GRAPHIC FUNCTION

The Force Sensor 4D graphic function is one of "4D graphic" functions, which 3D graphically display robots, tools, parts, and others on the *i*Pendant. A 3D graphic model to which robot internal data (1D) is added is called a 4D graphic model. For this function, force data obtained from a force sensor is used as the information of the fourth dimension. This function displays the path of the origin of the tool frame specified for a force control schedule during the force control operation and the magnitude of force at each point on the path with a line on the 4D graphic screen.
This function allows you to check force generated during the force control operation while comparing it with the positions of the workpiece and tool.

CONTENTS

> **NOTE**
> 1 To use this function, '4D graphic' (R764) is required. (Ensure that [4D Graphics] is displayed as [Installed] in the [Options] screen.)
> (Refer to "Introduction: 3.1.3 Options Screen".)
> 2 If any operation of this function is performed while the "4D graphic" (R764) option is not installed, the "No. 454 4D Graphics is not ordered" alarm is issued. Install the "4D graphic" (R764) option.
> (Refer to "Optional Function OPERATOR'S MANUAL (B-83284EN-2)".)

4.1 USING THE FORCE SENSOR 4D GRAPHIC FUNCTION

Overview

This section describes how to use the Force Sensor 4D graphic function. The following screens are provided for this function: Setting for Force Display screen and 4D graphic screen.
The screen is divided into two panes (right and left).
The screen on the right (the [4D graphic] screen) is automatically displayed.
The screen on the left shows the [Setting for Force Display File / Setting for Force Display] screen.

> **NOTE**
> This function uses the force data file generated with the “Force Data Log” function.
> (Refer to "Basic Function Guide: 2.3 FORCE DATA LOG FUNCTION")

Below is the procedure for displaying the [FS 4D graphic Force display] screen.

Procedure for displaying the [FS 4D graphic Force display] screen

1 First, use the "force data log function" to record the force data during the force control operation.
This function uses a force data file generated by the "force data log function".
(Refer to "Basic Function Guide: 2.3 FORCE DATA LOG FUNCTION")
2 Press the [MENU] key on the teach pendant of the robot controller.
The menu is displayed.
3 Select [UTILITIES]->[Force Sensor].
The [UTILITIES Force Sensor] screen is displayed.
(Refer to "Basic Function Guide: 3 FORCE SENSOR UTILITIES SCREEN".)

4 Move the cursor over [4D graphic] and press F3 [DETAIL].
The 4D graphic force display screen is divided into two panes (right and left).
5 In the [Setting for Force Display File / Setting for Force Display] screen on the left, set parameters.
(Refer to "Auxiliary Function Guide: 4.2 SETTING FOR FORCE DISPLAY FILE / SETTING FOR FORCE DISPLAY SCREEN".)
6 Review the force data in the screen on the right (the [4D graphic] screen).
(Refer to "Auxiliary Function Guide: 4.3 4D GRAPHIC SCREEN".)

4.2 SETTING FOR FORCE DISPLAY FILE / SETTING FOR FORCE DISPLAY SCREEN

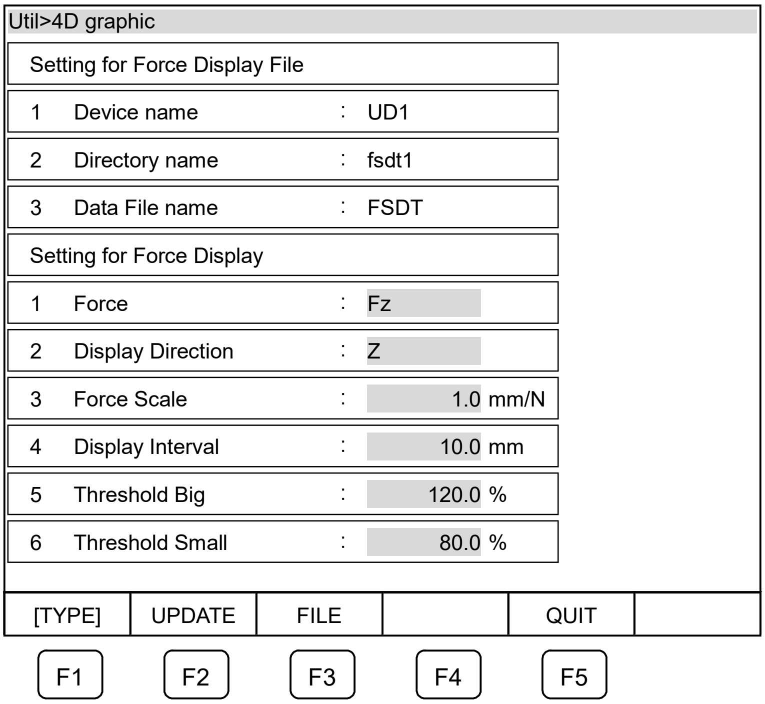
Overview

Open the Setting for Force Display screen with the following procedure and set required parameters.
Settings are configured in the [FS 4D graphic Force display] screen (the [Setting for Force Display File / Setting for Force Display] screen).
(Refer to "Auxiliary Function Guide: 4.1 USING THE FORCE SENSOR 4D GRAPHIC FUNCTION".)
The setting items are divided into two categories: [Setting for Force Display File] and [Setting for Force Display]. Configure settings for each category.

Procedure for setting the [Setting for Force Display File / Setting for Force Display] screen

1 Display the [FS 4D graphic Force display] screen.
(Refer to "Auxiliary Function Guide: 4.1 USING THE FORCE SENSOR 4D GRAPHIC FUNCTION".)

The [Setting for Force Display File / Setting for Force Display] screen is displayed.



2 Move the cursor over [Directory name] and press [ENTER] key or click the input box.
The [FS 4D graphic /Directory List] screen is displayed.

Util>4D graphic

Directory List

1	FSDT1
2	FSDT2
3	FSDT3
4	FSDT4

[TYPE]	UPDATE			QUIT	
F1	F2	F3	F4	F5	

3 Move the cursor over a directory to be used for force display and press [ENTER] key or click item of directory list.
The [Setting for Force Display File / Setting for Force Display] screen is displayed.

4 Move the cursor over [Data File name] and press [ENTER] key or click the input box.
The [FS 4D graphic /File List] screen is displayed.

Util>4D graphic

File List

1	FSDT0010	2017- 6-25	15:56
2	FSDT0009	2017- 6-25	15:53
3	FSDT0008	2017- 6-25	15:51

[TYPE]	UPDATE			QUIT	
F1	F2	F3	F4	F5	

5 Move the cursor over a file to be used for force display and press [ENTER] key or click item of data file list.
The [Setting for Force Display File / Setting for Force Display] screen is displayed.

6 In the [Setting for Force Display File / Setting for Force Display] screen, set each item for [Setting for Force Display].

Util>4D graphic

Setting for Force Display File		
1	Device name	UD1
2	Directory name	fsdt1
3	Data File name	FSDT0001
Setting for Force Display		
1	Force	Fz
2	Display Direction	Z
3	Force Scale	5.0 mm/N
4	Display Interval	10.0 mm
5	Threshold Big	120.0 %
6	Threshold Small	80.0 %

[TYPE]	UPDATE	FILE		QUIT	
F1	F2	F3	F4	F5	

7 Press F5 [QUIT].

Selecting a force display file

The setting items for [FS 4D graphic] are as follows.

Table 4.2 (a) Force Display File Selection

Item	Description
Device name	Specify a device containing force data files. Select [MC:] (memory card) or [UD1:] (USB memory). "Default: MC:"
Directory name	Specify the name of a directory in the above device that contains force data files. Move the cursor over [Directory name] and press F3 [FILE] to display the list of directory that exist in the device in the ascending order of names. You can also input or change the directory name directly. "Default: FSDT1"
Data File name	Specify the name of a force data file in the above directory. Pressing F3 [FILE] displays a list of files with extension DT in the directory in descending order of name. The descending order is used because a larger number is contained in the name of a newer force data file generated by the "force data log function". You can also input or change the file name directly. * To enter the name directly, enter the name without the ".DT" extension. "Default: FSDT"

NOTE

1 Up to 100 directories can be displayed in the screen. If the device contains more than 100 directories or no directory, an alarm (No. 455 or No. 459) is issued.

2 Up to 1000 files can be displayed in the screen. If the directory contains more than 1000 files or no file with extension DT, an alarm (No. 456 or No. 459) is issued.

Setting for Force Display

The setting items for [Setting for Force Display] are as follow.

Table 4.2 (b) Setting for Force Display

Item	Description
Force	Select which direction of force is to be displayed. There are the following four options: [Fx], [Fy], [Fz], and [resultant]. The 'X', 'Y', and 'Z' directions are the directions with the axes of the user frame specified in the schedule data for other than the 'Contouring' function. For the 'Contouring' function, these directions are the directions with the axes of the tool frame specified in the schedule data when [Control Frame] is set to [Tool Frame] or the directions with the axes of the user frame specified in the schedule data when [Control Frame] is set to [User Frame]. When [Pushing Dir Auto Chg] is set to 'UserFrame X-Y', however, [Fx] and [Fy] indicate the force in the pushing direction automatically changed. For example, when [Pushing Dir.] in the schedule data is set to ' ±X ', [Fx] is the force in the pushing direction and [Fy] is the force in the direction perpendicular to the pushing direction. When [Pushing Dir.] in the schedule data is set to '±Y ', [Fy] is the force in the pushing direction and [Fx] is the force in the direction perpendicular to the pushing direction. [resultant] indicates the square root of the sum of the squares of the force in the three directions and the same as the magnitude of force. (Refer to "Basic Function Guide: 1.5.5 Contouring Function") "Default: Fz"

Display Direction	Select which axis direction in the world frame in the [4D graphic] screen is to be used for displaying lines indicating the force. Select from [X], [Y], or [Z]. Specify a direction in which you can easily check the force in the screen. The direction perpendicular or nearly perpendicular to the path of the origin of the tool frame during the force control operation is recommended. "Default: Z"
Force Scale	Specify the length of each line indicating the force in the [4D graphic] screen. The unit indicates that a force of 1N is displayed with a line of the specified length in mm in the screen. "Default: 1 mm/N"
Display Interval	Specify the intervals in which to display lines indicating force in the [4D graphic] screen. A force data file contains the positions of the origin of the tool frame. When there are multiple data items in the specified display interval, the line for the data item in which the absolute value of the recorded magnitude of force is the maximum is displayed. "Default: 10 mm"
Threshold Big	When the absolute value of force is larger than ([Insert Force] or [Contouring Force] in the schedule data) x (Threshold Big)/100, the force is displayed with a red line in the [4D graphic] screen. Enter the threshold. "Default: 120%"
Threshold Small	When the absolute value of force is smaller than ([Insert Force] or [Contouring Force] in the schedule data) x (Threshold Small)/100, the force is displayed with a white line in the [4D graphic] screen. Enter the threshold. "Default: 80%"

4

NOTE

1 When the absolute value of force is larger than or equal to [Threshold Small] and smaller than or equal to [Threshold Big], the force is displayed with a blue line.
2 For a force data file created using a controller for which software version 7DC2/07 or earlier is used, the force is always displayed with a blue line regardless of the magnitude of force.
3 When pushing force is changed with the function of changing target pushing force during 'Contouring', the color of the line is also determined according to 'Contouring Force' in the schedule data.
(Refer to "Basic Function Guide 1.5.5.7 Other functions of the contouring function".)

Function keys

The function keys have the following functions.

Table 4.2 (c) Function keys

Key	Label	Description
F1	[TYPE]	Switches to a menu item other than the [FS 4D graphic Force display] screen.
F2	UPDATE	Updates the [4D graphic] screen according to the current parameter setting when the screen is open. If the [4D graphic] screen is not open, first open the screen. When the *i*Pendant displays two or three screens, if this setting screen is located on a right screen (second or third screen), label 'UPDATE' is not displayed and the [4D graphic] screen is not updated. (Refer to "Auxiliary Function Guide: 4.3 4D GRAPHIC SCREEN".)
F5	QUIT	Returns to the [force sensor utilities] screen.

4.3 4D GRAPHIC SCREEN

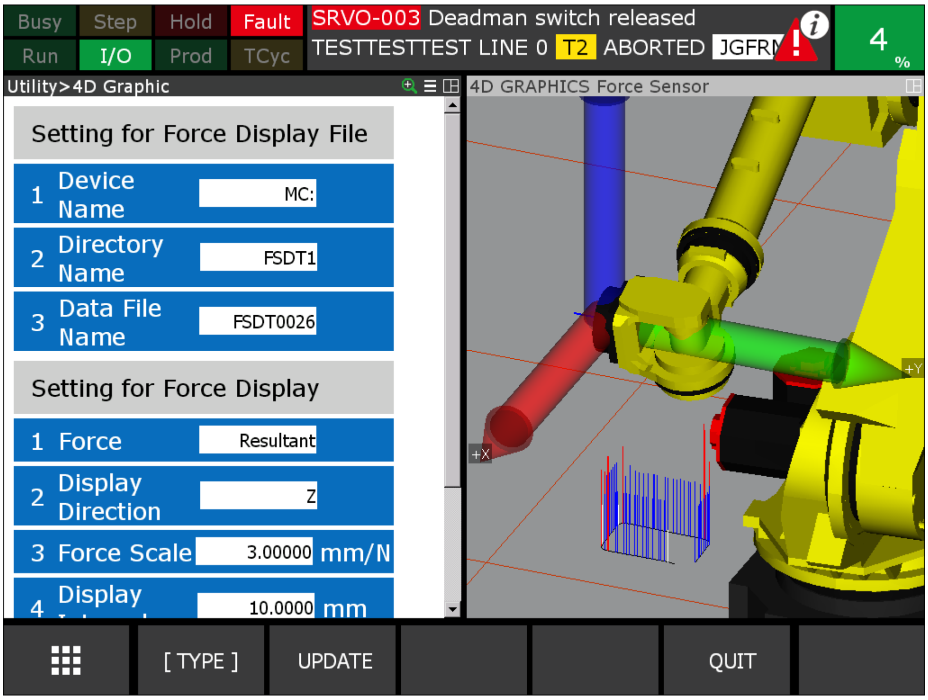
Overview

After setting required parameters as described in Section 4.2, open the [4D graphic] screen.
Load a force sensor data file to display the force.
(Refer to "Auxiliary Function Guide: 4.2 SETTING FOR FORCE DISPLAY SCREEN".)

The path of the origin of the tool frame specified for a force control schedule during the force control operation is displayed with black lines.
The magnitude of the force at each point on the path is indicated with the length of a blue, red, or white line.
A red line indicates that the force exceeds the [Threshold Big]. A white line indicates that the force does not reach the threshold small.

Procedure for updating the [4D graphic] screen

1 Display the [FS 4D graphic Force display] screen.
(Refer to "Auxiliary Function Guide: 4.1 USING THE FORCE SENSOR 4D GRAPHIC FUNCTION".)
2 In the [Setting for Force Display File/ Setting for Force Display] screen, set parameters.
(Refer to "Auxiliary Function Guide: 4.2 SETTING FOR FORCE DISPLAY SCREEN".)
3 Press F2 [UPDATE].
The [4D graphic] screen is updated.



> **NOTE**
> 1 If no force data is recorded in the force data file, the function does not display force data and issues alarm FORC-457.
> 2 Up to 500 lines can be displayed. The 501st and subsequent lines are not displayed and alarm FORC-458 is issued.

Maintenance Guide

1 TROUBLESHOOTING

This chapter explains action to be taken when alarms are issued.

CONTENTS

1.1 COMMON ACTION TO ALL ALARMS

If alarm is issued during force control, check the following items at first:

(1) Are the tool frame and user frame correct?
(Refer to "Basic Function Guide: 1.2 TEACHING PROCEDURE".)

(2) Is the hand grasping a workpiece tightly?
(Refer to "Basic Function Guide: 1.1 NOTES/RESTRICTIONS".)

(3) Is the approach point taught correctly?
(Refer to "Basic Function Guide: 1.2 TEACHING PROCEDURE".)

(4) Check if the robot mastering data is correct.
Perform the orthogonal jog and check if the robot moves in the correct direction.

1.2 WHEN A TIMEOUT ERROR OCCURS

Unless force control terminates within a set time, an alarm is issued.

- Alarms of this type include alarm No. 264, "STOP.G Insertion timeout error", issued in case of insertion function.

If such an alarm is issued, check the following:

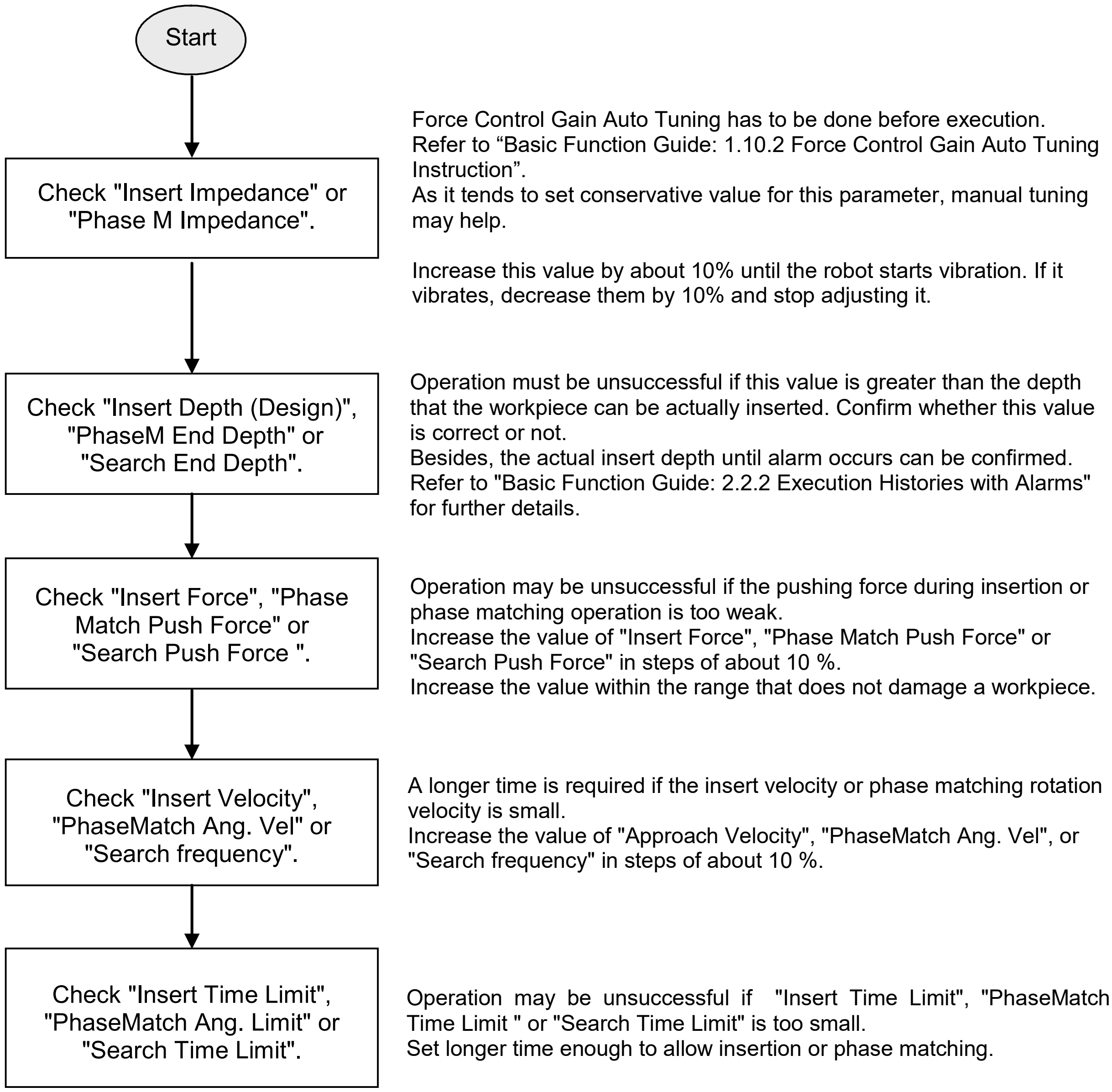


Fig. 1.2 When a timer out error occurs

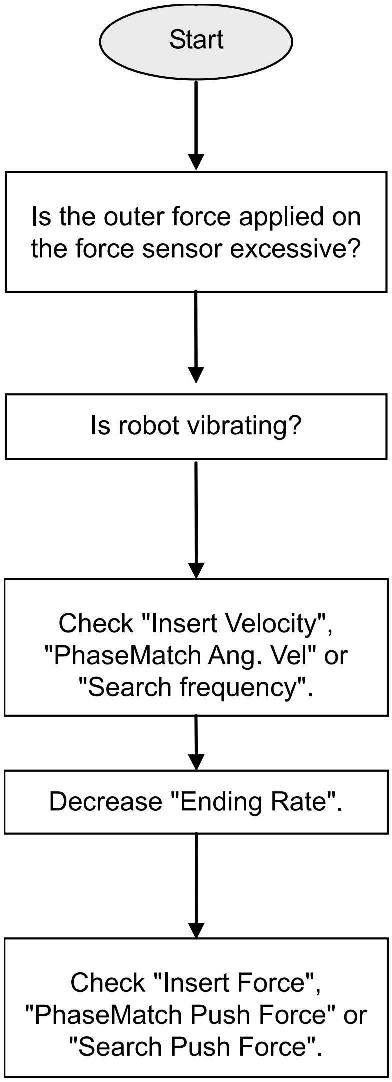
1.3 WHEN A FORCE LIMIT ALARM OCCURS

There are several types of force limit alarms including alarm FORC-158, and FORC-159.
(Refer to "APPENDIX: B ALARM CODES OF FORCE CONTROL".)

An alarm FORC-158/159 occurs

If an alarm FORC-158 or FORC-159 occurs while moving between taught points regardless of force control instructions, it may be caused by the inertial force due to acceleration/deceleration. Reduce the weight or moment of tools attached to the force sensor, or decrease the motion speed or acceleration at the position where the alarm occurred.

A force limit alarm occurs during execution of force control instructions



Confirm whether the outer force applied on the force sensor by a grinder or nut runner is excessive or not.
Check the maximum force applied on the force sensor during force control or just before the alarm stop. Refer to "Basic Function Guide: 2.2.2 Execution Histories with Alarms" for further details.
Further more, the force and moment during the force control may be graphically displayed. Refer to "Basic Function Guide: 2.3 FORCE DATA LOG FUNCTION" for further details.

When a function other than contouring function is used, retry automatic force control gain auto tuning. (Refer to "Basic Function Guide: 1.10.2 Force Control Gain Auto Tuning Instruction".)
If robot still vibrates or contouring function is in use, decrease the force control gain manually. (For the value change direction, refer to "Basic Function Guide: 1.6 FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".)

The value of "Insert Velocity", "PhaseMatch Ang. Vel" or "Search frequency" may be too large. Decrease the value in steps of about 10%.

"Ending Rate" is displayed on the performance screen.
Decrease this value in steps of about 5%.

If the value of "Insert Force", "PhaseMatch Push Force" or "Search Push Force" is too large, the force limit alarm may often be issued.
Decrease the value in steps of about 10%.

Fig. 1.3 When a force limit alarm occurred

An alarm from FORC-216 to FORC-221 occurs

Particularly when one of the alarms from FORC-216 to FORC-221 is issued, increase the value of "Force Limit" on the performance screen.
When an alarm is issued, change the value of the corresponding component as follows.

Table 1.3 Alarms No. 216-221

Alarm	Description
Alarm FORC-216 is issued.	Increase the [X] component value for [Force Limit].
Alarm FORC-217 is issued.	Increase the [Y] component value for [Force Limit].
Alarm FORC-218 is issued.	Increase the [Z] component value for [Force Limit].
Alarm FORC-219 is issued.	Increase the [W] component value for [Force Limit].
Alarm FORC-220 is issued.	Increase the [P] component value for [Force Limit].
Alarm FORC-221 is issued.	Increase the [R] component value for [Force Limit].

1.4 WHEN THE ROBOT MOTION DIRECTION IS NOT CORRECT WHILE EXECUTING FORCE CONTROL

If the robot moves in an unintended direction during the force control, check the following items.

(1) Check if the tool frame and user frame are correct. Also, check the tool frame number, user frame number, and pushing direction for the schedule data.
(Refer to "Basic Function Guide: 1.2 TEACHING PROCEDURE".)

(2) Check the approach point position. Ensure that the workpiece is not in contact with anything at the approach point.
(Refer to "Basic Function Guide: 1.2 TEACHING PROCEDURE".)

(3) To execute multiple force control instructions consecutively, make sure to use the customize function.
(Refer to "Basic Function Guide:1.7 SUCCESSIVE EXECUTION OF FORCE CONTROL INSTRUCTIONS (CUSTOMIZATION FUNCTION)".)

(4) Check the force sensor attachment.
- If the force sensor was attached before shipment, ensure that the original position is not changed. Ensure that the fixing bolts are not loose.
- If you attached the force sensor yourself, or for a fixed mount type, ensure that the force sensor was attached with the correct procedures.
(Refer to "Introduction: 3 INSTALLING FORCE SENSOR".)

(5) Check if the robot mastering data is correct.
Perform the orthogonal jog and check if the robot moves in the correct direction.

