# FANUC Robot series

## R-30*i*B/R-30*i*B Mate

### Force Sensor

# OPERATOR'S MANUAL

B-83424EN/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 observed to ensure the safe use of the robot.
Before attempting to use the robot, be sure to read this chapter thoroughly.

Before using the functions related to robot operation, read the relevant operator's manual to become familiar with those functions.

For the safety of the operator and the system, follow all safety precautions when operating a robot and its peripheral devices installed in a work cell.
In addition, refer to the “FANUC Robot SAFETY HANDBOOK (**B-80687EN**)”.

# 1 DEFINITION OF USER

The user can be classified as follows.

**Operator**:
- Turns the robot controller power ON/OFF
- Starts the robot program with operator’s panel

**Programmer**:
- Operates the robot
- Teaches the robot inside the safety fence

**Maintenance engineer**:
- Operates the robot
- Teaches the robot inside the safety fence
- Maintenance (repair, adjustment, replacement)

- “An operator” ***cannot*** work inside the safety fence
- “Programmer”, “Teaching operator”, and “Maintenance engineer” ***can*** work inside the safety fence. The working activities inside the safety fence include lifting, setting, teaching, adjusting, maintenance, etc.
- To work inside the safety fence, the person must be trained on proper robot operation.

During the operation, programming, and maintenance of your robotic system, programmer, teaching operator and maintenance engineer must operate with circumspection by using following safety precautions.

- Adequate clothes for the operation
- Safety shoes
- A helmet

# 2 DEFINITION OF SAFETY NOTATIONS

To ensure the safety of user 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 attempting to use the oscillator.

| 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 DANGER, WARNING, and CAUTION is to be indicated. |

- Check this manual thoroughly, and keep it handy for the future reference.

# 3 USER SAFETY

User safety is the primary safety consideration. As it is very dangerous to enter the operating-area of the robot during its automatic operation, adequate safety precautions must be observed.

The following lists the general safety precautions. Careful consideration must be made to ensure user safety.

(1) We obligate the User to take a FANUC training courses.

> FANUC provides various training courses. Contact your local FANUC representative for details.

(2) Even when the robot is stationary, it is possible that the robot is still in a ready to move state, and is waiting for a signal. In this state, the robot is regarded as still in motion. To ensure user safety, provide the system with an alarm to indicate visually or aurally that the robot is in motion.
(3) Install a safety fence with a gate so that no user can enter the safety fence inside without passing through the gate. Install an interlocking device, a safety plug, and so forth in the safety gate so that the robot is stopped as the safety gate is opened.

> The controller is designed to receive this interlocking signal of the door switch. When the safety fence is opened and this signal received, the controller stops the robot (Please refer to **"STOP TYPE OF ROBOT" in SAFETY PRECAUTIONS** for detail of stop type). For connection, refer to below **Fig.3 (b).**

(4) Provide the peripheral devices with appropriate grounding (Class A, Class B, Class C, and Class D).
(5) Recommend to install the peripheral device outside of the motion range.
(6) Draw an outline on the floor, clearly indicating the range of the robot motion, including the tools such as a hand.
(7) Install a mat switch or photoelectric switch on the floor with an interlock to a visual or aural alarm that stops the robot when a user enters the motion range.
(8) If necessary, install a safety lock so that no one except the user in charge can turn the power on the robot.

The circuit breaker installed in the controller is designed to disable anyone from turning it on when it is locked with a padlock.

(9) When adjusting each peripheral device independently, make sure to turn the power off the robot.
(10) Operators must take the gloves off while manipulating the operator's panel or teach pendant. Operation with gloved fingers may cause an operation error.
(11) Programs, system variables, and other information can be saved on memory card or USB memories. Be sure to save the data periodically in case the data is lost in an accident.
(12) The robot must be transported and installed by accurate procedure recommended by FANUC. Wrong transportation or installation may cause the robot to fall, resulting in severe injury to workers.
(13) In the first operation of the robot after installation, the operation should be restricted to low speeds. Then, the speed should be gradually increased to check the operation of the robot.
(14) Before the robot is started, it should be checked that no one is in the area of the safety fence. At the same time, a check must be made to ensure that there is no risk of hazardous situations. If detected, such a situation should be eliminated before the operation.
(15) Do not operate the robot under the following conditions. Otherwise, the robot and peripheral equipment can be adversely affected, or workers can be severely injured.
- Flammable
- Explosive
- Massive dose of Radiation
- Under water, high (heavy) Humidity
- Transport human or animals
- Stepladder (climb or hang down)
- Outdoor
(16) When connecting the peripheral devices related to stop(safety fence etc.) and each signal (external emergency , fence etc.) of robot, be sure to confirm the stop movement and do not take the wrong connection.
(17) In preparing the trestle, please secure the maintenance engineer safety at high place in reference to Fig. 3 (c). Design with the Scaffolding and Safety-belt with circumspection.

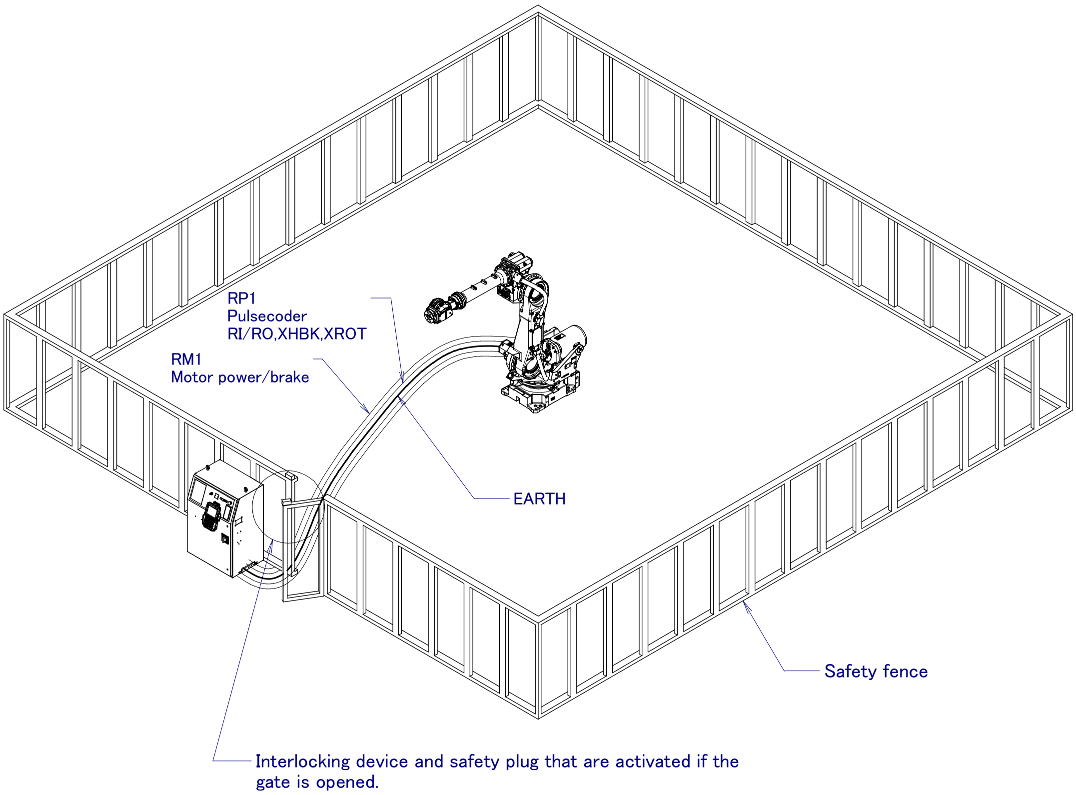
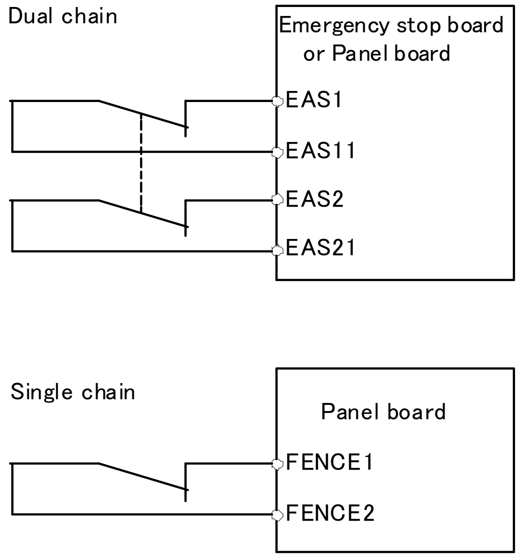



**Fig. 3 (a) Safety fence and safety gate**

> ⚠ **WARNING**
> When you close a fence, please confirm that there is not a person from all directions of the robot.




(Note)

For the R-30*i*B, the R-30*i*B Mate
Terminals EAS1,EAS11,EAS2,EAS21 are provided on the emergency stop board.

Refer to the ELECTRICAL CONNCETIONS Chapter of CONNECTION of
R-30*i*B controller maintenance manual (B-83195EN) or
R-30*i*B Mate controller maintenance manual (B-83525EN)
for details.

**Fig. 3 (b) Limit switch circuit diagram of the safety fence**

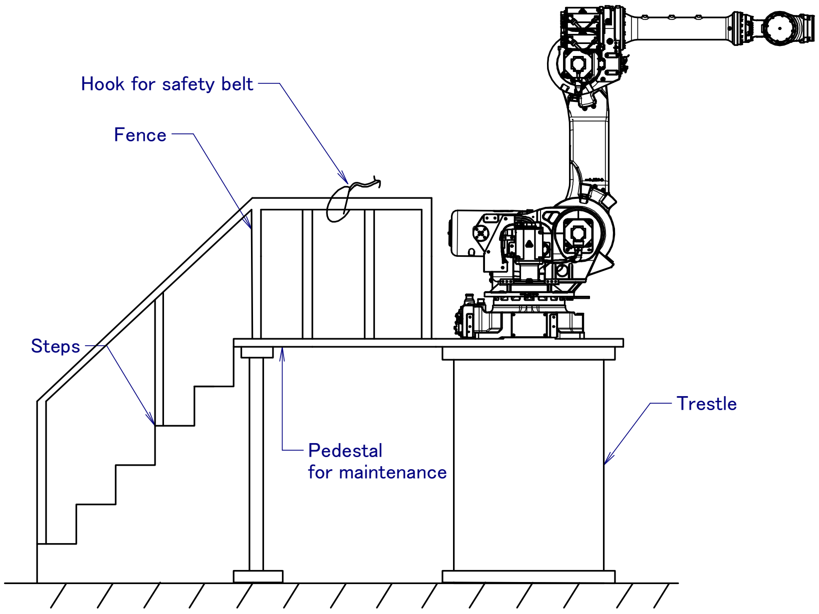



**Fig. 3 (c) Pedestal for maintenance**

## 3.1 OPERATOR SAFETY

The operator is a person who operates the robot system. In this sense, a worker who operates the teach pendant is also an operator. Operator cannot work inside the safety fence.

(1) If you don’t need to operate the robot, turn the power off the robot controller, or press the “EMERGENCY STOP” button, and then proceed your work.
(2) Operate the robot system outside of the robot motion range.

(3) Install a safety fence with a safety gate to prevent any worker other than the operator from entering the dangerous area unexpectedly and the worker from entering a hazardous area.
(4) Install one or more necessary quantity of EMERGENCY STOP button(s) within the operator's reach in appropriate location(s) based on the system layout.

| |
|---|
| The robot controller is designed to be connected to an external EMERGENCY STOP button. With this connection, the controller stops the robot operation (Please refer to "STOP TYPE OF ROBOT" in SAFETY PRECAUTIONS for detail of stop type), when the external EMERGENCY STOP button is pressed. See the diagram below for connection. |

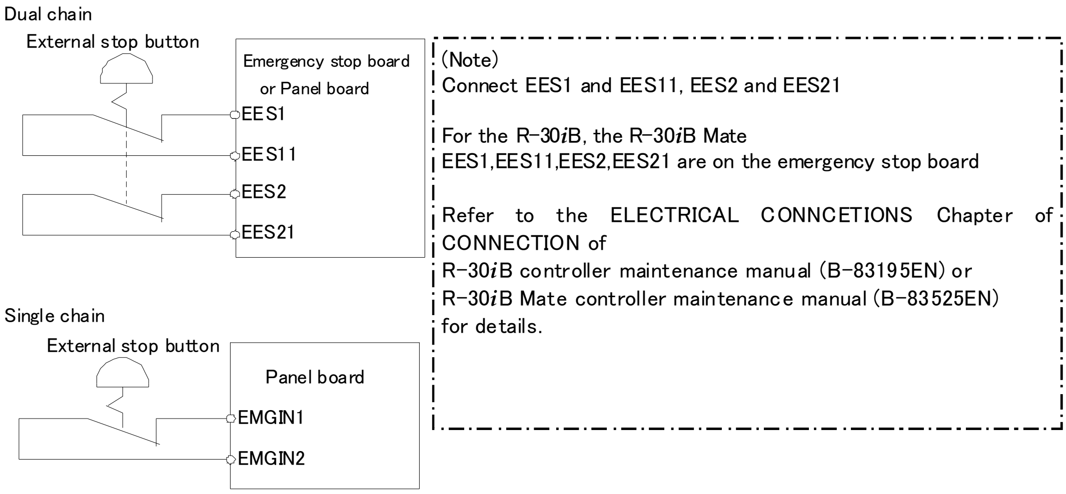



**Fig. 3.1 Connection diagram for external emergency stop button**

# 3.2 SAFETY OF THE PROGRAMMER

While teaching the robot, the operator must enter the motion range of the robot. Please ensure the safety of programmer.

(1) Unless it is specifically necessary to enter the robot motion range, carry out all tasks outside the area.
(2) Before teaching the robot, check that the robot and its peripheral devices are all in the normal condition.
(3) If it is inevitable to enter the robot motion range to teach the robot, check the locations, settings, and other conditions of the safety devices (such as the EMERGENCY STOP button, the DEADMAN switch on the teach pendant) before entering the area.
(4) The programmer must be extremely careful not to let anyone else enter the robot motion range.
(5) Programming must be done outside of the safety fence as far as possible. If programming needs to be done in the area of the safety fence, the programmer must take the following precautions:
   - Before entering the safety fence area, ensure that there is no risk of hazardous situation in the area.
   - Be ready to press the emergency stop button whenever it is necessary.
   - Operate the Robot at low speed.
   - Before starting programming, check the entire system status to ensure that no remote instruction to the peripheral equipment or motion would harm user .

| |
|---|
| Our operator panel is provided with an emergency stop button and a key switch (mode switch) for selecting the automatic operation mode (AUTO) and the teach modes (T1 and T2). Before entering the inside of the safety fence for the purpose of teaching, set the switch to a teach mode, remove the key from the mode switch to prevent other people from changing the operation mode carelessly, then open the safety gate. If the safety gate is opened with the automatic operation mode set, the robot stops (Please refer to "**STOP TYPE OF ROBOT**" in SAFETY PRECAUTIONS for detail of stop type). After the switch is set to a teach mode, the safety gate is disabled. The programmer should understand that the safety gate is disabled and is responsible for keeping other people from entering the inside of the safety fence. |

Teach pendant is provided with a switch to enable/disable robot operation from teach pendant and DEADMAN switch as well as emergency stop button. These button and switch function as follows:
(1) Emergency stop button: Causes the stop of the robot (Please refer to "STOP TYPE OF ROBOT" in SAFETY PRECAUTIONS for detail of stop type) when pressed.
(2) DEADMAN switch: Functions are different depending on the teach pendant enable/disable switch setting status.
**(a) Enable:** Servo power is turned off and robot stops when the operator releases the DEADMAN switch or when the operator presses the switch strongly.
**(b) Disable:** The DEADMAN switch is disabled.
(Note) The DEADMAN switch is provided to stop the robot when the operator releases the teach pendant or presses the pendant strongly in case of emergency. The R-30*i*B/R-30*i*B Mate employs a 3-position DEADMAN switch, which allows the robot to operate when the 3-position DEADMAN switch is pressed to its intermediate point. When the operator releases the DEADMAN switch or presses the switch strongly, the robot stops immediately.

The operator's intention of starting teaching is determined by the controller through the dual operation of setting the teach pendant enable/disable switch to the enable position and pressing the DEADMAN switch. The operator should make sure that the robot could operate in such conditions and be responsible in carrying out tasks safely.

Based on the risk assessment by FANUC, number of operation of DEADMAN switch should not exceed about 10000 times per year.

The teach pendant, operator panel, and peripheral device interface send each robot start signal. However the validity of each signal changes as follows depending on the mode switch and the DEADMAN switch of the operator panel, the teach pendant enable switch and the remote condition on the software.

| Mode | Teach pendant enable switch | Software remote condition | Teach pendant | Operator panel | Peripheral device |
|---|---|---|---|---|---|
| AUTO mode | On | Local | Not allowed | Not allowed | Not allowed |
| | | Remote | Not allowed | Not allowed | Not allowed |
| | Off | Local | Not allowed | Allowed to start | Not allowed |
| | | Remote | Not allowed | Not allowed | Allowed to start |
| T1, T2 mode | On | Local | Allowed to start | Not allowed | Not allowed |
| | | Remote | Allowed to start | Not allowed | Not allowed |
| | Off | Local | Not allowed | Not allowed | Not allowed |
| | | Remote | Not allowed | Not allowed | Not allowed |

**T1,T2 mode: DEADMAN switch is effective.**

(6) To start the system using the operator's panel, make certain that nobody is in the robot motion range and that there are no abnormal conditions in the robot motion range.
(7) When a program is completed, be sure to carry out the test operation according to the following procedure.
(a) Run the program for at least one operation cycle in the single step mode at low speed.
(b) Run the program for at least one operation cycle in the continuous operation mode at low speed.
(c) Run the program for one operation cycle in the continuous operation mode at the intermediate speed and check that no abnormalities occur due to a delay in timing.
(d) Run the program for one operation cycle in the continuous operation mode at the normal operating speed, and check that the system operates automatically without trouble.
(e) After checking the completeness of the program through the test operation above, execute it in the automatic operation mode.
(8) While operating the system in the automatic operation mode, the teach pendant operator must leave the safety fence.

## 3.3 SAFETY OF THE MAINTENANCE ENGINEER

For the safety of maintenance engineer personnel, pay utmost attention to the following.

(1) Must never be in the area during its operation.
(2) A hazardous situation may occur when the robot or the system, are kept with their power-on during maintenance operations. Therefore, for any maintenance operation, the robot and the system must be put into the power-off state. If necessary, a lock should be in place in order to prevent any other person from turning on the robot and/or the system. In case maintenance needs to be executed in the power-on state, the emergency stop button must be pressed.
(3) If it becomes necessary to enter the robot operation area while the power is on, press the emergency stop button on the operator panel, or the teach pendant before entering the area. The maintenance personnel must indicate that maintenance work is in progress and be careful not to allow other people to operate the robot carelessly.
(4) When entering the area enclosed by the safety fence, the maintenance engineer must check the entire system in order to make sure that there is no dangerous situation around. In case the worker needs to enter the safety area whilst a dangerous situation exists, extreme care must be taken, and entire system status must be carefully monitored.
(5) Before the maintenance of the pneumatic system is started, the supply pressure should be shut off and the pressure in the piping should be reduced to zero.
(6) Before the start of maintenance, check the robot and its peripheral devices are all in the normal condition.
(7) Do not operate the robot in the automatic mode while anybody is in the robot motion range.
(8) In maintaining the robot parallel to a wall or instrument, or when multiple workers are working nearby, make certain that their escape path is not obstructed.
(9) When a tool is mounted on the robot, or any moving device other than the robot is installed, such as belt conveyor, careful attention required for those motion.
(10) Assign an expert near the operator panel who can press the EMERGENCY STOP button whenever he sees the potential danger.
(11) In case of replacing a part, please contact your local FANUC representative. Wrong procedure may cause the serious damage to the robot and the worker.
(12) Make sure that no impurity into the system in while (in) replacing or reinstalling components.
(13) Turn off the circuit breaker to protect again electric shock in handling each unit or printed circuit board in the controller during inspection. If there are two cabinets, turn off the both circuit breaker.
(14) A part should be replaced with a part recommended by FANUC. If other parts are used, malfunction or damage would occur. Especially, a fuse that is not recommended by FANUC should not be used. Such a fuse may cause not only a damage to the internal parts of the controller but also a fire.
(15) When restarting the robot system after completing maintenance work, make sure in advance that there is no person in the motion range and that the robot and the peripheral devices are not abnormal.
(16) In case of remove the motor or brake, suspend the arm by crane or other equipment beforehand to avoid falling.
(17) Whenever grease is spilled on the floor, remove them as soon as possible to prevent from falling.
(18) The following parts are heated. If a maintenance engineer needs to touch such a part in the heated state, the worker should wear heat-resistant gloves or use other protective tools.
   - Servo motor
   - Inside of the controller
   - Reducer
   - Gearbox
   - Wrist unit
(19) Maintenance must be done with appropriate lightning. Be careful that those lightning will not cause any further danger.
(20) When a motor, reducer, or other heavy load is handled, a crane or other equipment should be used to protect maintenance engineers from excessive load. Otherwise, the maintenance engineers would be severely injured.

(21) Must never climb or step on the robot even in the maintenance. If it is attempted, the robot would be adversely affected. In addition, a misstep can cause injury to the worker.
(22) Secure a pedestal and wear the safety belt in performing the maintenance work in high place.
(23) Remove all the spilled oil or water and metal chips around the robot in the safety fence after completing the maintenance.
(24) All the related bolts and components must return to the original place in replacing the parts. If some parts are missing or left (remained), repeat the replacement work until complete the installation.
(25) In case robot motion is required during maintenance, the following precautions should be taken :
- Secure an escape route. And during the maintenance motion itself, monitor continuously the whole system so that your escape route will not become blocked by the robot, or by peripheral equipment.
- Keep vigilant attention for the potential danger. and to press the emergency stop button whenever it is necessary.

(26) Periodic inspection required. (Refer to the robot mechanical manual and controller maintenance manual.) A failure to do the periodical inspection can may adversely affect the performance or service life of the robot and may cause an accident
(27) After replacing some parts, a test run required by the predetermined method. (See TESTING section of “Controller operator’s manual”. During the test run, the maintenance staff must work outside the safety fence.

# 4 SAFETY OF THE TOOLS AND PERIPHERAL DEVICES

## 4.1 PRECAUTIONS IN PROGRAMMING

(1) Adopt a limit switch or other sensor to detect a dangerous state and, if necessary, design the program to stop the robot when the sensor signal is received.
(2) Design the program to stop the robot when an abnormal condition occurs in any other robots or peripheral devices, even though the robot itself is normal.
(3) For a system in which the robot and its peripheral devices are in synchronous motion, particular care must be taken in programming in order not to interfere with each other.
(4) Provide a suitable interface between the robot and its peripheral devices so that the robot can detect the states of all devices in the system, and can be stopped according to the states.

## 4.2 PRECAUTIONS FOR MECHANISM

(1) Keep the component cells of the robot system clean, operate the robot where insulated from the influence of grease, water, and dust.
(2) Don’t use unconfirmed liquid for cutting fluid and cleaning fluid.
(3) Adopt limit switches or mechanical stoppers to limit the robot motion, and avoid the robot from collisions against peripheral devices or tools.
(4) Observe the following precautions about the mechanical unit cables. Failure to follow precautions may cause mechanical troubles.
- Use mechanical unit cable that have required user interface.
- Do not add user cable or hose to inside of mechanical unit.
- Please do not obstruct the movement of the mechanical unit when cables are added to outside of mechanical unit.
- In the case of the model that a cable is exposed, please do not perform remodeling (Adding a protective cover and fix an outside cable more) obstructing the behavior of the outcrop of the cable.

- When installing user peripheral equipment on the robot mechanical unit, please pay attention that equipment does not interfere with the robot itself.

(5) The frequent power-off stop for the robot during operation causes the trouble of the robot. Please avoid the system construction that power-off stop would be operated routinely. (Refer to bad case example.) Please perform power-off stop after reducing the speed of the robot and stopping it by hold stop or cycle stop when it is not urgent. (Please refer to "STOP TYPE OF ROBOT" in SAFETY PRECAUTIONS for detail of stop type.)

(Bad case example)

- Whenever poor product is generated, a line stops by emergency stop and power-off of the robot is incurred.
- When alteration is necessary, safety switch is operated by opening safety fence and power-off stop is incurred for the robot during operation.
- An operator pushes the emergency stop button frequently, and a line stops.
- An area sensor or a mat switch connected to safety signal operates routinely and power-off stop is incurred for the robot.
- Power-off stop is regularly incurred due to an inappropriate setting for Dual Check Safety (DCS).

(6) Power-off stop of Robot is executed when collision detection alarm (SRVO-050) etc. occurs. Please try to avoid unnecessary power-off stops. It may cause the trouble of the robot, too. So remove the causes of the alarm.

# 5 SAFETY OF THE ROBOT MECHANICAL UNIT

## 5.1 PRECAUTIONS IN OPERATION

(1) Operating the robot in the jog mode, set it at an appropriate speed so that the operator can manage the robot in any eventuality.

(2) Before pressing the jog key, be sure to comprehend the robot movement by the key in advance.

## 5.2 PRECAUTIONS IN PROGRAMMING

(1) Design to arrange avoiding mutual interfere when various robot’s operation area crossover significantly.

(2) Be sure to specify the predetermined work origin in a motion program so that the robot starts from the origin and terminates at the origin. Make it possible for the operator to distinguish easily that the robot motion has terminated at a glance.

## 5.3 PRECAUTIONS FOR MECHANISMS

Keep the motion range areas of the robot clean, and operate the robot in an environment free of grease, water, and dust.

## 5.4 PROCEDURE TO MOVE ARM WITHOUT DRIVE POWER IN EMERGENCY OR ABNORMAL SITUATIONS

For emergency or abnormal situations (e.g. persons trapped in or pinched by the robot), brake release unit can be used to move the robot axes without drive power.

Please refer to controller maintenance manual and mechanical unit operator's manual for using method of brake release unit and method of supporting robot.

# 6 SAFETY OF THE END EFFECTOR

## 6.1 PRECAUTIONS IN PROGRAMMING

(1) Circumspect program with sufficient delay required for the program after executing some control command in adopting actuators (pneumatic, hydraulic, and electric)
(2) Adopt limit switches for the end effector, and control the robot system by monitoring the state.

# 7 STOP TYPE OF ROBOT

There are following three types of Stopping Robot.

### Power-Off Stop (Category 0 following IEC 60204-1)

Servo power is turned off, and the robot stops immediately. Servo power is turned off when the robot is moving, and the motion path of the deceleration is uncontrolled.
"**Power-Off stop**" performs following processing.

- An alarm is generated, and then the servo power turns off. Instantly the robot stops.
- Execution of the program is paused.

Frequent Power-Off stop of the robot during operation can cause mechanical problems of the robot.
Avoid system designs that require routine or frequent Power-Off stop conditions.

### Controlled stop (Category 1 following IEC 60204-1)

The robot is decelerated until it stops, and servo power is turned off.
"**Controlled stop**" performs following processing.

- The alarm "**SRVO-199 Controlled stop**" occurs along with a decelerated stop. The program execution is paused.
- An alarm is generated, and then the servo power turns off.

### Hold (Category 2 following IEC 60204-1)

The robot is decelerated until it stops, and servo power remains on.
"**Hold**" performs following processing.

- The robot operation is decelerated until it stops. Execution of the program is paused.

⚠ **WARNING**
The stopping distance and time of Controlled stop are longer than those of Power-Off stop. A risk assessment for the whole robot system which takes into consideration the increased stopping distance and stopping time, is necessary when Controlled stop is used.

When the emergency stop button is pressed or the FENCE is open, the stop type of robot is Power-Off stop or Controlled stop. The configuration of stop type for each situation is called *stop pattern*. The stop pattern is different according to the controller type or option configuration.

There are the following 3 Stop patterns.

| Stop pattern | Mode | Emergency stop button | External Emergency stop | FENCE open | SVOFF input | Servo disconnect |
|---|---|---|---|---|---|---|
| A | AUTO | P-Stop | P-Stop | C-Stop | C-Stop | P-Stop |
| | T1 | P-Stop | P-Stop | - | C-Stop | P-Stop |
| | T2 | P-Stop | P-Stop | - | C-Stop | P-Stop |
| B | AUTO | P-Stop | P-Stop | P-Stop | P-Stop | P-Stop |
| | T1 | P-Stop | P-Stop | - | P-Stop | P-Stop |
| | T2 | P-Stop | P-Stop | - | P-Stop | P-Stop |
| C | AUTO | C-Stop | C-Stop | C-Stop | C-Stop | C-Stop |
| | T1 | P-Stop | P-Stop | - | C-Stop | P-Stop |
| | T2 | P-Stop | P-Stop | - | C-Stop | P-Stop |

P-Stop: Power-Off stop
C-Stop: Controlled stop
-: Disable

The following table indicates the Stop pattern according to the controller type or option configuration.

| Option | R-30*i*B/ R-30*i*B Mate |
|---|---|
| Standard | A (*) |
| Controlled stop by E-Stop (A05B-2600-J570) | C (*) |

(*) R-30*i*B / R-30*i*B Mate does not have servo disconnect. R-30*i*B Mate does not have SVOFF input.

The stop pattern of the controller is displayed in "Stop pattern" line in software version screen. Please refer to "Software version" in operator's manual of controller for the detail of software version screen.

## "Controlled stop by E-Stop" option

When "**Controlled stop by E-Stop**" (A05B-2600-J570) option is specified, the stop type of the following alarms becomes Controlled stop but only in AUTO mode. In T1 or T2 mode, the stop type is Power-Off stop which is the normal operation of the system.

| Alarm | Condition |
|---|---|
| SRVO-001 Operator panel E-stop | Operator panel emergency stop is pressed. |
| SRVO-002 Teach pendant E-stop | Teach pendant emergency stop is pressed. |
| SRVO-007 External emergency stops | External emergency stop input (EES1-EES11, EES2-EES21) is open. |
| SRVO-408 DCS SSO Ext Emergency Stop | In DCS Safe I/O connect function, SSO[3] is OFF. |
| SRVO-409 DCS SSO Servo Disconnect | In DCS Safe I/O connect function, SSO[4] is OFF. |

**Controlled stop** is different from **Power-Off stop** as follows:

- In Controlled stop, the robot is stopped on the program path. This function is effective for a system where the robot can interfere with other devices if it deviates from the program path.
- In Controlled stop, physical impact is less than Power-Off stop. This function is effective for systems where the physical impact to the mechanical unit or EOAT (End Of Arm Tool) should be minimized.
- The stopping distance and time of Controlled stop is longer than the those of Power-Off stop, depending on the robot model and axis. Please refer to the operator's manual of a particular robot model for the data of stopping distance and time.

When this option is loaded, this function cannot be disabled.

The stop type of DCS Position and Speed Check functions is not affected by the loading of this option.

⚠ **WARNING**

The stopping distance and time of Controlled stop are longer than those of Power-Off stop. A risk assessment for the whole robot system which takes into consideration the increased stopping distance and stopping time, is necessary when this option is loaded.

150626

# TABLE OF CONTENTS

# APPENDIX

# 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.

## 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/ R-30*i*B Mate 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)" for other operations common to FANUC Robots.

## Contents of this manual

| | |
|---|---|
| **Chapter 1** | How to use this manual. |
| **Chapter 2** | An outline of the force sensor and the force control functions. |
| **Chapter 3** | Operations, teaching, and setup of the force control functions with the force sensor. |
| **Chapter 4** | How to check the status of the force sensor, the execution history of the foce control functions, and the graphical display of the force data log. |
| **Chapter 5** | Descript the screen of force sensor utilities. |
| **Chapter 6** | How to use the function of Weight and Gravity Center Calculation. |
| **Chapter 7** | How to use the function of TP Program Auto Generation. |
| **Chapter 8** | How to measure workpiece’s mass while robot moves. |
| **Chapter 9** | How to check recorded force with 4D graphics function. |
| **Chapter 10** | See this chapter when the alarms occur. |
| **Appendix A** | Types of screens and hierarchical configuration of these screens. |
| **Appendix B** | Types of alarms, how to check alarms, and how to recover from alarms. |
| **Appendix C** | How to setup the attatchment type of force sensor |

## Related manuals

The following manuals are available for using the force sensor.

| | |
|---|---|
| **R-30*i*B/R-30*i*B Mate** CONTROLLER<br>OPERATOR’S MANUAL<br>(Basic Operation)<br>B-83284EN | Topics: Robot functions, operations, programing, interfaces, alarms<br>Use: Application design, Robot operation, teaching, system design |
| **R-30*i*B** CONTROLLER<br>MAINTENANCE MANUAL<br>B-83195EN | Topics: System installation, start-up, connection to peripheral equipment, maintenance<br>Use: System installation, start-up, connection, Maintenance |
| **R-30*i*B Mate** CONTROLLER<br>MAINTENANCE MANUAL<br>B-83525EN | Topics: System installation, start-up, connection to peripheral equipment, maintenance<br>Use: System installation, start-up, connection, maintenance |
| **R-30*i*B/R-30*i*B Mate** CONTROLLER<br>Force Sensor<br>OPERATOR’S MANUAL (this manual)<br>B-83424EN | Topics: Force sensor functions, operations, programming, alarms<br>Use: Teaching, installation |
| **R-30*i*B/R-30*i*B Mate** CONTROLLER<br>Force Control Deburring Package<br>OPERATOR’S MANUAL<br>B-83424EN-1 | Topics: Force Control Deburring Package functions, operations, programming, alarms<br>Use: Teaching, installation |

| | |
|---|---|
| **R-30*i*B/R-30*i*B Mate** CONTROLLER<br>Sensor Mechanical Unit/Control Unit<br>OPERATOR'S MANUAL<br>B-83434EN | Topics: Connection of the sensors, robots and controllers,<br>maintenance of the sensors,<br>design of the adapter for tool<br>Use: Connection of the sensors, maintenance |

# 2 OVERVIEW OF FORCE SENSOR AND FORCE CONTROL

This chapter describes an overview of the force sensor configurations and the force control functions.

**CONTENTS**



## 2.1 FORCE SENSOR 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. Refer to table 2.3 (b).

### 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.

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

**Table 2.1 Force sensor attachment**

| Attachment type | Description |
|---|---|
| Hand mount sensor | This is the standard configuration. |
| 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. |

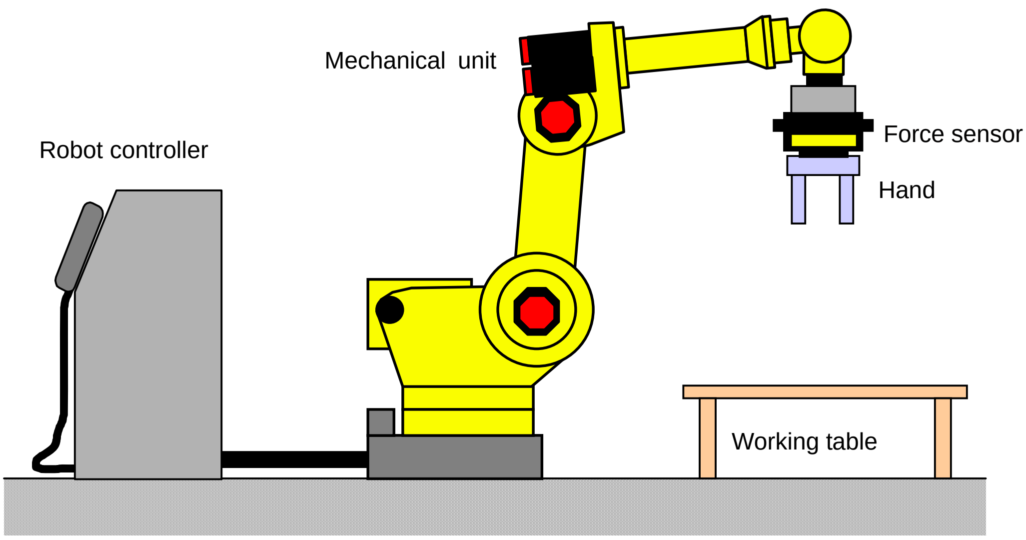



**Fig.2.1(a) Standard configuration (hand mount sensor)**

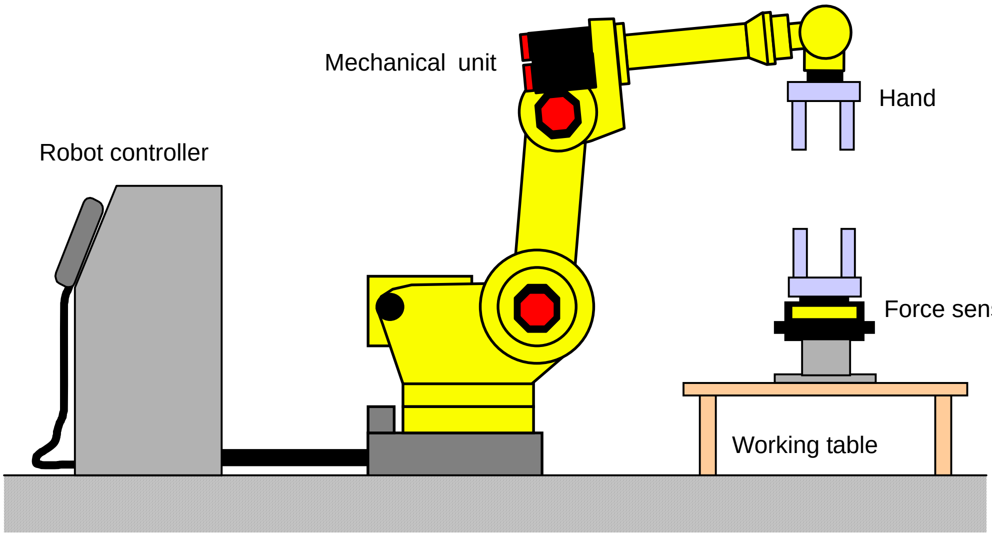



**Fig.2.1(b) Fixed configuration (fixed mount sensor)**

## Setting of Force Sensor Attachment

The setting is not usually needed, but in the following cases the setting of force sensor is necessary. For details, refer to Appendix C, "FORCE SENSOR ATTACHMENT SETTING FUNCTION".

1 The attachment type is "HAND", if either of the following condition is met.
  - Offset adapter plate between robot flange and the force sensor.
  - 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)

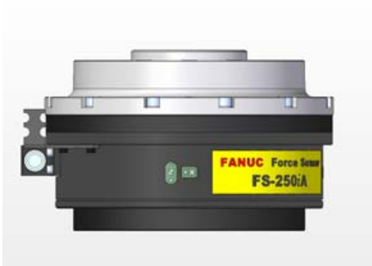
2 The attachment type is "FIXED", if the sensor is mounted on a remote fixture.

## Types of Standard Adapters

For some series of force sensors, there are two types of standard adapters, as are shown in Fig.2.1.

1 Standard adapter (torque wrench needed) : Torque wrench is required to mount the force sensor to the adapter.

2 Standard adapter (torque wrench not needed) : Force sensor is factory mounted to the adapter and torque wrench is not required to mount the adapter to the robot wrist.




**Standard adapter (torque wrench needed)**


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

**Fig.2.1(c) FS-250iA's Standard adapters**

# 2.2 FUNCTIONS ENABLED BY FORCE CONTROL

## 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, shaft insertion, and phase match insertion. For each application, optimum setting can be made.
For detailed application examples, see Section 3.3, "FORCE CONTROL INSTRUCTIOINS".

## Conditions for enabling Force Control

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.

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 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.

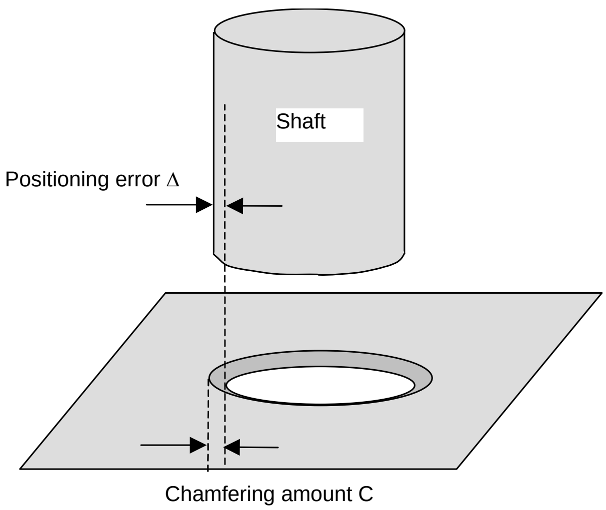



**Fig. 2.2 Application example of the force control function**

- 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.
  For further details, see Subsection 3.5.6, "Search Function" or Subsection 3.5.6.5, "Hole Search".

# 2.3 TYPES OF FORCE CONTROL INSTRUCTIONS

## Instructions for programming

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

## Instructions related to force control

There are nine types of force control instructions as shown in Table 2.3(a). "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 (a) Instructions related to force control**

| Instruction | Description |
|---|---|
| FORCE CTRL | Instruction for executing force control.<br>There are 13 force control functions in total. Select an appropriate function according to the workpiece and the type of application.<br>After selecting a function, set the basic parameters such as a force value and velocity value using the force schedule data.<br>For details, see Section 3.3, "FORCE CONTROL INSTRUCTIONS" and Section 3.5, "SCHEDULE DATA". |
| SENSOR DIAGNOSIS | This instruction checks whether the force sensor has a problem. See Subsection 3.10.1, "Force Sensor Diagnosis Instructions". |
| GET DIAG DATA | This instruction checks whether the force sensor has a problem. See Subsection 3.10.1, "Force Sensor Diagnosis Instructions". |
| AUTO TUNING ON/OFF | This instruction is used to automatically tune the gain that decides force control responsiveness.<br>See Subsection 3.10.2, "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.<br>See Subsection 3.10.3, "Torque Error Acquisition Instructions". |
| END COND ON/OFF | This instruction automatically measures the depth by which the workpiece is inserted.<br>See Subsection 3.10.4, "End Condition Acquisition Instructions". |

## 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]

For overview information about the schedule number and label number, see Table 2.3 (b). For details on the force control instructions, see section 3.3, "FORCE CONTROL INSTRUCTIONS".

**Table 2.3 (b)**

| Item | Description |
|---|---|
| **Schedule Number** | A schedule is a data set designed to perform a specific force control function<br>The 15 executable functions specified in the schedule data are as follows. For details on the following functions, see 3.3 “FORCE CONTROL INSTRUCTIONS” and 3.5 “SCHEDULE DATA”. With the 3-axis force sensor, available function is limited to "Constant Push" or "Contouring" or "Contouring End".<br><br>• Constant Push.<br>• Face Match<br>• Shaft Insert<br>• Groove Insert<br>• Square Insert<br>• Phase Match Ins.<br>• Ins. Phase Match<br>• Search<br>• Phase Search<br>• Hole Search<br>• Clutch Search<br>• Contouring• Contouring End<br>• Threading |
| **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. |

## 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. For details, see Section 3.5, "SCHEDULE DATA".

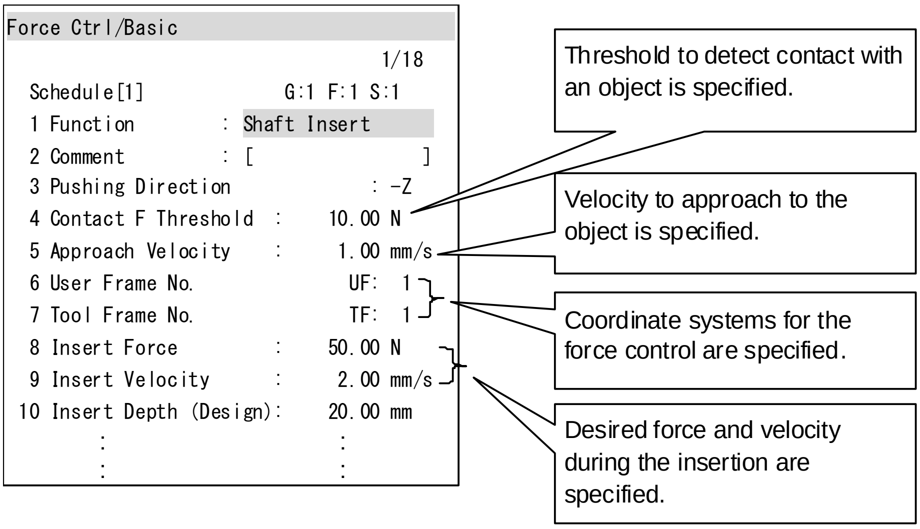



**Fig. 2.3 Schedule setup for the force control**

# 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 Chapter 8 "MASS MEASUREMENT BY FORCE SENSOR".

# 3 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.

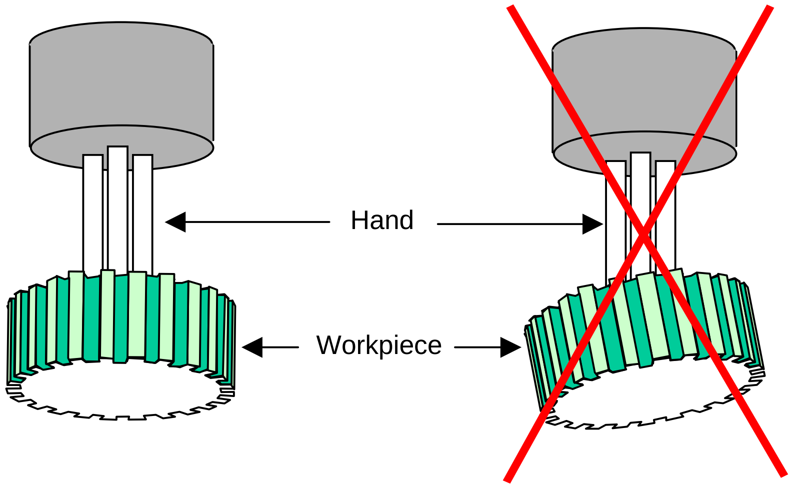
In addition to the robot motion and logic instructions, the force control instructions are programmed for the desired production operation. The basic and the performance data in the force schedule are used to operate the robot during the execution of the force control instruction. The basic data defines 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, see Section 3.5, "SCHEDULE DATA".

**CONTENTS**



## 3.1 NOTES / RESTRICTIONS

1. Collision detection is disabled during the force control operation. The function is enabled again once the execution of the force control instruction is completed.
2. Brake control is disabled during the force control operation. Brake control is enabled again once the execution of the force control instruction is completed.
3. Robot speed override is not applied during the force control operation except for the contouring operation. (e.g. Insertion is performed at the insertion velocity, despite the robot speed override setting).
4. The Force control instruction cannot be restarted after a temporary stop, nor can it be executed backwards.
5. Design a rigid hand with sufficient holding force to prevent a workpiece from slipping or shifting during force control.
6. Refer to Section 2.1, “FORCE SENSOR OVERVIEW” for sensor configurations, and Appendix C, “FORCE SENSOR ATTACHMENT SETTING FUNCTION” for the sensor set-up procedure.




The hand can hold the workpiece securely during force control.

The workpiece is shifted during force control.

**Fig.3.1 Sample hand design**

# 3.2 TEACHING PROCEDURE

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 is as described below:

1 Specify the tool frame and user frame as shown in Fig.3.2(a).
- 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.
- 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.

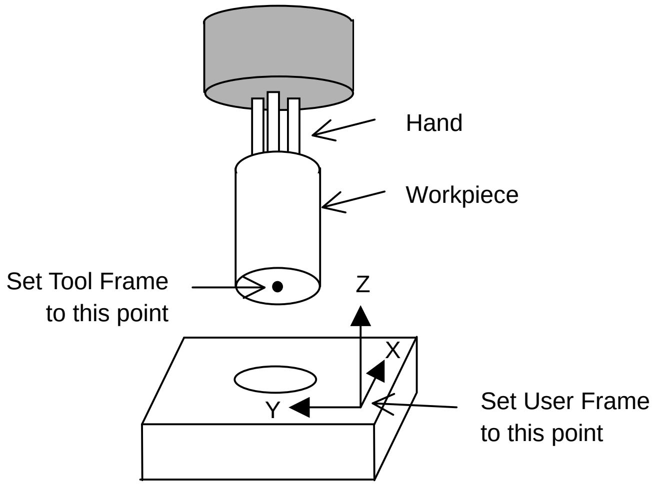


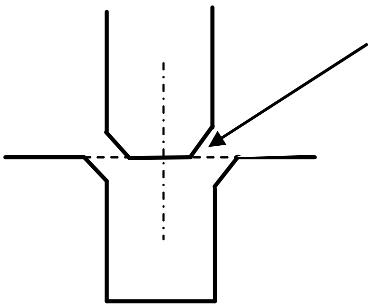

**Fig.3.2(a) Set the user frame and tool frame**

2 Select the tool frame and user frame specified above, and then create a robot operation program as shown in Fig.3.2(b). Add an approach point, where the robot switches from normal position control to force control, to the program and teach its position.
Several functions are provided for force control (see Section 3.3, "FORCE CONTROL INSTRUCTIONS"). The way to teach an approach point slightly varies from function to function. Refer to Fig.3.2(c) and teach this point correctly.

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

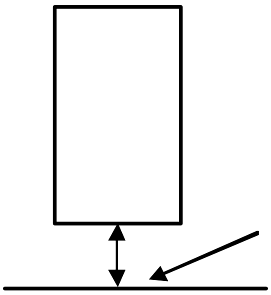
**Fig.3.2(b) Create a TP program with an approach point**

For “Shaft Insert”, “Groove Insert”, “Square Insert”, “Ins. Phase Match” , “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.

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



Teach an approach point about 2 to 5mm above the plane.

For “Clutch Search”

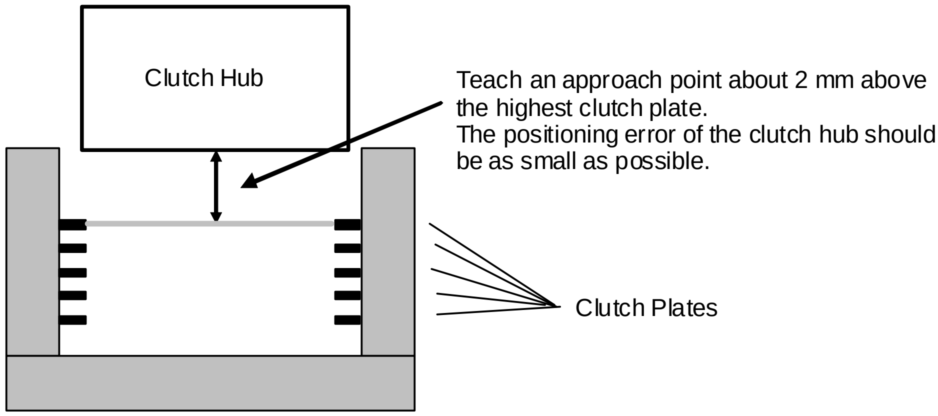



**Fig.3.2(c) Teach an approach point**

3 Insert a Force control instruction behind the approach point, as is shown in Fig.3.2(d). For details on the force control instructions, see section 3.3, "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.3.2(d) Add a force control instruction to the TP program**

4 Specify the Basic data of the Schedule data. For the basic data, see Section 3.5, "SCHEDULE DATA". The parameters to be set vary depending on the force control instruction. Refer to Subsection 3.5.2, “Constant Push / Face Match” ~ 3.5.7, “Contouring Function” for further details.
5 Insert an Auto tuning instruction to the program and then perform Force control gain automatic tuning. For automatic tuning of Force control gain, see Subsection 3.10.2, " Force Control Gain Auto Tuning Instruction".
6 After the Auto tuning instruction has been executed normally, delete the Auto tuning instruction from the program.
7 Execute the force control instruction and adjust basic data of the force schedule. When necessary, specify the performance data of the force schedule

# 3.3 FORCE CONTROL INSTRUCTIONS

Fig. 3.3(a) and Fig.3.3(b) show the screens for selecting Force control instructions.

Selecting F1(INST) in the left-hand screen in Fig.3.3(a) shows the right-hand “Instruction” screen.

```
TEST
                                  1/1
[End]




[ INST ]                    [ EDCMD ]
```

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

F1 F2 F3 F4 F5

**Fig.3.3(a) Selection of force control instruction**

Choose [3 Force Control]. The following selection screen is displayed.

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

**Fig.3.3(b) Force control instruction selection screen**

Select [1 FORCE CTRL] to add a force control instruction to the TP program, as is shown in Fig.3.3(c).

```
TEST
                                  1/2
   1:   FORCE CTRL[...:]
    :   ErrorLBL[0]
[End]

Enter value

      DIRECT INDIRECT [CHOICE]
```

F1 F2 F3 F4 F5

**Fig.3.3(c) Adding a force control instruction**

## Overview

The “FORCE CTRL” instruction provides the functions shown in Table 3.3 classified by application. Select the most suitable function for the operation from these instructions.
For details of the functions, see the corresponding items in Section 3.5, "SCHEDULE DATA".
With the 3-axis force sensor, available function is limited to "Constant Push" or "Contouring" or "Contouring End".

**Table 3.3 Types of force control functions**

| Function | Description |
|---|---|
| Unused | Schedule data is not used. Force control cannot be performed using an Unused schedule. See Subsection 3.5.1 “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. See Subsection 3.5.2 “Constant Push / Face Match”. |

| Function | Description |
|---|---|
| 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. See Subsection 3.5.2 “Constant Push / Face Match”. |
| Shaft Insert | This function inserts a cylindrical mechanical component such as a shaft or a positioning pin. See Subsection 3.5.3 “Shaft Insert / Bearing Insert / Groove Insert / Square Insert”. |
| Groove Insert | This function inserts a quadrangular prism workpiece into a groove. See Subsection 3.5.3 “Shaft Insert / Bearing Insert / Groove Insert / Square Insert”. |
| Square Insert | This function inserts a quadrangular prism workpiece into a rectangular hole. See Subsection 3.5.3 “Shaft Insert / Bearing Insert / Groove Insert / Square Insert”. |
| Phase Match Ins. | This function first performs phase matching then performs insertion, such as inserting a key shaft to a hole with key way and gear engagement. This function is similar to "Phase Search". The number of parameters to be set for this function is smaller than that for "Phase Search", and consequently this function provides limited capabilities. See Subsection 3.5.4 “Phase Match Insert”. |
| Ins. Phase Match | Phase matching that is preceded by insertion can be done. This function performs reversely with “Phase Match Insert”. See Subsection 3.5.5 “Insert Phase Match”. |
| 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. See Subsection 3.5.6 “Search Function”. |
| Phase Search | This function performs phase matching of teeth, such as the key shaft insertion and the gear engagement. See Subsection 3.5.6 “Search Function”. This function is similar to the "Phase Match Ins." function but differs in the following:<br>• When the torque is sensed during phase matching, "Phase Search" causes an inversion in the search direction.<br>"Phase Search" performs phase matching by slightly changing the rotation velocity and torque so as not to damage the workpiece.<br>• "Phase Match Ins." first performs phase matching then performs insertion, while "Phase Search" performs phase matching only. To perform insertion successively after phase matching, execute "Shaft Insert" in succession.<br>For successive execution, see Section 3.7, "SUCCESSIVE EXECUTION OF FORCE CONTROL INSTRUCTIONS". |
| 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, See Section 3.7 “SUCCESSIVE EXECUTION OF FORCE CONTROL INSTRUCTIONS”. See Subsection 3.5.6 “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. See Subsection 3.5.6 “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. See Subsection 3.5.7, "Contouring Function". |
| Contouring End | This instruction ends Contouring being executed. See Subsection 3.5.7, "Contouring Function". |
| Threading | This instruction fastens screws with robot wrist or extended axis. Tightening torque is checked by force force sensor. See Subsection 3.5.8, "Threading Function". |

## Instruction

```
FORCE CTRL[ 1 ]
ERROR LBL[ 0 ]
```

Schedule Number

Error Label Number

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 Section 3.5, "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. The following (Fig.3.3 (d)) is an example that when an error occurs while executing Force control, the robot releases the hand, the failed workpiece is released and the robot restarts the operation for the following workpiece.

### Selecting force control functions

Force control functions listed in Table 3.3 are selected on the schedule data setting screen. See Section 3.5, "SCHEDULE DATA".

```
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:   ! Go out 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 Number is 1.
Error Label Number is specified to 2.

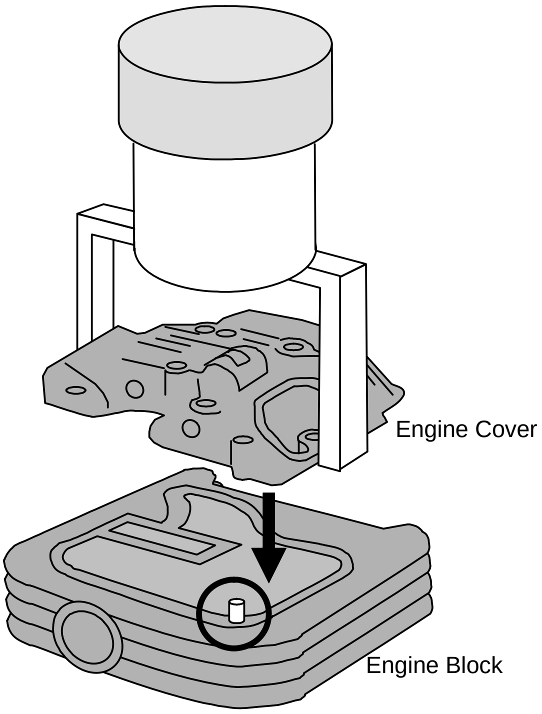
If Force control error occurs,
Jump here.

**Fig.3.3 (d) Example of error recovery**

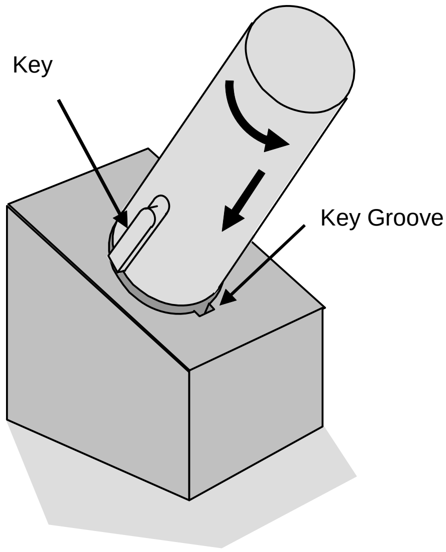
A program, as shown in Fig. 3.4 in Section 3.4, "SAMPLE PROGRAM", can also be created to perform retry operation when an error occurs. See Fig. 3.4 for details.

For the retry function, see Subsection 3.7.2, "Retry".

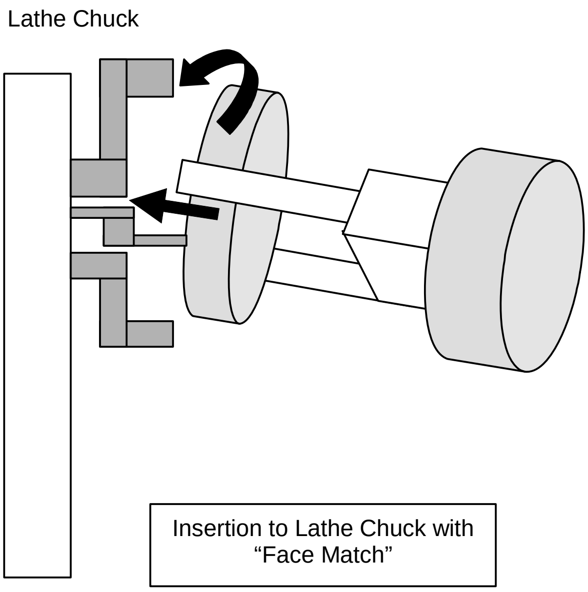
Fig. 3.3 (e) shows diagrams of force control applications.



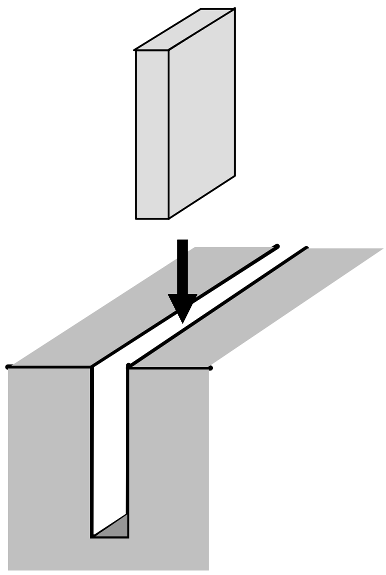

Engine Assembly with “Shaft Insert”
(Insertion of Knock Pin)




Transmission Assembly
with “Phase Match Ins.”

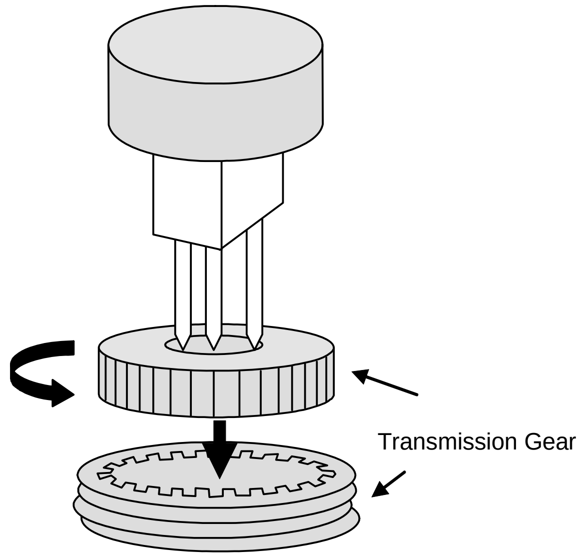



Insertion to Lathe Chuck with
“Face Match”

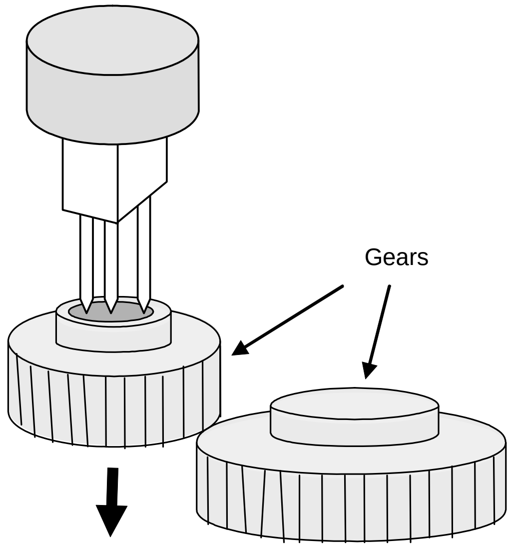


Insertion of a Quadrangular Prism Part
into a Groove with "Groove Insert"

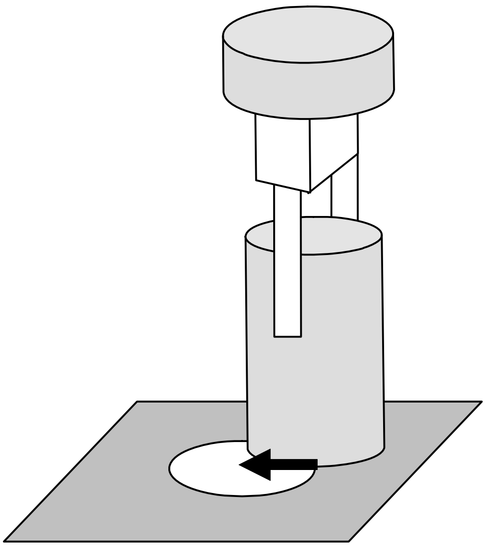
**Fig.3.3 (e) Applications of force control(1/3)**



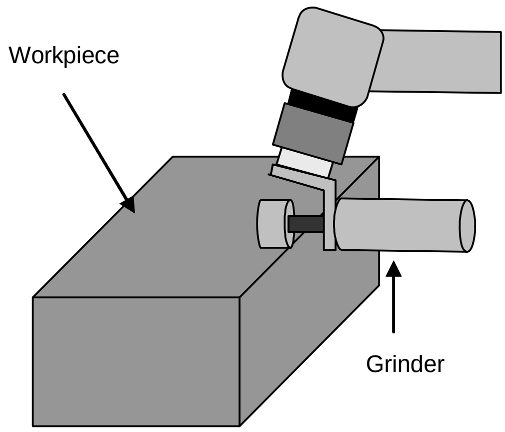

Transmission Assembly with
"Clutch Search"




“Phase Matching of Gear Parts with
"Phase Search"

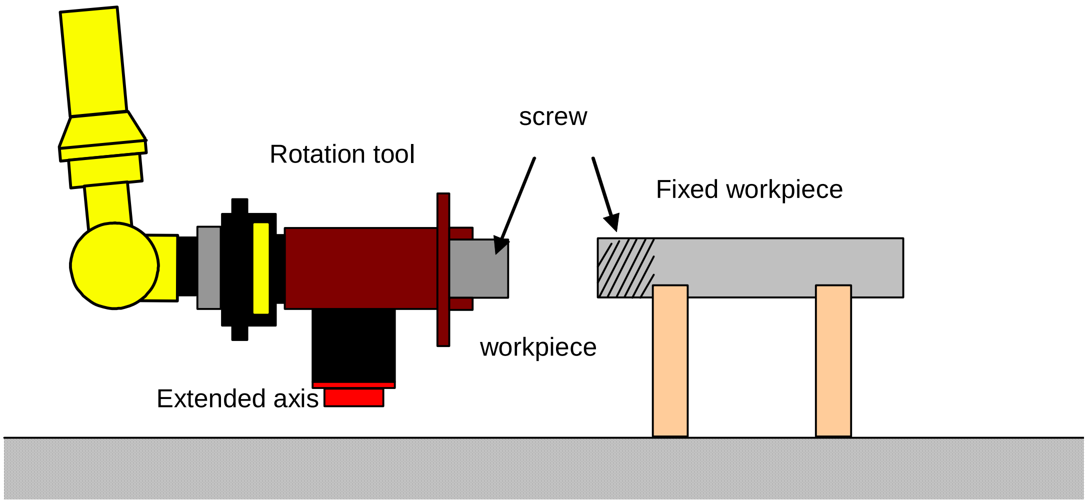


Search for Insertion Hole Position with
"Hole Search"




Grinding the surface of work with "Contouring"

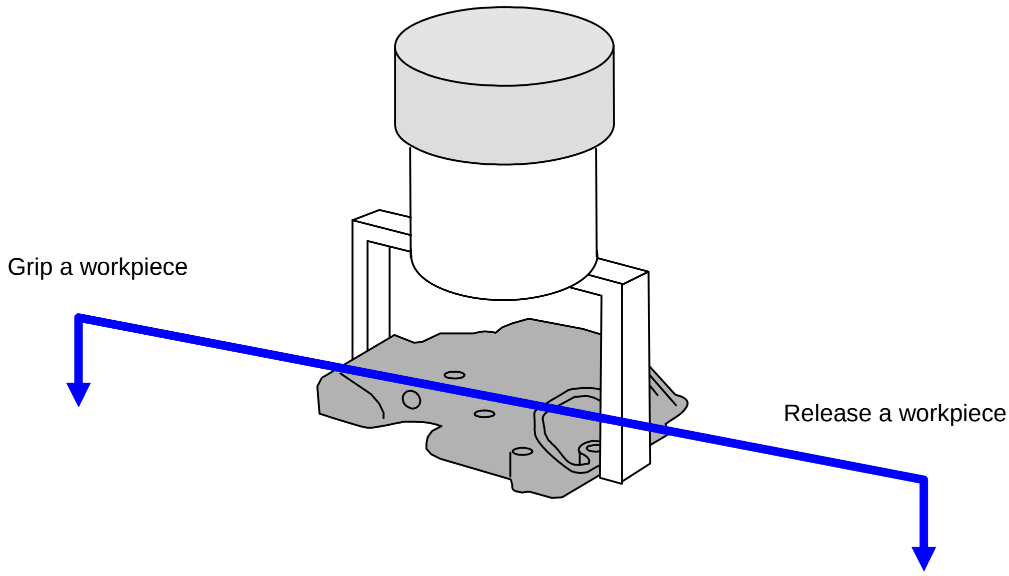
**Fig.3.3 (e) Applications of force control(2/3)**




"Threading" : Extended axis is used for threading with tightening torque

**Fig.3.3 (e) Applications of force control(3/3)**

Fig. 3.3 (f) shows a diagram of mass measurement while moving with a force sensor.




Workpiece mass measurement while moving

**Fig.3.3 (f) Other Application of force sensor**

# 3.4 SAMPLE PROGRAM