APPENDIX

A
B
C
D
E
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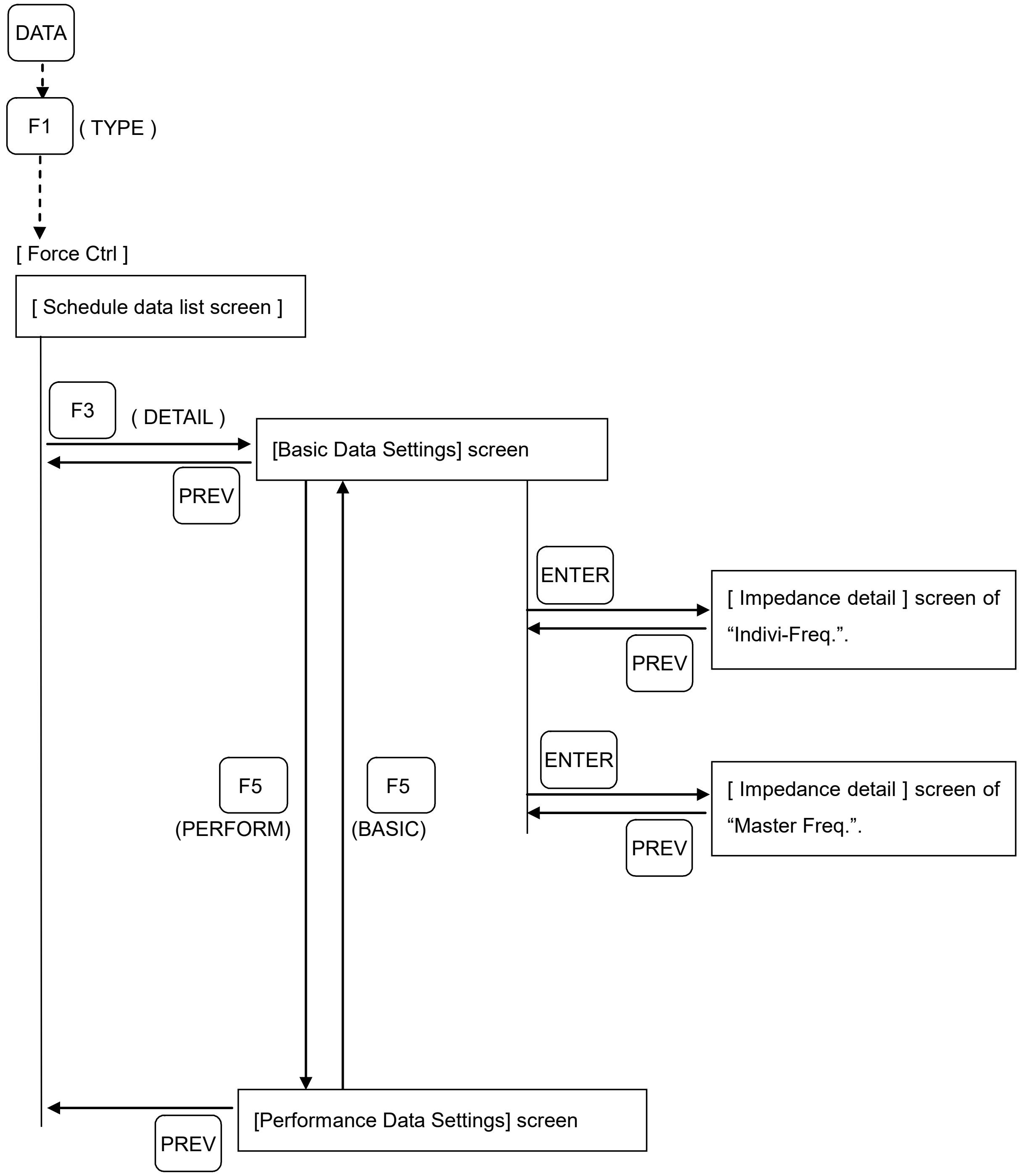
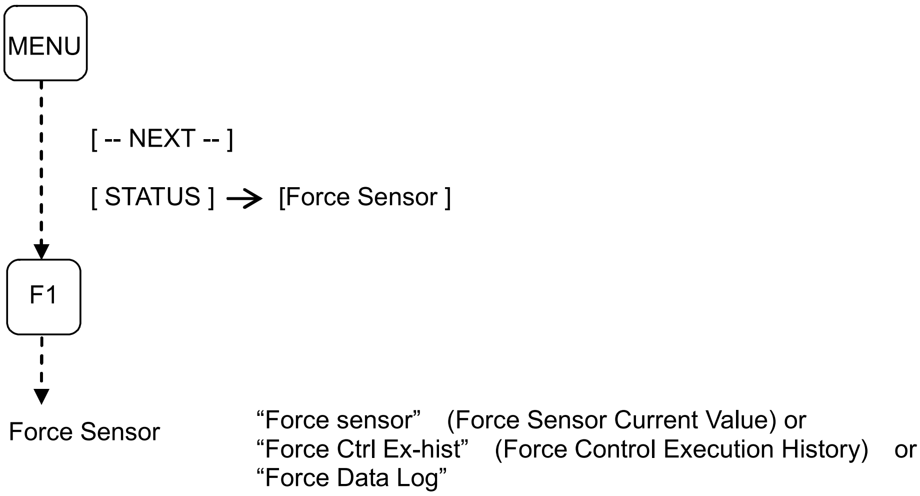
A

A FORCE CONTROL MENU MAP

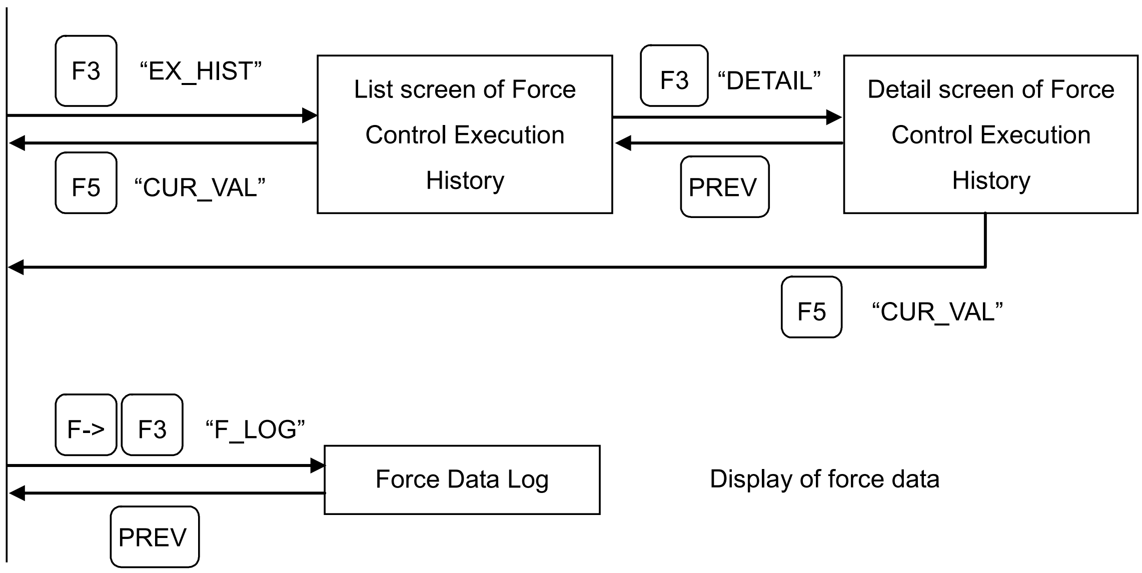
[Schedule data] screen



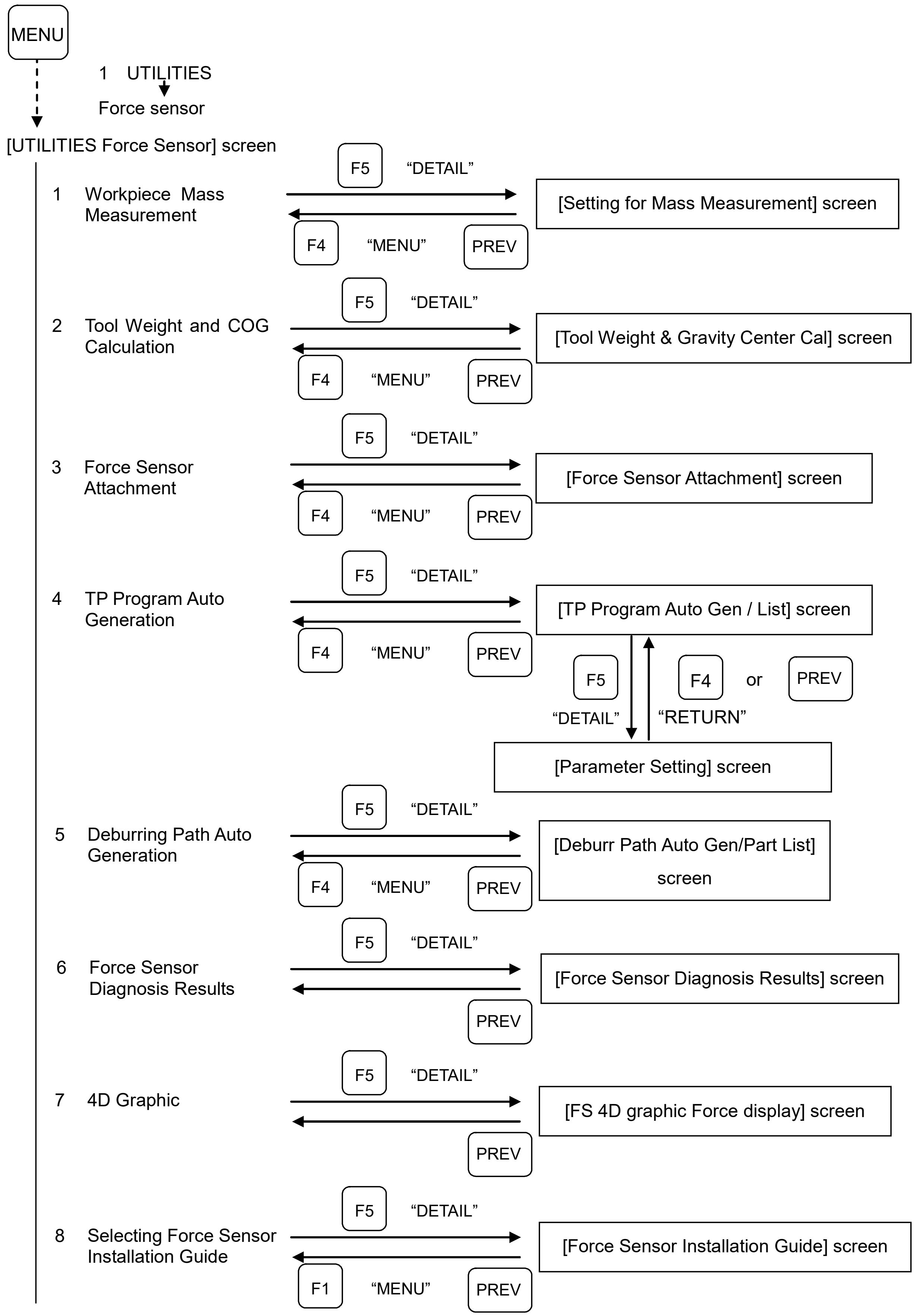
Force Sensor Status screen



“Force sensor” (Force Sensor Current Value)



Force Sensor Utilities screen



B ALARM CODES OF FORCE CONTROL

When an alarm occurs, refer to the following alarm code.

> **NOTE**
> If an alarm that is not found in the following tables occurs, contact us.

FORC-001 Main board type is wrong

Cause:	The controller's main board does not have a force sensor interface.
Remedy:	Use the following steps to implement measures. 1 Make sure that the controller's main board has a force sensor interface 2 If it does not have a force sensor interface, replace it with the one that has a force sensor interface. 3 If the main board type is unknown, contact the FANUC service center.

FORC-004 Communication error

Cause:	Software internal error
Remedy:	Use the following steps to implement measures. 1 Turn the controller OFF then ON again. 2 If it occurs again, replace the controller's main board. 3 Contact the FANUC service center and report the error status.

FORC-005 Robot not mastered

Cause:	Robot mastering is not completed.
Remedy:	Perform mastering. (Refer to "R-30*i*B/R-30*i*B Mate CONTROLLER OPERATOR'S MANUAL (Basic Operation)" (B-83284EN).)

FORC-006 Sensor board is disabled 2

Cause:	Software internal error
Remedy:	Use the following steps to implement measures. 1 Turn the controller OFF then ON again. 2 If it occurs again, replace the controller's main board. 3 Contact the FANUC service center and report the error status.

FORC-007 Memory initialization error

Cause:	An error related to memory initialization occurred inside the software. The capacity of the memory may be insufficient, or the memory may be destroyed.
Remedy:	Contact the FANUC service center and report the error status.

FORC-008 Option is not loaded

Cause:	The software option required for the force control schedule (force control fitting) is not incorporated into the controller. Or the software option required for the force control deburring package is not incorporated into the controller.
Remedy:	Install the software option (force control fitting or force control deburring package). Contact the FANUC service center.

FORC-011 Force group mismatch

Cause:	Motion group of force control is mismatched to the default motion group of the program.
Remedy:	Check the default motion groups of the program.

FORC-012 Time out error occurred

Cause:	Software internal error
Remedy:	Use the following steps to implement measures. 1 Turn the controller OFF then ON again. 2 If it occurs again, replace the controller's main board. 3 Contact the FANUC service center and report the error status.

FORC-013 Communications error

Cause:	Software internal error
Remedy:	Use the following steps to implement measures. 1 Turn the controller OFF then ON again. 2 If it occurs again, replace the controller's main board. 3 Contact the FANUC service center and report the error status.

FORC-014 Invalid tool number

Cause:	The tool number is set to 0.
Remedy:	Please set the correct tool number.

FORC-015 Force sensor error exceed limit

Cause:	As a result of the force sensor diagnosis the error of the force sensor exceeded the tolerance.
Remedy:	Check the force sensor values. Contact the FANUC service center and report the error status.

FORC-016 Diagnosis normal end

Cause:	Force sensor is normal.
Remedy:	No action is required.

FORC-017 Diag. data has been set

Cause:	Force Sensor Diagnosis Instruction is executed with a 3-axis Force sensor and its data has been set. These values can be seen on Force Sensor Diagnosis Results screen. [UTILITIES] → [Force Sensor] → [Force Sensor Diagnosis Results])
Remedy:	No action is required.

FORC-018 Uninitialized data

Cause:	Initial force sensor data is uninitialized.
Remedy:	Please initialize the force sensor data.

FORC-019 Tolerance data is 0 or less

Cause:	Tolerance data is uninitialized.
Remedy:	Please set up the system variable $CCS_GRP.$INIT_TOL.

FORC-020 Servo is not ready

Cause:	Immediately after force control execution, an emergency stop was performed, or a servo alarm was issued.
Remedy:	Use the following steps to implement measures. 1 Check the surroundings for abnormalities. 2 If no abnormality is found, reset the alarm then re-execute, or turn off the power then turn on the power again. 3 If normal execution is still disabled, contact the FANUC service center and report the error status.

FORC-022 OFFSET/VOFFSET not executed

Cause:	The position offset condition instruction or Vision offset condition instruction required for the user frame compensation has not been executed. Or the specified Vision register number is illegal.
Remedy:	Implement any of the following measures. • Specify the position register number to be used for the user frame compensation in the position offset condition instruction. • Specify the Vision register number to be used for the user frame compensation in the Vision offset condition instruction. • Verify the Vision register number.

FORC-023 Force sensor error occurred

Cause:	Force sensor error has been occurred.
Remedy:	The already generated alarm concerning the force sensor is not released. Refer to the remedy of the generated alarm.

FORC-024 Force control error occurred

Cause:	The error occurred during the force control. The error jump is not done, because label number is 0.
Remedy:	Refer to the remedy of the force control alarm generated before this alarm.

FORC-025 Function type is unused

Cause:	Cannot execute FORCE CTRL instruction because Unused is selected.
Remedy:	Select the appropriate function type.

FORC-026 Init data has been set

Cause:	The force sensor data diagnosis has been set now.
Remedy:	No action is required.

FORC-027 Another tuning already enabled

Cause:	Another tuning mode is already enabled.
Remedy:	Abort the program and remove another tuning instruction.

FORC-028 Internal error(%d) occurred

Cause:	Software internal error
Remedy:	Contact the FANUC service center and report the error status.

FORC-029 Ext-Axis is invalid

Cause:	Extended Axis which is set rotation mechanism of ”Threading” function is invalid for use.
Remedy:	Implement any of the following measures. • Ensure that "J518" (Extended Axes Control) and "J613" (Continuous Turn) are ordered. • Selected number axis is connected. • Selected number axis is not integrated. • Selected number axis is rotary axis • Selected number axis is able to rotate continuously.

FORC-030 The memory device doesn't exist

Cause:	The save destination for the force log data is not found.
Remedy:	Provide a USB or memory card storage device. Or stop logging the force data.

FORC-034 Vision Reg non-existent

Cause:	[User Frame Compensation] in the [Performance Data Settings] screen uses the Vision register but the "*i*RVision" option is not installed in the robot controller.
Remedy:	Implement any of the following measures. • Set [User Frame Compensation] to [Off] in the [Performance Data Settings] screen or use the position register. • "Add the *i*RVision" option. To add the option, contact our sales representative.

FORC-035 Vision OFFSET is invalid

Cause:	[User Frame Compensation] in the [Performance Data Settings] screen uses the Vision register but the Vision offset instruction is disabled.
Remedy:	Use the following procedure to enable the Vision offset instruction. 1 Press the [TYPE] key on the teach pendant of the robot controller and select [SET] -> [General]. 2 Set [Enable VOFFSET] to [ENABLED].

FORC-036 Vision Register wrong Type

Cause:	[User Frame Compensation] in the [Performance Data Settings] screen uses the Vision register but the Vision register offset type is not set to the position offset.
Remedy:	Set Vision Register's type Fixed Frame Offset.

FORC-037 Fixed sensor option is not ordered

Cause:	The software option required for the Fixed sensor is not incorporated into the controller.
Remedy:	Install the software option (Fixed sensor). Contact the FANUC service center.

FORC-038 Please set sensor frame

Cause:	Sensor frame for fixed sensor is not set.
Remedy:	Make one of the following changes: • To fix the force sensor to the working table, set the sensor frame. (Refer to "APPENDIX: C.4 FIXING FORCE SENSOR ON THE WORKING TABLE".) • To attach the force sensor to the robot wrist, change the attachment type. (Refer to "APPENDIX: C.5 CHANGING ONLY SENSOR ATTACHMENT TYPE".)

FORC-039 Please reboot controller

Cause:	After changing the sensor frame with the [Force Sensor Attachment] function, the robot controller must be rebooted.
Remedy:	Reboot the robot controller. If this alarm does not disappear, contact the FANUC service center.

FORC-040 Can't exec. F/C with hand sensor

Cause:	[Sensor attachment] is set as "HAND" in "FORCE SENSOR ATTACHMENT SETTING FUNCTION" for M-1*i*A/0.5A.
Remedy:	The force sensor can be used only with Fixture mount for M-1*i*A/0.5A. Refer to "APPENDIX: C.4, FIXING FORCE SENSOR ON THE WORKING TABLE".

FORC-041 This controller isn't supported

Cause:	The combination of the robot and controller is wrong.
Remedy:	Contact the FANUC service center and report the error status.

FORC-042 Vision Register is not set

Cause:	The values are not set in the Vision Register which is designated in VOFFSET CONDITION instruction.
Remedy:	Check the Vision Register index and execute *i*RVision.

FORC-050 Force Sensor can't be connected

Cause:	Force Sensor can't be connected.
Remedy:	Do not execute “SENSOR CONNECT” while the robot is moving.

FORC-051 Force Sensor can't be disconnected

Cause:	Force Sensor cannot be disconnected.
Remedy:	Do not execute “SENSOR DISCONNECT” while the robot is moving.

FORC-052 Force Sensor disconnection

Cause:	Tried to execute Force control while force sensor is disconnected.
Remedy:	Attach the force sensor.

FORC-053 FS disconnect internal error

Cause:	Software internal error
Remedy:	Contact the FANUC service center and report the error status.

FORC-054 Port setting is incorrect

Cause:	The RS-232-C port settings are not configured or are incorrect.
Remedy:	Configure the RS-232-C port settings appropriately for the connected Force Sensor.

FORC-055 Communication with FS timeout

Cause:	Communication with the Force Sensor connected via the RS-232-C port timed out.
Remedy:	• Confirm that the connector of the sensor cable is firmly plugged in. • Replace the sensor cable. • Replace the sensor head.

FORC-101 Default data is incorrect

Cause:	Software internal error
Remedy:	Contact the FANUC service center and report the error status.

FORC-103 Index value is incorrect

Cause:	Index value of FORCE CTRL instruction is not correct.
Remedy:	Set the index value of FORCE CTRL instruction correctly.

FORC-105 Force group is incorrect

Cause:	The force group of programs has not been existed in this system.
Remedy:	Teach the instruction for which an error occurred on this system again.

FORC-106 Mass data is out of range

Cause:	The mass data which has been calculated by input data is out of range.
Remedy:	Input the appropriate data.

FORC-107 Damper data is out of range

Cause:	The damper data which has been calculated by input data is out of range.
Remedy:	Input the appropriate data.

FORC-108 Input data is out of minimum

Cause:	The input data is out of minimum range.
Remedy:	Input the appropriate data.

FORC-109 Input data is out of maximum

Cause:	The input data is out of maximum range.
Remedy:	Input the appropriate data.

FORC 110 Can not use memory card

Cause:	You attempted to select the memory card for an R-30*i*BMate Plus controller.
Remedy:	For an R-30*i*BMate Plus controller, the memory card cannot be used. Select a different device such as [UD: (USB memory)].

FORC-111 WARN Rotation velocity is limited

Cause:	The rotation axis of threading is not on J6 of a robot. Rotation velocity is limited for safety.
Remedy:	This is not an error. If fast rotation is needed, design the tool so that the rotation axis of threading corresponds to J6 of the robot first and set a Tool frame whose origin is on J6.

FORC-114 Converted individual difference

Cause:	Because the “Ending Condition Switch” in Performance data is changed, “Individual diff. (-)” in Basic data is converted.
Remedy:	Ensure that the value of [Individual Diff. (-)] is correct in the [Basic Data Settings] screen.

FORC-115 Insert direction is changed

Cause:	The groove direction is changed and as a result matches the insert direction, so the insert direction is changed.
Remedy:	Ensure that [Insert Direction] is correct in the [Basic Data Settings] screen.

FORC-116 SoftFloat Combi. is prohibited

Cause:	"SoftFloat" and "Force Control" were executed simultaneously.
Remedy:	Don’t execute "SoftFloat" and "Force Control" simultaneously.

FORC-117 Auto tuning not done

Cause:	Cannot set “Phase Match Imp. Rate” in Performance data because impedance parameters auto tuning is not finished.
Remedy:	Perform the impedance parameters auto tuning previously.

FORC-118 Groove direction is changed

Cause:	"Insert Direction" in Basic data is changed because the modified groove direction is the same as "Insert Direction". This alarm is issued only in "Groove Insert".
Remedy:	Ensure that [Insert Direction] is correct in the [Basic Data Settings] screen.

FORC-119 Customize infinit loop

Cause:	In successive execution of force control, a schedule specifies another schedule as the parent, but the former schedule is also specified as the parent by the latter schedule.
Remedy:	There is a parent number specification that causes a loop of parent-child relationship. Check the schedule data, and correct the parent number specification.

FORC-120 Customize exceed rty-child num

Cause:	You attempted to set a schedule number that already has a child schedule for retry (draw) for [Customize Parent Number] in the [Performance Data Settings] screen for a schedule set for retry (draw) in continuous execution of the force control.
Remedy:	For a schedule, only one child schedule for retry (draw) operation can be specified. Implement any of the following measures. • When setting a new schedule as the child schedule for retry (draw) operation: Set "Customize Parent Number" for the existing schedule for retry (draw) operation to 0, and specify "Customize Parent Number" for a new schedule. • When the specified parent schedule number is incorrect: Correct the parent schedule number.

FORC-121 Customize exceed ins-child num

Cause:	You attempted to set a schedule number that already has a child schedule for insert for [Customize Parent Number] in the [Performance Data Settings] screen for a schedule set for insert.
Remedy:	For a schedule, only one child schedule for insertion can be specified. Implement any of the following measures. • When setting a new schedule as the child schedule for insertion: Set "Customize Parent Number" for the existing child schedule for insertion to 0, and specify "Customize Parent Number" for the new schedule. • When the specified parent schedule number is incorrect: Correct the parent schedule number. • When the child schedule to be specified is a schedule for retry (draw) operation. The child schedule for retry (draw) operation has the following features: (1) The user frame and tool frame are the same as those for the parent schedule. (2) The insertion direction of the child schedule is the same as that of the parent schedule, but the orientation is opposite to that of the parent schedule. (Example: If the insertion direction of the parent is -Z, the insertion direction of the child schedule for retry (draw) operation is +Z.) After setting (1) and (2) correctly, set "Customize Parent Number".

FORC-122 Customize exceed retry num

Cause:	A child schedule for retry operation is specified as a parent schedule.
Remedy:	A child schedule for retry operation cannot be specified as a parent schedule. Implement any of the following measures. • When using more than one schedule to perform retry (draw) operation. Specify an insertion schedule to be paired with retry (draw) operation as the parent schedule. • When a wrong schedule number is specified. Specify correct schedule data for insertion. • When the insertion direction of the schedule specified as the parent is incorrect. Because the insertion direction of the parent schedule is the same as the insertion direction of the parent of that parent schedule, but their orientations are opposite to each other, that parent schedule is regarded as a child schedule data for retry (draw) operation. Correct the insertion direction of that parent schedule data.

FORC-123 Customize synchro change OK

Cause:	This is not an error. Parameters are copied between schedule data having a parent-child relationship.
Remedy:	Because this is not an error, no action need not be taken.

FORC-124 Customize syncro change NG

Cause:	This is not an error. Parameters are copied between schedule data having a parent-child relationship.
Remedy:	Because this is not an error, no action need not be taken.

FORC-125 Customize intr. TP err0

Cause:	Software internal error
Remedy:	Contact the FANUC service center and report the alarm status.

FORC-126 Customize Auto.Exec Set. err

Cause:	Parameters of customized schedules Auto.Cont.Exec. is inappropriate.
Remedy:	Check Function, Frame, Parent number, Child number, 'User Frame Compensation' etc. (Refer to "Basic Function Guide: 1.7.5 Customization Automatic Continuous Execution Function".)

FORC-127 Signal Output for ERR Set.err

Cause:	Parameters of Signal Output for ERR is inappropriate.
Remedy:	Check Signal Type, Signal Number.

FORC-128 Turn on Gain Auto Modify

Cause:	"F.Ctrl. Gain Auto Modify" is turned off. For a force control instruction between the 'AUTO TUNING ON' instruction and the 'AUTO TUNING OFF' instruction, the "F.Ctrl. Gain Auto Modify" switch needs to be turned on.
Remedy:	Using automatic force control gain tuning, turn on "F.Ctrl. Gain Auto Modify" on the corresponding schedule data screen. If automatic force control gain tuning is not performed, the'AUTO TUNING ON' instruction may be executed somewhere improperly. Review and correct the program so that the'AUTO TUNING ON' instruction is not executed improperly.

FORC-129 Direction is same as ins. dir.

Cause:	You attempted to set parameters for the insert direction on the [Search Basic Param.] screen or the [Search Performance Param.] screen for the "Search" function. This alarm is issued only in the "Search" function.
Remedy:	Parameters cannot be set for the insert direction on the [Search Basic Param.] screen or the [Search Performance Param.] screen. Check whether the insertion direction and search direction are correct.

FORC-130 Illegal insert data index

Cause:	Software internal error
Remedy:	Contact the FANUC service center and report the error status.

FORC-131 WARN Cannot execute Gain Auto Tuning

Cause:	Not ready to execute force control gain auto tuning.
Remedy:	Move the robot in X, Y, and Z directions at the speed of several hundreds mm/s, and return to the original position. Execute force control gain auto tuning again before releasing the deadman switch or applying an emergency stop. If the deadman switch has been released or emergency stop has been applied, start over from moving the robot in X, Y, and Z directions.

FORC-151 F/S FPGA version error (F:%d^1)

Cause:	The version of FPGA is improper.
Remedy:	Contact the FANUC service center and report the error status.

FORC-158 F/S gauge data overflow (F:%d^1)

Cause:	Sensor head output exceeded the limit value.
Remedy:	Use the following steps to implement measures. 1 Move the robot to the position that it does not contact any object to take away the overload from the force sensor. 2 Turn the controller OFF then ON again. 3 If the alarm occurs even after the reboot of the controller, a drastic acceleration/deceleration may have caused the alarm. Reduce the weight of tools attached to the force sensor, or decrease the motion speed or acceleration at the position where the alarm occurred. 4 If the tool such as grinder or nut-runner is attached to the robot, make sure that it does not exert big force to the sensor. Decrease the tool rotation speed, if possible. 5 Replace the sensor head.

FORC-159 F/S sensor limit overflow (F:%d^1)

Cause:	Excessive load were put on the sensor head.
Remedy:	Use the following steps to implement measures. 1 Ensure that the robot does not come in contact with surrounding objects. A collision may have caused the alarm. 2 If the robot does not come in contact with objects, a drastic acceleration/deceleration may have caused the alarm. Reduce the weight of tools attached to the force sensor, or decrease the motion speed or acceleration at the position where the alarm occurred. 3 If the tool such as grinder or nut-runner is attached to the robot, make sure that it does not exert big force to the sensor. Reduce the force by taking measures such as decreasing the rotating velocity. 4 Make sure that the value of “Insert Force” in Basic data is too big. If not, go to the next step. 5 If the alarm occurred with appropriate parameter force instruction values, an improper force control gain may have resulted in an oscillation. Decrease the value of Master Frequency of “force control gain” gradually. 6 Move the robot to the reference position and clear the force sensor from the force sensor current value screen. (Refer to "Basic Function Guide: 2.1 FORCE SENSOR CURRENT VALUE SCREEN".) 7 Execute the force sensor diagnosis instruction to verify that the force sensor functions properly. If “Diagnosis normal end” is displayed, the sensor can be uses as is. If “Force sensor error exceed limit” is displayed, replace the sensor head. (Refer to "Basic Function Guide: 1.10.1 Force Sensor Diagnosis Instructions".)

FORC-160 F/S cable is cut (F:%d^1)

Cause:	The force sensor cable is broken. Or a sensor cable is loosely connected to the force sensor. The force sensor head may be broken.
Remedy:	Use the following steps to implement measures. 1 Make sure that the sensor cable is properly connected to the force sensor. 2 Replace the sensor cable. 3 Confirm that the R-30*i*B Plus main board has a Force sensor Interface. 4 Replace the force sensor head.

FORC-161 F/S calibration data not loaded

Cause:	Force sensor Calibration data has not been loaded correctly.
Remedy:	In case of 6 axis force sensor, copy "CCSCB2.CM" file from the CD-R which is appendix of the force sensor to a memory card or USB memory. Perform the same file with a teach pendant.

FORC-162 F/S temperature data overflow (F:%d^1)

Cause:	Temperature output error occurred in the sensor head.
Remedy:	Use the following steps to implement measures. 1 Move the robot to the position that it does not contact any object. 2 Turn the controller OFF then ON again. 3 If the alarm occurs even after the reboot of the controller, replace the sensor head.

FORC-164 F/S temp. lower limit error (F:%d^1)

Cause:	Temperature of the sensor head is too low.
Remedy:	Use the following steps to implement measures. 1 Check if the surrounding temperature is too low or if there is any cold object in the vicinity. Check [Temperature] in the force sensor current value screen and ensure that [Temperature] is 0 °C or higher. 2 If the temperature around the sensor head is appropriate, reboot the controller. 3 If the alarm occurs even after the reboot of the controller, replace the main board of the controller. 4 If the alarm occurs even after the replacement of the main board, replace the sensor head.

FORC-165 F/S temp. upper limit error (F:%d^1)

Cause:	Temperature of the sensor head is too high.
Remedy:	Use the following steps to implement measures. 1 Check if the surrounding temperature is too high or if there is any hot object in the vicinity. Check [Temperature] in the force sensor current value screen and ensure that [Temperature] is 60 °C or lower. 2 If the temperature around the sensor head is appropriate, reboot the controller. 3 If the alarm occurs even after the reboot of the controller, replace the main board of the controller. 4 If the alarm occurs even after the replacement of the main board, replace the sensor head.

FORC-171 F/S output data frozen (F:%d^1)

Cause:	The output data of the sensor head are frozen. (Force sensor returns constant data)
Remedy:	Use the following steps to implement measures. 1 Check the force sensor output in TP (force sensor status screen). If values change from time to time, it may be in the course of recovery, so watch the situation for a while. 2 If constant values are displayed for a certain amount of time, ensure that the sensor cable is properly connected and that it is not broken. 3 If there is nothing wrong with the sensor cable, replace the main board of the controller. 4 If the alarm occurs even after the replacement of the main board, replace the sensor head.

FORC-175 F/S force differential limit (F:%d^1)

Cause:	Differential value of the force during force control is too large.
Remedy:	Use the following steps to implement measures. 1 Ensure that the robot does not come in contact with surrounding objects. A collision may have caused the alarm. 2 If the robot has a grinder or nut runner attached, a great force may be applied by that tool. Reduce the force by taking measures such as decreasing the rotating velocity. Or if such a tool is used together, Set [Force Denoising Sw] to [On] in the [Performance Data Settings] screen. 3 If the robot has a grinder or nut runner attached, it may be oscillating. Decrease the [Master Freq.] value of the force control gain in small steps. 4 If the alarm occurs even with a lower [Master Freq.] value, decrease the value of [Insert Force] or [Pushing Force] in the [Basic Data Settings] screen. 5 For the [Contouring] function, increase the value of [Force Change Limit] in the [Performance Data Settings] screen.

FORC-180 F/S ITP counter error (F:%d^1)

Cause:	Communication failed.
Remedy:	Use the following steps to implement measures. 1 Move the robot to the position that it does not contact any object. 2 Turn the controller OFF then ON again. 3 If the alarm occurs even after the reboot of the controller, ensure that the sensor cable is properly connected and that it is not broken. 4 If there is nothing wrong with the sensor cable, replace the main board of the controller. 5 If the alarm occurs even after the replacement of the main board, replace the sensor head.

FORC-181 Force sensor type error (F:%d^1)

Cause:	The controller can not judge Force sensor type properly.
Remedy:	Use the following steps to implement measures. 1 Turn the controller OFF then ON again. 2 If the alarm occurs even after the reboot of the controller, ensure that the force sensor cable is properly connected and that it is not broken. 3 If there is nothing wrong with the sensor cable, replace the force sensor.

FORC-183 Mass Measure execution error

Cause:	The value of [Reg. No. Basis Measure], [Reg. No. Mass Measure], or [Reg. No. Mass Result] is illegal for the mass measurement function with the force sensor. Or the mass measurement function with the force sensor and the force control function were executed at the same time. (Refer to "Auxiliary Function Guide: 3 WORKPIECE MASS MEASUREMENT FUNCTION".)
Remedy:	Check the following settings. • When "Mass Measurement SW" is ON, don’t change the values of "Reg. No. Basis Measure", "Reg. No.Mass Measure", "Reg. No. Mass Result". In order to change these values, set OFF to "Mass Measurement SW" first. • Check if "Reg. No. Basis Measure", "Reg. No. Mass Measure","Reg. No. Mass Result" are different. • Check if "Reg. No. Basis Measure", "Reg. No. Mass Measure","Reg. No. Mass Result" are positive integers. • Don’t execute "Basis Measurement" and "Mass Measurement" simultaneously. • Don’t execute "Mass Measurement" and "Force Control" simultaneously.

FORC-184 Mass Measure timeout error

Cause:	[Max. Data Record Time] was exceeded by the elapsed time for [Basis Measure] or [Mass Measurement] in the mass measurement function with the force sensor. (Refer to "Auxiliary Function Guide: 3 WORKPIECE MASS MEASUREMENT FUNCTION".)
Remedy:	1 Check the start timing and end timing of "Basis Measurement" or "Mass Measurement". 2 Increase "Max. Data Record Time".

FORC-188 Auto Tuning SW is turned off

Cause:	"F.Ctrl. Gain Auto Modift" switch is turned off.
Remedy:	This is not an error. If you desire to execute Force Control Gain Auto Tuning Instruction again, turn on "F.Ctrl. Gain Auto Modift" again.

FORC-199 Single singularity error (F:%d^1)

Cause:	The axis, which might become singularity, has approached a singularity point during the force control.
Remedy:	The following two types of orientations result in single singularity. • The [J5] angle is 0 [deg]. • [J2], [J3], and [J5] are in the same straight line. Perform the force control with positions and orientations that keep well away from these states.

FORC-201 Complex singularity error (F:%d^1)

Cause:	J1 and J6 have reached nearby singularity point during the force control.
Remedy:	Don't execute the force control in a posture that J6 comes on the axis of J1. (The robot hand reaches right above the robot base.)

FORC-203 Envelope limit error

Cause:	The axial angle approached the higher or lower limit of the movable range.
Remedy:	Do not perform the force control operation in a position near the higher or lower limit of the axial movable range.

FORC-211 Servo error occurred (F:%d^1)

Cause:	Servo error occurred.
Remedy:	Another servo error occurred at the same time. Do measures of the another alarm.

FORC-216 X Force Limit (F:%d^1)

Cause:	The 'X' component of the force exceeded the higher limit value.
Remedy:	Use the following steps to implement measures. 1 Check the position of the approach point so that the robot does not contact to the object. 2 Ensure that an excessive force is not applied by tools. Tools that may apply an excessive force include grinders and nut runners. If these tools are used together, Set [Force Denoising Sw] to [On] in the [Performance Data Settings] screen. 3 If an excessive force is not applied by tools, an improper force control gain may have resulted in an oscillation. Decrease the [Master Freq.] value of the force control gain in small steps. 4 The velocity in the insert direction was so high that an impact force may have been applied. Decrease [Insert Velocity], [PhaseMatch Insert Vel], or [Search Insert Vel] by 10% at a time in the [Basic Data Settings] screen. 5 Decrease [Insert Force] by 10% at a time in the [Basic Data Settings] screen. 6 Increase the “X” component of [Force Limit], [Phase M Force Limit], or [Insert Force Limit] by 10% at a time in the [Performance Data Settings] screen.

FORC-217 Y Force Limit (F:%d^1)

Cause:	The 'Y' component of the force exceeded the higher limit value.
Remedy:	Similar to FORC-216. (Refer to "FORC-216".)

FORC-218 Z Force Limit (F:%d^1)

Cause:	The 'Z' component of the force exceeded the higher limit value.
Remedy:	Similar to FORC-216. (Refer to "FORC-216".)

FORC-219 W Moment Limit (F:%d^1)

Cause:	The “W” component of the moment exceeded the higher limit value.
Remedy:	Similar to FORC-216. (Refer to "FORC-216".)

FORC-220 P Moment Limit (F:%d^1)

Cause:	The “P” component of the moment exceeded the higher limit value.
Remedy:	Similar to FORC-216. (Refer to "FORC-216".)

FORC-221 R Moment Limit (F:%d^1)

Cause:	The “R” component of the moment exceeded the higher limit value.
Remedy:	Similar to FORC-216. (Refer to "FORC-216".)

FORC-223 Ilegal end force control (F:%d^1)

Cause:	An error occurred during force control.
Remedy:	Another force control alarm is issued at the same time. Refer to the description of remedy for the alarm.

FORC-224 Inverse kinematics Error

Cause:	Software internal error
Remedy:	Change the position and orientation of the robot and execute force control. If this error occurs again, Contact the FANUC service center and report the error status.

FORC-225 Forward kinematics Error

Cause:	Software internal error
Remedy:	Change the position and orientation of the robot and execute force control. If this error occurs again, Contact the FANUC service center and report the error status.

FORC-260 Force at the end is not ok (F:%d^1)

Cause:	When force control was executed with “Force End Judgment Switch” set to ON, the magnitude of force did not become larger than the product of “Min. Force Rate” and “Insert(Pushing) Force” within the time limit.
Remedy:	Implement any of the following measures. • Increase the insert depth setting. • Increase [Pushing Time] or [Insert Time Limit]. • Decrease [Min. Force Rate] in the [Performance Data Settings] screen. • Change the schedule data settings by changing the force control gain settings, etc. • Check if there is anything wrong with the workpiece.

FORC-261 Torque at the end is not ok (F:%d^1)

Cause:	When force control was executed with “Torque End Judgment Switch” set to ON, the magnitude of torque did not become smaller than “Max. Torque”.
Remedy:	Implement any of the following measures. • Change the force control gain settings. • Increase [Max. Torque] in the [Performance Data Settings] screen. • Change the schedule data settings by increasing [Pushing Time] or [Insert Time Limit], etc. • Check if there is anything wrong with the workpiece.

FORC-262 End Force and Torque is not ok (F:%d^1)

Cause:	When force control was executed with “Force End Judgment Switch” and “Torque End Judgment Switch” set to ON, the magnitude of force did not become larger than the product of “Min. Force Rate” and “Insert(Pushing) Force” and the magnitude of torque did not become smaller than “Max. Torque” within the time limit.
Remedy:	See "FORC-260" and "FORC-261". (Refer to "FORC-216" and "FORC-261".)

FORC-263 Approach timeout error (F:%d^1)

Cause:	The workpiece could not contact to the object in a limit time.
Remedy:	Use the following steps to implement measures. 1 Check the distance between the approach position and the contact position is too long. (5mm is appropriate.) 2 Set [Approach Velocity] to a value that is larger than the current one in the [Basic Data Settings] screen. 3 If automatic contouring is used in the “Contouring” function, set [Approach Velocity] to a value that is larger than the current one in the [Basic Data Settings] screen, check and modify the approaching direction, or set the force control start position to a position that is closer to the contacting object. A change made to the start position will affect the contouring operation, so also check and modify the other teaching points at the same time.

FORC-264 Insertion timeout error (F:%d^1)

Cause:	Insertion could not finish in a limit time.

Remedy:	Check the following settings.
	• In case of “Shaft Insert”:
	    • Ensure that the orientation of the workpiece does not change greatly during the insertion.
	    • Ensure that the clearance between the inserting object and the inserted object is not too small.
	    • Ensure that the value of [Insert Velocity] is not too small in the [Basic Data Settings] screen.
	    • Ensure that the value of [Insert Time Limit] is not too small in the [Basic Data Settings] screen.
	• In case of “Phase Search”:
	    • Ensure that [PhaseMatch Ang. Limit] is not too small.
	    • Ensure that [PhaseMatch Push Force] is not too small.
	    • Ensure that [PhaseMatch Torque] is not too small.
	• In case of “Hole Search” or “Clutch Search”:
	    • Ensure that [Size of Search Range] is not too small in the [Search Basic Param.] screen.
	    • Ensure that [Search Push Force] is not too small.
	    • Ensure that [Target Force] or [Target Torque] is not too small in the [Search Basic Param.] screen.

FORC-265 Angle change limit error (F:%d^1)

Cause:	The orientation of the workpiece changes bigger than the limit value during insertion. Or if you use “Face Match” function of the contouring function, the orientation difference between the tool frame and the teaching point exceeds the designated value.

Remedy:	Use the following steps to implement measures.
	1 Check the orientation of workpiece is correct.
	2 Ensure that the value of [Change MAX Limit] is not too small in the [Basic Data Settings] screen.
	3 If the “Face Match” of the “Contouring” function is used, check the following settings and situations.
	    • Check the value of [Orient.Chg. UpperLim]
	    • Check the teaching points.
	    • Check the situations of the system such as the workpiece and tools.

FORC-266 Insert depth is abnormal (F:%d^1)

Cause:	At the “Threading” function after the generated torque surpassed the “Target torque”, the insert depth did not reach the “Minimum depth”.
Remedy:	Check the following settings and situations. • Turn the screw manually to check that the screw can be tightened to the extent that [Minimum depth] is exceeded. • Ensure that [Target Torque] is not too small.

FORC-267 Rotation timeout error (F:%d^1)

Cause:	Threading could not finish in a limit time.
Remedy:	Check the following settings and situations. • Check that the screw can manually be tightened. • Ensure that the orientation of the workpiece does not change greatly while tightening the screw. • Ensure that [Rotation Velocity] is not too small. • Ensure that [Rotation Time Limit] is not too small.

FORC-269 Insert direction error (F:%d^1)

Cause:	Insertion direction acquired by the end condition acquisition is wrong.
Remedy:	Execute the end condition acquisition again.

FORC-270 Insert length error (F:%d^1)

Cause:	Insertion length acquired by the end condition acquisition is wrong.
Remedy:	Execute the end condition acquisition again.

FORC-271 Invalid teaching (F:%d^1)

Cause:	The sign of the force command during the torque error acquisition is different from the one during the force control.
Remedy:	Reverse the sign of “Insert Force” in Basic data, or execute the torque error acquisition again.

FORC-272 Simple Customize error (F:%d^1)

Cause:	A force schedule with “Simple Customize Sw” ON is executed before other force schedule with “Simple Customize Sw” OFF was executed. Or a force control schedule with the ”Simple Customize” function enabled was executed consecutively more than the number of times specified for [Cont. Exec. Max. Count] in the [Performance Data Settings] screen.
Remedy:	Use the following steps to implement measures. 1 Execute a.force schedule with “Simple Customize Sw” OFF before executing a force schedule with “Simple Customize Sw” ON. Force sensor initial values are acquired in a force schedule for which Simple Customize is invalid and it is used as a basis of force sensor in a force schedule for which Simple Customize is valid. 2 Increase the value of “Cont. Exec. Max. Count” of a force schedule with “Simple Customize Sw” ON. 3 If the alarm still occurs, contact FANUC.

FORC-273 Retry Setting error (F:%d^1)

Cause:	“User Frame No.”, “Tool Frame No.”, “Insert Direction” of a force schedule with “Simple Customize Sw” and “Retry Sw” ON are wrong. Or internal data of Simple Customize function are inappropriate.
Remedy:	Use the following steps to implement measures. 1 “User Frame No.” and “Tool Frame No.” of a schedule for retry have to be same as those of a schedule which was executed just before. “Insert Direction” of the schedule for retry has to be opposite of the schedule which was executed just before. Confirm that “Function” of the schedule that was executed before.is not “Contour” or “Contour End”. 2 If “Customize Parent Number” of a force schedule which was executed before.is not zero, check above conditions for all parent schedules. 3 If “Customize Auto. Cnt. Exec. Sw” of a force schedule that was executed before is ON, check above conditions for all child schedules. 4 If the alarm still occurs, contact FANUC.

FORC-276 Num.Reg. number error

Cause:	“End Register Number“ of Force Control End by Register function is invalid.
Remedy:	The value of “End Register Number“ shall be 1 and more to max number of register or less.

FORC-277 ContactP.is close to SensorOrg

Cause:	The ContactP.is too close to SensorOrg.
Remedy:	Extend the distance between the 3-Axis ContactP. and the center of 3-axis FS flange in the z direction (which is written on the body of FS) to 17mm or bigger.

FORC-278 Overrun error (F:%d^1)

Cause:	The workpiece was inserted longer than the specified length.
Remedy:	Use the following steps to implement measures. 1 Check that the distance between the approach point and the Insertion finishing point is appropriate. 2 Ensure that [Insert Depth (Design)] is set to a proper value in the [Basic Data Settings] screen. 3 Increase the value of [Individual Diff. (+)] in the [Basic Data Settings] screen.

FORC-279 Contouring aborted

Cause:	During contouring , an error or emergency stop occurred or the program was terminated forcibly. Alternatively, a jog operation was performed during contouring.
Remedy:	Implement any of the following measures. • When an error occurred: Remove the cause of the error and resume at the contouring start point. • When an emergency stop occurred: Perform a reset and resume at the contouring start point. • When a jog operation was performed during contouring: Resume at the contouring start point.

FORC-280 Cntr. Prohibited Com bi. Err.

Cause:	Prohibited combination is executed.
Remedy:	Do not execute the contouring with prohibited combination. Prohibited combination: • Function that cannot be used with the [Pushing Dir Auto Chg] function: “Successive Execution of Force Control Instructions (Customization Function)” • Function that cannot be used with the [Chk Push Chg Vel] function: “Deact.PushDirMotion” or “Change Push. Force” or “Monit Push Dir Depth” • Function that cannot be used with the [Monit Min Push F] function: “Deact.PushDirMotion” or “Change Push. Force” or “Monit Push Dir Depth” • Function that cannot be used with the [Monit Push Dir Depth] function: “Deact.PushDirMotion” or “Successive Execution of Force Control Instructions (Customization Function)” or “Chk Push Chg Trav Vel” or “Monit Min Push F” • Function that cannot be used with the [Pushing Dir Auto Chg] function (FCNCHCFR): “Successive Execution of Force Control Instructions (Customization Function)” • Function that cannot be used with the [Face Match] function: 3 Axis Force Sensor or “Control frame” is set to “User Frm Fixed” or “Change Push. Force” or “Pushing Dir Auto Chg” or “Monit Push Dir Depth”or “Auto.Follow”or “The function of Changing a target pushing direction(FCNCHCFR)”or “The function of Changing a contact point(FCNCH3CTP)” • Function that cannot be used with the 'automatic contouring' function: “Control frame is Tool Frame” or “Control frame is User Frm Fixed” or “Successive Execution of Force Control Instructions (Customization Function)” or “User Frame Compensation” or “Min. Error Dir.” or “Chk Overload Chg Trav Vel” or “Overload F. Detect” or “Deact.PushDirMotion” or “Change Push. Force” or “Pushing Dir Auto Chg” or “Chk Push Chg Trav Vel” or “Monit Min Push F” or “Monit Push Dir Depth” or “2 Direction Push” or “Face Match” or “The function of Changing target pushing force(FCNCHPFN)” or “The function of Changing a target pushing direction(FCNCHCFR)” or “The function of Changing a contact point(FCNCH3CTP)” or “The function of Changing a force control gain(FCNCHFCG)”)

FORC-281 Contouring start (F:%d^1)

Cause:	Contouring started.
Remedy:	This message does not indicate an error but indicates the start of contouring.

FORC-282 Contouring end (F:%d^1)

Cause:	Contouring ended.
Remedy:	This message does not indicate an error but indicates the end of contouring.

FORC-283 Contouring limit error (F:%d^1)

Cause:	During contouring, the tool moved away from a taught path excessively.
Remedy:	Use the following steps to implement measures. 1 Check if the workpiece or tool is secured at the correct position. 2 Check if the workpiece and tool are apart from each other excessively at teach points. 3 Increase the value of “Push Dist. Limit” on the basic screen. If “2 Direction Push” is valid and switch(es) of “Push Dist. Limit Individual” are ON, increase the limit value(s).

FORC-284 Contour.Push.F.Inadequate.Err.

Cause:	While executing “Monit Min Push F” function, pushing force has been less than a designated value for “Monit Time” in a row.
Remedy:	Check taught points, the TP Program, the target force, Force Control Gain, etc.

FORC-285 Auto tuning is impossible

Cause:	With the contouring function, the automatic force control gain tuning function cannot be executed. (Refer to "Basic Function Guide: 1.10.2 Force Control Gain Auto Tuning Instruction".)
Remedy:	Modify the force control gain manually. (Refer to "Basic Function Guide: 1.6 FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".) Increase the master frequency from about 0.5 Hz in steps of 0.25 Hz for LRMate, M-10*i*A or M-20*i*A series robot. Increase the master frequency from about 0.1 Hz in steps of 0.1 Hz for M-710*i*C, R-1000*i*A, R-2000*i*B or R-2000*i*C series robot.If even a slight vibration is observed, do not increase the gain anymore.

FORC-286 Cntr. UF Fixed Combi. Err.

Cause:	A function has been set to User Frame origin to the Control Frame origin. These functions cannot be used together.
Remedy:	Change the setting that cannot be used together with the function that sets the User Frame origin to the Control Frame origin. You might also set [Control Frame] to something other than "User Frame FIXED". The following settings cannot be used together with this function: • "Chk Overload Chg Trav Vel Sw" is enabled, and "Monitoring Force" is "traveling direction". • "Overload F. Detect Sw." is enabled, and "Monitoring Force" is "traveling direction". • "Change Push. Force Sw." is enabled. • The switch for "Pushing Dir Auto Chg" is enabled. • "Monit Push Dir Depth Sw" is enabled.

FORC-287 Contour.Dep.Mon.Func.Err.

Cause:	“Monit Push Dir Depth” function issues an alarm.
Remedy:	If the depth exceeds “End Depth” without contact, check the settings.

FORC-288 Cntr.Dep.Mon.Rept.CountOver

Cause:	The repeat counter exceeds “Max Repeat Count” when executing “Monit Push Dir Depth” function.
Remedy:	Check taught points, the TP Program, “Max Repeat Count”, etc.

FORC-289 Cntr.AutoPush.DirChange Err.

Cause:	“Pushing Dir Auto Chg” function issues an alarm.
Remedy:	Check the following settings. • The pushing direction must be ±X or ±Y. • The Control Frame must be User Frame. • At the beginning of a contouring, a pushing direction must not to be parallel to a traveling direction. • Do not restart the contouring when executing “Pushing Dir Auto Chg” function with “Chk Push Chg Trav Vel” function or “Monit Push Dir Depth” function.

FORC-290 Cntr.Param. Changed at Start

Cause:	At the start of Contouring, parameters for Contouring were changed.
Remedy:	This is not an error. (Refer to "Basic Function Guide: 1.5.5.7 Other functions of the contouring function".)

FORC-291 Contour.Param.Change.Err.

Cause:	The values for changing parameters during a contouring are inappropriate.
Remedy:	Check the following settings. • Check that the values for changing are appropriate. • Check whether the functions those cannot be used together are valid or not. (Refer to "Basic Function Guide: 1.5.5.6 Parameters".)

FORC-292 2 Dir. Push Func. error

Cause:	The values for "2 Dir Push Func" are inappropriate.
Remedy:	Check the following settings. • When "Chk Push Chg Trav Vel Sw" is "Dir 2" or "Dir 1&2", make "2 Dir Push Func" valid • When “Monit Min Push F Sw" is "Dir 2" or "Dir 1&2", make "2 Dir Push Func" valid • When "2 Dir Push Func" is valid, make the value of "Contouring Force 2" 0.01 N or larger. • When "2 Dir Push Func" is valid, "Pushing Dir Auto Chg" is valid and control frame is user frame, make the pushing direction ±Z. • When "2 Dir Push Func" is valid, make "Pushing Direction" in Basic data different direction from " Pushing Direction 2".

FORC-293 Cntr.FaceMatch Set. error

Cause:	Setting values for “Face Match” are inappropriate.
Remedy:	Set the length from the axis to the contact point to a value between 0 and 2000 mm. Or set the maximum rotating speed for Face Match to a value from zero to five deg/s.

FORC-294 Auto.Cntr. Set. error

Cause:	Setting values for “Auto.Follow” are inappropriate.
Remedy:	Check the following settings. 1 If “Aprch.Dir.Ang InptNumReg No.” is 0, set “Pushing Dir.” in Basic data to ±Z. 2 If “Aprch.Dir.Ang InptNumReg No.” is not 0, set the value of the designated Numerical Register to the value that is greater than or equal to 360 and less than or equal to -360.

FORC-295 Cntr.TPP Auto.Gen. Set. error

Cause:	Setting values for “TPProgramAuto.Gen.” are inappropriate.
Remedy:	Check the parameters in TPProgramAuto.Gen.Param. designated by “TPProgramAuto.Gen.Param.No.” and set it appropriately.

FORC-296 F. Ctrl during Contouring

Cause:	During contouring, another type of force control instruction such as shaft insertion was executed.
Remedy:	Contouring and another type of force control instruction such as shaft insertion cannot be executed simultaneously. Remove all other types of force control instructions.

FORC-297 Contouring option is not ordered

Cause:	The software option required for the contouring function is not incorporated into the controller.
Remedy:	Install the software option (Force control contouring). Contact the FANUC service center.

FORC-298 Change Moving Vel. Set. error

Cause:	The values of "Chk Overload Chg Trav Vel" or "Chk Push Chg Trav Vel" are inappropriate.
Remedy:	Check the following settings. • Set the value of "Min. Force" smaller than value of "Max. Force" or Set the value of "Min. • Force Rate" smaller value of "Max. Force Rate".

FORC-299 I/O or Num.Reg. number error

Cause:	The values for Contouring are inappropriate.
Remedy:	Check the following settings. • Change the register number of function which is valid in contouring. • The register number shall be 1 and more to max number of register or less. • If “Auto.Follow” is used and “End Pos. Designate” is set to “Pos.Reg.”, check X, Y in the designated position register.

FORC-300 Change Push. Force Set. error

Cause:	The values of "Change Push. Force" are inappropriate.
Remedy:	Set the value of "Min. Speed" smaller than value of "Max. Speed".

FORC-301 Illegal physical ITP (F:%d^1)

Cause:	Software internal error
Remedy:	Contact the FANUC service center and report the error status.

FORC-316 Illegal F/C axis number (F:%d^1)

Cause:	Software internal error
Remedy:	Contact the FANUC service center and report the error status.

FORC-320 Unfinished master (F:%d^1)

Cause:	Robot is not mastered yet.
Remedy:	Master the robot, then turn the controller OFF then ON again.

FORC-324 Illegal joint singular (F:%d^1)

Cause:	Software internal error
Remedy:	Contact the FANUC service center and report the error status.

FORC-326 Illegal F/S range (F:%d^1)

Cause:	Software internal error
Remedy:	Contact the FANUC service center and report the error status.

FORC-329 Not Supported Robot

Cause:	The "Face Match" function of the "Contouring" function is being executed with a robot other than one of the following: LRMate200*i*D series, M-10*i*A series, M-10*i*D series, CR-7*i*A series, CR-14*i*A/L, CR-15*i*A, CR-35*i*A, CRX series, M-20*i*A series, M-20*i*B series, M-20*i*D series, or M-710*i*C/20L. Or, the "Auto Follow" function of the "Contouring" function is being executed with a robot other than one of the following: LRMate200*i*D series, M-10iA series, M-10iD series, CR-7iA series, CR-14iA/L, CR-15iA, or CRX series.
Remedy:	With a robot other than one of the following, the "Face Match" function of the "Contouring" function cannot be used: LRMate200*i*D series, M-10*i*A series, M-10*i*D series, CR-7*i*A series, CR-14*i*A/L, CR-15*i*A, CRX series, CR-35*i*A, M-20*i*A series, M-20*i*B series, M-20*i*D series, and M-710*i*C/20L. With a robot other than one of the following, the "Auto Follow" function of the "Contouring" function cannot be used: LRMate200*i*D series, M-10iA series, M-10iD series, CR-7iA series, CR-14iA/L, CR-15iA, and CRX series.

FORC-330 Auto.Follow Move UpperLim err

Cause:	Reached the moving upper limit during a contouring with “Auto.Follow”.
Remedy:	Implement any of the following measures. • Check the setting values of Move UpperLim. 1(Dist.From Strt.CtP), Move UpperLim. 2(Total Move Dist.), Move UpperLim. 3(Total Move Time). • If you do not want to issue this alarm, set “NrmlEnd for MoveUpperLim” appropriately.

FORC-331 Auto.Follow Not Contact err

Cause:	Not in contact situation occurs successively during a contouring with “Auto.Follow”.
Remedy:	Use the following steps to implement measures. 1 Ensure that [Gravity Compensation] is [ENABLED]. If it is not [ENABLED], change the force control gain. 2 Check if a contact occurs at the start time. If so, change the start position. 3 If the alarm occurs even after the above measures are implemented, contouring is not possible under the current system situation.

FORC-332 Auto.Follow Continuing err

Cause:	The robot could not follow the work-piece appropriately during a contouring with “Auto.Follow”.
Remedy:	Use the following steps to implement measures. 1 Ensure that [Gravity Compensation] is [ENABLED]. If it is not [ENABLED], change the force control gain. 2 Check if a contact occurs at the start time. If so, change the start position. 3 If the alarm occurs even after the above measures are implemented, contouring is not possible under the current system situation.

FORC-333 Cntr.TPP.Gen. GetPointNum Over

Cause:	The number of getting position exceeds the upper limit during a contouring with “TPProgramAuto.Gen.”.
Remedy:	Implement any of the following measures. • Check the parameters in TPProgramAuto.Gen.Param. designated by “TPProgramAuto.Gen.Param.No.” and set the parameters appropriately. • Lessen the total contouring distance given by the teaching points.

FORC-334 Cntr. Generate TPProgram

Cause:	TP Program has been generated successfully with “TPProgramAuto.Gen.”.
Remedy:	This message indicates that the TP Program was successfully generated. It is not an error.