```
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]
```

Lines 1–10: Handles the workpiece.

Lines 11–19: The handled workpiece is fitted into another workpiece by the force control.

Line 21: If force control insertion is successful, control returns to the beginning to the program to repeat processing.

Lines 22–26: 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, see Subsection 3.7.2, "Retry".

Lines 28–52: If a failure occurs while the workpiece is being pulled out, an alarm is issued.

**Fig. 3.4 Sample program**

# 3.5 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. To open the schedule data screen, select the following:

DATA → F1 [TYPE] → [Force Ctrl]

After the completion of the operation illustrated above, the Schedule data list screen appears as shown in Fig. 3.5(a). A schedule item having no settings is indicated as “Unused” in the “Function” column. If a function is specified, the function name is indicated in the “Function” column. There are 14 kinds of function names now as shown in Table 3.3 of the Section 3.3.

The Schedule data list screen has two types of the screen (Fig3.5(a))、these screens can be switched by pushing [F5] on these screens.

The comment that is set in the detailed schedule data screen described in this section is displayed on the right side of schedule data list1. Additionally the user frame No., the tool frame No. and the customize parent No. are displayed on the right side of schedule data list2. For details on the customization function, see Subsection 3.7.3, "Specifying the Parent-Child Relationship".

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 Phase Match Ins.  [                 ]
   9 Ins. Phase Match  [                 ]
  10 Groove Insert     [                 ]

[ 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 Phase Match Ins.  U: 0   T: 1   P:  0
   9 Ins. Phase Match  U: 0   T: 1   P:  0
  10 Groove Insert     U: 0   T: 1   P:  0

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

**Fig.3.5(a) Schedule data list screen**

## Function keys

The function keys indicated in Fig. 3.5(a) have the following functions:

| 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 | Allows you to display the detailed schedule data screen. |
| Shift + F4 | COPY | Copies the data of a schedule item to another one. |
| F5 | LIST1 / LIST2 | Allows you to switch between list1 and list2. |

On these screens, position the cursor to the schedule item to be specified, then press “F3, DETAIL”. The detailed data screen appears as shown in Fig. 3.5(b). The detailed data is divided into two types: basic data, which must be specified, and performance data, which is specified, for instance, only when special operation needs to be adjusted. Under certain conditions, some objects may require the setting of the performance data. Usually, only the basic data will be enough

```
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


[ TYPE ]  GROUP  NUMBER  DEFAULT PERFORM
```

F1 F2 F3 F4 F5

**Fig.3.5(b) Example of detailed data**

### Function keys

The function keys indicated in Fig. 3.5(b) have the following functions:

| 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. |
| 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. |

## 3.5.1 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”. To avoid confusion, it is recommended that “Unused” also be selected for schedule data that has been used for force control but which is no longer needed because, for instance, the workpiece has been changed.

Function selection screen

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

Basic screen

```
Force Ctrl/Detail
                                    3/4
  Schedule[1]           G:1 F:1 S:1
  1 Function        : Unused
  2 Comment         : [               ]
  3 User Frame No.             UF:  1
  4 Tool Frame No.             UT:  1


[ TYPE ]  GROUP   NUMBER
```

F1 F2 F3 F4 F5

**Fig.3.5.1 Teaching “Unused” detailed data**

### Function keys

The function keys indicated in Fig. 3.5.1 have the following functions:

| 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. |

### 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"

### ［Basic Data Screen］

### 1 Function

A desired function is selected from "Function selection screen" in Fig.3.5.1. For the functions, see Table 3.3 or from the Subsection 3.5.2 to 3.5.7.

### 2 Comment

Enter a comment for identifying the schedule data.

### 3 User Frame No.

This is the user frame number. The number of the user frame used most recently is displayed for guidance.

### 4 Tool Frame No.

This is the tool frame number. The number of the tool frame used most recently is displayed for guidance.

## 3.5.2 Constant Push / Face Match

### Overview

In the menu of "Constant Push" function, the settings for a soft push of a workpiece at a single point, such as for the arrangement of components along a guide, can be made.
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.
"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]
Otherwise, if you use 3-axis force sensor, its own parameters are added in the basic screen of "Constant Push" (Fig.3.5.2(a)). Refer to [Basic Data Screen]
And in case of using 3-axis force sensor, "Face Match" function can't be used.

Function selection screen

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

Basic screen

```
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  DEFAULT 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         : Constant Push
 1 Pushing Impedance   : [Master Freq. ]

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

Performance screen

```
Force Ctrl/Perform
                                        1/25
 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:  OFF
11 Settling Switch          :OFF
12   Settling Time      :     1.00 sec
13   Settling Rate      :   100.00 %
   Force Limit
14  X:  500.00 Y:  500.00 Z:  500.00 N
15  W:   50.00 P:   50.00 R:   50.00N*m
16 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
17 Force End Judgment Switch : OFF
18   Min. Force Rate   :     80.00 %
     Judgment Result   :       -------
      Force Average  Z:       0.00 N
19 Approach Acc. Time :       0.70 sec
20 Force Denoising Sw    :  OFF
21 Signal Output for ERR SW: OFF
22   Output Signal Type   :   DO
23   Output Signal Number:       0
24 Frc.Ctrl. End by REG SW : OFF
25   End Register Number :       0

[ TYPE ] GROUP  NUMBER  DEFAULT  BASIC
   F1     F2      F3      F4      F5
```

**Fig.3.5.2(a) Teaching “Constant Push” detailed data**

Function selection screen

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

Basic screen

```
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 Pushing Time         :    20.00 sec
 11 F.Ctrl. Gain Auto Modify  :      OFF
      Prev. Result      : No Change
 12 Force Control Gain :          Detail


 [ TYPE ] GROUP  NUMBER  DEFAULT 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
```

Performance screen

```
Force Ctrl/Perform
                                          1/28
  Schedule[1]              G:1 F:1 S:1
  1 Function          : Face Match
  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 Settling Switch          :OFF
 12   Settling Time       :     1.00 sec
 13   Settling Rate       :   100.00 %
    Force Limit
 14  X:  500.00 Y:  500.00 Z:  500.00 N
 15  W:   50.00 P:   50.00 R:   50.00N*m
 16 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
 17 Force End Judgment Switch : OFF
 18   Min. Force Rate   :      80.00 %
      Judgment Result   :        -------
       Force Average  Z:        0.00 N
 19 Torque End Judgment Switch: OFF
 20   Max. Torque       :      0.50 N*m
      Judgment Result   :        -------
       Torque Average W:     0.00 N*m
                      P:     0.00 N*m
 21 Vel. End Judgment Switch  : OFF
 22   Max. Velocity     :       0.30 mm/s
      Judgment Result   :        -------
       Vel. Average   Z:        0.00 mm/s
 23 Fast Ins. Switch    :        ON
 24   Fast Ins. Multiplier :      2.00
 25   Fast Ins. Acc. Time:     0.40 sec
 26 Approach 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
   F1      F2      F3      F4      F5
```

**Fig.3.5.2(b) Teaching “Face Match” detailed data**

### Function keys

The function keys indicated in Fig. 3.5.2(a) and (b) have the following functions:

| 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. |
| 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. |

### G F S

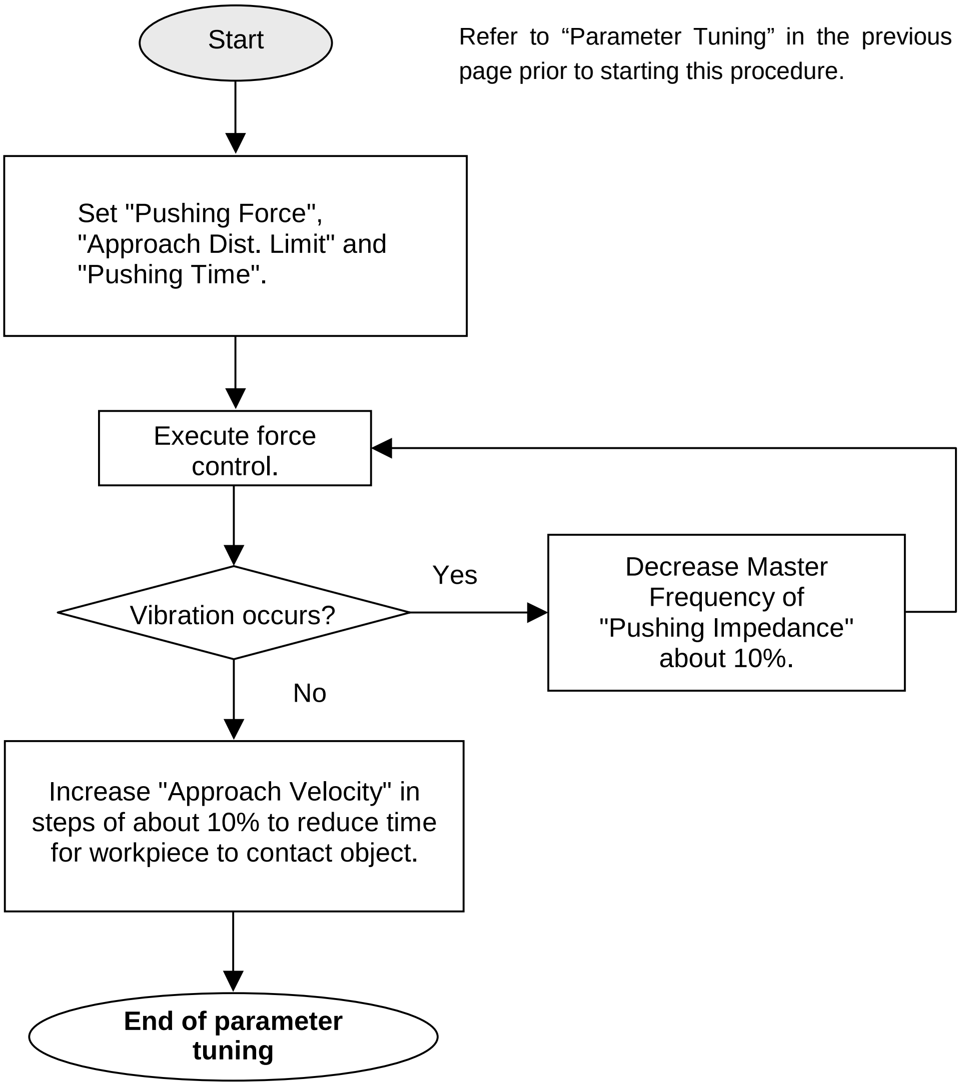
G represents a motion group number at the time of teaching. F represents a force control number. S represents a force sensor number. (These settings cannot be changed.)
"Defaults : 1 1 1"

## Parameter tuning

The following parameter setting sequence is used:

1 Set "Pushing Direction", "User Frame No.", and "Tool Frame No.".
2 Make an automatic force control gain adjustment. (See Subsection 3.9.2.)
3 Set the parameters on the basic screen.
4 Tune parameters on the performance screen as required.

For the outline of force control instruction programming, see Section 3.1, "NOTES/RESTRICTIONS", and Section 3.2, "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.




## ［Basic Data Screen］

**Parameters shown in this section must be set.**

### 1 Function

A desired function is selected from "Function selection screen" in Fig.3.5.2. In this case, choose from “Constant Push” or “Face Match”.

### 2 Comment

Enter a comment for identifying the schedule data.

### 3 Pushing Direction

This is the pushing direction in the user frame of “User Frame No.”
“Default : -Z”
If the "Function" is "Constant Push", the message in front of the setting value of the pushing direction means as follows:

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. For details, see Section 3.8, "User Frame Compensation".

User: The "User Frame Compensation" in the "Performance data" is set to other than "TOOL FRAME". For details, see Section 3.8, "User Frame Compensation".

### 4 Contact F Threshold

This is the threshold to judge contact to the work object. The cycle time might deteriorate when this value is enlarged too much because an actual pushing begins after contact.
“Default : 10 N”

### 5 Approach Velocity

This is the target speed until coming in contact with the work object.
“Default : 1 mm/sec”

### 6 User Frame No.

This is the user frame number used at force control. Set the user frame number that is set along Section 3.2, “TEACHING PROCEDURE”.
“Default : 0”

### 7 Tool Frame No.

This is the tool frame number used at force control. Set the tool frame number that is set along Section 3.2, “TEACHING PROCEDURE”.
“Default : 1”

### 8 Pushing Force

This is the target pushing force in “Pushing Direction”.
"Unit : N"

### 9 Approach Dist. Limit

Specify a distance that the workpiece can move during force control. An alarm is issued if the workpiece does not contact the object when the workpiece has moved a distance greater than the value specified in this parameter.
“Default : 5 mm”

### 10 Pushing Time

This item specifies a time to be used for constant pushing or face matching. When a specified time has elapsed after contact, constant pushing or face matching ends.
“Default : 20 sec”

### [In the case of Constant Push and Not 3-axis force sensor]
### [In the case of Face Match]

### 11 F.Ctrl. Gain Auto Modify

This item is the switch used for automatic force control gain tuning. For details, see Subsection 3.9.2, "Force Control Gain Auto Tuning Instruction".
"Default : OFF"

### 12 Force Control Gain

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, see Section 3.6, "FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".

### [In the case of Constant Push and 3-axis force sensor]

The following parameters from "3-Axis FS ContactP. Position(Constant Push and 3-axis FS)" to "Distance(3-Axis ContactP. Position)" are specific to 3-axis force sensor. See section 3.9, "3-AXIS FORCE SENSOR SETTING" that has conceptual diagrams.

### 11 3-Axis FS ContactP. Position (Constant Push and 3-axis FS)

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.
The choices mean as follows:

TOOL:

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

USER:

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.

### 12 Setting Method (3-Axis ContactP. Position) (Constant Push and 3-axis FS)

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.
Choices are as follows:

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.:

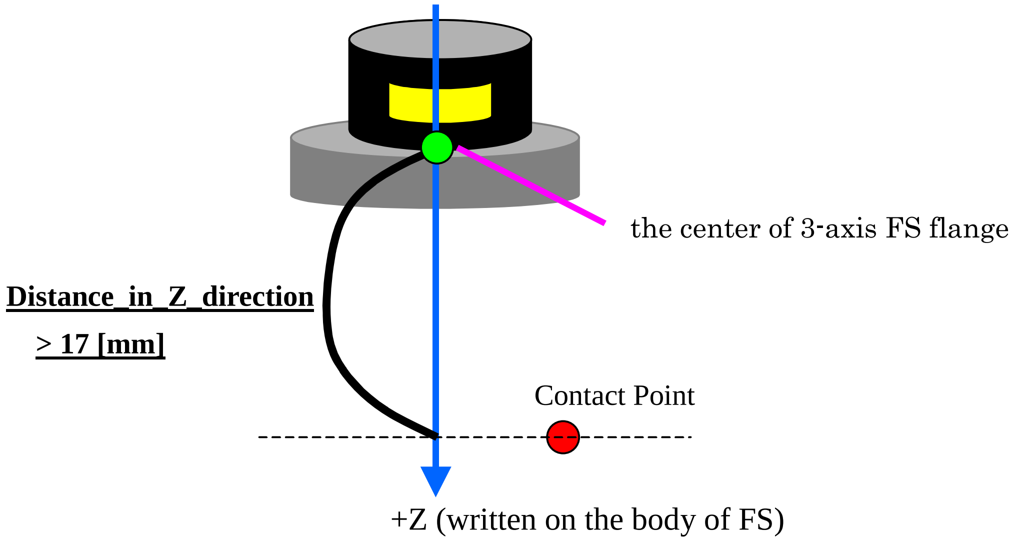
The position of a contact point is set to the values of X, Y, Z that are set to the position register, designated by after-mentioned "Pos. Reg. No.", at the beginning of the force control.
If "3-Axis FS ContactP. Position" is "TOOL", the position of a contact point is set to the values of the position 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.".

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) must be larger than 17 [mm] during the force control. Be careful about this especially when the distance changes dynamically with robot motion.




## 13 Pos. Reg. No. (3-Axis ContactP. Position) (Constant Push and 3-axis FS)

This parameter specifies a position register number if "Setting Method" is set to "Pos. Reg." for the 3-axis force sensor.

## 14 Distance (3-Axis ContactP. Position) (Constant Push and 3-axis FS)

This parameter specifies a distance if "Setting Method" is set to "PushDirShift" for the 3-axis force sensor.
"Unit : mm"

## 15 F.Ctrl. Gain Auto Modify (Constant Push and 3-axis FS)

This item is the switch used for automatic force control gain tuning. For details, see Subsection 3.9.2, "Force Control Gain Auto Tuning Instruction".
"Default : OFF"

## 16 Force Control Gain (Constant Push and 3-axis FS)

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, see Section 3.6, "FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".

## [Performance Data Screen]

**Parameters shown in this section are for advanced users.**

### 1 Function

A desired function is selected from "Function selection screen" in Fig.3.5.2. In this case, choose from “Constant Push” or “Face Match”.

### 2 Comment

Enter a comment for identifying the schedule data.

### 3 Simple Customize Sw

This parameter specifies a switch for "Simple Customize" function. It enables to execute the schedule data being edited after any other schedule.
For details, see Subsection 3.7.3, "Simple Customization Function".
"Default: OFF"

### 4 Cont. Exec. Max. Count

It designates how many force schedules with "Simple Customize Sw" ON can be executed successively.
For details, see Subsection 3.7.3, "Simple Customization Function".
"Default : 1"

### 5 Customize Parent Number

This item is set when force control is executed successively. For details, see Subsection 3.7.3, "Specifying the Parent-Child Relationship".
"Default: 0"

### 6 Customize ParaChg Connection

This item is set when force control is executed successively. For details, see Subsection 3.7.3, "Specifying the Parent-Child Relationship".
"Default: OFF "

### 7 Customize Auto. Cnt. Exec. Sw (Customize Auto. Cnt. Exec.)

This parameter specifies a switch for "Customize Auto. Cnt. Exec." function.
"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.
For details, see Subsection 3.7.5, "Customization Automatic Continuous Execution Function".
"Default: OFF"

### 8 Auto. Cnt. Exec. Child No. (Customize Auto. Cnt. Exec.)

This parameter specifies a schedule data number of its child schedule data. The child schedule data is a schedule data that is executed next.
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.

### 9 Schedule No. Output Reg. No. (Customize Auto. Cnt. Exec.)

This parameter specifies a Numeric Register Number to which "Customize Auto. Cnt. Exec." function output the execution state.

When "Customize Auto. Cnt. Exec." function is executing, this function outputs a running schedule data number. If the series of the schedule data ends normally, this function outputs 0.
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.

### 10 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.
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".
For details, see Section 3.8, "User Frame Compensation".
"Default : OFF"

### 11 Settling Switch

Settling involves reducing the pushing force after pushing is completed. Settling is useful if the workpiece tends to vibrate because of the impact caused by the removal of the robot hand, for instance.
"Default : OFF"

### 12 Settling Time

Settling is performed over this “Settling Time”.
"Default : 1 sec"

### 13 Settling Rate

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 %"

### 14 Force Limit
### 15

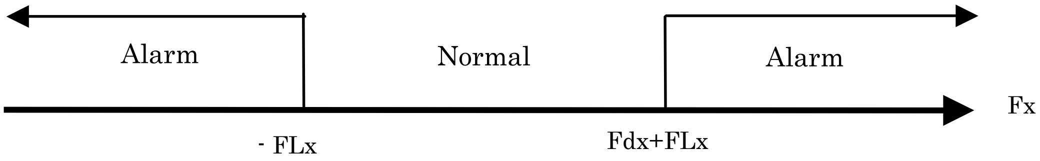
If generated force satisfies one of the expressions below, an alarm(FORC-216 - FORC-221) is issued. See Appendix B, "ALARM CODES OF FORCE CONTROL" and remove a cause of the alarm. Increase the values of this parameter after all measures are taken. Values are set for forces in the X, Y, and Z directions 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)

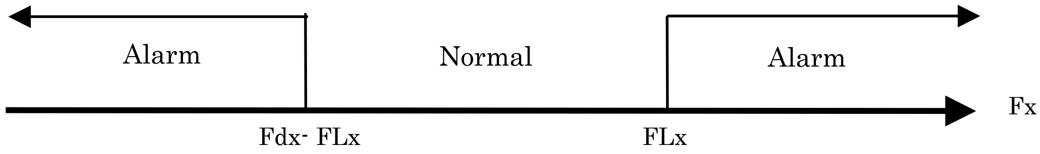
Fx: Force generated during pushing or face matching (X direction)
FLx: X component of the force limit

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.
"Unit : N, N*m"

When Fdx > 0




When Fdx < 0




## 16 Torque Error Compensate SW

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 Subsection 3.9.3, “Torque Error Acquisition Instruction”)
"Default : OFF"

### Torque Error Data W P R

These data are specified by the torque error acquisition. The data are estimated from the moment information obtained from the force sensor when a push is made with a constant force of “Torque Error Fd”. 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.)
"Default : 0 N*m"

### Torque Error Fd

This is specified by the torque error acquisition. This indicates the pushing force used for making the estimation. If “Torque Error Compensate SW” is turned ON, this setting is used to correct the torque error. (The setting cannot be modified.)
"Unit : N"

## 17 Force End Judgment Switch

This item is the switch of the function for ending operation after checking whether a proper force has been generated. When this switch is turned ON in “Constant Push” or “Face Match”, the operation can be ended even within “Pushing Time” of “Basic data” if the result of force judgment below is “SUCCESS”. If the result of force judgment is not “SUCCESS” even after the “Pushing Time” has passed, an alarm is issued. (In “Face Match”, when more than two of “Force End Judgment Switch”, “Torque End Judgment Switch” and “Vel. End Judgment Switch” are turned ON, the operation can be ended even within “Pushing Time” if the result of judgment is “SUCCESS” for valid functions.)
"Default : OFF"

## 18 Min. Force Rate

This value is used for force judgment. If the magnitude of generated force in “Pushing Direction” is greater than “Min. Force Rate” x “ Pushing Force” / 100, the result of judgment is “SUCCESS”.
"Default : 80 %"

### Judgment Result

This item indicates the result of force judgment at the end of “Constant Push” or “Face Match”. If the magnitude of force in “Pushing Direction” at the end of “Constant Push” or “Face Match” is greater than “Min. Force Rate” x “ Pushing Force” / 100, “SUCCESS” is indicated. If not, “FAILURE” is indicated.
"Default : -----"

### Force Average

This item indicates the axis of “Pushing Direction” and the average magnitude of force in “Pushing Direction” at the end of “Constant Push” or “Face Match”.
"Default : Z:0 N"

## 19 Torque End Judgment Switch

This parameter does not exist with “Constant Push”.
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. When this switch is turned ON in “Face Match”, the operation can be ended even within “Pushing Time” of “Basic data” if the result of torque judgment below is “SUCCESS”. If the result of torque judgment is not “SUCCESS” even after “Pushing Time” has passed, an alarm is issued. (In “Face Match”, when more than two of “Force End Judgment Switch”, “Torque End Judgment Switch” and “Vel. End Judgment Switch” are turned ON, the operation can be ended even within “Pushing Time” if the result of judgment is “SUCCESS” for valid functions.)
"Default : OFF"

## 20 Max. Torque

This parameter does not exist with “Constant Push”.
The value of this parameter is used for torque judgment. If the magnitude of generated torque is about less than “Max. Torque”, the result of judgment is “SUCCESS”.
"Default : 5 N*m"

### Judgment Result

This parameter does not exist with “Constant Push”.
This parameter indicates the result of torque judgment at the end of “Face Match”. If the magnitude of torque at the end of face match operation is about less than “Max. Torque”, “SUCCESS” is indicated. If not, “FAILURE” is indicated.
"Default : : -----"

### Torque Average

This parameter does not exist with “Constant Push”.
This parameter indicates rotations about the axes other than “Pushing Direction” and the average magnitude of torque about each of the axes at the end of “Face Match”. (If the axis for “Pushing Direction” is Z, for example, 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.)
"Default : W:0 N*m
P:0 N*m"

### 21 Vel. End Judgment Switch

This parameter does not exist with "Constant Push".

This item is a switch of the function for ending operation after checking whether the velocity in the pushing direction has been decreased sufficiently. When this switch is turned "ON" in face match, the operation can be ended even within "Pushing Time" in the Basic data if the result of the pushing direction velocity judgment below is "SUCCESS". If the result of the pushing direction velocity judgement below is not "SUCCESS" even after "Pushing Time" has passed, an alarm is issued. (In face match, if two or more of "Force End Judgment Switch", "Torque End Judgment Switch", and "Vel. End Judgment Switch" are "ON", the operation can be ended even within "Pushing Time" when the result of the judgment is "SUCCESS" for all the functions that are ON.)

"Default : OFF"

### 22 Max. Velocity

This parameter does not exist with "Constant Push".

The value of this parameter is used for the pushing direction velocity judgment. If the magnitude of the pushing direction velocity is approximately equal to or less than "Max. Velocity", the result of the judgment is "SUCCESS".

"Default : 0.3 mm/s"

### Judgment Result

This parameter does not exist with "Constant Push".

This parameter indicates the result of the pushing direction velocity judgment at the end of face match. If the magnitude of the pushing direction velocity at the end of face match is approximately equal to or less than "Max. Velocity", "SUCCESS" is indicated; otherwise, "FAILURE" is indicated.

"Default : -----"

### Vel. Average

This parameter does not exist with "Constant Push".

This parameter indicates the axis of "Pushing Direction", as well as the average magnitude of "Pushing Dir. Velocity" at the end of face match.

"Default : Z:0 mm/s"

### 23 Fast Ins. Switch

This parameter does not exist with “Constant Push”.

This item is the switch of the function for the fast adjustment of workpiece’s posture.

"Default : ON"

### 24 Fast Ins. Multiplier

This parameter does not exist with “Constant Push”.

This item determines the speed of the workpiece’s posture adjustment. In case that “Fast Ins. Switch” is ON, posture adjustment becomes faster by increasing this value. For the safety, increase this value in step of 0.5.

"Default : 2"

### 25 Fast Ins. Acc. Time

This parameter does not exist with “Constant Push”.

This item determines the acceleration time for adjusting the posture. In case that “Fast Ins. Switch” is ON, posture adjustment becomes faster by decreasing this value. For the safety, decrease this value in step of 0.1.

"Default : 0.4sec"

### 26 Approach Acc. Time

This item specifies acceleration time that the speed becomes “Approach Velocity” of “Basic data” after executing force control instruction.
"Unit : sec"

### 27 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"

### 28 Signal Output for ERR SW

This parameter enables the "Signal Output for ERR" function. This function sends out a designated signal when an alarm is issued while contouring.
"Default : OFF"

### 29 Output Signal Type (Signal Output for ERR)

This parameter specifies the kind of a signal that "Signal Output for ERR" function sends out when an alarm is issued while contouring.
"DO", "RO", "FLAG" are available for the kind of a signal.

### 30 Output Signal Number (Signal Output for ERR)

This parameter specifies the signal number that "Signal Output for ERR" function sends out when an alarm is issued while contouring.

### 31 Frc.Ctrl. End by REG SW

"Constant Push" and "Face Match" usually ends after "Pushing Time" has elapsed. If "Force End Judgment Switch" or "Torque End Judgment Switch" is ON and its ending condition is met, the force control ends before it. 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"

### 32 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"

## 3.5.3 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.

Function selection screen

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

Basic screen

```
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   DEFAULT  PERFORM
```

F1 F2 F3 F4 F5

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

Performance 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 ] GROUP  NUMBER  DEFAULT  BASIC
```

F1 F2 F3 F4 F5

**Fig.3.5.3(a) Teaching “Shaft Insert” “Groove Insert” and “Square Insert” Detailed Data (1/2)**

Performance 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 ] GROUP  NUMBER  DEFAULT  BASIC
    F1     F2      F3      F4      F5
```

**Fig.3.5.3(b) Teaching “Shaft Insert” “Groove Insert” and “Square Insert” Detailed Data (2/2)**

## Function keys

The function keys indicated in Fig. 3.5.3(a) and (b) have the following functions:

| 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. |
| 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. |

## G F S

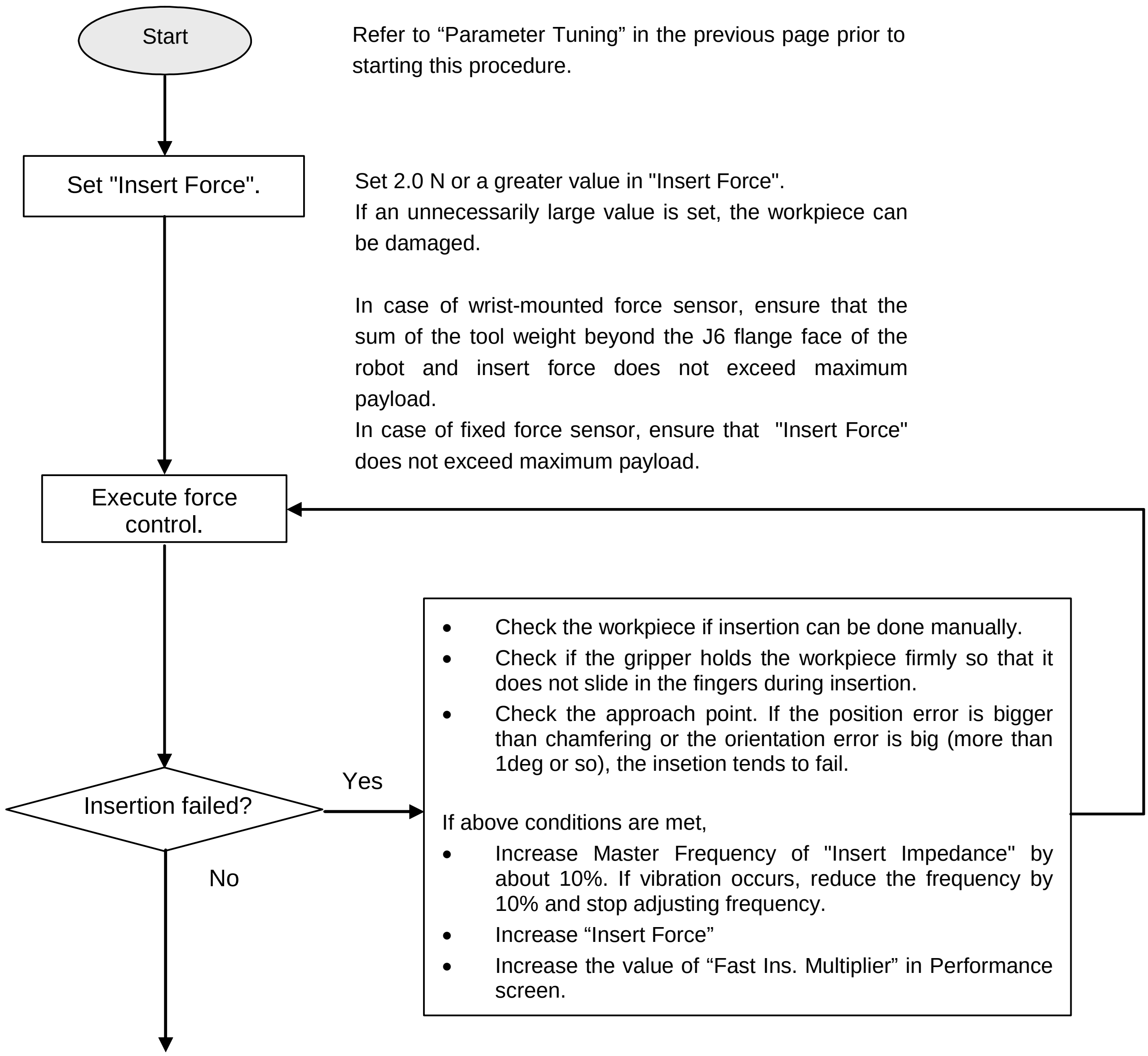
G represents a motion group number at the time of teaching. F represents a force control number. S represents a force sensor number. (These settings cannot be changed.)
“Defaults : 1 1 1”

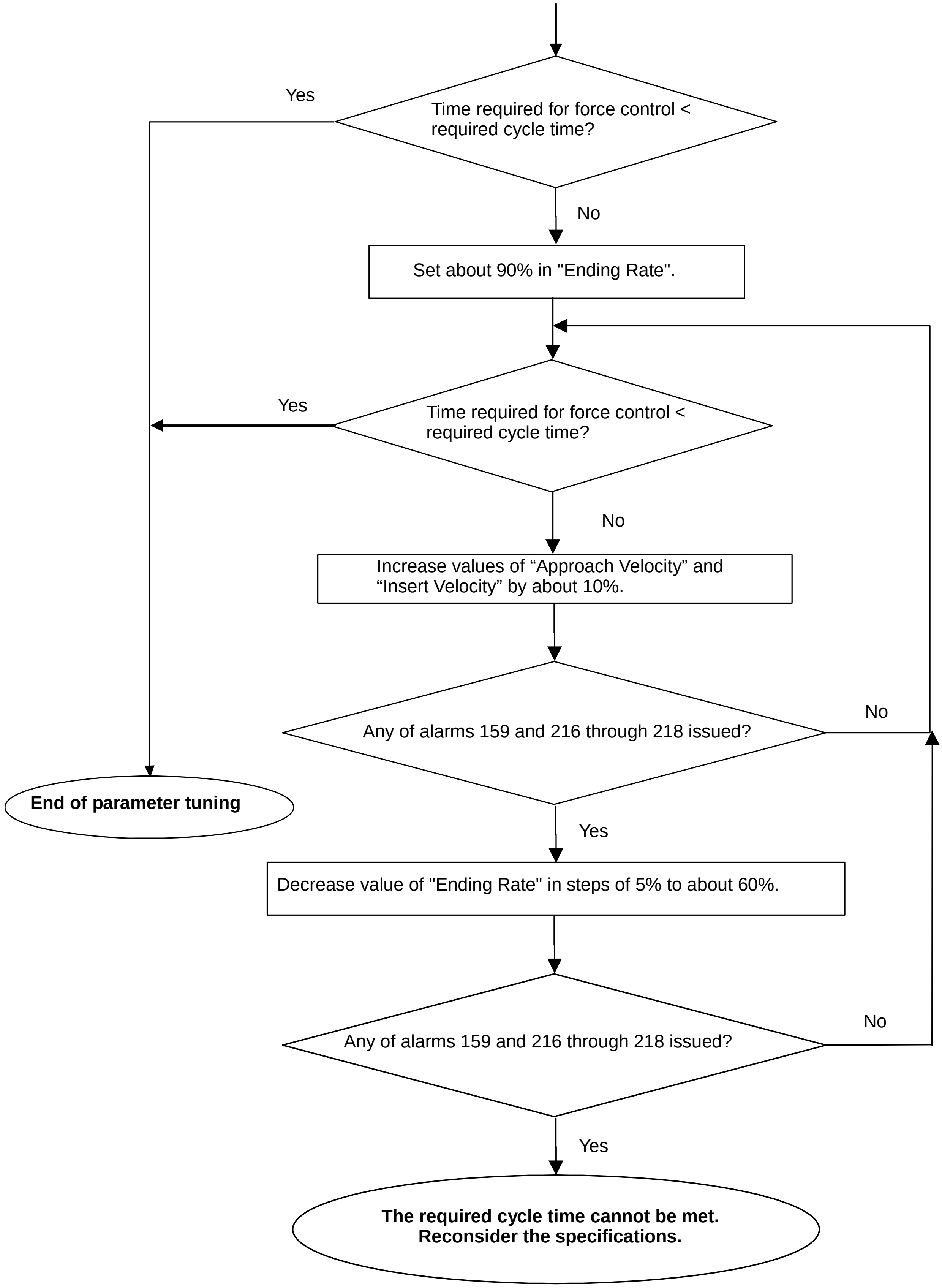
# Parameter tuning

The following parameter setting sequence is used:

1 Set "Insert Direction", "User Frame No.", "Tool Frame No.", and "Insert Depth (Design)".
2 Make an automatic force control gain adjustment. (See Subsection 3.9.2.)
3 Set the parameters on the basic screen.
4 Tune parameters on the performance screen as required.

For the outline of force control instruction programming, see Section 3.1, "NOTES/RESTRICTIONS", and Section 3.2, "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.




Yes
Time required for force control <
required cycle time?
No
Set about 90% in "Ending Rate".
Yes
Time required for force control <
required cycle time?
No
Increase values of “Approach Velocity” and
“Insert Velocity” by about 10%.
No
Any of alarms 159 and 216 through 218 issued?
End of parameter tuning
Yes
Decrease value of "Ending Rate" in steps of 5% to about 60%.
No
Any of alarms 159 and 216 through 218 issued?
Yes
The required cycle time cannot be met.
Reconsider the specifications.

## [Basic Data Screen]

**Parameters shown in this section must be set.**

### 1 Function

A desired function is selected from "Function selection screen" in Fig.3.5.3(a). In this case, choose from “Shaft Insert”, “Bearing Insert”, “Groove Insert” and “Square Insert”.

### 2 Comment

Enter a comment for identifying the schedule data.

### 3 Insert Direction

This is the insertion direction in the user frame of “User Frame No.”
“Default : -Z”

### Groove Direction

This is only for "Groove Insert".
The longer direction of the groove into which the workpiece is to be inserted is indicated in the user frame of "User Frame No."
"Default: Y"

### 4 Contact F Threshold

This is the threshold to judge contact to the work object. The cycle time might deteriorate when this value is enlarged too much because an actual Insertion begins after contact.
“Default : 1 N”

### 5 Approach Velocity

This is the target speed until coming in contact with the work object.
“Default : 1 mm/sec”

### 6 User Frame No.

This is the user frame number used at force control. Set the user frame number that is set along Section 3.2, “TEACHING PROCEDURE”.
“Default : 0”

### 7 Tool Frame No.

This is the tool frame number used at force control. Set the tool frame number that is set along Section 3.2, “TEACHING PROCEDURE”.
“Default : 1”

### 8 Insert Force

This is the target insertion force in “Insert Direction”. If the target force should be small at the beginning of the insertion, refer to "24 Init Force Keep Depth" in the "Performance data".
"Unit : N"

### 9 Insert Velocity

This is the target insertion velocity in “Insert Direction”.
“Default : 2 mm/sec”

### 10 Insert Depth (Design)

This is the depth of insertion from the insertion start point to insertion end point.
“Default : 20 mm”

### 11 Individual Diff. (+)

This is the allowable positive tolerance to “Insert Depth (Design)”, due to differences between individual workpieces. If the depth of insertion exceeds the value of (“Insert Depth (Design)”- “Individual Diff. (-)” + “Individual Diff. (+)”), an alarm is issued.
“Default : 3 mm”

### 12 Individual Diff. (-)

This is the allowable negative tolerance to “Insert Depth (Design)”, due to differences between individual workpieces. If the depth of insertion reaches (“Insert Depth (Design)” – “Individual Diff. (-)”, the system assumes that insertion has been performed successfully.
“Default : 0 mm”

### 13 Pushing Time

This is the length of push time after the system assumes the insertion to have been successful. Through this push, the individual differences indicated above are compensated.
“Default : 0 sec”

### 14 Check Orientation Change

This is the switch for checking how the orientation has been changed in insertion, in comparison with the orientation in teaching. Usually, this switch is turned ON.
“Default : ON”

### 15 Change MAX Limit

This is the maximum allowable change from the teaching orientation during insertion if “Check Orientation Change” described above is ON. If the actual orientation change exceeds this “Change MAX Limit”, an alarm is issued.
“Default : 3 deg”

### 16 Insert Time MAX Limit

This is the maximum length of insertion 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 (Refer to “Pushing Time”) is excluded from the insertion time.
“Default : 20 sec”

### 17 F.Ctrl. Gain Auto Modify

This item is the switch used for automatic force control gain tuning. For details, see Subsection 3.9.2, "Force Control Gain Auto Tuning Instruction".
"Default : OFF"

### 18 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, see Section 3.6, "FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".

## [Performance Data Screen]

**Parameters shown in this section are for advanced users.**

### 1 Function

A desired function is selected from "Function selection screen" in Fig.3.5.3(a).

In this case, choose from “Shaft Insert”, “Bearing Insert”, “Groove Insert” and “Square Insert”.

### 2 Comment

Enter a comment for identifying the schedule data.

### 3 Simple Customize Sw

This parameter specifies a switch for "Simple Customize" function. It enables to execute the schedule data being edited after any other schedule.
For details, see Subsection 3.7.3, "Simple Customization Function".
"Default: OFF"

### 4 Retry Sw

It is set when the schedule data being edited is used as a retry for a previously executed schedule.
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.
For details, see Subsection 3.7.3, "Simple Customization Function".
"Default: OFF "

### 5 Cont. Exec. Max. Count

It designates how many force schedules with "Simple Customize Sw" ON can be executed successively.
For details, see Subsection 3.7.3, "Simple Customization Function".
"Default : 1"

### 6 Customize Parent Number

This item is set when force control is executed successively. For details, see Subsection 3.7.3, "Specifying the Parent-Child Relationship".
"Default: 0"

### 7 Customize ParaChg Connection

This item is set when force control is executed successively. For details, see Subsection 3.7.3, "Specifying the Parent-Child Relationship".
"Default: OFF"

### 8 Customize Auto. Cnt. Exec. Sw (Customize Auto. Cnt. Exec.)

This parameter specifies a switch for "Customize Auto. Cnt. Exec." function.
"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.
For details, see Subsection 3.7.5, "Customization Automatic Continuous Execution Function".
"Default: OFF"

### 9 Auto. Cnt. Exec. Child No. (Customize Auto. Cnt. Exec.)

This parameter specifies a schedule data number of its child schedule data. The child schedule data is a schedule data that is executed next.
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.

### 10 Schedule No. Output Reg. No. (Customize Auto. Cnt. Exec.)

This parameter specifies a Numeric Register Number to which "Customize Auto. Cnt. Exec." function output the execution state.
When "Customize Auto. Cnt. Exec." function is executing, this function outputs a running schedule data number. If the series of the schedule data ends normally, this function outputs 0.
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.

### 11 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. The switch must be used in combination with the OFFSET or VOFFSET instruction. For details, see Section 3.8, "User Frame Compensation".
“Default : OFF”

### 12 Settling Switch

Settling involves reducing the pushing force after pushing is completed. Settling is useful if the workpiece tends to vibrate because of the impact caused by the removal of the robot hand, for instance.
“Default : OFF”

### 13 Settling Time

Settling is performed over this “Settling Time”.
“Default : 1 sec”

### 14 Settling Rate

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 %”

### 15 Initial Insert Force

This is the target insertion force at the beginning of 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 "24 Init Force Keep Depth" in the "Performance data", too.
"Unit : N"

### 16 Velocity Switch

This is the switch for adjusting “Insert Velocity” in “Basic data” during insertion. This switch is useful when starting insertion slowly and then increasing the insertion velocity from a certain stage of insertion. When parameter No.20 “Velocity Constant Switch” of the performance data is turned ON, the velocity is controlled so that it does not exceed the “Insert Velocity” of the basic data regardless of the value of “Adjustment Gain”.
“Default : ON”

### 17 Adjustment Gain

The actual Insert Velocity during velocity adjustment is “ Insert Velocity” in “Basic data” multiplied by this “Adjustment Gain”.
“Default : 2”

### 18 Starting Rate

Velocity adjustment starts when the insertion depth reaches (“Insert Depth (Design)” in “Basic data”) x “Starting Rate”/100.
“Default : 30 %”

### 19 Ending Rate

Velocity adjustment ends when the insertion depth reaches (“Insert Depth (Design)” in “Basic data”) x “Ending Rate”/100. The velocity command becomes zero if the workpiece goes deeper than this value to prevent an excessive collision force.
“Default : 90 %”

### 20 21 Force Limit

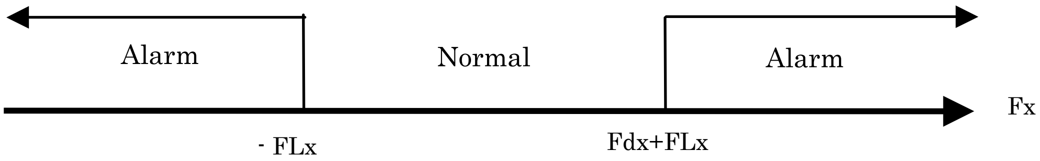
If generated force satisfies one of the expressions below, an alarm(FORC-216 - FORC-221) is issued. See Appendix B, "ALARM CODES OF FORCE CONTROL" and remove a cause of the alarm. Increase the values of this parameter after all measures are taken. Values are set for forces in the X, Y, and Z directions 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)

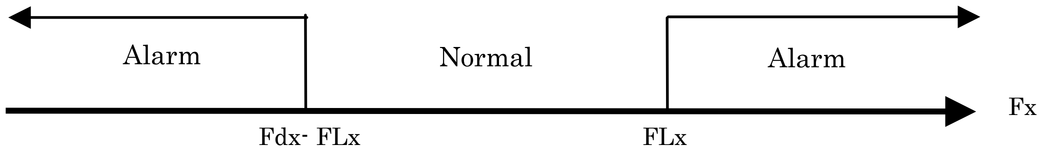
Fx: Force generated during phase matching (X direction)
FLx: X component of the phase matching force limit
Fdx: Target force in the X direction. If the insertion direction is X or -X, Fdx is "Insert Force". Otherwise, Fdx = 0.

The same relationship holds for Y, Z, W, P, and R.
"Unit : N, N*m"

When Fdx > 0




When Fdx < 0




### 22 Ending Condition Switch

If this switch is turned ON, whether the insertion is successful is judged using "Insert Depth" described below, instead of "Insert Depth (Design)" in "Basic data", and "Insert DIR" instead of "Insert Direction", also in "Basic data". Execute the end condition acquisition instruction before turning on this switch.(Refer to Subsection 3.9.4, "End Condition Acquisition Instruction")
"Default : OFF"

### Insert Depth

This data is specified by the end condition acquisition. The depth of insertion is estimated from the actual insertion. If "Ending Condition Switch" is set ON, this "Insert Depth" ,instead of "Insert Depth (Design)" in "Basic data", is used to judge whether the insertion is successful. (The setting cannot be modified.)
"Default : 0 mm"

### Approach Length

This data is specified by the end condition acquisition. 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 setting cannot be modified.)
"Default : 0 mm"

### Insert DIR

This data is specified by the end condition acquisition. 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. (The setting cannot be modified.)
"Default : [0, 0, -1]"

### 23 Torque Error Compensate SW

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 Subsection 3.9.3, "Torque Error Acquisition Instruction")
"Default : OFF"

### Torque Error Data W P R

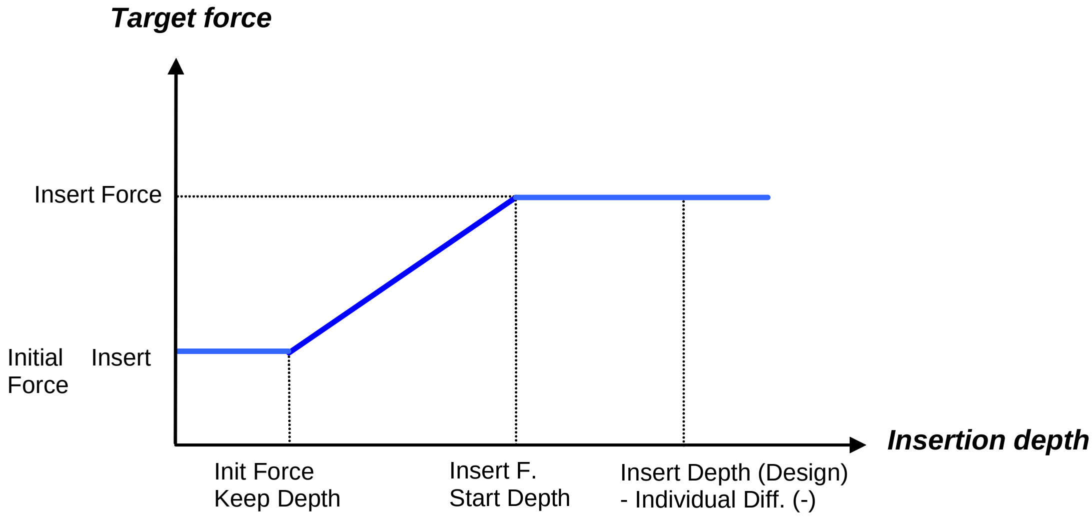
These data are specified by the torque error acquisition. The data are estimated from the moment information obtained from the force sensor when a push is made with a constant force of “Torque Error Fd”. W, P, and R are the values about the X-axis, Y-axis, and Z-axis, respectively, of the user frame used. If “Torque Error Compensate SW” is turned ON, these values are used to correct the torque error. (The values cannot be modified.)
“Default : 0 N*m”

### Torque Error Fd

This is specified by the torque error acquisition. This indicates the pushing force used for making the estimation. If “Torque Error Compensate SW” is turned ON, this setting is used to correct the torque error. (The setting cannot be modified.)
"Unit : N"

### 24 Init Force Keep Depth

The target insertion force during the period from the start of insertion until the insertion depth is reached is “Initial Insert Force” of the Performance data.
(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 mm"




### 25 Insert F. Start Depth

The target force is changed so that the target force during insertion becomes “Insert Force” of “Basic data” when the insertion depth has reached this depth after exceeding “Init Force Keep 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 mm"

## 26 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. If this switch is turned ON when shaft insertion, bearing insertion, groove insertion, or square insertion operation is performed, the speed during insertion can be controlled not to exceed “Insert Velocity” of the “Basic data”.
(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"

## 27 Force End Judgment Switch

This item is the switch of the function for ending operation after checking whether a proper force has been generated. When this switch is turned ON in shaft insertion operation, bearing insertion, groove insertion, or square insertion, the operation can be ended if the “Judgment Result” described below is “SUCCESS” after the workpiece is inserted to the specified depth. If it is not “SUCCESS” even after “Insert Time MAX Limit” of the “Basic data” has passed, an alarm is issued. (If both of “Force End Judgment Switch” and “Torque End Judgment Switch” are turned ON, the operation can be ended when the result of judgment is “SUCCESS” for both after the workpiece is inserted to the specified depth.)
"Default : OFF"

## 28 Min. Force Rate

The value of this item is used for force judgment. If the magnitude of generated force in “Insert Direction” is greater than “Min. Force Rate” x “Insert Force” / 100, the result of judgment is “SUCCESS”.
"Default : 80 %"

### Judgment Result

This item indicates the result of force judgment at the end of shaft insertion, bearing insertion, groove insertion, or square insertion operation. If the magnitude of force in “Insert Direction” at the end of shaft insertion, bearing insertion, groove insertion, or square insertion operation is greater than “Min. Force Rate” x “Insert Force” / 100, “SUCCESS” is indicated. If not, “FAILURE” is indicated.
"Default : -----"

### Force Average

This item indicates the axis of “Insert Direction” and the average magnitude of force in “Insert Direction” at the end of shaft insertion, bearing insertion, groove insertion, or square insertion operation.
"Default : Z:0 N"

## 29 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. When this switch is turned ON in shaft insertion, bearing insertion, groove insertion, or square insertion operation, the operation can be ended if the “Judgment Result” described below is “SUCCESS” after the workpiece is inserted to the specified depth. If it is not “SUCCESS” even after “Insert Time MAX Limit” of “Basic data” has passed, an alarm is issued. (If both of “Force End Judgment Switch” and “Torque End Judgment Switch” are turned ON, the operation can be ended when the result of judgment is “SUCCESS” for both after the workpiece is inserted to the specified depth.)
"Default : OFF"

### 30 Max. Torque

The value of this parameter is used for torque judgment. If the magnitude of generated torque is less than “Max. Torque”, the result of judgment is “SUCCESS”.
"Default : 5 N*m"

### Judgment Result

This parameter indicates the result of torque judgment at the end of shaft insertion, bearing insertion, groove insertion, or square insertion operation. If the magnitude of torque at the end of shaft insertion, bearing insertion, groove insertion, or square insertion operation is less than “Max. Torque”, “SUCCESS” is indicated. If not, “FAILURE” is indicated.
"Default : -----"

### Torque Average

This parameter indicates rotations about the axes other than “Insert Direction” and the average magnitude of torque about each of the axes at the end of shaft insertion, bearing insertion, groove insertion, or square insertion operation. (If the axis for “Insert Direction” is Z, for example, W for indicating rotation about the X-axis and P for indicating rotation about the Y-axis are displayed. Similarly, If the axis for “Insert Direction” is X, P and R are displayed. If the axis for “Insert Direction” is Y, W and R are displayed.)
"Default : W:0 N*m
P:0 N*m"

### 31 Fast Ins. Switch

This item is the switch of the function for the fast adjustment of workpiece’s posture.
“Default : ON”

### 32 Fast Ins. Multiplier

This item determines the speed of the workpiece’s posture adjustment. In case that “Fast Ins. Switch” is ON, posture adjustment becomes faster by increasing this value. For the safety, increase this value in step of 0.5.
“Default : 2”

### 33 Fast Ins. Acc. Time

This item determines the acceleration time for adjusting the posture. In case that “Fast Ins. Switch” is ON, posture adjustment becomes faster by decreasing this value. For the safety, decrease this value in step of 0.1.
“Default : 0.4sec”

### 34 Approach Acc. Time

This item specifies acceleration time that the speed becomes “Approach Velocity” of “Basic data” after executing force control instruction.
"Unit : sec"

### 35 Insert Acc. Time

This item specifies acceleration time that the speed becomes “Insert Velocity” of “Basic data” after force exceeds “Contact F Threshold” of “Basic data”.
"Unit : sec"

### 36 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"

### 37 Signal Output for ERR SW

This parameter enables the "Signal Output for ERR" function. This function sends out a designated signal when an alarm is issued while contouring.
"Default : OFF"

### 38 Output Signal Type (Signal Output for ERR)

This parameter specifies the kind of a signal that "Signal Output for ERR" function sends out when an alarm is issued while contouring.
"DO", "RO", "FLAG" are available for the kind of a signal.

### 39 Output Signal Number (Signal Output for ERR)

This parameter specifies the signal number that "Signal Output for ERR" function sends out when an alarm is issued while contouring.

### 40 Frc.Ctrl. End by REG SW

"Shaft Insert", "Groove Insert" and "Square Insert" usually ends after it has reached "Insert Depth (Design)". If "Force End Judgment Switch" or "Torque End Judgment Switch" is ON, the force control does not end until its condition is satisfied. 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"

### 41 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"

# 3.5.4 Phase Match Insert

## Overview

In the “Phase Match Insert” menu, the settings for insertion that is preceded by phase matching, such as key insertion and spline insertion for a car transmission, can be specified.

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.

Function selection screen

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

Basic screen

```
Force Ctrl/Basic
                                       1/23
 Schedule[1]            G:1 F:1 S:1
 1 Function         : Phase Match Ins.
 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 PhaseMatch Depth     :   20.00 mm
 9 PhaseMatch Push Force:   30.00 N
10 PhaseMatch Insert Vel:    0.00 mm/s
11 PhaseMatch Ang. Vel  :    3.00 deg/s
12 Insert Force         :    50.00 N
13 Insert Velocity      :     2.00 mm/s
14 Insert Depth (Design):    20.00 mm
15 Individual Diff. (+) :     3.00 mm
16 Individual Diff. (-) :     0.00 mm
17 Pushing Time         :     0.00 sec
18 Check Orientation Change   : ON
19   Change MAX Limit   :     3.00 deg
20 Insert Time Limit    :    20.00 sec
21 PhaseMatch Time Limit:    30.00 sec
22 F.Ctrl. Gain Auto Modify :        OFF
     Prev. Result      : No Change
23 Force Control Gain :            Detail

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

Performance screen(1/2)

```
Force Ctrl/Perform
                                       1/37
 Schedule[1]            G:1 F:1 S:1
 1 Function         : Phase Match Ins.
 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
 8 Phase Match Imp. Rate:    1.00
 9 Phase Match Torque   :    1.00 N*m
10 P/M Reduce Depth Rate:   80.00 %
11 Settling Switch            : OFF
12   Settling Time      :    1.00 sec
13   Settling Rate      :  100.00 %
14 Initial Insert Force :   50.00 N
15 Velocity Adjust Switch     : ON
16   Adjustment Gain    :    2.00
17   Starting Rate      :   30.00 %
18   Ending Rate        :   90.00 %
   Phase M Force Limit
19  X:  500.00 Y:  500.00 Z:  500.00 N
20  W:   50.00 P:   50.00 R:   50.00N*m
   Insert Force Limit
21  X:  500.00 Y:  500.00 Z:  500.00 N
22  W:   50.00 P:   50.00 R:   50.00N*m
23 Ending Condition Switch    : OFF
     Insert Depth       :     0.00 mm
     Approach Length    :     0.00 mm
     Insert DIR
    [     0.000,      0.000,     -1.000]

[ TYPE ] GROUP  NUMBER  DEFAULT  BASIC
   F1      F2      F3      F4      F5
```

Force Ctrl/Gain screen

```
Force Ctrl/Gain
                                       1/2
 Schedule[1]            G:1 F:1 S:1
   Function         : Phase Match Ins.
 1 Phase M Impedance   : [Master Freq. ]
 2 Insert Impedance    : [Master Freq. ]

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

**Fig.3.5.4(a) Teaching “Phase Match Ins.” detailed data (1/2)**

Performance screen(2/2)

```
Force Ctrl/Perform
                                          24/37
 24 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
 25 Velocity Constant Switch   : ON
 26 Force End Judgment Switch  : OFF
 27   Min. Force Rate  :       80.00 %
      Judgment Result  :          -------
       Force Average  Z:        0.00 N
 28 Torque End Judgment Switch:  OFF
 29   Max. Torque      :      0.50 N*m
      Judgment Result  :          -------
       Torque Average W:      0.00 N*m
                      P:      0.00 N*m
 30 Approach Acc. Time       :  0.70 sec
 31 PhaseMatch Acc. Time     :  0.70 sec
 32 Insert Acc. Time         :  0.70 sec
    PhaseMatch ForceControl Valid Switch
 33    X: OFF         Y: OFF
 34 Force Denoising Sw    :    OFF
 35 Signal Output for ERR SW:  OFF
 36   Output Signal Type  :    DO
 37   Output Signal Number:       0
 38 Frc.Ctrl. End by REG SW : OFF
 39   End Register Number :      0

 [ TYPE ] GROUP  NUMBER  DEFAULT  BASIC
   F1      F2      F3      F4      F5
```

**Fig.3.5.4(b) Teaching “Phase Match Ins.” detailed data (2/2)**

## Function keys

The function keys indicated in Fig. 3.5.4(a) and (b) have the following functions:

| 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. |
| 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. |

## 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”

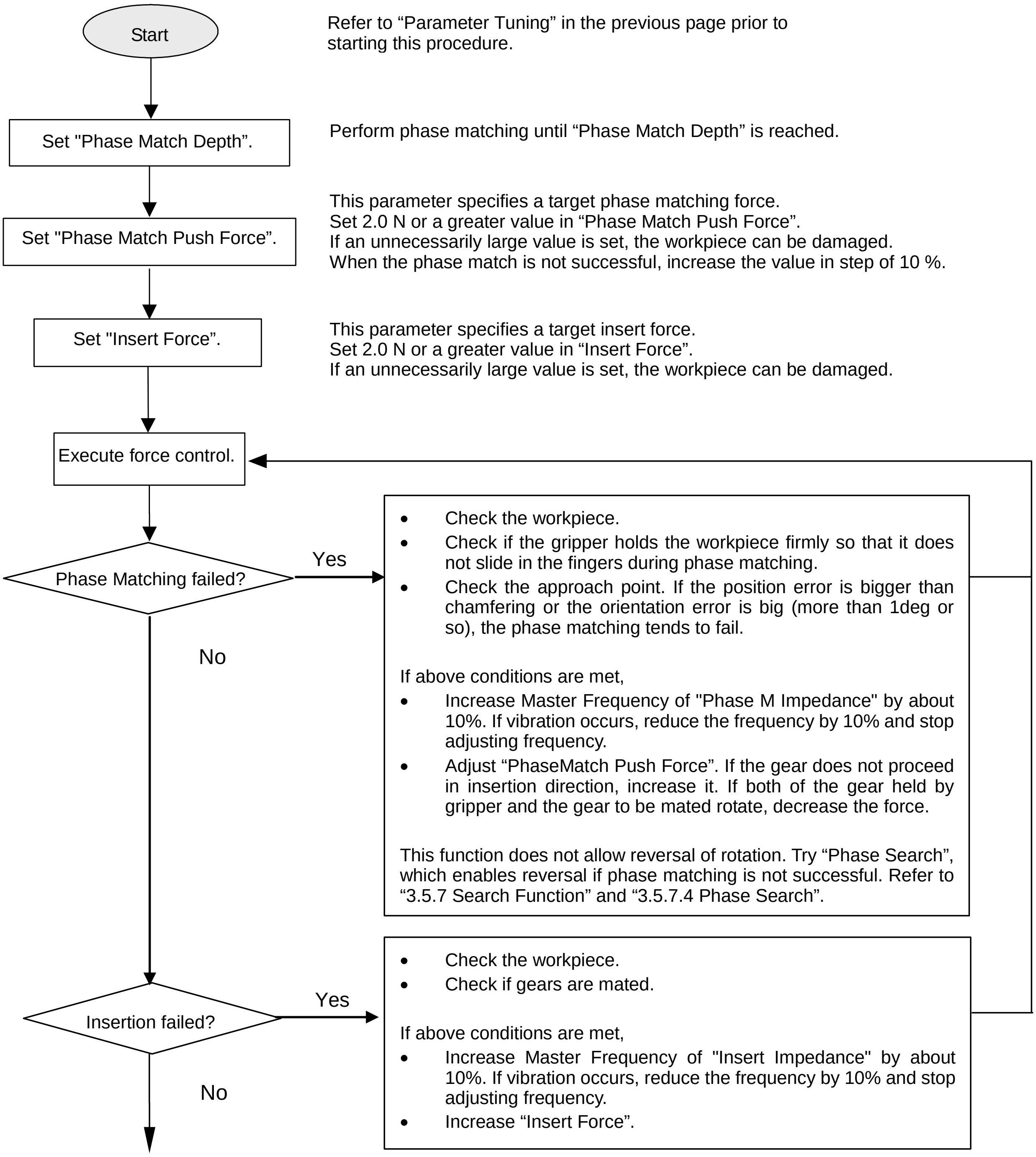
## Parameter tuning

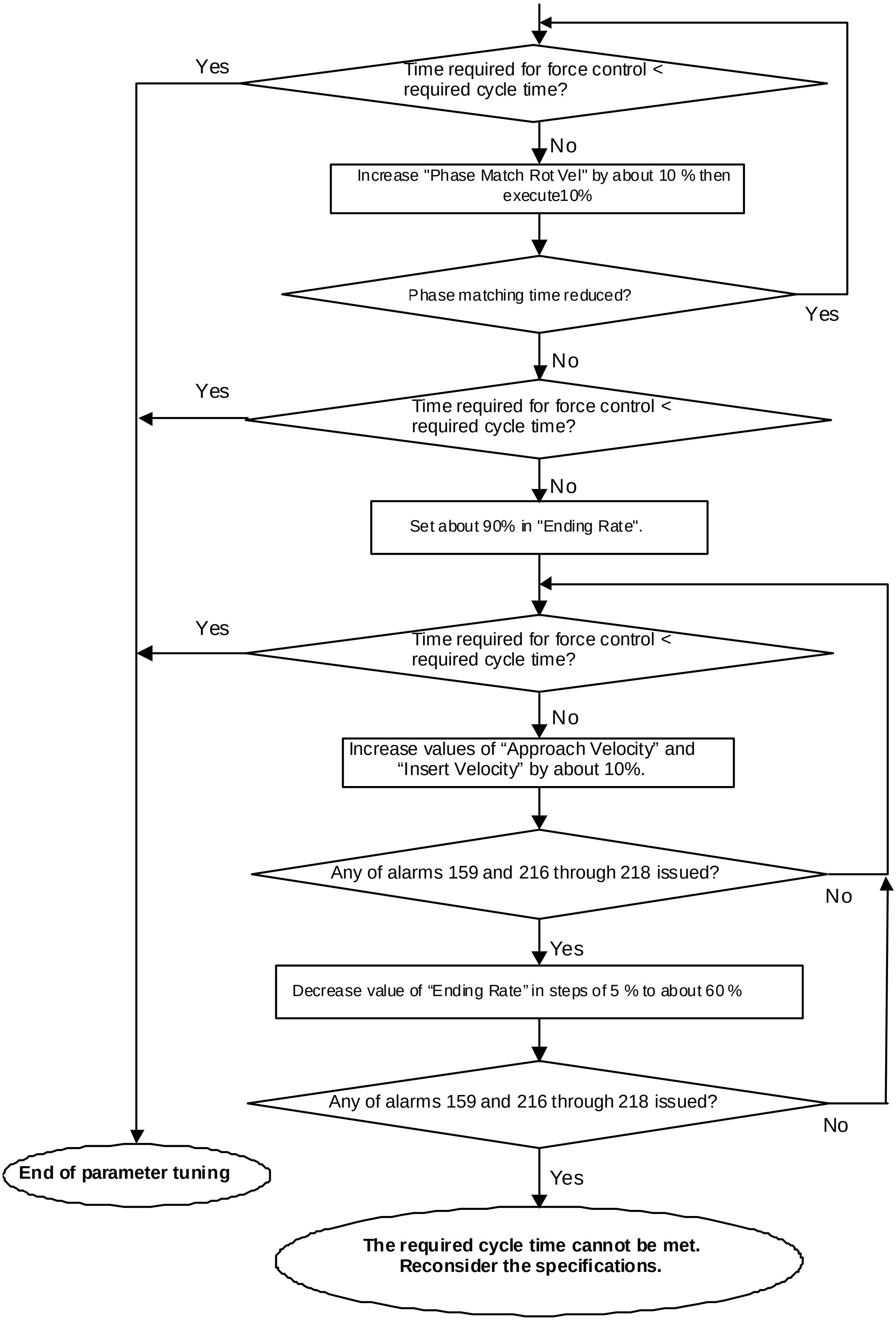
The following parameter setting sequence is used:

1 Set "Insert Direction", "User Frame No.", "Tool Frame No.", and "Insert Depth (Design)".

2 Make an automatic force control gain adjustment. (See Subsection 3.9.2.)
3 Set the parameters on the basic screen.
4 Tune parameters on the performance screen as required.

For the outline of force control instruction programming, see Section 3.1, "NOTES/RESTRICTIONS", and Section 3.2, "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.




Time required for force control < required cycle time?
Yes
No
Increase "Phase Match Rot Vel" by about 10 % then execute10%
Phase matching time reduced?
Yes
No
Time required for force control < required cycle time?
Yes
No
Set about 90% in "Ending Rate".
Time required for force control < required cycle time?
Yes
No
Increase values of “Approach Velocity” and “Insert Velocity” by about 10%.
Any of alarms 159 and 216 through 218 issued?
No
Yes
Decrease value of “Ending Rate” in steps of 5 % to about 60 %
Any of alarms 159 and 216 through 218 issued?
No
Yes
End of parameter tuning
The required cycle time cannot be met. Reconsider the specifications.

## ［Basic Data Screen］

**Parameters shown in this section must be set.**

### 1 Function

From "Function selection screen" in Fig. 3.5.4,(a) select a function to be set. In this case, Choose “Phase Match Ins.”.

### 2 Comment

Enter a comment for identifying the schedule data.