FORC-335 Auto.Follow Total Move Dist Lim err

Cause:	The total travel distance while ”Auto.Follow” function of Contour is enabled reached the upper limit (“Total Move Dist.” in Contour/AutoFollow screen).
Remedy:	1 Check the value of “Total Move Dist.” in Contour/AutoFollow screen and change it if necessary. 2 If the alarm should not be issued when the total travel distance reached the upper limit, set ”2”, ”1,2”, “2,3” or “1, 2, 3” to “NrmlEnd for MoveUpperLim” in Contour/AutoFollow screen.

FORC-336 Auto.Follow Total Move Time Over err

Cause:	The total time while ”Auto.Follow” function of Contour is enabled reached the upper limit (“Total Move Time” in Contour/AutoFollow screen).
Remedy:	1 Check the value of “Total Move TIme” in Contour/AutoFollow screen and change it if necessary. 2 If the alarm should not be issued when the total time reached the upper limit, set ”3”, ”2,3”, “1,3” or “1, 2, 3” to “NrmlEnd for MoveUpperLim” in Contour/AutoFollow screen.

FORC-420 Search Retry Limit (F:%d^1)

<table>
<tr><td>Cause:</td><td>The upper limit of the number of search operations is exceeded.
This alarm is issued in "Search", "Phase Search", "Hole Search", and "Clutch Search".</td></tr>
<tr><td>Remedy:</td><td>Use the following steps to implement measures.
1 Check whether the workpiece is abnormal.
2 If the robot does not perform search operation though no position or phase match has occurred, and this error occurs in a short time, the "Target Force" or "Target Torque" parameter value may be too small. Increase the parameter value in steps of about 20 percent until the robot operates.
3 When a corresponding workpiece into which another workpiece is to be inserted is not secured, the corresponding workpiece may move together with the inserted workpiece (interaction) during search operation. Observe the workpieces, and if interaction is confirmed, decrease the "Push Force" value (for "Search", "Hole Search", and "Clutch Search) or the "PhaseMach Push Force" value (for "Phase Search") until interaction is eliminated. If interaction is still confirmed after the parameter value has been decreased, this problem cannot be eliminated by parameter tuning. Secure the workpiece into which the other workpiece is to be inserted.
4 If the hand does not have enough grasping force, the workpiece into which another workpiece is to be inserted may move together with the workpiece to be inserted, which can disable position or phase matching. Observe the workpieces, and if interaction is confirmed, modify the hand so that it can grasp the workpiece securely.
5 If the search instruction does not terminate though search operation has been performed normally, the "Search End Depth" value (for "Search", "Hole Search", and "Clutch Search") or the "PhaseMatch End Depth" value (for "Phase Search) may be too large. Enter a correct value.
6 Check the "Retry Count" on the search performance screen. When the tact is not tight, increase the retry count. Increasing the retry count decreases the frequency of occurrence of this error.</td></tr>
</table>

FORC-421 Search Range over (F:%d^1)

<table>
<tr><td>Cause:</td><td>Search does not terminate even when the parameter-set "Size of Search Range" plus "Search Range Margin" has been exceeded. This alarm is issued in "Search", "Phase Search", "Hole Search", and "Clutch Search".</td></tr>
<tr><td>Remedy:</td><td>1 Check whether the range to be searched and the "Size of Search Range" parameter match.
2 The velocity in the insertion direction may be too high.
• For "Search", "Hole Search", and "Clutch Search":
Decrease "Search Frequency".
• For "Phase Search":
Decrease "PhaseMatch Ang. Vel".
3 If the cycle time is enough, reverse the travel direction at the point where the higher limit of the search range is reached.
Set "Reverse Switch" to ON.</td></tr>
</table>

FORC-422 Search Frc/Vel wrong (F:%d^1)

<table>
<tr><td>Cause:</td><td>The target force (torque) or target velocity (angle velocity) for search operation is set to 0.
This alarm is issued in "Search", "Phase Search", "Hole Search", and "Clutch Search".</td></tr>
<tr><td>Remedy:</td><td>If the target force (torque) or target velocity (angle velocity) for search operation is 0, search operation cannot be performed. Set a non-zero value.
The target force (torque) or target velocity (angle velocity) parameter is as follows:
• For "Search" and "Clutch Search":
  • If the search direction is [X], [Y], [Z]: [Target Force], [Target Velocity] in the [Search Basic Param.] screen
  • If the search direction is [W], [P], [R]: [Target Torque], [Target Angular Velocity] in the [Search Basic Param.] screen
• For "Phase Search":
On <u>the basic screen</u>, "PhaseMatch Torque" or "PhaseMatch Ang. Vel"
• For "Hole Search":
On <u>the search basic screen</u>, "Target Force" or "Target Velocity"</td></tr>
</table>

FORC-423 Search Vel order error (F:%d^1)

Cause:	The value of [Velocity Order] is not correct in the [Search Basic Param.] screen. This alarm is issued in "Search", "Hole Search", and "Clutch Search".
Remedy:	Set [Velocity Order] in the [Search Basic Param.] screen as follows. • For each search direction, set a different integer. For example, set the direction with the highest velocity to 1, the direction with the next-highest velocity to 2, and so forth. • Set 0 for those directions in which search operation is not performed.

FORC-425 Search range param. error (F:%d^1)

Cause:	There is an illegal relationship between parameters "Size of Search Range" and "Clearance & Chamfer". This alarm is issued in "Search", "Hole Search", and "Clutch Search".
Remedy:	Ensure that [Size of Search Range] in the [Search Basic Param.] is equal to or larger than [Clearance & Chamfer].

FORC-426 Search velocity Calc. error (F:%d^1)

Cause:	[Search frequency] in the [Basic Data Settings], [Size of Search Range] in [Search Basic Param.], or [Clearance & Chamfer] is not correct. This alarm is issued in "Search", "Hole Search", and "Clutch Search".
Remedy:	Check the following settings. • On [Basic Data Settings] screen, set "Search Frequency" to a non-zero value. • On [Search Basic Param.] screen, set "Size of Search Range" and "Clearance & Chamfer" to non-zero values.

FORC-427 Search reverse SW invalid (F:%d^1)

Cause:	The [Reverse Switch] setting is wrong in the [Search Performance Param.] screen. This alarm is issued in "Search", "Hole Search", and "Clutch Search".
Remedy:	If a search is performed in multiple directions, [Reverse Switch] must be [On] in the [Search Performance Param.] screen for directions other than the direction with the largest velocity order (the slowest direction). If this switch is OFF, set it to ON. "Reverse Switch" is displayed on the search performance screen.

FORC-428 Search velocity MAX error (F:%d^1) (When the software is 7DF1 Series)

Cause:	The absolute value of the automatically calculated velocity or angular velocity is too large. This alarm occurs with "Search", "Hole Search", "Clutch Search", and "Phase Search".
Remedy:	Implement any of the following measures. • Decrease "Search Frequency" on the [Basic Data Settings] screen • Decrease "Size of Search Range" on the [Search Basic Param.] screen. • Decrease "Clearance & Chamfer" on the [Search Basic Param.] screen. • For "Search", "Hole Search", and "Clutch Search", decrease the absolute values of (Target Velocity) or (Target Angular Velocity) on the Search Basic screen. For "Phase Search", decrease the absolute value of (PhaseMatch Ang. Vel) on the Basic screen.

FORC-428 Search velocity MAX error (F:%d^1) (When the software is 7DF3 Series and later)

Cause:	The absolute value of the velocity or angular velocity that is set is too large. This alarm occurs with "Search", "Hole Search", "Clutch Search", and "Phase Search".
Remedy:	Implement any of the following measures. • For "Search", "Hole Search", and "Clutch Search", decrease the absolute value of (Target Velocity) or (Target Angular Velocity) on the Search Basic screen. • For "Phase Search", decrease the absolute value of (PhaseMatch Ang. Vel) on the Basic screen.

FORC-452 Illegal cool down rate (F:%d^1)

Cause:	Settling rate is out of range.
Remedy:	Set the value of 0 – 100 to “Settling Rate” in [Performance Data Settings] screen.

FORC-453 Illegal tool weight get time (F:%d^1)

Cause:	Software internal error
Remedy:	Contact the FANUC service center and report the error status.

FORC-454 4D Graphics is not ordered

Cause:	4D Graphics option (R764) is not ordered.
Remedy:	Order 4D Graphics option.

FORC-455 No folder is found

Cause:	There are no folders that are designated in 4D graphic Force display screen in the selected device. Refer to subsection, "Force Sensor 4D Graphic function" in "R-30*i*B/R-30*i*B Mate CONTROLLER Force Sensor OPERATOR'S MANUAL (B-83424EN)".
Remedy:	1 Check if the device that is designated in 4D graphic Force display screen is inserted to a slot of a Robot controller. 2 Check the device whether it contains folders or not.

FORC-456 No file is found

Cause:	There are no files that are designated in 4D graphic Force display screen in the selected folder. Refer to subsection, "Force Sensor 4D Graphic function" in "R-30*i*B/R-30*i*B Mate CONTROLLER Force Sensor OPERATOR'S MANUAL (B-83424EN)".
Remedy:	1 Check if the device that is designated in 4D graphic Force display screen is inserted to a slot of a Robot controller. 2 Check the device whether it contains folders that are designated in 4D graphic Force display screen in the selected device. 3 Check if there are files whose extension is DT in the folders that are designated in 4D graphic Force display screen.

FORC-457 No appropriate data

Cause:	The file does not contain appropriate data.
Remedy:	1 Check the DT file whether it is created by Force Data Log function. 2 Execute Force Data Log function and make data file again.

FORC-458 Display data overflow

Cause:	The number of displayed data for "Force Sensor 4D Graphic function" exceeds limit.
Remedy:	Increase "Display Interval" in 4D graphic Force display screen.

FORC-459 Too many folders or files

Cause:	There are too many folders in device or too many files in folder for "Force Sensor 4D Graphic function".
Remedy:	1 If there are more than 101 folders in the device that is designated in 4D graphic Force display screen, decrease the number of folders to less than 101. 2 If there are more than 1001 files whose extension is DT in the folders that are designated in 4D graphic Force display screen, decrease the number of files to less than 1001.

FORC-460 Illegal force coordinate

Cause:	Force coordinate that is set in force control (Phase match) icon of Tablet UI is not appropriate.
Remedy:	Set the force control coordinate system data X, Y, W, P to 0 if “Integrated sensor” is selected in phase match.

FORC-479 Illegal vision user comp. data (F:%d^1)

Cause:	Vision compensated user frame is wrong.
Remedy:	Acquire the offset data with vision again.

FORC-480 UI parameters are not set

Cause:	UI settings in force control icon of Tablet UI are not complete.
Remedy:	Set all parameters in setting screen of force control icon and make it completed.

FORC-481 Illegal insertion direction (F:%d^1)

Cause:	Software internal error
Remedy:	Contact the FANUC service center and report the error status.

FORC-484 Illegal insertion force (F:%d^1)

Cause:	The value of “Insert Force” is smaller than the lower limit.
Remedy:	Implement any of the following measures. • For other than “Contouring”: Set the absolute value of [Insert Force] or [Pushing Force] to 0.3 [N] or larger in the [Basic Data Settings] screen. • For “Contouring”: Set the absolute value of [Pushing Force] to 0.01 [N] or larger in the [Basic Data Settings] screen.

FORC-485 Setting torque error failed (F:%d^1)

Cause:	Failed to acquire the torque error data.
Remedy:	Use the following steps to implement measures. 1 Check the distance between the approach position and the contact position is too long. (5mm is appropriate.) 2 Make the value of “Approach Velocity” in [Basic Data Settings] screen faster than the present value.

FORC-487 Setting end cond. failed(USE) (F:%d^1)

Cause:	Insertion direction acquired by the end condition acquisition is wrong.
Remedy:	Execute the end condition acquisition again.

FORC-489 Illegal pushing depth (F:%d^1)

Cause:	The value of “Individual Diff (-)” in Basic data is less than 0 or bigger than the value of “Insert Depth(Design)” in Basic data.
Remedy:	Make the value of ‘“Individual Diff (-)” positive and smaller than the value of “Insert depth(design).

FORC-490 Illegal rotation angle max (F:%d^1)

Cause:	Software internal error
Remedy:	Contact the FANUC service center and report the error status.

FORC-491 Illegal decelerate time (F:%d^1)

Cause:	Software internal error
Remedy:	Contact the FANUC service center and report the error status.

FORC-492 Illegal decel depth rate (F:%d^1)

Cause:	Software internal error
Remedy:	Contact the FANUC service center and report the error status.

FORC-493 Illegal rotation direction (F:%d^1)

Cause:	Software internal error
Remedy:	Contact the FANUC service center and report the error status.

FORC-494 Illegal initial Fd (F:%d^1)

Cause:	The sign of “Initial Insert Force” in Performance data is different from the sign of “Insert Force.
Remedy:	Match the sign of [Initial Insert Force] in the [Performance Data Settings] screen with the sign of [Insert Force] in the [Basic Data Settings] screen.

FORC-495 Illegal velocity adjust gain (F:%d^1)

Cause:	“Velocity Adjust Gain” in Performance data is not appropriate.
Remedy:	Set [Adjustment Gain] to a value between 0 and 3 in the [Performance Data Settings] screen.

FORC-496 Illegal starting rate (F:%d^1)

Cause:	“Starting Rate” in Performance data is not appropriate.
Remedy:	Set [Starting Rate] to 12.5 or larger in the [Performance Data Settings] screen.

FORC-497 Illegal ending rate (F:%d^1)

Cause:	“Ending Rate” in Performance data is not appropriate.
Remedy:	Set [Ending Rate] to 95 or lower in the [Performance Data Settings] screen.

FORC-498 Invalid rotation velocity (F:%d^1)

Cause:	The rotation velocity is invalid.
Remedy:	If the rotation axis set matches the J6 rotation axis, set "Rotation Velocity" in Basic Data to 200 deg/s or less. If the rotation axis does not match the J6 rotation axis, set "Rotation Velocity" in Basic Data to 5 deg/s or less.

FORC-500 Illegal reduction ratio (F:%d^1)

Cause:	Software internal error
Remedy:	Contact the FANUC service center and report the error status.

FORC-502 Illegal overrun length (F:%d^1)

Cause:	The value of “Individual Diff.(+)” in Basic data is not appropriate.
Remedy:	Set [Individual Diff. (+)] to a value between 0 and 10,000 in the [Basic Data Settings] screen.

FORC-503 Change push force to less than %.1f N

Cause:	Pushing Force is greater than Contact F Threshold.
Remedy:	Reduce Pushing Force to less than the value in the message.

FORC-504 Parameter Auto Tune failed

Cause:	Appropriate values were not found in the force control parameter auto tuning.
Remedy:	Reduce Pushing Force or raise Generated Force MAX Limit, and execute auto tuning again.

FORC-505 Parameter Auto Tune interrupted

Cause:	The HOLD key or the emergency stop button was pressed during auto tuning of force control, or an alarm occurred.
Remedy:	Check the alarm history, take the appropriate action, and execute auto tuning again.

FORC-506 Parameter Auto Tune internal error1 (Er:%d)

Cause:	An internal error occurred in the auto tuning software for force control.
Remedy:	Contact the FANUC service center. Please provide the error number listed after the message.

FORC-507 Parameter Auto Tune internal error2

Cause:	An internal error occurred in the auto tuning software for force control.
Remedy:	Contact the FANUC service center.

FORC-508 Parameter Auto Tune internal error3

Cause:	An internal error occurred in the auto tuning software for force control.
Remedy:	Contact the FANUC service center.

FORC-509 ParamAutoTune: Disable Customize function

Cause:	Force control parameter auto tuning was executed when the customization function was enabled.
Remedy:	Disable the customization function, and then execute auto tuning. For information about the customization function, refer to "Basic Functions Guide: 1.7 SUCCESSIVE EXECUTION OF FORCE CONTROL INSTRUCTIONS (CUSTOMIZATION FUNCTION)".

FORC-510 ParamAutoTune: Disable User Frame Compensation

Cause:	Force control parameter auto tuning was executed when User Frame Compensation was enabled.
Remedy:	Disable User Frame Compensation, and then execute auto tuning. For information about User Frame Compensation, refer to "Basic Functions Guide: 1.8 USER FRAME COMPENSATION".

FORC-511 Use ParamAutoTune instead of the old one

Cause:	The force control gain auto tuning function was executed instead of the force control parameter auto tuning function for force control.
Remedy:	Use the Parameter Auto Tuning function for force control. For information about force control parameter auto tuning, refer to "Basic Functions Guide: 1.10 FORCE CONTROL PARAMETER AUTO TUNING".)

FORC-512 Set Max Force Limit over Pushing Force

Cause:	Force control parameter auto tuning was executed with Pushing Force greater than Generated Force MAX Limit.
Remedy:	Set Pushing Force to a value smaller than Generated Force MAX Limit, and execute force control parameter auto tuning.

FORC-513 ParamAutoTune: Reset Contact stop

Cause:	Force control parameter auto tuning was executed during contact stop.
Remedy:	Release the contact stop, and then execute force control parameter auto tuning.

FORC-514 ParamAutoTune: Set to AUTO mode

Cause:	Force control parameter auto tuning was executed in a mode other than AUTO mode while using the tablet TP.
Remedy:	When using the tablet TP, set AUTO mode, and then execute force control parameter auto tuning.

FORC-515 ParamAutoTune: Disable TP

Cause:	Force control parameter auto tuning was executed in AUTO mode with TP enabled when using iPendant.
Remedy:	When using AUTO mode with iPendant, disable TP, and then execute force control parameter auto tuning.

FORC-516 ParamAutoTune: Reset alarm

Cause:	Force control parameter auto tuning was executed while an alarm was active.
Remedy:	Clear the alarm, and then execute force control parameter auto tuning.

FORC-517 ParamAutoTune: Cannot exec, because of contact detection

Cause:	Executing force control parameter auto tuning will not succeed because the operation will be stopped by the contact stop function in this robot position/orientation with Shaft Insert or Square Insert.
Remedy:	Consider changing the start position for auto tuning or disabling the contact stop function.

FORC-518 ParamAutoTune: Reduce orient error

Cause:	In the case of Shaft Insert or Square Insert, force control parameter auto tuning failed because the insertion could not be performed. The cause is that the orientation error is too large.
Remedy:	Reduce the orientation error, and then execute force control parameter auto tuning.

FORC-519 ParamAutoTune: Unable to tune with this hand

Cause:	Force control parameter auto tuning failed because a slight vibration had occurred during force control.
Remedy:	Auto tuning is not possible with the current hand. Change to a light, short hand and execute force control parameter auto tuning, or adjust the parameters manually.

FORC-520 ParamAutoTune: Unable to tune in this position

Cause:	Force control parameter auto tuning failed because an excessive force was generated during force control. The generated force exceeded "Generated Force MAX Limit", or if the contact stop function is enabled, the contact stop threshold was about to be exceeded.
Remedy:	Either raise "Generated Force MAX Limit" or change the robot position or orientation, and then execute force control parameter auto tuning again.

FORC-542 Rotate angle limit (F:%d^1)

Cause:	The rotation angle exceeded “Rotation Ang. Limit” before the threading finished normally when “Rotation Mechanism” is “Robot”.
Remedy:	Increase the value of “Rotation Ang. Limit” in [Basic data screen].

FORC-546 No custom cont. exe. (F:%d^1)

Cause:	Force control instructions for which no parent-child relationship was set were executed successively.
Remedy:	Implement any of the following measures. • When specification of the parent-child relationship was neglected Specify the first force control instruction as the parent in the parameters for the second force control executed (set the schedule data number of the first one for [Customize Parent Number] in the [Performance Data Settings] screen) before execution. • When two force control instructions are executed independently of each other It is necessary to move the robot to the position where the force control starts (approach position) before executing the second force control. Teach the approach position.

FORC-547 Customize no parent (F:%d^1)

Cause:	Immediately before execution of a child force control instruction, the force control instruction specified as the parent was not executed.
Remedy:	Immediately after executing the force control instruction specified as the parent, execute the child force control instruction. Do not execute another force control instruction between the parent and child force control instructions.

FORC-549 Customize parent err (F:%d^1)

Cause:	When the parent force control terminated with an error, the child force control that does not perform retry (draw) operation was executed.
Remedy:	Implement any of the following measures. • When performing assembly operation by executing more than one force control instruction successively, the child force control for insertion cannot be executed unless the parent force control terminates normally (the child force control for retry operation can be executed). Check the error that occurred during the parent force control, make modifications so that the error will no longer occur, then reexecute. • To execute the force control on a child for a retry operation, [User Frame] and [Tool Frame] must match those for the parent and the reverse [Insert Direction] must be specified. Check [User Frame], [Tool Frame], and [Insert Direction] in the [Basic Data Settings] screen.

FORC-550 Customize intr. err0 (F:%d^1)

Cause:	Software internal error
Remedy:	Contact the FANUC service center and report the error status.

FORC-631 Force sensor is abnormal

Cause:	Force sensor is abnormal.
Remedy:	Check the following settings and situations. • Robot is mastered. • Force sensor calibration data is loaded. • Force sensor cable is connected.

FORC-632 Can't get variables

Cause:	Software internal error
Remedy:	Contact the FANUC service center and report the error status.

FORC-633 Can't set variables

Cause:	Software internal error
Remedy:	Contact the FANUC service center and report the error status.

FORC-634 Can't use WCG in case of fixed FS

Cause:	In case of fixed force sensor, “Tool Weight and Center of Gravity Calculation Function” can't be executed.
Remedy:	If the force sensor is attached to a robot wrist, change the attachment type from fixed to hand in “Force Sensor Attachment Setting Function”, then execute “Tool Weight and Center of Gravity Calculation Function

FORC-635 Can't use WCG with this robot

Cause:	In case of M-1*i*A/05A, “Tool Weight and Center of Gravity Calculation Function” can't be executed.
Remedy:	Don’t execute “Tool Weight and Center of Gravity Calculation Function” , for M-1*i*A/05A

FORC-636 No calib data for mass measure.

Cause:	There is no calibration data for mass measurement.
Remedy:	Obtain the calibration data for mass measurement. For information about the calibration data for mass measurement, refer to "Auxiliary Function Guide: 3.2.2 Obtaining the Calibration Data for Workpiece Mass Measurement".

FORC-637 No init force for mass measure.

Cause:	No initial value has been set for the force sensor for mass measurement.
Remedy:	Set an initial value for the force sensor for mass measurement. For information about the initial value for the force sensor for mass measurement, refer to "Auxiliary Function Guide: 3.2.3 Measuring and Calibrating Workpiece Mass".

FORC-638 Orient change lim err(%s deg)

Cause:	There was an excessive change in the orientation angle during mass measurement.
Remedy:	Keep the total amount of change in the orientation angle W and P direction during mass measurement to within 5deg.

FORC-641 Recording positions failed

Cause:	Recording positions failed. The real cause is the alarm just below this one in alarm history.
Remedy:	Please check the alarm history and then retry again.

FORC-642 Too many recorded positions

Cause:	The edge taught with ROBOGUIDE is too long (> 3 meters).
Remedy:	Keep the edge taught with ROBOGUIDE within 3 meters, and then generate the data file again. (Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1).)

FORC-643 No enough recorded positions

Cause:	The length of the edge taught with ROBOGUIDE is insufficient (< 10 mm).
Remedy:	Make the edge taught with ROBOGUIDE 10 mm or more, and then generate the data file again. (Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1).)

FORC-644 No enough edge points

Cause:	Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1).
Remedy:	Use the following steps to implement measures. 1 Please finish running *i*RVision Debur. Line Output vision process. 2 Refer to "3.2.3.1 Monitor display during execution" in the above manual, and check the detected edge. Then modify "*i*RVision Debur. Line Output vision process" based on those results.

FORC-645 Too many edge points detected

Cause:	The edge detected by the "*i*RVision Debur. Line Output" function is too long.
Remedy:	Divide the long edge into shorter edges in ROBOGUIDE. (Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1).)

FORC-647 Generating TP program failed

Cause:	Generating TP program failed. The real cause is the alarm just below this one in alarm history.
Remedy:	Address the cause of the alarm that caused this alarm, and then try again. (Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1).)

FORC-648 Too many teach points

Cause:	Too many teach points.
Remedy:	Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1). Increase the value of [Distance Threshold], [Angle Threshold], or [Orient Change Thres.] on the [Deburr Path Auto Gen/Parameters] screen.

FORC-649 Parameter setting error

Cause:	Parameter setting not initialized or it is not correct. The real cause is the alarm just below this one in alarm history.
Remedy:	Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1). A message appears when the [Deburr Path Auto Gen/Parameters] for the edge is opened. Follow the message and modify the parameter, and then try again.

FORC-650 NOT for robot with Ext axes

Cause:	Robots with extended axes are NOT supported.
Remedy:	Please change to robot without extended axes to use this function. (Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1).)

B

FORC-651 Cannot find matched edge line

Cause:	Cannot find an edge in the initial data that is close to any of the edges detected by "*i*RVision Debur. Line Output".
Remedy:	Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1). Refer to "3.2.3.1 Monitor display during execution" in the above manual, and check the detected line. Then modify "*i*RVision Debur. Line Output vision process" based on those results.

FORC-652 Contour Schedule error

Cause:	The setting of the specified contouring schedule data is wrong.
Remedy:	Please set the specified contouring schedule correctly. The maximum value for the force control Schedule Number is 50. If you manually set the specified schedule from "Unused" to "Contouring" or another force control function, reset it to "Unused" and try again (Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1)).

FORC-653 Invalid data file

Cause:	The data file is not loaded correctly.
Remedy:	Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1). Load the data file correctly as in "2.5.3 Load the Data File" in the above manual. For information about the data file, refer to table 2.5.2.1 in "2.5.2.1 Generated data file".

FORC-654 Target not found

Cause:	Some targets are not found.
Remedy:	Please find all targets. (Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1).)

FORC-655 Target distance too small

Cause:	Target distance is too small.
Remedy:	Please confirm all target distance are greater than 15mm. (Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1).)

FORC-656 Target matching error

Cause:	The detected target distance does not match the taught target distance. (>10mm)
Remedy:	Check on the execution monitor whether the target was misdetected. (Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1).)

FORC-657 PTPINIT not executed

Cause:	PTPINIT has not been executed.
Remedy:	Execute the edge detection program (DG_{PartName}_{EdgeNo}.TP) from the beginning. (Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1).)

FORC-658 Edge point not reachable

Cause:	Some edge position is not reachable.
Remedy:	Please adjust the workpiece position, start point of edge or TCP and then try again. (Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1).)

FORC-659 Approach point setting error

Cause:	Approach point setting of the edge is wrong.
Remedy:	In the [Approach/Return] tab of the property page in the ROBOGUIDE tool, select "Add approach point", set a negative Acr value, and then try again. (Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1).)

FORC-660 Part name too long

Cause:	Part name is too long.
Remedy:	Shorten the part name in ROBOGUIDE to 17 characters or less, and then try again. (Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1).)

FORC-661 Edge point location error

Cause:	All edge point in the data file are not in the same plane.
Remedy:	Delete the specified edge in ROBOGUIDE, and then specify an edge that is in the same plane. Please teach the edge in the same plane and then generate data files again. (Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1).)

FORC-662 Edge point orient error

Cause:	The orientation of some edge points in the data file are wrong.
Remedy:	Delete the specified edge in ROBOGUIDE, and then specify the edge again so that all edge points have the correct orientation and generate data files again. (Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1).)

FORC-663 Edge line overlapped

Cause:	The edge line in the data file overlapped.
Remedy:	Delete the specified overlapping edge in ROBOGUIDE. Specify the edge again so that edges do not overlap. Please do not overlap the edge while teaching it and generate data files again. (Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1).)

FORC-664 Edge shape at start point mismatch

Cause:	The shape of the actual workpiece near the start point of the edge is significantly different from the shape in the CAD illustration. This is particularly likely to occur when a start point is set near a corner.
Remedy:	Delete the specified edge in ROBOGUIDE, and then set the start point of the edge data in a spot away from a corner. Generate the data files again. (Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1).)

FORC-665 "%s".TP is generated.

Cause:	The TP Program for the edge was generated.
Remedy:	This message is not an alarm. (Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1).)

FORC-666 Auto retreat setting error

Cause:	The setting for the auto retreat function is incorrect.
Remedy:	Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1). Check the following settings on the Auto Retreat Settings screen, and then try again. (For information about the Auto Retreat screen, refer to "4.3.1 Auto Retreat Settings Screen" in the above manual.) • The register number for all parameters is not 0, and all settings are different. • Pos. Reg. No. for "For Retreat Position" is not 0. • If "Call Program after Retreat" is enabled, the correct program name is set.

FORC-667 Edge is far away from targets

Cause:	The edge is too far away from the target.
Remedy:	Set the target to a position close to the edge, and then generate the data files again. (Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1).)

FORC-668 Target distance too large

Cause:	One of the distances among the three targets is greater than 1 meter.
Remedy:	Teach in ROBOGUIDE so that the distances between all targets is within 1 meter, and then generate the data files again. (Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1).)

FORC-669 Part ID not assigned

Cause:	A part ID is not set.
Remedy:	Set a part ID for all parts on the Part List screen, and then try again. (Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1).)

FORC-670 Edge shape at end point mismatch

Cause:	The shape of the actual workpiece near the end point of the edge is significantly different from the shape in the CAD illustration. This is particularly likely to occur when an end point is set near a corner.
Remedy:	Delete the specified edge in ROBOGUIDE, and then set the end point of the edge data in a spot away from a corner. Generate the data files again. (Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1).)

FORC-671 No edge points in tool's travel dir

Cause:	The specified edge was not found along the traveling direction of the tool.
Remedy:	Refer to "R-30*i*B Plus/R-30*i*B Mate Plus CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL" (B-83934EN-1). • Check the setting of the "Reverse Traveling Direction" parameter. For information about "Reverse Traveling Direction", refer to "2.1.5.2 [Deburr Path Generation] Setting" in the above manual. • Check that edges near the specified edge were not misdetected. For information about the misdetection of edges, refer to "A.2.4 Failure Examples of Deburring Path Auto Generation" in the above manual.

FORC-1000

Cause:	This alarm does not actually occur, however, it may appear in the alarm number on the Force Ctrl Ex-hist screen.
Remedy:	When any of the following conditions is met during execution of the FORCE statement, 1000 will be displayed. • An emergency stop occurred. • The HOLD button was pressed. • The HOLD signal was received. • In T1/T2 mode, the deadman switch was released or pushed in. • In T1/T2 mode, the shift key was released. Execute the FORCE statement so that any of the above can be avoided.

C FORCE SENSOR ATTACHMENT SETTING FUNCTION

C.1 OVERVIEW

If the sensor is mounted on a remote fixture such as a working table, or the sensor is attached to a robot wrist with a standard adapter plate (torque wrench NOT needed type), or the sensor is attached to a robot wrist with a standard adapter plate (torque wrench needed type) and the sensor position is moved from a standard position to other position such as a tip of a hand, the procedures described in this chapter are necessary.

> **NOTE**
> If a force sensor is already attached to a robot wrist with a standard adapter plate (torque wrench needed type) when it is delivered from FANUC factory and the sensor attachment position is not changed, the procedures described in this chapter are not necessary.
> (Refer to "Introduction: 2.1 FORCE SENSOR OVERVIEW".)

In the [Force Sensor Attachment] screen, the following settings for the force sensor are configured.

- [Force Sensor Attachment]:
  Select the force sensor attachment type. The setting whether force sensor is attached to the robot wrist or fixed on the working table can be done.
- [Parameter for setting]:
  Set the sensor frame. The setting of sensor frame that indicates the position and orientation of force sensor can be done. The sensor frame is fixed to the sensor itself and as Fig.C.1 shows, Z-axis is on the central axis, and X- and Y-axis are perpendicular to Z-axis. The origin of the frame is a center point of a bottom plane of the sensor. Each axis (+X, -X, +Y, -Y, +Z, -Z) is written on the label. (Y-axis is perpendicular to a plane of paper in figures in this chapter)
  This function makes a correlation between the sensor frame and a robot frame.

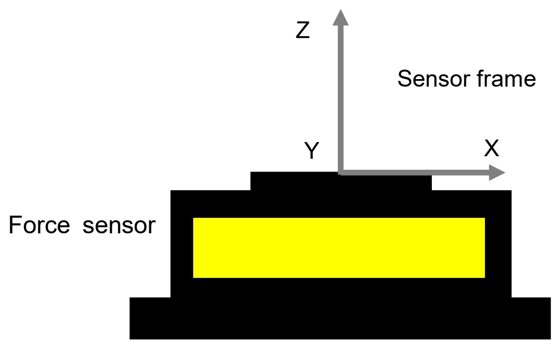
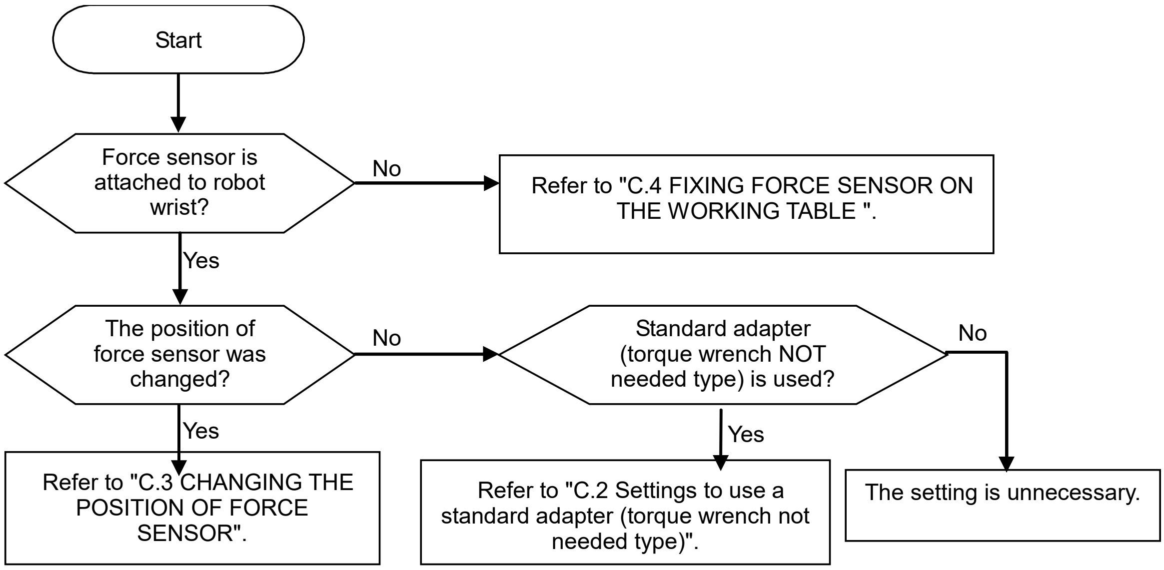


Fig. C.1 Sensor frame of force sensor

Refer to the proper section by following the flowchart below.



⚠CAUTION

If force control instruction is executed with the wrong setting of force sensor attachment or sensor frame, robot may operate with unexpected motion. Be sure to set these parameters carefully.

C.2 USING THE STANDARD ADAPTER (TORQUE WRENCH NOT NEEDED TYPE)

Sensor frame for the standard adapter (torque wrench needed) is set at shipment as shown in Fig.C.2. In case of the standard adapter (torque wrench not needed), it is necessary to set sensor frame by this program. Refer to the following instructions to set the sensor frame for the standard adapter (torque wrench not needed).

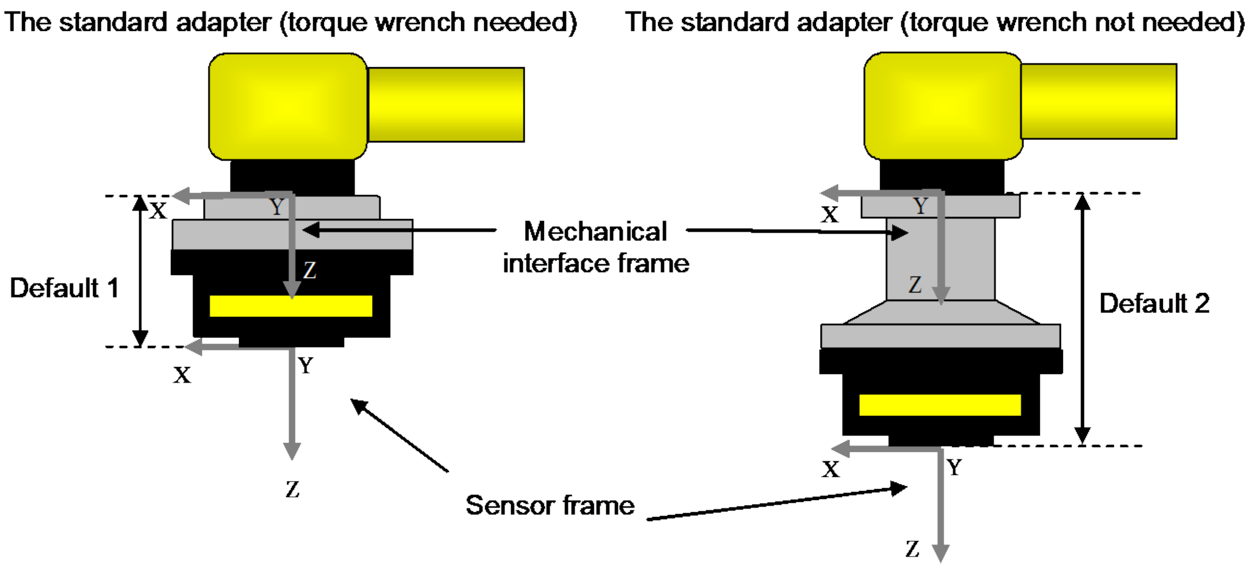


Fig. C.2 Sensor frame in case of wrist mounted force sensor

C.2.1 How to Start the Program

The program for settings of force sensor attachment is executed from the [UTILITIES Force Sensor] screen.
(Refer to "Basic Function Guide: 3 FORCE SENSOR UTILITIES SCREEN".)

How to launch the program for settings

1 Display the [UTILITIES Force Sensor] screen.
(Refer to "Basic Function Guide: 3 FORCE SENSOR UTILITIES SCREEN".)

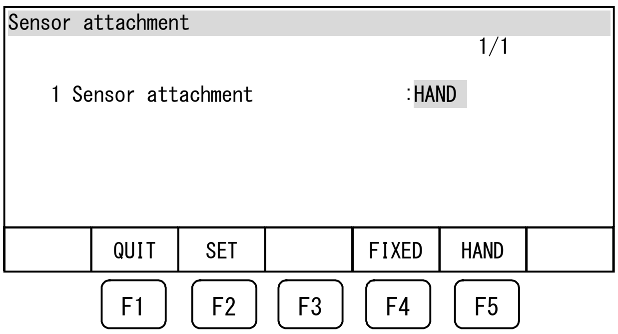
2 Move the cursor over [Force Sensor Attachment] and press F3 [DETAIL].
The [Force Sensor Attachment] screen is displayed.

C.2.2 Setting Force Sensor Attachment

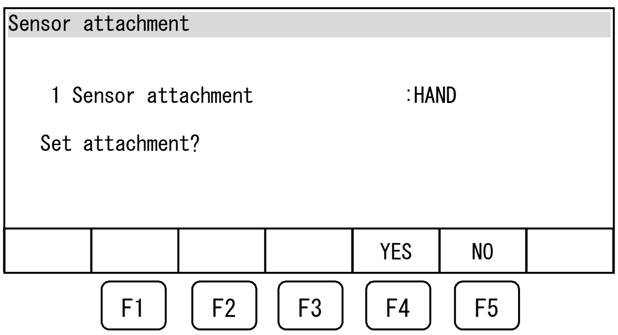
In the [Force Sensor Attachment] screen, the force sensor attachment type can be set. The force sensor attachment type includes [HAND] and [FIXED], and the standard setting is [FIXED]. If the screen is not displayed, the setting is already set to “HAND” and proceed to “C.2.3 Setting of sensor frame”.

How to set the attachment type

1 Launch the program for settings.
(Refer to "APPENDIX: C.2.1 How to Start the Program".)
The [Force Sensor Attachment] screen is displayed as below.



2 After choosing F5 [HAND] , press F2 [SET]
By pressing F2 [SET] the message ”Set attachment?” is displayed on the screen. If F4 [YES] is selected, the setting on the screen is recorded and the screen is shifted to sensor frame setting screen. (Refer to Section C.2.3, “Setting of sensor frame”.) If F5 [NO] is selected, go back to the current setting screen.



How to quit the program

In order to quit this program, press F1 [QUIT]. In this case the setting of sensor frame will not be done. By pressing F1 [QUIT] with changing the setting, the message “Quit without setting attachment?” is displayed on the screen. If F4 [YES] is selected, quit without updating. If F5 [NO], go back to the current setting screen.

```
Sensor attachment

  1 Sensor attachment            :HAND

 Quit without setting attachment?

|      |      |      |      | YES  |  NO  |      |
        F1     F2     F3     F4     F5
```

Function Keys

The function keys indicated have the following functions.

Table C.2.2 Function Keys

Key	Label	Description
F1	QUIT	Quit this program.
F2	SET	Set sensor attachment type using parameter.
F4	FIXED	Select sensor attachment type to “Fixed”.
F5	HAND	Select sensor attachment type to “Hand”.

C.2.3 Setting sensor frame

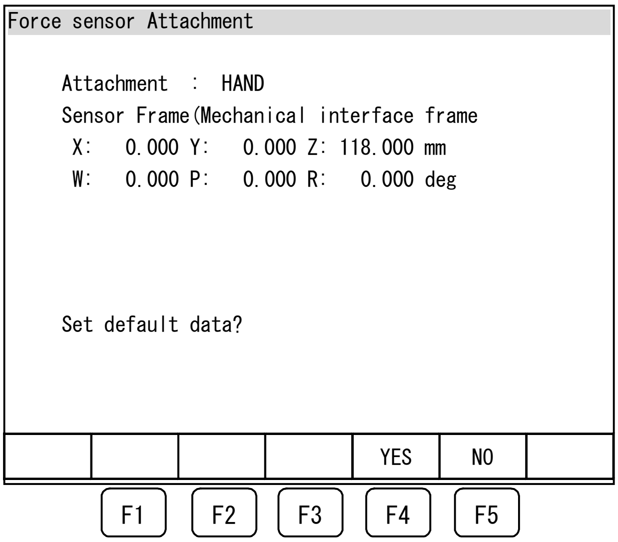
In the [Force Sensor Attachment] screen, the setting of sensor frame in case of wrist mounted force sensor can be done.

Procedure for setting the sensor frame

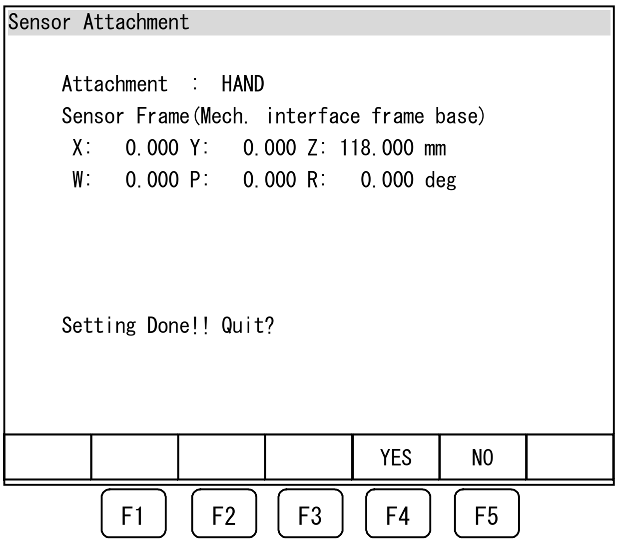
1 Display the [Force Sensor Attachment] screen.
(Refer to "APPENDIX: C.2.2 Setting Force Sensor Attachment".)

```
Sensor attachment
                                        1/2
   Attachment  :  HAND
   Sensor Frame(Mech. interface frame base)
    X:    0.000 Y:    0.000 Z: 118.000 mm
    W:    0.000 P:    0.000 R:    0.000 deg

   Parameter for setting
    1 Tool Frame No. for Sensor frame UT: 1
    2 Offset for Sensor frame    :  0.00 mm

   DEFAULT1: Torque wrench is necessary
   DEFAULT2: Torque wrench is NOT necessary

|      | QUIT | SET  |DEFAULT1|DEFAULT2|      |      |
        F1     F2     F3       F4       F5
```

2 To set the sensor frame for the type for which torque wrench is not needed, press F4 [DEFAULT2]. A confirmation message 'Set default data?' is displayed. If F4 [YES] is selected, sensor frame for the adapter (torque wrench not needed) is set. If F5 [NO] is selected, go back to the current setting screen.



3 After the setting is finished, the message “Setting Done!! Quit?” is displayed on the screen. If F4 [YES] is selected, quit the program and the message “[SETFSAT] Please reboot controller” is displayed on the screen. If F5 [NO], go back to the current setting screen.



Function Keys

The function keys indicated have the following functions.

Table C.2.3 Function Keys

Key	Label	Description
F1	QUIT	Quit this program.
F2	SET	Set sensor frame using parameter.
F3	DEFAULT1	Select sensor frame for the standard adapter (torque wrench needed type). In case of the force sensor which does not have the standard adapter (torque wrench NOT needed type), the item “DEFAULT” is displayed here.

Key	Label	Description
F4	DEFAULT2	Select sensor frame for the standard adapter (torque wrench not needed type). In case of the force sensor which does not have the standard adapter (torque wrench NOT needed type), no item is displayed here.

C.3 CHANGING THE POSITION OF FORCE SENSOR

In case of changing the position of force sensor from normal position at shipment, it is necessary to set sensor frame by this function. As Fig.C.3 shows, sensor frame for the standard adapter is set at shipment. It must be changed to that for the used adapter. Refer to the following instructions

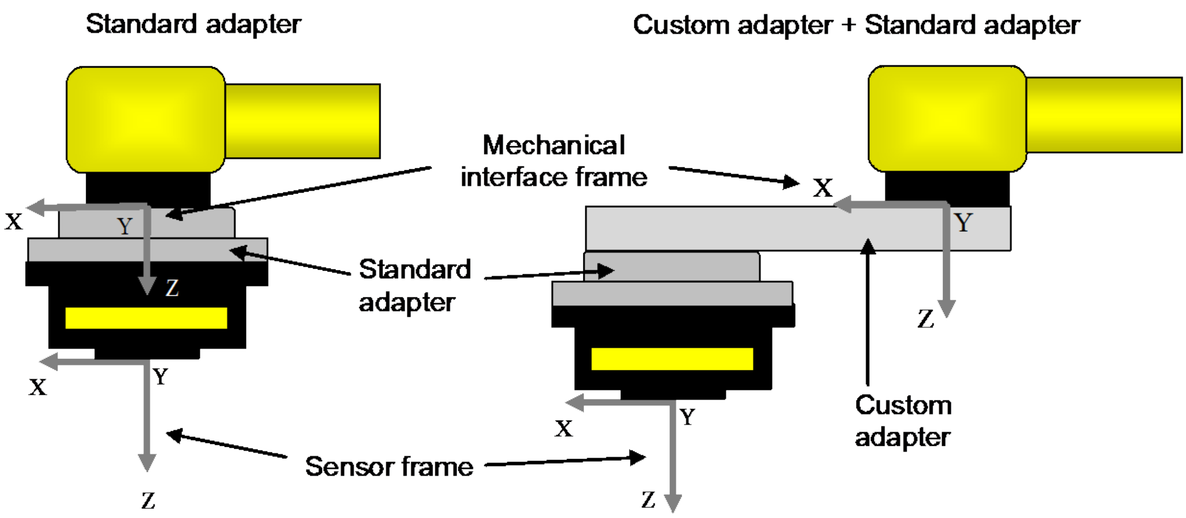


Fig. C.3 Sensor frame in case of wrist mounted force sensor

C.3.1 Preparation

In order to set sensor frame, a tool frame is temporarily used.

- Sensor frame is defined on the basis of mechanical interface frame. If the position of force sensor can be estimated, input the position to the tool frame directly.
- Each axis of tool frame must be the same as that of sensor frame.

In the program that is described below, the number of tool frame is needed.
After setting sensor frame, this tool frame is not necessary any more.

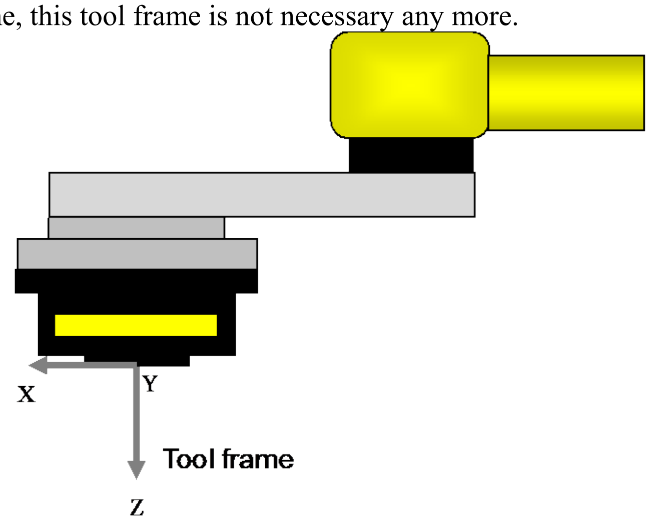


Fig. C.3.1 (a) An example of teaching tool frame1

If it's impossible to estimate the position of force sensor, a special jig whose tip is pointed as shown in Fig. C.3.1 (b) is needed.

- The tip position of the jig should be on the central axis of the force sensor.
  Teach this tip position of the jig for the tool frame.
  (Refer to "Fig. C.3.1 (b)".)
- In this tool frame, the Z direction must be the same as the one in the sensor frame, and the X and Y directions must be parallel to their counterparts.

After setting sensor frame, this tool frame is not necessary any more.

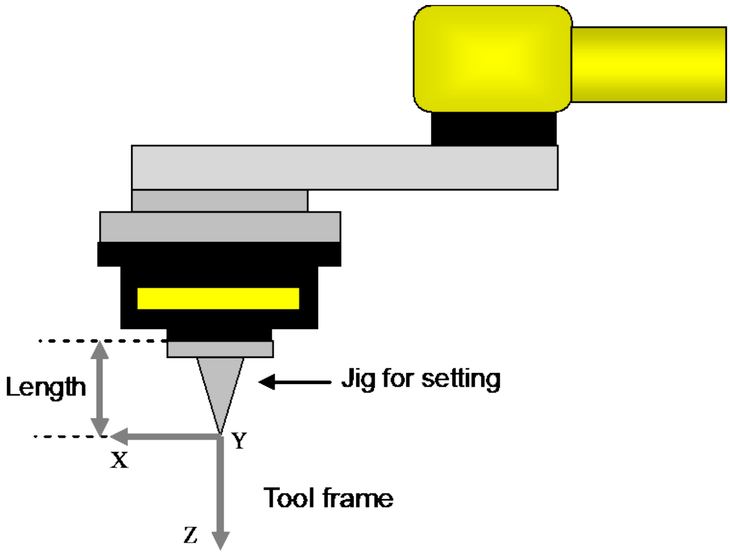


Fig. C.3.1 (b) An example of teaching tool frame2

> **NOTE**
> In this program the number of tool frame and the length of the jig are needed.

C.3.2 How to Start the Program

The program for settings of force sensor attachment is executed from the [UTILITIES Force Sensor] screen.
(Refer to "Basic Function Guide: 3 FORCE SENSOR UTILITIES SCREEN".)

How to launch the program for settings

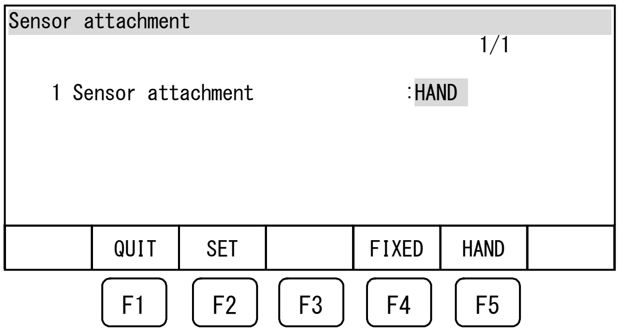
1. Display the [UTILITIES Force Sensor] screen.
   (Refer to "Basic Function Guide: 3 FORCE SENSOR UTILITIES SCREEN".)
2. Move the cursor over [Force Sensor Attachment] and press F3 [DETAIL].
   The [Force Sensor Attachment] screen is displayed.

C.3.3 Setting Force Sensor Attachment

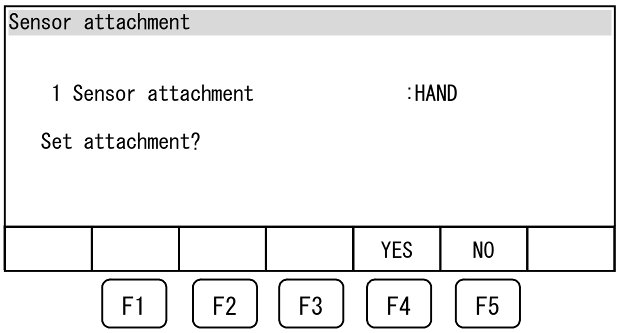
In the [Force Sensor Attachment] screen, the force sensor attachment type can be set. The force sensor attachment type includes [HAND] and [FIXED], and the standard setting is [FIXED]. If the screen is not displayed, the setting is already set to "HAND" and proceed to "C.3.4 Setting of sensor frame".

How to set the attachment type

1 Launch the program for settings.
(Refer to "APPENDIX: C.3.2 How to Start the Program".)
The [Force Sensor Attachment] screen is displayed as below.

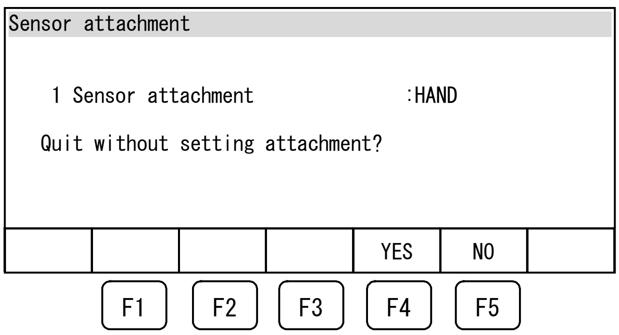


2 After choosing F5 [HAND] , press F2 [SET]
By pressing F2 [SET] the message ”Set attachment?” is displayed on the screen. If F4 [YES] is selected, the setting on the screen is recorded and the screen is shifted to sensor frame setting screen. (Refer to Section C.2.3, “Setting of sensor frame”.) If F5 [NO] is selected, go back to the current setting screen.



How to quit the program

In order to quit this program, press F1 [QUIT]. In this case the setting of sensor frame will not be done.
By pressing F1 [QUIT] with changing the setting, the message “Quit without setting attachment?” is displayed on the screen. If F4 [YES] is selected, quit without updating. If F5 [NO], go back to the current setting screen.



Function Keys

The function keys indicated have the following functions.

Table C.3.3 Function Keys

Key	Label	Description
F1	QUIT	Quit this program.
F2	SET	Set sensor attachment type using parameter.
F4	FIXED	Select sensor attachment type to “Fixed”.
F5	HAND	Select sensor attachment type to “Hand”.

C.3.4 Setting Sensor Frame

In the [Force Sensor Attachment] screen, the setting of sensor frame in case of wrist mounted force sensor can be done.

Procedure for setting the sensor frame

1 Display the [Force Sensor Attachment] screen.
(Refer to "APPENDIX: C.3.3 Setting Force Sensor Attachment".)
2 Select [Tool Frame No. for Sensor frame] and enter a value.
3 Select [Offset for Sensor frame] and enter a value.
If the sensor base is taught for the tool frame, enter '0'.
If the jig for teaching is used, enter the length of the jig.

```
Sensor attachment
                                              1/2
    Attachment  :  HAND
    Sensor Frame(Mech. interface frame base)
     X:   0.000 Y:   0.000 Z: 118.000 mm
     W:   0.000 P:   0.000 R:   0.000 deg

    Parameter for setting
     1 Tool Frame No. for Sensor frame UT: 1
     2 Offset for Sensor frame   :  0.00 mm

    DEFAULT1: Torque wrench is necessary
    DEFAULT2: Torque wrench is NOT necessary

        | QUIT | SET | DEFAULT1 | DEFAULT2 |     |
          F1     F2     F3         F4        F5
```

Table C.3.4 (a) [Force Sensor Attachment]: screen

Parameter	Description
[Tool Frame No. for Sensor frame]	This parameter specifies tool frame number for teaching sensor frame. DEFAULT: 1
[Offset for Sensor frame]	This parameter specifies the difference between sensor frame and tool frame in Z direction. DEFAULT: 0.00 mm

4 Press F2 [SET].
A confirmation message 'Set Sensor frame?' is displayed.

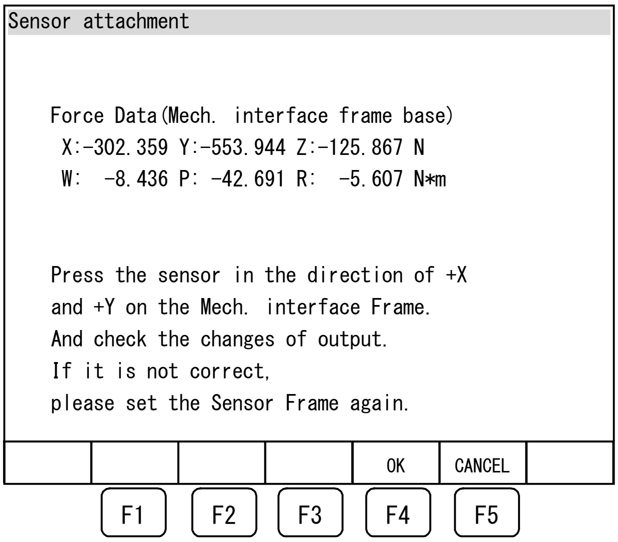
```
Sensor attachment

   Attachment  :  HAND
   Sensor Frame(Mech. interface frame base)
    X:   0.000 Y:   0.000 Z: 118.000 mm
    W:   0.000 P:   0.000 R:   0.000 deg

   Parameter for setting
    1 Tool Frame No. for Sensor frame UT: 1
    2 Offset for Sensor frame   :  0.00 mm

   Set Sensor frame?

|      |      |      |      | YES  |  NO  |      |
        F1     F2     F3     F4     F5
```

5 Press F4 [YES].
The setting parameters confirmation screen is displayed as below.
* If F5 [NO] is pressed, the screen returns to the [Force Sensor Attachment] screen.