### 3 Insert Direction

This is the insertion direction in the user frame of “User Frame No.”
“Default : -Z”

### 4 Contact F Threshold

This is the threshold to judge contact to the work object. The cycle time might deteriorate when this value is enlarged too much because an actual Insertion begins after contact.
“Default : 1 N”

### 5 Approach Velocity

This is the target speed until coming in contact with the work object.
“Default : 1 mm/sec”

### 6 User Frame No.

This is the user frame number used at force control. Set the user frame number that is set along Section 3.2, “TEACHING PROCEDURE”.
“Default : 0”

### 7 Tool Frame No.

This is the tool frame number used at force control. Set the tool frame number that is set along Section 3.2, “TEACHING PROCEDURE”.
“Default : 1”

### 8 PhaseMatch Depth

This is the threshold of insertion depth at which phases are assumed to be matched and then start the inserting motion without phase matching.
“Default : 20 mm”

### 9 PhaseMatch Push Force

This is the force of pushing to the insertion face in phase matching.
"Unit : N"

### 10 PhaseMatch Insert Vel

This is the insertion speed in phase matching.
“Default: 0 mm/sec”

### 11 PhaseMatch Ang. Vel

This is the workpiece rotation speed in phase matching.
“Default : 3 deg/sec”

### 12 Insert Force

This is the target insertion force in “Insert Direction”.

"Unit : N"

### 13 Insert Velocity

This is the target insertion velocity in “Insert Direction”.
“Default : 2 mm/sec”

### 14 Insert Depth (Design)

This is the depth of insertion from the start point of force control to the end point of force control.
“Default : 20 mm”

### 15 Individual Diff. (+)

This is the allowable positive tolerance to “Insert Depth (Design)”, due to differences between individual workpieces. If the depth of insertion exceeds the value of (“Insert Depth (Design)” – Individual Diff (-) + “Individual Diff. (+)”), an alarm is issued.
“Default : 3 mm”

### 16 Individual Diff. (-)

This is the allowable negative tolerance to “Insert Depth (Design)”, due to differences between individual workpieces. If the depth of insertion reaches (“Insert Depth (Design)” – “Individual Diff. (-)”, the system assumes that insertion has been performed successfully.
“Default : 0 mm”

### 17 Pushing Time

This is the length of push time after the system assumes the insertion to have been successful. Through this push, the individual differences indicated above are compensated.
“Default : 0 sec”

### 18 Check Orientation Change

This is the switch for checking how the orientation has been changed in insertion, in comparison with the orientation in teaching. Usually, this switch is turned ON.
“Default : ON”

### 19 Change MAX Limit

This is the maximum allowable change from the teaching orientation during insertion if “Check Orientation Change” described above is ON. If the actual orientation change exceeds this “Change MAX Limit”, an alarm is issued.
“Default : 3 deg”

### 20 Insert Time Limit

This is the maximum length of insertion 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 (Refer to “Pushing Time”) is excluded from the insertion time.
“Default : 20 sec”

### 21 PhaseMatch Time Limit

The phase matching time is the time from the start of insertion after contact to the work object until phase matching is regarded as successful. If this time has elapsed before "Phase Match Depth" is reached, an alarm is issued.
"Default: 30 sec"

### 22 F.Ctrl. Gain Auto Modify

This item is the switch used for automatic force control gain tuning. For details, see Subsection 3.9.2, "Force Control Gain Auto Tuning Instruction".
"Default : OFF"

### 23 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, see Section 3.6, "FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".

## ［Performance Data Screen］

**Parameters shown in this section are for advanced users.**

### 1 Function

From "Function selection screen" in Fig. 3.5.4(a), select a function to be set. In this case, choose “Phase Match Ins.”.

### 2 Comment

Enter a comment for identifying the schedule data.

### 3 Simple Customize Sw

This parameter specifies a switch for "Simple Customize" function. It enables to execute the schedule data being edited after any other schedule.
For details, see Subsection 3.7.3, "Simple Customization Function".
"Default: OFF"

### 4 Cont. Exec. Max. Count

It designates how many force schedules with "Simple Customize Sw" ON can be executed successively.
For details, see Subsection 3.7.3, "Simple Customization Function".
"Default : 1"

### 5 Customize Parent Number

This item is set when force control is executed successively. For details, see Subsection 3.7.3, "Specifying the Parent-Child Relationship".
"Default: 0"

### 6 Customize ParaChg Connection

This item is set when force control is executed successively. For details, see Subsection 3.7.3, "Specifying the Parent-Child Relationship".
"Default: OFF"

### 7 User Frame Compensation SW

This is a switch for correcting a user frame set on a work target plane through vision. This parameter is useful when a work target is not positioned correctly. The switch must be used in combination with the OFFSET or VOFFSET instruction. For details, see Section 3.8, "User Frame Compensation".
“Default : OFF”

### 8 Phase Match Imp. Rate

The force control gain of phase matching is set based on "Insert Impedance". This value indicates the ratio of “Force Control Gain” at the time of phase matching to "Insert Impedance". As this value increases, the operation speed decreases. This value can be specified only after force control gain auto tuning.

### 9 Phase Match Torque

This is the target torque of rotation axis in phase matching.
“Default : 10 N*m”

### 10 P/M Reduce Depth Rate

When the insertion depth reaches ("Phase Match Depth" in "Basic data") x (P/M Reduce Depth Rate) / 100, the rotation speed is reduced to ("Phase Match Rot Vel" in "Basic data") x 0.3. When the workpiece is hurt or insertion stops because of forcing to rotate forcibly more though the phase matches, it is effective to reduce this value.
"Default : 80 %"

### 11 Settling Switch

Settling means reducing the pushing force after pushing is completed. Settling is useful if the workpiece tends to vibrate because of the impact caused by the removal of the robot hand, for instance.
"Default : OFF"

### 12 Settling Time

Settling is performed over this "Settling Time".
"Default : 1 sec"

### 13 Settling Rate

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 %"

### 14 Initial Insert Force

This is the target insertion force at the beginning of 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".
"Unit : N"

### 15 Velocity Adjust Switch

This is the switch for adjusting "Insert Velocity" in "Basic data" during insertion. This switch is useful when starting insertion slowly and then increasing the insertion velocity from a certain stage of insertion.
(If "Velocity Constant Switch" of the performance data is turned ON, control can be exercised so that "Insert Velocity" is not exceeded.)
"Default : ON"

### 16 Adjustment Gain

The actual Insert Velocity during velocity adjustment is " Insert Velocity" in "Basic data" multiplied by this "Adjustment Gain".
"Default : 2"

### 17 Starting Rate

Velocity adjustment starts when the insertion depth reaches ("Insert Depth (Design)" in "Basic data") x "Starting Rate" / 100.
"Default : 30 %"

### 18 Ending Rate

Velocity adjustment ends when the insertion depth reaches ("Insert Depth (Design)" in "Basic data") x "Ending Rate" / 100. The velocity command becomes zero if the workpiece goes deeper than this value to prevent an excessive collision force.
"Default : 90 %"

## 19 Phase M Force Limit

**20**

If force generated during phase matching satisfies one of the expressions below, an alarm(FORC-216 - FORC-221) is issued. See 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)

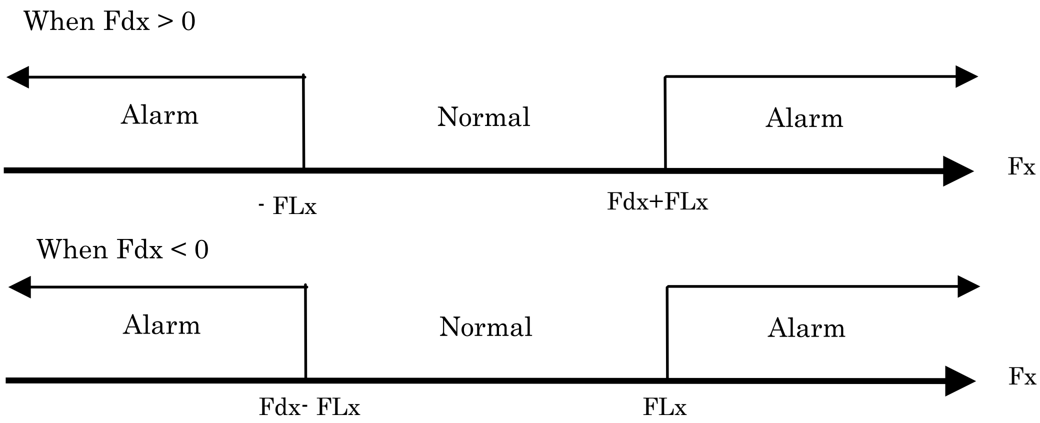
FLx: X component of the phase matching force limit

Fdx: Target force in the X direction

If the insertion direction is X or -X, Fdx is "Phase Match Push F". Otherwise, Fdx = 0.

The same relationship holds for Y, Z, W, P, and R.

"Unit : N, N*m"




## 21 Insert Force Limit

**22**

This parameter is used to check the force value during insertion while the phase matching force limit is used during phase matching. The range that causes an alarm is the same as the range for the phase matching force limit.

"Unit : N, N*m"

## 23 Ending Condition Switch

If the switch is turned ON, whether the insertion is successful is judged using “Insert Depth” described below, instead of “Insert Depth (Design)” in “Basic data”, and “Insert DIR” instead of “Insert Direction”, also in “Basic data”. Execute the end condition acquisition instruction before turning on this switch.(Refer to Subsection 3.9.4, “End Condition Acquisition Instruction”)

“Default : OFF”

## Insert Depth

This data is specified by the end condition acquisition. The depth of insertion is estimated from the actual insertion. If “Ending Condition Switch” is set ON, this “Insert Depth” ,instead of “Insert Depth (Design)” in “Basic data”, is used to judge whether the insertion is successful. (The setting cannot be modified.)

“Default : 0 mm”

### Approach Length

This data is specified by the end condition acquisition. 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 setting cannot be modified.)
“Default : 0 mm”

### Insert DIR

This data is specified by the end condition acquisition. 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. (The setting cannot be modified.)
“Default : [0, 0, -1]”

### 24 Torque Error Compensate SW

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 Subsection 3.9.3, “Torque Error Acquisition Instruction”)
“Default : OFF”

### Torque Error Data W P R

These data are specified by the torque error acquisition. The data are estimated from the moment information obtained from the force sensor when a push is made with a constant force of “Torque Error Fd”. 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.)
“Default : 0 N*m”

### Torque Error Fd

This is specified by the torque error acquisition. This indicates the pushing force used for making the estimation. If “Torque Error Compensate SW” is turned ON, this setting is used to correct the torque error. (The setting cannot be modified.)
"Unit : N"

### 25 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. If this switch is turned ON when shaft insertion, bearing insertion, groove insertion, or square insertion operation is performed, the speed during insertion can be controlled not to exceed “Insert Velocity” of the “Basic data”.
(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"

### 26 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. When this switch is turned ON, the force control operation can be ended if the “Judgment Result” described below is “SUCCESS” after the workpiece is inserted to the specified depth. If it is not “SUCCESS” even after “Insert Time Limit” of the “Basic data” has passed, an alarm is issued. (If both of “Force End Judgment Switch” and “Torque End Judgment Switch” are turned ON, the force control operation can be ended when the result of judgment is “SUCCESS” for both after the workpiece is inserted to the specified depth.)
“Default : OFF”

### 27 Min. Force Rate

The value of this item is used for force judgment. If the magnitude of generated force in “Insert Direction” is greater than “Min. Force Rate” x “Insert Force” / 100, the result of judgment is “SUCCESS”.
“Default : 80 %”

### Judgment Result

This item indicates the result of force judgment at the end of force control operation. If the magnitude of force in “Insert Direction” at the end of force control operation is greater than “Min. Force Rate” x “Insert Force” / 100, “SUCCESS” is indicated. If not, “FAILURE” is indicated.
“Default : -----“

### Force Average

This item indicates the axis of “Insert Direction” and the average magnitude of force in “Insert Direction” at the end of force control operation.
“Default : Z:0 N”

### 28 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. When this switch is turned ON, the force control operation can be ended if the “Judgment Result” below is “SUCCESS” after the workpiece is inserted to the specified depth. If it is not “SUCCESS” even after “Insert Time Limit” of the “Basic data” has passed, an alarm is issued. (If both of “Force End Judgment Switch” and “Torque End Judgment Switch” are turned ON, the force control operation can be ended when the result of judgment is “SUCCESS” for both after the workpiece is inserted to the specified depth.)
“Default : OFF”

### 29 Max. Torque

The value of this parameter is used for torque judgment. If the magnitude of generated torque is less than “Max. Torque”, the result of judgment is “SUCCESS”.
“Default : 5 N*m”

### Judgment Result

This parameter indicates the result of torque judgment at the end of force control operation. If the magnitude of torque at the end of force control operation is less than “Max. Torque”, “SUCCESS” is indicated. If not, “FAILURE” is indicated.
“Default : -----“

### Torque Average

This parameter indicates rotations about the axes other than “Insert Direction” and the average magnitude of torque about each of the axes at the end of force control operation. (If the axis for “Insert Direction” is Z, for example, W for indicating rotation about the X-axis and P for indicating rotation about the Y-axis are displayed. Similarly, if the axis for “Insert Direction” is X, P and R are displayed. If the axis for “Insert Direction” is Y, W and R are displayed.)
“Default : W:0 N*m
P:0 N*m”

### 30 Approach Acc. Time

This item specifies acceleration time that the speed becomes “Approach Velocity” of “Basic data” after executing force control instruction.
"Unit : sec"

### 31 PhaseMatch Acc. Time

This item specifies acceleration time that the speed becomes “PhaseMatch Insert Vel” of “Basic data” after force exceeds “Contact F Threshold” of “Basic data”.
"Unit : sec"

### 32 Insert Acc. Time

This item specifies acceleration time that the speed becomes “Insert Velocity” of “Basic data” after depth exceeds “Phase Match Depth” of “Basic data”.
"Unit : sec"

### 33 PhaseMatch ForceControl Valid Switch

This item is the switch of the function for force control in translation direction. Force control is done in the direction that this switch is “ON”. In the direction that this switch is “OFF”, force control is not done.
“Default X: OFF Y: OFF”

### 34 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"

### 35 Signal Output for ERR SW

This parameter enables the "Signal Output for ERR" function. This function sends out a designated signal when an alarm is issued while contouring.
"Default : OFF"

### 36 Output Signal Type (Signal Output for ERR)

This parameter specifies the kind of a signal that "Signal Output for ERR" function sends out when an alarm is issued while contouring.
"DO", "RO", "FLAG" are available for the kind of a signal.

### 37 Output Signal Number (Signal Output for ERR)

This parameter specifies the signal number that "Signal Output for ERR" function sends out when an alarm is issued while contouring.

### 38 Frc.Ctrl. End by REG SW

"Phase Match Ins." usually ends after it has reached "Insert Depth (Design)". If "Force End Judgment Switch" or "Torque End Judgment Switch" is ON, the force control does not end until its condition is satisfied. 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"

### 39 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"

## 3.5.5 Insert Phase Match

### Overview

In the “Insert Phase Match” menu, the settings for phase matching that is preceded by insertion can be specified. By the combination of "Shaft Insert" and "Phase Search", the same operation can be realized, but this function can shorten the total execution time of force control.
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.

Function selection screen

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

Basic screen

```
Force Ctrl/Basic
                                        1/24
  Schedule[1]              G:1 F:1 S:1
  1 Function         : Ins. Phase Match
  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 Insert Depth         :    20.00 mm
  9 Insert Force         :    50.00 N
 10 Insert Velocity      :     2.00 mm/s
 11 PhaseMatch Push Force:    30.00 N
 12 PhaseMatch Insert Vel:     0.00 mm/s
 13 PhaseMatch Ang. Vel  :     3.00 deg/s
 14 Total Depth (Design) :    20.00 mm
 15 Individual Diff. (+) :     3.00 mm
 16 Individual Diff. (-) :     0.00 mm
 17 Pushing Time         :     0.00 sec
 18 Check Orientation Change   : ON
 19   Change MAX Limit   :     3.00 deg
 20 PhaseMatch Angle Limit:   10.00 deg
 21 Insert Time Limit    :    20.00 sec
 22 Total Time Limit     :    30.00 sec
 23 F.Ctrl. Gain Auto Modify :       OFF
      Prev. Result     : No Change
 24 Force Control Gain :          Detail

 [ TYPE ] GROUP  NUMBER  DEFAULT PERFORM
```

F1 F2 F3 F4 F5

Force Ctrl/Gain screen

```
Force Ctrl/Gain
                                        1/2
  Schedule[1]              G:1 F:1 S:1
    Function         : Ins. Phase Match
  1 Insert Impedance    : [Master Freq. ]
  2 Phase M Impedance   : [Master Freq. ]

 [ TYPE ] GROUP  NUMBER  [CHOICE]
```

F1 F2 F3 F4 F5

Performance screen(1/2)

```
Force Ctrl/Perform
                                        1/41
  Schedule[1]              G:1 F:1 S:1
  1 Function         : Ins. Phase Match
  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
  8 Phase Match Torque    :     1.00 N*m
  9 P/M Reverse Switch        : ON
 10   Retry Number        :  10000
 11   Retry Multiplier    :      1.00
 12 P/M Range Margin      :      3.00 deg
 13 P/M Reduce Depth Rate:   95.00 %
 14 Settling Switch           : OFF
 15   Settling Time       :     1.00 sec
 16   Settling Rate       :   100.00 %
 17 Initial Insert Force :    50.00 N
 18 Velocity Adjust Switch    : ON
 19   Adjustment Gain     :     2.00
 20   Starting Rate       :    30.00 %
 21   Ending Rate         :    90.00 %
    Insert Force Limit
 22  X:  500.00 Y:  500.00 Z:  500.00 N
 23  W:   50.00 P:   50.00 R:   50.00N*m
    Phase M Force Limit
 24  X:  500.00 Y:  500.00 Z:  500.00 N
 25  W:   50.00 P:   50.00 R:   50.00N*m
 26 Ending Condition Switch   : OFF
      Insert Depth        :      0.00 mm
      Approach Length     :      0.00 mm
      Insert DIR
     [     0.000,     0.000,    -1.000]


 [ TYPE ] GROUP  NUMBER  DEFAULT  BASIC
```

F1 F2 F3 F4 F5

**Fig.3.5.5(a) Teaching “Ins.Phase Match” Detailed Data (1/2)**

Performance screen(2/2)

```
Force Ctrl/Perform
                                        27/41
 27 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
 28 Velocity Constant Switch   : ON
 29 Force End Judgment Switch  : OFF
 30   Min. Force Rate  :       80.00 %
      Judgment Result  :         -------
       Force Average  Z:        0.00 N
 31 Fast Ins. Switch   :         OFF
 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 PhaseMatch Acc. Time    :  0.70 sec
    PhaseMatch ForceControl Valid Switch
 37    X: OFF         Y: OFF
 38 Force Denoising Sw    :    OFF
 39 Signal Output for ERR SW:  OFF
 40   Output Signal Type  :    DO
 41   Output Signal Number:       0
 42 Frc.Ctrl. End by REG SW : OFF
 43   End Register Number :      0

 [ TYPE ] GROUP  NUMBER  DEFAULT  BASIC
   F1      F2      F3      F4      F5
```

**Fig.3.5.5(b) Teaching "Ins.Phase Match" Detailed Data (2/2)**

### Function keys

The function keys indicated in Fig. 3.5.5(a) and (b) have the following functions:

| 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. |
| 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. |

### 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"

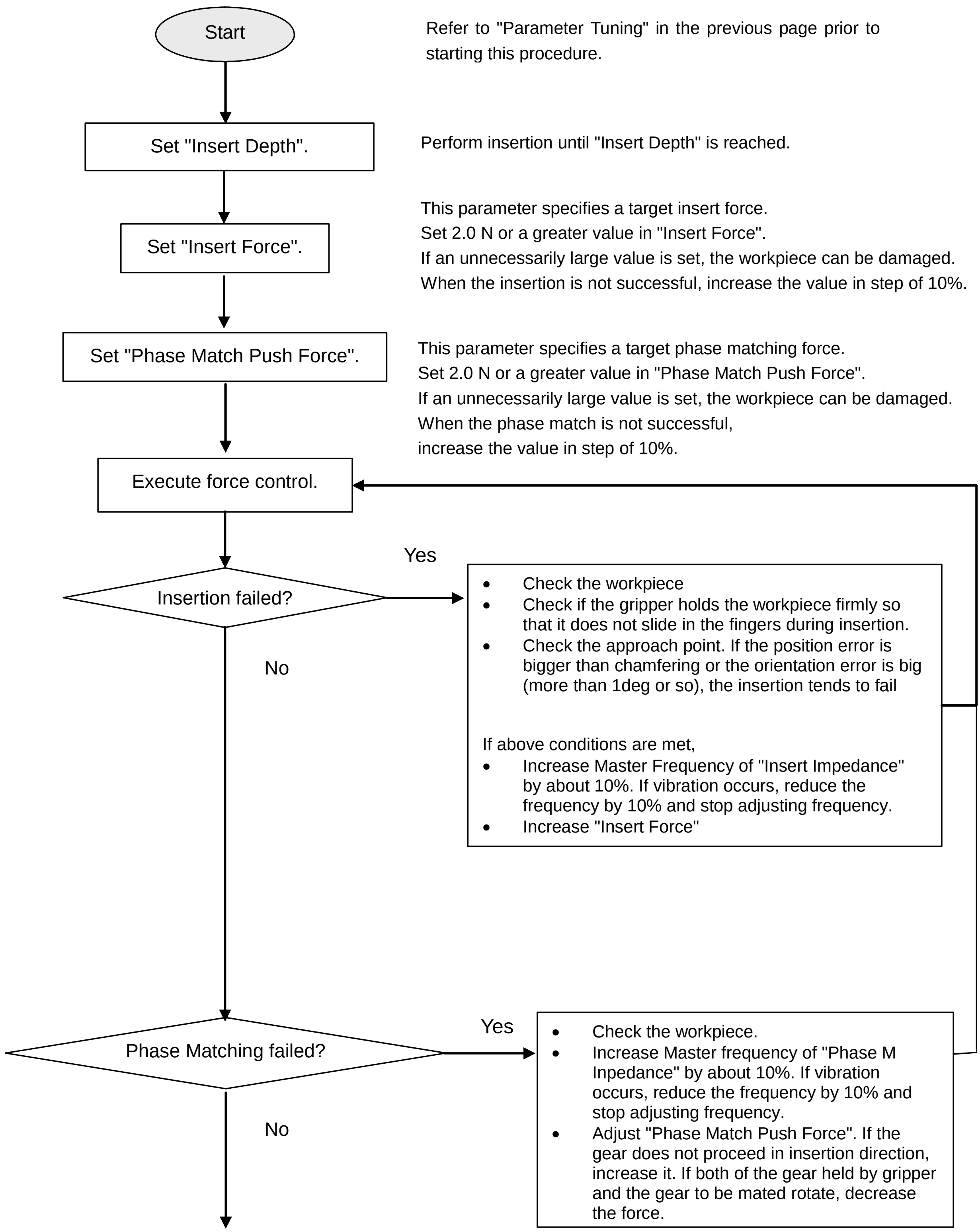
## Parameter tuning

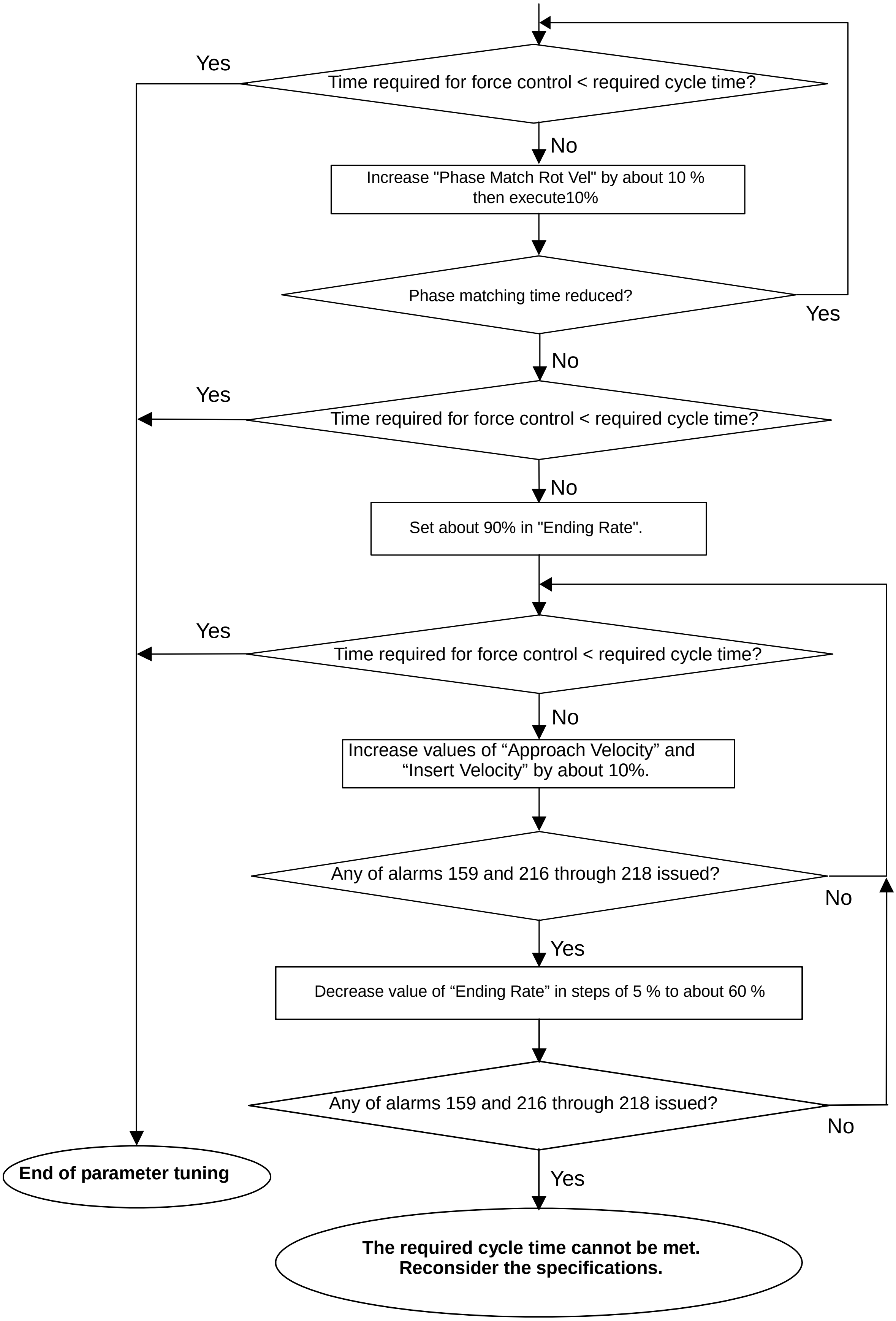
The following parameter setting sequence is used:

1 Set "Insert Direction", "User Frame No.", "Tool Frame No.", and "Total Depth (Design)".
2 Make an automatic force control gain adjustment. (See Subsection 3.9.2.)
3 Set the parameters on the basic screen.

4 Tune parameters on the performance screen as required.

For the outline of force control instruction programming, see Section 3.1, "NOTES/RESTRICTIONS", and Section 3.2, "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.




Yes
Time required for force control < required cycle time?
No
Increase "Phase Match Rot Vel" by about 10 %
then execute10%
Phase matching time reduced?
Yes
No
Yes
Time required for force control < required cycle time?
No
Set about 90% in "Ending Rate".
Yes
Time required for force control < required cycle time?
No
Increase values of “Approach Velocity” and
“Insert Velocity” by about 10%.
Any of alarms 159 and 216 through 218 issued?
No
Yes
Decrease value of “Ending Rate” in steps of 5 % to about 60 %
Any of alarms 159 and 216 through 218 issued?
No
End of parameter tuning
Yes
The required cycle time cannot be met.
Reconsider the specifications.

## [Basic Data Screen]

**Parameters shown in this section must be set.**

### 1 Function

From "Function selection screen" in Fig. 3.5.5(a), select a function to be set. In this case, Choose “Ins. Phase Match”.

### 2 Comment

Enter a comment for identifying the schedule data.

### 3 Insert Direction

This is the insertion direction in the user frame of “User Frame No.”
“Default : -Z”

### 4 Contact F Threshold

This is the threshold to judge contact to the work object. The cycle time might deteriorate when this value is enlarged too much because an actual Insertion begins after contact.
“Default : 1 N”

### 5 Approach Velocity

This is the target speed until coming in contact with the work object.
“Default : 1 mm/sec”

### 6 User Frame No.

This is the user frame number used at force control. Set the user frame number that is set along Section 3.2, “TEACHING PROCEDURE”.
“Default : 0”

### 7 Tool Frame No.

This is the tool frame number used at force control. Set the tool frame number that is set along Section 3.2, “TEACHING PROCEDURE”.
“Default : 1”

### 8 Insert Depth

This is the threshold for ending insertion. After the insertion of this depth, the mode changes to phase matching.
“Default : 20 mm”

### 9 Insert Force

This is the target insertion force in “Insert Direction”.
"Unit : N"

### 10 Insert Velocity

This is the target insertion velocity in “Insert Direction”.
“Default : 2 mm/sec”

### 11 PhaseMatch Push Force

This is the target push force in phase matching.
"Unit : N"

### 12 PhaseMatch Insert Vel

This is the target velocity in phase matching.
“Default: 0 mm/sec”

### 13 Phase Match Rot Vel

This is the workpiece rotation speed in phase matching.
“Default : 3 deg/sec”

### 14 Total Depth (Design)

This is the depth of insertion from the start point of force control to the end point of force control.
“Default : 20 mm”

### 15 Individual Diff. (+)

This is the allowable positive tolerance to “Insert Depth (Design)”, due to differences between individual workpieces. If the depth of insertion exceeds the value of (“Total Depth (Design)” – Individual Diff (-) + “Individual Diff. (+)”), an alarm is issued.
“Default : 3 mm”

### 16 Individual Diff. (-)

This is the allowable negative tolerance to “Insert Depth (Design)”, due to differences between individual workpieces. If the depth of insertion reaches (“Total Depth (Design)” – “Individual Diff. (-)”, the system assumes that insertion has been performed successfully.
“Default : 0 mm”

### 17 Pushing Time

This is the length of push time after the system assumes the insertion to have been successful. Through this push, the individual differences indicated above are compensated.
“Default : 0 sec”

### 18 Check Orientation Change

This is the switch for checking how the orientation has been changed in insertion, in comparison with the orientation in teaching. Usually, this switch is turned ON.
“Default : ON”

### 19 Change MAX Limit

This is the maximum allowable change from the teaching orientation during insertion if “Check Orientation Change” described above is ON. If the actual orientation change exceeds this “Change MAX Limit”, an alarm is issued.
“Default : 3 deg”

### 20 PhaseMatch Angle Limit

Phase matching is performed within the angular range set in this parameter. If “P/M Reverse Switch” of ”Performance screen” is set to ON, phase matching is continued by reversing the direction when the upper angular range limit is reached.
“Default : 10 deg”

### 21 Insert Time Limit

The insert time is the time from the start of insertion after contact to the work object until insertion is regarded as successful. If this time has elapsed before "Insert Depth" is reached, an alarm is issued.
“Default : 20 sec”

### 22 Total Time Limit

This is the maximum length of total 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 (Refer to “Pushing Time”) is excluded from the insertion time.
"Default: 30 sec"

### 22 F.Ctrl. Gain Auto Modify

This item is the switch used for automatic force control gain tuning. For details, see Subsection 3.9.2, "Force Control Gain Auto Tuning Instruction".
"Default : OFF"

### 23 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, see Section 3.6, "FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".

## [Performance Data Screen]

**Parameters shown in this section are for advanced users.**

### 1 Function

From "Function selection screen" in Fig. 3.5.5(a), select a function to be set. In this case, choose “Phase Match Ins.”.

### 2 Comment

Enter a comment for identifying the schedule data.

### 3 Simple Customize Sw

This parameter specifies a switch for "Simple Customize" function. It enables to execute the schedule data being edited after any other schedule.
For details, see Subsection 3.7.3, "Simple Customization Function".
"Default: OFF"

### 4 Cont. Exec. Max. Count

It designates how many force schedules with "Simple Customize Sw" ON can be executed successively.
For details, see Subsection 3.7.3, "Simple Customization Function".
"Default : 1"

### 5 Customize Parent Number

This item is set when force control is executed successively. For details, see Subsection 3.7.3, "Specifying the Parent-Child Relationship".
"Default: 0"

### 6 Customize ParaChg Connection

This item is set when force control is executed successively. For details, see Subsection 3.7.3, "Specifying the Parent-Child Relationship".
"Default: OFF"

### 7 User Frame Compensation SW

This is a switch for correcting a user frame set on a work target plane through vision. This parameter is useful when a work target is not positioned correctly. The switch must be used in combination with the OFFSET or VOFFSET instruction. For details, see Section 3.8, "User Frame Compensation".
“Default : OFF”

### 8 Phase Match Torque

This is a target torque for turning the workpiece at the time of phase matching.
"Default: 10 N*m"

### 9 P/M 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 : ON”

### 10 Retry Number

If the workpiece cannot be inserted by the upper search range limit is reached, and "P/M 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: 10000"

### 11 Retry Multiplier

If the workpiece cannot be inserted by 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, "Phase Match 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”

### 12 P/M Range Margin

Search operation is performed in the range specified by " PhaseMatch Angle Limit" of “Basic data”. An alarm is issued when the upper search range limit plus the value specified in this parameter is reached.
“Default : 3 deg”

### 13 P/M Reduce Depth Rate

When the workpiece is inserted by ("Total Depth" of “Basic data”) × "this value" / 100, the phase matching angular velocity is decreased to (“Phase Match Rot Vel” of “Basic data”) × 0.3. 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 %”

### 14 Settling Switch

Settling means reducing the pushing force after pushing is completed. Settling is useful if the workpiece tends to vibrate because of the impact caused by the removal of the robot hand, for instance.
“Default : OFF”

### 15 Settling Time

Settling is performed over this “Settling Time”.
“Default : 1 sec”

### 16 Settling Rate

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 %”

### 17 Initial Insert Force

This is the target insertion force at the beginning of 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”.
"Unit : N"

### 18 Velocity Adjust Switch

This is the switch for adjusting “Insert Velocity” in “Basic data” during insertion. This switch is useful when starting insertion slowly and then increasing the insertion velocity from a certain stage of insertion.
“Default : ON”

### 19 Adjustment Gain

The actual Insert Velocity during velocity adjustment is “ Insert Velocity” in “Basic data” multiplied by this “Adjustment Gain”.
“Default : 2”

### 20 Starting Rate

Velocity adjustment starts when the insertion depth reaches (“Insert Depth (Design)” in “Basic data”) x “Starting Rate” / 100.
“Default : 30 %”

### 21 Ending Rate

Velocity adjustment ends when the insertion depth reaches (“Insert Depth (Design)” in “Basic data”) x “Ending Rate”/100. The velocity command becomes zero if the workpiece goes deeper than this value to prevent an excessive collision force.
“Default : 90 %”

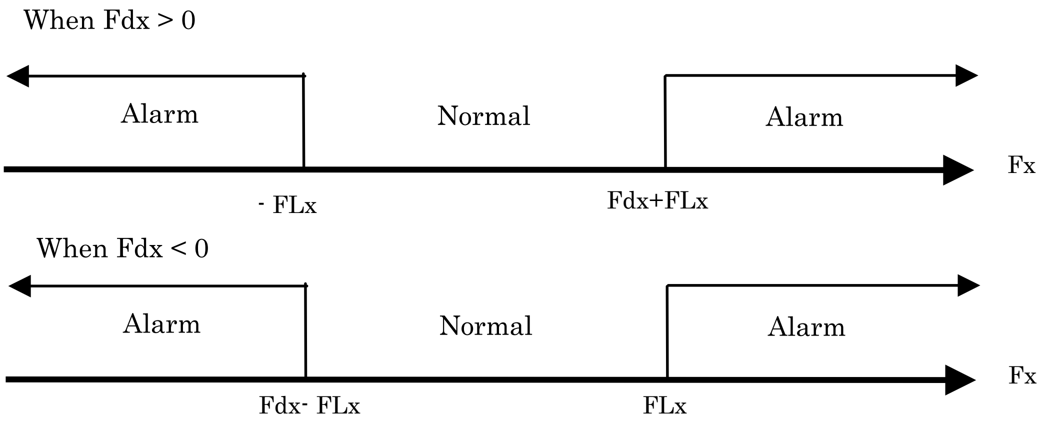
### 22 Insert Force Limit
### 23

If force generated during insertion satisfies one of the expressions below, an alarm(FORC-216 - FORC-221) is issued. See 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.
"Unit : N, N*m"




### 24 25 Phase M Force Limit

This parameter is used to check the force value during phase matching while the insert force limit is used during insertion. The range that causes an alarm is the same as the range for Insert Force Limit.
"Unit : N, N*m"

### 26 Ending Condition Switch

If the switch is turned ON, whether the insertion is successful is judged using “Insert Depth” described below, instead of “Insert Depth (Design)” in “Basic data”, and “Insert DIR” instead of “Insert Direction”, also in “Basic data”. Execute the end condition acquisition instruction before turning on this switch.(Refer to Subsection 3.9.4, “End Condition Acquisition Instruction”)
“Default : OFF”

### Insert Depth

This data is specified by the end condition acquisition. The depth of insertion is estimated from the actual insertion. If “Ending Condition Switch” is set ON, this “Insert Depth”, instead of “Insert Depth (Design)” in “Basic data”, is used to judge whether the insertion is successful. (The setting cannot be modified.)
“Default : 0 mm”

### Approach Length

This data is specified by the end condition acquisition. 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 setting cannot be modified.)
“Default : 0 mm”

### Insert DIR

This data is specified by the end condition acquisition. 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. (The setting cannot be modified.)
“Default : [0, 0, -1]”

### 27 Torque Error Compensate SW

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 Subsection 3.9.3, “Torque Error Acquisition Instruction”)
“Default : OFF”

### Torque Error Data W P R

These data are specified by the torque error acquisition. The data are estimated from the moment information obtained from the force sensor when a push is made with a constant force of “Torque Error Fd”. 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.)
“Default : 0 N*m”

### Torque Error Fd

This is specified by the torque error acquisition. This indicates the pushing force used for making the estimation. If “Torque Error Compensate SW” is turned ON, this setting is used to correct the torque error. (The setting cannot be modified.)
"Unit : N"

### 28 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. If this switch is turned ON when shaft insertion, bearing insertion, groove insertion, or square insertion operation is performed, the speed during insertion can be controlled not to exceed “Insert Velocity” of the “Basic data”.
(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"

### 29 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. When this switch is turned ON, the force control operation can be ended if the “Judgment Result” described below is “SUCCESS” after the workpiece is inserted to the specified depth. If it is not “SUCCESS” even after “Total Time Limit” of the “Basic data” has passed, an alarm is issued.
“Default : OFF”

### 30 Min. Force Rate

The value of this item is used for force judgment. If the magnitude of generated force in “Insert Direction” is greater than “Min. Force Rate” x “PhaseMatch Push Force” / 100, the result of judgment is “SUCCESS”.
“Default : 80 %”

### Judgment Result

This item indicates the result of force judgment at the end of force control operation. If the magnitude of force in “Insert Direction” at the end of force control operation is greater than “Min. Force Rate” x “PhaseMatch Push Force” / 100, “SUCCESS” is indicated. If not, “FAILURE” is indicated.
“Default : -----“

### Force Average

This item indicates the axis of “Insert Direction” and the average magnitude of force in “Insert Direction” at the end of force control operation.
“Default : Z:0 N”

### 31 Fast Ins. Switch

This item is the switch of the function for the fast adjustment of workpiece’s posture.
“Default : OFF”

### 32 Fast Ins. Multiplier

This item determines the speed of the workpiece’s posture adjustment. In case that “Fast Ins. Switch” is ON, posture adjustment becomes faster by increasing this value. For the safety, increase this value in step of 0.5.
“Default : 2”

### 33 Fast Ins. Acc. Time

This item determines the acceleration time for adjusting the posture. In case that “Fast Ins. Switch” is ON, posture adjustment becomes faster by decreasing this value. For the safety, decrease this value in step of 0.1.
“Default : 0.4sec”

### 34 Approach Acc. Time

This item specifies acceleration time that the speed becomes “Approach Velocity” of “Basic data” after executing force control instruction.
"Unit : sec"

### 35 Insert Acc. Time

This item specifies acceleration time that the speed becomes “Insert Velocity” of “Basic data” after force exceeds “Contact F Threshold” of “Basic data”.
"Unit : sec"

### 36 PhaseMatch Acc. Time

This item specifies acceleration time that the speed becomes “PhaseMatch Insert Vel” of “Basic data” after depth exceeds “Insert Depth” of “Basic data”.
"Unit : sec"

### 37 PhaseMatch ForceControl Valid Switch

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.
“Default X: OFF Y: OFF”

### 38 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"

### 39 Signal Output for ERR SW

This parameter enables the "Signal Output for ERR" function. This function sends out a designated signal when an alarm is issued while contouring.
"Default : OFF"

#### 40 Output Signal Type (Signal Output for ERR)

This parameter specifies the kind of a signal that "Signal Output for ERR" function sends out when an alarm is issued while contouring.
"DO", "RO", "FLAG" are available for the kind of a signal.

#### 41 Output Signal Number (Signal Output for ERR)

This parameter specifies the signal number that "Signal Output for ERR" function sends out when an alarm is issued while contouring.

#### 42 Frc.Ctrl. End by REG SW

"Ins. Phase Match" usually ends after it has reached "Total Depth (Design)". If "Force End Judgment Switch" is ON, the force control does not end until its condition is satisfied. 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"

#### 43 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"

## 3.5.6 Search Function

### 3.5.6.1 Outline of the search function

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.

#### Types of search functions

The search function enables search operations in up to five directions (two translation directions and three rotation directions) other than the insertion direction A typical search function requires search operation in one to three directions depending on the type of search

Force control software provides four types of search functions. .

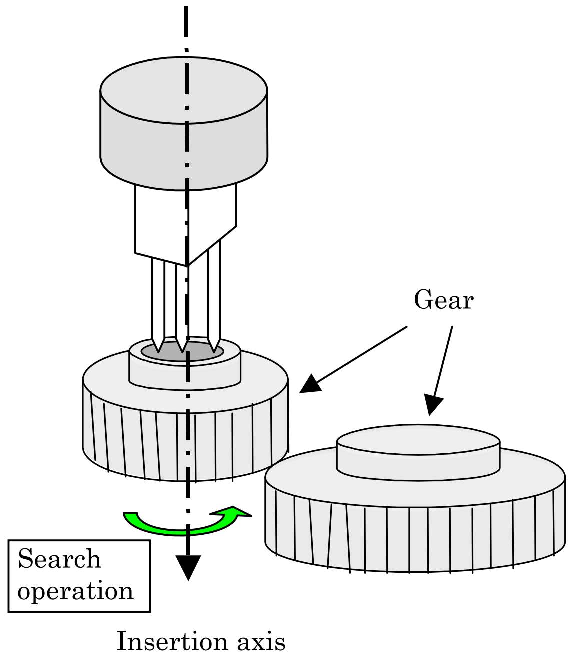
(1) "Search":
This function enables search operations in up to five directions. The user specifies actual search directions in parameters. For details of the parameters, see Subsection 3.5.6.3, "Search".

(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. 3.5.6.1(a). For details of parameters, see Subsection 3.5.6.4, "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. 3.5.6.1(b). For details of parameters, see Subsection 3.5.6.5, "Hole search".

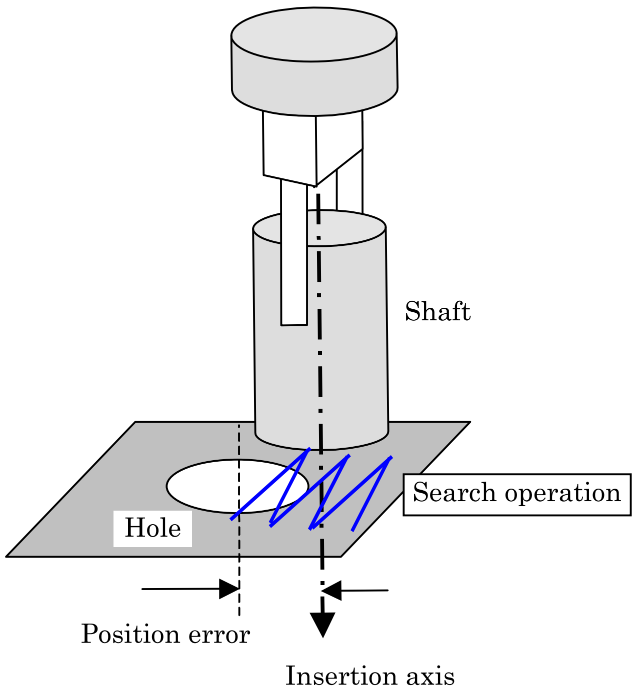
(4) "Clutch Search":

This function is used for clutch assembly . As shown in Fig. 3.5.6.1(c), 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, see Subsection 3.5.6.6, "Clutch search".




Search operation about the insertion axis (phase matching) is performed by "Phase Search".

**Fig. 3.5.6.1(a) Phase search**




Search operation in a plane perpendicular to the insertion axis is performed by "Hole Search".

**Fig. 3.5.6.1(b) Position search in a plane**

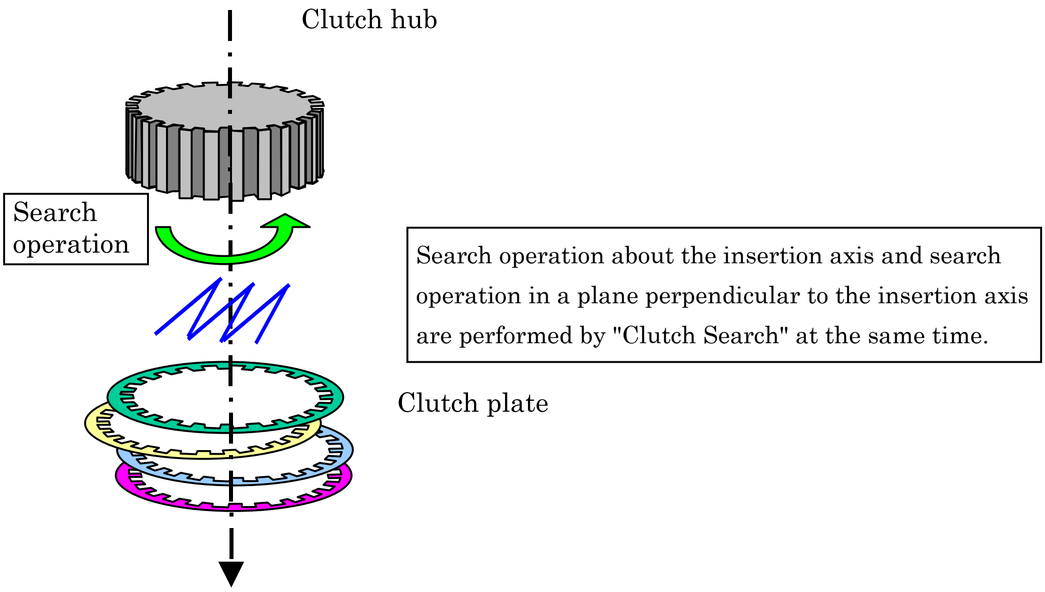



**Fig. 3.5.6.1(c) Clutch assembly (A phase search and position search in a plane are made simultaneously.)**

### 3.5.6.2 Parameter tuning

#### Search range setting

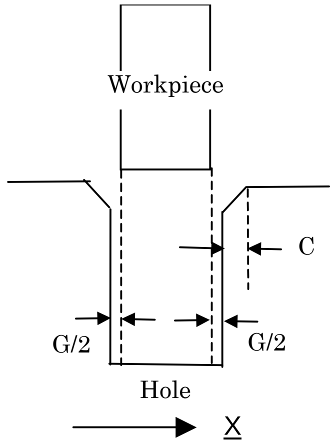



**Fig. 3.5.6.2(a)**

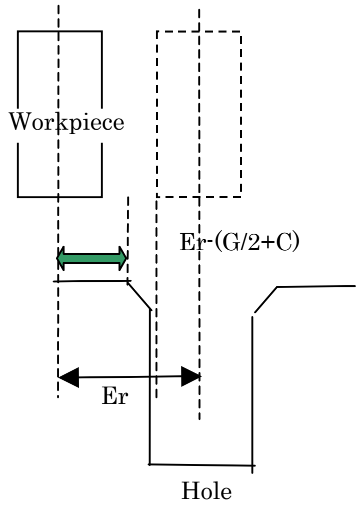



**Fig.3.5.6.2(b)**

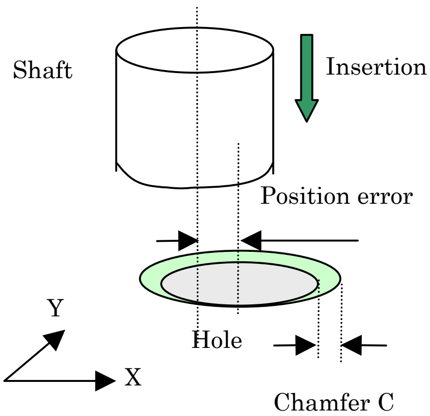



**Fig. 3.5.6.2(c)**

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. 3.5.6.2(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. 3.5.6.2(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.

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. 3.5.6.2(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 $2\times(Er-(G/2+C))$ is required.

Accordingly, a search range with some margin added is:
$2\times(Er-(G/2+C))+\alpha$
When the value of $\alpha$ is large, the probability of success in search operation increases. If the value of $\alpha$ 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. 3.5.6.2(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.

## Search frequency, clearance and chamfer amount setting

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.
A complicated calculation is required to set an optimal path. With the search function, a search path is automatically calculated using parameters such as "Size of Search Range", "Search Frequency", and "Clearance & Chamfer".

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. 3.5.6.2(d).

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. 3.5.6.2(e), so that the entire range cannot be searched.
Fig. 3.5.6.2(f) shows a search path when the velocity in the X direction is 4 times greater than the velocity in the Y direction. Fig. 3.5.6.2(g) shows a search path when the velocity in the X direction is 8 times greater than the velocity in the Y direction.

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.

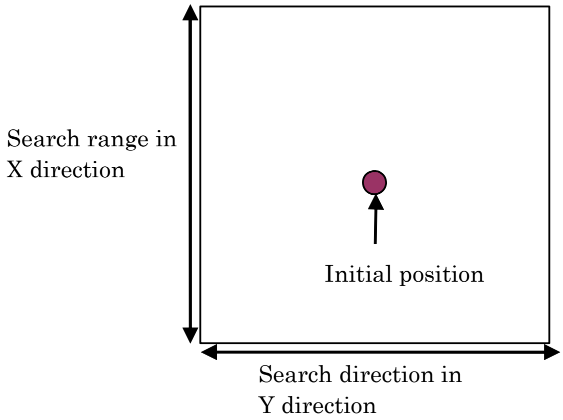



**Fig. 3.5.6.2(d)**

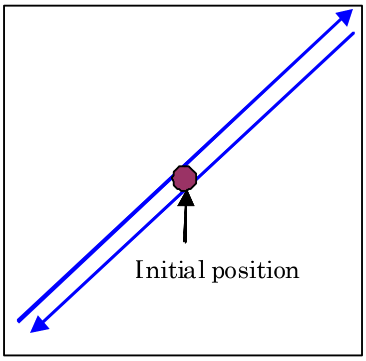



**Fig. 3.5.6.2(e)**

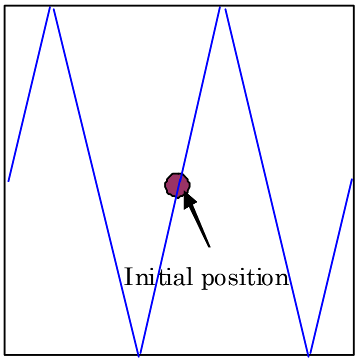



**Fig. 3.5.6.2(f)**

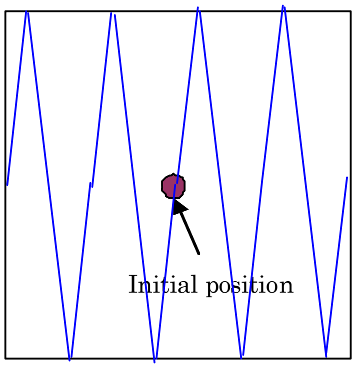



**Fig. 3.5.6.2(g)**

Determination of optimal velocities in the X and Y directions must take various conditions into consideration and is very complicated.
With the search function, the parameters "Clearance & Chamfer", "Size of Search Range", and "Search Frequency" are available for automatic calculation of velocities to be specified in the search directions.
"Clearance & Chamfer" specifies the value of (C+G/2) mentioned in "Search range setting" above.
"Search Frequency" specifies the frequency of reciprocating motion in the direction for which the highest velocity is specified.
When these values are set, a "Target Velocity" in each direction is automatically calculated.

## 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.

## 3.5.6.3 Search

### Overview

Search operation can be performed in up to five directions.
The parameters on the basic screen and performance screen must always be specified.

Function selection screen

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

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

Basic screen

```
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:  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  DEFAULT 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

Performance 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

 [ TYPE ] GROUP  NUMBER  DEFAULT  BASIC
```

F1 F2 F3 F4 F5

**Fig. 3.5.6.3 "Search" screens(1/2)**

Search basic 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
```

Search performance 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
```

**Fig. 3.5.6.3 "Search" screens(2/2)**

## Function keys

The function keys indicated in Fig. 3.5.6.3 have the following functions:

| 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. |
| 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. |

## G F S

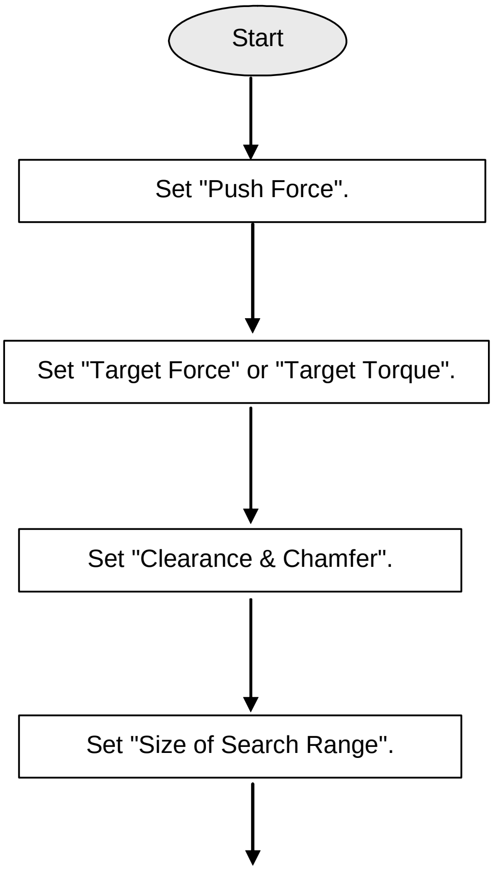
G represents a motion group number at the time of teaching. F represents a force control number. S represents a force sensor number. (These values cannot be changed.)
"Default G F S: 1 1 1"

## Parameter tuning

The following parameter setting sequence is used:

1 Set "Insert Direction", "User Frame No.", "Tool Frame No.", and "Search End Depth".
2 Determine a desired search direction, then set "Search Valid Switch" and "Force control Valid Switch". When "Search Valid Switch" is set to ON for a direction, "Force control Valid Switch" must be set to ON for the same direction.
3 For the direction valid for search, set "Velocity Order".
4 Make an automatic force control gain adjustment. (See Subsection 3.9.2)
5 Set the parameters on the basic screen.
6 Tune parameters on the performance screen as required.

For the outline of force control instruction programming, see Section 3.1, "NOTES/RESTRICTIONS", and Section 3.2, "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.

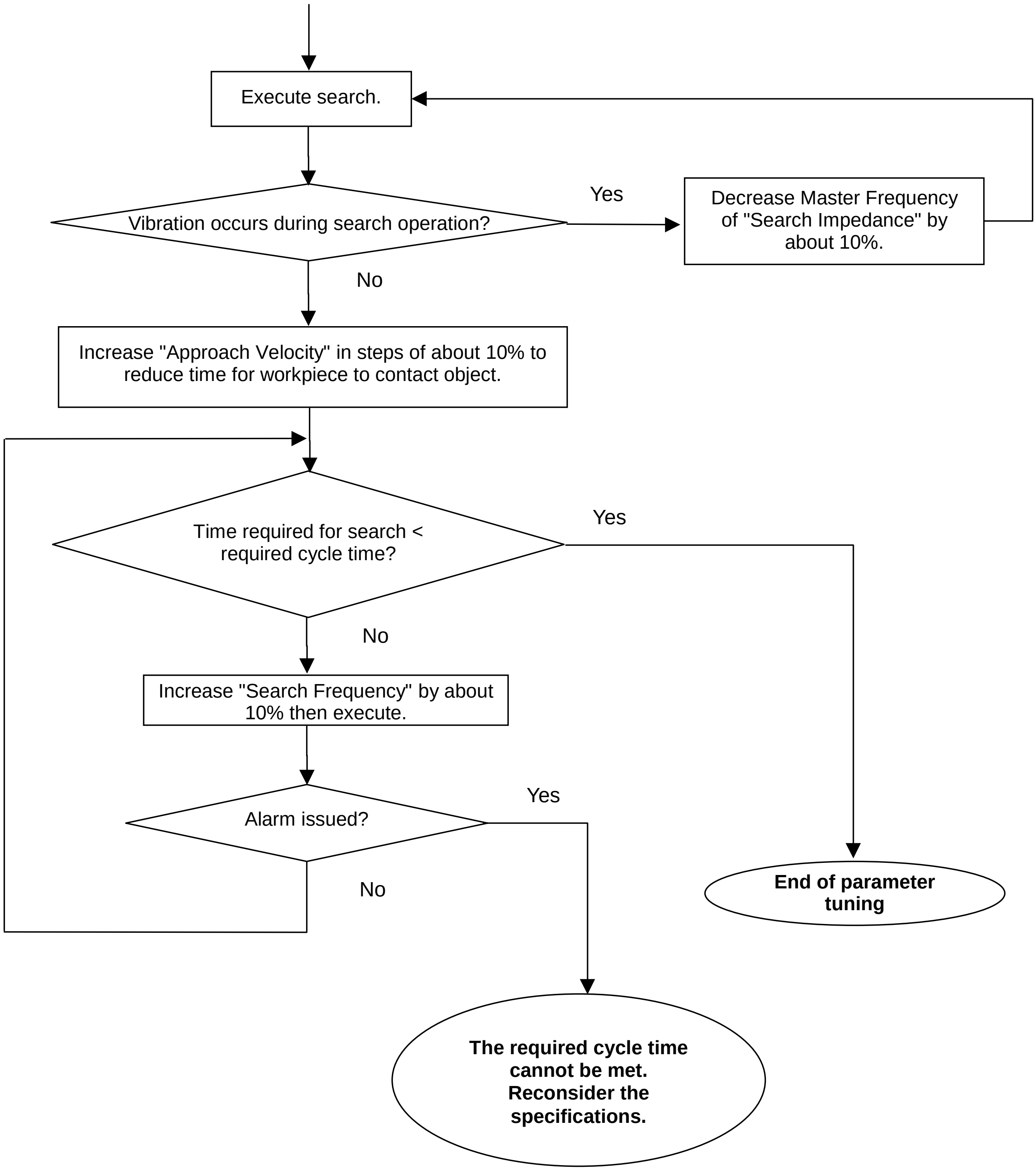



This parameter specifies a target pushing force during search operation.
Set 2.0 N or a greater value in "Push Force".
If an unnecessarily large value is set, the workpiece can be damaged.
When the phase is not successful match, increase the value in step of 10%.

"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 3.5.7.2, "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 3.5.7.2, "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 3.5.7.2, "Parameter tuning".


Execute search.
Vibration occurs during search operation?
Yes
Decrease Master Frequency of "Search Impedance" by about 10%.
No
Increase "Approach Velocity" in steps of about 10% to reduce time for workpiece to contact object.
Time required for search < required cycle time?
Yes
No
Increase "Search Frequency" by about 10% then execute.
Alarm issued?
Yes
No
End of parameter tuning
The required cycle time cannot be met. Reconsider the specifications.

## ［Basic data setting screen］

**Parameters shown in this section must be set.**

### 1 Function

From the submenu shown on the function selection screen of Fig.3.5.6.3, select a function to be set. In this case, select "Search".

### 2 Comment

Enter a comment for identifying schedule data.

### 3 Insert Direction

An insertion direction is represented in the set user frame.
"Default: -Z"

### 4 Contact F Threshold

This is the threshold to judge contact to the work object. An actual insertion operation starts after a touch. So, if an excessively large value is set in this parameter, the cycle time can deteriorate.
"Default: 1 N"

### 5 Approach Velocity

Operation velocity to be used until a work target is touched.
"Default: 1 mm/sec"

### 6 User Frame No.

Number of a user frame to be used at the time of insertion. Enter the number of a user frame set according to Section 3.2, "TEACHING PROCEDURE".
"Default: 0"

### 7 Tool Frame No.

Number of a tool frame to be used at the time of insertion. Enter the number of a tool frame set according to Section 3.2, "TEACHING PROCEDURE".
"Default: 1"

### 8 Search End Depth

This is the threshold for determining success in search and ending search operation.
"Default: 5 mm"

### 9 Push Force

Target force value for pushing a workpiece against an insertion surface at the time of search.
If insertion is unsuccessful when a match is found in position and phase, increase this value in steps of about 10%. If a workpiece to accept an inserted workpiece rotates together with the inserted workpiece, decrease this value in steps of about 10%.

### 10 Search Insert Vel

This is the operation velocity to be used after a work target is touched.
"Default: 0 mm/s"

### 11 Search Frequency

Parameter for determining a search velocity. When search operation is performed in multiple directions, a search velocity is automatically calculated by this parameter, "Size of Search Range", and "Clearance & Chamfer". For one-direction search operation, this parameter is not used.
"Default: 1 Hz"

### 12 Search Basic Param.

This parameter is used to switch to a screen for setting basic parameters for search path determination. Move the cursor to this line, then press the ENTER key. The screen display switches to the search parameters basic screen. For the parameters that can be set on this screen, see the description of "Search parameters basic screen".

### 13 Individual Diff.(+)

Allowable additional depth of insertion when the depth of insertion is greater than "Insert Depth (Design)" due to the differences in individual workpieces. If the actual depth of insertion exceeds (Insert Depth (Design) – Individual Diff. (-) + this value), an alarm is issued.
"Default: 3 mm"

### 14 Individual Diff.(-)

Allowable shortage in depth of insertion when the depth of insertion is less than "Insert Depth (Design)" due to the differences in individual workpieces. If the actual depth of insertion reaches (Insert Depth (Design) - this value), the insertion is assumed to be successful.
"Default: 0 mm"

### 15 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. This value represents a time used for such pushing operation.
"Default: 0 sec"

### 16 Search Time MAX Limit

This search time means the period of time from the start of search operation after touching a work target until search operation is assumed to be successful. 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").
"Default: 20 sec"

### 17 F.Ctrl. Gain Auto Modify

This item is the switch used for automatic force control gain tuning. For details, see Subsection 3.9.2, "Force Control Gain Auto Tuning Instruction".
"Default : OFF"

### 18 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, see Section 3.6, "FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".

## ［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.

### 1 Search Valid Switch
### 2

Search operation is performed in those directions with this switch set to ON. To perform search operation in the X, Y, and W directions, for example, set the switch to ON for those directions, and set the switch to OFF for the other directions.
If the switch is set to ON for a direction, the "Force Control Valid switch" for the direction is also set to ON.
If the switch is set to OFF, the "Force Control Valid switch" remains unchanged.

### 3 Force Control Valid Switch
### 4

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.

### 5 Velocity Order
### 6

When multiple search directions are involved, determine the order of operation velocities. The highest velocity is specified for the direction for which 1 is set. The second highest velocity is specified for the direction for which 2 is set. As the number specified for a direction increases, the velocity decreases. Specify integers starting with 1 sequentially. If non-sequential numbers, such as 1 and 3, are specified, an error occurs. If the same order number is specified for two or more directions, an error also occurs. Be sure to specify a unique number for each direction.
When only one direction is involved, specify 1 for the direction.

### 7 Target Velocity
### 8 Target Angular Velocity

Target velocity (angular velocity) for operating a workpiece.
When multiple search directions are involved, this parameter need not be specified. From "Velocity Order", "Search Frequency", "Clearance & Chamfer", "Size of Search Range", and "Repeat Number", a target velocity (angular velocity) is automatically calculated and set.
When search operation is performed in the X, Y, or Z direction:
"Default: 1 mm/sec"
When search operation is performed in the W, P, or R direction:
"Default: 0 deg/sec"

### 9 Target Force
### 10 Target Torque

Target force (torque) in a search direction. Determine a value according to the items of target force and target torque described in Subsection 3.5.6.2, "Parameter tuning".
If "Force 420 Error" occurs with little motion made, increase this value in steps of about 10% to 20%. If a position or phase match point is passed, decrease this value in steps of about 10% to 20%.
"Unit : N, N*m"

### Clearance & Chamfer

### 12 Clearance

The chamfer amount is the sum of the chamfer amount of a workpiece to be inserted and the chamfer amount of a workpiece to accept a workpiece to be inserted. See Fig. 3.5.6.2(a), and the setting items of search frequency, and clearance and chamfer amount in Subsection 3.5.6.2, "Parameter tuning".
The clearance is the gap between a workpiece to be inserted and a workpiece to accept a workpiece to be inserted.
For both values, make measurements in a search direction.
Calculate [(measured chamfer amount) + clearance/2], then set the result of calculation in this parameter.
When search operation is performed in the X, Y, or Z direction:
"Default: 1 mm"
When search operation is performed in the W, P, or R direction:
"Default: 1 deg"

### 13 Size of Search Range
### 14

For each search direction, determine a search range, then set the value in this parameter.
Determine a value according to the description of "Search range setting" in Subsection 3.5.6.2, "Parameter tuning".
When search operation is performed in the X, Y, or Z direction:
"Default: 10 mm"
When search operation is performed in the W, P, or R direction:
"Default: 10 deg"

### 15 Repeat Number
### 16

When a work target has a structure that repeats the same pattern as in the case of the teeth of a gear, specify the number of patterns. For example, if the size of search range is 30 deg in the rotation direction about the insertion axis, and the teeth pitch is 5 deg, specify the repeat number 6 in this parameter. When no particular pattern is involved, specify 1.
"Default: 1"

## [Performance data setting screen]
**Parameters shown in this section are for advanced users.**

### 1 Function
From the submenu shown on the function selection screen of Fig.3.5.6.3, select a function to be set. In this case, select "Search".

### 2 Comment
Enter a comment for identifying schedule data.

### 3 Simple Customize Sw
This parameter specifies a switch for "Simple Customize" function. It enables to execute the schedule data being edited after any other schedule.
For details, see Subsection 3.7.3, "Simple Customization Function".
"Default: OFF"

### 4 Cont. Exec. Max. Count
It designates how many force schedules with "Simple Customize Sw" ON can be executed successively.
For details, see Subsection 3.7.3, "Simple Customization Function".
"Default : 1"

### 5 Customize Parent Number
This item is set when force control is executed successively. For details, see Subsection 3.7.3, "Specifying the Parent-Child Relationship".
"Default: 0"

### 6 Customize ParaChg Connection
This item is set when force control is executed successively. For details, see Subsection 3.7.3, "Specifying the Parent-Child Relationship".
"Default: OFF"

### 7 Customize Auto. Cnt. Exec. Sw (Customize Auto. Cnt. Exec.)
This parameter specifies a switch for "Customize Auto. Cnt. Exec." function.
"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.
For details, see Subsection 3.7.5, "Customization Automatic Continuous Execution Function".
"Default: OFF"

### 8 Auto. Cnt. Exec. Child No. (Customize Auto. Cnt. Exec.)
This parameter specifies a schedule data number of its child schedule data. The child schedule data is a schedule data that is executed next.
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.

### 9 Schedule No. Output Reg. No. (Customize Auto. Cnt. Exec.)
This parameter specifies a Numeric Register Number to which "Customize Auto. Cnt. Exec." function output the execution state.

When "Customize Auto. Cnt. Exec." function is executing, this function outputs a running schedule data number. If the series of the schedule data ends normally, this function outputs 0.
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.

### 10 User Frame Compensation SW

This is a switch for correcting a user frame set on a work target plane through vision. This parameter is useful when a work target is not positioned correctly. The switch must be used in combination with the OFFSET or VOFFSET instruction. For details, see Section 3.8, "User Frame Compensation".
"Default: OFF"

### 11 Search acc. Time

Specify an acceleration/deceleration time constant for search velocity.
"Default: 0.1 sec"

### 12 Decel. Depth Rate

When the workpiece is inserted by the basic data "Search End Depth" × "this value"/100, the velocity (angular velocity) in a search direction is decreased to the basic data "Target Velocity (Angular Velocity)" × 0.1. If an attempt to move the workpiece forcibly damages the workpiece or stops insertion even when a position or phase match is ensured, decrease this value.
"Default: 95%"

### 13 Search Performance Param.

Parameter for search path determination. Move the cursor to this line, then press the ENTER key. The screen display switches to the screen for setting parameters required to increase search performance. For the parameters that can be set on this screen, see the description of the search parameters performance screen.

### 14 Settling Switch

Operation for weakening the pushing force upon completion of insertion is referred to as "settling". This parameter is useful if the workpiece vibrates because of a shock occurring when the hand is released after completion of insertion.
"Default: OFF"

### 15 Settling Time

"Settling" is performed for this time.
"Default: 1 sec"

### 16 Settling Rate

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%

### 17 Initial Insert Force

Target force at the start of 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".
"Unit : N"

### 18 19 Force Limit

If force generated during search satisfies one of the expressions below, an alarm(FORC-216 - FORC-221) is issued. See 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, the alarm is issued in the following cases:
When Fdx > 0, Fx < -FLx or Fx > Fdx + FLx
When Fdx < 0, Fx > FLx or Fx < Fdx - FLx
A similar check is made in the Y, Z, W, P, and R directions.
"Unit : N, N*m"

### 20 Torque Error Compensate SW

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. (For details, see Subsection 3.9.3, "Torque Error Acquisition Instructions".
"Default: OFF"

### Torque Error Data W P R

Values set by estimation from the moment information obtained by the force sensor when the workpiece is actually pushed by "Torque Error Fd" according to "torque error acquisition". 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. (These cannot be changed.)
"Default: 0 N*m"

### Torque Error Fd

An actually applied pushing force at the time of "torque error acquisition" is set as this value. When "Torque Error Compensate SW" is set to ON, torque error compensation is performed using this value. (This cannot be changed.)
"Unit : N"

### 21 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. If this switch is set to ON at the search function, the speed along the "Insert Direction" during search operation can be controlled not to exceed "Velocity Constant".

- If "Search Insert Vel" of the basic data is zero, the speed does not exceed "Velocity Constant".
- If "Search Insert Vel" of the basic data is not zero, the speed does not exceed "Search Insert Vel" regardless of the value of "Velocity Constant".

"Default : ON"

### 22 Velocity Constant

The speed along the "Insert Direction" during search operation is clamped to this value or below. If the target speed is greater than this value, the speed is clamped to this value.
"Default : 5mm/sec"

### 23 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. When this switch is turned ON, the force control operation can be ended if the result of force judgment below is "SUCCESS" after the workpiece is inserted to the specified depth. If the result of force judgment below is not "SUCCESS" even after "Search Time Limit" of the "Basic data" has passed, an alarm is issued. (If both of "Force End Judgment Switch" and "Torque End Judgment Switch" are turned ON, the force control operation can be ended when the result of judgment is "SUCCESS" for both after the workpiece is inserted to the specified depth.)
"Default : OFF"

### 24 Min. Force Rate

The value of this item is used for force judgment. If the magnitude of generated force in "Insert Direction" is greater than "Min. Force Rate" x "Search Push Force" / 100, the result of judgment is "SUCCESS".
"Default : 80 %"

### Judgment Result

This item indicates the result of force judgment at the end of force control operation. If the magnitude of force in "Insert Direction" at the end of force control operation is greater than "Min. Force Rate" x "Search Push Force" / 100, "SUCCESS" is indicated. If not, "FAILURE" is indicated.
"Default : -----"

### Force Average

This item indicates the axis of "Insert Direction" and the average magnitude of force in "Insert Direction" at the end of force control operation.
"Default : Z:0 N"

### 25 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. When this switch is turned ON, the force control operation can be ended if the result of torque judgment below is "SUCCESS" after the workpiece is inserted to the specified depth. If the result of torque judgment below is not "SUCCESS" even after "Search Time Limit" of the "Basic data" has passed, an alarm is issued. (If both of "Force End Judgment Switch" and "Torque End Judgment Switch" are turned ON, the force control operation can be ended when the result of judgment is "SUCCESS" for both after the workpiece is inserted to the specified depth.)
"Default : OFF"

### 26 Max. Torque

The value of this parameter is used for torque judgment. If the magnitude of generated torque is about less than "Max. Torque", the result of judgment is "SUCCESS".
"Default : 5 N*m"

### Judgment Result

This parameter indicates the result of torque judgment at the end of force control operation. If the magnitude of torque at the end of force control operation is about less than "Max. Torque", "SUCCESS" is indicated. If not, "FAILURE" is indicated.

"Default : -----"

### Torque Average

This parameter indicates rotations about the axes other than "Insert Direction" and the average magnitude of torque about each of the axes at the end of force control operation. (If the axis for "Insert Direction" is Z, for example, W for indicating rotation about the X-axis and P for indicating rotation about the Y-axis are displayed. Similarly, If the axis for "Insert Direction" is X, P and R are displayed. If the axis for "Insert Direction" is Y, W and R are displayed.)

"Default : W:0 N*m
P:0 N*m"

### 27 Approach Acc. Time

This item specifies acceleration time that the speed becomes "Approach Velocity" of "Basic data" after executing force control instruction.

"Unit : sec"

### 28 Search Acc. Time

This item specifies acceleration time that the speed becomes "Search Insert Vel" of "Basic data" after force exceeds "Contact F Threshold" of "Basic data".

"Unit : sec"

### 29 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"

### 30 Signal Output for ERR SW

This parameter enables the "Signal Output for ERR" function. This function sends out a designated signal when an alarm is issued while contouring.

"Default : OFF"

### 31 Output Signal Type (Signal Output for ERR)

This parameter specifies the kind of a signal that "Signal Output for ERR" function sends out when an alarm is issued while contouring.

"DO", "RO", "FLAG" are available for the kind of a signal.

### 32 Output Signal Number (Signal Output for ERR)

This parameter specifies the signal number that "Signal Output for ERR" function sends out when an alarm is issued while contouring.

### 33 Frc.Ctrl. End by REG SW

"Search" usually ends after it has reached "Search End Depth". If "Force End Judgment Switch" or "Torque End Judgment Switch" is ON, the force control does not end until its condition is satisfied. 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"

### 34 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"

## [Search parameters performance screen]
## Parameters shown in this section are for advanced users.

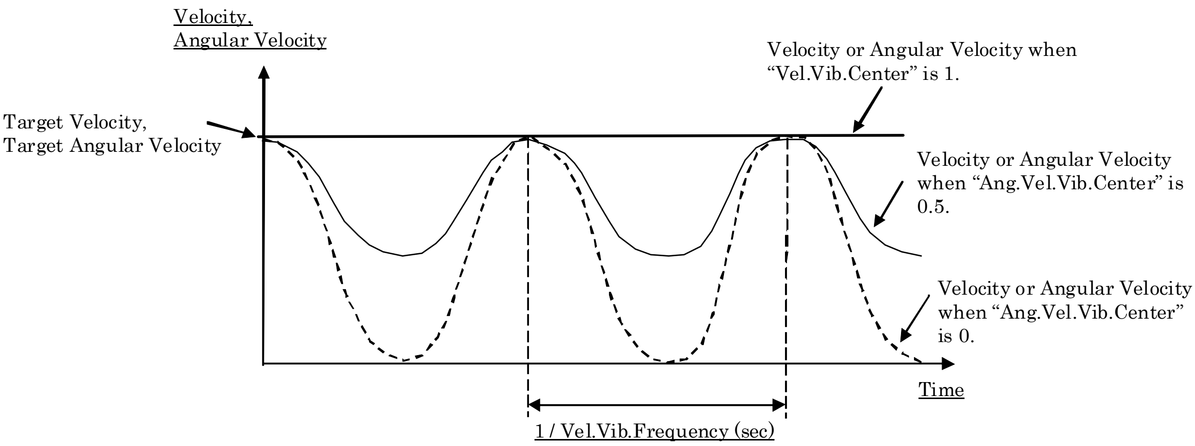
Each parameter on this screen is available for each of the six directions: X, Y, Z, W, P, and R.

### Vel. Vib. Center
### 2

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:
$V = Vd \{ (1-C) \cos(2\pi ft) + C\}$
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, 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: 1" (for no vibration)

### 3 Vel. Vib. Frequency
### 4

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: 1 Hz"



### 5 Weaving Time
6

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: 1 sec"

### 7 Weaving Frequency
8

Vibration frequency in weave operation.
"Default: 1 Hz"

### 9 Reverse Switch
10

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: ON"

### 11 Retry Number
12

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: 10000"

### 13 Retry Magnification
14

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: 1"

### 15 Search Range Margin
16

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:
"Default: 3 mm/sec"
When search operation is performed in the W, P, or R direction:
"Default: 3 deg/sec"

## 3.5.6.4 Phase search

### Overview

Function selection screen

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

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

Basic screen

```
Force Ctrl/Basic
                                        1/18
  Schedule[1]           G:1 F:1 S:1
  1 Function          : Phase 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 PhaseMatch End Depth :    5.00 mm
  9 PhaseMatch Push Force:   50.00 N
 10 PhaseMatch Insert Vel:    0.00 mm/s
 11 PhaseMatch Ang. Vel  :    1.00 deg/s
 12 PhaseMatch Torque    :    1.00 N*m
 13 PhaseMatch Ang. Limit:   10.00 deg
 14 Individual Diff. (+) :    3.00 mm
 15 Individual Diff. (-) :    0.00 mm
 16 Pushing Time         :    0.00 sec
 17 PhaseMatch Time Limit:   20.00 sec
 18 F.Ctrl. Gain Auto Modify :       OFF
      Prev. Result      : No Change
 19 Force Control Gain :          Detail

[ TYPE ] GROUP  NUMBER  DEFAULT 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

Phase matching performance 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
```

Performance screen

```
Force Ctrl/Perform
                                        1/32
  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
 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 Force Denoising Sw    :   OFF
 29 Signal Output for ERR SW: OFF
 30   Output Signal Type  :   DO
 31   Output Signal Number:       0
 32 Frc.Ctrl. End by REG SW : OFF
 33   End Register Number  :      0

[ TYPE ] GROUP  NUMBER  DEFAULT  BASIC
```

F1 F2 F3 F4 F5

**Fig. 3.5.6.4 "Phase Search" screens**

### Function keys

The function keys indicated in Fig. 3.5.6.4 have the following functions:

| 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. |
| 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. |

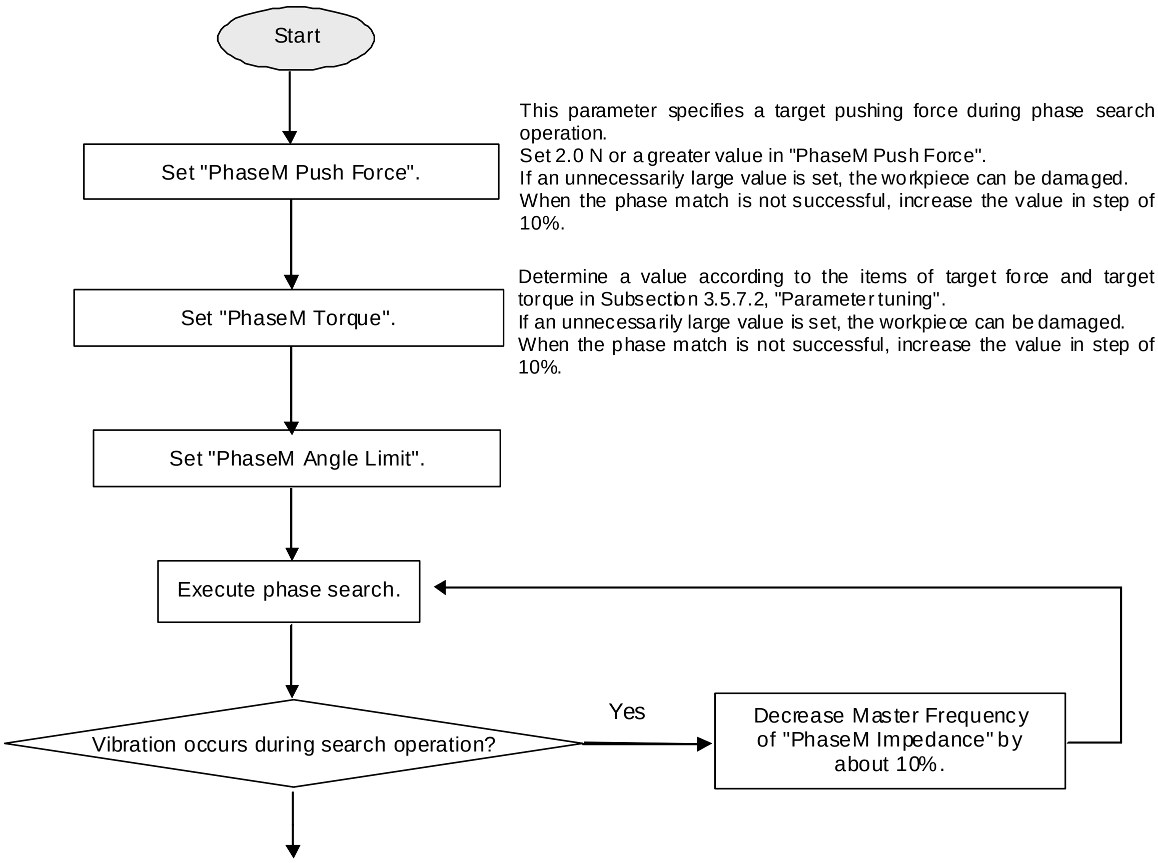
### G F S

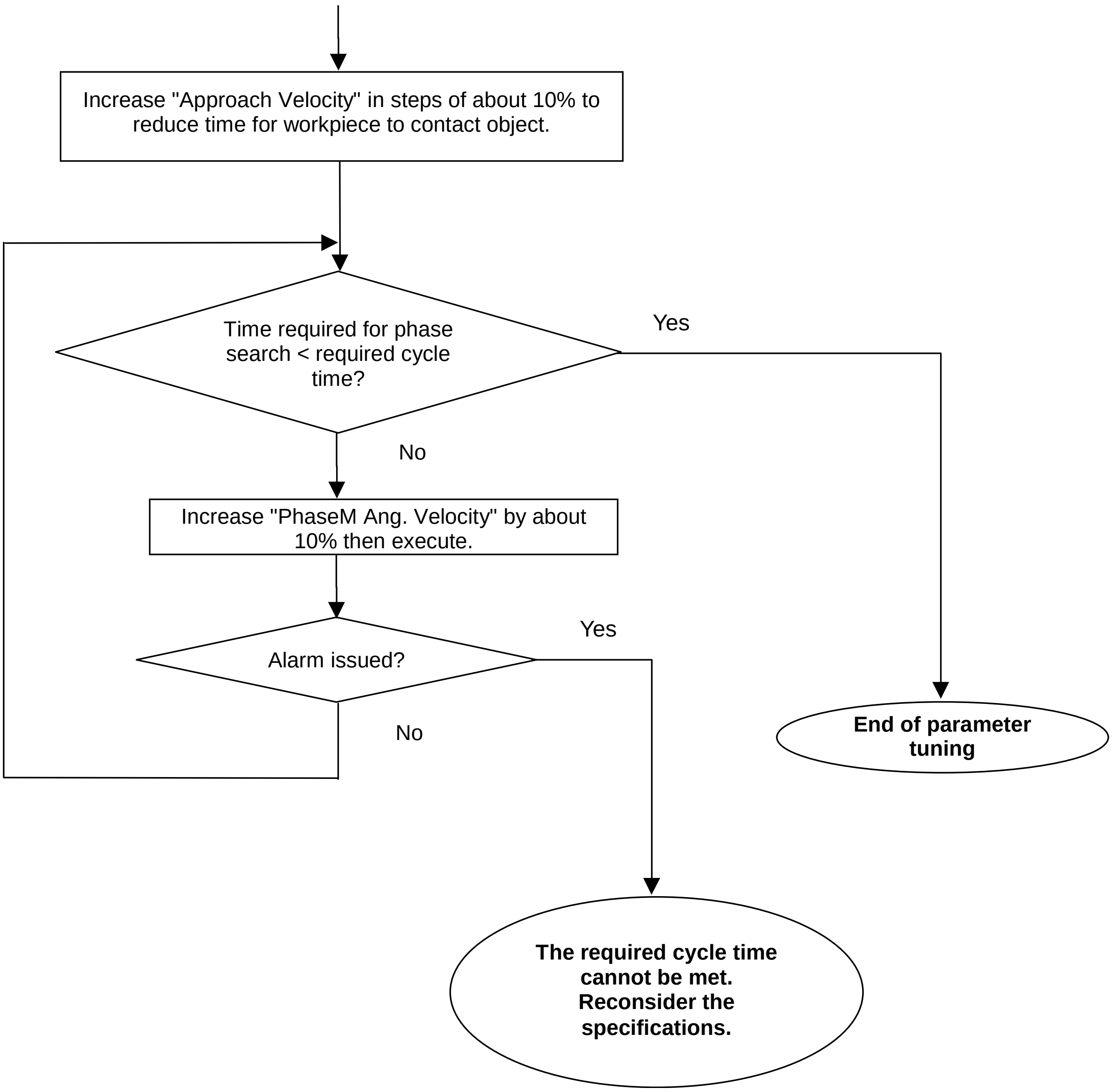
G represents a motion group number at the time of teaching. F represents a force control number. S represents a force sensor number. (These values cannot be changed.)
"Default G F S: 1 1 1"

## Parameter tuning

The following parameter setting sequence is used:
1 Set "Insert Direction", "User Frame No.", "Tool Frame No.", and "PhaseM End Depth".
2 Make an automatic force control gain adjustment. (See Subsection 3.9.2)
3 Set the parameters on the basic screen.
4 Tune parameters on the performance screen as required.

For the outline of force control instruction programming, see Section 3.1, "NOTES/RESTRICTIONS", and Section 3.2, "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.




Increase "Approach Velocity" in steps of about 10% to reduce time for workpiece to contact object.
Time required for phase search < required cycle time?
Yes
No
Increase "PhaseM Ang. Velocity" by about 10% then execute.
Alarm issued?
Yes
No
End of parameter tuning
The required cycle time cannot be met. Reconsider the specifications.

## ［Basic data setting screen］

**Parameters shown in this section must be set.**

### 1 Function

From the submenu shown on the function selection screen of Fig.3.5.6.4, select a function to be set. In this case, select "Phase Search".

### 2 Comment

Enter a comment for identifying schedule data.

### 3 Insert Direction

An insertion direction is represented in the set user frame.
"Default: -Z"

### 4 Contact F Threshold

Threshold for determining that a work target is touched. An actual insertion operation starts after a touch. So, if an excessively large value is set in this parameter, the cycle time can deteriorate.
"Default: 1 N"

### 5 Approach Velocity

Operation velocity to be used until a work target is touched.
"Default: 1 mm/sec"

### 6 User Frame No.

Number of a user frame to be used at the time of insertion. Enter the number of a user frame set according to Section 3.2, "TEACHING PROCEDURE".
"Default: 0"

### 7 Tool Frame No.

Number of a tool frame to be used at the time of insertion. Enter the number of a tool frame set according to Section 3.2, "TEACHING PROCEDURE".
"Default: 1"

### 8 PhaseM End Depth

Insertion depth threshold for determining success in phase matching and ending phase matching operation.
"Default: 5 mm"

### 9 PhaseM Push Force

Target force value for pushing a workpiece against an insertion surface at the time of phase matching.
If insertion is unsuccessful when a match is found in phase, increase this value in steps of about 10%. If a workpiece to accept an inserted workpiece rotates together with rotation for phase matching, decrease this value in steps of about 10%.
"Unit : N"

### 10 PhaseMatch Insert Vel

This is the operation velocity to be used after a work target is touched.
"Default: 0 mm/s"

### 11 PhaseM Ang. Velocity

Target angular 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 deg/sec"

### 12 PhaseM Torque

Target torque for turning the workpiece at the time of phase matching. Determine a value according to the items of target force and target torque described in Subsection 3.5.6.2, "Parameter tuning". 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%.
"Default: 10 N*m"

### 13 PhaseM Angle Limit

Phase matching is performed within the angular range set in this parameter. 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 deg"

### 14 Individual Diff.(+)

Allowable additional depth of insertion when the depth of insertion is greater than "Insert Depth (Design)" due to the differences in individual workpieces. If the actual depth of insertion exceeds (Insert Depth (Design) – Individual Diff. (-) + this value), an alarm is issued.
"Default: 3 mm"

### 15 Individual Diff.(-)

Allowable shortage in depth of insertion when the depth of insertion is less than "Insert Depth (Design)" due to the differences in individual workpieces. If the actual depth of insertion reaches (Insert Depth (Design) - this value), the insertion is assumed to be successful.
"Default: 0 mm"

### 16 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. This value represents a time used for such pushing operation.
"Default: 0 sec"

### 17 Search Time MAX Limit

This search time means the period of time from the start of search operation after touching a work target until search operation is assumed to be successful. If "PhaseM 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").
"Default: 20 sec"

### 18 F.Ctrl. Gain Auto Modify

This item is the switch used for automatic force control gain tuning. For details, see Subsection 3.9.2, "Force Control Gain Auto Tuning Instruction".
"Default : OFF"

### 19 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, see Section 3.6, "FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".

## [Performance data setting screen]

**Parameters shown in this section are for advanced users.**

### 1 Function

From the submenu shown on the function selection screen of Fig.3.5.6.4, select a function to be set. In this case, select "Phase Search".

### 2 Comment

Enter a comment for identifying schedule data.

### 3 Simple Customize Sw

This parameter specifies a switch for "Simple Customize" function. It enables to execute the schedule data being edited after any other schedule.
For details, see Subsection 3.7.3, "Simple Customization Function".
"Default: OFF"

### 4 Cont. Exec. Max. Count

It designates how many force schedules with "Simple Customize Sw" ON can be executed successively.
For details, see Subsection 3.7.3, "Simple Customization Function".
"Default : 1"

### 5 Customize Parent Number

This item is set when force control is executed successively. For details, see Subsection 3.7.3, "Specifying the Parent-Child Relationship".
"Default: 0"

### 6 Customize ParaChg Connection

This item is set when force control is executed successively. For details, see Subsection 3.7.3, "Specifying the Parent-Child Relationship".
"Default: OFF"

### 7 Customize Auto. Cnt. Exec. Sw (Customize Auto. Cnt. Exec.)

This parameter specifies a switch for "Customize Auto. Cnt. Exec." function.
"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.
For details, see Subsection 3.7.5, "Customization Automatic Continuous Execution Function".
"Default: OFF"

### 8 Auto. Cnt. Exec. Child No. (Customize Auto. Cnt. Exec.)

This parameter specifies a schedule data number of its child schedule data. The child schedule data is a schedule data that is executed next.
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.

### 9 Schedule No. Output Reg. No. (Customize Auto. Cnt. Exec.)

This parameter specifies a Numeric Register Number to which "Customize Auto. Cnt. Exec." function output the execution state.
When "Customize Auto. Cnt. Exec." function is executing, this function outputs a running schedule data number. If the series of the schedule data ends normally, this function outputs 0.
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.

### 10 User Frame Compensation SW

This is a switch for correcting a user frame set on a work target plane through vision. This parameter is useful when a work target is not positioned correctly. The switch must be used in combination with the OFFSET or VOFFSET instruction. For details, see Section 3.8, "User Frame Compensation".
"Default: OFF"

### 11 PhaseM acc. Time

Specify an acceleration/deceleration time constant for phase matching angular velocity.
"Default: 0.1 sec"

### 12 Decel. Depth Rate

When the workpiece is inserted by the basic data "PhaseM End Depth" × "this value"/100, the phase matching angular velocity is decreased to the basic data "PhaseM Ang. Velocity" × 0.1. 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%"

### 13 Phase Performance Param.

This item can be used to switch to the phase matching performance screen. On this screen, high-level parameters for phase matching can be set. See the description of the phase matching performance screen.

### 14 Settling Switch

Operation for weakening the pushing force upon completion of insertion is referred to as "settling". This parameter is useful if the workpiece vibrates because of a large shock occurring when the hand is released after completion of insertion.
"Default: OFF"

### 15 Settling Time

"Settling" is performed for this time.
"Default: 1 sec"

### 16 Settling Rate

Finally, the force is "reduced" to ("PhaseM Push Force") × ("settling rate")/100. When 100% is specified, settling operation is not practically performed. When 0% is specified, the force is reduced to 0.
"Default: 100%"

### 17 Initial Insert Force

Target force at the start of 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 "PhaseM Push Force".
"Unit : N"

### 18 Force Limit
### 19

If force generated during search satisfies one of the expressions below, an alarm(FORC-216 - FORC-221) is issued. See 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:
When Fdx > 0, Fx < -FLx or Fx > Fdx + FLx
When Fdx < 0, Fx > FLx or Fx < Fdx - FLx
A similar check is made in the Y, Z, W, P, and R directions.
"Unit : N, N*m"

### 20 Torque Error Compensate SW

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. (For details, see Subsection3.9.3, "Torque Error Acquisition Instructions".
"Default: OFF"

### Torque Error Data W P R

Values set by estimation from the moment information obtained by the force sensor when the workpiece is actually pushed by "Torque Error Fd" according to "torque error acquisition". 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. (These cannot be changed.)
"Default: 0 N*m"

### Torque Error Fd

An actually applied pushing force at the time of "torque error acquisition" is set as this value. When "Torque Error Compensate SW" is set to ON, torque error compensation is performed using this value. (This cannot be changed.)
"Unit : N"

### 21 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. If this switch is set to ON at the search function, the speed along the "Insert Direction" during search operation can be controlled not to exceed "Velocity Constant".

- If "Search Insert Vel" of the basic data is zero, the speed does not exceed "Velocity Constant".
- If "Search Insert Vel" of the basic data is not zero, the speed does not exceed "Search Insert Vel" regardless of the value of "Velocity Constant".

"Default : ON"

### 22 Velocity Constant

The speed along the "Insert Direction" during search operation is clamped to this value or below. If the target speed is greater than this value, the speed is clamped to this value.
"Default : 5mm/sec"

### 23 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. When this switch is turned ON, the force control operation can be ended if the result of force judgment below is "SUCCESS" after the workpiece is inserted to the specified depth. If the result of force judgment below is not "SUCCESS" even after "PhaseMatch Time Limit" of the "Basic data" has passed, an alarm is issued.
"Default : OFF"

### 24 Min. Force Rate

The value of this item is used for force judgment. If the magnitude of generated force in "Insert Direction" is greater than "Min. Force Rate" x "PhaseMatch Push Force" / 100, the result of judgment is "SUCCESS".
"Default : 80 %"

### Judgment Result

This item indicates the result of force judgment at the end of force control operation. If the magnitude of force in "Insert Direction" at the end of force control operation is greater than "Min. Force Rate" x "PhaseMatch Push Force" / 100, "SUCCESS" is indicated. If not, "FAILURE" is indicated.
"Default : -----"

### Force Average

This item indicates the axis of "Insert Direction" and the average magnitude of force in "Insert Direction" at the end of force control operation.
"Default : Z:0 N"

### 25 Approach Acc. Time

This item specifies acceleration time that the speed becomes "Approach Velocity" of "Basic data" after executing force control instruction.
"Unit : sec"

### 26 PhaseMatch Acc. Time

This item specifies acceleration time that the speed becomes "PhaseMatch Insert Vel" of "Basic data" after force exceeds "Contact F Threshold" of "Basic data".
"Unit : sec"

### 27 PhaseMatch ForceControl Valid Switch

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.
"Default X: OFF Y: OFF"

### 28 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"

### 29 Signal Output for ERR SW

This parameter enables the "Signal Output for ERR" function. This function sends out a designated signal when an alarm is issued while contouring.
"Default : OFF"

### 30 Output Signal Type (Signal Output for ERR)

This parameter specifies the kind of a signal that "Signal Output for ERR" function sends out when an alarm is issued while contouring.
"DO", "RO", "FLAG" are available for the kind of a signal.

### 31 Output Signal Number (Signal Output for ERR)

This parameter specifies the signal number that "Signal Output for ERR" function sends out when an alarm is issued while contouring.

### 32 Frc.Ctrl. End by REG SW

"Phase Search" usually ends after it has reached "PhaseMatch End Depth". If "Force End Judgment Switch" is ON, the force control does not end until its condition is satisfied. 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"

### 33 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"

## [Phase Matching performance screen]

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

### 1 Ang. Vel. Vib. Center

Set a value of 0 to 1 in this parameter to vibrate a target angular velocity during search.
Change the target angular velocity during search operation according to the following expression:

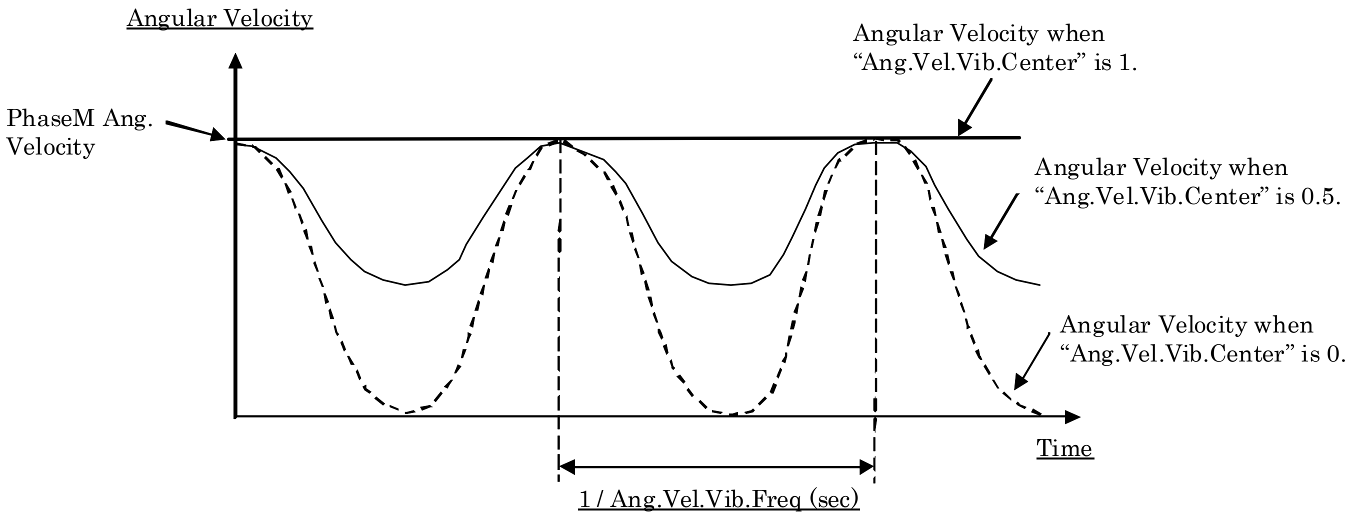
$V = Vd \{ (1-C) \cos(2\pi ft) + C\}$

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, "PhaseM Ang. 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 angular velocity operation is performed at "PhaseM Ang. Velocity".
"Default: 1" (for no vibration)

### 2 Ang. Vel. Vib. Freq.

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 Hz"




### 3 Weaving Time

Weave operation finely vibrates moment at a location where an angular match is found during search. For the time specified in this parameter, weave operation is performed.
"Default: 1 sec"

### 4 Weaving Frequency

Vibration frequency in weave operation.
"Default: 1 Hz"

### 5 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: ON"

### 6 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: 10000"

### 7 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, "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"

### 8 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.
"Default: 3 deg/sec"

### 3.5.6.5 Hole search

## Overview

Function selection screen

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

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

Basic 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  DEFAULT 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 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

 [ TYPE ] GROUP  NUMBER  DEFAULT  BASIC
   F1      F2      F3      F4      F5
```

**Fig. 3.5.6.5 "Hole Search" screens(1/2)**

Search basic 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
```

Search performance 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
```

**Fig. 3.5.6.5 "Hole Search" screens(2/2)**

### Function keys

The function keys indicated in Fig. 3.5.6.5 have the following functions:

| 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. |
| 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. |

### G F S

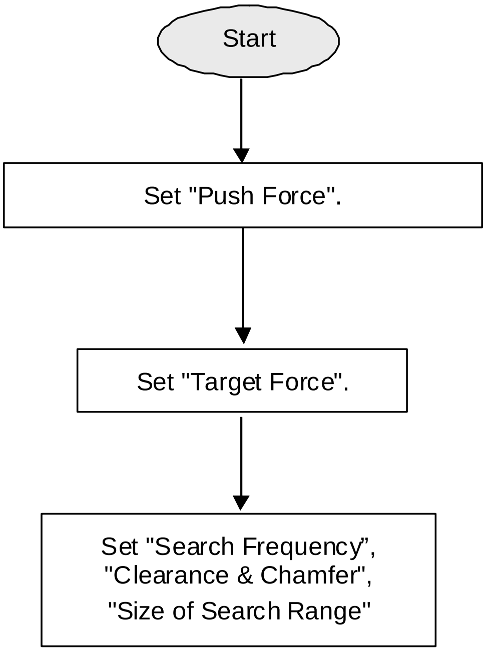
G represents a motion group number at the time of teaching. F represents a force control number. S represents a force sensor number. (These values cannot be changed.)
"Default G F S: 1 1 1"

## Parameter tuning

The following parameter setting sequence is used:

1. Set "Insert Direction", "User Frame No.", "Tool Frame No.", and "Search End Depth".
2. For two search directions, set "Velocity Order".
3. Make an automatic force control gain adjustment. (See Subsection 3.9.2)
4. Set the parameters on the basic screen.
5. Tune parameters on the performance screen as required.

For the outline of force control instruction programming, see Section 3.1, "NOTES/RESTRICTIONS", and Section 3.2, "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.



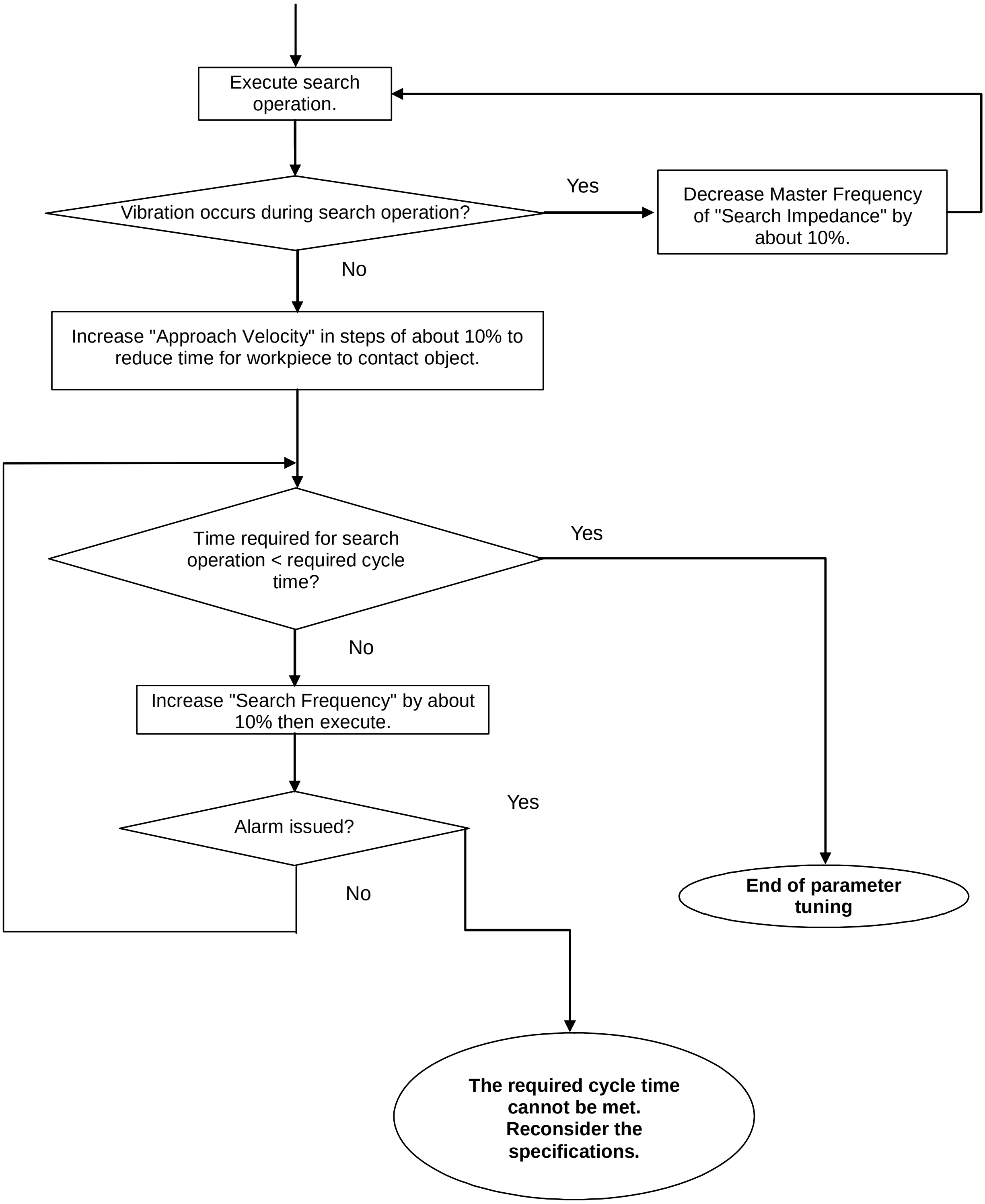

This parameter specifies a target pushing force during search operation.
Set 2.0 N or a greater value in "Push Force".
If an unnecessarily large value is set, the workpiece can be damaged.
When the phase is not successful match, increase the value in step of 10%.

"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 3.5.6.2, "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 3.5.6.2, "Parameter tuning" for more detail.




## ［Basic data setting screen］

**Parameters shown in this section must be set.**

### 1 Function

From the submenu shown on the function selection screen of Fig.3.5.6.5, select a function to be set. In this case, select "Hole Search".

### 2 Comment

Enter a comment for identifying schedule data.

### 3 Insert Direction

An insertion direction is represented in the set user frame.
"Default: -Z"

### 4 Contact F Threshold

Threshold for determining that a work target is touched. An actual insertion operation starts after a touch. So, if an excessively large value is set in this parameter, the cycle time can deteriorate.
"Default: 1 N"

### 5 Approach Velocity

Operation velocity to be used until a work target is touched.
"Default: 1 mm/sec"

### 6 User Frame No.

Number of a user frame to be used at the time of search. Enter the number of a user frame set according to Section 3.2, "TEACHING PROCEDURE".
"Default: 0"

### 7 Tool Frame No.

Number of a tool frame to be used at the time of search. Enter the number of a tool frame set according to Section 3.2, "TEACHING PROCEDURE".
"Default: 1"

### 8 Search End Depth

Insertion depth threshold for determining success in hole search and ending hole search operation.
"Default: 5 mm"

### 9 Push Force

Target force value for pushing a workpiece against an insertion surface at the time of hole search.
If a workpiece to be inserted passes by the hole without being inserted when a positional match is found between the workpiece to be inserted and the hole, increase this value in steps of about 10%. If a workpiece to accept an inserted workpiece rotates together with rotation for phase matching, decrease this value in steps of about 10%.
"Unit : N"

### 10 Search Insert Vel

This is the operation velocity to be used after a work target is touched.
"Default: 0 mm/s"

### 11 Search Frequency

Parameter for determining a search velocity. When a workpiece is to be inserted in the Z direction, for example, the search directions are the X and Y directions. The values of "Target Velocity" in the X and Y directions are automatically calculated by this parameter, "Size of Search Range" and "Clearance & Chamfer" in the X and Y directions. Set "Size of Search Range" and "Clearance & Chamfer" on the search parameters basic screen.
"Default: 1 Hz"

### 12 Search Basic Param.

This parameter is used to switch to a screen for setting basic parameters for search path determination.

See the description of the search parameters basic screen.

### 13 Individual Diff.(+)

Allowable additional depth of insertion when the depth of insertion is greater than "Insert Depth (Design)" due to the differences in individual workpieces. If the actual depth of insertion exceeds (Insert Depth (Design) – Individual Diff. (-) + this value), an alarm is issued.
"Default: 3 mm"

### 14 Individual Diff.(-)

Allowable shortage in depth of insertion when the depth of insertion is less than "Insert Depth (Design)" due to the differences in individual workpieces. If the actual depth of insertion reaches (Insert Depth (Design) - this value), the insertion is assumed to be successful.
"Default: 0 mm"

### 15 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. This value represents a time used for such pushing operation.
"Default: 0 sec"

### 16 Search Time MAX Limit

This search time means the period of time after touching a work target until search operation is assumed to be successful. 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").
"Default: 20 sec"

### 17 F.Ctrl. Gain Auto Modify

This item is the switch used for automatic force control gain tuning. For details, see Subsection 3.9.2, "Force Control Gain Auto Tuning Instruction".
"Default : OFF "

### 18 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, see Section 3.6, "FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".

## ［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.

### 1 Velocity Order

In "Hole Search", search operation is performed in two directions. Determine the order of operation velocities between the two directions. A higher velocity is specified for the direction for which 1 is set. A lower velocity is specified for the direction for which 2 is set. If a number other than 1 and 2 is specified, an error occurs. If the same order number is specified for both directions, an error also occurs. Be sure to specify a unique number for each direction.

### 2 Target Velocity

Target velocity for operating workpiece.

This parameter is automatically calculated, so that user need not specify this parameter.
"Default: 1 mm/sec"

### 3 Target Force

Target force in search direction.
Determine value according to the items of target force and target torque described in Subsection 3.5.6.2, "Parameter tuning". 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 "Force 264 Error" or "Force 420 Error" occurs with little motion made, increase this value in steps of about 10% to 20%. If a position or phase match point is passed, decrease this value in steps of about 10% to 20%.

### 4 Clearance & Chamfer

The amount of chamfer for workpiece to be inserted or a workpiece to accept a workpiece to be inserted on the mating plane.
The clearance is a gap between a workpiece to be inserted and a workpiece to accept a workpiece to be inserted.
For both values, make measurements in a search direction.
Calculate [(measured chamfer amount) × 2 + (clearance)], then set the result of calculation in this parameter.
"Default: 1 mm"

### 5 Size of Search Range

For each search direction, determine a search range, then set the value in this value.
Determine value according to the description of "Search range setting" in Subsection 3.5.6.2, "Parameter tuning".
at "Default: 10 mm"

### 6 Repeat Number

In "Hole Search", specify 1 for this parameter.
"Default: 1"

## [Performance data setting screen]

**Parameters shown in this screen are for advanced users.**

The performance data setting screen for "Hole Search" is almost same as the performance data setting screen for "Phase Search". See the description of the performance data setting screen in Subsection 3.5.6.4, "Phase search".
The "phase matching performance screen" for "Phase Search" is replaced by the "search parameters performance screen" for "Hole Search".

## [Search parameters performance screen]

**Parameters shown in this screen are for advanced users.**

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". For details, see Subsection 3.5.6.3, "Search" and Subsection 3.5.6.4, "Phase search". Note, however, that in "Hole Search", search operation is performed only in two directions on a plane, so that parameters for the two directions only are displayed on the screen.

## 3.5.6.6 Clutch search

### Overview

Function selection screen

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

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

Basic 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  DEFAULT 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 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

 [ TYPE ] GROUP  NUMBER  DEFAULT  BASIC
   F1      F2      F3      F4      F5
```

**Fig. 3.5.6.6(a) "Clutch Search" screens (1/2)**

Search basic 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
```

Search performance 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
```

**Fig. 3.5.6.6(b) "Clutch Search" screens (2/2)**

## Function keys

The function keys indicated in Fig. 3.5.6.6(a) and (b) have the following functions:

| 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. |
| 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. |

## 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 values cannot be changed.)

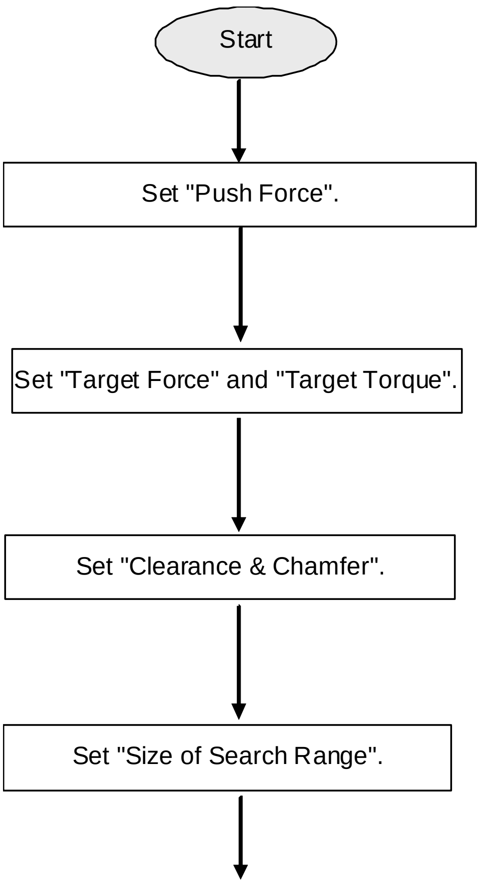
"Default G F S: 1 1 1"

## Parameter tuning

The following parameter setting sequence is used:

1 Set "Insert Direction", "User Frame No.", "Tool Frame No.", and "Search End Depth".
2 For three search directions, set "Velocity Order".
3 Make an automatic force control gain adjustment. (See Subsection 3.9.2)
4 Set the parameters on the basic screen.
5 Tune parameters on the performance screen as required.

For the outline of force control instruction programming, see Section 3.1, "NOTES/RESTRICTIONS", and Section 3.2, "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.

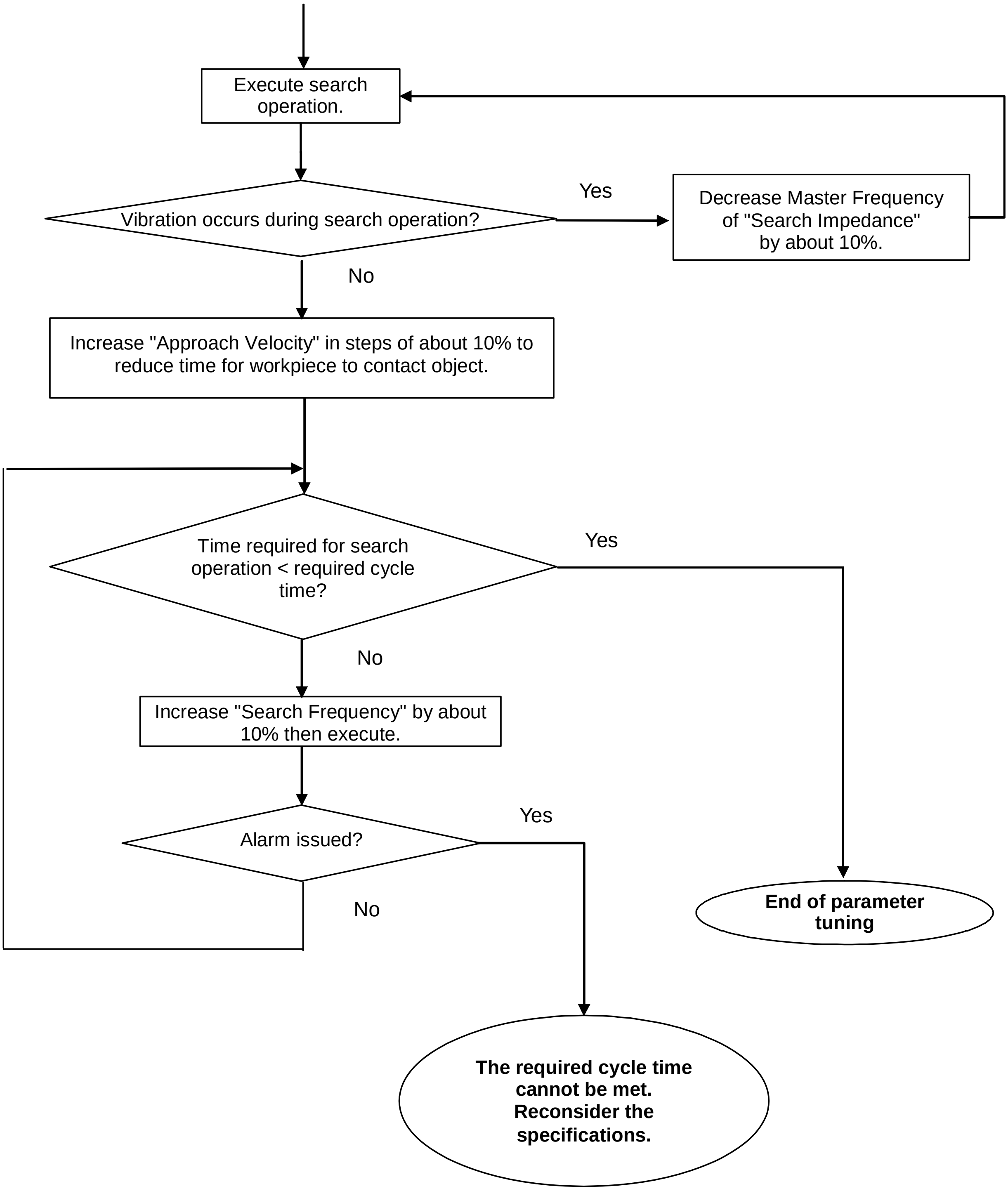



This parameter specifies a target pushing force during search operation.
Set 2.0 N or a greater value in "Push Force".
If an unnecessarily large value is set, the workpiece can be damaged.
When the phase is not successful match, increase the value in step of 10%.

"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 3.5.7.2, "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 3.5.7.2, "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 3.5.7.2, "Parameter tuning".


Execute search operation.
Vibration occurs during search operation?
Yes
Decrease Master Frequency of "Search Impedance" by about 10%.
No
Increase "Approach Velocity" in steps of about 10% to reduce time for workpiece to contact object.
Time required for search operation < required cycle time?
Yes
No
Increase "Search Frequency" by about 10% then execute.
Alarm issued?
Yes
No
End of parameter tuning
The required cycle time cannot be met. Reconsider the specifications.

## ［Basic data setting screen］

### Parameters shown in this section must be set.

### 1 Function

From the submenu shown on the function selection screen of Fig.3.5.6.6, select a function to be set. In this case, select "Clutch Search".

### 2 Comment

Enter a comment for identifying schedule data.

### 3 Insert Direction

An insertion direction is represented in the set user frame.
"Default: -Z"

### 4 Contact F Threshold

Threshold for determining that a work target is touched. An actual insertion operation starts after a touch. So, if an excessively large value is set in this parameter, the cycle time can deteriorate.
"Default: 1 N"

### 5 Approach Velocity

Operation velocity to be used until a work target is touched.
"Default: 1 mm/sec"

### 6 User Frame No.

Number of a user frame to be used at the time of insertion. Enter the number of a user frame set according to Section 3.2, "TEACHING PROCEDURE".
"Default: 0"

### 7 Tool Frame No.

Number of a tool frame to be used at the time of insertion. Enter the number of a tool frame set according to Section 3.2, "TEACHING PROCEDURE".
"Default: 1"

### 8 Search End Depth

Insertion depth threshold for determining success in insertion and ending insertion operation.
"Default: 5 mm"

### 9 Push Force

Target force value for pushing a workpiece against an insertion surface at the time of insertion.
If a workpiece to be inserted is not inserted successfully when a positional match is found between the workpiece to be inserted and the hole, increase this value in steps of about 10%. If a workpiece to accept an inserted workpiece rotates together with rotation for phase matching, decrease this value in steps of about 10%.
"Unit : N"

### 10 Search Insert Vel

This is the operation velocity to be used after a work target is touched.
"Default: 0 mm/s"

### 11 Search Frequency

Parameter for determining a search velocity. When a workpiece is to be inserted in the Z direction, for example, the search directions are the X, Y, and R directions. The values of "Target Velocity" in the X, Y, and R directions are automatically calculated by this parameter, and "Size of Search Range" and "Clearance & Chamfer" in the X, Y, and R directions. Set "Size of Search Range" and "Clearance & Chamfer" on the search parameters basic screen.
"Default: 1 Hz"

### 12 Search Basic Param.

This parameter is used to switch to a screen for setting basic parameters for search path determination.
See the description of the search parameters basic screen.

### 13 Individual Diff.(+)

Allowable additional depth of insertion when the depth of insertion is greater than "Insert Depth (Design)" due to the differences in individual workpieces. If the actual depth of insertion exceeds (Insert Depth (Design) – Individual Diff. (-) + this value), an alarm is issued.
"Default: 3 mm"

### 14 Individual Diff.(-)

Allowable shortage in depth of insertion when the depth of insertion is less than "Insert Depth (Design)" due to the differences in individual workpieces. If the actual depth of insertion reaches (Insert Depth (Design) - this value), the insertion is assumed to be successful.
"Default: 0 mm"

### 15 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. This value represents a time used for such pushing operation.
"Default: 0 sec"

### 16 Search Time MAX Limit

This search time means the period of time from the start of search operation after touching a work target until search operation is assumed to be successful. 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").
"Default: 20 sec"

### 17 F.Ctrl. Gain Auto Modify

This item is the switch used for automatic force control gain tuning. For details, see Subsection 3.9.2, "Force Control Gain Auto Tuning Instruction".
"Default : OFF"

### 18 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, see Section 3.6, "FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".

## [Search parameters basic 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.

### 1 Velocity Order

In clutch search, search operation is performed in three directions. Determine the order of operation velocities among the three directions. The highest velocity is specified for the direction for which 1 is set. The second highest velocity is specified for the direction for which 2 is set. As the number specified for a direction increases, the velocity decreases. Specify integers from 1 to 3. If the same order number is specified for two or more directions, an error occurs. Be sure to specify a unique number for each direction.

### 2 Target Velocity
### 3 Target Angular Velocity

Target velocity (angular velocity) for operating a workpiece.
This parameter is automatically calculated, so that the user need not specify this parameter.
When search operation is performed in the X, Y, or Z direction:
"Default: 1 mm/sec"
When search operation is performed in the W, P, or R direction:
"Default: 1 deg/sec"

### 4 Target Force
### 5 Target Torque

Target force (torque) in a search direction.
Determine a value according to the items of target force and target torque described in Subsection 3.5.6.2, "Parameter tuning". 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 "Force 264 Error" or "Force 420 Error" occurs with little motion made, increase this value in steps of about 10% to 20%. If a position or phase match point is passed, decrease this value in steps of about 10% to 20%.
"Unit : N, N*m"

### 6 Clearance & Chamfer
### 7 Clearance

The chamfer amount is a chamfer amount for a workpiece to be inserted or a workpiece to accept a workpiece to be inserted on the mating plane.
The clearance is a gap between a workpiece to be inserted and a workpiece to accept a workpiece to be inserted.
For both values, make measurements in a search direction.
Calculate [(measured chamfer amount) × 2 + (clearance)], then set the result of calculation in this parameter.
When search operation is performed in the X, Y, or Z direction:
"Default: 1 mm"
When search operation is performed in the W, P, or R direction:
"Default: 1 deg"

### 8 Size of Search Range
### 9

For each search direction, determine a search range, then set the value in this parameter.

Determine a value according to the description of "Search range setting" in Subsection 3.5.6.2, "Parameter tuning".
When search operation is performed in the X, Y, or Z direction:
"Default: 10 mm"
When search operation is performed in the W, P, or R direction:
"Default: 10 deg"

### 10 Repeat Number

When a work target has a structure that repeats the same pattern as in the case of the teeth of a gear, specify the number of patterns. For example, if the size of search range is 30 deg in the rotation direction about the insertion axis, and the teeth pitch is 5 deg, specify the repeat number 6 in this parameter. When no particular pattern is involved, specify 1.
"Default: 1"

## [Performance data setting screen]

### Parameters shown in this screen are for advanced users.

The performance data setting screen for "Clutch Search" is almost the same as the performance data setting screen for "Phase Search". See the description of the performance data setting screen in Subsection 3.5.6.4, "Phase search".
The "phase matching performance screen" described for "Phase Search" is replaced by the "search parameters performance screen" for "Clutch Search".

## [Search parameters performance screen]

### Parameters shown in this screen are for advanced users.

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". For details, see Subsection 3.5.6.3, "Search" and Subsection 3.5.6.4, "Phase search". Note, however, that with the clutch search function, search operation is performed only in the three directions (the rotation direction about an insertion axis, and the two directions on a plane perpendicular to the insertion axis), so parameters for the three directions only are displayed on the screen.

# 3.5.7 Contouring Function

## 3.5.7.1 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.

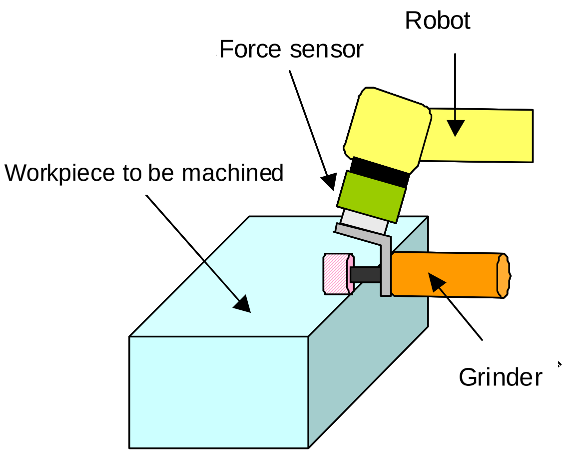



Fig. 3.5.7.1(a) Example of Surface Grinding (with Tool Held by Robot)

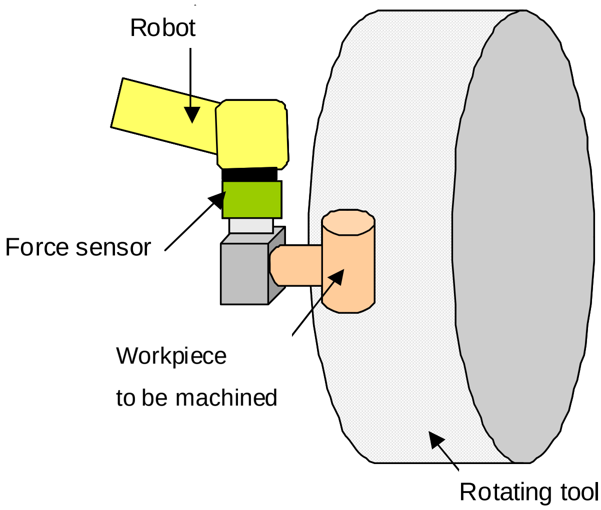



Fig. 3.5.7.1(b) Example of Buffing (with Workpiece Held by Robot)

## 3.5.7.2 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. 3.5.7.2(a) shows an example where the posture of the robot changes halfway, and Fig. 3.5.7.2(b) shows an example where the traveling direction is reversed.

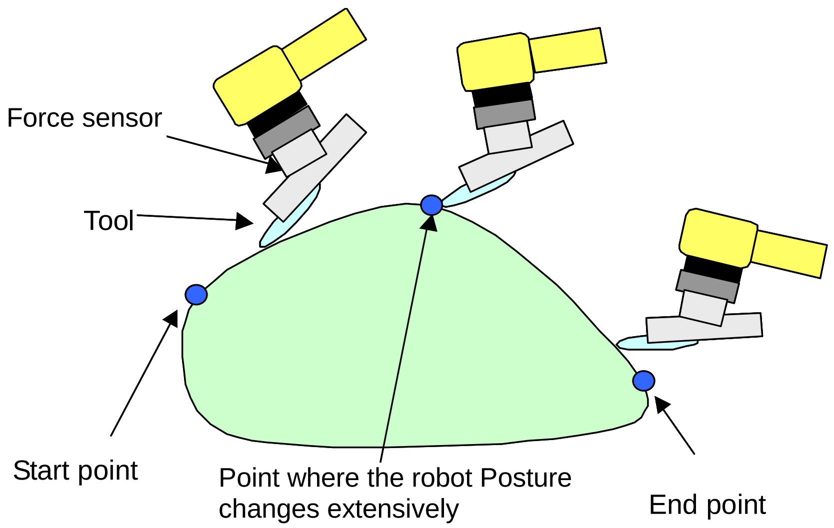



**Fig. 3.5.7.2(a) Setting of teaching points where posture of robot changes**

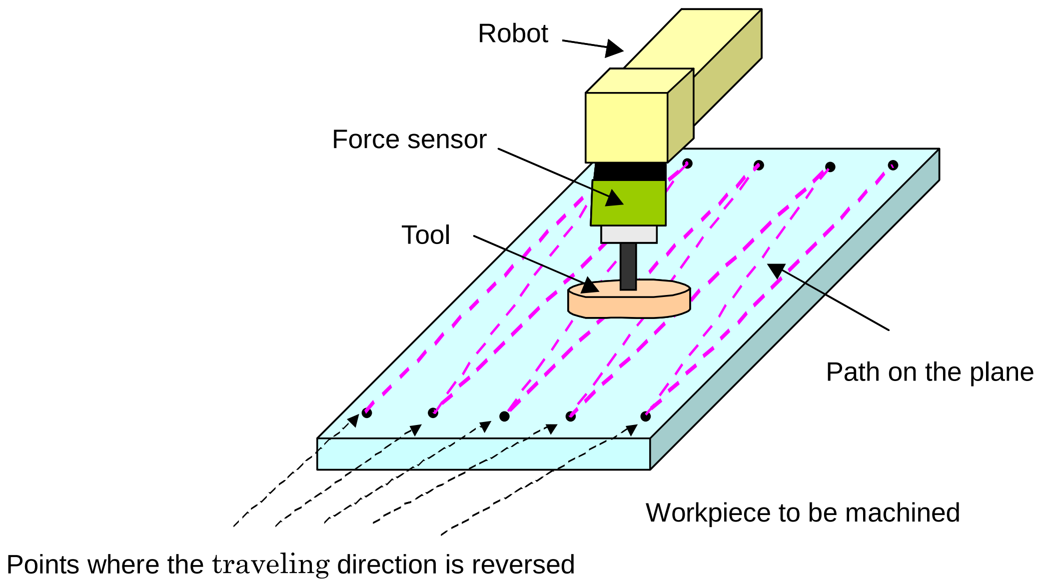



**Fig. 3.5.7.2(b) Setting of teaching points where traveling direction is reversed**

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.
Select the user frame if the push direction is constant, for example, if a workpiece is ground by pushing the workpiece in a constant direction against a secured grinder or buff. (See Fig. 3.5.7.2(c).)
Select the tool frame in an application where the pushing direction varies momentarily. (See Fig. 3.5.7.2(d).)
Set the frame so that the pushing direction matches one of the X-axis, Y-axis, and Z-axis of the frame used.

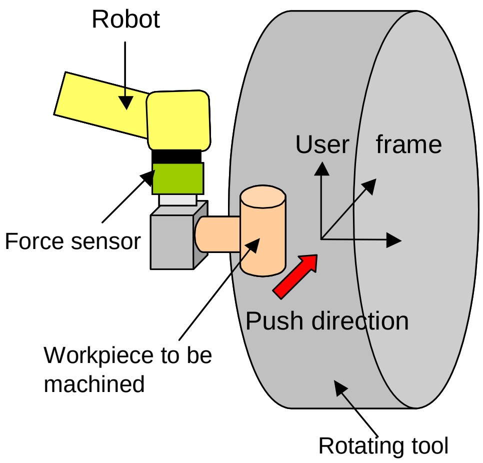



**Fig. 3.5.7.2 (c) Control based on user frame**

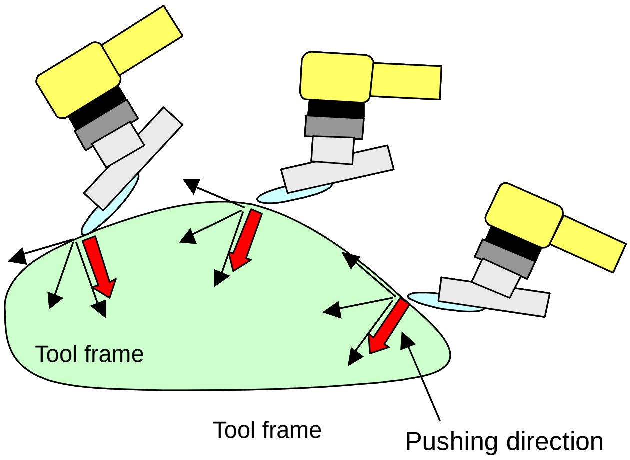



**Fig. 3.5.7.2 (d) Control based on tool frame**

## 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. 3.5.7.2(e), set the teaching point so that $\theta 1$ and $\theta 2$ match whenever possible.

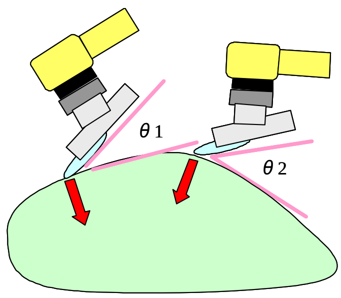



**Fig. 3.5.7.2(e) Posture at teach points**

## 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. 3.5.7.2(f)). Even though each teach point is off the surface of the workpiece, the tool will contact the workpiece when using the contouring function.

Note: 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. For details of this function, see Chapter 6, "TP PROGRAM AUTO GENERATION FUNCTION".

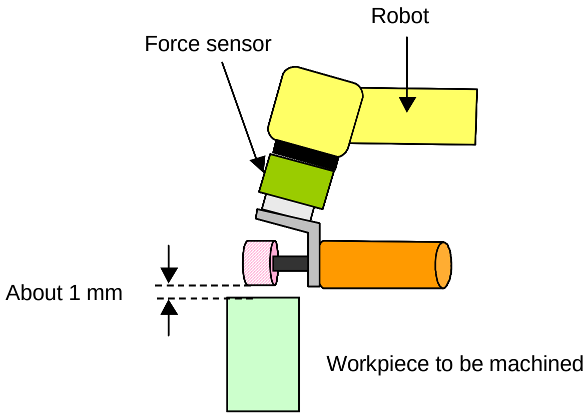



**Fig. 3.5.7.2(f) Example of teach point setting**

The distance from Teach Points to workpiece surface should be almost same for all teach points. If the direction from Start point to a next teach point is same or similar to a push direction, an excessive force may be exerted to the workpiece when the tool makes contact with it.(Fig.3.5.7.2(h)) Keep the distance from start point to the workpiece almost same as that from other teach points. (Fig.3.5.7.2(g)

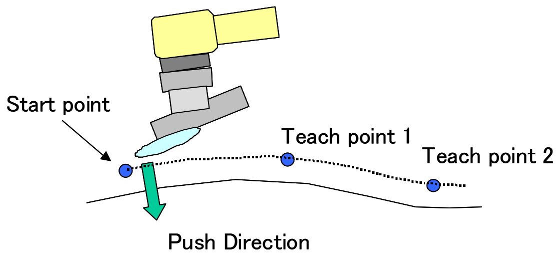



**Fig. 3.5.7.2(g) Good example**

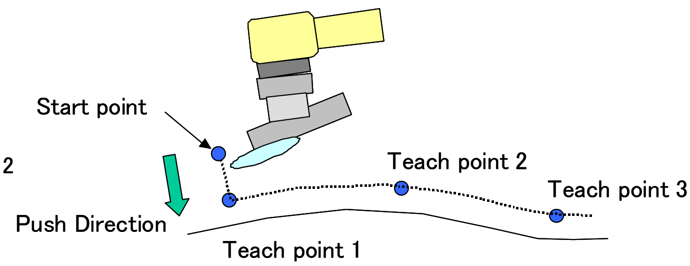



**Fig. 3.5.7.2(h) Bad example**

## 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 3.5.7.2(i). This motion is continued until the tool makes contact with the part and the desired programmed force is attained. The first method is called before contact. 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 3.5.7.2(j). After detecting contact with the part the robot starts it’s motion in the traveling direction, while maintaining the programmed force. The second method is called after contact. (See Performance Screen Item "Motion Start" in Subsection 3.5.7.6, "Parameters")

In the first method shown in Fig. 3.5.7.2(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) (described in Subsection 3.5.7.6, "Parameters"), and (V) is defined as the traveling direction speed.