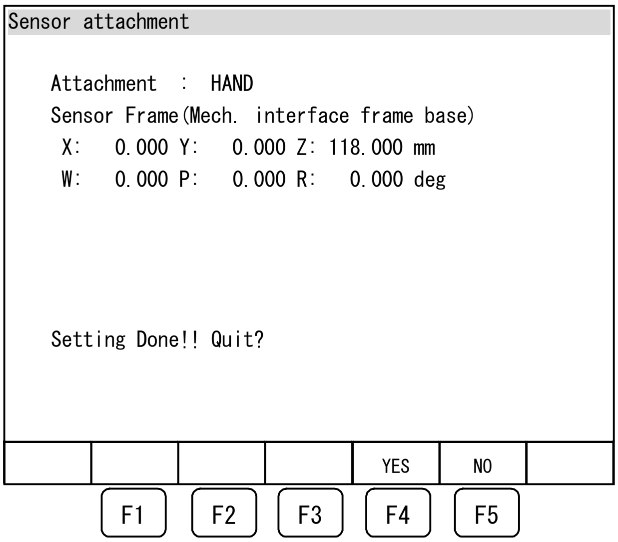
```
Sensor attachment

   Attachment  :  HAND
   Parameter for setting
    1 Tool Frame No. for Sensor frame UT: 1
    2 Offset for Sensor frame   :  0.00 mm

   Make sure that selected Tool Frame has
   the same direction as the Sensor Frame.
   If setting of frame is illegal,
   robot may make an unexpected motion.

|      |      |      |      |CONFIRM|CANCEL|      |
        F1     F2     F3     F4      F5
```

6 Check that the directions of the tool frame match those of the sensor frame by moving in the X, Y, and Z directions of the tool frame that are displayed in the screen.

7 If the directions of the tool frame match those of the sensor frame, press F4 [CONFIRM].
The force data are displayed.
 * If the directions of the tool frame do not match those of the sensor frame, press F5 [CANCEL].
 The [Force Sensor Attachment] screen is displayed.
 Configure the tool frame settings again starting from Step 2.



8 Follow the instructions on the screen to review the force data output.
9 When the review is done, press F4 [OK].
The new sensor frame will be set.
When the sensor frame is set, a confirmation message 'Setting Done!! Quit?' is displayed.
 * If the force data output is not correct, press F5 [CANCEL].
 This returns to the [Force Sensor Attachment] screen.
 Review the tool frame, force sensor calibration data, etc. and configure settings again starting from Step 2.



10 Press F4 [YES].
 * If F5 [NO] is pressed, the screen returns to the [Force Sensor Attachment] screen.
11 If the '[SETFSAT] Please reboot controller' message is displayed, reboot the robot controller.

How to set to default

To reset the sensor frame settings to default, perform the following steps.

> **NOTE**
> Note that by resetting to default, the sensor frame that was set in 'Procedure for setting the sensor frame' will be deleted.

1 Display the [Force Sensor Attachment] screen.
(Refer to "APPENDIX: C.3.3 Setting Force Sensor Attachment".)

2 Press F3 [DEFAULT1] or F4 [DEFAULT2]. By pressing F3 [DEFAULT1] or F4 [DEFAULT2] the message “Set default data?” is displayed on the screen.

```
Force sensor Attachment

    Attachment  :  HAND
    Sensor Frame(Mechanical interface frame
     X:   0.000 Y:   0.000 Z: 118.000 mm
     W:   0.000 P:   0.000 R:   0.000 deg



    Set default data?



                          YES     NO
        F1     F2     F3     F4     F5
```

3 Press F4 [YES].
The sensor frame settings for cases where a standard adapter is used for attachment will be configured.
When the default data are set, a confirmation message 'Setting Done!! Quit?' is displayed.
* If press F5 [NO] is clicked, the screen returns to the [Force Sensor Attachment] screen.

```
Sensor Attachment

    Attachment  :  HAND
    Sensor Frame(Mech. interface frame base)
     X:   0.000 Y:   0.000 Z: 118.000 mm
     W:   0.000 P:   0.000 R:   0.000 deg



    Setting Done!! Quit?



                          YES     NO
        F1     F2     F3     F4     F5
```

4 Press F4 [YES].
   * If F5 [NO] is pressed, the screen returns to the [Force Sensor Attachment] screen.
5 If the '[SETFSAT] Please reboot controller' message is displayed, reboot the robot controller.

Function Keys

The function keys indicated have the following functions.

Table C.3.4 (b) Function Keys

Key	Label	Description
F1	QUIT	Quit this program.
F2	SET	Set sensor frame using parameter.
F3	DEFAULT1	Select sensor frame for the standard adapter (torque wrench needed). In case of the force sensor which does not have the standard adapter (torque wrench NOT needed type),, the item “DEFAULT” is displayed here.
F4	DEFAULT2	Select sensor frame for the standard adapter (torque wrench not needed). In case of the force sensor which does not have the standard adapter (torque wrench NOT needed type), no item is displayed here.

C.4 FIXING FORCE SENSOR ON THE WORKING TABLE

In case of fixing force sensor on the working table, the setting of sensor frame must be done by this function. Sensor frame is set on the basis of world frame. Refer to the following instructions

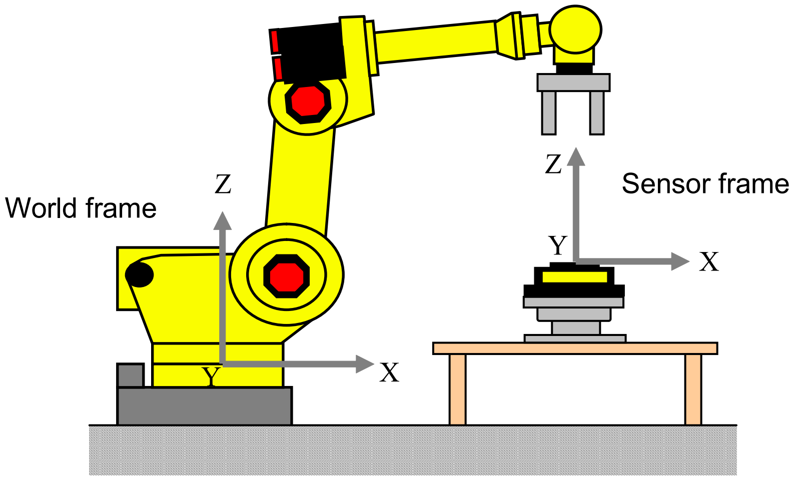


Fig. C.4 Sensor frame for fixed sensor

C.4.1 Preparation

In order to set sensor frame, a user frame is temporarily used.
Sensor frame is defined on the basis of world frame. If the position of force sensor can be estimated, input the position to the user frame directly.
Here, each axis of user frame must be the same as that of sensor frame.
In the program that is described below, the number of user frame is needed. After setting sensor frame, this user frame is not necessary any more.

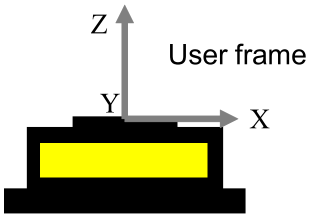


Fig. C.4.1 (a) An example of teaching user frame1

If it's impossible to estimate the position of force sensor, a special jig as shown in Table 4.1 and Fig. C.4.1 (b) is needed.

Table C.4.1 Specification for frame setting jig

Name	Specification
Frame setting jig, for FS-10*i*A	A05B-1407-K001
Frame setting jig, for FS-40*i*A	A05B-1407-K101
Frame setting jig, for FS-100*i*A	A05B-1407-K201
Frame setting jig, for FS-250*i*A	A05B-1407-K301

Teach User frame on the surface of the jig, where Z-axis of user frame is the same as that of sensor frame and X- and Y- axes are parallel to those of sensor frame.
In this program the number of user frame and the thickness of the jig are needed.
After setting sensor frame, this user frame is not necessary any more.

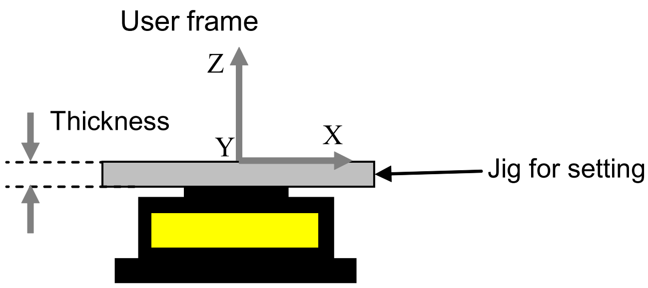


Fig. C.4.1 (b) An example of teaching user frame2

C.4.2 How to Start the Program

The program for settings of force sensor attachment is executed from the [UTILITIES Force Sensor] screen.
(Refer to "Basic Function Guide: 3 FORCE SENSOR UTILITIES SCREEN".)

How to launch the program for settings

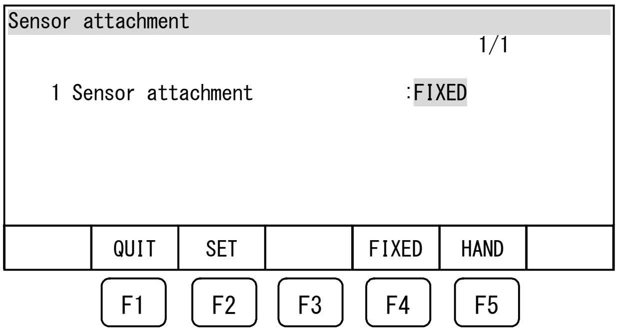
1 Display the [UTILITIES Force Sensor] screen.
(Refer to "Basic Function Guide: 3 FORCE SENSOR UTILITIES SCREEN".)
2 Move the cursor over [Force Sensor Attachment] and press F5 [DETAIL].
The [Force Sensor Attachment] screen is displayed.

C.4.3 Setting Force Sensor Attachment

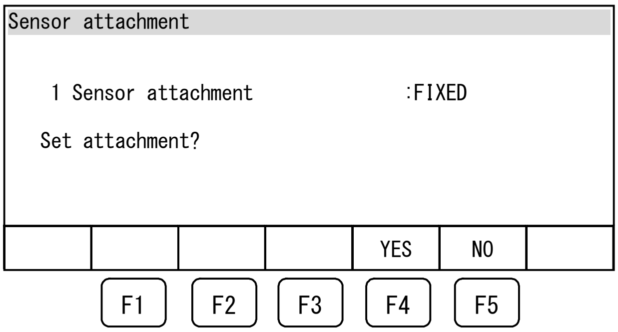
In the [Force Sensor Attachment] screen, the force sensor attachment type can be set. The force sensor attachment type includes "HAND" and "FIXED", and the standard setting is "FIXED".

How to set the attachment type

1 Launch the program for settings.
(Refer to "APPENDIX: C.4.2 How to Start the Program".)
The [Force Sensor Attachment] screen is displayed as below.



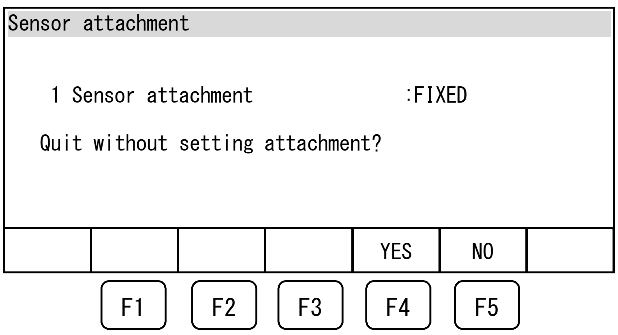
2 After choosing F4 [FIXED] , press F2 [SET]
By pressing F2 [SET] the message ”Set attachment?” is displayed on the screen. If F4 [YES] is selected, the setting on the screen is recorded and the screen is shifted to sensor frame setting screen. (Refer to Section C.4.4, “Setting sensor frame”.) If F5 [NO] is selected, go back to the current setting screen.



3 Press F4 [YES].
The [Force Sensor Attachment] screen is displayed.
* If F5 [NO] is pressed, the screen returns to the previous screen without reflecting the set attachment type.

How to quit the program

In order to quit this program, press F1 [QUIT]. In this case the setting of sensor frame will not be done.
By pressing F1 [QUIT] with changing the setting, the message “Quit without setting attachment?” is displayed on the screen. If F4 [YES] is selected, quit without updating. If F5 [NO], go back to the current setting screen.



Function Keys

The function keys indicated have the following functions.

Table C.4.3 Function Keys

Key	Label	Description
F1	QUIT	Quit this program.
F2	SET	Set sensor attachment type using parameter.
F4	FIXED	Select sensor attachment type to “Fixed”.
F5	HAND	Select sensor attachment type to “Hand”.

C.4.4 Setting Sensor Frame

In the [Force Sensor Attachment] screen, the setting of sensor frame in case of remotely fixed force sensor can be done.

Procedure for setting the sensor frame

1. Display the [Force Sensor Attachment] screen.
   (Refer to "APPENDIX: C.4.3 Setting Force Sensor Attachment".)
2. Select [User Frame No. for Sensor frame] and enter a value.
3. Select [Offset for Sensor frame] and enter a value.
   If the sensor base is taught for the user frame, enter '0'.
   If the jig for teaching is used, enter the length of the jig.

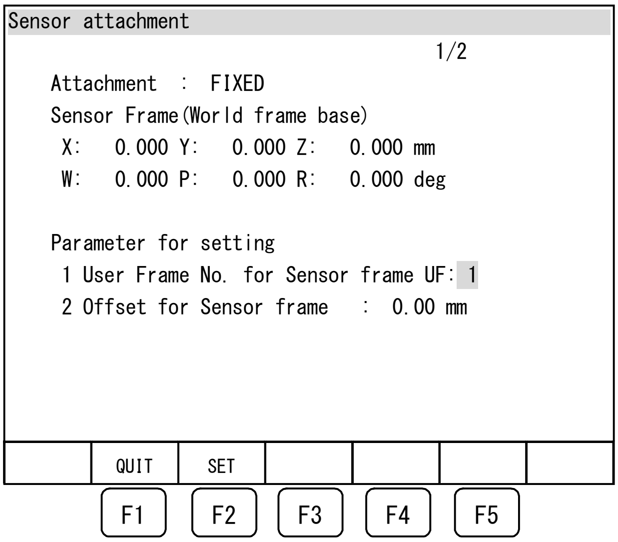


Table C.4.4 (a) [Force Sensor Attachment] screen

Parameter	Description
[User Frame No. for Sensor frame]	This parameter specifies user frame number for teaching sensor frame. "DEFAULT: 1"
[Offset for Sensor frame]	This parameter specifies the difference between sensor frame and tool frame in Z direction. "DEFAULT: 0.00 mm"

4 Press F2 [SET].
A confirmation message 'Set Sensor frame?' is displayed.

```
Sensor attachment

   Attachment  :  FIXED
   Sensor Frame(World frame base)
    X:   0.000 Y:   0.000 Z:   0.000 mm
    W:   0.000 P:   0.000 R:   0.000 deg

   Parameter for setting
    1 User Frame No. for Sensor frame UF: 1
    2 Offset for Sensor frame   :  0.00 mm

   Set Sensor frame?

|      |      |      |      | YES  |  NO  |      |
        F1     F2     F3     F4     F5
```

5 Press F4 [YES].
A frame confirmation screen is displayed as below.
* If F5 [NO] is pressed, the screen returns to the [Force Sensor Attachment] screen.

```
Sensor attachment

   Attachment  :  FIXED
   Parameter for setting
    1 User Frame No. for Sensor frame UF: 1
    2 Offset for Sensor frame   :  0.00 mm

   Make sure that selected User Frame has
   the same direction as the Sensor Frame.
   If setting of frame is illegal,
   robot may make an unexpected motion.

|      |      |      |      |CONFIRM|CANCEL|      |
        F1     F2     F3     F4     F5
```

6 Check that the directions of the tool frame match those of the sensor frame by moving in the X, Y, and Z directions of the user frame that are displayed in the screen.

7 If the directions of the user frame match those of the sensor frame, press F4 [CONFIRM].
The force data are displayed.
* If the directions of the user frame do not match those of the sensor frame, press F5 [CANCEL].
The [Force Sensor Attachment] screen is displayed.
Configure the sensor frame settings again starting from Step 2.

```
Sensor attachment

   Force Data(World frame base)
    X:-302.359 Y:-553.944 Z:-125.867 N
    W:  -8.436 P: -42.691 R:  -5.607 N*m

   Press the sensor in the direction of +X
   and +Y on the World Frame.
   And check the changes of output.
   If it is not correct,
   please set the Sensor Frame again.

                              OK    CANCEL
          F1    F2    F3    F4    F5
```

8 Follow the instructions on the screen to review the force data output.
9 When the review is done, press F4 [OK].
The new sensor frame will be set.
When the sensor frame is set, a confirmation message 'Setting Done!! Quit?' is displayed.
* If the force data output is not correct, press F5 [CANCEL].
This returns to the [Force Sensor Attachment] screen.
Review the user frame, force sensor calibration data, etc. and configure settings again starting from Step 2.

```
Sensor Attachment

    Attachment  :  FIXED
    Sensor Frame(World frame base)
     X:   0.000 Y:   0.000 Z:   0.000 mm
     W:   0.000 P:   0.000 R:   0.000 deg

    Setting Done!! Quit?

                              YES   NO
          F1    F2    F3    F4    F5
```

10 Press F4 [YES].
* If F5 [NO] is pressed, the screen returns to the [Force Sensor Attachment] screen.
11 If the '[SETFSAT] Please reboot controller' message is displayed, reboot the robot controller.

Function Keys

The function keys indicated have the following functions.

Table C.4.4 (b) Function Keys

Key	Label	Description
F1	QUIT	Quit this program.
F2	SET	Set sensor frame using parameter.

C.5 CHANGING ONLY SENSOR ATTACHMENT TYPE

The procedure to change sensor attachment type without changing the setting of sensor frame is as follows.

C.5.1 How to Start the Program

The program for settings of force sensor attachment is executed from the [UTILITIES Force Sensor] screen.
(Refer to "Basic Function Guide: 3 FORCE SENSOR UTILITIES SCREEN".)

How to launch the program for settings

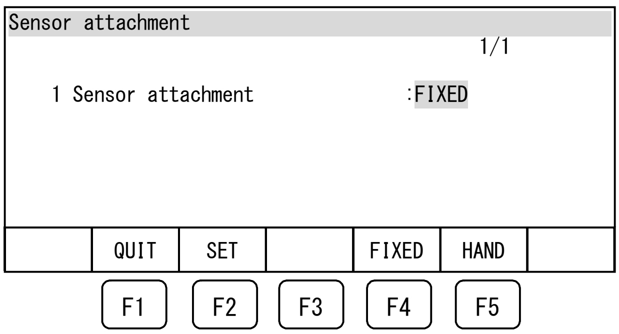
1 Display the [UTILITIES Force Sensor] screen.
(Refer to "Basic Function Guide: 3 FORCE SENSOR UTILITIES SCREEN".)
2 Move the cursor over [Force Sensor Attachment] and press F3 [DETAIL].
The [Force Sensor Attachment] screen is displayed.

C.5.2 Setting Force Sensor Attachment

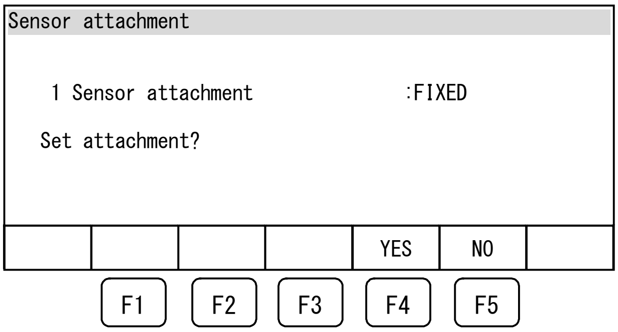
In the [Force Sensor Attachment] screen, the force sensor attachment type can be set. There are two force sensor attachment types: [HAND] mount and [FIXED] mount. The default is [FIXED].

How to set the attachment type

1 Launch the program for settings.
(Refer to "APPENDIX: C.5.1 How to Start the Program".)
The [Force Sensor Attachment] screen is displayed as below.



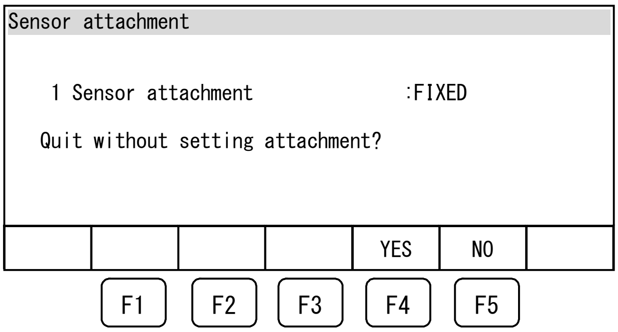
2 After choosing F4 [FIXED] or F5 [HAND] , press F2 [SET]
By pressing F2 [SET] the message ”Set attachment?” is displayed on the screen. If F4 [YES] is selected, the setting on the screen is recorded and the screen is shifted to sensor frame setting screen. (Refer to Section C.5.3, “Setting sensor frame”.) If F5 [NO] is selected, go back to the current setting screen.



3 Press F4 [YES].
The [Force Sensor Attachment] screen is displayed.
* If F5 [NO] is pressed, the screen returns to the previous screen without reflecting the set attachment type.

How to quit the program

In order to quit this program, press F1 [QUIT]. In this case the setting of sensor frame will not be done.
By pressing F1 [QUIT] with changing the setting, the message “Quit without setting attachment?” is displayed on the screen. If F4 [YES] is selected, quit without updating. If F5 [NO], go back to the current setting screen.



Function Keys

The function keys indicated have the following functions.

Table C.5.2 Function Keys

Key	Label	Description
F1	QUIT	Quit this program.
F2	SET	Set sensor attachment type using parameter.
F4	FIXED	Select sensor attachment type to “Fixed”.
F5	HAND	Select sensor attachment type to “Hand”.

C.5.3 Setting Sensor Frame

In this screen the setting of sensor frame can be done. The procedure not to change the setting of sensor frame is as follows.

Procedure for setting the sensor frame

1 Display the [Force Sensor Attachment] screen.
(Refer to "APPENDIX: C.5.2 Setting Force Sensor Attachment".)

For the hand mount, a screen similar to the one below is displayed.

```
Sensor attachment
                                        1/2
    Attachment  :  HAND
    Sensor Frame(Mech. interface frame base)
     X:   0.000 Y:   0.000 Z: 118.000 mm
     W:   0.000 P:   0.000 R:   0.000 deg

    Parameter for setting
     1 Tool Frame No. for Sensor frame UT: 1
     2 Offset for Sensor frame   :  0.00 mm

    DEFAULT1: Torque wrench is necessary
    DEFAULT2: Torque wrench is NOT necessary

         QUIT     SET    DEFAULT1 DEFAULT2
          F1      F2       F3       F4       F5
```

For the fixed mount, a screen similar to the one below is displayed.

```
Sensor attachment
                                        1/2
    Attachment  :  FIXED
    Sensor Frame(World frame base)
     X:   0.000 Y:   0.000 Z:   0.000 mm
     W:   0.000 P:   0.000 R:   0.000 deg

    Parameter for setting
     1 User Frame No. for Sensor frame UF: 1
     2 Offset for Sensor frame   :  0.00 mm

         QUIT     SET
          F1      F2       F3       F4       F5
```

2 Press F1 [QUIT].
The program exits.

D SYSTEM FILES OF FORCE SENSOR/FORCE CONTROL

There are following system files for force sensor/force control.
If [System files] or [ALL of above] is executed on the [FILE] screen, the system files related to the force sensor / force control are saved in the external storage device.

Procedure for saving system files related to the force sensor / force control

1 Press the [MENU] key on the teach pendant of the robot controller.
2 Press [FILE] -> [FILE] from the menu and press the [ENTER] key.
The [FILE] screen is displayed.
3 Press F4 [BACKUP].
4 Select [System files] or [ALL of above] from the menu and press F4 [YES].
System files related to the force sensor / force control are saved in the external device.

System files related to the force sensor / force control include:

Table D SYSTEM FILES OF FORCE SENSOR/FORCE CONTROL

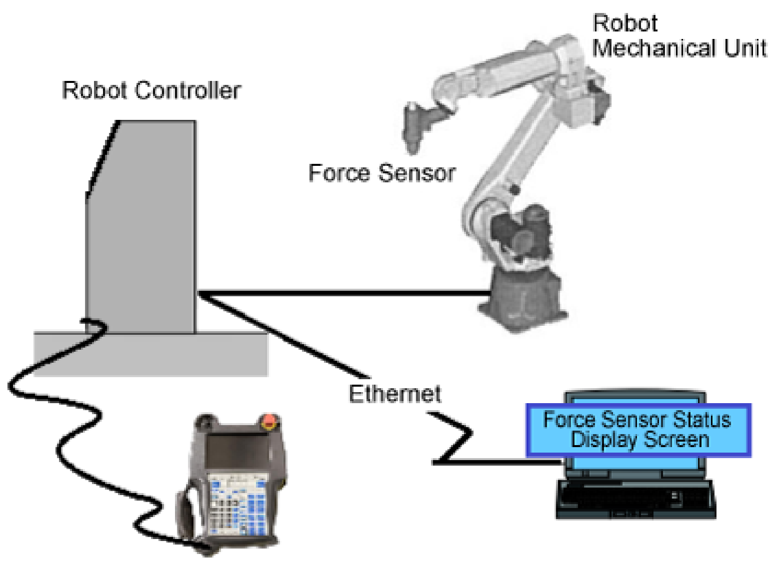
File name	description
SYSFSCDL.SV	Force control schedule data are stored.
SYSFSCB2.SV	Calibration data for 6-axis force sensor (FS-15*i*A, FS-40*i*A, FS-100*i*A, FS-250*i*A) are stored.
SYSFSCB3.SV	Setting data for 3-axis force sensor (FS-15*i*Ae) are stored.
SYSFFLR.SV	Execution histories of force control instructions are stored.
SYSFORCE.SV	System setting data for force control and mass measurement function, and the results of the weight and gravity center calcuration function are stored.
SYSMTPGN.SV	Parameters for TP program auto generation function are stored.
SYSPTPGN.SV	Parameters for Force Control Deburring Package are stored.

E FORCE DATA DISPLAY FUNCTION (PC)

E.1 OVERVIEW

With the force data display function (PC), you can perform the following.
- Display the status received from the force sensor in real time with the present values and a graph
- Log the received data for a certain period of time and output the results to a file

The force data display function (PC) is used on a different PC from the robot controller.
The force sensor data collected by the robot controller is received and displayed using HTTP communication.



E.1.1 Operating Environment

The force data display function (PC) operates in the following environment.

Supported OS
- Windows 10

Supported browsers
- Microsoft Edge
- Google Chrome
- Internet Explorer 11

Supported controller software version
- 7DF1/P26 or later, 7DF3/P05 or later, 7DF5

E.1.2 Connection Method

Connect the Ethernet connector on the front of the MAIN board of the robot controller to the PC using an Ethernet cable.
Prepare Ethernet cables that meet the following specifications.