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.

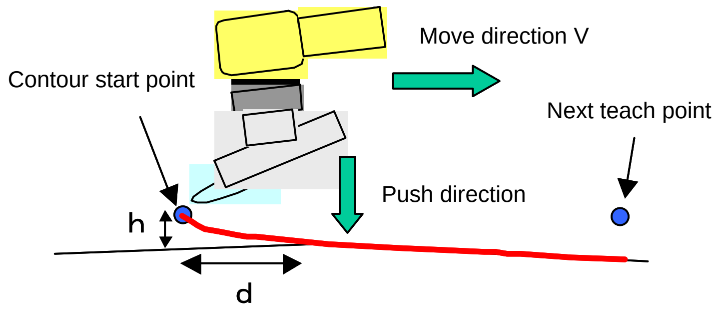



**Fig. 3.5.7.2(i) Move in the pushing direction and in the traveling direction at the same time from the starting point**

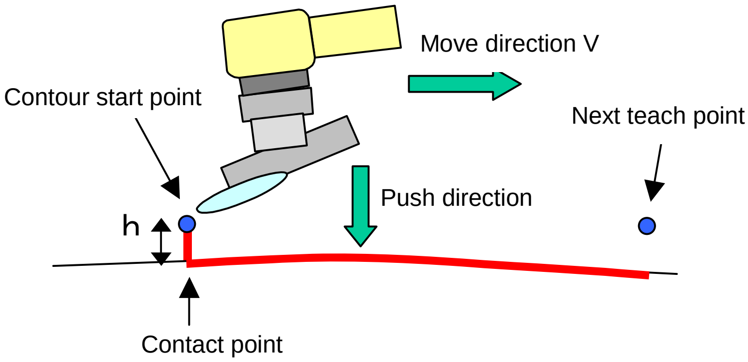



**Fig. 3.5.7.2(j) Move in the pushing direction first and after detecting a contact move in the traveling direction also**

## 3.5.7.3 Gravity compensation for the force sensor

In addition to force exerted between tool and workpiece, the force sensor also detects the affects 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.

<u>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. 3.5.7.1(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. 3.5.7.1(b).</u>

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, see 6, "WEIGHT AND GRAVITY CENTER CALCULATION".

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

### 3.5.7.4 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. 3.5.7.4 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.

Regarding setting parameters such as pushing force, for contouring function, see Subsection 3.5.7.6, "Parameters".

### 3.5.7.5 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.

# 3.5.7.6 Parameters

## Overview

### Parameters for "Contouring"

The parameters for "Contouring" are indicated in Fig. 3.5.7.6(a). 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.

Function selection screen

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

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

Basic 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  DEFAULT PERFORM
   F1      F2      F3      F4     Perf
```

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]
   F1      F2      F3      F4      F5
```

Performance 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
 8 Min. Error Dir.    : None
   Force Limit
 9  X:  500.00 Y:  500.00 Z:  500.00 N
10  W:   50.00 P:   50.00 R:   50.00N*m
   Force Change Limit
11  X:  200.00 Y:  200.00 Z:  200.00 N
12 Pushing Dir. Velocity:     0.00 mm/s
13 Motion Start        : before contact
14 Chk Overload Chg Trav Vel Sw: OFF
15   Monitoring Force      :  travel
16   Min. Force            :    2.00 N
17   Max. Force            :    8.00 N
18   Min. Speed Rate       :     1.00 %
19 Overload F. Detect Sw.:   OFF
20   Output Num.Reg. No.  :            0
21   Monitoring Force      :  travel
22   OvrF.Judgment Thres.:   30.00 N
23 Deact.PushDirMotion Sw:   OFF
24   Input Num.Reg. No.   :            0
25 Change Push. Force Sw.:   OFF
26   Min. Speed            :     2.0 mm/s
27   Max. Speed            :    50.0 mm/s
28 Pushing Dir Auto Chg: OFF
29 Chk Push Chg Trav Vel Sw   : OFF
30   Min. Force Rate           :   5.0 %
31   Max. Force Rate           :  70.0 %
32   Min. Speed Rate           :  1.00 %

[ TYPE ] GROUP  NUMBER  DEFAULT  BASIC
   F1      F2      F3      F4      F5
```

**Fig. 3.5.7.6(a) Screen for "Contouring"(1/2)**

Performance 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  DEFAULT  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  DEFAULT  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  DEFAULT  BASIC
```

F1 F2 F3 F4 F5

**Fig. 3.5.7.6(b) Screen for "Contouring"(2/2)**

## Function keys

The function keys shown in Fig. 3.5.7.6(a) have the following functions:

| 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. |

| Key | Item | Description |
|---|---|---|
| F3 | NUMBER | Allows you to display the screen for another schedule number. |
| 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. |

**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 values cannot be changed.)
"Default G F S: 1 1 1"

### Parameters for "Contouring End"

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

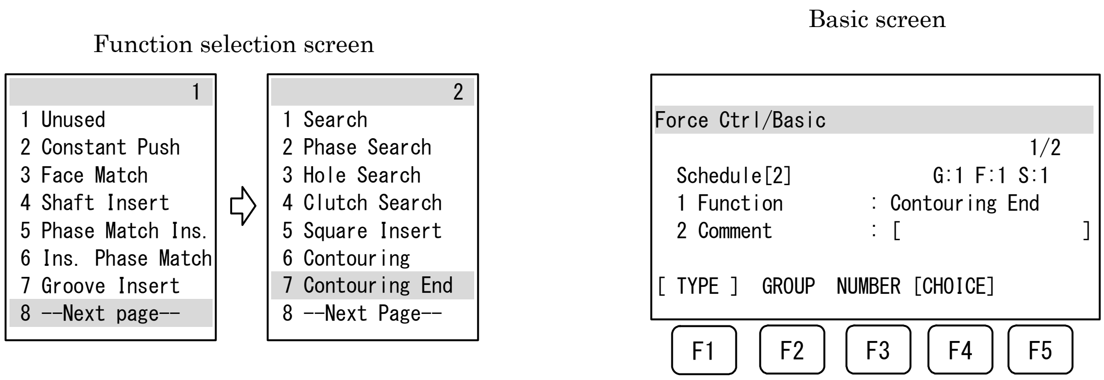



**Fig. 3.5.7.6(c) Screen for "Contouring End"**

### Parameter setting and tuning

To use Contouring function, set the parameters as described below.

1 Set the parameters on the basic screen.

a) Set "Control Frame".
Select tool frame or user frame.
See Subsection 3.5.7.2, "Teaching of the Contouring Function".

b) Set "Tool Frame No." and "User Frame No.".
Set tool frame number and user frame number to be used during contouring.

c) Set "Pushing Direction".
Set one of ±X, ±Y, and ±Z of "Control Frame" as pushing direction.

d) Set "Contouring Force" and "Contact F Threshold".
The proper pushing force depends on the grinder and the material of the workpiece to be machined. If a proper value cannot be found, first set a small value from 0.5 to 1 N then increase the value until a proper value can be determined.
Ensure that "Contact F Threshold" is smaller than "Contouring Force".

e) Set "Approach Velocity".
"Approach Velocity" is the speed in the pushing direction from the start point of contouring until a contact is made with the workpiece. By increasing this value, the required time until a contact is made with the workpiece can be reduced. In this case, however, overcutting can occur because a force greater than the setting is applied immediately when a contact is made with the workpiece.

f) Set "Push Dist. Limit".
During contouring, the tool moves in the pushing direction apart slightly from the taught path. Specify a maximum distance value that can be moved in the pushing direction. If the robot moves longer than "Push Dist. Limit", the robot stops with an alarm.

g) Set "Force Control Gain".

With Contouring function, automatic force control gain tuning (Subsection 3.9.2) cannot be executed. So, "Force Control Gain" must be manually set. As "Force Control Gain" become greater, performance for following up the surface of a workpiece becomes higher during contouring operation.
In order to set "Force Control Gain", see Section 3.6, "FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)". Increase the master frequency from about 0.5 Hz in steps of 0.25 Hz. If even a slight vibration is observed, do not increase the gain any more.

2 Tune the parameters on the performance screen as needed.

For an overview of force control instruction programming, see Section 3.1, "NOTES/RESTRICTIONS," and Section 3.2, "TEACHING PROCEDURE".
For details of each parameter, see the subsequent pages.

## ［Basic data setting screen］
**Parameters shown in this section must be set.**

### 1 Function
Select a function from the submenu shown on the function selection screen of Fig. 3.5.7.6(a). Here, select "Contouring".

### 2 Comment
Enter a comment for identifying schedule data.

### 3 Pushing Direction
This parameter specifies a direction in which the tool is pushed, by selecting an axis of the control frame used.
"Default : -Z"
The message in front of the setting value of the pushing direction means as follows:

AutoChg : "Pushing Dir Auto Chg" of in the "Performance data" is valid
Tool : "Control Frame" in the "Basic data" is "Tool Frame"
User : "Control Frame" in the "Basic data" is "User Frame"

### 4 Contact F Threshold
This parameter is the threshold for judging a contact made with the workpiece. Actual contouring operation starts after a contact is made. Specify a value smaller than "Contouring Force".
"Default : 1N"

### 5 Approach Velocity
This parameter specifies a target operation speed used in the pushing direction until a contact is made with the workpiece. By increasing the value of this parameter, the time required until a contact is made can be reduced. In this case, however, overcutting can occur because a force greater than the setting is applied immediately when a contact is made with the workpiece.
"Default : 1mm/sec"

### 6 Control Frame
Determine whether to perform pushing in the tool frame or user frame. Select the user frame if a held workpiece is ground by pushing the workpiece in a constant direction against a secured grinder or buff. Select the tool frame in an application where the push direction varies momentarily. If the workpiece is pushed against the grinder or buff so that they always contact at one point on the tool surface (i.e. remote TCP), select "User Frm Fixed".
"Default : Tool Frame"

### 7 User Frame No.

This parameter specifies a user frame number used during Contouring. Enter a user frame number set according to Section 3.2, "TEACHING PROCEDURE".
"Default : 0"

### 8 Tool Frame No.

This parameter specifies a tool frame number used during Contouring. Enter a tool frame number set according to Section 3.2, "TEACHING PROCEDURE".
"Default : 1"

### 9 Contouring Force

This parameter specifies a target pushing force to be used for actual pushing operation. The target pushing force is changed if "the function of changing target pushing force during a contouring" (refer to (1) in Subsection 3.5.7.7, "Other functions of the contouring function") is used.
"Unit : N"

### 10 Push Dist. Limit

During Contouring, the tool also moves in the pushing direction apart slightly from the taught path. Specify a maximum distance value that can be moved in the pushing direction.
If a movement is made beyond this maximum value, the robot stops with an alarm.
"Default : 50mm"

### [In the case of Not 3-axis force sensor]

### 11 Force Control Gain

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, see Section 3.6, "FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".

### [In the case of 3-axis force sensor]

**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. See section 3.9, "3-AXIS FORCE SENSOR SETTING" that has conceptual diagrams.**

### 11 3-Axis FS ContactP. Position (3-axis FS)

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 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.
The choices mean as follows:

TOOL:

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

USER:

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.

## 12 Setting Method (3-Axis ContactP. Position) (3-axis FS)

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.
The choices mean as follows:

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.

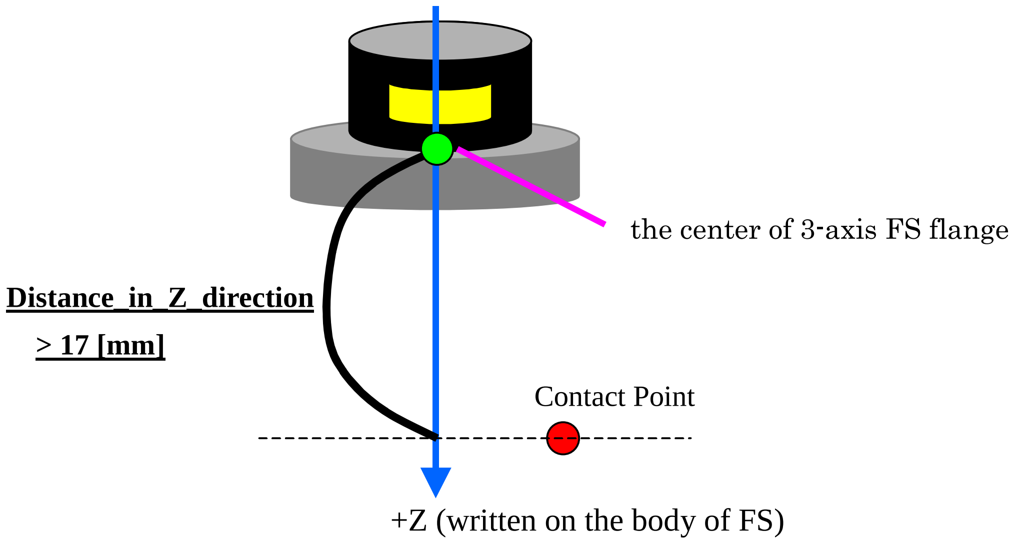
Pos. Reg.:

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.

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) must be larger than 17 [mm] during the force control. Be careful about this especially when the distance changes dynamically with robot motion.




### 13 Pos. Reg. No. (3-Axis ContactP. Position) (3-axis FS)

This parameter specifies a position register number if "Setting Method" is set to "Pos. Reg." for the 3-axis force sensor.

### 14 Distance (3-Axis ContactP. Position) (3-axis FS)

This parameter specifies a distance if "Setting Method" is set to "PushDirShift" for the 3-axis force sensor.
"Unit : mm"

### 15 Force Control Gain (3-axis FS)

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, see Section 3.6, "FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".

## ［Performance data setting screen］

**Parameters shown in this section are for advanced users.**

### 1 Function

Select a function from the submenu shown on the function selection screen of Fig. 3.5.7.6(a). Here, select "Contouring".

### 2 Comment

Enter a comment for identifying schedule data.

### 3 Simple Customize Sw

This parameter specifies a switch for "Simple Customize" function. It enables to execute the schedule data being edited after any other schedule.
For details, see Subsection 3.7.3, "Simple Customization Function".
"Default: OFF"

### 4 Cont. Exec. Max. Count

It designates how many force schedules with "Simple Customize Sw" ON can be executed successively.
For details, see Subsection 3.7.3, "Simple Customization Function".
"Default : 1"

### 5 Customize Parent Number

This parameter is set when force control is executed successively. For details, see Subsection 3.7.3, "Specifying Parent-Child Relationship".
"Default : 0"

### 6 Customize ParaChg Connection

This parameter is set when force control is executed successively. For details, see Subsection 3.7.3, "Specifying Parent-Child Relationship".
"Default : OFF"

### 7 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. The switch must be used in combination with the OFFSET or VOFFSET instruction. For details, see Section 3.8, "User Frame Compensation".
"Default : OFF"

### 8 Min. Error Dir.

This parameter is valid only when the tool frame is selected with "Control Frame" on the basic screen. During Contouring, the tool moves apart slightly from the taught path. The tool can be moved along the taught path in one direction other than the push direction. Specify such a direction.
"Default : None"

### 9 Force Limit
### 10

When a generated force satisfies the expressions below, an alarm(FORC-216 - FORC-221) is issued. See 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.

"Unit : N, N*m"

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)

where

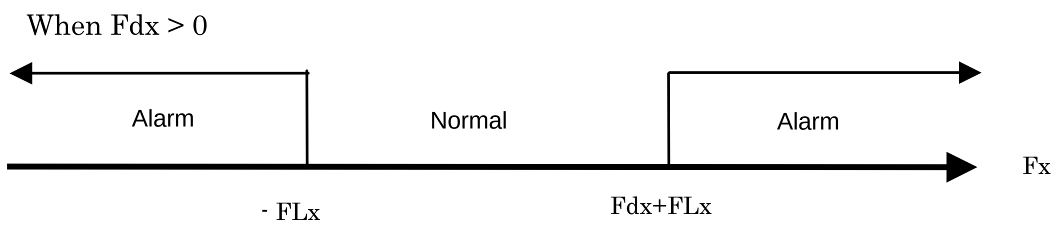
Fx: Force generated during push or face match operation (in the X direction)

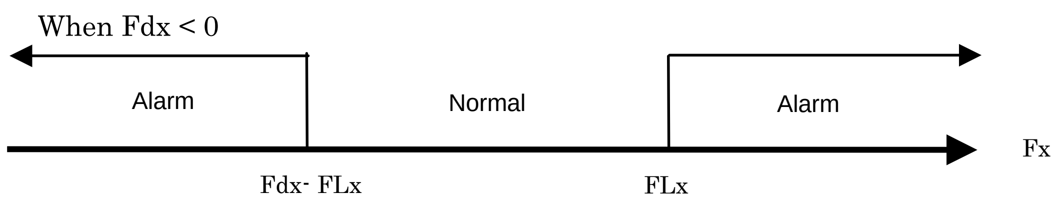
FLx: X component of "Force Limit"

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.




For the X, Y, or Z direction: "Default : 10N"

For the W, P, or R direction: "Default : 100N*m"

## 11 Force Change Limit

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. Set each of the three directions, X, Y, and Z.

"Unit : N"

## 12 Pushing Dir. Velocity

This parameter specifies speed in the pushing direction. Usually, 0 may be specified. However, if the curvature of a workpiece is so large that the workpiece and tool move apart from each other during Contouring operation, set a value from about 1 mm/sec to 10 mm/sec.

"Default : 0 mm/sec"

## 13 Motion Start

This parameter specifies a start motion in traveling direction of the contouring. The choices of this parameter mean as follows:

- "before contact" : start to move before a contact made with a workpiece
- "after contact" : start to move after a contact made with a workpiece

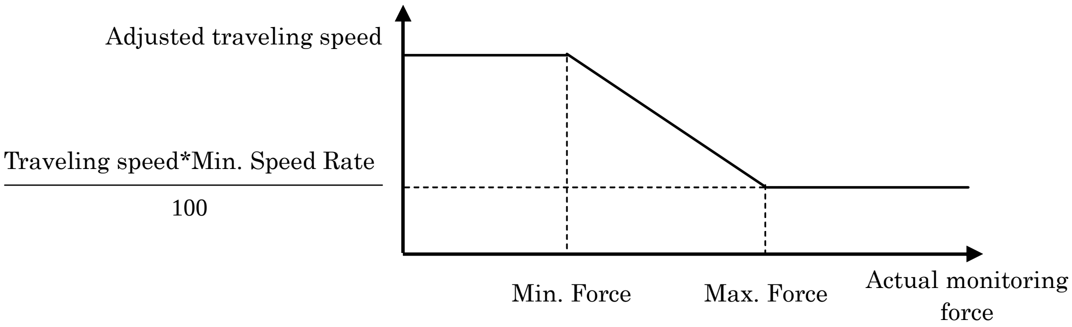
For details, see Fig. 3.5.7.2(i), Fig. 3.5.7.2(j).

"Default : before contact"

## 14 Chk Overload Chg Trav Vel Sw

This parameter is a switch for the "Chk Overload Chg Trav Vel" function that changes a moving velocity depending on generated force. 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.
"Default : OFF"

The adjusted traveling speed is calculated from "Min. Force", "Max. Force", "Min. Speed Rate" and actual monitoring force.




## 15 Monitoring Force (Chk Overload Chg Trav Vel)

This parameter specifies which force to be monitored with the "Chk Overload Chg Trav Vel" 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

## 16 Min. Force (Chk Overload Chg Trav Vel)

The "Chk Overload Chg Trav Vel" function does not change the moving velocity when monitoring force is less than this parameter.
"Default : 0.2 N"

## 17 Max. Force (Chk Overload Chg Trav Vel)

When monitoring force is greater than or equal to this parameter, the "Chk Overload Chg Trav Vel" function reduces the moving velocity to the value determined by "Min. Speed Rate" which is described below.
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 : 0.8 N"

## 18 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.
This value must be between 0.001 and 100, otherwise this function does not work.
"Default : 1 %"

### 19 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.
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"

### 20 Output Num.Reg. No. (Overload F. Detect)

This parameter specifies a Numeric Register Number to which the "Overload F. Detect" function output judgment whether excessive force is detected or not.
The output values of the Numeric Register mean as follows:

- 1 : Excessive force is detected
- 0 : Excessive force is not detected

### 21 Monitoring Force (Overload F. Detect)

This parameter specifies which force to be monitored with the "Overload F. Detect" 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

### 22 OvrF.Judgment Thres. (Overload F. Detect)

This parameter specifies a threshold for detecting excessive force. 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.
"Default : 3 N"

As an application of the "Overload F. Detect" function, a sample TP Program is shown in Fig. 3.5.7.6(c). 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.)

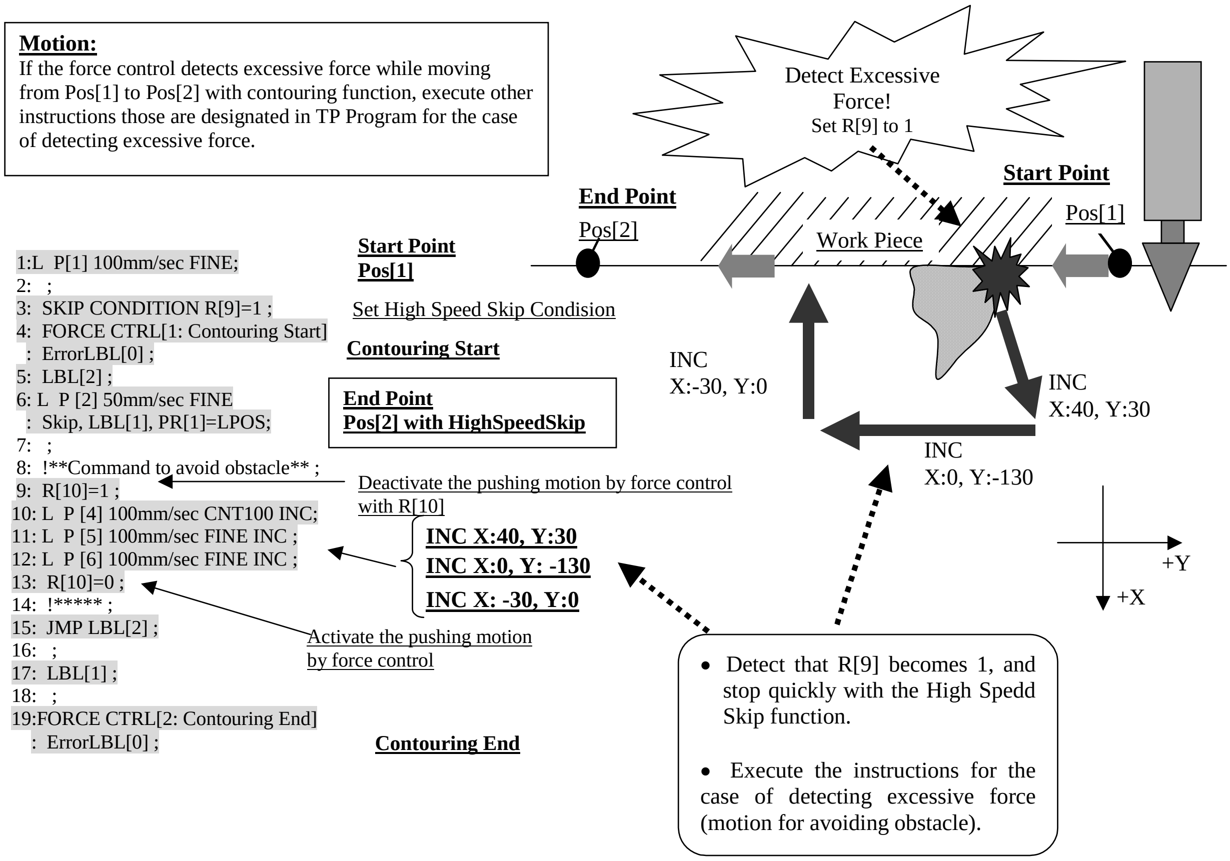



**Fig. 3.5.7.6(d) Example TP Program using the "Overload F. Detect" function and the High Speed Skip Function**

## 23 Deact.PushDirMotion Sw

This parameter specifies a switch to deactivate pushing motion in a pushing direction by force control in response to a Numeric Register Value during a contouring.
"Default : OFF"

## 24 Input Num.Reg. No. (Deact. Push. Dir. Motion)

This parameter specifies a Numeric Register Number for deactivating pushing motion by force control in the "Deact. Push. Dir. 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

## 25 Change Push. Force Sw.

This parameter specifies a switch for changing pushing force depending on the traveling velocity. This "Change Push. Force" function reduces desired pushing force when the traveling velocity is small.
"Default : OFF"

## 26 Min. Speed (Change Push. Force)

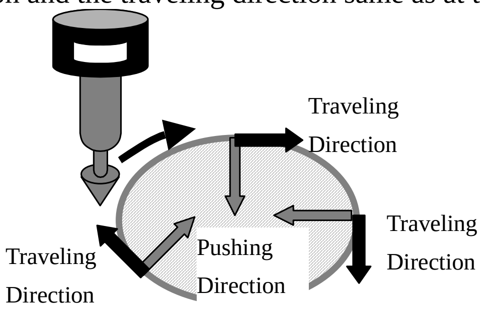
When the traveling velocity is smaller than this value, the "Change Push. Force" function reduces pushing force as small as possible.
"Default : 2 mm/sec"

## 27 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. 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 mm/sec"

## 28 Pushing Dir Auto Chg

This parameter enables the "Pushing Dir Auto Chg" function. This function changes the pushing direction automatically in response to the traveling direction.
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.




This function has the following restrictions:

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 (described in 3.5.7.7 (1)) before or during a contouring is prohibited.
Changing a target pushing direction (described in 3.5.7.7 (2)) 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

When using this function, the force data from the "Force Data Log Function"(described in 4.3) is read as follows

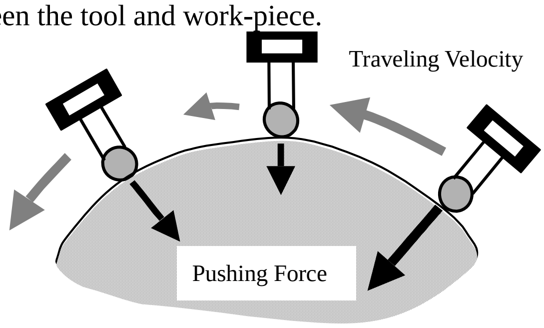
When "Pushing Direction" is set to ±X:
Fx : Force in a pushing direction,
Fy : Force in a traveling direction,
Fz :Force in the Z direction of "User Frame".
When "Pushing Direction" is set to ±Y:
Fx : Force in a traveling direction,
Fy : Force in a pushing direction,
Fz :Force in the Z direction of "User 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".

Note that this function changes the pushing direction internally and when using this function, the pushing direction is different from the "Pushing Direction" of the "Basic data".
"Default : OFF"

## 29 Chk Push Chg Trav Vel Sw

This parameter enables the "Chk Push Chg Trav Vel" function. This function reducess 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.
This "Chk Push Chg Trav Vel" function checks the pushing direction force and maintains contact between the tool and work-piece.




This function has the following restrictions:

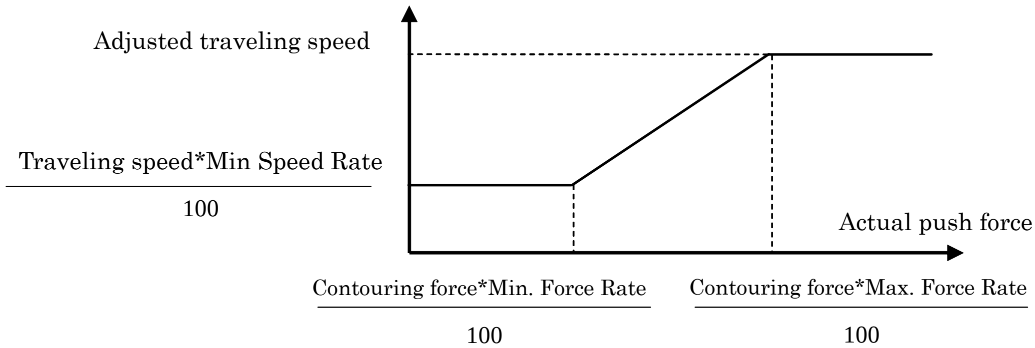
This function is effective once the workpiece makes contact to the object (the contact means that generated force exceeds "Contact F Threshold"). The moving velocity does not change before contact.

The following functions cannot be used together:

"Deact.PushDirMotion" function
"Change Push. Force" function
"Monit Push Dir Depth" function

"Default : OFF"

The adjusted traveling speed is calculated from "Min. Force Rate", "Max. Force Rate", "Min. Speed Rate" and actual force in pushing direction.




## 30 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).
"Default : 5 %"

### 31 Max. Force Rate (Chk Push Chg Trav Vel)

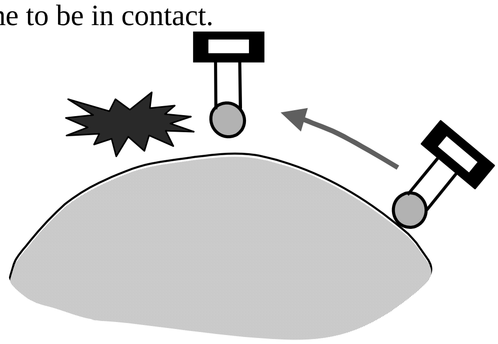
When the generated force in a pushing direction is greater than or equal to target force × "Min. Force Rate" / 100 and less than target force × "Max. Force Rate" / 100, the "Chk Push Chg Trav Vel" function reduces the traveling velocity to a value determined by "Min. Force Rate" and "Max. Force Rate" and "Min. Speed Rate" (described below). 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 %"

### 32 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 %"

### 33 Monit Min Push F Sw

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. When the generated force in a pushing direction is less than a value determined by "Min. Force Rate"(Monit Min Push F) (described bellow) for a period in a row, designated by "Monit Time" (described bellow), 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.



This function has the following restrictions:

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

"Default : OFF"

### 34 Min. Force Rate (Monit Min Push F)

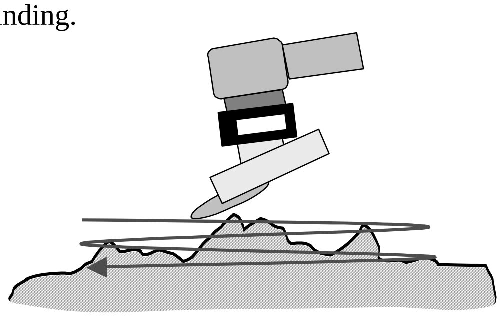
"Monit Min Push F" function compares generated force in a pushing direction with target force × "Min. Force Rate" / 100.
"Default : 10 %"

### 35 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. "Default : 1 sec"

### 36 Monit Push Dir Depth Sw

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. 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.

See also example TP Programs described in Fig. 3.5.7.6(d), Fig. 3.5.7.6(e).

- "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
- 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.
- This function has following restrictions:
  - 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:
    As described in Fig.3.5.7.6(c), 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"
"Default : OFF"

### 37 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.
The setting value of the "Numeric Register" specified 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

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.

### 38 Monit Motion Output Reg No (Monit Push Dir Depth)

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.

### 39 End Depth (Monit Push Dir Depth)

This parameter specifies a depth limit for the monitoring the depth action of the "Monit Push Dir Depth" function.
"Default : 2 mm"

### 40 Max Depth Per Path (Monit Push Dir Depth)

This parameter specifies a depth limit for an action between "Start" and, "Continue" or "End" for the monitoring depth action of the "Monit Push Dir Depth" function.
"Default : 0.5 mm"

### 41 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".

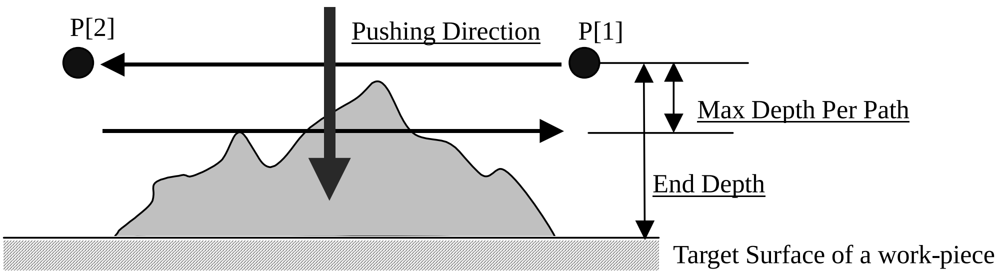
### 42 Monit Domain Rate (Monit Push Dir Depth)

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.
"Default : 80 %"

As an application of the "Monit Push Dir Depth" function, example TP Programs are shown in Fig. 3.5.7.6(d), Fig. 3.5.7.6(e).

**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"



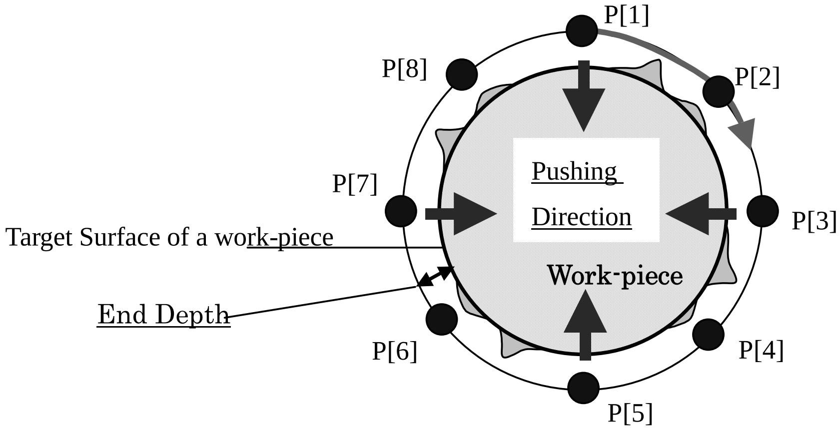

Monit Motion Input Reg No: 1
Monit Motion Output Reg No: 2

```
 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. 3.5.7.6(e) 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. 3.5.7.6(f) Example TP Program 2 of "Monit Push Dir Depth" function: Grind with going around motion**

### 43 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"

### 44 Signal Output for ERR SW

This parameter enables the "Signal Output for ERR" function. This function sends out a designated signal when an alarm is issued while contouring.
"Default : OFF"

### 45 Output Signal Type (Signal Output for ERR)

This parameter specifies the kind of a signal that "Signal Output for ERR" function sends out when an alarm is issued while contouring.
"DO", "RO", "FLAG" are available for the kind of a signal.

### 46 Output Signal Number (Signal Output for ERR)

This parameter specifies the signal number that "Signal Output for ERR" function sends out when an alarm is issued while contouring.

### 47 2 Direction Push

This parameter enables the "2 Direction Push" function. This function pushes in a second direction that is a different direction from the "Pushing Direction" in "Basic data".
If a setting of other function of contouring function uses the second direction, enable this function and set parameters of this function.
This function has the following restrictions:

If an axis that is designated by "Min. Error Dir." in "Performance data" is the same as an axis that is designated by "Pushing Direction 2" described below, the "Min. Error Dir." function takes priority over the "2 Direction Push" function.

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 (described in 3.5.7.7 (2)) before or during a contouring is prohibited

"Default : OFF"

### 48 Pushing Direction 2 (2 Direction Push)

This parameter specifies a direction as the second pushing direction in which the "2 Direction Push" function pushes. Set a direction of the used control frame to be the direction that is different from "Pushing Direction" in the "Basic data".
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

### 49 Contouring Force 2 (2 Direction Push)

This parameter specifies a target pushing force in the second pushing direction that is designated by "Pushing Direction 2". The target pushing force is changed if "the function of changing target pushing force during a contouring" (refer to (1) in Subsection 3.5.7.7, "Other functions of the contouring function") is used.
"Unit : N"

### 50 Approach Velocity 2 (2 Direction Push)

This parameter specifies a target operation speed used in the second pushing direction until a contact is made with the workpiece. By increasing the value of this parameter, the time required until a contact is made can be reduced. In this case, however, overload and overcutting can occur because a force greater than the setting is applied immediately when a contact is made with the workpiece.
"Default : 0 mm/sec"

### 51 Pushing Dir. Vel. 2 (2 Direction Push)

This parameter specifies speed in the second pushing direction after a contact is made. Usually, 0 may be specified. However, if the workpiece and tool move apart from each other during contouring, set this value.
"Default : 0 mm/sec"

### 52 Push Dist. Limit Individual (2 Direction Push)
### 53

During a contouring, the path that robot moves actually is different from the taught path.
"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.
This parameter specifies whether to monitor the deviation and its upper limit in each direction individually. If the deviation exceeds the upper limit in the direction that the monitoring is valid, the robot stops with an alarm.
"Default of Monitoring Sw : X : OFF, Y : OFF, Z : OFF"

### 54 Face Match

This item switches the screen display to the screen for setting the "Face Match" function of "Contouring". Move the cursor to this line and then press the "ENTER" key, and the screen display switches to the "Contour/FaceMatch" screen.
For robots other than the M-710iC/20L and the LRMate200iD and for 3-axis force sensors, this screen is not displayed.
The indication after "Face Match" represents the following:

- OFF : The "Face Match" function of "Contouring" is disabled.
- ON : The "Face Match" function of "Contouring" is enabled.

For details, see the description of [Contour/FaceMatch screen] below.

### 55 Auto.Follow

This item switches the screen display to the screen for setting the "Auto.Follow" function of "Contouring". Move the cursor to this line and then press the "ENTER" key, and the screen display switches to the "Contour/AutoFollow" screen.
For robots other than the LRMate200iD, this screen is not displayed.
The indication after "Auto.Follow" represents the following:

- OFF : The "Auto.Follow" function of "Contouring" is disabled.
- ON : The "Auto.Follow" function of "Contouring" is enabled.

For details, see the description of [Contour/AutoFollow screen] below.

### 56 TPProgramAuto.Gen.Sw.

This item is a switch of the function for automatically generating a TP Program after the execution of contouring. In contrast to the "TP Program auto generation" function, to be executed with KAREL, as described in Chapter 7, this function is called the "contouring 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.
- 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.".
  For details of parameters, see Chapter 7,
  "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.". For an explanation of the format of the output file, see Section 7.4, "OUTPUTTING PARAMETER SETTING AND RECORDED POSITIONS TO TEXT FILE" of Chapter 7,
  "TP PROGRAM AUTO GENERATION FUNCTION".
- Notes on generating a TPP based on the parameters of the "TP Program auto generation" function are the same as those described in Section 7.5, "NOTES". Note also that when "Auto.Follow" is executed, velocity adjustment cannot be made.
- When the robot is moved with a generated TP Program, it may move on a path different from the one on which it was actually moved. Before executing a generated TP Program, be sure to check the positions in it.
- 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:
  - Section 7.3, "REGENERATING TP PROGRAM WITH MODIFIED PARAMETERS"
  - Section 7.4, "OUTPUTTING PARAMETER SETTING AND RECORDED POSITIONS TO TEXT FILE"
- During the execution of the force control instruction "Contouring", do not change the parameter specified with "TPProgramAuto.Gen.Param.No.".
- When the cursor is on this line, it is possible to move to the setting screen of the "TP Program auto generation" function by pressing the function key displayed as "GROUP".

"Default: OFF"

### 57 TPProgramAuto.Gen.Param.No. (TP Program Auto Generation)

This parameter specifies the TP Program auto generation parameter number used by the contouring TP Program auto generation function to generate 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.

When the cursor is on this line, it is possible to move to the setting screen of the "TP Program auto generation" function by pressing the function key displayed as "GROUP".

### 58 Pos.Acquisition.Cond (TP Program Auto Generation)

This parameter sets the condition for acquiring the position for the contouring TP Program auto generation function to generate a TP Program. With the setting of this parameter, a TP Program is generated as described 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.
When the cursor is on this line, it is possible to move to the setting screen of the "TP Program auto generation" function by pressing the function key displayed as "GROUP".
"Default: Aftr.Aprch."

## [Contour/FaceMatch screen]

This screen is for setting the "Face Match" function of "Contouring".
For robots other than the M-710iC/20L and the LRMate200iD and for 3-axis force sensors, this screen is not displayed.

### 1 Function

To change the function to another function, make a selection from a submenu such as that shown on the function selection screen of Fig. 3.5.7.6 (a).

### 2 Comment

Enter a comment for identifying schedule data.

### 3 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. When this switch is "ON", face match operation is performed in the specified direction.

- Notes on setting and executing the item:
  - 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 M-710iC/20L and the LRMate200iD
  - 3-axis force sensor (FS-15iAe)
  - 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)"

"Default: OFF"

### 4 FaceMatchDir

This parameter specifies whether to perform face match operation in each direction when the contouring function is executed. The directions for which operation can be set are displayed. For the face match directions for which operation can be set, select between "ON" and "OFF". For each direction, face match is executed if the setting is "ON", and is not executed if it is "OFF".
The face match directions for which operation can be set are as follows:

- 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"

"Default: OFF, OFF"

### 5 Dist.Of ContactP. from Axis

This parameter sets the maximum length expected from each rotation axis to the contact portion for each face match direction. For each direction in which to perform face match, set "Dist.Of ContactP. from Axis" to the maximum length from the first portion where the objects subject to face match are expected to contact with each other to each rotation axis. By setting "Dist.Of ContactP. from Axis" appropriately, it may be possible to perform face match operation faster and more stably.
The face match directions are as follows:

- 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"

### 6 FaceMatch Max Rotation Velocity

This item is the maximum rotation velocity [deg/sec] in each face match 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.
"Default: 1.0 deg/s, 1.0 deg/s"

### 7 AftrCntct FaceMtch UpperLim Time

This item is the upper limit time [sec] for performing face match after contact (after the generated force exceeds "Contact F Threshold") when "Motion Start" in the Performance data is "after contact". 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 sec"

### 8 Orientation Chg. Chk. Sw

This item is a switch of the function for checking for posture changes against the teach posture during a contouring. 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"

### 9 Orient.Chg. UpperLim (Orientation Chg. Chk.)

This item is the upper limit value when checking for posture changes. 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 deg/s"

## [Contour/AutoFollow screen]

This screen is for setting the "Auto.Follow" function of "Contouring".
For robots other than the LRMate200iD, this screen is not displayed.

### 1 Function

To change the function to another function, make a selection from a submenu such as that shown on the function selection screen of Fig. 3.5.7.6 (a).

### 2 Comment

Enter a comment for identifying schedule data.

### 3 Auto.Follow Sw.

This item is a switch of the function for automatic contouring. 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 force control instruction "Contouring" is executed, the robot moves in the approach direction, and after contact (after the generated force exceeds "Contact F Threshold"), automatically contours the other object. 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.

- Notes on setting and executing the item:
  - 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.
  - 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.
  - 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.
  - 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"
    Items to set for the "Auto.Follow Sw."
- 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
  - 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"
    "Min. Error Dir."
    "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 Sw."

- "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"
- Ending method:
  - If an operation such as the following is performed, it ends abnormally. (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 not in AUTO mode, releasing the SHIFT button or releasing the deadman switch during contouring operation.
    Pressing the HOLD button during contouring.
  - 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.

"Default: OFF"

### 4 Travel.Dir. to Push.Dir.

This parameter sets the relation of the traveling direction to the pushing direction.

- "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.

### Move UpperLim.

For "Move UpperLim.", set three upper limits. 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.

### 5 1: Dist.From Strt.CtP (Move UpperLim.)

This is the first upper limit of Move UpperLim. For the position during contouring operation, set the upper limit value [mm] on the position where the first contact is judged to have been made (the generated force exceeds "Contact F Threshold").
"Default: 100 mm"

### 6 2: Total Move Dist. (Move UpperLim.)

This is the second upper limit of Move UpperLim. Set the upper limit value [mm] on the total movement distance along the object to contour, by assuming the position where the first contact is judged to have been made (the generated force exceeds "Contact F Threshold") to be 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 mm"

### 7 3: Total Move Time (Move UpperLim.)

This is the third upper limit of Move UpperLim. Set the upper limit value [sec] on the elapsed time from the time the first contact is judged to have been made (the generated force exceeds "Contact F Threshold").

"Default: 20 sec"

### 8 End Pos. Designate

Set this item to end the force control instruction "Contouring" normally when the position during contouring operation reaches a designated position.

- "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.

"Default: None"

### 9 Pos.Reg. No. (End Pos. Designate)

If "End Pos. Designate" is set to "Pos.Reg.", this item specifies the position register number at which the operation is to end after the position that is set in the designated position register is reached.

In the designated position register, set the position at which the operation is to end. In the designated position register, set a position on the user frame or the tool frame designated with "User Frame No." or "Tool Frame No." in the Basic data.

- Notes on setting and executing the item:

  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. 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.

### 10 In Position Thres. (End Pos. Designate)

This item is the threshold value [mm] used to judge whether the designated position is reached if "End Pos. Designate" is not "None". 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.

- Notes on setting the item:

  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.

"Default: 0 mm"

## 11 Aprch.Dir.Ang InptNumReg No.

This item is the Numeric Register number to use to set the approach direction in which to move when "Auto.Follow" 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.

- Notes on setting the item:
  - 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.

## 12 NrmlEnd for MoveUpperLim

This item is the setting for assuming that the operation ends normally, not abnormally, if the movement upper limit is reached. Of the first (Dist.From Strt.CtP), second (Total Move Dist.), and third (Total Move Time) movement upper limits, specify the one to cause the operation to be assumed to end normally if reached.

- "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"

### 13 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. 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"

### 14 End Num.Reg. No. (End by Num.Reg)

This item specifies the Numeric Register number that is used to end the force control instruction "Contouring" normally.

## 3.5.7.7 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 "Contouring Force", "Contouring Force 2" in a "Basic data" determines target force and the target pushing force cannot be changed during force control of the "schedule data".
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.
  The pushing force set with FCNCHPFN is reset automatically at the end process of the "Contouring" instruction or "Contouring End" (the pushing force 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.

### Arguments of FCNCHPFN(ARG1, ARG2)

- ARG1:
  Select to restore or change target-pushing force.
  - 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"
  - 1 : Change a target pushing force to a designated value in "Pushing Direction" in a "Basic data"

- 2 : Change a target pushing force to a designated value in "Pushing Direction 2" in a "Performance data"

  If ARG1 equals to 0, ARG2 is not need to be set.
  If ARG1 equals to 2, "2 Direction Push" in a "Performance data" must be valid.
- ARG2:
  Designate target pushing force to change pushing force.
  The ARG2 unit is N.
- ARG1, ARG2 can take Numeric Register.

### Example Setting of FCNCHPFN Arguments

- 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)
  FCNCHPF(2, 30)

### Example TP Program

An example TP Program that changes target pushing force during a contouring is shown in Fig. 3.5.7.7(1). 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. 3.5.7.7(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.

### Functions that cannot be combined

The following functions cannot be used together:

- Successive Execution Of Force Control Instructions (See Section 3.7, "Successive Execution Of Force Control Instructions (Customization 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. This function can change only the direction designated by "Pushing Direction" and cannot change the direction designated by "Pushing Direction 2". The combination of this function and 2 Direction Push is prohibited.

### 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.
  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.

### 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.
  - Rotate the control frame designated degrees in the "Too Frame" of a "Basic data"
  - Rotate the control frame designated degrees in the "User Frame" of a "Basic data"
  - 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 3.5.7.7(a), Table 3.5.7.7(b).

**Table 3.5.7.7(a) The rotating method of the control frame by ARG1 and ARG2 settings**

| Setting of ARG1 | The rotating method of the control frame |
|---|---|
| ARG1 = 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")<br>• ARG2 and ARG3 don't matter and are not necessary to be set. |
| ARG1 = 1 | • Rotate a control frame by designated W, P, and R degrees in a "Tool Frame" of a "Basic data".<br>• 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.<br>• 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. |

| Setting of ARG1 | The rotating method of the control frame |
|---|---|
| ARG1 = 2 | • Rotate a control frame by designated W, P, and R degrees in a "User Frame" of a "Basic data".<br>• 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.<br>• 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. |
| ARG1 = 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.<br>• 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").<br>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.<br>• 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. |

**NOTE**

If a control frame is a "Tool Frame", the relation between the "Tool Frame" and the posture of a robot is newly determined for force control internally at the moment of the rotating and changing of the control frame.
After the rotation and change of the control frame, the relation between the robot posture and the new internal "Tool Frame" is being kept and the target pushing direction is being changed during the contouring based on the modified "Tool Frame".

**Table 3.5.7.7(b) The changing method of the control frame by ARG3 setting**

| Setting of ARG3 | The changing method of the control frame |
|---|---|
| ARG3 = none or 0 | Set a control frame to a "Control Frame Cf" of a "Basic data".<br><br>NOTE<br>If ARG3 is none, the control frame becomes the "Control Frame Cf" of the "Basic data". |
| ARG3 = 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". |
| ARG3 = 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". |

- ARG1, ARG2 and ARG3 can take Numeric Register.

## Example Setting of FCNCHCFR Arguments

- 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. 3.5.7.7(2). 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. 3.5.7.7(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.

### Functions that cannot be combined

The following functions cannot be used together:

- 2 Direction Push
- Successive Execution Of Force Control Instructions (See Section 3.7, "Successive Execution Of Force Control Instructions (Customization 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.

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".

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.

### 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.
  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.

### Arguments of FCNCH3CTP (ARG1, ARG2)

- ARG1:
  Setting for a setting method for a contact point.
  - 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.
  - 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.
  - 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.

  If ARG1 equals to 0, ARG2 is not need to be set.
- ARG2:
  - 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.
- ARG1, ARG2 can take Numeric Register.

### Example Setting of FCNCH3CTP Arguments

- 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. 3.5.7.7(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. 3.5.7.7(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 an explanation of force control gain, see Section 3.6, "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.

### 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.)
  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.

### FCNCHFCG (ARG1, ARG2, ARG3, and ARG4)

- In ARG1, set the method of changing the force control gain. The settings of ARG1 are as follows:
  - 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.
  - 1: Change the force control gain with "Master Frequency". For an explanation of "Master Frequency", see Section 3.6, "FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".

- 2: Change the force control gain with "Individual Frequency". For an explanation of "Individual Frequency", see Section 3.6, "FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)".

- If ARG1 is 0, ARG2 and the subsequent arguments are not necessary.
- If ARG1 is 1, ARG2 is necessary.
- If ARG1 is 2, ARG2, ARG3, and ARG4 are necessary.
- Numeric Registers can be used for the arguments.

**Table 3.5.7.7 (c) Changing the force control gain with argument settings**

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

**NOTE**

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

## Examples of setting FCNCHFCG arguments

- 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. 3.5.7.7 (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.

### Function that cannot be used concurrently with this function

This function cannot be used concurrently with the following function.

- Customization function (For an explanation of this function, see Section 3.7, "SUCCESSIVE EXECUTION OF FORCE CONTROL INSTRUCTIONS (CUSTOMIZATION FUNCTION)".)

## (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". (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 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. 3.5.7.7(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. 3.5.7.7(e) TP Program example restoring the changed pushing force, pushing direction, contact point, and force control gain to their settings in the Basic data**

**NOTE**

In this example, a Time Before instruction is used in the seventh line. Without the Time Before instruction, the program may stop momentarily at teach position [4] if the operation velocity is high.

## 3.5.8 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 about TCP with the robot alone; and performing threading by rotating a workpiece by 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.

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.

### 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 continuous turn option (J613) exists, and the continuous turn setting is made appropriately.

### 3.5.8.1 Parameter

### Overview

#### Parameters for "Threading"

The parameters for "Threading" are indicated in Fig. 3.5.8.1 (a). The parameters displayed on the basic screen must be set at all times.

Function selection screen

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

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

```
                     3
 1 Threading
 2
 3
 4
 5
 6
 7
 8 --next page--
```

Basic 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  DEFAULT 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   CHOICE
   F1       F2      F3      F4      F5
```

Performance 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  DEFAULT BASIC
   F1       F2      F3      F4      F5
```

**Fig. 3.5.8.1(a) Teaching “Threading” detailed data**

### Function keys

The function keys to use are as given below.

| 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 data number. |
| Shift + F4 | DEFAULT | Allows you to return schedule settings to their defaults. |
| F5 | PERFORM / BASIC | Allows you to switch between Performance data setting screen and Basic data setting screen. |

### G F S

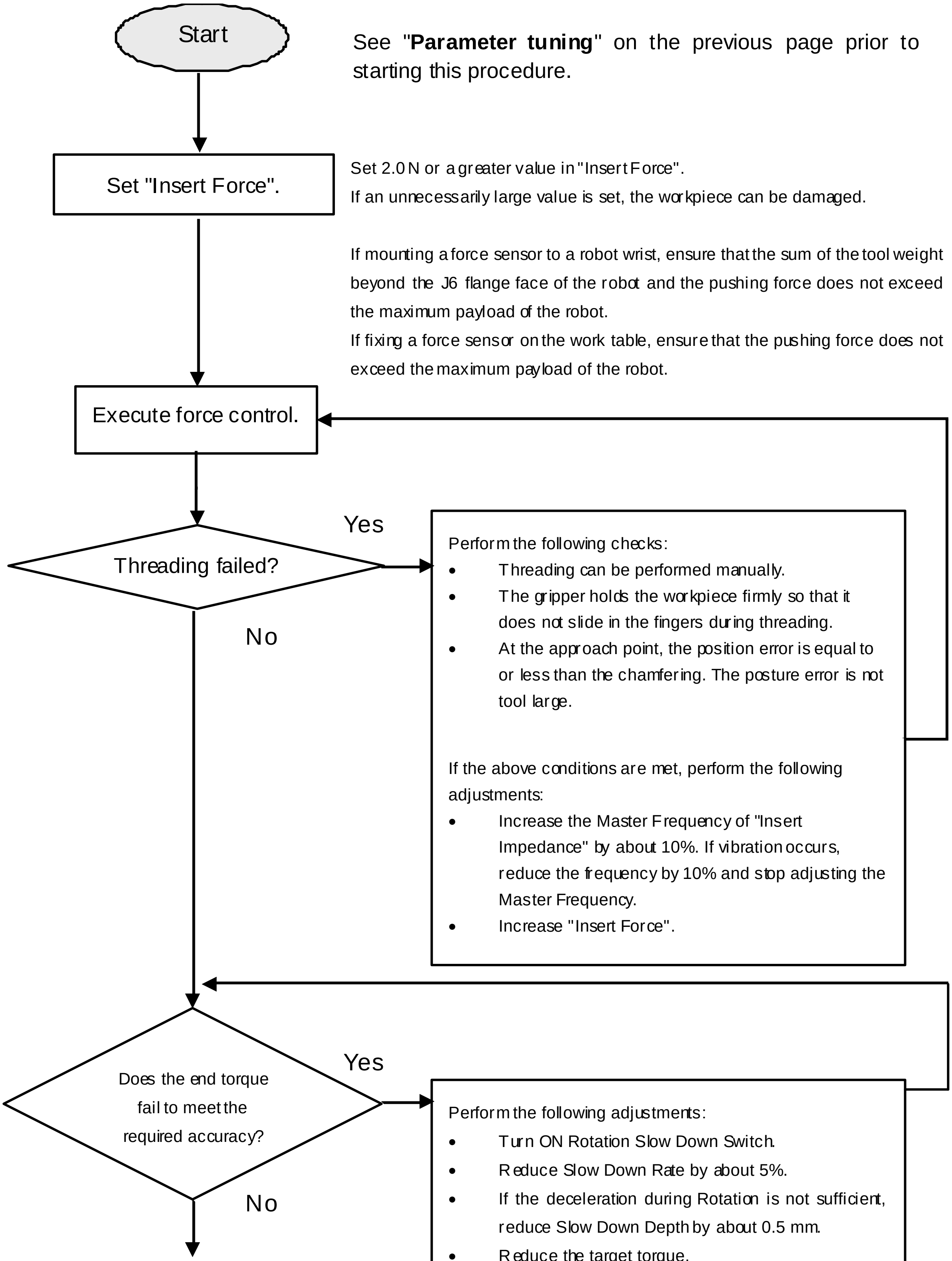
G represents the motion group at the time of teaching. F represents a force control number. S represents a force sensor number. (These settings cannot be changed.)
"Default G F S: 1 1 1"

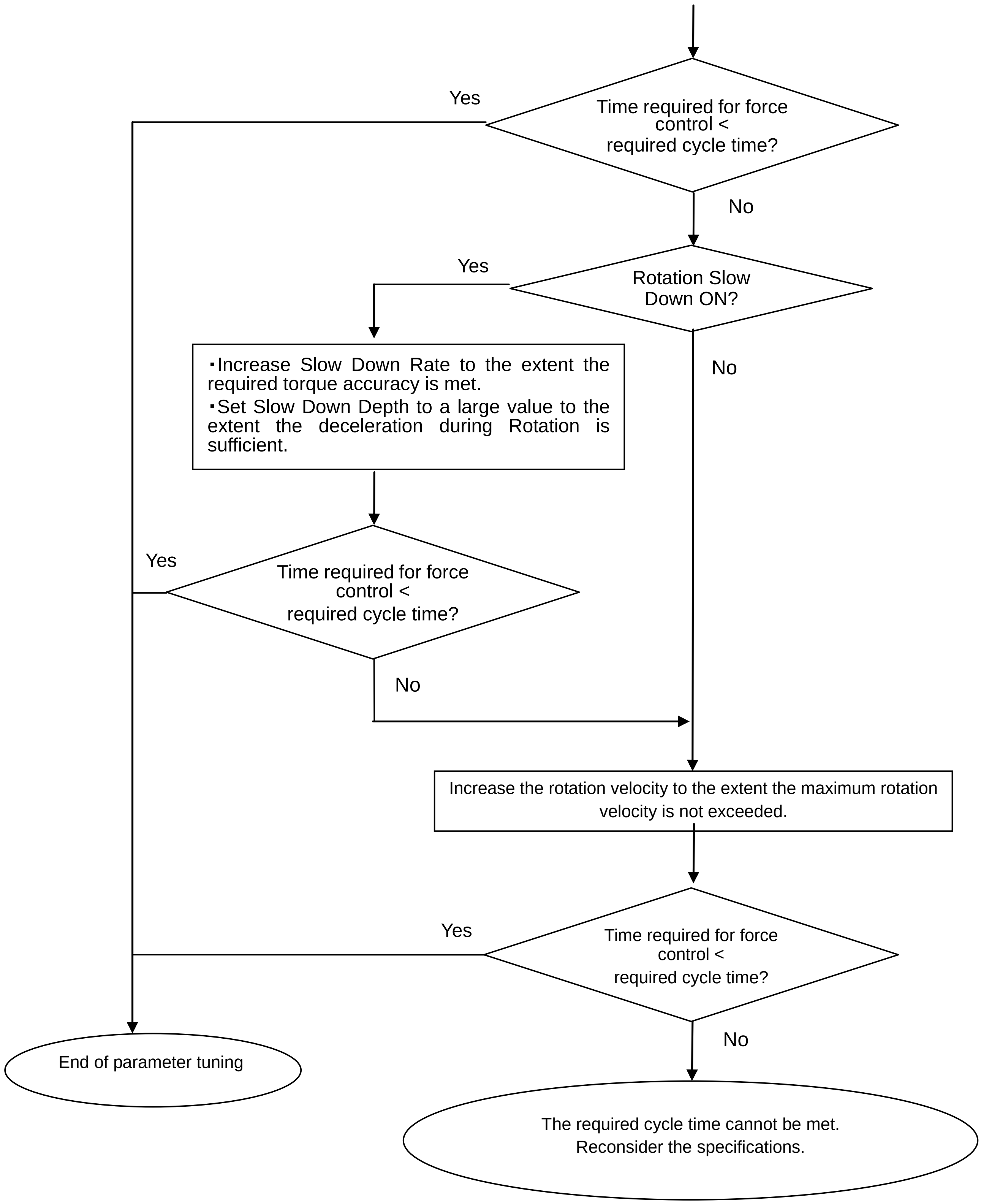
## Parameter tuning

The following parameter setting sequence is used:

1 Set "Rotation Mechanism", "Insert Direction", "Screw Helix Dir.", and "Rotate Direction".
2 Set "User Frame No." and "Tool Frame No.".
3 Set "Target Torque", "Rotation Velocity", "Minimum depth", and "Maximum depth".
4 Make automatic force control gain adjustment. (See Subsection 3.9.2.)
5 Tune the parameters on the performance screen as required.

For an outline of force control instruction programming, see Section 3.1, "NOTES/RESTRICTIONS", and Section 3.2, "TEACHING PROCEDURE".
For details of each parameter, see the pages that follow.
The procedure for tuning other parameters after the completion of automatic force control gain adjustment is shown below.


Start
See "**Parameter tuning**" on the previous page prior to starting this procedure.
Set "Insert Force".
Set 2.0 N or a greater value in "Insert Force".
If an unnecessarily large value is set, the workpiece can be damaged.
If mounting a force sensor to a robot wrist, ensure that the sum of the tool weight beyond the J6 flange face of the robot and the pushing force does not exceed the maximum payload of the robot.
If fixing a force sensor on the work table, ensure that the pushing force does not exceed the maximum payload of the robot.
Execute force control.
Threading failed?
Yes
No
Perform the following checks:
• Threading can be performed manually.
• The gripper holds the workpiece firmly so that it does not slide in the fingers during threading.
• At the approach point, the position error is equal to or less than the chamfering. The posture error is not tool large.
If the above conditions are met, perform the following adjustments:
• Increase the Master Frequency of "Insert Impedance" by about 10%. If vibration occurs, reduce the frequency by 10% and stop adjusting the Master Frequency.
• Increase "Insert Force".
Does the end torque fail to meet the required accuracy?
Yes
No
Perform the following adjustments:
• Turn ON Rotation Slow Down Switch.
• Reduce Slow Down Rate by about 5%.
• If the deceleration during Rotation is not sufficient, reduce Slow Down Depth by about 0.5 mm.
• Reduce the target torque.




## [Basic data setting screen]

### 1 Function

From a submenu such as that shown on the function selection screen of Fig. 3.5.8.1 (a), select the function to set. In this case, select "Threading".

## 2 Comment

Enter a comment for identifying schedule data.

## 3 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"

## 4 Insert Direction

This item represents the direction for insertion in the preset user frame.
"Default: -Z"

## 5 Screw Helix Dir.

This item is used to specify whether the screw to fasten is right handed or left handed. This is used to determine the rotate direction.
"Default: Right Handed"

## 6 Rotate Direction

This item is used to specify whether to rotate in the tightening direction or the loosening direction. This is used to determine the rotation direction and judge the operation mode. If "Loosen" is selected, extraction mode is assumed.
"Default: Tighten"

## 7 Contact F Threshold

This is the threshold for judging whether contact is made with the work object.
"Unit: N"

## 8 Approach Velocity

This is the target movement velocity assumed until contact is made with the work object.
"Default: 1 mm/s"

## 9 User Frame No.

This is the number of the user frame used during threading or extraction.
"Default: 0"

## 10 Tool Frame No.

This is the number of the tool frame used during threading or extraction.
"Default: 1"

## 11 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.

### 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.

## 12 Rotation Velocity

This is the target velocity in the rotation direction. If not using auxiliary axis, enter it in deg/s. If using auxiliary axis, enter it in rpm. The direction is decided from "Insert Direction", "Screw Helix Dir.", and "Rotate Direction", so enter them as absolute values.
"Default: 1 deg/s"

### 13 Rotation Ang. Limit

This is the operation upper limit assumed if no auxiliary axis is 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. 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.)
"Default: 0 deg"

### 14 Insert Force

This is the target force in the insertion direction.
"Unit: N"

### 15 Insert Velocity

This is the target velocity in the insert 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 mm/s"

### 16 Minimum depth

If this depth is not reached at the end of force control, an alarm is issued. In extraction mode, force control ends normally if this depth is reached.
"Default: 20 mm"

### 17 Maximum depth

If the torque does not reach the target value even after this depth is exceeded, an alarm is issued.
"Default: 30 mm"

### 18 Rotation Time Limit

If force control is not ended even after this time has passed, an alarm is issued.
"Default: 20 sec"

### 19 F.Ctrl. Gain Auto Modify

This is the switch used in automatic force control gain adjustment.
"Default: OFF"

### 20 Force Control Gain

This switches the screen display to the screen for setting the force control gain. Move the cursor to this line and then press the "ENTER" key, and the screen display switches to the "Force Ctrl/Gain" screen.

## [Performance data setting screen]

### 1 Function

From the submenu shown on the "function selection screen", select the function to set. In this case, select "Threading".

### 2 Comment

Enter a comment for identifying schedule data.

### 3 Simple Customize Sw

Set this item to execute force control successively. When this switch is set to ON, force control can be executed after any force control schedule. For details, see Subsection 3.7.3, "Simple Customization Function".
"Default: OFF"

### 4 Retry Sw

Set this item to use this force control schedule as a retry for a previously executed schedule. If the item is "OFF", the robot moves by the distance specified in "Insert Depth (Design)" 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. For details, see Subsection 3.7.3, "Simple Customization Function".
"Default: OFF"

### 5 Cont. Exec. Max. Count

This item specifies how many successive times the simple customization function can execute an effective force control schedule. For details, see Subsection 3.7.3, "Simple Customization Function".
"Default: 1"

### 6 Customize Parent Number

Set this item to execute force control successively. For details, see Subsection 3.7.4, "Customization Function".
"Default: 0"

### 7 Customize ParaChg Conct

Set this item to execute force control successively. For details, see Subsection 3.7.4, "Customization Function".
"Default: OFF"

### 8 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. Set this item to "ON" for all schedule data subject to Customize Auto. Cnt. Exec., whether it be a parent or a child.
For details, see Subsection 3.7.5, "Customization Automatic Continuous Execution Function".
"Default: OFF"

### 9 Auto. Cnt. Exec. Child No. (Customize Auto. Cnt. Exec.)

This parameter specifies the number of the next schedule data subject to Customize Auto. Cnt. Exec. 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.

### 10 Schedule No. Output Reg. No. (Customize Auto. Cnt. Exec.)

This parameter specifies the number of the Numeric Register to which to output the execution state of Customize Auto. Cnt. Exec.
When Customize Auto. Cnt. Exec. is being executed, the number of the schedule data under execution is output. If the series of schedule data combined together with Customize Auto. Cnt. Exec. ends normally, 0 is output to the 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.

### 11 User Frame Compensation

This is the switch for correcting the user frame that is set for the work object face, using *i*RVision. This is useful if the slope of the work object may vary. This item must be used concurrently with the OFFSET or VOFFSET instruction. For details, see Section 3.8, "USER FRAME COMPENSATION".
"Default: OFF"

### 12 Rotation Slow Down Switch

This item is a switch of the function for decelerating when the depth specified with Slow Down Depth is reached.
"Default: OFF"

### 13 Slow Down Depth

This is the depth at which start deceleration if the Rotation Slow Down Switch is ON.
"Default: 20 mm"

### 14 Slow Down Rate

This is the rate of deceleration if the Rotation Slow Down Switch is ON. After Slow Down Depth, the rotation velocity multiplied by this rate is regarded as the target value.
"Default: 30 %"

### 15 Force Limit
### 16

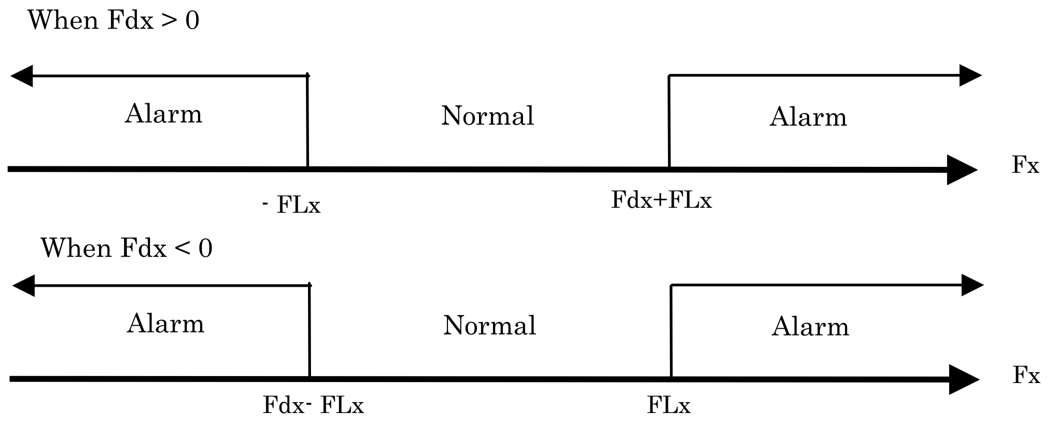
If the generated force satisfies one of the expressions below, an alarm (FORC-216 - FORC-221) is issued. See Appendix B, "ALARM CODES FOR FORCE CONTROL" first to remove the cause of the alarm. If the alarm persists even after all possible measures are taken, increase the values of this parameter. Set 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 $Fdx < 0$)

where 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.
"Unit: N, N*m"




## 17 Force Control Valid Sw

Select whether to perform force control in directions other than the insertion direction and the rotation direction in insert mode. 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.
"Default: X: ON Y: ON W: ON P: ON"

## 18 Torque Error Compensate SW

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. (For details, see Subsection 3.9.3, "Torque Error Acquisition Instruction".)
"Default: OFF"

### Torque Error Data W P R

These values are estimated from the moment information obtained from the force sensor with "TRQ ERROR" when pushing is actually performed with "Torque Error Fd", and are set. 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. (These values cannot be changed.)
"Default: 0 Nm"

### Torque Error Fd

During "TRQ ERROR", the actual pushing force is set as the value of this item. If "Torque Error Compensate SW" is turned "ON", this setting is used to correct the torque error. (The setting cannot be changed.)
"Unit: N"

## 19 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. When this switch is turned "ON", the velocity during threading can be prevented from exceeding "Insert Velocity" in the Basic data.
"Default: ON"

### 20 Force End Judgment Switch

This item is a switch of the function for ending operation after checking whether a proper force has been generated. When this switch is turned "ON", the operation can be ended if result of the force judgment below after the target torque is reached is "SUCCESS". If the force judgment below is not "SUCCESS" even after "Insert Time Limit" in the Basic data has passed, an alarm is issued.
"Default: OFF"

### 21 Min. Force Rate

The value of this item is used for force judgment. If the magnitude of the generated force in "Pushing Direction" is greater than "Min. Force Rate" x "Contouring Force" / 100, the result of the judgment is "SUCCESS".
"Default: 80 %""

### Judgement Result

This item indicates the result of the force judgment at the end of the threading function. If the magnitude of "Pushing Direction" at the end of the function is greater than "Min. Force Rate" x "Contouring Force" / 100, "SUCCESS" is indicated; otherwise, "FAILURE" is indicated.
"Default: -----"

### Force Average

This item indicates the axis of "Pushing Direction", as well as the average magnitude of the force in "Pushing Direction" at the end of the threading function.
"Default: Z: 0 N"

### 22 Fast Ins. Switch

This item is a switch of the function for speeding up posture correction operation.
"Default: ON"

### 23 Fast Ins. Multiplier

This parameter represents the speed of posture correction operation. If "Fast Ins. Switch" is ON, posture correction operation becomes faster by increasing this value. For safety, increase this value in steps of about 0.5.
"Default: 2"

### 24 Fast Ins. Acc. Time

This item is the acceleration time for posture adjustment operation. If "Fast Ins. Switch" is ON, posture adjustment operation becomes faster by decreasing this value. For safety, decrease this value in steps of about 0.1.
"Unit: sec"

### 25 Approach Acc. Time

This item is the time from the start of the force control instruction until the velocity reaches "Approach Velocity" in the Basic data.
"Unit: sec"

### 26 Rotation Acc. Time

This item is the time from the time the force exceeds "Contact F Threshold" in the Basic data until the velocity in the rotation direction reaches "Rotation Velocity" in the Basic data.
"Unit: sec"

### 27 Force Denoising Sw

This item is a switch of the function for removing large noise from 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

If this function is enabled, with the threading function, a delay may occur in force data, and the tightening torque may greatly exceed the target value due to coasting.
"Default: OFF"

### 28 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.
"Default: OFF"

### 29 Output Signal Type (Signal Output for ERR)

This parameter specifies the type of the signal that the Signal Output for ERR function outputs if an error occurs during force control.
The type of signal that can be specified are DO, RO, and FLAG.

### 30 Output Signal Number (Signal Output for ERR)

This parameter specifies the number of the signal that the Signal Output for ERR function outputs if an error occurs during force control.

### 31 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. Use this if, for example, wishing to add a user-unique condition to the ending conditions.
"Default: OFF"

### 32 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"

# 3.6 FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)

## Overview

If ENTER key is pressed while the cursor is positioned to any "XXX(Approach/Pushing/Insert) Impedance" item in the basic data of each schedule, either of the screens shown below appears. For a schedule other than "Contour", if force control gain (See 3.10.2 Force Control Gain Auto Tuning.) auto tuning is performed, this screen usually does not have to be used. However, even after auto tuning was done, further manual adjustment may be needed especially if outstanding vibration is observed under force control or if the operation under force control does not respond well. Note: Auto Tuning is not supported for contouring.

The default setting is "Master Frequency". Unless very fine-tuning is required, the settings of "Master Frequency" are used. It changes frequency for all directions (X,Y,Z,W,P,R) proportionally.

In some cases, the frequency should be changed independently. For example, increase frequency of W, P, R to speed up the orientation correction during insertion. Or set very small values to frequency of W, P, R to keep the orientation constant. Use “Individual Frequency” screen for these purposes.

```
Impedance detail                    JOINT  10 %
                                           1/1
 Input Master Frequency
   Insertion Direction      :    Z
   Master Frequency         :    1.0 [Hz]

[ TYPE ]
```

**Fig. 3.6 (a) “Master Frequency” Screen**

```
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 ]
```

**Fig. 3.6 (b) “Individual Frequency” Screen**

```
Impedance detail
                                         1/6
 Input Damper,Spring
  Damper    (XYZ:N*s/m  WPR:N*s*m)
  1   X:    15607.8     W:      156.1
  2   Y:    15607.8     P:      156.1
  3   Z:    15607.8     R:      156.1
  Environment Spring
         (XYZ:N/m)          (WPR:N*m)
  4   X:    98066.5     W:      980.7
  5   Y:    98066.5     P:      980.7
  6   Z:    98066.5     R:      980.7

[ TYPE ]
```

**Fig. 3.6 (c) “Damper and Spring” Screen**

## "Master Frequency" Screen

### Insertion Direction

This indicates the direction in which insertion is performed. This value cannot be changed.

### Master Frequency

This is the parameter for determining the response in force control. The parameter for determining the response in the insertion direction is called the master frequency. As the value of "Master Frequency" increases, the response in force control increases, but the vibration may also increase. As the value of "Master Frequency" decreases, the vibration decreases, but the response in force control also decreases, resulting in sluggish operation. When the value of "Master Frequency" is changed by a certain ratio, the frequencies in the five directions other than the insertion direction also change by the same ratio.

If a schedule is "Contour", set it about 0.5Hz for LRMate, M-10iA or M-20iA series robot, 0.1Hz for M-710iC, R-1000iA, R-2000iB or R-2000iC se ries robot as an initial value. Observe whether the robot does not vibrate during force control and increase it by about same value.

### "Individual Frequency" Screen

#### Individual Frequency

This is one of the parameters that determine the response in force control. Unlike the master frequency, the response can be changed on a direction-by-direction basis.
As the direction value of "Frequency" increases, the response in 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.

### "Damper and Spring" Screen (Reserved for advanced applications)

#### Damper

This is one of the parameters that determine the response in force control. As this "Damper" value decreases, the response in force control increases, but the vibration may also increase. As this "Damper" value increases, the vibration decreases, but the response in force control also decreases, resulting in sluggish operation.

#### Environment Spring

This is one of the parameters that determine the response in force control. The value of this parameter is automatically set when the force control gain auto tuning instruction is executed.
No modification is needed.

## 3.7 SUCCESSIVE EXECUTION OF FORCE CONTROL INSTRUCTIONS (CUSTOMIZATION FUNCTION)

There are 13 types of "FORCE CTRL" instructions in total as mentioned in Section 3.3, "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.
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 Subsection 3.7.3.

(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 Subsection 3.7.4.

(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 Subsection 3.7.5.

## 3.7.1 Combination of Force Control Operations

Fig. 3.7.1 shows the following operations:

(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.

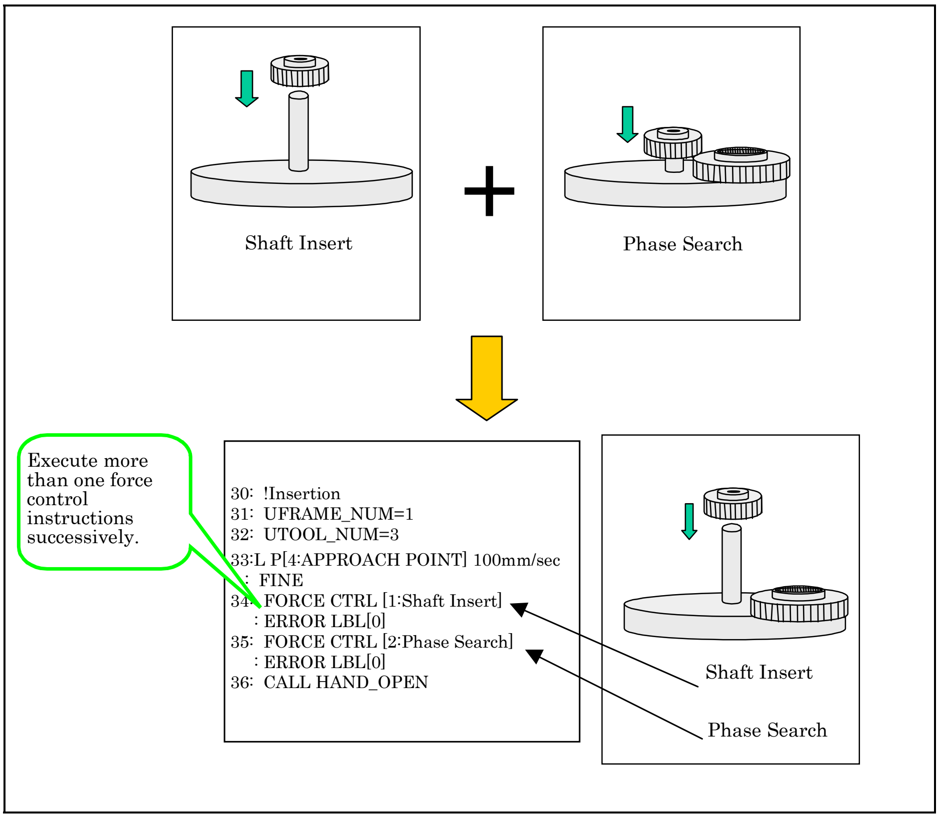



**Fig. 3.7.1 Combination of force control operations**

## 3.7.2 Retry

Fig.3.7.2 shows an example in which when a failure occurs during force control, the workpiece is drawn out by executing force control instructions that causes reverse operation. Such retry operation can improve the percentage of success.

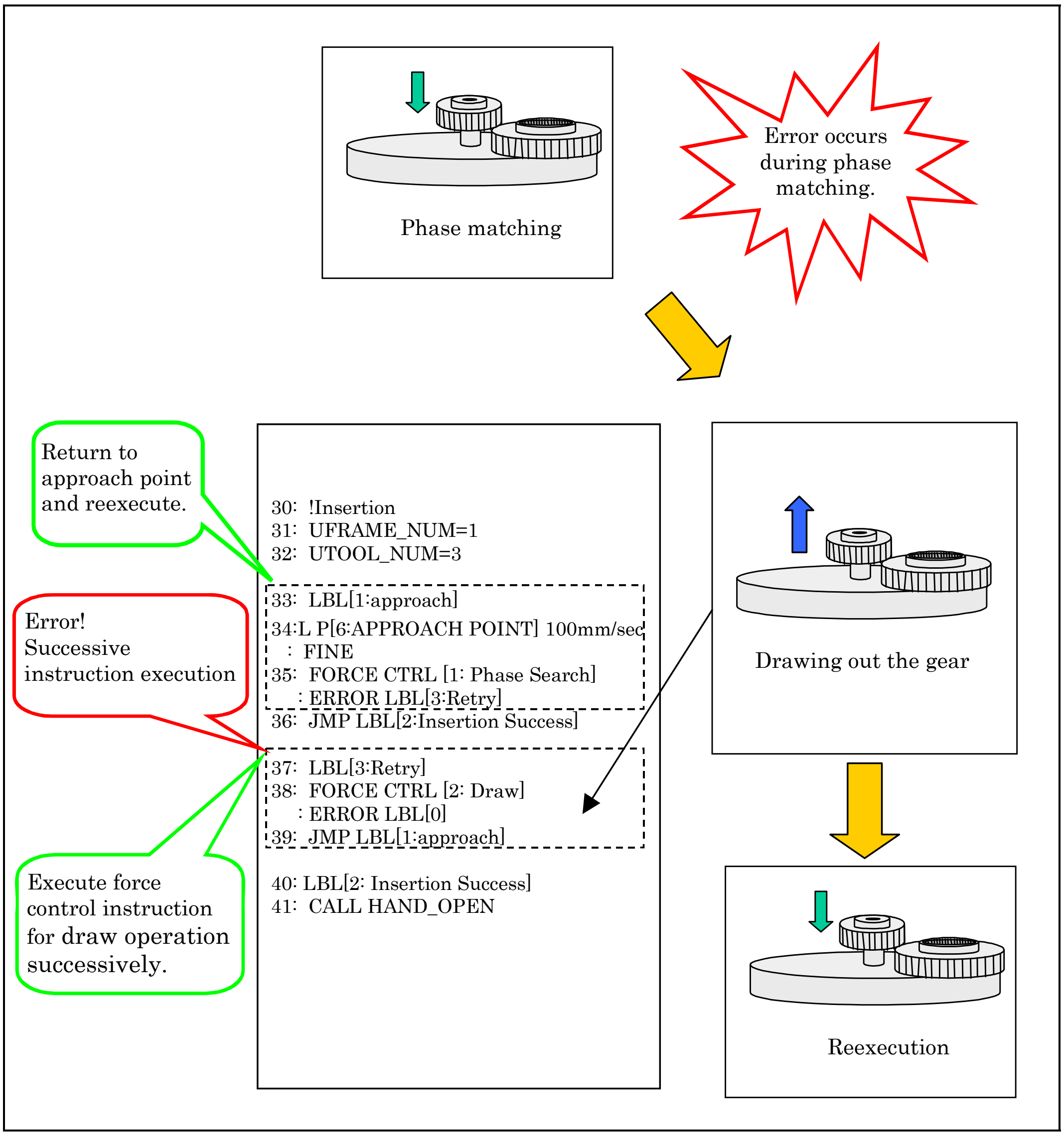



**Fig. 3.7.2 Retry**

## 3.7.3 Simple Customization Function

If this function is valid for a force schedule, it can be executed after any other force schedule. In the following subsections, how to use this function for a combination of Force Control Operations (refer to Subsection 3.7.1) or for a Retry (refer to Subsection 3.7.2) are explained. Only "Shaft Insert", "Groove Insert", "Square Insert" can be used for a Retry.

### 3.7.3.1 Combination of force control operations by simple customization function

Take a sample program in Fig 3.7.3.1(a) as an example. Three Force control instructions ("Shaft Insert"→ "Phase Search"→"Shaft Insert") are executed successively.

For a first force control instruction (Shaft Insert , schedule 1), "Simple Customization" is invalid.
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.

```
            :              :
 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.3.7.3.1(a) Example TP Program for "Simple Customize" function: Three schedule data are executed.**

```
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
```

```
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
```

```
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. 3.7.3.1(b) Example Schedule Data for "Simple Customize" function**

# Performance data setting screen

## 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.

NOTE: If it is executed with this switch OFF after other schedule, the actual force may be bigger than command force designated as "Push Force" or "Insert Force".

"Default : OFF"

### Retry Sw (it exists only for "Shaft Insert", "Groove Insert", "Square Insert")

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.3.7.3.1(a), 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"

## 3.7.3.2 Retry by simple customization function

Take a sample program for retry in Fig 3.7.3.2(a) as an example. Three Force control instructions ("Shaft Insert" → "Phase Search" → "Shaft Insert") are executed successively and one force control instruction(schedule 4) withdraws a workpiece if any one of the three force control instructions failed. "Shaft Insert", "Groove Insertv, "Square Insert" can be used as a retry schedule.
Set parameters of schedule 4 as follows.

```
          :                 :
 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. 3.7.3.2(a) Example TP Program of Retry by "Simple Customize" function**

```
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. 3.7.3.2(b) Example Schedule Data for Retry by "Simple Customize" function**

# Basic data setting screen

## 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" (refer to Subsection 3.7.4) or "customization automatic continuous execution function" (refer to Subsection 3.7.5) 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.

## 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" (refer to Subsection 3.7.4) or "customization automatic continuous execution function" (refer to Subsection 3.7.5) 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.

## 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" (refer to Subsection 3.7.4) or "customization automatic continuous execution function" (refer to Subsection 3.7.5) 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.

# Performance data setting screen

## Simple Customize Sw

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.
NOTE: If it is executed with this switch OFF after other schedule, retry is prone to fail.
"Default : OFF"

## Retry Sw (it exists only for “Shaft Insert”, “Groove Insert”, “Square Insert”)

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.

If it is "ReturnPos1",
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(refer to Subsection 3.7.4), the robot withdraws a workpiece to a starting point of previous schedule.
- If a previously executed force schedule has a Parent Schedule(refer to Subsection 3.7.4), the robot withdraws a workpiece to a starting point of previous schedule’s greatest parent schedule. Take an example in Fig.3.7.3.2(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.
- If "Customize Auto. Cnt. Exec. Sw" of a previous force schedule is ON(refer to Subsection 3.7.5), the robot withdraws a workpiece to a starting point of it.

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(refer to Subsection 3.7.4), the robot withdraws a workpiece to a starting point of previous schedule.
- If a previously executed force schedule has a Parent Schedule(refer to Subsection 3.7.4), 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.3.7.3.2(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)
- If "Customize Auto. Cnt. Exec. Sw" of a previous force schedule is ON(refer to Subsection 3.7.5), the robot withdraws a workpiece to a starting point of it.

"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.3.7.3.2(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"

> **NOTE**
> 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.

## 3.7.4 Customization Function

By setting parent-child relationship among several force schedules, it is possible to realize combined motion (refer to Subsection 3.7.1) and a retry motion (refer to Subsection 3.7.2). This function is similar to Simple Customization function(refer to Subsection 3.7.3) but it defines the order of execution of schedules. It also enables to automatically copy the force control gains between parent and child schedule.

### 3.7.4.1 Specifying the parent-child relationship

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.
Take a program in which three force control instructions are successively executed as an example.(fig. 3.7.3(a)) 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.
Since schedule data 1 has no parent, its parent number is set to 0 as in the case of executing just a single instruction.(Fig. 3.7.3(b)) For schedule data 2, "Customize Parent Number" is set to 1 as shown in Fig. 3.7.3(c) because schedule data 1 is specified as the parent. Similarly, for schedule data 3, "Customize Parent Number" is set to 2 because schedule data 2 is specified as the parent. (Fig. 3.7.3(d))

```
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. 3.7.4.1(a) Example TP Program for "Simple Customize" function: Three schedule data are executed.**

```
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
```

```
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
```

```
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. 3.7.4.1(b) Example Schedule Data for "Customize" function**

## Performance data setting screen

### 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 Connection

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:

(1) P2C: Parameter data is copied from the parent to child schedule data.
(2) C2P: Parameter data is copied from the child to parent schedule data.
(3) BothD: When modification to the parent or child schedule data is made, parameter data is copied to the other.
(4) OFF: Even when impedance parameters are modified, copy is not taken.

"Default: OFF"

### 3.7.4.2 Combination of force control operations by customization function

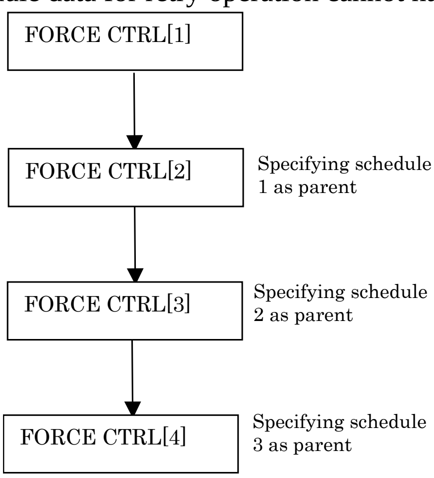
Whenever force control instructions are executed successively, the parent-child relationship must always be specified as described in Subsection 3.7.4.1. Note that if multiple force control instructions are successively executed without specifying the parent-child relationship, the actual pushing force may become greater than the set value when a second or subsequent force control instruction is executed.

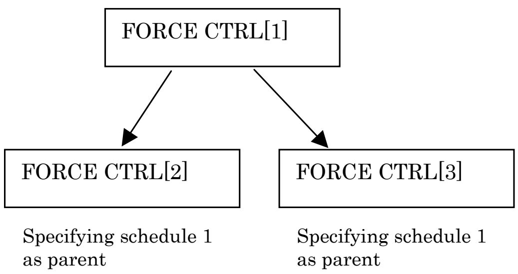
### 3.7.4.3 Retry by customization function

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.

### 3.7.4.4 Notes and restrictions

(1) 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.
(2) 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. 3.7.4.4(a) Example for successive execution of force control instructions(1/2)**

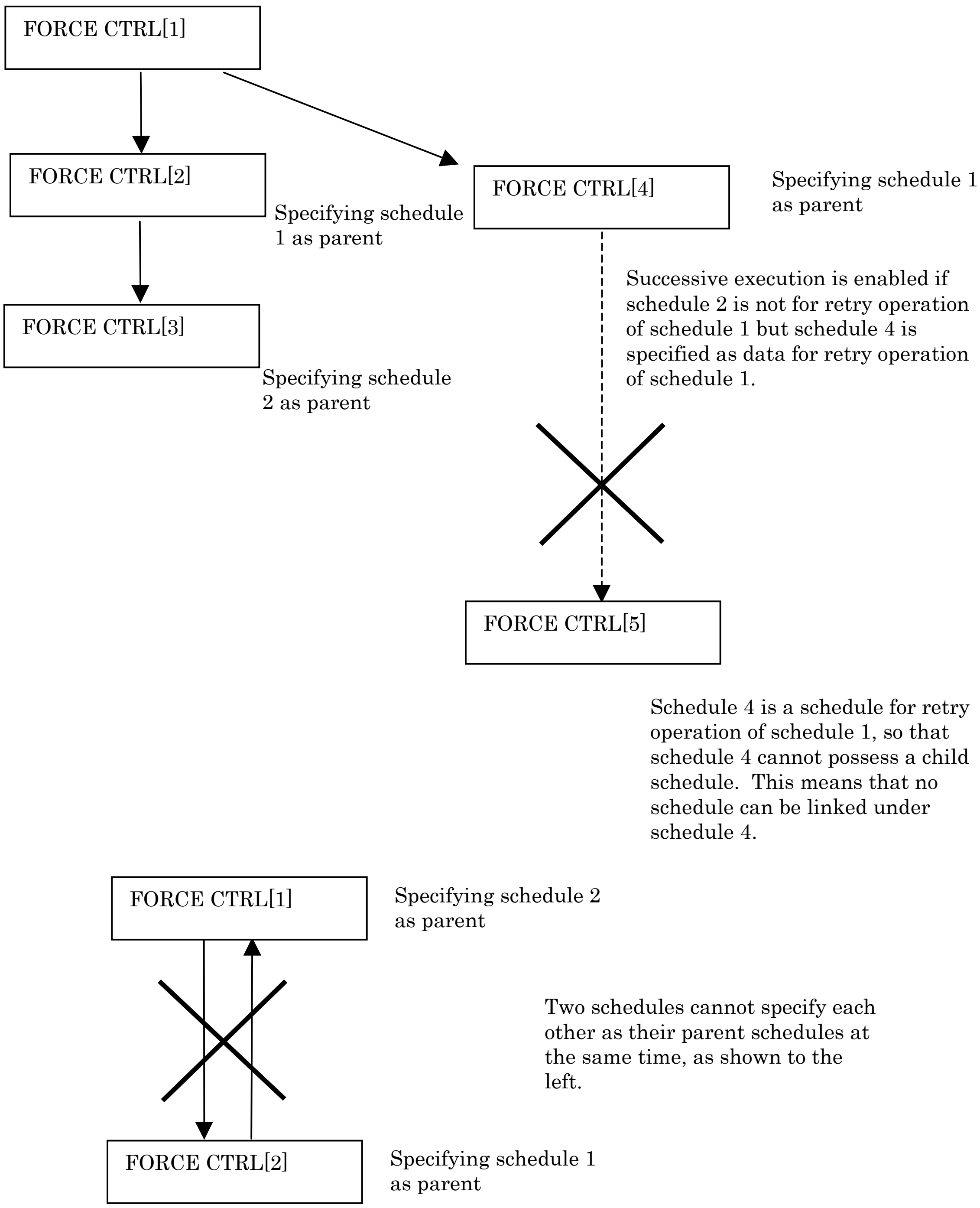


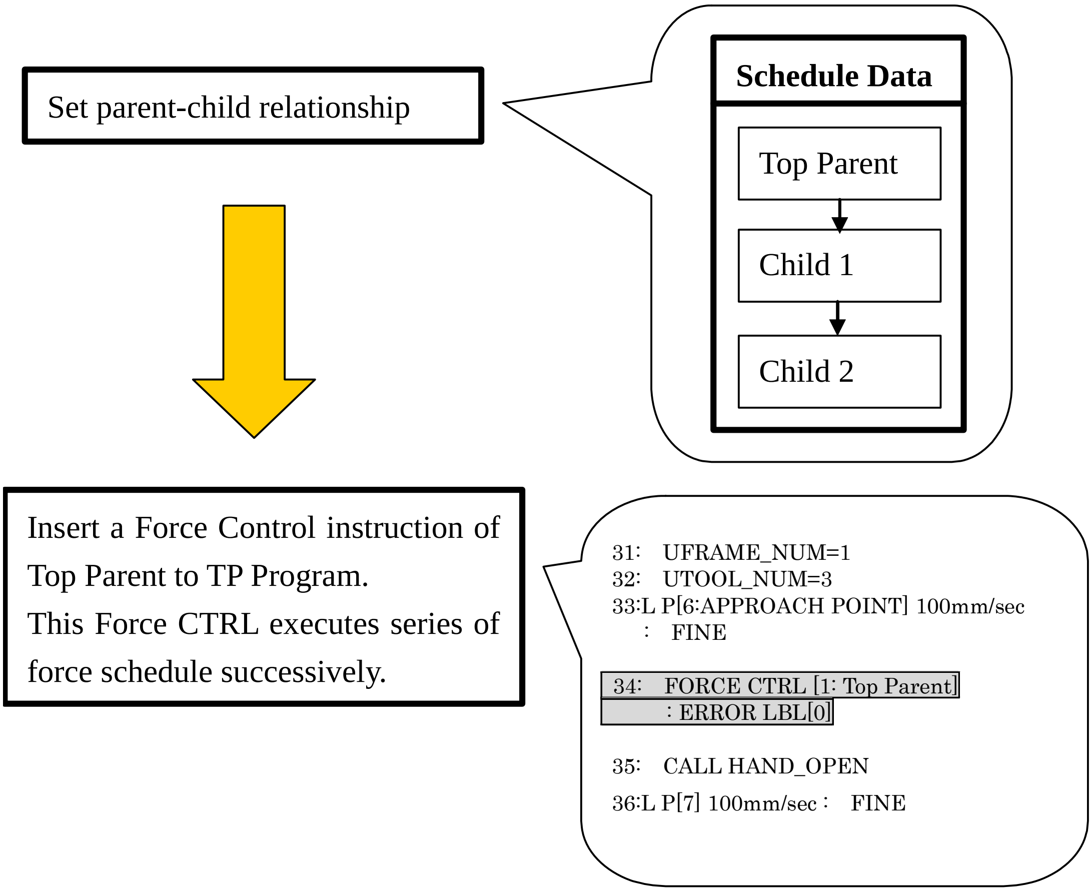

**Fig. 3.7.4.4(b) Example for successive execution of force control instructions(2/2)**

## 3.7.5 Customization Automatic Continuous Execution Function

"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.
"Customize Auto. Cnt. Exec." can omit wasted time at the start and end of "series of force control instructions".

"Customize Auto. Cnt. Exec." is simple to use. To execute "Customize Auto. Cnt. Exec.", only to insert one "FORCE CTRL" command in TPP as following and set schedule data. The parameters of the schedule data are the switch and parent-child relationship. Additionally you can know the failed schedule data number of the series by setting the Register No. to output the number.




"Customize Auto. Cnt. Exec." function has the following feature:

- The difference between "Customization Function"(Subsection 3.7.4) and "Customize Auto. Cnt. Exec."

  "Customization Function":

  Insert all force control instructions of the schedule data that are combined with the parent-child relationship into TP Program.

  It takes some time (about 0.3sec) to switch a parent force control to the child force control when executing the force control instructions successively.

  "Customize Auto. Cnt. Exec." function:

  Insert a single force control instruction of the top parent schedule data into TP Program.

  "Customize Auto. Cnt. Exec." function can automatically search the child from a parent and execute the series of the force control that are set in the schedule data and are combined with the parent-child relationship.

  It does not take the time to switch a parent force control to the child force control when executing the force control with the parent-child relationship.

- "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.

Set the parameters of "Customize Auto. Cnt. Exec." function as follows：

- Customization Function links the schedule data by setting the parent with "Customize Parent Number".
  "Customize Auto. Cnt. Exec." function links the schedule data by setting the parent and the child. "Customize Parent Number" designates the parent schedule data number. "Auto. Cnt. Exec. Child No." designates the child schedule data number. If a schedule data does not have a child, set "Auto. Cnt. Exec. Child No." to 0.
  Set "Customize Parent Number" of the child, designated by "Auto. Cnt. Exec. Child No." of its parent, to the schedule data number of the parent. In other words, there must be no contradiction with "Auto. Cnt. Exec. Child No." of the parent and "Customize Parent Number" of its child.
- 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 "Customize Auto. Cnt. Exec. Sw" to ON for all schedule data that are combined with "Customize Auto. Cnt. Exec." function.
- "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.
- 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.
- In the series of the schedule data, following parameters related to the setting of the coordinate must be same:
  - "User Frame No. "
  - "Tool Frame No."
  - "User Frame Compensation"
- 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.".
- 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"
- In the series of the schedule data, the parameters that the value of top parent is used and the value of other child that leads from the top parent is not used (the setting is not concerned) are the following:
  - "Schedule No. Output Reg. No." of "Customize Auto. Cnt. Exec. " function
  - "Gravity Compensation Switch"
  - "Force Denoising Sw"
  - "Signal Output for ERR SW"
  - "Frc.Ctrl. End by REG SW", "End Register Number"
- Relating to the above, in the series of the schedule data, as to the following parameters, the values of each schedule data are used:
  - Data of "Torque Error Compensate"
  - Data of "Ending Condition"
  - "Contact F Threshold"
  - Setting of "Force End Judgment" and "Torque End Judgment"
- In the series of the schedule data, the setting of the pushing direction such as "Insert Direction" or "Pushing Direction" can be different.
- If "Customize Auto. Cnt. Exec. Sw" is valid, the schedule data that is regarded as the schedule data for retry operation for Customization Function is not regarded as the schedule data for retry operation. This intends to all the schedule data for "Customize Auto. Cnt. Exec" function can have a child.
- 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)

- 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.
- "Change MAX Limit" for "Check Orientation Change" checks the orientation change from the orientation at the start of its schedule data.
- Search range of search function is based on the position at the start of its schedule data.
- 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.

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.(fig. 3.7.5(a))
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.
Set "Customize Auto. Cnt. Exec. Sw" of schedule data 1, schedule data 2, schedule data3 to "ON" to execute "Customize Auto. Cnt. Exec." function as shown in fig. 3.7.5(b). Then set "Customize Parent Number" and "Auto. Cnt. Exec. Child No. " of each schedule data. In this case schedule data 1 is the top parent schedule data.
For schedule data 1:

Since schedule data 1 has no parent, its "Customize Parent Number" is set to 0 as in the case of executing just a single instruction as shown in Fig. 3.7.5(b).
To set schedule data 2 to the child of schedule data 1, "Auto. Cnt. Exec. Child No. " is set to 2 as shown in Fig. 3.7.5(b).

For schedule data 2:

To set schedule data 1 to the parent of schedule data 2, "Customize Parent Number" is set to 1 as shown in Fig. 3.7.5(b).
To set schedule data 3 to the child of schedule data 3, "Auto. Cnt. Exec. Child No. " is set to 3 as shown in Fig. 3.7.5(b).

For schedule data 3:

To set schedule data 2 to the parent of schedule data 3, "Customize Parent Number" is set to 2 as shown in Fig. 3.7.5(b).
Since schedule data 3 has no child, "Auto. Cnt. Exec. Child No. " is set to 0 as shown in Fig. 3.7.5(b).

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.

```
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. 3.7.5(a) Example TP Program for "Customize Auto. Cnt. Exec." function: Three schedule data are automatically and successively executed with a single force control instruction**

```
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
 7   Customize ParaChg Conct:OFF
 8 Customize Auto. Cnt. Exec. Sw : ON
 9   Auto. Cnt. Exec. Child No.  :   2
10   Schedule No. Output Reg. No.:   5
```

```
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
 6   Customize ParaChg Conct:OFF
 7 Customize Auto. Cnt. Exec. Sw : ON
 8   Auto. Cnt. Exec. Child No.  :   3
 9   Schedule No. Output Reg. No.:   0
```

```
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
 7   Customize ParaChg Conct:OFF
 8 Customize Auto. Cnt. Exec. Sw : ON
 9   Auto. Cnt. Exec. Child No.  :   0
10   Schedule No. Output Reg. No.:   0
```

**Fig. 3.7.5(b) Example Schedule Data for "Customize Auto. Cnt. Exec." function**

# 3.8 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 iRVision. For example, it facilitates the precise fitting by offsetting the moving direction based on the results of iRVision.

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.".

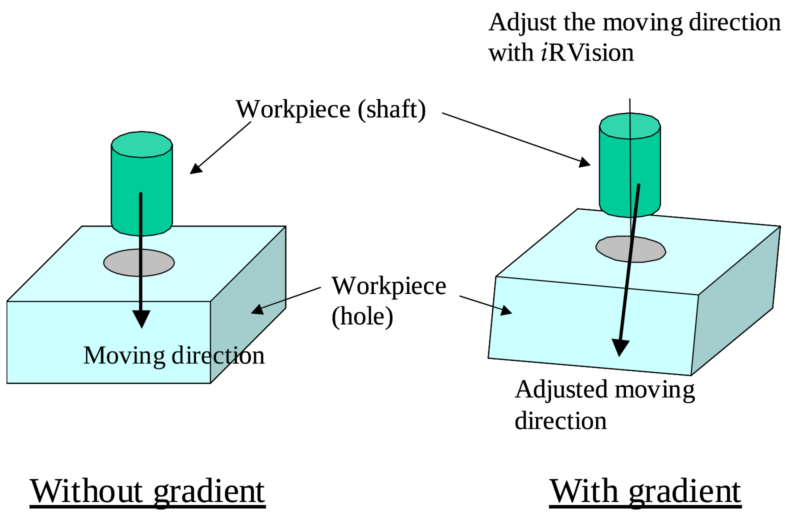



**Fig.3.8(a) Adjustment of moving direction by user frame compensation**

## How to use

There are two methods; One method (1) uses OFFSET CONDITION instruction and another method (2) uses VOFFSET CONDITION instruction. In addition, there is method (3) for [Constant Push]. The method (3) compensates based on a tool coordinate system.

The method 1 adjusts the moving direction with designated Position Register. The method 2 adjusts the moving direction with designated Vision Register. Refer to "*i*RVision OPERATOR'S MANUAL (Reference) (B-83304EN)" etc, for how to set offset value to Position Register or Vision Register with a vision system.

The method (3) (In the case of [Constant Push]) compensates the position of the user coordinate system internally 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". If "User Frame Compensation" is set to "TOOL FRAME", "Tool" is displayed at the "Pushing Direction". If "User Frame Compensation" is set to other than "TOOL FRAME", "User" is displayed at the "Pushing Direction".

### method1 use OFFSET CONDITION INSTRUCTION

1-1 Designate the Position Register number which OFFSET CONDITION instruction uses. The Fig.3.8(b) shows a sample TP program.

1-2 Copy the offset values that are detected by *i*RVision to the Position Register. Refer to "*i*RVision OPERATOR'S MANUAL (Reference) (B-83304EN)" etc, for detailed information.

1-3 Set [POS REG] to [User Frame Compensation SW] in Performance screen of force control schedule. (Fig.3.8(c))

```
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

**Fig.3.8(b) Sample TP program which uses OFFSET CONDITION instruction**

```
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
```

**Fig.3.8(c) User Frame Compensation SW (select POS REG)**

## method 2 use VOFFSET CONDITION INSTRUCTION

2-1 Designate the Vision Register number which VOFFSET CONDITION instruction uses. The Fig.3.8(d) shows a sample TP program.

2-2 Copy the offset values that are detected by *i*RVision to the Vision Register. Refer to “*i*RVision OPERATOR’S MANUAL (Reference)(B-83304EN)” etc, for detailed information.

2-3 Set [VISION REG] to [User Frame Compensation SW] in Performance screen of force control schedule. (Fig.3.8(e))

```
TEST
                                        1/4
  1: UFRAME_NUM=1
  2: VOFFSET CONDITION VR[1]
  3: L[1:approach point] 100mm/sec
   :   FINE VOFFSET
  4:   FORCE CTRL[1]
   :   ERROR LBL[0]
 [END]
```

Use VR[1] for offset compensation

Force Control instruction

**Fig.3.8(d) Sample TP program which uses VOFFSET CONDITION instruction**

```
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
```

**Fig.3.8(e) Vision Compensation SW (select VISION REG)**

> ⚠ **CAUTION**
> 1 The *i*RVision option is necessary in order to use VOFFSET CONDITION instruction.
> 2 Enable Vision Offset Command (VOFFSET). Press MENUS button on the teach pendant and select “SETUP” --> F1 “General”. Move the cursor to “Enable VOFFSET” and select F4 “ENABLED”.
> 3 Set Vision Register’s type as [Fixed Frame Offset].

### method 3 use Tool Coordinate System (In the case of [Constant Push])

3-1 Set [User Frame Compensation SW] to [TOOL FRAME] in Performance screen of force control schedule. (Fig.3.8(f))

```
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 %
```

**Fig.3.8(f) User Frame Compensation (select TOOL FRAME)**

# 3.9 3-AXIS FORCE SENSOR SETTING

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.
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 subsection 3.5.2, "Constant Push / Face Match" for “Contant Push” and in subsection 3.5.7.6, "Parameter" for “Contour”. Conceptual diagrams for them are given in this section for better understanding.

Refer to Fig.3.9(a) and Fig.3.9(b) first.
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.3.9(c), Fig.3.9(e), Fig.3.9(f) and Fig.3.9(g). In case of “Contant Push”, Fig.3.9(g) is unrelated.
If the contact point is fixed to a floor, refer to Fig.3.9(d), Fig.3.9(h) and Fig.3.9(i).

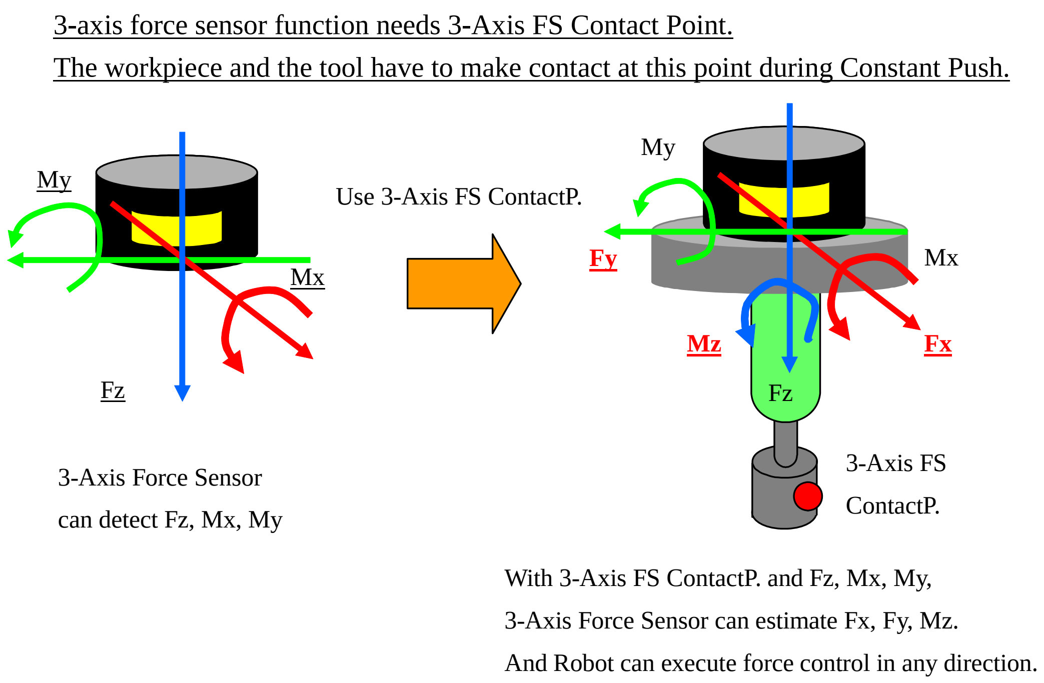
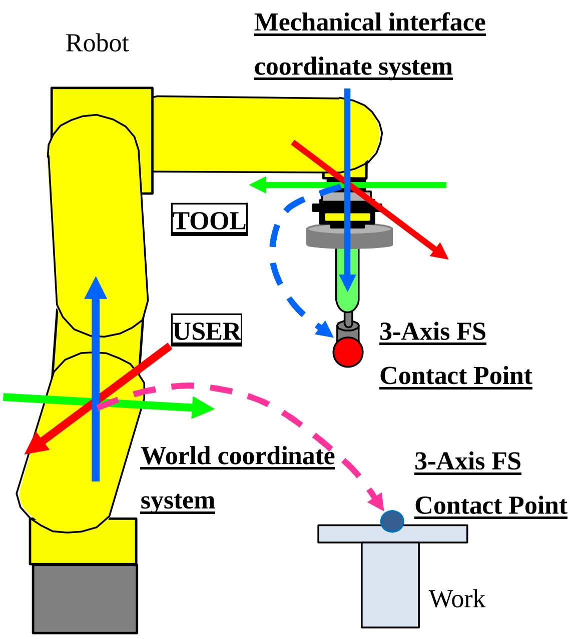



**Fig.3.9(a) 3-Axis FS ContactP. Position**

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" :

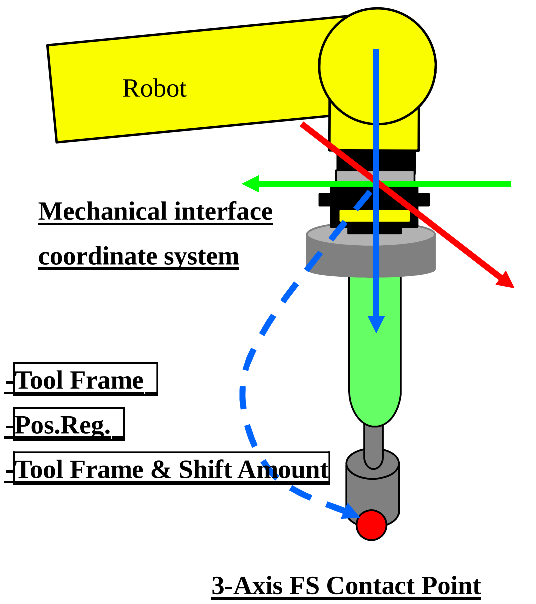
The position of the 3-Axis FS Contact Point is given on the world coordinate system.

If the contact point is fixed on the world coordinate system (floor), select it.

**Fig.3.9(b) Setting of "3-Axis FS ContactP. Position"**

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.

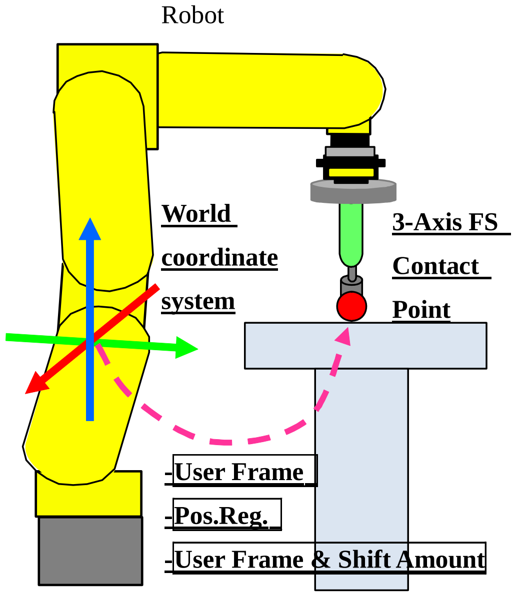
"Setting Method" is "Push Dir Shift"

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.3.9(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.3.9(d) If "3-Axis FS ContactP. Position" is USER**

| 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.

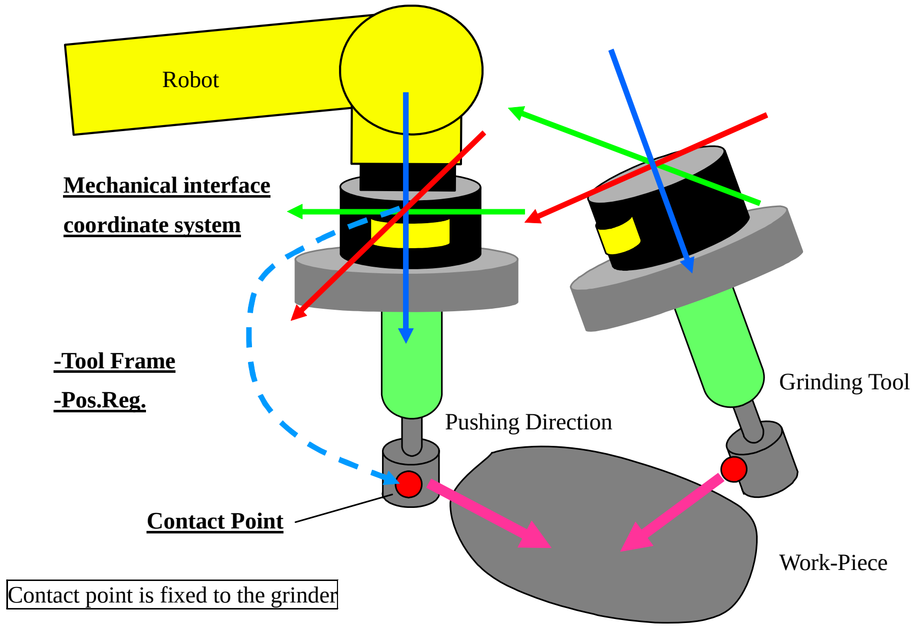



**Fig.3.9(e) Example 1 of setting TOOL to "3-Axis FS ContactP. Position"**

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.

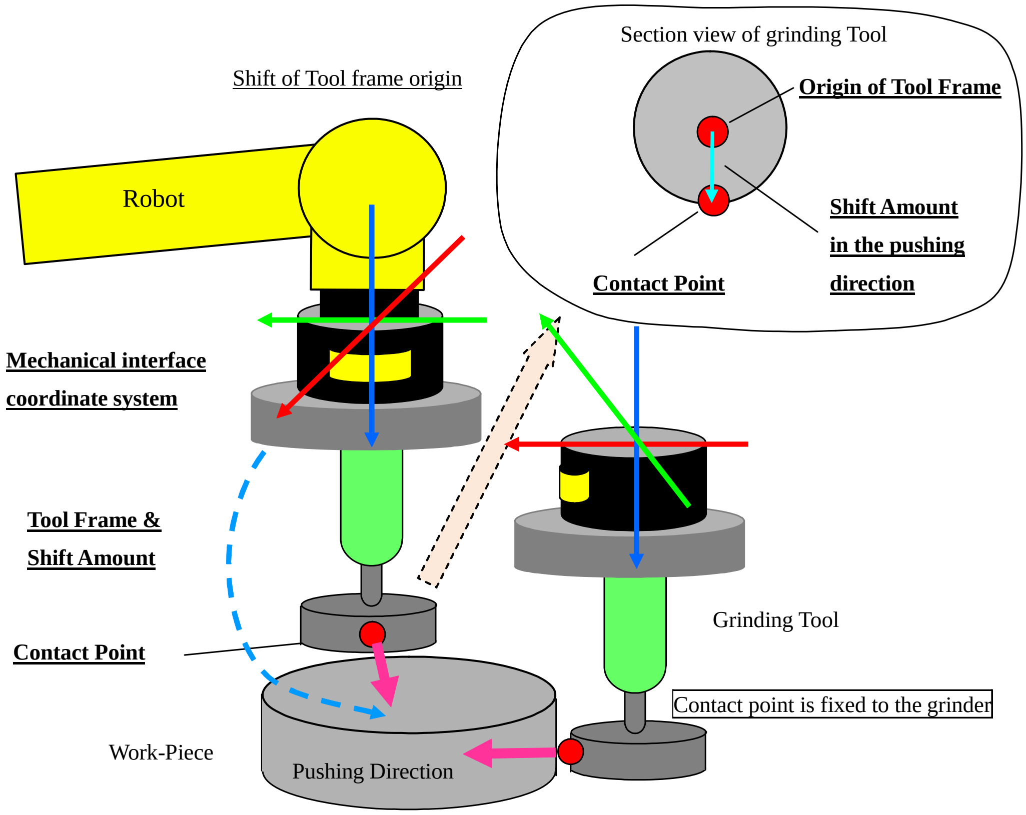



**Fig.3.9(f) Example 2 of setting TOOL to "3-Axis FS ContactP. Position"**

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.

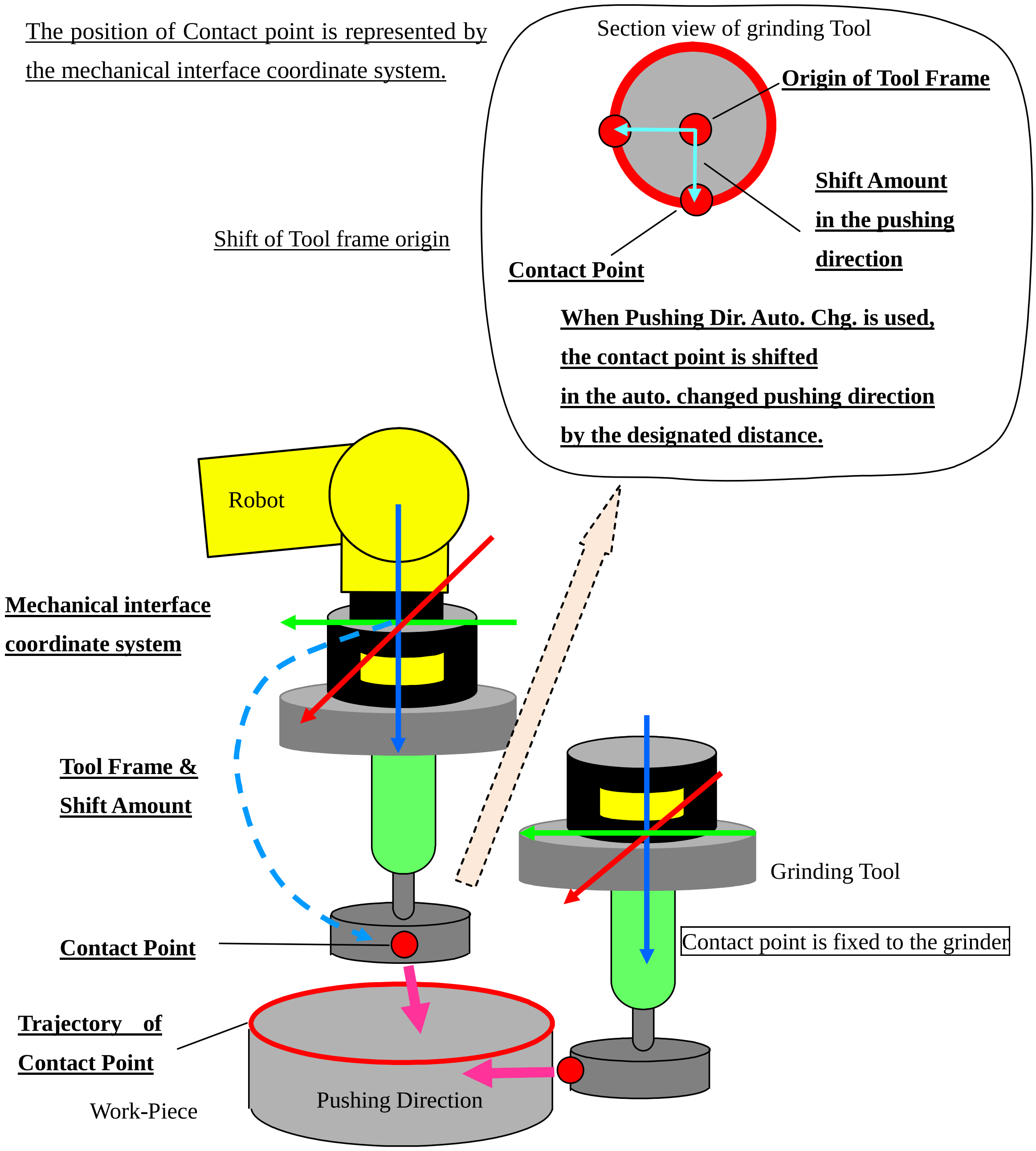



**Fig.3.9(g) Example 3 of setting TOOL to "3-Axis FS ContactP. Position"**

Example 1 of setting USER to "3-Axis FS ContactP. Position" “Setting Method” is “Frame”

The position of Contact point is represented by the world coordinate system.

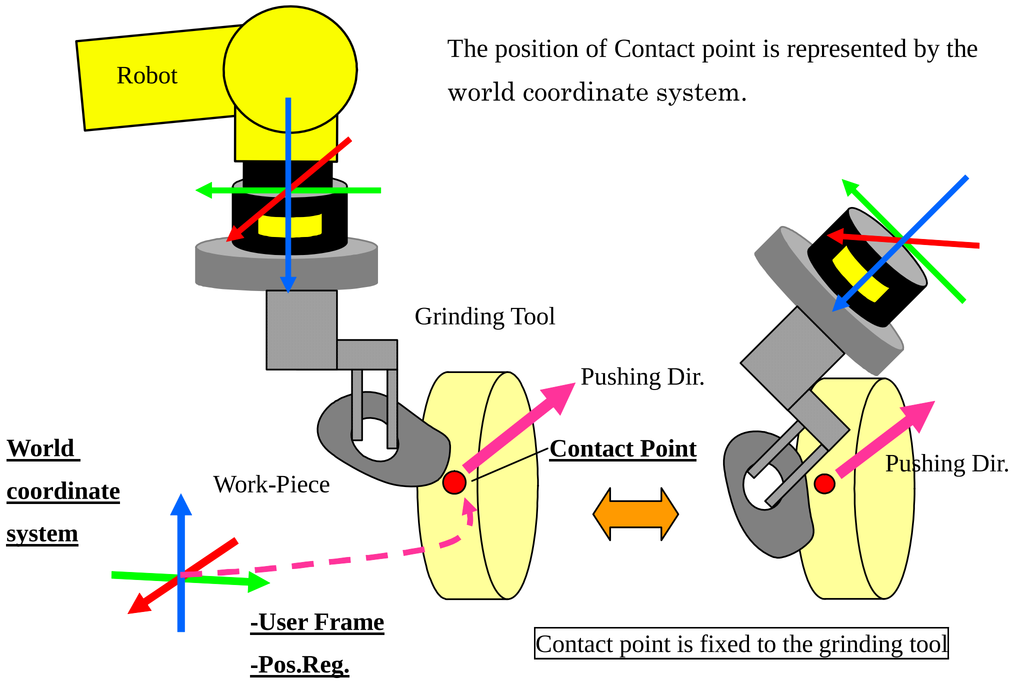



**Fig.3.9(h) Example 1 of setting USER to "3-Axis FS ContactP. Position"**

Example 2 of setting UJSER to "3-Axis FS ContactP. Position" “Setting Method” is “Push.

The position of Contact point is represented by the world coordinate system.

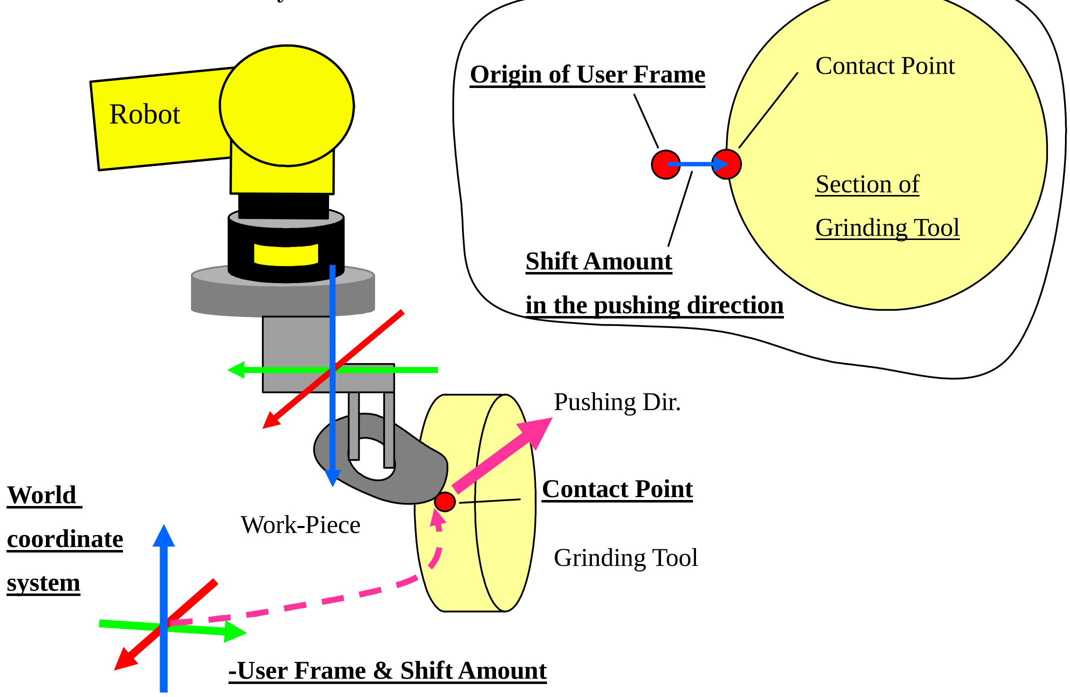



**Fig.3.9(i) Example 2 of setting USER to "3-Axis FS ContactP. Position"**

# 3.10 OTHER INSTRUCTIONS RELATED TO FORCE CONTROL

Fig. 3.10(a) and Fig. 3.10(b) show how to select an instruction related to force control.

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

**Fig.3.10(a) Selection of instruction related to force control**

Select “3 Force Control”. The following options are displayed:

```
     Instruction              Instruction
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--
```

**Fig.3.10(b) Options of instruction related to force control**

Select the required instruction from nine options. Fig. 3.10(c) shows an example when 「AUTO TUNING ON」 is selected on the screen shown in Fig. 3.10(b).

```
TEST
                                   1/2
   1:  AUTO TUNING ON

[End]



                      [CHOISE]
```

**Fig.3.10(c) Teaching of instruction related to force control**

For details of the individual options, see the corresponding subsections:

| | | |
|---|---|---|
| SENSOR DIAGNOSIS<br>GET DIAG DATA | ==> | Subsection 3.10.1, "Force Sensor Diagnosis Instructions" |
| AUTO TUNING ON<br>AUTO TUNING OFF | ==> | Subsection 3.10.2, "Force Control Gain Auto Tuning Instruction" |
| TORQUE ERROR ON<br>TORQUE ERROR OFF | ==> | Subsection 3.10.3, "Torque Error Acquisition Instruction" |
| END CONDITION ON<br>END CONDITION OFF | ==> | Subsection 3.10.4, "End Condition Acquisition Instruction" |

## 3.10.1 Force Sensor Diagnosis Instructions

### Overview

Force sensor diagnosis instructions are used to verify if a force sensor is damaged (e.g. after a collision or prolonged use). There are two instructions available. 1. SENSOR DIAGNOSIS and 2.GET DIAG DATA, See Fig.3.10.1.1 for application details .
For 3-Axis Force sensor, it is not necessary to use this instruction as the sensor has a self-dianosis function. If it is executed, the dianosis is not done but force values are recorded and they can be checked in Fig.3.10.1.2.

### Instruction

#### GET DIAG DATA

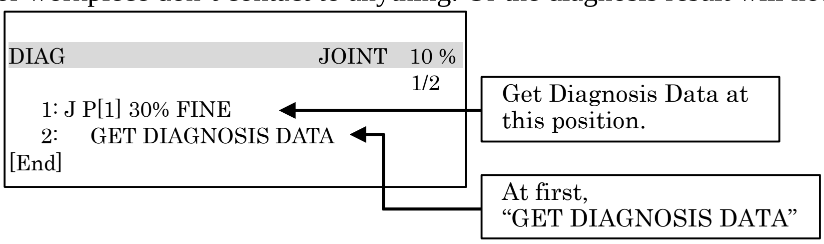
When using force sensor for the first time, it is recommended that the user execute the GET DIAG DATA instruction to acquire sensor data at a taught robot position. This instruction acquires the force sensor data needed for "SENSOR DIAGNOSIS". It must be executed before executing "SENSOR DIAGNOSIS". 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

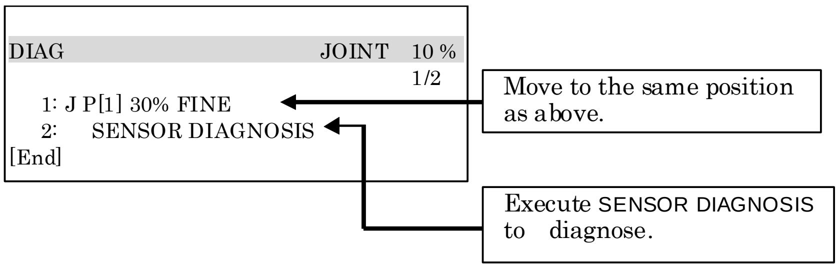
To check the force sensor status after a collision or repeated use, move the robot to the same taught position, and execute "SENSOR DIAGNOSIS" instruction. This instruction compares the force sensor data acquired by executing the "GET DIAG DATA" instruction with the current data to determine if the force 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 dianosis is not done but force values are recorded. The message "FORC-017 Diag. data has been set" is displayed.

### 3.10.1.1 How to execute force sensor diagnosis instructions

Execute the GET DIAG DATA instruction to acquire sensor data at a taught robot position. Be sure that the force sensoer, tool or workpiece don't contact to anything. Or the diagnosis result will not be accurate.




To check force sensor state, execute the following program:




When execution terminates normally, "Diagnosis normal end" is issued.
When execution terminates abnormally, "Force sensor error exceed limit" is issued.

**Fig.3.10.1.1 Specifying force sensor diagnosis instruction**

### 3.10.1.2 Display results of force sensor diagnosis instructions

Force sensor data when the "Force Sensor Diagnosis Instructions" are executed are displayed in "Force Sensor Diagnosis Results" screen. Open this screen from force sensor utilities screen. Refer to Chapter 5 "FORCE SENSOR UTILITIES SCREEN"
To open the menu screen, select the following.

MENU → 「 1 UTILITIES 」→「 Force Sensor 」

→ F3 「6 Force Sensor Diagnosis Results」

```
Force Sensor Diagnosis
                                        1/1
  1 Initial Data
    Fx     56.3 Fy     23.7 Fz    341.1 N
    Mx   14.62         9.24 Mz    13.58 N*m
    Temperature      34.7  C

  2 Diagnostic Data
    Fx     68.2 Fy     35.9 Fz    330.2 N
    Mx   13.08 My      1.06 Mz    17.22 N*m
    Temperature      33.6  C

  3 Number of F Limit alarm :          5

[EXIT]
```

F1 F2 F3 F4 F5

**Fig.3.10.1.2 Force Sensor Diagnosis Results screen**

#### 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.

#### 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.

#### Number of F Limit alarm

The number of "FORC-159 F/S sensor limit overflow" occurred.

## 3.10.2 Force Control Gain Auto Tuning Instruction

### Overview

Force control gain determines the robot’s responsiveness against outside force during force control execution. Robot responsiveness also depends on the workpieces, the posture of robot, and the rigidity of the tool. Force control gain parameters for each work 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 such cases, manual adjustment of the gain is required to optimize the robot performance.

> ⚠ **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 Teach the program. Refer to Steps 1-5 of Section 3.2, “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  DEFAULT PERFORM
```

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.

5 Step 1 to 4 is completed if “FORCE CTRL” instruction ends without any alarms and the program pause on line 6. (Go to Step 6.) 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.)