- Twisted-pair cable
- Shielded

E.1.3 Startup Method

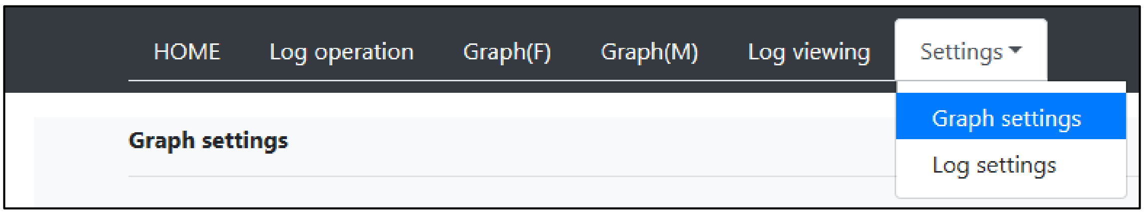
The startup method of the force data display function (PC) is as follows:

1 Launch the Web browser.
2 In the address bar, enter the following URL and press the "Enter" key to display the HOME screen of the force data display function (PC).
http://IP address/frh/force/fsmonitor.htm

Enter the IP address of the robot controller as the IP address.
For details on how to set the IP address of the robot controller, refer to "Setup IP Address" in "OPERATOR'S MANUAL (Basic Operation) (B-83284EN)". If you do not know the IP address, contact your network administrator.

E.2 DESCRIPTION OF EACH SCREEN

To display each screen, click the corresponding item on the top bar that appears at the top of the screen. An overview of each item is given below.

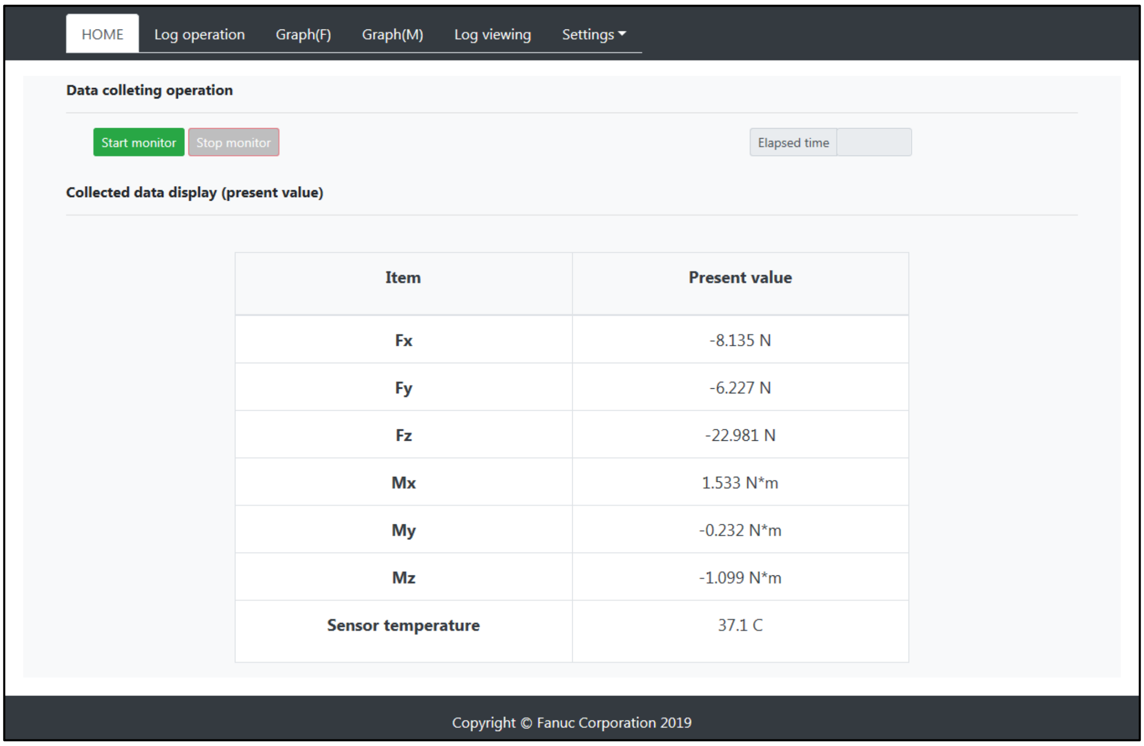


Screen	Overview	Display method
HOME	Allows you to start or stop collecting force sensor data. It is possible to check force sensor output.	Click "HOME" on the top bar.
Log operation	Allows you to log the force sensor data and operate the recorded log history.	Click "Log operation" on the top bar.
Graph(F)	Displays the force in the X, Y, and Z directions of the force sensor in a graph.	Click "Graph(F)" on the top bar.
Graph(M)	Displays the moment around X, Y, and Z of the force sensor in a graph.	Click "Graph(M)" on the top bar.
Log viewing	Displays the log data selected from the log history.	Click "Log viewing" on the top bar.
Graph settings	Allows you to set parameters related to the graph display.	Select "Graph settings" from "Settings" on the top bar.
Log settings	Allows you to set parameters related to log recording.	Select "Log settings" from "Settings" on the top bar.

E.2.1 HOME Screen

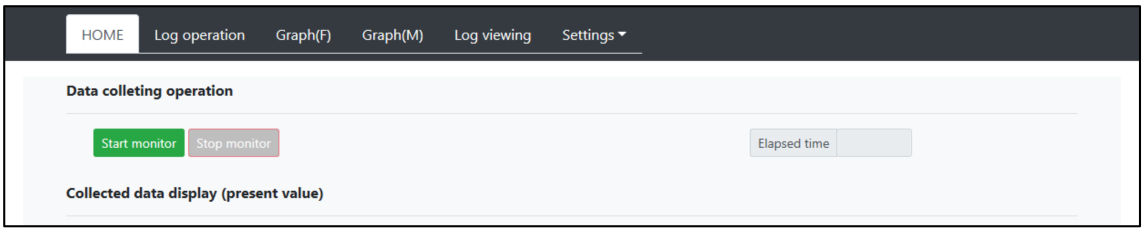
On the HOME screen, you can perform the following:

- Start and stop data collection
- Check the force sensor output



E.2.1.1 Starting and stopping data collection

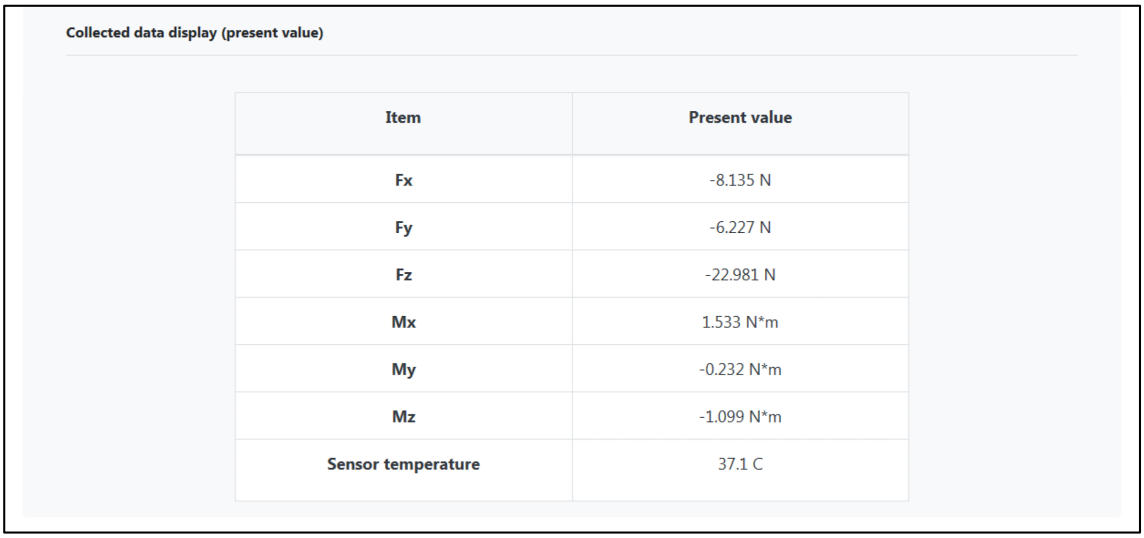
In the "Data collecting operation" area, you can start and stop data collection.



Item	Description
Start monitor	Click to start data collection.
Stop monitor	Click to stop data collection.
Elapsed time	The elapsed time since data collection has started is displayed.

E.2.1.2 Checking the force sensor output

In the "Collected data display (present value)" area, you can check the present values of force sensor output.



Collected data display (present value)

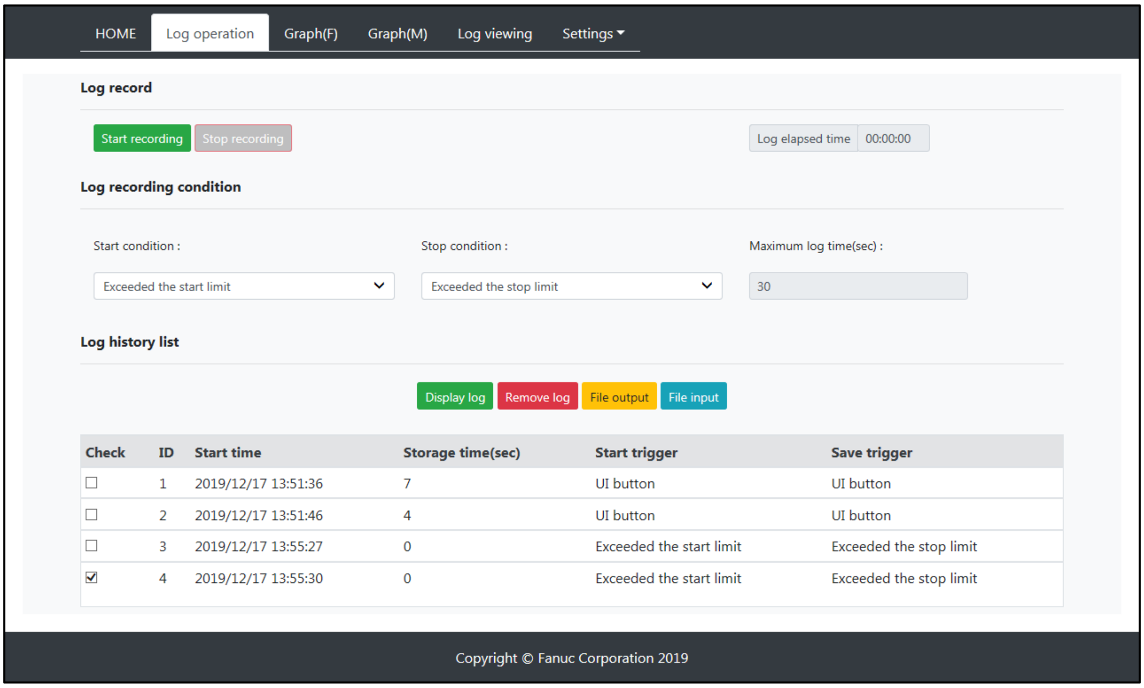
Item	Present value
Fx	-8.135 N
Fy	-6.227 N
Fz	-22.981 N
Mx	1.533 N*m
My	-0.232 N*m
Mz	-1.099 N*m
Sensor temperature	37.1 C

Item	Unit	Description
Fx	N	The Fx (force in the X direction) is displayed.
Fy	N	The Fy (force in the Y direction) is displayed.
Fz	N	The Fz (force in the Z direction) is displayed.
Mx	N*m	The Mx (moment around X) is displayed.
My	N*m	The My (moment around Y) is displayed.
Mz	N*m	The Mz (moment around Z) is displayed.
Sensor temperature	C	The sensor temperature is displayed.

E.2.2 Log Operation Screen

On the Log operation screen, you can perform the following:

- Set log recording conditions
- Start and stop log recording
- Display log history list
- Display log data
- Delete log data
- Save log data
- Load log data



E.2.2.1 Setting log recording conditions

You can set the log recording conditions in the "Log recording condition" area.
To record logs, set the recording conditions (start and stop conditions). Log recording starts when the start condition is met and stops when the stop condition is met. Log recording also stops if the maximum log time is exceeded.
The procedure for setting the log recording conditions is as follows.

1 Under Start condition, select one of the following:
- UI button
- Below the start limit
- Exceeded the start limit

Item	Description
UI button	When you click Start recording, force sensor data recording starts.
Below the start limit	When the present value of force sensor is below the start limit, force sensor data recording starts.
Exceeded the start limit	When the present value of force sensor has exceeded the start limit, force sensor data recording starts.

Refer to "E.2.6 Log Settings Screen" for the start limit.

2 Under Stop condition, select one of the following:
- UI button
- Below the stop limit
- Exceeded the stop limit

Item	Description
UI button	When you click Stop recording, force sensor data recording stops.
Below the stop limit	When the present value of force sensor is below the stop limit, force sensor data recording stops.
Exceeded the stop limit	When the present value of force sensor has exceeded the stop limit, force sensor data recording stops.

Refer to "E.2.6 Log Settings Screen" for the stop limit.

3 Set the maximum log time.

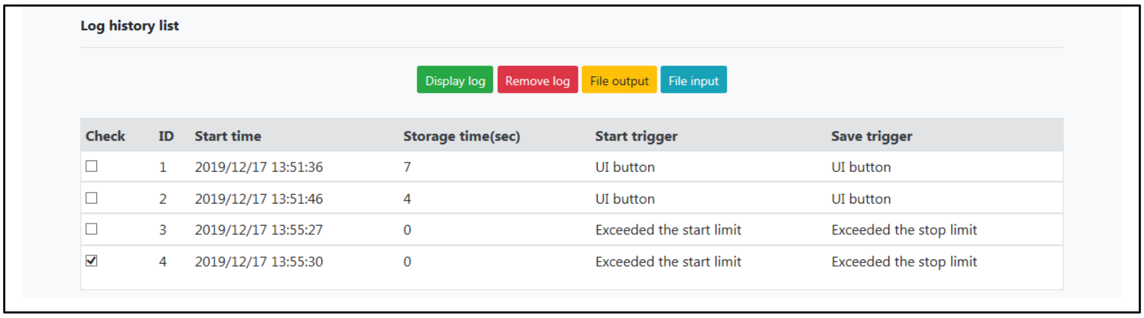
E.2.2.2 Starting and stopping log recording

You can enable or disable log recording in the "Log record" area.

Item	Description
Start recording	Click to enable log recording. After you click the button, log recording starts when the start condition is met. If “UI button” is selected in Start condition, log recording starts when this button is clicked.
Stop recording	Click to disable log recording. Clicking this button stops log recording. If “UI button” is selected in Stop condition, log recording stops when this button is clicked.
Log elapsed time	The elapsed time since log recording was started is displayed. When the maximum log time (refer to “E.2.6 Log Settings Screen”) of the Log recording condition is reached, log recording stops.

E.2.2.3 Displaying the log history list

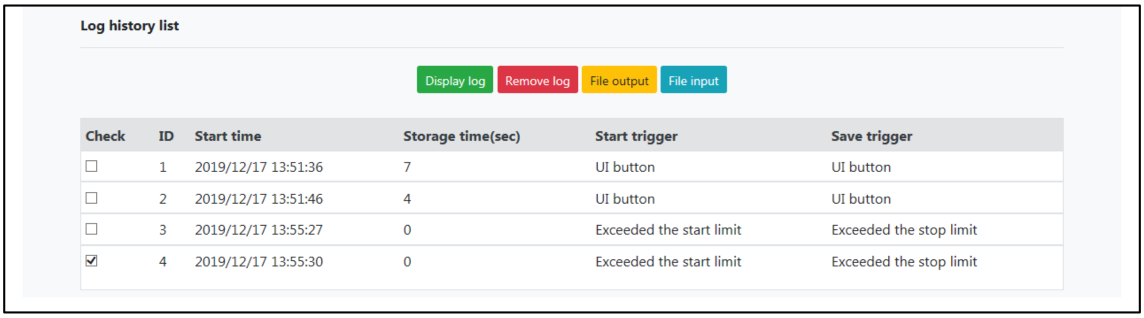
The "Log history list" area lists the history of the recorded logs.
Logs can be displayed, deleted, and output to files from the displayed log history. Output log files can also be loaded.



Item	Description
Check	Allows you to select the target log.
ID	This number is incremented every time the log is recorded. It is reset if the WEB page is reopened.
Start time	Displays the date and time that the log was recorded.
Storage time(sec)	Displays the duration for which the log was saved.
Start trigger	Displays the condition that started logging.
Save trigger	Displays the condition that stopped logging.

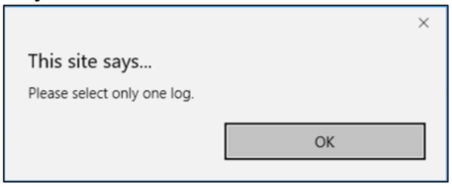
E.2.2.4 Displaying log data

The procedure for displaying the log data is as follows:



1 Under Check in the "Log history list" area, select the check box of the log to display, and then click "Display log". The selected log is displayed on the Log viewing screen.

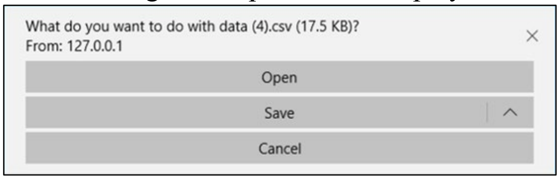
If two or more check boxes are selected, the following message is displayed.
Click "OK", and then select only one check box.

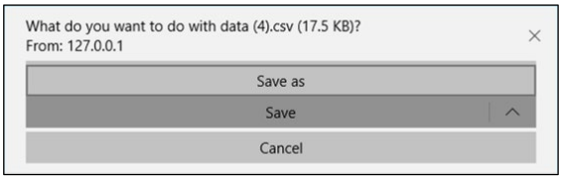


E.2.2.5 Outputting log data

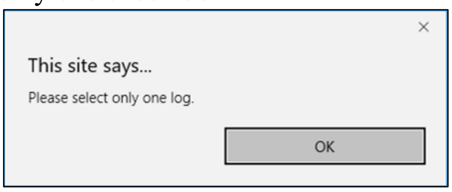
The procedure for outputting a log to a file is as follows:

1 Under Check in the "Log history list" area, select the check box of the log to output, and then click [File output]. The screen for selecting a file operation is displayed.

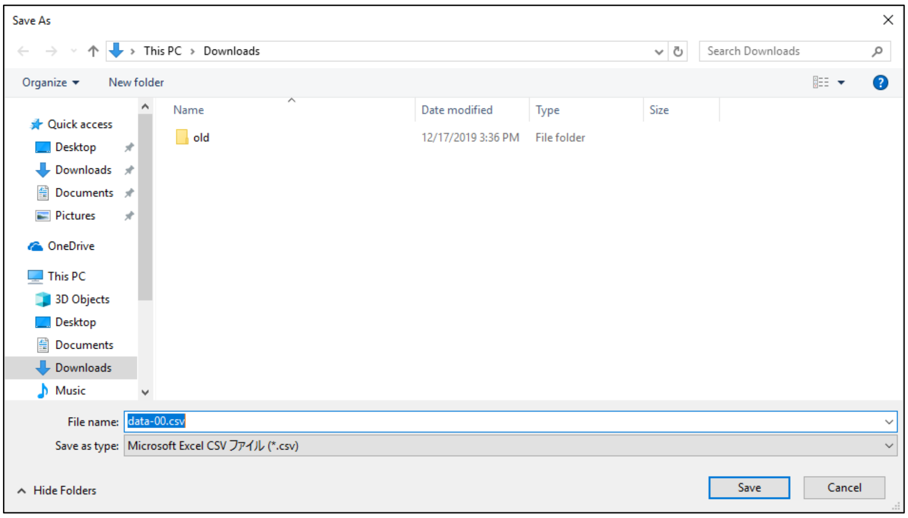




If two or more check boxes are selected, the following message is displayed.
Click "OK", and then select only one check box.



2 From "Save", click "Save as". The Save As screen is displayed.

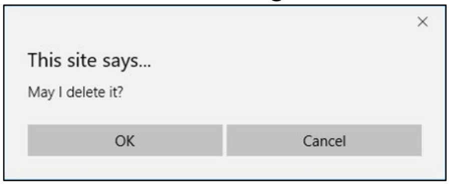


3 Specify the destination folder and file name, and then click "Save".

E.2.2.6 Deleting log data

The procedure for deleting log data is as follows:

1 Under Check in the "Log history list" area, select the check boxes of the logs to delete (more than one log can be selected), and then click "Remove log". The following message is displayed.

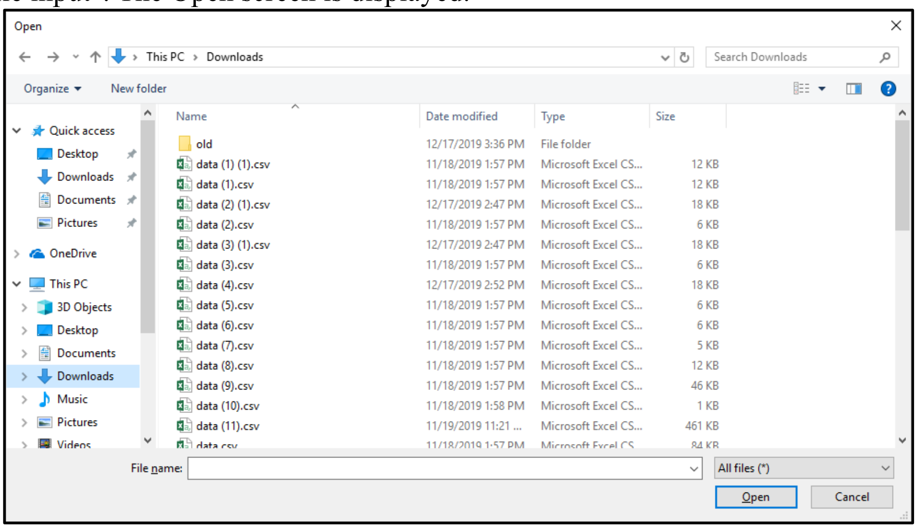


2 Click "OK". The selected log data is deleted.

E.2.2.7 Loading log files

The procedure for loading a log file that has been output is as follows:

1 Click "File input". The Open screen is displayed.



2 Select the log file to load, and then click "Open". The selected log is added to the Log history list.

E.2.3 Graph Display Screen

This screen displays the values of the force sensor in a graph.
The following two screens are available according to the values to display.

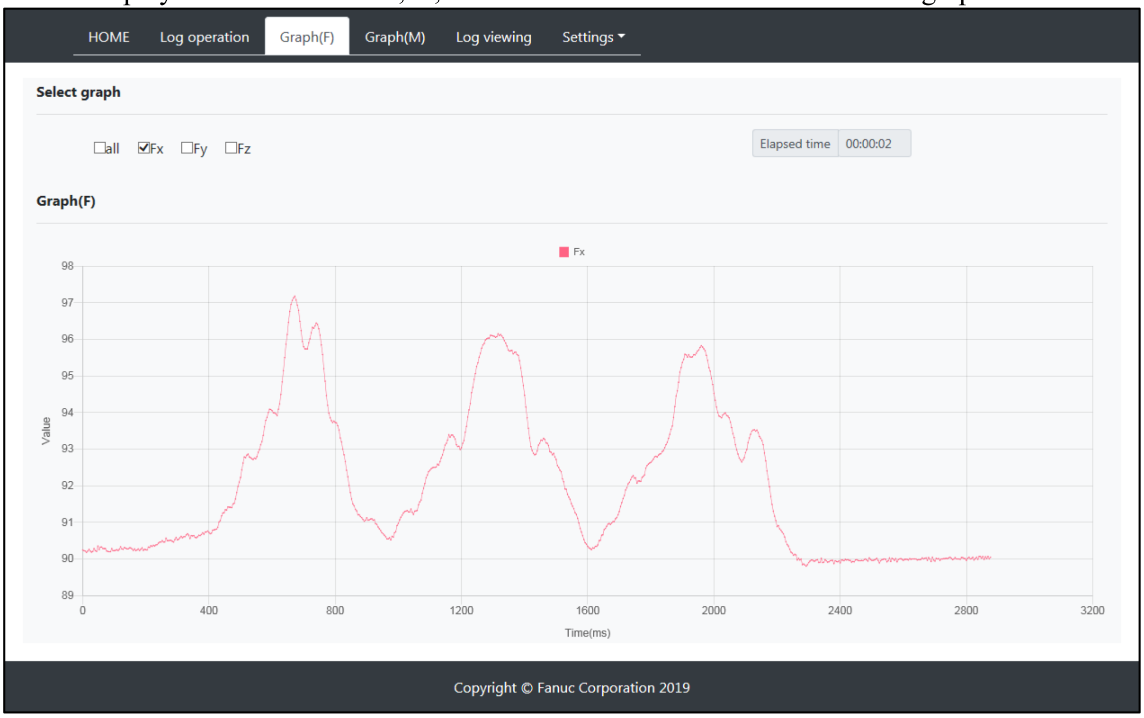
- Graph(F) screen
  This screen displays the force in a graph.
- Graph(M) screen
  This screen displays the moment in a graph.

The functional details of the graph display are as follows:

- A graph of the data selected in Select graph is displayed.
- The vertical axis is the value (force unit: N, moment unit: N*m), and the horizontal axis is time (unit: msec).
- When force sensor data collection starts (refer to E.2.1.1), the data collected at control interval is displayed on the graph.
- When force sensor data collection is started, the graph is initialized.
- When force sensor data collection is stopped, the graph display stops.
- The scale of the vertical axis corresponds to the setting of the scale in the Graph settings.
- The number of points to plot corresponds to the setting of Horizontal axis scale in the Graph settings.
- The renewal interval of display is approximately 120 msec.

E.2.3.1 Graph(F) screen

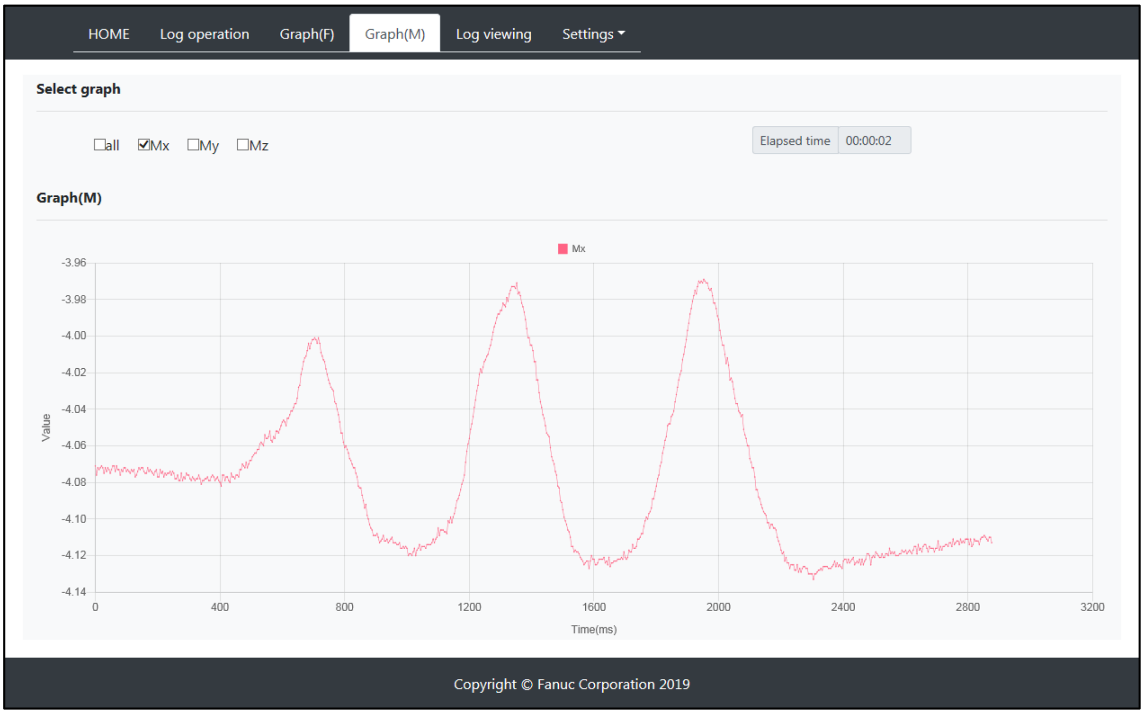
This screen displays the force in the X, Y, and Z directions of the force sensor in a graph.



Item	Description
Select graph check boxes	Select the force that you want to display. • all Displays Fx, Fy, and Fz. • Fx Displays the force in the X direction. • Fy Displays the force in the Y direction. • Fz Displays the force in the Z direction.
Elapsed time	The elapsed time is displayed.