6 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) Execute the program repeatedly until 「Prev. Result」 of the schedule data is successively 「No Change」.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  DEFAULT PERFORM
```

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」.

7 The operation is completed when smooth insertion is confirmed.

8 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 Section 3.6, “FORCE CONTROL GAIN (Impedance Parameters)”.)
   (2) Execute force control gain auto tuning again. Go back to Step 2.

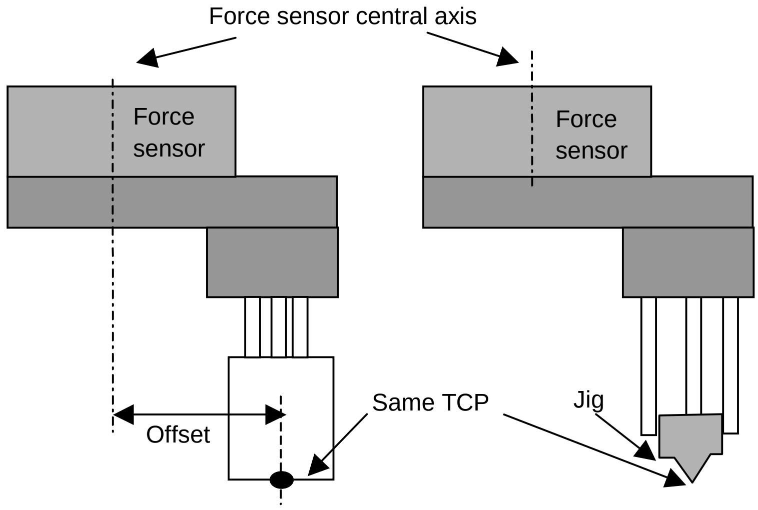
## 3.10.3 Torque Error Acquisition Instruction

### 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.




## Instruction

### TORQUE ERROR ON
### TORQUE ERROR OFF

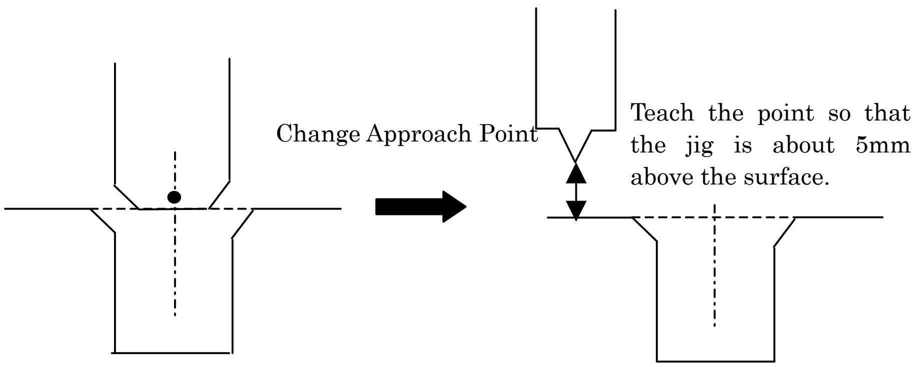
Torque error acquisition is performed for any FORCE CTRL instruction executed between “TORQUE ERROR ON” instruction and “TORQUE ERROR OFF” instruction. An actual procedure is described in the following.

## Torque Error Acquisition Procedure

1 Teach the program. Refer to Section 3.2, “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”.
In case that function is "Shaft Insert", "Groove Insert" , "Phase Match Ins.", "Square Insert", “Search”, “Phase Search", "Hole Search", or "Clutch Search", copy the program to another one, and change approach point which should be close to fitting position. 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.

5 Torque error acquisition is completed if “FORCE CTRL” instruction ends without any alarms and the program completes. (Go to Step 6.) 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.)

6 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.

## Procedure for using the acquired torque error data

1 The torque error data acquired by the above procedure can be confirmed on the schedule data performance screen. For details of this screen, see Section 3.5, "SCHEDULE DATA".

The torque values are displayed in "Torque Error Data W, P, and R". W, P, and R indicate the moments about the X-axis, Y-axis, and Z-axis of the user frame (UF), respectively.

2 Set "Torque Error Compensate SW" on the performance screen to "ON". Torque error compensation is performed by "Torque Error Data W", "Torque Error Data P", "Torque Error Data R", and "Torque Error Fd".

# 3.10.4 End Condition Acquisition Instruction

## Overview

End condition is criterion for judging whether operation by force control function is complete. It should be usually set in the schedule data screen. (Refer to Section 3.5, “Schedule Data”.) If a specified end condition is not same as an actual end condition, the data during the execution of force control function is acquired and set. End condition acquisition is performed for any “FORCE CTRL” statement executed between “END CONDITION ON” instruction and “END CONDITION OFF” instruction. Specifically, the function acquires and sets the values of “Insert Depth”, “Approach Length” and “Insert DIR” of the performance data, which is described later.

## 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 Teach the program. Refer to Section 3.2, “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]
     :  ErrorLBL[0]
   5:   END CONDITION OFF
 [End]
```

Add these instructions

3 Execute the program created in Steps 1-2.
4 End condition acquisition is completed if the “FORCE CTRL” instruction ends normally and the program complete. (Go to Step 5.) 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.)
5 Delete the instructions added at Step 2 from the program .

```
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. The end conditions acquired using the above procedure can be confirmed on the schedule data performance screen. For details of this screen, see Section 3.5, "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.

2. Set the "Ending Condition Switch" on the performance 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".

# 4 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**



## 4.1 FORCE SENSOR CURRENT VALUE SCREEN

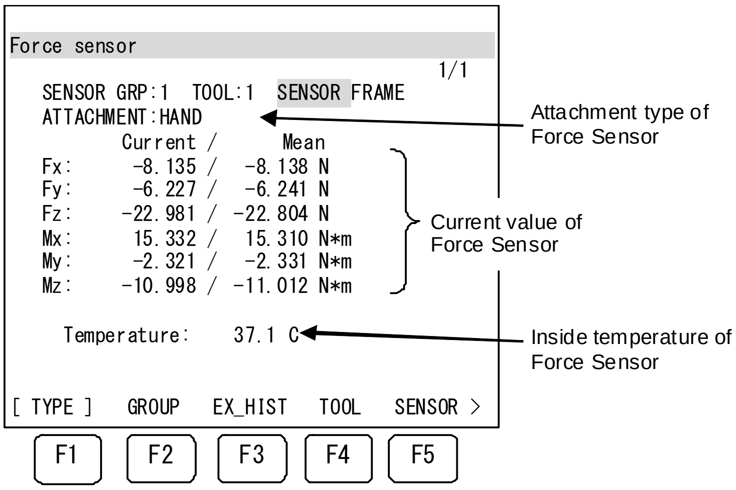



**Fig.4.1(a) Force sensor current value screen**

Making the following selection displays the Force sensor current value screen, as is shown in Fig.4.1(a).

MENU → " 0 -- NEXT -- " → " 4 STATUS "

→ F1 [ TYPE ] → " Force Sensor "

On this screen, the attatchment type, current values and inside temperature of the force sensor can be checked.

The Current value screens of the Hand mount force sensor and Fixed mount force sensor are shown in Fig.4.1(a) and Fig.4.1(b) respectively.
The unit of Fx, Fy, Fz is N and the unit of Mx, My, Mz is N*m.

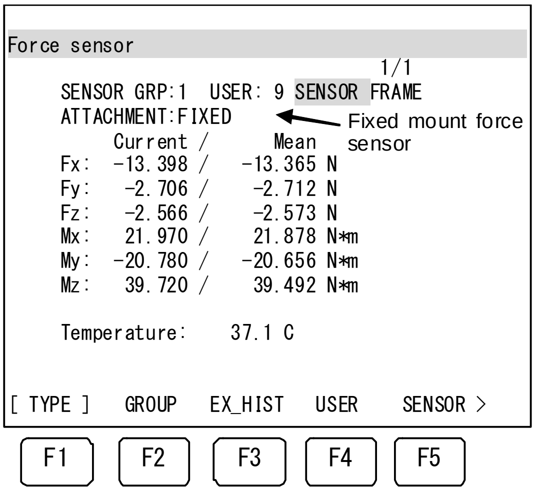



**Fig.4.1(b) Current value screen of fixed force sensor**

## Function Key

On the Current value screen of Hand mount force sensor, the function keys have the following functions.

| Key | Label | Description |
|---|---|---|
| F1 | TYPE | Switches the Force sensor status screen to other status screen |
| F2 | GROUP | Switches force sensor groups |
| F3 | EX_HIST | Displays execution histories of the force control instructions. Refer to Section 4.2 for further details. |
| F4 | TOOL | Displays the output of the force sensor on the basis of the currently selected tool coordinate system. |
| F5 | SENSOR | Displays the force values in the sensor frame. |
| [Next]+F1 | CLEAR | All force values become zero. |

For the Fixed mount Force Sensor, the function keys F1, F2, F3, F5 have the same functions as those of the Hand mount Force Sensor, while the function key F4 has different meaning from that of the Hand Force Sensor.

| Key | Label | Description |
|---|---|---|
| F4 | USER | Displays the force value in the current user frame. |

# 4.2 EXECUTION HISTORIES OF FORCE CONTROL INSTRUCTIONS

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 Subsection 4.2.1 for further details.
- Execution histories of force control instructions with alarms
  →Refer to Subsection 4.2.2 for further details.

# 4.2.1 All Execution Histories

## 4.2.1.1 List screen of all execution histories

Press F3 “EX_HIST” on the Force sensor current value screen (Fig.4.1(a) or Fig.4.1(b)), to display the list of all execution histories (Fig.4.2.1.1).
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.).

```
Force Ctrl Ex-hist
  list (all        )                   1/20
No. Program name     Sch.    Time
  1 SAMPLE3          [   3]  5-22 15:30:23
  2 SAMPLE1          [   1]  5-22 15:11:11
  3 A0000            [   2]  5-22 14:32:34
  4 A0000            [   5]  5-21 12:10:45
  5                  [   0]
  6                  [   0]
  7                  [   0]
  8                  [   0]
  9                  [   0]
 10                  [   0]

[ TYPE ]  DETAIL  ALARM  CUR_VAL
   F1       F2      F3     F4      F5
```

**Fig.4.2.1.1 List screen of all execution histories**

### Function Key

The function keys on this screen have the following functions.

| Key | Label | Description |
|---|---|---|
| F1 | TYPE | Switches the Force sensor status screen to other status screen |
| F3 | DETAIL | Displays the detail information of the selected execution history. Refer to Subsection 4.2.1.2 for further details |
| F4 | ALARM | Only displays the execution histories with alarms. Refer Subsection 4.2.2 for further details. |
| F5 | CUR_VAL | Switches to the Force sensor current value Screen. Refer to Section 4.1 for further details. |

## 4.2.1.2 Detail screen of all execution histories

Select a line in the screen (Fig.4.2.1.2) and then pressing F3 “Detail” to display the details of the selected execution history (Fig.4.2.1.2).

```
Force Ctrl Ex-hist
                                         1/15
  hist[  1] (all      )
  1 Time              2010- 5-12   9:25:58
  2 Program name      SAMPLE3
  3 Schedule          [  3]
  4 Function          Phase Search
  5 Alarm Number
    1:    0 2:    0 3:    0 4:    0 5:    0
  6 Arrival depth   5.004  mm
  7 Working time    5.300  sec
  8 Orient change   .005  deg
    End force   (dir.  N   / around  N m)
  9           X (    0.080/     0.3000)
 10           Y (    0.020/     0.5000)
 11           Z (    0.100/     0.0200)
    Generated force Min. /Max.
 12 X direction [N]     -1.080/    0.425
 13 Y direction [N]     -0.006/    0.140
 14 Z direction [N]     -0.256/    0.117
 15 around X [N m]    -0.006/    0.352
 16 around Y [N m]     0.100/    0.709
 17 around Z [N m]    -0.519/    0.100

[TYPE]          NUMBER          CUR_VAL
```

F1 F2 F3 F4 F5

**Fig.4.2.1.2 Detail screen of execution history**

The items in the detail screen of the execution history (Fig.4.2.1.2) are listed in Table 4.2.1.2.

**Table 4.2.1.2 Items in 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 Number | The number of occurred alarm. (This item displays the previous five records.) |
| 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: second) |
| 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. |
| 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. |

## Function Key

The function keys on this screen have the following functions.

| Key | Label | Description |
|---|---|---|
| F1 | TYPE | Switches the Force sensor status screen to other status screen. |
| F3 | NUMBER | Switches to other execution history with the same number as the line number in Fig.4.2.1.1. |
| F5 | CUR_VAL | Switches to Force sensor current value screen. Refer to Section 4.1 for further details. |

## 4.2.2 Execution Histories with Alarms

### 4.2.2.1 List screen of execution histories with alarms

Press F4 “ALARM” key on the list screen(Fig.4.2.1.1) to display only the execution histories with alarms (Fig.4.2.2.1).
Each line of this screen shows an executed force control instruction, together with the TP program name and schedule data number. The last forty execution histories with alarms are recorded in order, starting with the last execution history on the top of the list.

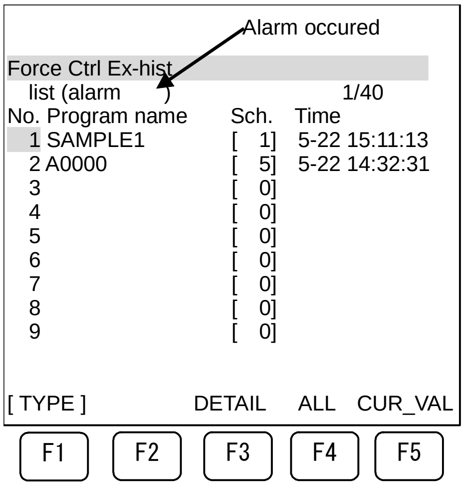



**Fig.4.2.2.1 List screen of execution histories with alarms**

### Function Key

The function keys have the following functions.

| Key | Label | Description |
|---|---|---|
| F1 | TYPE | Switches the Force sensor status screen to other status screen |
| F3 | DETAIL | Displays the detail information of the selected execution history with alarm. Refer to Subsection 4.2.2.2 for further details. |
| F4 | ALL | Switches to the list screen of all execution histories. |
| F5 | CUR_VAL | Switches to Force sensor current value screen. Refer to Section 4.1 for further details. |

### 4.2.2.2 Detail screen of execution histories with alarms

Select a line from the list (Fig.4.2.2.1), and then press F3 “Detail” to displays the details of the selected execution history with alarm (Fig.4.2.2.2).

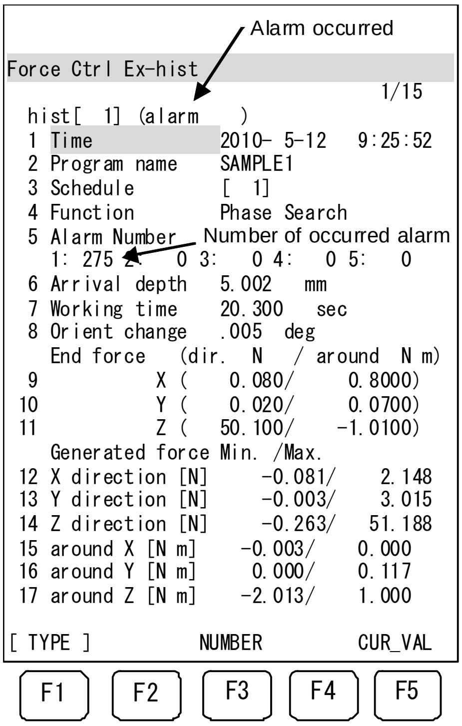



**Fig.4.2.2.2 Detail screen of the execution history with alarm**

The items on the detail screen of the execution history with alarm (Fig.4.2.2.2) are listed in Table 4.2.2.2.

**Table 4.2.2.2 Items in the 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 Number | The number of occurred alarm. (This item displays the previous five records.) |
| 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: second) |
| 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. |
| 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. |

The causes of alarms may be concluded according to the information on this screen.

For instance, in Fig.4.2.2.2, 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”.

Pressing “Prev” key in Fig.4.2.2.2 switches to the list screen of execution histories with alarms (Fig.4.2.2.1).

# 4.3 FORCE DATA LOG FUNCTION

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.

1 Press [NEXT] key on the Force sensor current value screen (Fig.4.1(a) or Fig.4.1(b)) to change the label of function key F3 (Fig.4.3(a)).

```
Force sensor
                                      1/1
    SENSOR GRP:1  TOOL: 1 SENSOR FRAME
    ATTACHMENT:HAND
        Current /       Mean
    Fx:  -13.358 /   -13.376 N
    Fy:   -2.733 /    -2.710 N
    Fz:   -2.594 /    -2.543 N
    Mx:   21.640 /    21.827 N*m
    My:  -20.790 /   -20.653 N*m
    Mz:   39.440 /    39.513 N*m

    Temperature:    39.4 C

                  F_LOG    TOOL   SENSOR >
  F1       F2       F3       F4       F5
```

**Fig.4.3(a) Force sensor current value screen**

2 Press F3 “F_LOG” key on (Fig.4.3(a))to display “Force data log” (Fig.4.3(b)).

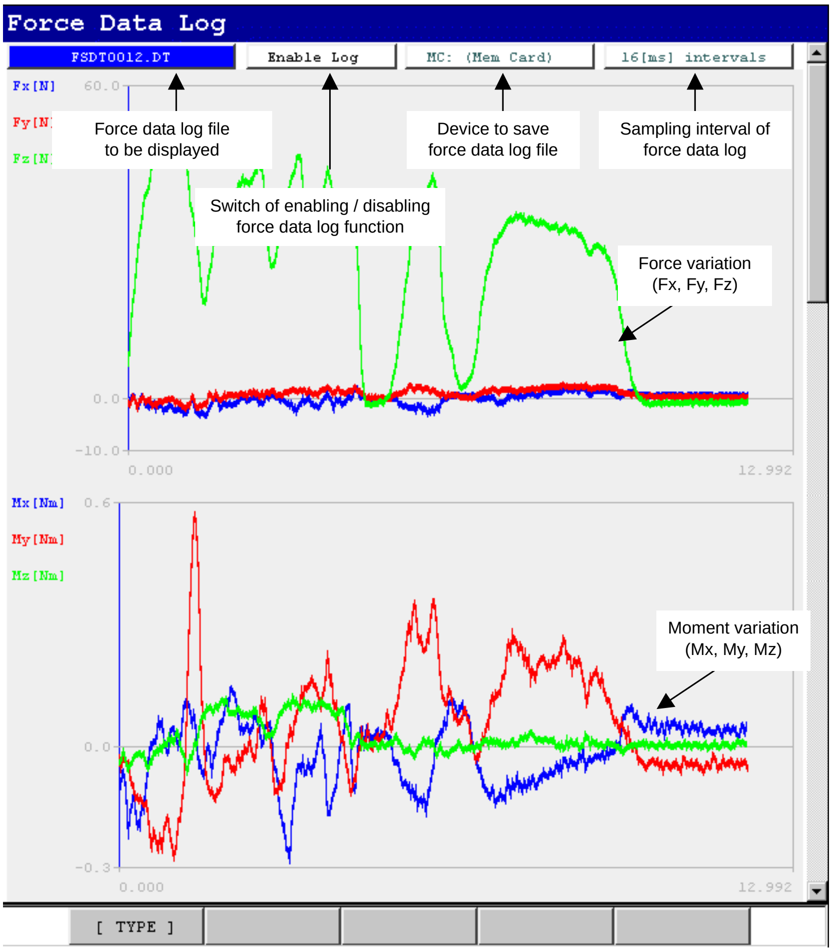



**Fig.4.3(b) Force Data Log screen**

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 Subsection 4.3.1 for further details.
- Enabling/disabling Force data log function
  → Refer to Subsection 4.3.2 for further details.
- Selecting device to save the force data log file
  → Refer to Subsection 4.3.3 for further details.
- Setting sampling interval of force data log
  → Refer to Subsection 4.3.4 for further details.

Pressing "Prev" key on the Force data log screen switches to Force sensor current value screen.

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.

**NOTE**

- The unit of Fx, Fy, Fz is N and the unit of Mx, My, Mz is N*m.
- The “Force Data Log” screen can only be displayed on *i*Pendant, but not a monochrome teach pendant.
- 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.

## 4.3.1 Selecting Force Data File

Press the button “FSDT****.DT” on the left top part of the “Force Data Log” screen to display the force data log files (Fig.4.3.1). Select a “.DT” file and press “Enter” to display the force data graphically.

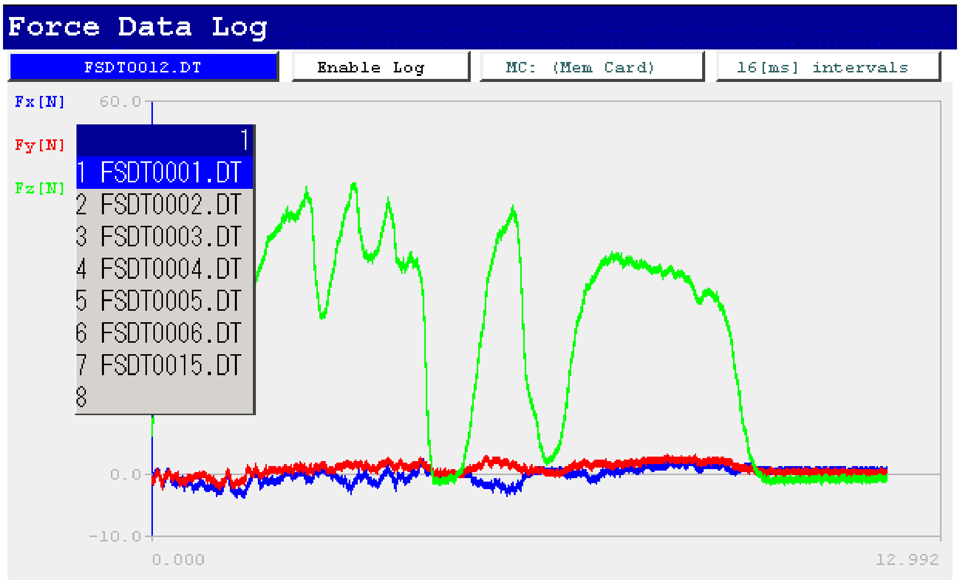



**Fig.4.3.1 Selecting the force data log file to be displayed graphically**

**NOTE**

- 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.
- 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.
- 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.

### Sample of Force Data Log File

The following shows a force data log file opened by Microsoft Excel. The force data log file is a text file punctuated by tabulator. The force, moment, and orientation data in this file are difference values from those at force control start point. 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.

Date and time when force control starts
TP program name
Schedule data number

| | | | |
|---|---|---|---|
| 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 |

: : : : :

Internal Timer
Time [sec]
Force: Fx, Fy,Fz [N]
Moment: Mx, My, Mz [N∗m]
Position: Px, Py, Pz [m]
Orientation: Rx, Ry, Rz [rad]

## 4.3.2 Enabling/Disabling Force Data Log Function

Select and press button “Enable Log” on the “Force Data Log” screen to switch the button to “Log Enabled” (Fig.4.3.2). The force data are recorded.if a force control instruction is executed with “Log Enabled” is ON, Toggle “Log Enabled” button to “Enable Log” to disable data logging.

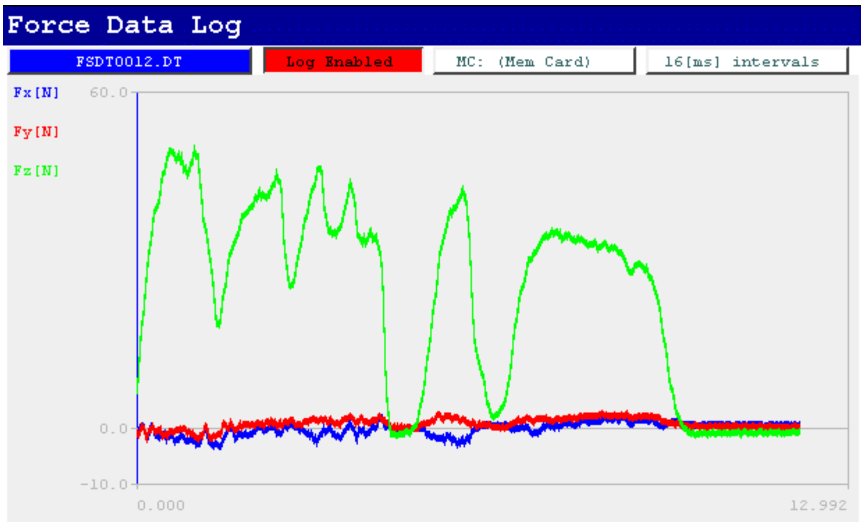



**Fig.4.3.2 Enabling/disabling force data log function**

> **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.

## 4.3.3 Selecting a Device to Save Force Data Log File

The force data file can be saved to device “MC: (Mem Card)”, “UD: (USB memory)”, “RD: (RAM Disk) or “FR: (FROM Disk)”. Press the button “MC: (Mem Card)” on “Force data log” screen to select a storage device for the force data file (Fig.4.3.3). The device “MC: (Mem Card)” or “UD: (USB memory)” is recommended. As for R-30iB Mate controller, “MC: (Mem Card)” can not be used.

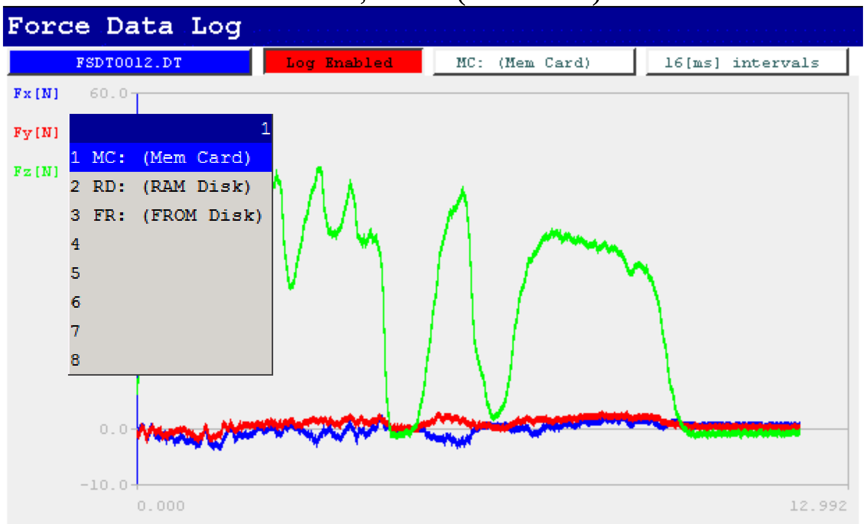



**Fig.4.3.3 Selecting a device to save the force data log file**

**NOTE**

- 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.

## 4.3.4 Setting the Sampling Interval of the Force Data Log

Press the button “16[ms] intervals” on “Force data log” screen to display the “Numeric keyboard” screen (Fig.4.3.4). Enter an integer and press “Enter” to sets the sampling interval of the force data log (unit: ms).

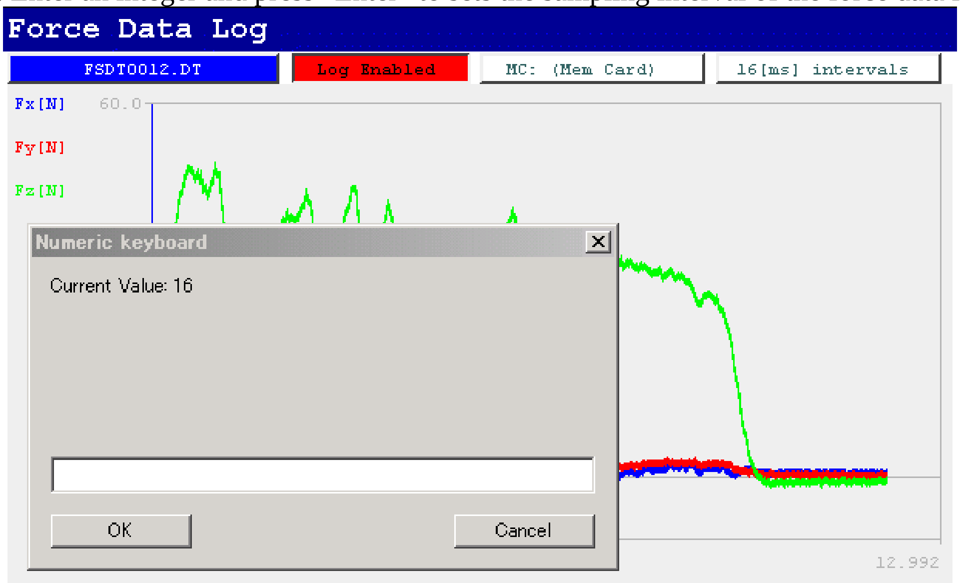



**Fig.4.3.4 Setting sampling interval of force data log**

> **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.

# 5 FORCE SENSOR UTILITIES SCREEN

On the force sensor utilities screen, the screen of ”Workpiece Mass Measurement Function”, “Tool Weight and COG Calcuration Function”, “Force Sensor Attachment Function” “TP Program Auto Generation Function”, “Deburring Path Auto Generation Function” or “Force Sensor Diagnosis Results Function” can be displayed. This section explains how to operate force sensor utilities screen.

## OUTLINES OF FORCE SENSOR UTILITIES SCREEN

To open the force sensor utilities screen, select the following

MENU →「1 UTILITIES」→ F1 [ TYPE ]

→「Force Sensor」

```
UTILITIES Force Sensor
                                          2/6
    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

[ TYPE ]         DETAIL
   F1       F2       F3       F4       F5
```

**Fig.5 Force sensor utilities screen**

On the force sensor utilities screen, push [F3] or [Enter] with pointing cursor to any item to display the screen of the function. Table.5 shows the overview of each function on the force sensor utilities screen. Refer to section of each function for detail.

**Table.5 Items in force sensor utilities screen**

| Item | Description |
|---|---|
| Workpiece Mass Measurement | Open the parameter setting screen of Mass Measurement function.Refer to [8 WORKPIECE MASS MEASUREMENT FUNCTION]. |
| Tool Weight and COG Calculation | Open the Menu screen of Tool Weight and Center of Gravity Calculation function. Refer to [6 TOOL WEIGHT AND CENTER OF GRAVITY CALCULATION FUNCTION]. |
| Force Sensor Attachment | Execute the setting program of force sensor attachment. Refer to [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 [7 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 iRVision 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/R-30*i*B Mate CONTROLLER Force Control Deburring Package OPERATOR'S MANUAL (B-83424EN-1). |
| Force Sensor Diagnosis Results | Open the results of force sensor diagnosis. Refer to [3.10.1 Force Sensor Diagnosis Instructions]. |
| 4D Graphic | Open the parameter setting screen of 4D Graphic.Refer to [9 FORCE SENSOR 4D GRAPHIC]. |

## Function keys

The function keys indicated in Fig. 5 have the following functions:

| 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. |

# 6 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.
When using the contouring function, be sure to execute this program.
It can be useful for other functions such as “Face Match “ if the orientation change is larger than, for example, 5deg.

**CONTENTS**



## 6.1 MENU SCREEN

The menu screen of weight and gravity center calcuration function is opened from the force sensor utilities screen. Refer to Chapter 5 "FORCE SENSOR UTILITIES SCREEN".
To open the menu screen, select the following.

MENU → 「1 UTILITIES」 → 「３Force Sensor」
→ F3 「2 Tool Weight and COG Calculation」

```
Tool Weight&Gravity Center Cal
                                                  1/5
     1 Set Points
     2 Execute
     3 Result
     4 Set Gravity Compensation Switch
     5 Change Parameters



   EXIT             DETAIL
```

F1 F2 F3 F4 F5

**Fig.6.1 The menu screen of weight and gravity center calcuration function**

On the “Menu” screen, select and execute one of the items listed in Table 6.1.

**Table 6.1 Items in "Menu" screen**

| Item | Description |
|---|---|
| Set Points | Teaches three points for measurement |
| Execute | Gets the force and moment at three taught points, and calculates the gravity and weight center of the tool |
| Result | Checks the calculation results |
| Set Gravity Compensation Switch | Determines whether to apply the calculation result to the schedule data |
| Change Parameters | Modifies the parameters of this program |

To select and execute a desired item, use one of the two following methods.

- Move the cursor to a desired item from 1 to 5 then press the "F3" key.
- Move the cursor to a desired item from 1 to 5 then press the "ENTER" key.

### Function keys

The function keys indicated in Fig.6.1 have the following functions:

| Key | Items | Description |
|---|---|---|
| F1 | EXIT | Allows you to go back the force sensor utilities screen. |
| F3 | DETAIL | Allows you to display the screen of each function. Refer to Table 6.1. |

## 6.2 TEACHING POSITIONS

Select "2: Set Points" on the "Menu" screen to display the "Set Points" screen.

- For a position which is not taught yet, "UNINIT" is displayed.
- For an already taught position, "RECORDED" is displayed.

```
                                      1/3
*** Set Points ***
Please set three diffrent points.
1 Approach point 1: [RECORDED]
2 Approach point 2: [UNINIT   ]
3 Approach point 3: [UNINIT   ]



  EXIT    DETAIL   CLEAR MOVE_TO RECORD
```

F1 F2 F3 F4 F5

**Fig.6.2(a) Set points screen**

### Function Key

The function keys have the following functions. The value of "X" in the description is 1, 2 or 3.

| 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 | If position X where the cursor is currently placed is "RECORDED", set the ON/OFF switch on the teach pendant to ON then hold down F4(MOVE_TO) while holding down the deadman's switch and the [SHIFT] key. The robot moves to position X. If the ON/OFF switch is set to OFF, the error message display field at the top of the screen displays the error message "Switch is turning OFF. Please Turn ON". |

| Key | Label | Description |
|---|---|---|
| SHIFT＋F5 | RECORD | The current position is saved and the display changes from “UNINIT” to “RECORDED”. |

It is necessary to teach three positions from the suggested list in Fig. 6.2(b).
If three positions are selected improperly, the weight and gravity center of the tool or workpiece cannot be calculated.

Five suggested positions are shown in Fig.6.2(b). Select any three of them to set the program.

| Position Number | Joint (J1,J2,J3,J4,J5,J6) (Unit: deg) | Orientation of robot flange |
|---|---|---|
| 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) |

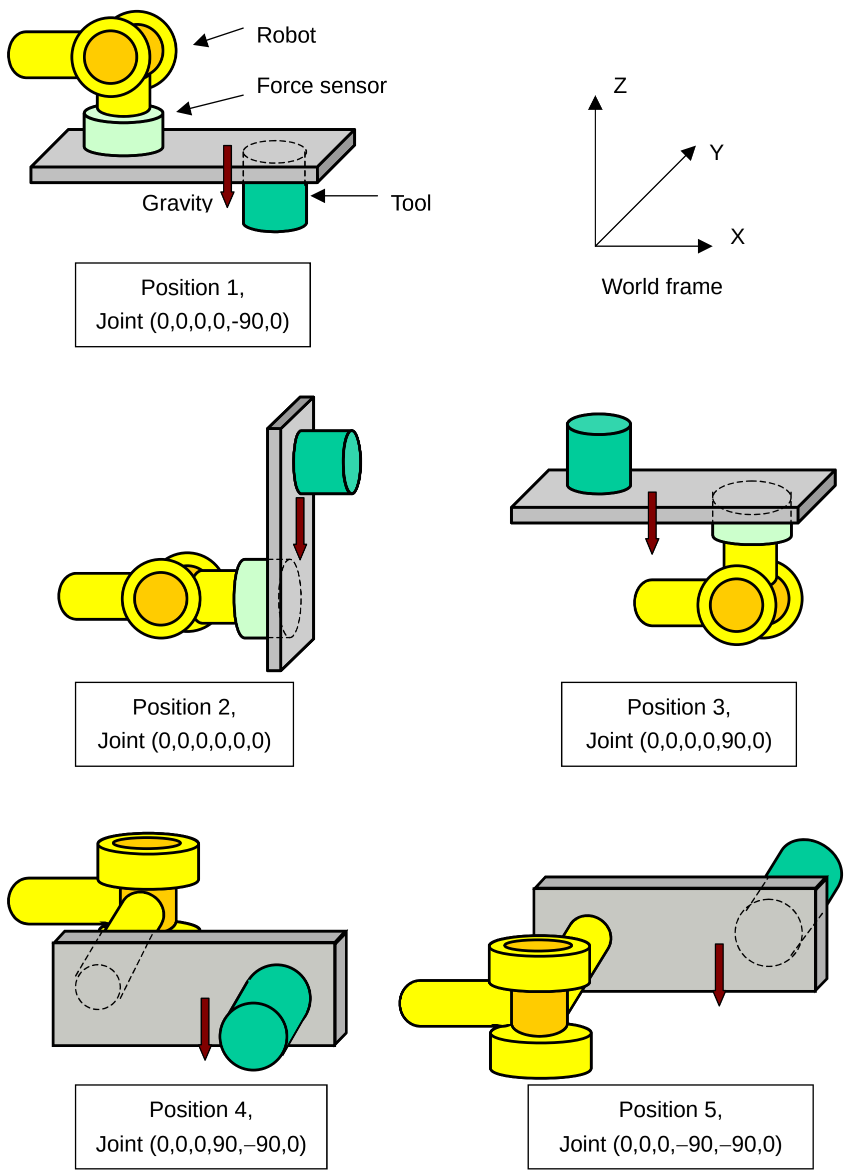



**Fig.6.2(b) Set the points**

**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.

## Detail Screen

As is shown in Fig.6.2(c), the detail screen displays a value in the specified axis format for J1 to J6 of position X selected on the “Set Points” screen. The unit of each axis is “deg” for a rotation axis and “mm” for a linear axis.

```
                                        1/6
*** Set Points ***
Approach 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

**Fig.6.2(c) When the position is already taught**

If the point is not taught, no value is set for this point and all axes display asterisks (*).

```
                                        1/6
*** Set Points ***
Approach point 2
  1    J1 : **********   deg
  2    J2 : **********   deg
  3    J3 : **********   deg
  4    J4 : **********   deg
  5    J5 : **********   deg
  6    J6 : **********   deg

  EXIT
```

F1 F2 F3 F4 F5

**Fig.6.2(d) When the position is not taught yet**

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”, as is shown in Fig.6.2(e) .

```
Value Limit Error!
DISPFORM2_2 LINE 564 T2 RUNNING JOINT
                                        1/6
*** Set Points ***
Approach 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

   DONE
```

F1 F2 F3 F4 F5

**Fig.6.2(e) Error message when improper values are entered**

# 6.3 CALCULATING THE WEIGHT AND GRAVITY CENTER OF THE TOOL

Selecting “3: Execute” on the “Menu” screen displays the “Execute” screen, as is shown in Fig.6.3(a).

```
***      Execute      ***
Are you ready to execute?




   YES      NO
```

F1 F2 F3 F4 F5

**Fig.6.3(a) Execute screen**

## Function keys

The function keys have the following functions.

| Key | Label | Description |
|---|---|---|
| F1 | YES | Starts execution and displays the “Now executing” screen. |
| F2 | NO | Returns to the “Menu” screen. |

Selecting F1(YES) on the screen starts execution. The robot moves sequentially to the three points set in Section 6.2, "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.
In this operation, it is necessary to set the ON/OFF switch on the teach pendant to ON.

> ⚠ **NOTE**
> - Pay attention to the robot’s movement for the override is automatically set to 10 %.
> - During the execution of this program, the robot moves to three points sequentially. Make sure that nothing interferes the robot’s movement.

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!!”.

```
***       Execute       ***
Now Executing!!
Now getting the force Sensor Data
 at Approach point 2!


  STOP
```

F1 F2 F3 F4 F5

**Fig.6.3(b) Moveing to taught points and obtaining force sensor data**

When the weight and gravity center are being calculated based on the obtained force sensor data, “Now calculating!!” is displayed under “Now executing!!”.

```
***       Execute       ***
Now Executing!!
Now Calculating!!



  STOP
```

F1 F2 F3 F4 F5

**Fig.6.3(c) Calculating the weight and gravity center of the tool**

If the calculation finishes normally, the calculation results are displayed, or the message indicated below is displayed and the program pauses until F1 (STOP) is pressed. Pressing F1 (STOP) displays the result of calculation.

| Message |
|---|
| Calculation is done.<br>F1:EXIT pressing displays the result. |

## 6.3.1 Confirming Calculation Results

The comment for the calculation result may be entered into “1 Comment” in the display screen of the calculation result, as is shown in Fig.6.3.1. Up to 9 results of calculation can be preserved. Enter a number from 1 to 9 in “2 Result Save No.”. By specifying a number, the corresponding result of calculation can be used later. To check the result of calculation corresponding to another number, see Section 6.4, “CALCULATION RESULTS”.

```
                                      1/3
***       Execute       ***
Normally Finished!
Mass              :            4.0   kg
Center of Gravity :      Sensor Frame
             X :             -25.5   mm
             Y :              -3.0   mm
             Z :              78.3   mm
  1 Comment   :
  2 Result Save No.      :     1 [1-9]
  3 Set to G. Compens. Value : Yes

  EXIT
```

F1 F2 F3 F4 F5

**Fig.6.3.1 Calculation Results**

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. If “Yes” is specified in “3 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, see Section 6.4, "CALCULATIOIN RESULTS”.

## 6.3.2 Error Display when Execution Starts

When F1(YES) is pressed to start the execution, the following error message may display.

(1) 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, as is shown in Fig.6.3.2(a).

```
Switch is turning OFF. Please Turn ON.
DISPFORM3     LINE 583     AUTO RUNNING

***       Execute       ***
Are you ready to execute?



  YES       NO
 F1    F2    F3    F4    F5
```

**Fig.6.3.2(a) When the ON/OFF switch is set to off**

(2) If all positions are not taught, the error message “Please set all points!” is displayed on the top line of the screen, as is shown in Fig.6.3.2(b).

```
Please set all points.
DISPFORM3_1 LINE 604 T2 RUNNING JOINT

***       Execute       ***
Please set all points.



  EXIT
 F1    F2    F3    F4    F5
```

**Fig.6.3.2(b) When there are positions not taught**

(3) 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, as is shown in Fig.6.3.2(c).

```
Same points exist. Please shift it.
DISPFORM3_11 LINE 626 T2 RUNNING

***       Execute       ***
Same points exist. Please shift it.



  EXIT
 F1    F2    F3    F4    F5
```

**Fig.6.3.2(c) When the same position is taught to more than one points**

- 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, as is shown in Fig.6.3.2(d).

```
P1&P3 position change not enough.
DISPFORM3_12 LINE 651 T2 RUNNING

***      Execute      ***
Position change not enough.
Please shift it.



  EXIT
```

F1 F2 F3 F4 F5

**Fig.6.3.2(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.

| 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 Section 6.6 for further details. |
| 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 Section 6.6 for further details. |
| 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 Section 6.6 for further details. |

## 6.3.3 Calculation Error

```

***      Execute      ***
Calculation Error occurred.


Mass Calc. Result Less than Error Th.



  EXIT
```

F1 F2 F3 F4 F5

**Fig.6.3.3 When the calculation error occurs**

- As is shown in Fig.6.3.3, if a calculation error occurs, the corresponding error message is displayed as indicated below. Take action according to the remedy indicated in the right-hand column.

| 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 Section 6.6 for further details. |
| 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. |

| Error message | Cause and remedy |
|---|---|
| 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. |

# 6.4 CALCULATION RESULTS

Select “3: Result” on the “Menu” screen to display the “Result” screen, as shown in Fig.6.4(a). 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.

```
                                          1/9
Res.:Mass   COG_X    Y      Z     Comment
+ 1:  23.0   53.0   8.2    7.4     TOOL1
  2: ***** ****** ****** ****** ********
  3: ***** ****** ****** ****** ********
  4: ***** ****** ****** ****** ********
  5: ***** ****** ****** ****** ********
  6: ***** ****** ****** ****** ********
  7: ***** ****** ****** ****** ********
  8: ***** ****** ****** ****** ********
  9: ***** ****** ****** ****** ********

  EXIT    DETAIL   CLEAR
```

F1 F2 F3 F4 F5

**Fig.6.4(a) List screen of calculation results**

## Function Key

The function keys have the following functions.

| 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.

## Detail Screen

As shown in Fig.6.4(b), 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. The unit of gravity is “mm”, and the unit of weight is “kg”. Move the cursor to items 1 through 6 to change the respective data.

```
                                        1/6
***   Results   ***
Result No.   :                   1
  1 Comment  :                Tool1
  2 Mass       :             23.0   kg
  Center of Gravity :  Sensor Frame
  3          X :             53.0   mm
  4          Y :              8.2   mm
  5          Z :              7.4   mm
  6 Set to G. Compens. Value :  Yes


  EXIT
```

F1 F2 F3 F4 F5

**Fig.6.4(b) When values are set**

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.   :                   2
  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

**Fig.6.4(c) When no value is set**

Press F2(YES) key on item “6 Set to G. Compens.Value”, to apply gravity compensation during the force control operation. The gravity compensation switch must be set to ON in the force schedule to enable gravity compensation. Refer to Section 6.5 for further details.

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 1~9) to be set.
If the specified calculation result is uninitialized, error message is displayed.

# 6.5 SETTING THE GRAVITY COMPENSATION SWITCH

This section describes the method of setting the gravity compensation switch for each schedule number.

Select “4: Set Gravity Compensation Switch” on the “Menu” screen to displays the “Setting of G. Compens. Switch” screen.

```
                                                   1/8
*** Setting of G. Compens. Switch ***
Setting of G. Compens. 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

  EXIT      ON       OFF     ALL_ON   ALL_OFF

  F1        F2       F3      F4       F5
```

**Fig.6.5(a) Setting the Gravity Compensation Switch**

## Function Key

The function keys have the following functions.

| 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. |

Select a schedule number by moving the cursor with the arrow keys. Alternatively, enter a desired schedule number with the numeric keys then press the [ENTER] key. The entered schedule number is displayed on the top line, and the cursor moves there.

```
                                                   1/8
*** Setting of G. Compens. Switch ***
Setting of G. Compens. of each Schedule.
  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


  EXIT      ON       OFF     ALL_ON   ALL_OFF

  F1        F2       F3      F4       F5
```

**Fig.6.5(b) When 20 is Entered**

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.

> **NOTE**
> - If a program is running, the Gravity Compensation Switch cannot be modified.

## 6.6 PARAMETER MODIFICATION

```
                                                1/5
*** Change Parameters ***
Force Sensor Parameter:
  1  Wait until Start             :   5000 ms
  2  Sampling Time                :    100 ms
  3  Mesurement Time              :   3000 ms
Calculation Parameters:
  4  Mass Error Threshold         :   0.10 kg
  5  Position Change Th.          :  20.00 deg


    EXIT   DEFAULT
```

F1  F2  F3  F4  F5

**Fig.6.6 Change Parameters screen**

As is shown in Fig.6.6, when “5: Change Parameters” is selected on the “Menu” screen, each item is displayed with the default set. The values (default values) of the following five items can be displayed and modified.

| Parameter | Description | Default Value |
|---|---|---|
| Waiting Time until Start | Waiting time between moving to a position and starting to obtain force sensor data | 5000 msec |
| Sampling Time | Sampling time of obtaining force sensor data | 100 msec |
| Measurement Time | Total measurement time of obtaining force sensor data | 3000 msec |
| Mass Error Threshold | The minimum mass of the tool that can be measured | 0.1 kg |
| Position change Th. | Orientation change between every two points among three teach points mentioned in Section 6.2 | 20.0 deg |

When modifying the value of an item from 1 to 5, move the cursor to the item with the arrow keys then enter a desired value. Next, press the [ENTER] key for setting. Alternatively, press the [ENTER] key then enter a desired value. Next, press the [ENTER] key for setting.

### Function Key

The function keys have the following functions.

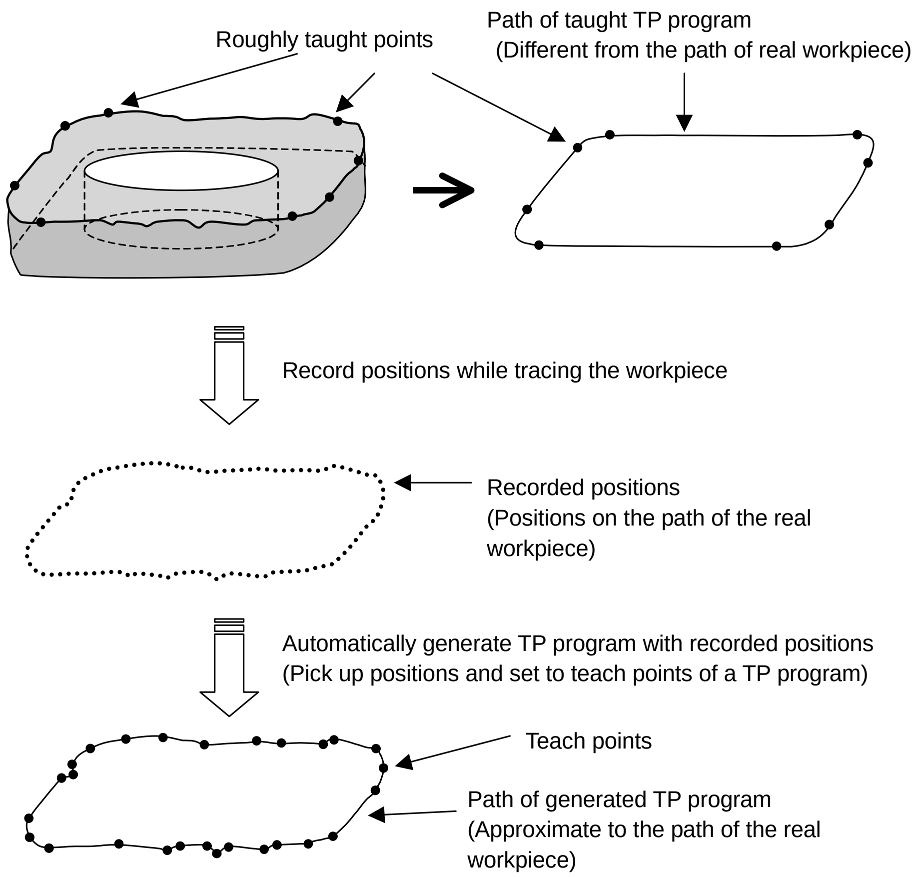
| Key | Label | Description |
|---|---|---|
| F1 | EXIT | Pressing F1(EXIT) or [Prev] returns the screen display to the “Menu” screen. |
| F2 | DEFAUL | Sets all items to the default values. |

## 6.7 NOTES

- Press “Select” key on the teach pendant or select “F1: Exit” on “Menu” screen to terminate this program. Upon termination, the screen display returns to the program list screen.
- The [Prev] and [Next] keys are disabled when [SHIFT] key is pressed.

# 7 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.




This function includes the following three KAREL programs.

| Program name | Description |
|---|---|
| MTPMONIT | • Record positions when tracing the path and generates TP program automatically. |
| MTPEND | • End recording positions. |
| MTPGENTP | • Regenerate the TP program with recorded positions and modified parameters. |

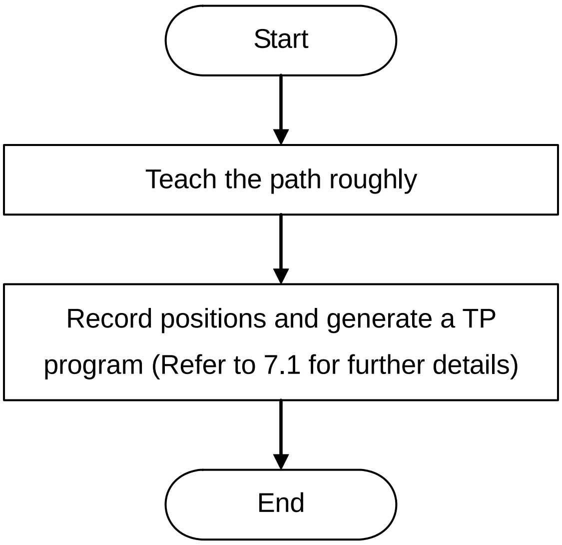
**CONTENTS**



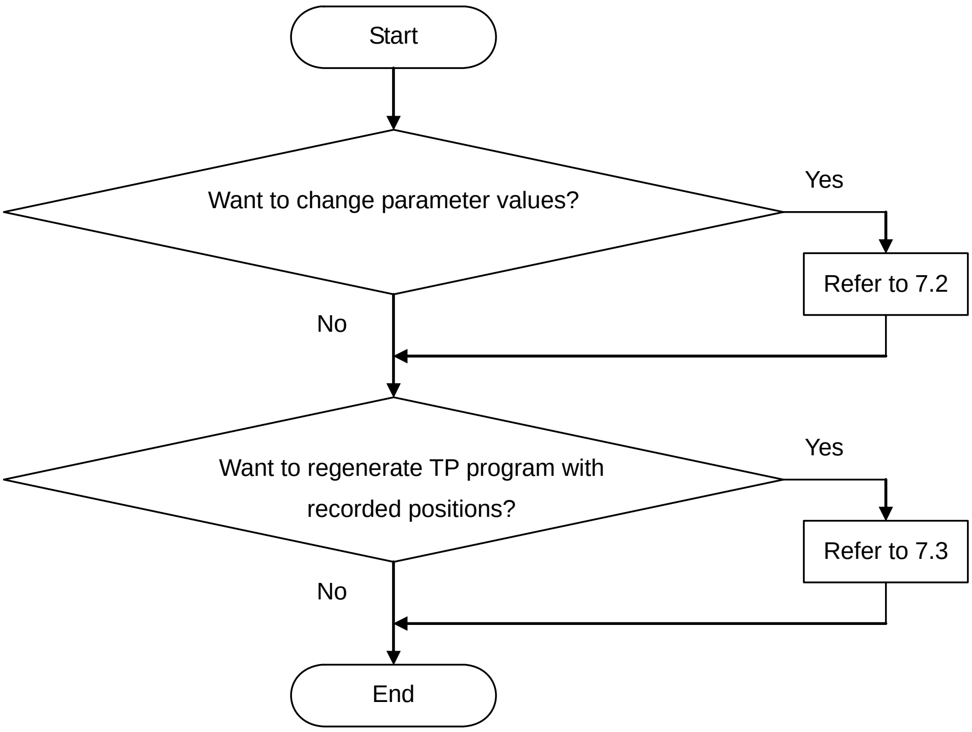
## How To Use This Function

Generally, this function has the following two usages. Follow the below procedures and refer to the corresponding sections for further details.

1 After tracing the path of the real workpiece, generate a TP program automatically to reappear the path.




2 Regenerate the TP program with positions recorded in procedure 1. If the error between the path of the TP program and that of the real workpiece is large, the error may be reduced by regenerating the TP program with modified parameters.




# 7.1 GENERATING TP PROGRAM AUTOMATICALLY AFTER RECORDING POSITIONS

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.

1 Create sample TP programs like the following M_MAIN_01.TP and M_MONT_01.TP. 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. In the program M_MONT_01.TP, the program MTPMONIT.PC is executed to record positions while tracing the path and generate TP program automatically.

```
M_MAIN_01.TP

1:J   P[1] 30% FINE              ← Approach point of Contouring
2:    RUN M_MONT_01              ← Executes M_MONT_01.TP to record positions.
                                   ("INST"→"Multiple control"→ "RUN" to insert "RUN" command)
3:    FORCE CTRL[1:]             ← Contouring starts
 :    ErrorLBL[0] ;                (Set schedule data number 1 to "Contouring")
4:L   P[2] 50mm/sec CNT100  ┐
5:L   P[3] 50mm/sec CNT100  ├Roughly taught path
6:L   P[4] 50mm/sec CNT100  ┘
          …
7:    FORCE CTRL[2:]             ← Contouring ends
 :    ErrorLBL[0] ;                (Set schedule data number 2 to "Contouring End")
8:    CALL MTPEND                ← Position recording ends
9:L   P[5] 50mm/sec FINE         ← Leave point of Contouring
[END]
```

```
M_MONT_01.TP

1:   CALL MTPMONIT(1)    ← Argument "1" is the parameter set number
                           (The argument can be an integer of 1~50, refer to 7.2)
```

**NOTE**

- It is necessary to set all group masks of program M_MONT_01.TP to "*" with the following procedures.
  1 Move the cursor to program M_MONT_01.TP in the "Select" screen.
  2 Press [NEXT] key, and pressing F2(Detail) key displays the "Program detail" screen.
  3 Move cursor to the "Group Mask" line and set all values right to "Group Mask" to "*".

2 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. The message of "M_PROG_01.TP is generated" is displayed if the TP program is successfully generated.

⚠ **NOTE**

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.

# 7.2 PARAMETER SETTING SCREEN

The list of parameter setting screen is opened from the force sensor utilities screen. Refer to Chapter 5 "FORCE SENSOR UTILITIES SCREEN".

.

## 7.2.1 List of Parameter Setting Screen

To open the list of parameter setting screen, select the following.

MENU → 「1 UTILITIES」→ 「3 Force Sensor」

→ F3 「4 TP Program Auto Generation」

Comments of 50 parameter settings are shown in this screen.

```
TP Program Auto Gen / List
                                        1/50
    No.   Comment
      1  [                ]
      2  [                ]
      3  [                ]
      4  [                ]
      5  [                ]
      6  [                ]
      7  [                ]
      8  [                ]
      9  [                ]
     10  [                ]

  EXIT     COPY     DETAIL  WRITE DT  READ DT
```

F1 F2 F3 F4 F5

**Fig.7.2.1 List of parameter setting screen**

### Function keys

The function keys indicated in Fig. 7.2.1 have the following functions:

| Key | Item | Description |
|---|---|---|
| F1 | EXIT | Back to the force sensor utilities screen. |
| F2 | COPY | To copy the parameter to another one.<br>(TP program name, output DT filename and recorded positions will not be copied.) |
| F3 | DETAIL | To display the parameter setting screen. |
| SHIFT+F4 | WRITE DT | To output parameter setting and recorded positions to text file. |
| SHIFT+F5 | READ DT | To read parameter setting from text file.<br>(Recorded positions will not be read.) |

## 7.2.2 Parameter Setting Detail Screen

On screen of Fig. 7.2.1, push the [F3] or [Enter] with pointing cursor to any item, a “Parameter setting” screen displays as Fig. 7.2.2.

```
Parameter Setting
                                             1/12
    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

    Read/Write Data and Setting from/to
     12 DT File      :          MTPDAT_01

     EXIT   DEFAULT
```

F1 F2 F3 F4 F5

**Fig.7.2.2 Parameters for TP program auto generation**

### Function keys

The function keys indicated in Fig. 7.2.2 have the following functions:

| Key | Item | Description |
|---|---|---|
| F1 | EXIT | Back the list of parameter setting screen. |
| F2 | DEFAULT | Reset all parameters to default values. |

## Parameters

Parameters for TP Program Auto Generation and position recording can be modified in the "Parameter Setting" screen.

| Name | Description | Default Value |
|---|---|---|
| Comment | Comment of parameter setting | |
| Interval | Sampling interval of position recording | 48 ms |
| Program Name | Name of the generated TP program. | M_PROG_**<br>(** 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. | 1.5 mm |
| 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. | 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. | 10.0 deg |
| General Velocity | Motion velocity in the generated TP program. | 50 mm/s |
| Cnt | Cnt value of Linear command and Circular command | 85 |

| Name | Description | Default Value |
|---|---|---|
| Use Circular Command | Switch of whether to use circular command in the corner. (This program detects the corner automatically)<br>• FALSE : Use Linear command for all teach points.<br>• TRUE : Use circular command in the corner. | FALSE |
| Use Angular Velocity | Switch of whether to use angular velocity in the corner. (This program detects the corner automatically)<br>• FALSE : Do NOT use [Angular Velocity] in the corner.<br>• TRUE : Use [Angular Velocity] in the corner. | FALSE |
| Angular Velocity | Angular velocity in the corner.<br>The parameter will be used only if the switch [Use Angular Velocity] is set TRUE and the robot orientation changes greatly in the corner. | 100 deg/s |
| DT file | Text file to output/read parameter setting and recorded positions to/from. | MTPDAT_**<br>(** is parameter setting number) |

# 7.3 REGENERATING TP PROGRAM WITH MODIFIED PARAMETERS

The TP program can be regenerated with recorded positions and modified parameters.

Create a TP program M_REGEN_01.TP like the following.
Execute TP program M_REGEN_01.TP to regenerate the TP program with recorded positions. The message of “M_PROG_01.TP is generated” is displayed if the TP program is successfully generated.

```
M_REGEN_01.TP

1:   CALL MTPGENTP(1)   ← Argument “1” is the parameter set number
```

# 7.4 OUTPUTTING PARAMETER SETTING AND RECORDED POSITIONS TO TEXT FILE

On screen of Fig. 7.2.1, push the [SHIFT+F4] key with pointing cursor to any item, the parameter setting and recorded positions can be output to a text file. Default text filename is MTPDAT_∗∗.DT. (If the used parameter set number is “1”, the file name is “MTPDAT_01.DT”) The message of “Writing to MTPDAT_01.DT is OK” is displayed when recorded positions are successfully output to a text file.

## Sample of an Output Text File

The following shows a sample of the output text file “MTPDAT_01.DT”.

```
Version,1
Comment,''
Interval,48
Mtp_prog,'M_PROG_01'
Tol_dist,1.5
Tol_angle,3.0
Tol_rot,10.0
Velocity,50
Cnt,85
Crc_cmd_enb,0
Rot_vel_enb,0
Rot_vel,100
DT_file,'MTPDAT_01'
Uf_num,5
Utool_num,5
Num_points,565
72.074,98.542,149.595,179.941,.757,-141.526,N,U,T,0,0,0
72.074,98.542,149.595,179.941,.757,-141.526,N,U,T,0,0,0
72.074,98.542,149.595,179.941,.757,-141.526,N,U,T,0,0,0
72.074,98.542,149.595,179.941,.757,-141.526,N,U,T,0,0,0
72.074,98.542,149.595,179.941,.757,-141.526,N,U,T,0,0,0
72.073,98.540,149.593,179.941,.757,-141.527,N,U,T,0,0,0
71.643,97.979,149.101,179.938,.753,-141.732,N,U,T,0,0,0
69.317,94.939,146.427,179.926,.730,-142.848,N,U,T,0,0,0
63.516,87.315,139.654,179.898,.670,-145.652,N,U,T,0,0,0
53.132,73.504,127.057,179.861,.560,-150.759,N,U,T,0,0,0
39.091,54.469,108.781,179.842,.407,-157.860,N,U,T,0,0,0
24.464,34.112,87.783,179.862,.249,-165.548,N,U,T,0,0,0
12.228,16.576,67.997,179.911,.123,-172.262,N,U,T,0,0,0
...
```

**NOTE**

Before writing/reading parameter setting and recorded positions to/from dt file, display “FILE” screen by following the below procedures, and then move to the folder where to write/read the text file. (If the text file is saved to the memory card, make sure a memory card is plugged in the controller.)

MENU → [ 7 FILE ] → [1 File」

# 7.5 NOTES

- The parameter setting cannot be modified if a program is being run.
- The maximum number of recorded positions depends on the empty capacity of the robot controller.
- Maximum number of teach points in the generated TP program is 2000.
- The tracing velocity when recording positions is suggested to be no greater than 5 mm/s, for the purpose of tracing the workpiece reliably.
- Set the parameter “Tolerant Distance” to be no greater than the curvature radius of the workpiece’s corner.
- If the parameter “Use Rotation Vel” is set TRUE, adjust the parameter “Rotation Velocity” on the basis of the curvature radius of the workpiece’s corner.
- Check the empty capacity of the storage where to save the text file before outputting recorded positions. (Necessary capacity can be estimated as follows: Number of recorded positions × 100 byte)

# 8 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**



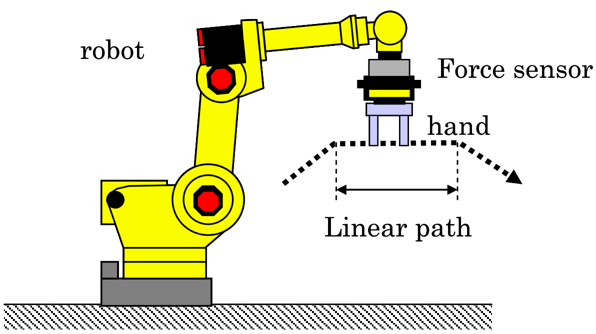
## 8.1 OVERVIEW AND HOW TO USE

### 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.
The workpiece has to travel in a linear path on the horizontal plane. If the path is slanted off the horizontal or it includes a curve, the calculated mass will have a bigger error.

### HOW TO USE

1. Set parameters from a “Parameter Setting Screen”. See section 8.2.
2. Make a TP program for mass measurement. Teach operation statements for “Basis Measurement” and “Mass Measurement” with the operation add instruction for the measurement. As it is mentioned above, the path has to be linear. See section 8.4.
3. Execute “Basis Measurement” when the robot does not have a workpiece (Fig. 8.1(a)).
4. Execute “Mass Measurement” when the robot has a workpiece (Fig. 8.1(b)). The workpiece’s mass is automatically calculated and it is written to a register which is designated in “Parameter Setting Screen“. The mass, measurement time, force amplitude, force standard deviation are displayed on “Result Display Screen”. If the mass is not accurate, make a fine adjustment of operation statements. See sections 8.3 and 8.5, “If the Mass is not Right”.



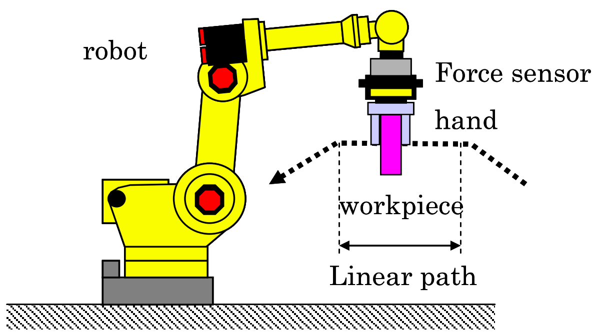




**Fig.8.1(a) Basis measurement (without a workpiece) Fig.8.1(b) Mass measurement (with a workpiece)**

**⚠ CAUTION**
- 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.
- The orientation of robot wrist has to be same for "Basis Measurement" and "Mass Measurement". Don't change the orientation while measurement.
- 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.

# 8.2 PARAMETER SETTING SCREEN

The parameters must be specified on the "Parameter Setting Screen".
The parameter setting screen of mass measurement function is opened from the force sensor utilities screen. Refer to Chapter 5 "FORCE SENSOR UTILITIES SCREEN".
If you already open the result screen of mass measurement (Fig.8.3(a)), parameter setting screen can be opened by simply pressing [F3] key.
Otherwise to open the menu screen, select the following.

MENU → 「 1 UTILITIES 」→ F1 「 Force Sensor 」

→ F3 「 1 Workpiece Mass Measurement 」

```
Setting for Mass Measurement
                                   1/5
  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


[ EXIT ]         RESULT
```
F1 F2 F3 F4 F5

**Fig. 8.2 Parameter setting screen**

## Function Keys

The function keys indicated in Fig. 8.2 have the following functions:

| Key | Item | Description |
|---|---|---|
| F1 | EXIT | Allows you to go back the force sensor utilities screen. |
| F3 | RESULT | Allows you to display the result screen. See section 8.3. |

### 1 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"

### 2 Reg. No. Basis Measure

This parameter designates register number which determines the start/stop timing of "Basis Measurement". As illustrated in section 8.4, 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.
"Default : 0"

### 3 Reg. No. Mass Measure

This parameter designates register number which determines the start/stop timing of "Mass Measurement". As illustrated in section 8.4, 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.
"Default : 0"

### 4 Reg. No. Mass Result

This parameter designates register number to which a calculated mass is written.
"Default : 0"

### 5 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.

## 8.3 RESULT DISPLAY SCREEN

A calculated mass, measurement time, force amplitude, force standard deviation are displayed in "Result Display Screen".
To open the screen , press "F3, RESULT" in the "Parameter Setting Screen" which is described in section 8.2.

MENU → 「1 UTILITIES」 → F1 「Force Sensor」
→ F3 「1 Workpiece Mass Measurement」 → F3 [ RESULT ]

```
Result of Mass Measurement
                                          1/7
  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


[ EXIT ]         SET
```

F1 F2 F3 F4 F5

**図 8.3(a) Result display screen**

## Function Keys

The function keys indicated in Fig. 8.3(a) have the following functions:

| Key | Item | Description |
|---|---|---|
| F1 | EXIT | Allows you to go back the force sensor utilities screen. |
| F3 | SET | Allows you to display the setting screen. See section 8.2. |

### 1 Calculated Mass

It is a calculated mass from “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”

### 2 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 includes big error. Extend the length of a linear path or reduce the travel speed.
“Unit : sec”

### 3 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 includes big error. Extend the length of a linear path or reduce the travel speed.
“Unit : sec”

### 4 Basis Measure F amp. (Force amplitude)

These are differences between maximum and minimum value of force data (Fx,Fy,Fz) during “Basis Measurement” (Fig. 8.3(b)). 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”

### 5 Mass Measure F amp. (Force amplitude)

These are differences between maximum and minimum value of force data (Fx,Fy,Fz) during “Mass Measurement” (Fig. 8.3(b)). 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"

**6 Basis Measure F STDEV (Force standard deviation)**

These are standard deviation of force data (Fx,Fy,Fz) during "Basis Measurement" (Fig. 8.3(b)). 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"

**7 Mass Measure F STDEV (Force standard deviation)**

These are standard deviation of force data (Fx,Fy,Fz) during "Mass Measurement" (Fig. 8.3(b)). 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"

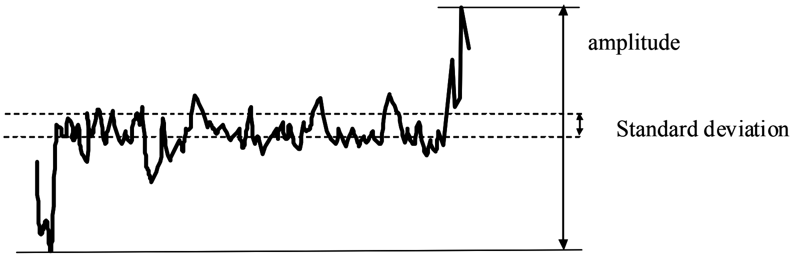



**Fig. 8.3(b) amplitude and standard deviation**

## 8.4 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. 8.4(a) and Fig. 8.4(b). In this example, the operation add instructions (TIME BEFORE and TIME AFTER) are used to measure only in a linear trajectory. See "R-30*i*B CONTROLLER OPERATOR'S MANUAL (Basic Operation)" (B-83284EN) Chapter 9 for TIME BEFORE instruction.