E.2.3.2 Graph (M) screen

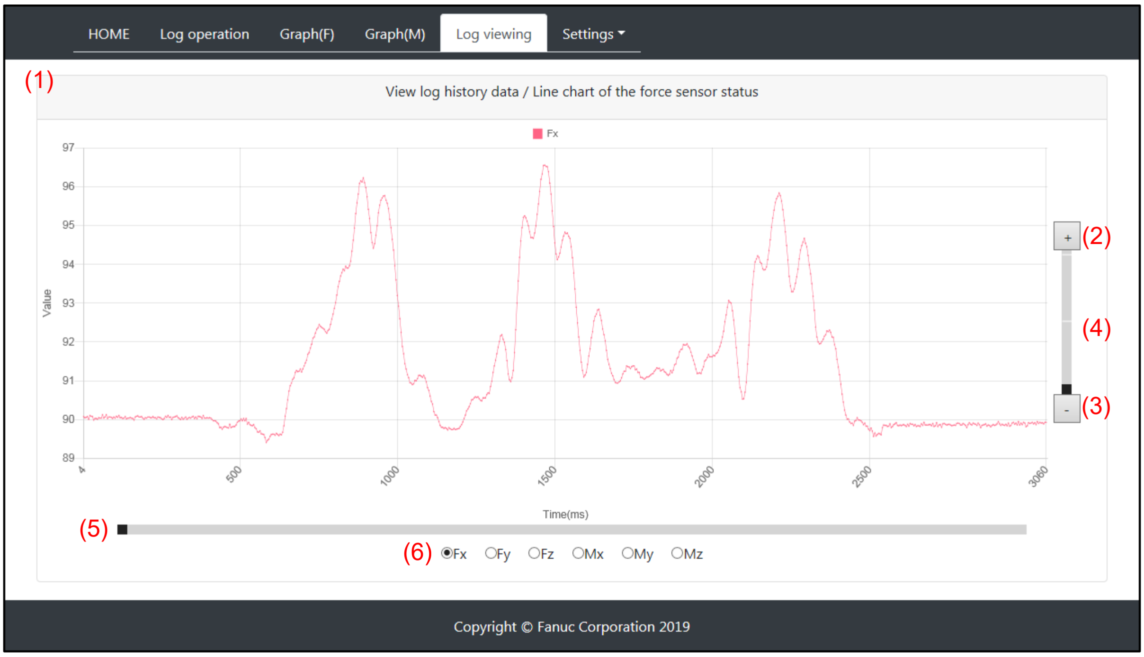
This screen displays the moment around X, Y, and Z of the force sensor in a graph.



Item	Description
Select graph check boxes	Select the moment that you want to display. • all Displays Mx, My, and Mz. • Mx Displays the moment around X. • My Displays the moment around Y. • Mz Displays the moment around Z.
Elapsed time	The elapsed time is displayed.

E.2.4 Log Viewing Screen

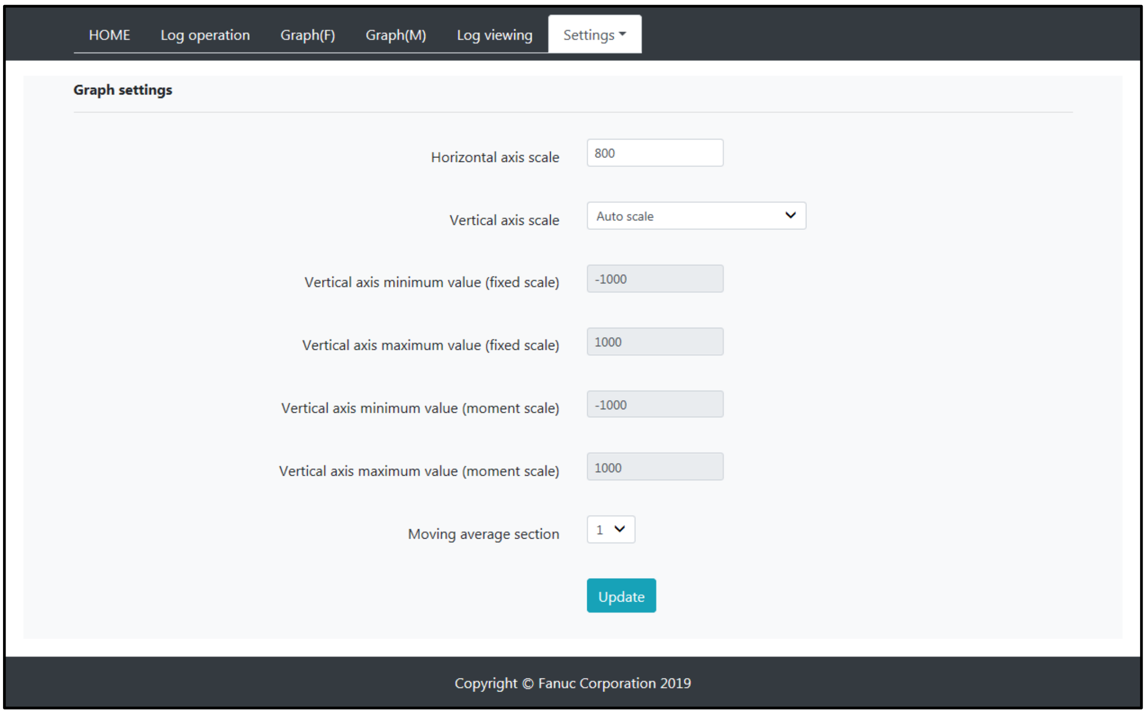
This screen displays the log data selected on the Log operation screen.
Displays the change in value in a graph along the time axis.
You can select which force sensor data to display.
You can zoom in/out the graph and move the time axis.



	Item	Description
(1)	Graph	Takes the time (unit: msec) on the horizontal axis and the value (force unit: N, moment unit: N*m) on the vertical axis.
(2)	Zoom in button	Click to move the scale slider up and zoom in the graph.
(3)	Zoom out button	Click to move the scale slider down and zoom out the graph.
(4)	Scale slider	Move the slider up to zoom in the graph. Move the slider down to zoom out the graph.
(5)	Left/Right movement slider	By clicking and moving the slider to the left or right, you can move the display range of the graph along the time axis.
(6)	Value selection	Select which values you want to display. • Fx Displays the force in the X direction. • Fy Displays the force in the Y direction. • Fz Displays the force in the Z direction. • Mx Displays the moment around X. • My Displays the moment around Y. • Mz Displays the moment around Z.

E.2.5 Graph Settings Screen

This screen is used to configure the graph display.
The display range of the graph and moving average section of the data can be set.



Item	Description
Horizontal axis scale	Enter the horizontal axis scale as an integer in the range of 1 to 150000. The default setting is 100.
Vertical axis scale	Select one of the following as the vertical axis scale. •Auto scale •Fixed scale The default setting is Auto scale. When Auto scale is selected, the following items cannot be set. •Vertical axis minimum value (fixed scale) •Vertical axis maximum value (fixed scale) •Vertical axis minimum value (moment scale) •Vertical axis maximum value (moment scale)
Vertical axis minimum value (fixed scale)	This is a setting item for the force graph. This can be set when Fixed scale is selected for Vertical axis scale. Enter the minimum value of the vertical axis scale (unit: N) in the range of -1000 to 999. The default setting is -1000. Fractional numbers can also be entered. If a value larger than Vertical axis maximum value (fixed scale) is input, an error will occur.
Vertical axis maximum value (fixed scale)	This is a setting item for the force graph. This can be set when Fixed scale is selected for Vertical axis scale. Enter the maximum value of the vertical axis scale (unit: N) in the range of -999 to 1000. The default setting is 1000. Fractional numbers can also be entered. If a value smaller than the Vertical axis minimum value (fixed scale) is input, an error will occur.

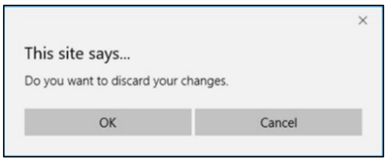
Item	Description
Vertical axis minimum value (moment scale)	This is a setting item for the moment graph. This can be set when Fixed scale is selected for Vertical axis scale. Enter the minimum value of the vertical axis scale (unit: N*m) in the range of -1000 to 999. The default setting is -1000. Fractional numbers can also be entered. If a value larger than the Vertical axis maximum value (moment scale) is input, an error will occur.
Vertical axis maximum value (moment scale)	This is a setting item for the moment graph. This can be set when Fixed scale is selected for Vertical axis scale. Enter the maximum value of the vertical axis scale (unit: N*m) in the range of -999 to 1000. The default setting is 1000. Fractional numbers can also be entered. If a value smaller than the Vertical axis minimum value (moment scale) is input, an error will occur.
Moving average section	Select a moving average section from 1 to 10. The default setting is 1. When the moving average section is set, the average of the last N measured values of force sensor (N = 1 to 10) is calculated and output to the graph. When 1 is set, the graph is displayed with only measured values. When 2 is set, the graph is displayed with the average of the measured value and the previous measured value. The higher the value, the smoother the graph but the delay will increase.
Update	Clicking this button verifies the values entered for the items. If at least one of an input values are out of range, an error message is displayed. If there is no problem with the input values, the values set for the graph are stored in the robot controller and the graph display is updated according to the settings.

E.2.5.1 Graph display settings

The procedure for setting the graph display is as follows:

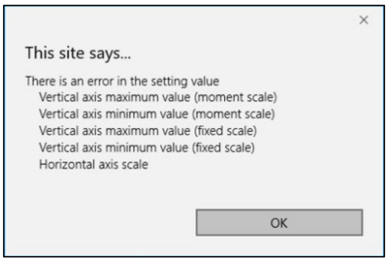
1. Refer to "E.2.5 Graph Settings Screen" and set the necessary items. Items change in color once the value is changed.

   The changes will not be applied until you click "Update". If you move to another page, the entered information is discarded. A confirmation screen is displayed. Click "OK" to discard the changes, or click "Cancel" to continue updating the settings.



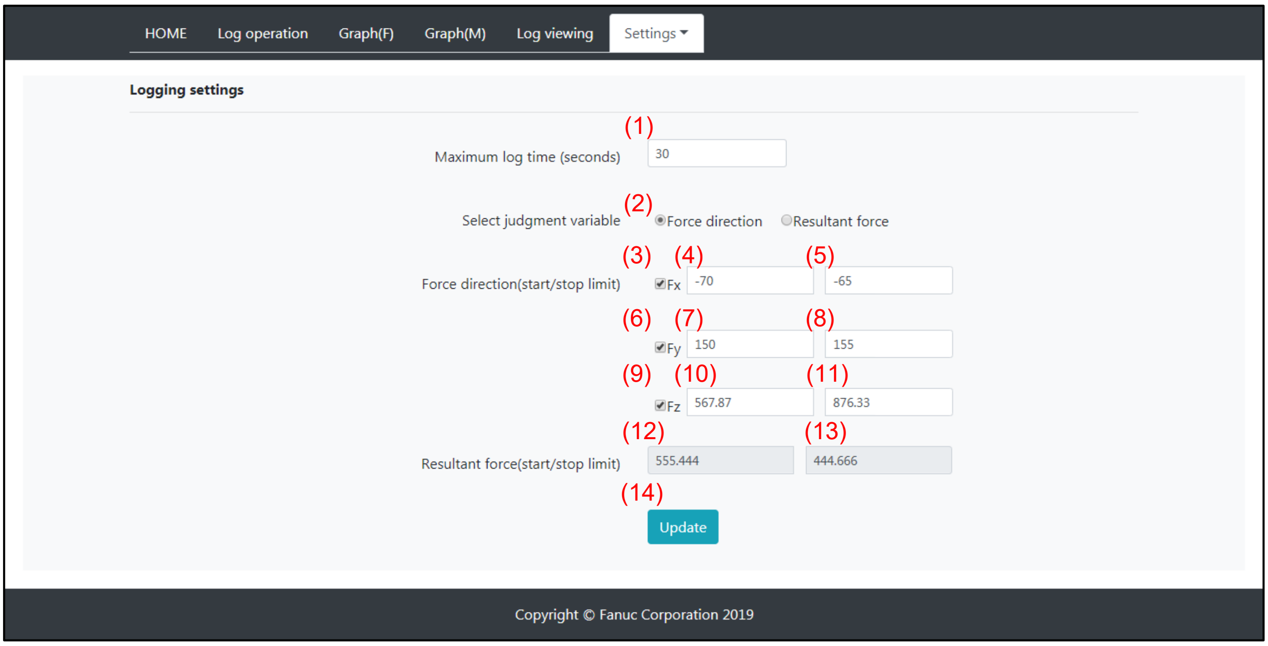
2. Click "Update". The changed contents are applied, and the colors of the items whose values have been changed are restored.

If at least one of an input values are out of range, an error message and names of items that have wrong values are displayed.
Clicking "OK" closes the error message and restores the value.
Enter the correct values to items that had wrong values, and then click "Update" again.



E.2.6 Log Settings Screen

This screen is used to set parameters related to log recording.
You can set the maximum log time and the judgment conditions for starting and stopping log recording.
If “Below (Exceeded) the start limit” is selected in the Log recording condition (refer to "E.2.2.1 Setting Log Recording Conditions"), the log recording will start if the force data is below (exceeded) the limit values set in this screen. This is same for stopping.



	Item	Description
(1)	Maximum log time (seconds)	Enter the maximum log time (unit: seconds) as an integer in the range of0 to 600. The default setting is 30.

	Item	Description
(2)	Select judgment variable	Select the value to be used for the limit from Force direction and Resultant force. • Force direction Sets the log start/stop limits for each force direction. • Resultant force Sets the log start/stop limits for the resultant force. The resultant force is calculated by SQRT (Fx^2 + Fy^2 + Fz^2). When Force direction is selected, Resultant force(start/stop limit) cannot be set. When Resultant force is selected, Force direction(start/stop limit) cannot be set.
(3)	Force direction Fx	This item can be set when Force direction is selected in Select judgment variable. Select the check box to enable the start limit and stop limit of Force direction Fx. The check box is selected by default.
(4)	Force direction Fx start limit	This item can be set when Force direction is selected in Select judgment variable. Enter the force direction Fx start limit in the range of -1000 to 1000. The default setting is -70. Fractional numbers can also be entered.
(5)	Force direction Fx stop limit	This item can be set when Force direction is selected in Select judgment variable. Enter the force direction Fx stop limit in the range of -1000 to 1000. The default setting is -65. Fractional numbers can also be entered.
(6)	Force direction Fy	This item can be set when Force direction is selected in Select judgment variable. Select the check box to enable the start limit and stop limit of Force direction Fy. The check box is not selected by default.
(7)	Force direction Fy start limit	This item can be set when Force direction is selected in Select judgment variable. Enter the force direction Fy start limit in the range of -1000 to 1000. The default setting is 151. Fractional numbers can also be entered.
(8)	Force direction Fy stop limit	This item can be set when Force direction is selected in Select judgment variable. Enter the force direction Fy stop limit in the range of -1000 to 1000. The default setting is 154. Fractional numbers can also be entered.
(9)	Force direction Fz	This item can be set when Force direction is selected in Select judgment variable. Select the check box to enable the start and stop limits of Force direction Fz. The check box is not selected by default.
(10)	Force direction Fz start limit	This item can be set when Force direction is selected in Select judgment variable. Enter the force direction Fz start limit in the range of -1000 to 1000. The default setting is -556. Fractional numbers can also be entered.
(11)	Force direction Fz stop limit	This item can be set when Force direction is selected in Select judgment variable. Enter the force direction Fy stop limit in the range of -1000 to 1000. The default setting is -559. Fractional numbers can also be entered.
(12)	Resultant force start limit	This item can be set when Resultant force is selected in Select judgment variable. Enter the resultant force start limit in the range of -1000 to 1000. The default setting is 580.376. Fractional numbers can also be entered. The resultant force is SQRT (Fx^2 + Fy^2 + Fz^2).

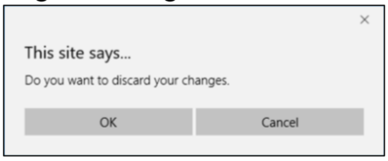
	Item	Description
(13)	Resultant force stop limit	This item can be set when Resultant force is selected in Select judgment variable. Enter the resultant force stop limit in the range of -1000 to 1000. The default setting is 583.456. Fractional numbers can also be entered. The resultant force is SQRT (Fx^2 + Fy^2 + Fz^2).
(14)	Update	Clicking this button verifies the values entered for the items. If at least one of an input values are out of range, an error message is displayed. If there is no problem with the input values, the values set for the graph are stored in the robot controller and the log record is started according to the settings.

E.2.6.1 Setting log record parameters

The procedure for setting the parameters for Log record is as follows.

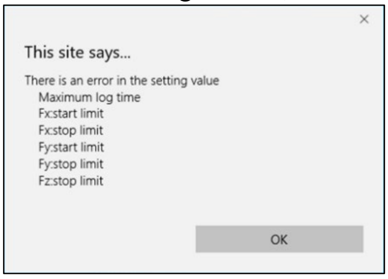
1 Refer to "E.2.6 Log Settings Screen" and set the necessary items. The color changes for items whose values have been changed.

The changes will not be applied until you click "Update". If you move to another page, the entered information is discarded. A confirmation screen is displayed. Click "OK" to discard the changes, or click "Cancel" to continue updating the settings.



2 Click "Update". The changed contents are applied, and the colors of the items whose values have been changed are restored.

If at least one of an input values are out of range, an error message and names of items that have wrong values are displayed.
Clicking "OK" closes the error message and restores the value.
Enter the correct values to items that had wrong values , and then click "Update" again.



F NON-FANUC FORCE SENSORS

F.1 OVERVIEW

Force sensors from manufacturers other than FANUC can be connected to the robot controller through the general force sensor interface option.
The same force control functions can be executed with these force sensors as those when a FANUC force sensor is connected.

F.1.1 Connectable Sensors

Force sensors that can be connected to a FANUC robot controller are provided by the sensor manufacturers below.

- SINTOKOGIO, LTD.
- WACOH-TECH Inc.
- ATI Industrial Automation

Be sure to select a force sensor that is compatible with the FANUC general force sensor interface. For details about compatible sensors, connection cables, robot mounting adapters, etc., contact the above sensor manufacturers.

F.1.2 Required Hardware and Software

The following hardware/software is required to connect a non-FANUC force sensor.

<u>RS232C/RS422 Converter Unit</u>

- A05B-2650-J080 (for R-30*i*B Mate Plus)
- A05B-2601-J358 (for R-30*i*B Plus A cabinet)

<u>Software options</u>

- General force sensor interface (A05B-2600-S506)
- Force sensor basic (A05B-2600-J876)

Depending on the force control functions that will be used, "Force Control Insert Function" or "Force Control Contouring Function" will also be required. For details, refer to table 1.3 (b) in "Basic Functions Guide: 1.3 FORCE CONTROL INSTRUCTIONS".

<u>Supported controller software version</u>

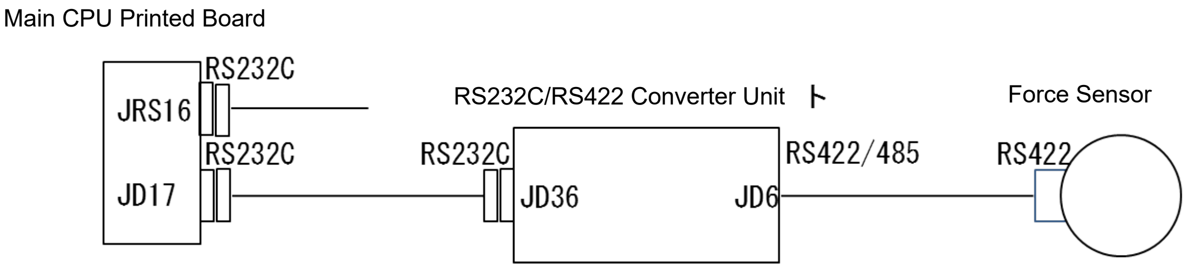
- 7DF3/P12 or later

F.2 FORCE SENSOR CONNECTION

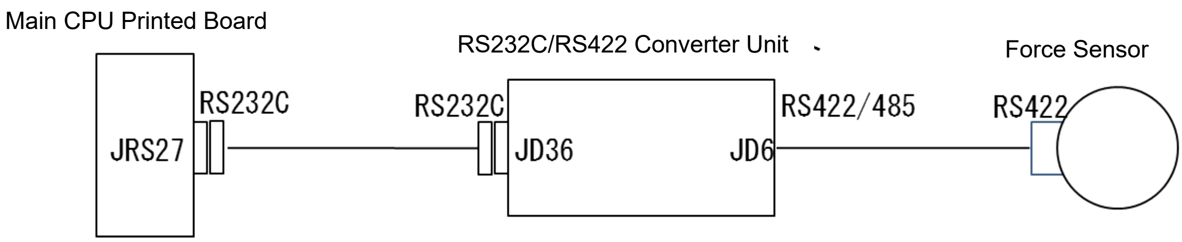
F.2.1 Connection

The communication standard for the general force sensor interface is RS422.
An RS422 port is not provided on the robot controller. You must use the RS232C/RS422 Converter Unit.

- For R-30*i*B Plus robot controller
  The R-30*i*B Plus has two RS232C ports, but the force sensor can be connected only to port 2 (JD17 connector of the main CPU printer board).
  Connect the force sensor to port 2 via the RS232C/RS422 Converter Unit, as shown below.



- For R-30*i*B Mate Plus robot controller
  The R-30*i*B Mate Plus has only one RS232C port.
  Connect the force sensor to port 1 (JRS27 connector of the main CPU printer board) via the RS232C/RS422 Converter Unit, as shown below.

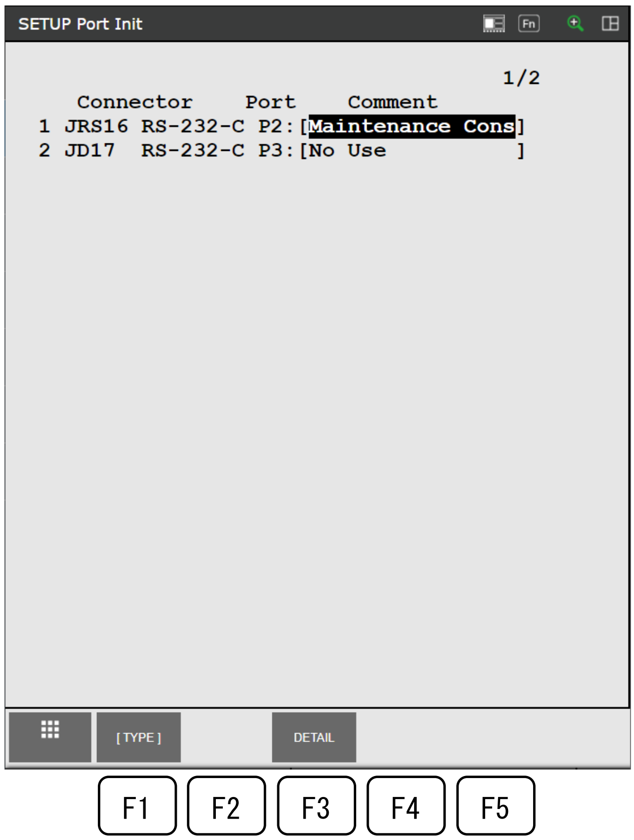


F.2.2 Port Settings

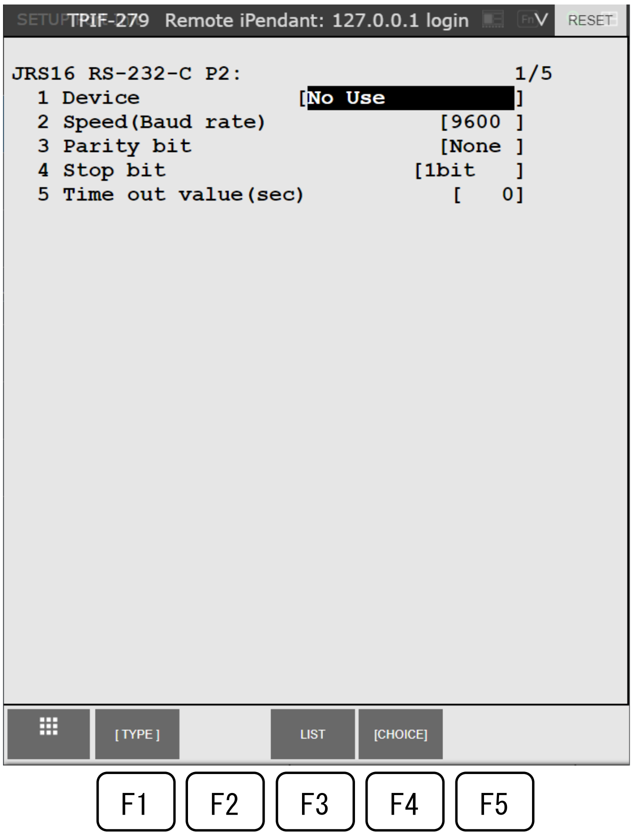
To start communication with the force sensor, the controller's communication ports must be configured. The communication ports are configured on the Port Settings screen [6. Settings: Port Settings].

Procedure

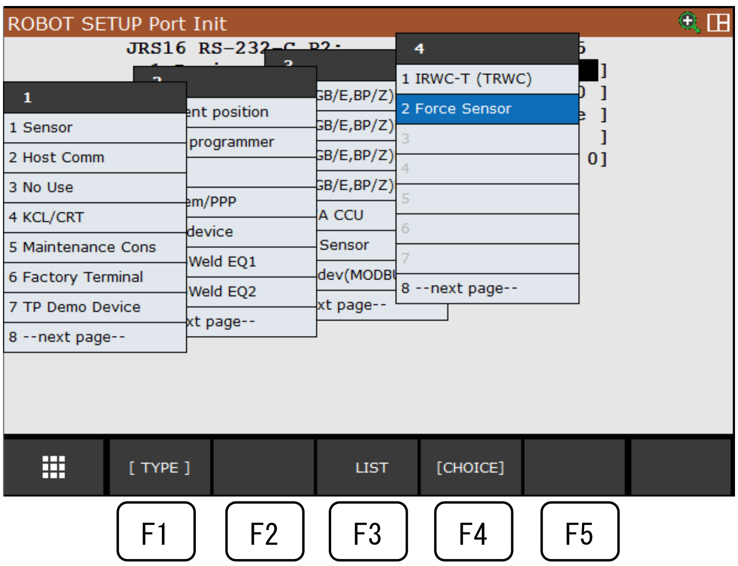
1 Press the "Screen Select" key to display the screen menu.
2 Select "6 Settings".
3 Press F1 [TYPE] to display the screen switch menu.
4 Select "Port Settings". The port list screen is displayed. (For the R-30*i*B Mate Plus, only port 1 is displayed.)



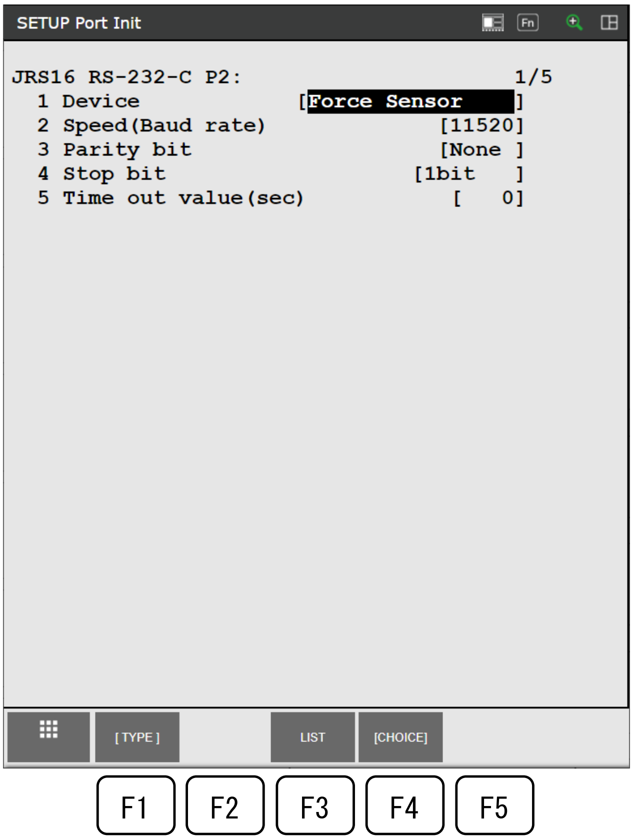
5 Move the cursor to port 2 (for R-30*i*B Plus) or to port 1 (for R-30*i*B Mate Plus), and press F3 "DETAIL".
The port settings screen is displayed.



6 Move the cursor to "Communication Device", and press F4 [CHOICE]. Select Force Sensor from the items.



7 Force Sensor is selected as the communication device, and the defaults appear for the other setting fields.
The values in the other fields are the default values for the FANUC-specified protocol. To change them, the settings must be changed on the force sensor. For instructions on how to change them, contact the force sensor manufacturer.



8 When complete, power off and then power on again.

NOTE

For R-30*i*B Plus, the settings for port 1 can be configured in the same way.
However, if Force Sensor is set as the communication device for both port 1 and port 2, communication with the force sensor will not be possible.
Do not set Force Sensor for port 1.

INDEX

REVISION RECORD

Edition	Date	Contents
02	Jun., 2021	• Added force control parameter auto tuning function and force data display function (PC). • Applied to R-30*i*B Mini Plus controller
01	Oct.,2017	

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