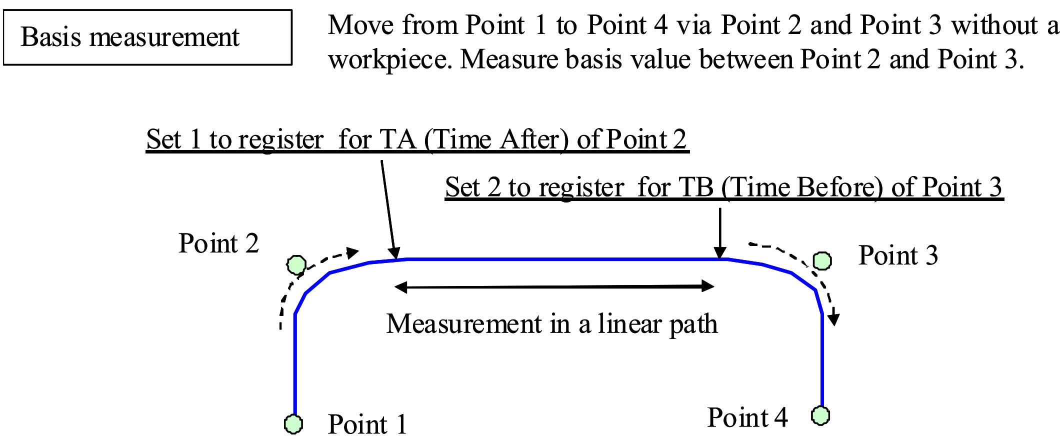



**Fig. 8.4(a) example of "Basis Measurement"**

| 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. |
|---|---|

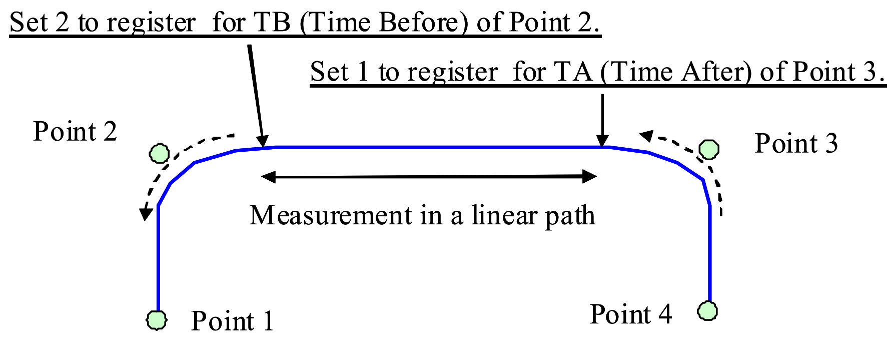



**Fig. 8.4(b) example of "Mass Measurement"**

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. 8.4(c) TP program example**

# 8.5 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 The workpiece and the robot are out of contact with surrounding objects when the robot is running.
2 Force sensor cable is not under heavy load.
3 The paths for measurement in “Basis Measurement” and “Mass Measurement” are linear and on horizontal plane.
4 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.
5 The orientation of robot wrist is same for “Basis Measurement” and “Mass Measurement” and it does not change during measurement.
6 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.
7 “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.
8 “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. 8.5(a), Fig. 8.5(b)). Take TP program in Fig 8.4(c) 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.
9 “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 (Fig. 8.5(a), Fig. 8.5(b)).

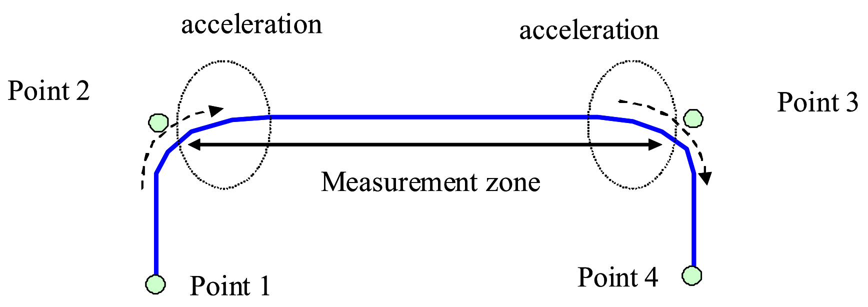



**Fig. 8.5(a) Measurement with accelerating zone**

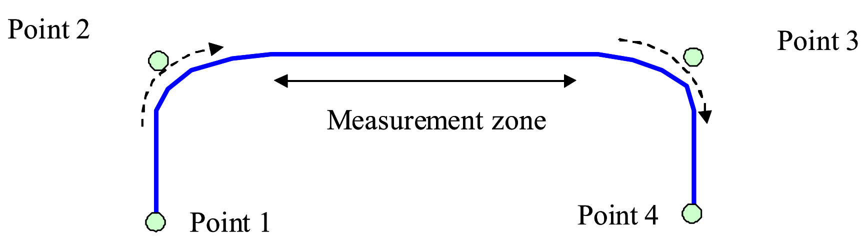



**Fig. 8.5(b) Measurement without accelerating zone**

# 9 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 iPendant. 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.

To use this function, "4D graphic" (R764) is required. For details of the 4D graphic functions, refer to "R-30iB/R-30iB Mate CONTROLLER Optional Function OPERATOR'S MANUAL (B-83284EN-2)".

**CONTENTS**



## 9.1 USING THE FORCE SENSOR 4D GRAPHIC FUNCTION

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.

1 First, use the "force data log function" (see Section 4.3) to record the force data during the force control operation. This function uses a force data file generated by the "force data log function".
2 Select 4D Graphic from the UTILITIES Force Sensor screen. The Setting for Force Display screen appears. Set required parameters. (See Section 9.2.)
3 Open the 4D GRAPHICS Force Sensor screen and check the force data. (See Section 9.3.)

## 9.2 SETTING FOR FORCE DISPLAY SCREEN

Open the Setting for Force Display screen with the following procedure and set required parameters.
The setting screen can be opened from the force sensor utilities screen. See Chapter 5, "FORCE SENSOR UTILITIES SCREEN".
On the utilities screen, move the cursor to "7 4D graphic" and press F3 "DETAIL" or the ENTER key. The screen shown in Fig. 9.2 (a) appears.

MENU → 「 1 UTILITIES 」 → 「Force Sensor 」

→ F3 「 7 4D graphic 」

```
FS 4D graphic Force display          ^ i
                                   1/9
   Setting for Force Display

  1 Device name           : UD1:
  2 Folder name           : fsdt1
  3 Data File name        : FSDT0001
  4 Force                 : Fz
  5 Display Direction     : Z
  6 Force Scale           :    5.0 mm/N
  7 Display Interval      :   10.0 mm
  8 Threshold Big         :  120.0 %
  9 Threshold Small       :   80.0 %

  EXIT        UPDATE [CHOICE] FILE
  F1     F2     F3     F4     F5
```

**Fig. 9.2 (a) Setting for Force Display screen**

## Function keys

The function keys have the following functions.

| Key | Label | Description |
|---|---|---|
| F1 | EXIT | Returns to the force sensor utilities screen. |
| F3 | 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. (See Section 9.3.)<br>When the iPendant 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. |
| F4 | CHOICE or FOLDER | Displays the relevant options when the cursor is positioned on "Device name", "Force", or "Display Direction". Displays the screen in which the folders in the selected device are listed in other cases. |
| F5 | FILE | Displays the screen in which the files in the selected folder in the selected device are listed. |

## 1 Device name

Specify a device containing force data files. Select MC: (memory card) or UD1: (USB memory).
"Default: MC:"

## 2 Folder name

Specify the name of a folder in the above device that contains force data files. Pressing F4 (FOLDER) displays a list of folders in the device in ascending order of name as shown in Fig. 9.2 (b). Moving the cursor to a folder name and pressing F3 (SELECT) displays the screen shown in Fig. 9.2 (a) again and automatically rewrites the folder name. You can also input or change the folder name directly.
"Default: FSDT1"

```
FS 4D graphic /Folder List           ^ i
       Folder List                   1/2
    No.  Folder Name
      1  FSDT1
      2  FSDT2


  EXIT          SELECT          FILE
  F1     F2     F3     F4     F5
```

**Fig. 9.2 (b) Folder List screen**

> **NOTE**
> - Up to 100 folders can be displayed in the screen shown in Fig. 9.2 (b). If the device contains more than 100 folders or no folder, an alarm is issued.

### 3 Data File name

Specify the name of a force data file in the above folder. Pressing F5 (FILE) displays a list of files with extension DT in the folder in descending order of name as shown in Fig. 9.2(c). 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". Moving the cursor to a data file name and pressing F3 (SELECT) displays the screen shown in Fig. 9.2 (a) again and automatically rewrites the data file name. You can also input or change the file name directly.
"Default: FSDT"

```
FS 4D graphic /File List          ^ i
      File List                    1/10
    No.  File Name     date        time
      1  FSDT0010    2015- 6-25  15:56
      2  FSDT0009    2015- 6-25  15:53
      3  FSDT0008    2015- 6-25  15:51
      4  FSDT0007    2015- 6-25  15:49
      5  FSDT0006    2015- 6-25  15:48
      6  FSDT0005    2015- 6-25  15:45
      7  FSDT0004    2015- 6-23  10:36
      8  FSDT0003    2015- 6-23  10:25
      9  FSDT0002    2015- 6-22  18:15
     10  FSDT0001    2015- 6-22  18:11

   EXIT          SELECT  FOLDER
   F1     F2     F3      F4      F5
```

**Fig. 9.2 (c) File List screen**

> **NOTE**
> - Up to 1000 files can be displayed in the screen shown in Fig. 9.2 (c). If the folder contains more than 1000 files or no file with extension DT, an alarm is issued.

### 4 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.
"Default: Fz"

"Default: Fz"

### 5 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. 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"

### 6 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"

### 7 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"

### 8 Threshold Big

When the absolute value of force is larger than ("Insert Force" or "Pushing Force" in the schedule data) × (Threshold Big)/100, the force is displayed with a red line in the 4D graphic screen.
"Default: 120%"

### 9 Threshold Small

When the absolute value of force is smaller than ("Insert Force" or "Pushing Force" in the schedule data) × (Threshold Small)/100, the force is displayed with a white line in the 4D graphic screen.
"Default: 80%"

**NOTE**

- 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.
- 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.
- When pushing force is changed with the function of changing target pushing force during “Contouring” (see Subsection 3.5.7.7), the color of the line is also determined according to "Contouring Force" in the schedule data.

# 9.3 4D GRAPHIC SCREEN

After setting required parameters as described in Section 9.2, open the 4D graphic screen.
The following two methods are available for opening this screen: Pressing ˆ *i* on the title bar of the Setting for Force Display screen (Related Views) and displaying the 4D graphic screen from the Position Display screen.

## 9.3.1 Opening the 4D Graphic Screen from "Related Views"

Press ˆ *i* on the title bar of the Setting for Force Display screen. The following "Related Views" menu appears.

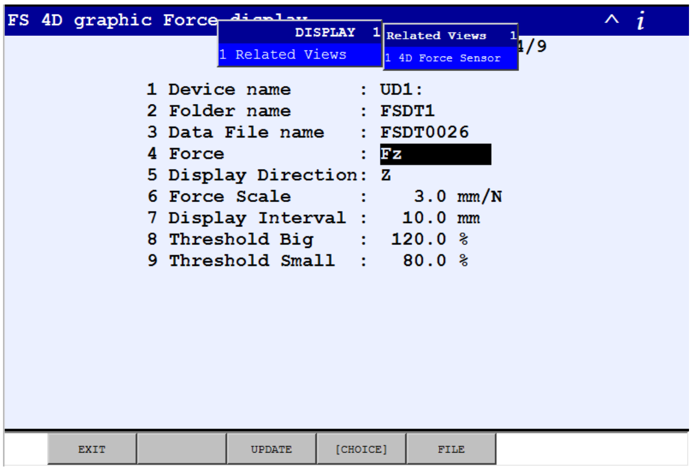



**Fig. 9.3.1 (a) Selecting the 4D graphic screen from Related Views**

When 4D Force Sensor is selected, the "4D GRAPHICS Force Sensor" screen automatically opens on the right side as shown in Fig. 9.3.1 (b). When the screen is already open, it opens again. The Force Sensor 4D graphic function reads the force data file selected as described in Section 9.2 and displays the force.
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.
In this figure, the jog frame is displayed together.

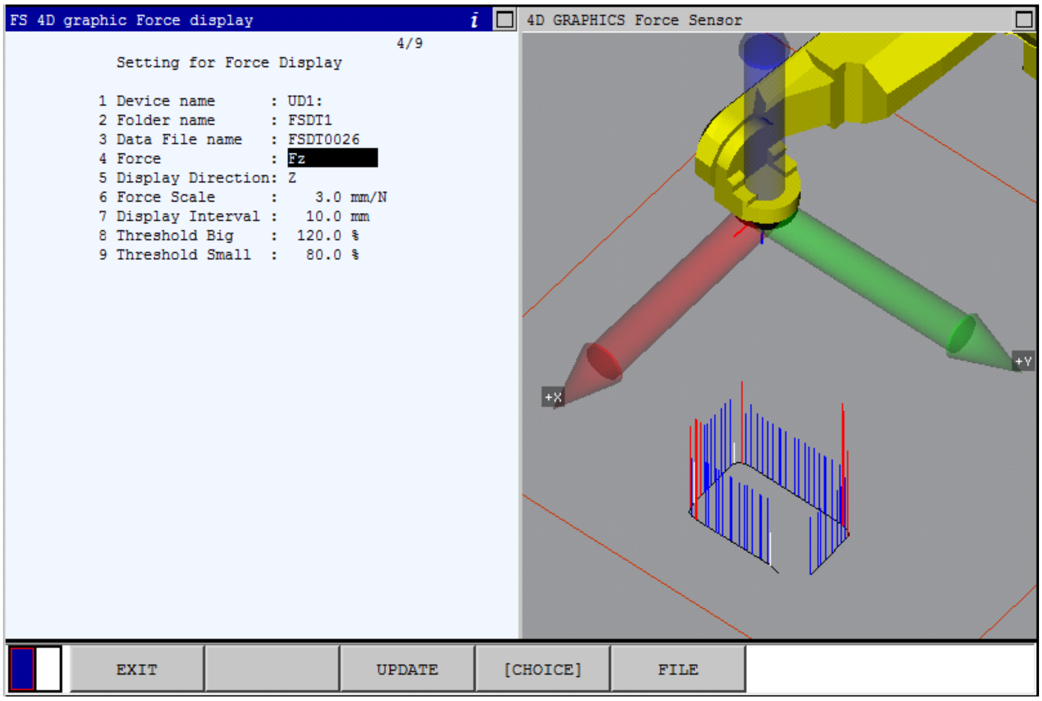



**Fig. 9.3.1 (b) Selecting the 4D graphic screen from Related Views**

> **NOTE**
> - If no force data is recorded in the force data file, the function does not display force data and issues alarm FORC-457.
> - Up to 500 lines can be displayed. The 501st and subsequent lines are not displayed and alarm FORC-458 is issued.

## 9.3.2 Opening the 4D Graphic Screen from the "Position Display" Screen

You can also open the 4D graphic screen from "Position Display".
Press F1 "TYPE" and select "4D Display".

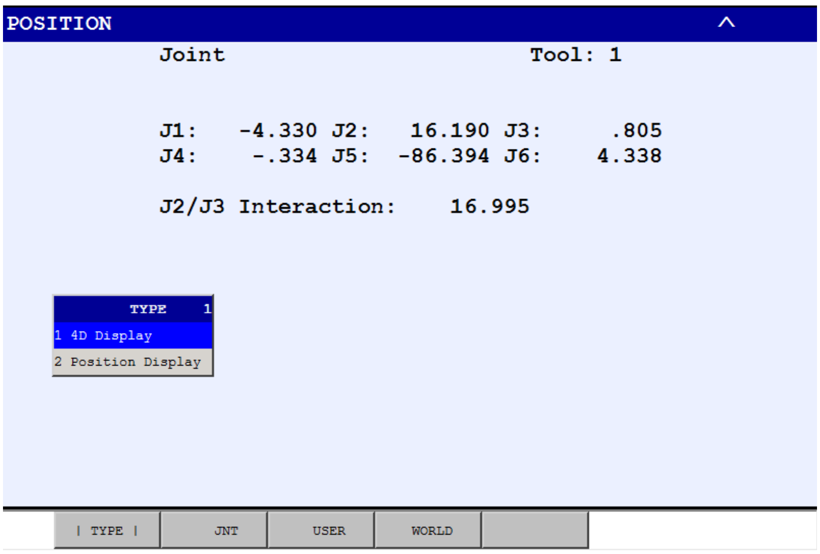



**Fig. 9.3.2 (b) Selecting the 4D graphic screen from the Position Display screen**

Then, press F1 "TYPE" and select "4D Force Sensor". The "4D GRAPHICS Force Sensor" screen appears. When the screen is already open, it opens again. The Force Sensor 4D graphic function reads the force data file selected as described in Section 9.2 and displays the force.

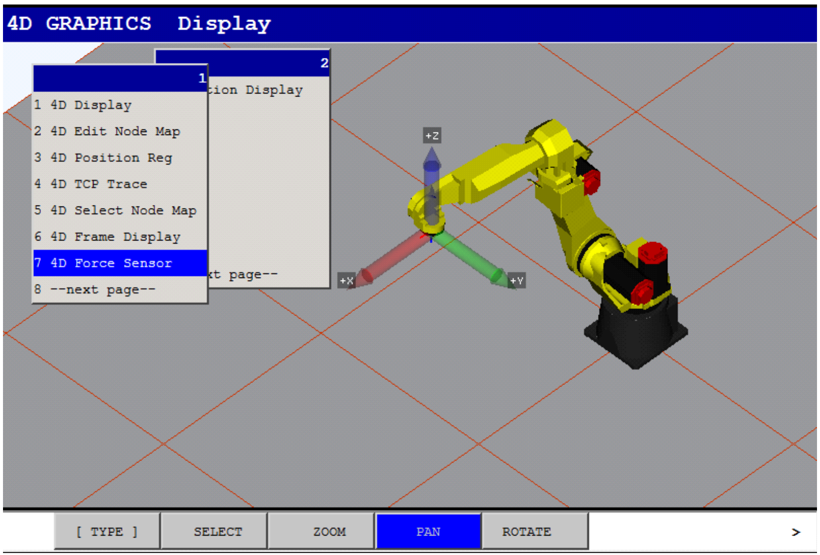



**Fig. 9.3.2 (c) Selecting the 4D GRAPHICS Force Sensor screen from the list of 4D GRAPHICS screens**

**NOTE**

- If no force data is recorded in the force data file, the function does not display force data and issues alarm FORC-457.
- Up to 500 lines can be displayed. The 501st and subsequent lines are not displayed and alarm FORC-458 is issued.

# 10 TROUBLESHOOTING

This chapter explains action to be taken when alarms are issued.

**CONTENTS**



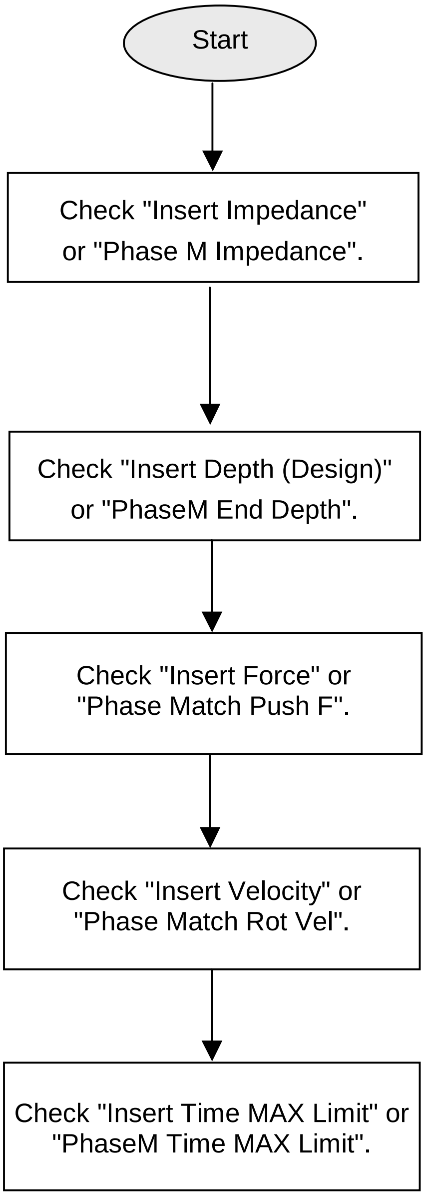
## 10.1 COMMON ACTION TO ALL ALARMS

If alarm is issued during force control, check the following items at first:

- Are the tool frame and user frame correct? →See Section 3.2, "TEACHING PROCEDURE".
- Is the hand grasping a workpiece tightly? →See Section 3.1, "NOTES/RESTRICTIONS".
- Is the approach point taught correctly? →See Section 3.2, "TEACHING PROCEDURE".

# 10.2 WHEN A TIMEOUT ERROR OCCURS

Unless force control terminates within a set time, an alarm is issued. Alarms of this type include alarm No. 275, "STOP.G Phase matching timeout", issued in case of phase matching function and alarm No. 264, "STOP.G Insertion timeout error", issued in case of insertion function. If such an alarm is issued, check the following:




Force Control Gain Auto Tuning has to be done before execution. Refer to 3.9.2 “Force Control Gain Auto Tuning Instruction”.
As it tends to set conservative value for this parameter, manual tuning may help.

Increase this value by about 10% until the robot starts vibration. If it vibrates, decrease them by 10% and stop adjusting it.

Operation must be unsuccessful if this value is greater than the depth that the workpiece can be actually inserted. Confirm whether this value is correct or not.
Besides, the actual insert depth until alarm occurs can be confirmed.
Refer to Subsection 4.2.2, “Execution histories with alarms” for further details

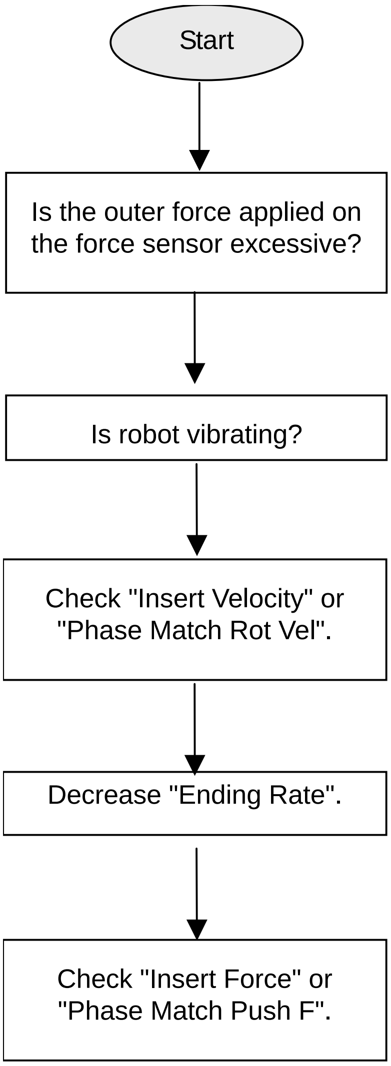
Operation may be unsuccessful if the pushing force during insertion or phase matching operation is too weak.
Increase the value of "Insert Force" or "Phase Match Push F" in steps of about 10 %.
Increase the value within the range that does not damage a workpiece.

A longer time is required if the insert velocity or phase matching rotation velocity is small.
Increase the value of "Approach Velocity", "Insert Velocity", or "Phase Match Rot Vel" in steps of about 10 %.

Operation may be unsuccessful if "Time MAX Limit" is too small.
Set longer time enough to allow insertion or phase matching.

# 10.3 WHEN A FORCE LIMIT ALARM OCCURS

There are several types of force limit alarms including alarm No.159, 175, 216, 217, 218, 219, 220, 221, and 544.




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 Subsection 4.2.2, “Execution histories with alarms” for further details.
Further more, the force and moment during the force control may be graphically displayed. Refer to Section 4.3, “Force Data Log Function” for further details.

When a function other than contouring function is used, retry automatic force control gain auto tuning. (See Subsection 3.9.2.)
If robot still vibrates or contouring function is in use, decrease the force control gain manually. (For the value change direction, see Section 3.6.)

The value of "Insert Velocity" or "Phase Match Rot Vel" 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" or "Phase Match Push F" is too large, the force limit alarm may often be issued.
Decrease the value in steps of about 10%.

Particularly when one of the alarms from No. 216 to No. 221 is issued, increase the value of "Force Limit" on the performance screen.

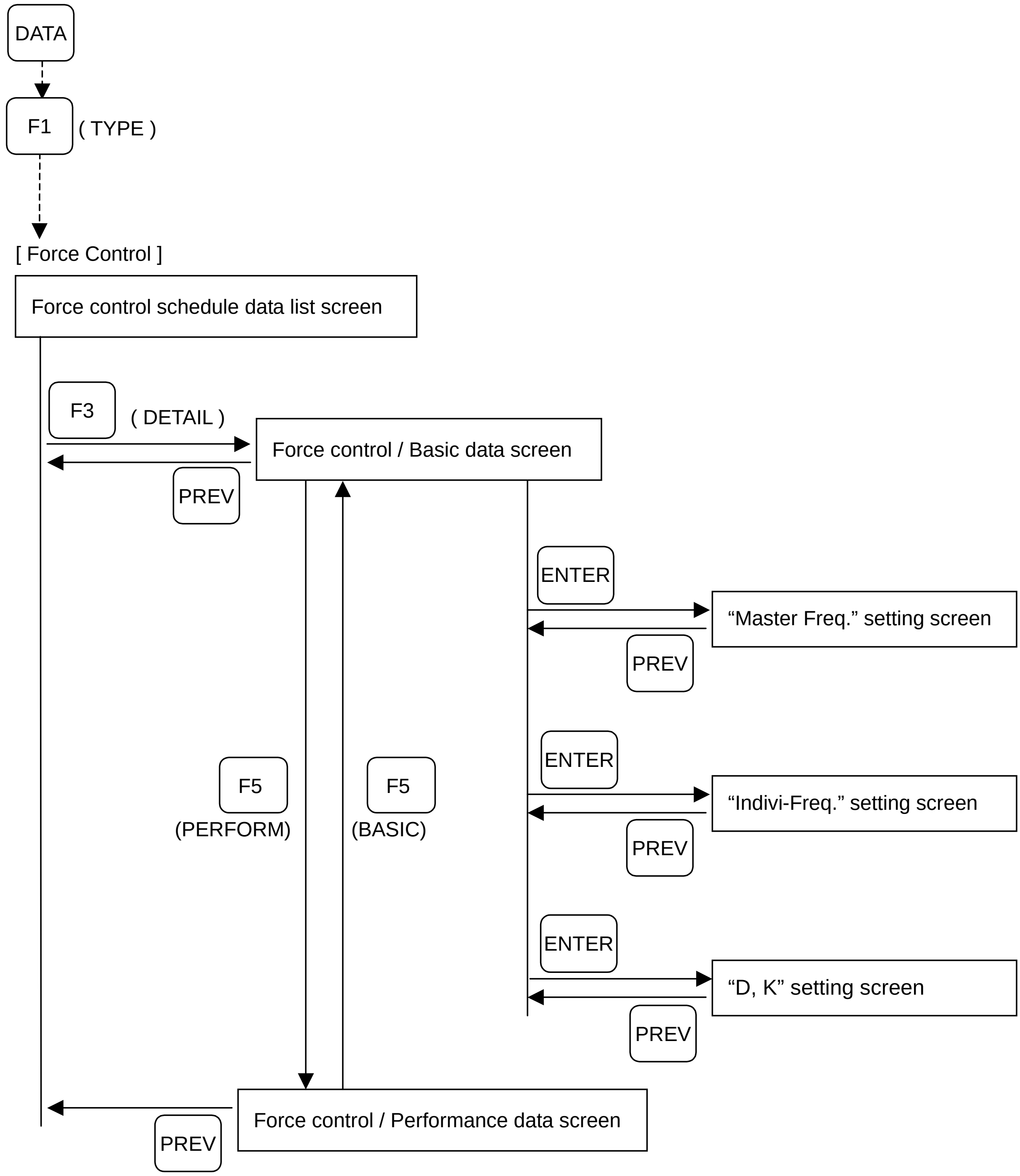
When an alarm is issued, change the value of the corresponding component as follows:

- Change the value of the X component when alarm No. 216 is issued.
- Change the value of the Y component when alarm No. 217 is issued.
- Change the value of the Z component when alarm No. 218 is issued.
- Change the value of the W component when alarm No. 219 is issued.
- Change the value of the P component when alarm No. 220 is issued.
- Change the value of the R component when alarm No. 221 is issued.

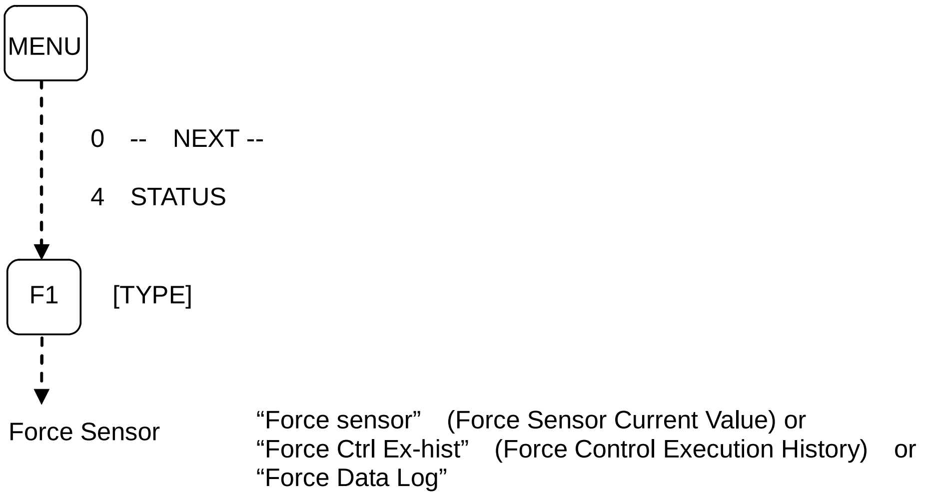
# APPENDIX

# A FORCE CONTROL MENU MAP

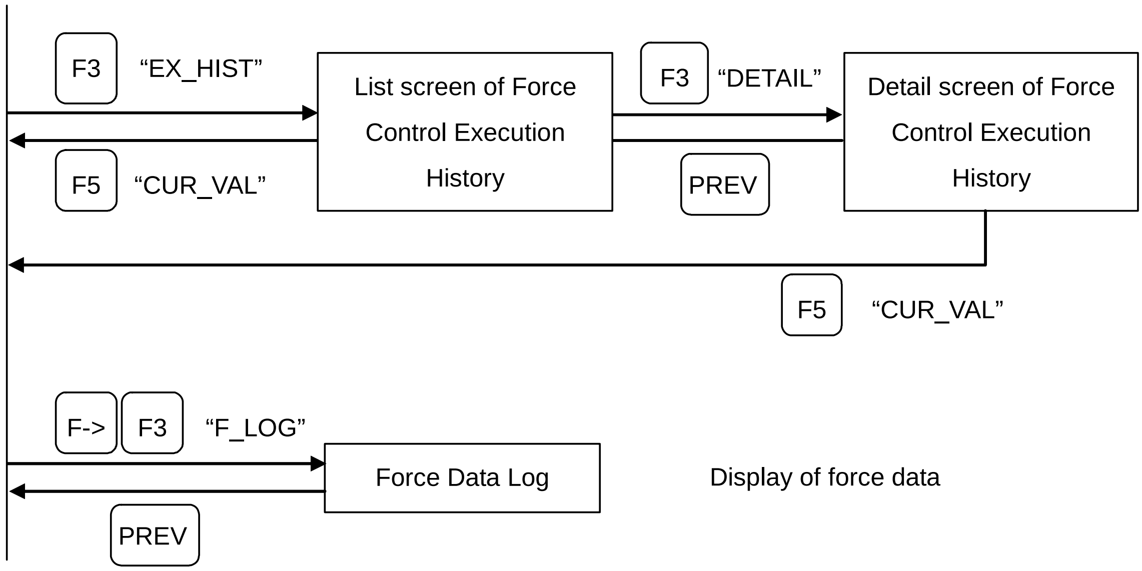
## Force Control schedule data screen



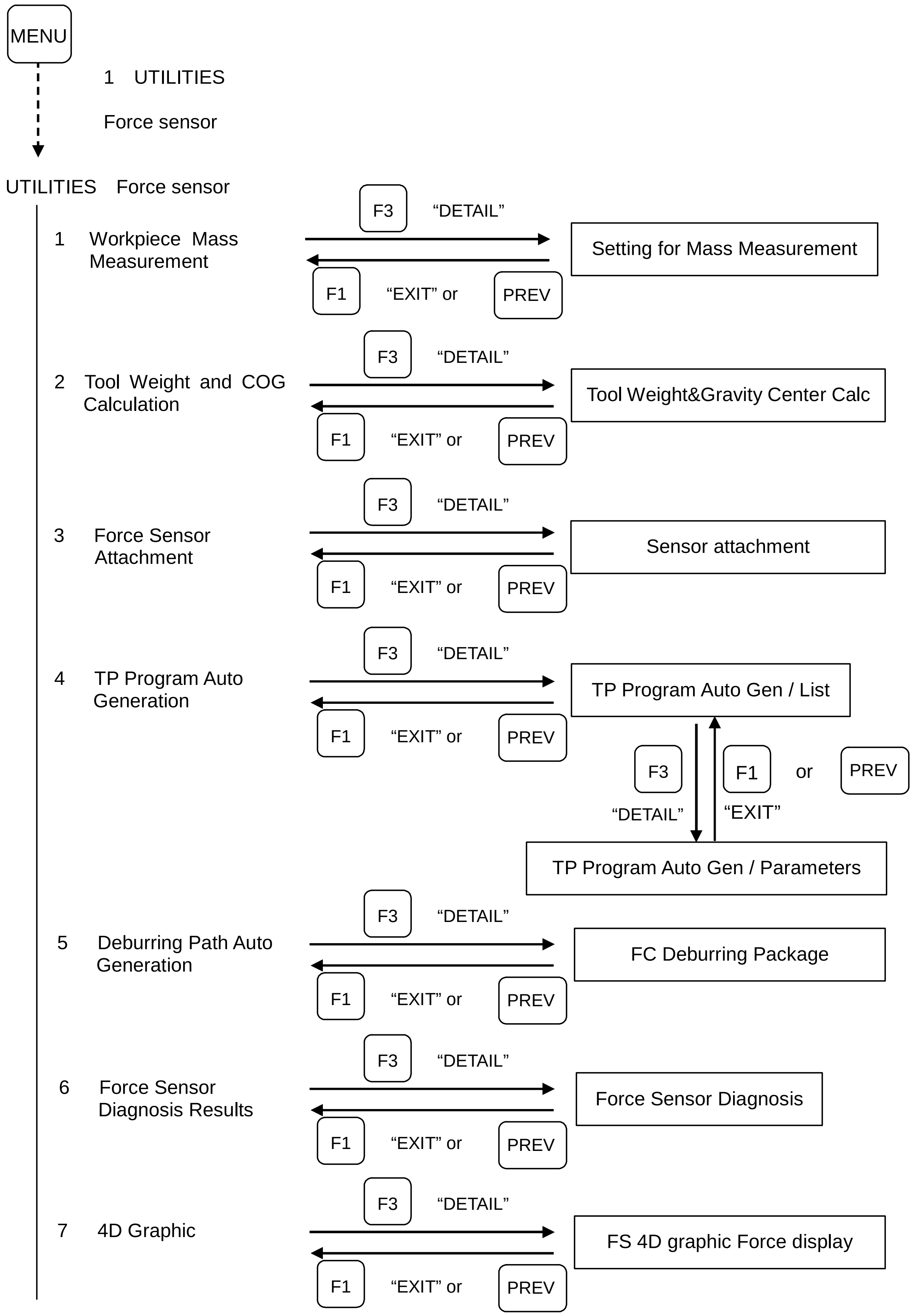
## Force Sensor Status screen




"Force sensor" (Force Sensor Current Value)



## Force Sensor Utilities screen



# B ALARM CODES OF FORCE CONTROL

### FORC-001 Sensor board doesn't exist
**Cause:** Software internal error
**Remedy:** 1. Turn the controller OFF then ON again. If it occurs again, replace the R-30*i*B controller's main board.
2. Contact the FANUC service center and report the error status.

### FORC-004 Communication error
**Cause:** Software internal error
**Remedy:** 1. Turn the controller OFF then ON again. If it occurs again, replace the R-30*i*B controller's main board.
2. Contact the FANUC service center and report the error status.

### FORC-005 Robot not mastered
**Cause:** Robot mastering is not completed.
**Remedy:** Perform mastering.

### FORC-006 Sensor board is disabled 2
**Cause:** Software internal error
**Remedy:** 1. Turn the controller OFF then ON again. If it occurs again, replace the R-30*i*B controller's main board.
2. 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 controlle
**Remedy:** Install the software option (force control fitting). 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:** 1. Turn the controller OFF then ON again. If it occurs again, replace the R-30*i*B controller's main board.

### FORC-013 Communications error
**Cause:** Software internal error
**Remedy:** 1. Turn the controller OFF then ON again. If it occurs again, replace the R-30*i*B controller's main board.
2. 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:** Check the surroundings for abnormalities.
If no abnormality is found, reset the alarm then reexecute, or turn off the power then turn on the power again.
If normal execution is still disabled, contact the FANUC service center and report the error status.

### FORC-022 OFFSET/VOFFSET not executed

**Cause:** FORCE CTRL instruction was executed before OFFSET CONDITION or VOFFSET CONDITION instruction needed for vision compensation. The vision register index may be inappropriate.

**Remedy:** Add OFFSET CONDITION or VOFFSET CONDITION instruction before FORCE CTRL instruction.
Confirm that the vision register index is appropriate.

### 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:** Check the items 1 to 5 shown below.

1. Your software contains J518 option.
2. Selected number axis is connected.
3. Selected number axis is not integrated.
4. Selected number axis is rotary axis
5. Selected number axis is able to rotate continuously.

### FORC-034 Vision Reg non-existent

**Cause:** The software option required for the Vision register is not incorporated into the controller, although “Vision Compensation SW” in Performance screen is “VISION REG”.

**Remedy:** 1. Set “OFF” or “POS REG” to “Vision Compensation SW” in Performance screen.
2. Install the software option for the Vision register. Contact the FANUC service center.

### FORC-035 Vision OFFSET is invalid

**Cause:** Vision OFFSET is invalid although “Vision Compensation SW” in Performance screen is “VISION REG”.

**Remedy:** Press MENUS button on the teach pendant and select “SETUP” --> F1 “General”. Move the cursol to “Enable VOFFSET” and select F4 “ENABLED”.

### FORC-036 Vision Register wrong Type

**Cause:** The software option required for the Vision register is not incorporated into the controller, although “Vision Compensation SW” in Performance screen is “VISION REG”.

**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:

1. In case of fixed force sensor, refer to Section C.4, “FIXING FORCE SENSOR ON THE WORKING TABLE”, and set sensor frame.
2. In case of hand sensor, refer to Section C.5, “CHANGING ONLY SENSOR ATTACHMENT TYPE”, and change sensor attachment type.

### FORC-039 Please reboot controller

**Cause:** After setting sensor frame by “FORCE SENSOR ATTACHMENT SETTING FUNCTION”, reboot is necessary.

**Remedy:** Reboot 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 Section 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 ForceSensor can't be connected

**Cause:** Force Sensor can't be connected.

**Remedy:** Do not execute “SENSOR CONNECT” while the robot is moving.

### FORC-051 ForceSensor can't be disconnected

**Cause:** Force Sensor cannot be disconnected.

**Remedy:** Do not execute “SENSOR DISCONNECT” while the robot is moving.

### FORC-052 ForceSensor 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-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 program has not been existed in this system.
**Remedy:** Create this instruction in 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-114 Converted individual difference

**Cause:** Because the “Ending Condition Switch” in Performance data is changed, “Individual diff. (-)” in Basic data is converted.
**Remedy:** Verify “Individual diff.(-)” in Basic data.

### FORC-115 Insert direction is changed

**Cause:** “Insert Direction” in Basic data is changed because the modified “Bearing Rotation Axis” is the same as “Insert Direction” and this case cannot be realistically.
**Remedy:** Verify “Insert Direction” in Basic data.

### 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:** Verify "Insert Direction" in Basic data.

### 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:** In successive execution of force control, an attempt was made to set in "Customize Parent Number" in the performance data of a schedule set for retry (draw) operation the number of another schedule, but that schedule already had a child schedule for retry (draw) operation.

**Remedy:** For a schedule, only one child schedule for retry (draw) operation can be specified. Make one of the following changes:

1. 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.
2. When the specified parent schedule number is incorrect
Correct the parent schedule number.

### FORC-121 Customize exceed ins-child num

**Cause:** In "Customize Parent Number" in the performance data of a schedule set for insertion, an attempt was made to set the number of another schedule, but that schedule already had a child schedule for insertion.

**Remedy:** For a schedule, only one child schedule for insertion can be specified. Make one of the following changes:

1. 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.
2. When the specified parent schedule number is incorrect
Correct the parent schedule number.
3. 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.

1. 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.
2. When a wrong schedule number is specified. Specify correct schedule data for insertion.
3. 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 syncro change OK

**Cause:** This is not an error. Parameters are copied between schedule data having a parent-child relationship.

**Remedy:** Because this it 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 it 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, Vision Compensation etc. Refer to subsection 3.7.5, "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:** An attempt was made to set a parameter for the insertion direction on the search basic screen or search performance screen of the "Search" function. This alarm is issued only in the "Search" function.

**Remedy:** On the search basic screen and search performance screen, no parameter can be set for the insertion direction. 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 Can not execute Gain Tuning

**Cause:** Force Control Gain Auto Tuning Instruction was executed when the robot is not prepared.

**Remedy:** Move the robot in X, Y and Z directions with about several hundred mm/s and get back to original position. Execute Force Control Gain Auto Tuning Instruction again.

### 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:**
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. If this alarm occurs again, go to the next step.
3. A sudden acceleration may have caused this error. Lighten the tool that is attached to the force sensor or decrease the TCP speed and acceleration where this 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:**
1. Make sure that the robot is not in touch with any object. If it is, it may have collided with it.
2. If it does not contact anything, a sudden acceleration might have caused this error. Lighten the tool or decrease the TCP speed and acceleration.
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. Decrease the tool rotation speed, if possible.
4. Make sure that the value of "Insert Force" in Basic data is too big. If not, go to the next step.
5. The robot might have vibrated due to a big "force control gain". Decrease the value of Master Frequency of "force control gain" gradually.
6. Move the robot to a base position and clear the force sensor output from a "Force Sensor Current Value Screen"(Refer to section 4.1). Make sure to check the force sensor by executing Force Sensor Diagnosis instruction (Refer to subsection 3.10.1).

### 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:** 1. Make sure that the sensor cable is properly connected to the force sensor.
2. Replace the sensor cable.
3. Replace the force sensor head.

### FORC-161 F/S calibration data not loaded

**Cause:** Calibration data has not been loaded correctly.

**Remedy:** 1. Controlled start the controller.
2. Load the force sensor calibration data, then cold start the controller.

### FORC-162 F/S temperature data overflow (F:%d^1)

**Cause:** Temperature output error occurred in the sensor head.

**Remedy:** 1. Move the robot to the position that it does not contact any object.
2. Turn the controller OFF then ON again. If this alarm occurs again, go to the next step.
3. 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:** 1.Check the temperature around the sensor head. If it is not so low, go to the next step.
2. Make sure that the sensor cables are connected correctly, no lines are cut. If there is nothing wrong, go to the next step.
3. Replace the R-30*i*B controller’s main board. If this alarm occurs again, go to the next step.
4. 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:** 1.Check the temperature around the sensor head. If it is not so high, go to the next step.
2. Make sure that the sensor cables are connected correctly, no lines are cut. If there is nothing wrong, go to the next step.
3. Replace the R-30*i*B controller’s main board. If this alarm occurs again, go to the next step.
4. 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:** 1.Check the force sensor output data on TP (Force sensor status screen). It is O.K. if the values change every moment. If the values keep same values, go to the next step.
2. Make sure that the sensor cables are connected correctly, no lines are cut. If there is nothing wrong, go to the next step.
3. Check a fuse in multiplexer if 3DL is also installed.
4. Replace theR-30*i*B controller’s main board. If this alarm occurs again, go to the next step.
5. 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:** 1. Check the position of the approach point so that the robot does not contact to the object.
2. 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. Set ON to “Force Denoising Sw” in the Performance data setting screen.
3. The robot might have vibrated due to a big “force control gain”. Decrease the value of Master Frequency of “force control gain” gradually.
4. Decrease the value of “Insert Force” or “Pushing Force” in Basic data.
5. In case of “Contour” function, increase the values of “Force Change Limit” in the Performance data setting screen.

### FORC-180 F/S ITP counter error (F:%d^1)

**Cause:** Communication failed.

**Remedy:** 1. Move the robot to the position that it does not contact any object.
2. Turn the controller OFF then ON again. If this alarm occurs again, go to the next step.
3. Make sure that the sensor cables are connected correctly, no lines are cut. If there is nothing wrong, go to the next step.
4. Replace the R-30*i*B controller’s main board. If this alarm occurs again, go to the next step.

5. Replace the sensor head.

### FORC-181 Force sensor type error (F:%d^1)

**Cause:** The controller can not judge Force sensor type properly.

**Remedy:** 1. Turn the controller OFF then ON again. If this alarm occurs again, go to the next step.
2. Check the sensor cable connectivity. Check also for cut lines.
3. Replace the sensor head.

### FORC-183 Mass Measure execution error

**Cause:** The values of "Reg. No. Basis Measure", "Reg. No. Mass Measure","Reg. No. Mass Result" are illegal for "Mass Measurement by a Force Sensor" (Chapter 8). Or "Mass Measurement" and "Force Control" were executed simultaneously.

**Remedy:** 1. 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.
2. Check if "Reg. No. Basis Measure", "Reg. No. Mass Measure","Reg. No. Mass Result" are different.
3. Check if "Reg. No. Basis Measure", "Reg. No. Mass Measure","Reg. No. Mass Result" are positive integers.
4. Don’t execute "Basis Measurement" and "Mass Measurement" simultaneously.
5. Don’t execute "Mass Measurement" and "Force Control" simultaneously.

### FORC-184 Mass Measure timeout error

**Cause:** The elapsed time of "Basis Measurement" and "Mass Measurement" exceeded "Max. Data Record Time" for "Mass Measurement by a Force Sensor" (Chapter 8).

**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:** There are two kinds of singularity orientation which causes this alarm.
J5 angle is 0 degree.
J2, J3 and J5 are on a line.
Be sure to execute the force control by a position and an orientation away enough 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 some joints have approached the stroke limit.

**Remedy:** Avoid executing the force control when each joint comes near the stroke limit.

### 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 force exceeds the limit.

**Remedy:** Check items 1 through 6 sequentially.
1. Check the position of the approach point so that the robot does not contact to the object.
2. 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. Set ON to “Force Denoising Sw” in the Performance data setting screen.
3. The robot may have vibrated due to an inappropriate “Force Control Gain”. Decrease “Master Frequency” of the “Force Control Gain” gradually.

4. If the velocity in insertion direction is too fast, the impact force may have exerted. Decrease the value of "Insert Velocity" on the basic screen in steps of 10%.
5. Decrease the value of "Insert Force" on the basic screen in steps of 10%.
6. Increase the X component of "Force Limit", "Phase M Force Limit" or "Insert Force Limit" on the performance screen in steps of 10%.

### FORC-217 Y Force Limit (F:%d^1)

**Cause:** The Y component of force exceeds the limit.
**Remedy:** Similar to FORC-216.

### FORC-218 Z Force Limit (F:%d^1)

**Cause:** The Z component of force exceeds the limit.
**Remedy:** Similar to FORC-216.

### FORC-219 W Moment Limit (F:%d^1)

**Cause:** The W component of force exceeds the limit.
**Remedy:** Similar to FORC-216.

### FORC-220 P Moment Limit (F:%d^1)

**Cause:** The P component of force exceeds the limit.
**Remedy:** Similar to FORC-216.

### FORC-221 R Moment Limit (F:%d^1)

**Cause:** The R component of force exceeds the limit.
**Remedy:** Similar 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:**
1. Increase the insertion depth,
2. Increase “Pushing Time” or “Insert Time MAX Limit”,
3. Decrease “Min. Force Rate” of the performance data, or
4. Modify the force control gain setting.

Modify the schedule data as mentioned above or check the workpiece for abnormalities.

### 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:**
1. Modify the force control gain setting,
2. Increase “Max. Torque” of the performance data, or
3. Increase “Pushing Time” or “Insert Time MAX Limit”.

Modify the schedule data as mentioned above or check the workpiece for abnormalities.

### 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.

### FORC-263 Approach timeout error (F:%d^1)

**Cause:** The workpiece could not contact to the object in a limit time.

**Remedy:** 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 faster than the present value.
3. If you use “Auto. Follow” function, set the value of “Approach Velocity” in Basic data larger than the present value or check the approach direction and modify it or set the start point of force control closer to the target object. And if you change the start point, check and modify other teaching points appropriately.

### FORC-264 Insertion timeout error (F:%d^1)

**Cause:** Insertion could not finish in a limit time.

**Remedy:** In case of “Shaft Insert”, check the items 1 to 4 shown below.
1. The orientation of the robot change too much during the force control. If so, correct the approach position.
2. The clearance between the workpiece and the object is too small.
3. “Insert Velocity” in Basic data is too small.
4. “Insert time MAX Limit” in Basic data is too short.
In case of “Phase Search”, check the items 5 to 7 shown below.
5. “PhaseMatch Ang. Limit” in Basic data is too small.
6. “PhaseMatch Push Force” in Basic data is too small.
7. “PhaseMatch Torque” in Basic data is too small.
In case of “Hole Search” or “Clutch Search”, check the items 8 to 10 shown below.
8. “Size of Search Range” in Search parameters Basic screen is too small.
9. “Search Push Force” in Basic data is too small.
10. “Target Force” or “Target Torque” in Search parameters Basic screen is too small.

### 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:** 1. Check the orientation of workpiece is correct.
2. Check “Change MAX Limit” in Basic data is too small.
3. If you use “Face Match” function of the contouring function, check the value of “Orient.Chg. UpperLim” or check teaching points or check the situation of the tool or the work-piece.

### 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 items 1 to 5 shown below.
1. The screw can be tighten by the hand until the insert depth overreach the “Minimum depth”.
2. “Target torque” in Basic data is too small.

### FORC-267 Rotation timeout error (F:%d^1)

**Cause:** Threading could not finish in a limit time.

**Remedy:** Check the items 1 to 5 shown below.
1. The screw can be tighten by the hand.
2. The orientation of the robot change too much during the force control. If so, correct the approach position.
3. “Rotation Velocity” in Basic data is too small.
4. “Rotation Time Limit” in Basic data is 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 schedule with “Simple Customize Sw” ON is executed more times than the value of “Cont. Exec. Max. Count”.

**Remedy:** 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:** 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-275 Phase matching timeout (F:%d^1)

**Cause:** Insertion time exceeded the upper limit during the phase match insertion.

**Remedy:** 1. Make the value of “PhaseMatch Ang. Vel” in Basic data larger than the present value.

2. Make the value of “PhaseMatch Torque” in Performance data larger than the present value.

3. Phase match insertion works well in a range of approximately 20 degrees. Make sure that the phases of the workpiece and the object match in this rotation.

4. Check that the clearance of the workpiece and the object might be too small.

### 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:** 1. Check that the distance between the approach point and the Insertion finishing point is appropriate.

2. Check that the value of “Insert Depth(Design)” in Basic data is appropriate.

3. Make the value of “Individual diff.(+)” in Basic data larger than the present value.

### 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:** 1. If an error occurs, correct the cause of the error then restart after returning to the contouring start point.

2. If an emergency stop occurs, make a reset then restart after returning to the contouring start point.

3. If a jog operation is executed, restart after returning to the contouring start point.

### FORC-280 Cntr. Prohibited Com bi. Err.

**Cause:** Prohibited combination is executed.

**Remedy:** Do not execute the contouring with prohibited combnation.
Prohibited combination:

- “Pushing Dir Auto Chg” and “Successive Execution of Force Control Instructions (Customization Function)”
- “Chk Push Chg Trav Vel” and “Deact.PushDirMotion” or “Change Push. Force” or “Monit Push Dir Depth”
- “Monit Min Push F” and “Deact.PushDirMotion” or “Change Push. Force” or “Monit Push Dir Depth”
- “Monit Push Dir Depth” and “Deact.PushDirMotion” or “Successive Execution of Force Control Instructions (Customization Function)” or “Chk Push Chg Trav Vel” or “Monit Min Push F”
- “The function of Changing a target pushing direction(FCNCHCFR)” and “Successive Execution of Force Control Instructions (Customization Function)”
- “Face Match” function and（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)”）
- “Auto.Follow” and（“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:** 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 (see Subsection 3.7.2) cannot be executed.

**Remedy:** Modify the force control gain manually. For the method of setting, see Section 3.6, "FORCE CONTROL GAIN (IMPEDANCE PARAMETERS)". Increase the master frequency from about 0.5 Hz in steps of 0.25 Hz for LRMate, M-10iA or M-20iA series robot. Increase the master frequency from about 0.1 Hz in steps of 0.1 Hz for M-710iC, R-1000iA, R-2000iB or R-2000iC series robot.If even a slight vibration is observed, do not increase the gain any more.

### FORC-286 Cntr. UF Fixed Combi. Err.

**Cause:** “Control frame” is set to “User Frm Fixed” and the combination is prohibited.

**Remedy:** Change “Control frame” in Basic data except “User Frm Fixed”.

### 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:** 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 message does not indicate an error but indicates the start of contouring with parameters changed by the changing parameters functions. These functions are addressed under the subsection 3.5.7.7, "Other functions of the contouring function".

### FORC-291 Contour.Param.Change.Err.

**Cause:** The values for changing parameters during a contouring are inappropriate.
**Remedy:** 1. Check that the values for changing are appropriate.
2. Check whether the functions those cannot be used together are valid or not. (See Subsection 3.5.8.7)

### FORC-292 2 Dir. Push Func. error

**Cause:** The values for "2 Dir Push Func" are inappropriate.
**Remedy:** 1. When "Chk Push Chg Trav Vel Sw" is "Dir 2" or "Dir 1&2", make "2 Dir Push Func" valid
2. When “Monit Min Push F Sw" is "Dir 2" or "Dir 1&2", make "2 Dir Push Func" valid
3. When "2 Dir Push Func" is valid, make the value of "Contouring Force 2" 0.01 N or larger.
4. When "2 Dir Push Func" is valid, "Pushing Dir Auto Chg" is valid and control frame is user frame, make the pushing direction ±Z.
5. 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:** Contact your local FANUC representative.

### FORC-294 Auto.Cntr. Set. error

**Cause:** Setting values for “Auto.Follow” are inappropriate.
**Remedy:** 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:** 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:** 1. Change the register number of function which is valid in contouring.
2. The register number shall be 1 and more to max number of register or less.
3. 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:** “Face Match” can be executed only with LRMate200iD, M-710iC/20L.
“Auto.Follow” can be executed only with LRMate200iD.
**Remedy:** “Face Match” can be executed only with LRMate200iD, M-710iC/20L.
“Auto.Follow” can be executed only with LRMate200iD.

### FORC-330 Auto.Follow Move UpperLim err

**Cause:** Reached the moving upper limit during a contouring with “Auto.Follow”.
**Remedy:** 1. Check the setting values of Move UpperLim. 1(Dist.From Strt.CtP), Move UpperLim. 2(Total Move Dist.), Move UpperLim. 3(Total Move Time).
2. 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:** 1. Check that gravity compensation is valid and at the beginning of the contouring the robot is not in contact with surroundings.
2. Change the starting point. Change the force control gain.
3. Under present circumstances, the robot can not follow the work-piece appropriately.

### FORC-332 Auto.Follow Continuing err

**Cause:** The robot could not follow the work-piece appropriately during a contouring with “Auto.Follow”.
**Remedy:** 1. Check that gravity compensation is valid and at the beginning of the contouring the robot is not in contact with surroundings.

2. Change the starting point. Change the force control gain.
3. Under present circumstances, the robot can not follow the work-piece appropriately.

### FORC-333 Cntr.TPP.Gen. GetPointNum Over

**Cause:** The number of getting position exceeds the upper limit during a contouring with “TPProgramAuto.Gen.”.

**Remedy:** 1. Check the parameters in TPProgramAuto.Gen.Param. designated by “TPProgramAuto.Gen.Param.No.” and set the parameters appropriately.

2. 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 does not indicate an error.

### FORC-420 Search Retry Limit (F:%d^1)

**Cause:** The upper limit of the number of search operations is exceeded. This alarm is issued in "Search", "Phase Search", "Hole Search", and "Clutch Search".

**Remedy:** 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.

### FORC-421 Search Range over (F:%d^1)

**Cause:** 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".

**Remedy:** 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. When the upper limit of the search range has been reached, search operation may terminate normally by reversing the advance direction instead of alarm issuance. If the cycle time is not tight, reverse the advance direction. Set "Reverse Switch" to ON.

### FORC-422 Search Frc/Vel wrong (F:%d^1)

**Cause:** 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".

**Remedy:** 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": On the search basic screen, "Target Force" (when the search direction is X, Y, or Z) or "Target Torque" (when the search direction is W, P, or R), or "Target Velocity" (when the search direction is X, Y, or Z) or "Target Angular Velocity" (when the search direction is W, P, or R)

For "Phase Search": On the basic screen, "PhaseMatch Torque" or "PhaseMatch Ang. Vel"

For "Hole Search": On the search basic screen, "Target Force" or "Target Velocity"

### FORC-423 Search Vel order error (F:%d^1)

**Cause:** The "Velocity Order" parameter value is illegal. This alarm is issued in "Search", "Hole Search", and "Clutch Search".

**Remedy:** 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. The "Velocity Order" parameter is displayed on the search basic screen.

### FORC-424 Search direction error (F:%d^1)

**Cause:** Search directions are invalid.

**Remedy:** Set different direction to the search direction 1 and 2 for 'cylinder hole search' and 'clutch ins.'.

### 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:** Set the parameters so that "Size of Search Range" ≥ "Clearance & Chamfer" on the search basic screen.

### FORC-426 Search velocity Calc. error (F:%d^1)

**Cause:** The value of the "Search Frequency", "Size of Search Range", or "Clearance & Chamfer" parameter is illegal. This alarm is issued in "Search", "Hole Search", and "Clutch Search".

**Remedy:** On the basic screen, set "Search Frequency" to a non-zero value.
On the search basic 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" parameter setting is illegal. This alarm is issued in "Search", "Hole Search", and "Clutch Search".

**Remedy:** When search operation is performed in more than one direction, the reverse switches for all directions except the direction with the largest value set as the velocity order (the direction of the slowest operation) must be set to ON. 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)

**Cause:** The absolute value of the automatically calculated velocity is too large. This alarm is issued in "Search", "Hole Search", and "Clutch Search".

**Remedy:** 1. Decrease "Search Frequency" on the basic screen.
2. Decrease "Size of Search Range" on the search basic screen.
3. Decrease "Clearance & Chamfer" on the search 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.

### 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-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-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:** If the force schedule is other than [Contour], make the absolute value of “Insert Force” or “Pushing Force” in Basic data 0.3 N or larger.
If the force schedule is [Contour], make the absolute value of “Contouring Force” in Basic data 0.01 N or larger.

### FORC-485 Setting torque error failed (F:%d^1)

**Cause:** Failed to acquire the torque error data.
**Remedy:** 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 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:** Make the sign of “Initial Insert Force” in Performance data same as the sign of “Insert Force” in Basic data.

### FORC-495 Illegal velocity adjust gain (F:%d^1)

**Cause:** “Velocity Adjust Gain” in Performance data is not appropriate.
**Remedy:** Set the value of 0 – 3 to “Velocity Adjust Gain” in Performance data.

### FORC-496 Illegal starting rate (F:%d^1)

**Cause:** “Starting Rate” in Performance data is not appropriate.
**Remedy:** Make the value of “Starting Rate” in Performance data larger than 12.5.

### FORC-497 Illegal ending rate (F:%d^1)

**Cause:** “Ending Rate” in Performance data is not appropriate.
**Remedy:** Make the value of “Ending Rate” in Performance data smaller than 95.

### 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 the value of 0 – 10000 to “Individual Diff.(+)” in Basic data.

### FORC-508 AIT X direction environment NG (F:%d^1)

**Cause:** An environmental characteristic in the X direction could not be acquired in the impedance parameters auto tuning.
**Remedy:** Modify the force control parameters in the following order, and execute the impedance parameters auto tuning again.

1. Impedance change for the environmental characteristic acquisition might be too rough. Enlarge the system variable, $CCSCH_GRPxx[i].$TD.$NUM_KEI[1] more than a present value. {Schedule number is calculated to "(xx-10)*5+i" by "xx" and "i" of $CCSCH_GRPxx[i]. Modify the appropriate $CCSCH_GRPxx[i].}
2. Desired force might be too small. Increase the desired force by several percents.
3. Desired force might be too large. Decrease the desired force by several percents.

### FORC-509 AIT Y direction environment NG (F:%d^1)

**Cause:** An environmental characteristic in the Y direction could not be acquired in the impedance parameters auto tuning.

**Remedy:** Modify the force control parameters in the following order, and execute the impedance parameters auto tuning again.

1. Impedance change for the environmental characteristic acquisition might be too rough. Enlarge the system variable, $CCSCH_GRPxx[i].$TD.$NUM_KEI[1] more than a present value. {Schedule number is calculated to "(xx-10)*5+i" by "xx" and "i" of $CCSCH_GRPxx[i]. Modify the appropriate $CCSCH_GRPxx[i].}
2. Desired force might be too small. Increase the desired force by several percents.
3. Desired force might be too large. Decrease the desired force by several percents.

### FORC-510 AIT Z direction environment NG (F:%d^1)

**Cause:** An environmental characteristic in the Z direction could not be acquired in the impedance parameters auto tuning.

**Remedy:** Modify the force control parameters in the following order, and execute the impedance parameters auto tuning again.

1. Impedance change for the environmental characteristic acquisition might be too rough. Enlarge the system variable, $CCSCH_GRPxx[i].$TD.$NUM_KEI[1] more than a present value. {Schedule number is calculated to "(xx-10)*5+i" by "xx" and "i" of $CCSCH_GRPxx[i]. Modify the appropriate $CCSCH_GRPxx[i].}
2. Desired force might be too small. Increase the desired force by several percents.
3. Desired force might be too large. Decrease the desired force by several percents.\

### FORC-511 AIT W direction environment NG (F:%d^1)

**Cause:** An environmental characteristic in the W direction could not be acquired in the impedance parameters auto tuning.

**Remedy:** Modify the force control parameters in the following order, and execute the impedance parameters auto tuning again.

1. Impedance change for the environmental characteristic acquisition might be too rough. Enlarge the system variable, $CCSCH_GRPxx[i].$TD.$NUM_KEI[1] more than a present value. {Schedule number is calculated to "(xx-10)*5+i" by "xx" and "i" of $CCSCH_GRPxx[i]. Modify the appropriate $CCSCH_GRPxx[i].}
2. Desired force might be too small. Increase the desired force by several percents.
3. Desired force might be too large. Decrease the desired force by several percents.

### FORC-512 AIT P direction environment NG (F:%d^1)

**Cause:** An environmental characteristic in the P direction could not be acquired in the impedance parameters auto tuning.

**Remedy:** Modify the force control parameters in the following order, and execute the impedance parameters auto tuning again.

1. Impedance change for the environmental characteristic acquisition might be too rough. Enlarge the system variable, $CCSCH_GRPxx[i].$TD.$NUM_KEI[1] more than a present value. {Schedule number is calculated to "(xx-10)*5+i" by "xx" and "i" of $CCSCH_GRPxx[i]. Modify the appropriate $CCSCH_GRPxx[i].}
2. Desired force might be too small. Increase the desired force by several percents.
3. Desired force might be too large. Decrease the desired force by several percents.

### FORC-513 AIT R direction environment NG (F:%d^1)

**Cause:** An environmental characteristic in the R direction could not be acquired in the impedance parameters auto tuning.

**Remedy:** Modify the force control parameters in the following order, and execute the impedance parameters auto tuning again.

1. Impedance change for the environmental characteristic acquisition might be too rough. Enlarge the system variable, $CCSCH_GRPxx[i].$TD.$NUM_KEI[1] more than a present value. {Schedule number is calculated to "(xx-10)*5+i" by "xx" and "i" of $CCSCH_GRPxx[i]. Modify the appropriate $CCSCH_GRPxx[i].}
2. Desired force might be too small. Increase the desired force by several percents.
3. Desired force might be too large. Decrease the desired force by several percents.

### FORC-514 AIT X direction unstable (F:%d^1)

**Cause:** Force of the X direction became excessive while acquiring an environmental characteristic in the impedance parameters auto tuning.

**Remedy:** Correct the error in the following order, and execute the impedance parameters auto tuning again.

1. Excessive force is generated during impedance parameters auto tuning. If there is any vibration source around the robot, stop the vibration source.
2. Desired force might be too small. Increase the desired force by several percents.

### FORC-515 AIT Y direction unstable (F:%d^1)

**Cause:** Force of the Y direction became excessive while acquiring an environmental characteristic in the impedance parameters auto tuning.

**Remedy:** Correct the error in the following order, and execute the impedance parameters auto tuning again.

1. Excessive force is generated during impedance parameters auto tuning. If there is any vibration source around the robot, stop the vibration source.
2. Desired force might be too small. Increase the desired force by several percents.

### FORC-516 AIT Z direction unstable (F:%d^1)

**Cause:** Force of the Z direction became excessive while acquiring an environmental characteristic in the impedance parameters auto tuning.

**Remedy:** Correct the error in the following order, and execute the impedance parameters auto tuning again.

1. Excessive force is generated during impedance parameters auto tuning. If there is any vibration source around the robot, stop the vibration source.
2. Desired force might be too small. Increase the desired force by several percents.

### FORC-517 AIT W direction unstable (F:%d^1)

**Cause:** Force of the W direction became excessive while acquiring an environmental characteristic in the impedance parameters auto tuning.

**Remedy:** Correct the error in the following order, and execute the impedance parameters auto tuning again.

1. Excessive force is generated during impedance parameters auto tuning. If there is any vibration source around the robot, stop the vibration source.
2. Desired force might be too small. Increase the desired force by several percents.

### FORC-518 AIT P direction unstable (F:%d^1)

**Cause:** Force of the P direction became excessive while acquiring an environmental characteristic in the impedance parameters auto tuning.

**Remedy:** Correct the error in the following order, and execute the impedance parameters auto tuning again.

1. Excessive force is generated during impedance parameters auto tuning. If there is any vibration source around the robot, stop the vibration source.
2. Desired force might be too small. Increase the desired force by several percents.

### FORC-519 AIT R direction unstable (F:%d^1)

**Cause:** Force of the R direction became excessive while acquiring an environmental characteristic in the impedance parameters auto tuning.

**Remedy:** Correct the error in the following order, and execute the impedance parameters auto tuning again.

1. Excessive force is generated during impedance parameters auto tuning. If there is any vibration source around the robot, stop the vibration source.
2. Desired force might be too small. Increase the desired force by several percents.

### FORC-520 AIT all switch OFF (F:%d^1)

**Cause:** The force control for all direction are disabled in the impedance parameters auto tuning.

**Remedy:** If the prepared default data of each application is used, this error should not occur. Try to copy the default data corresponding to the application onto the schedule data.

### FORC-521 AIT X direction fail (F:%d^1)

**Cause:** Impedance parameters auto tuning to the X direction could not be completed.

**Remedy:** Correct the error in the following order, and execute the impedance parameters auto tuning again.

1. If there is any vibration source around the robot, stop the vibration source.
2. Desired force might be too small. Increase the desired force by several percents.

### FORC-522 AIT Y direction fail (F:%d^1)

**Cause:** Impedance parameters auto tuning to the Y direction could not be completed.

**Remedy:** Correct the error in the following order, and execute the impedance parameters auto tuning again.

1. If there is any vibration source around the robot, stop the vibration source.
2. Desired force might be too small. Increase the desired force by several percents.

### FORC-523 AIT Z direction fail (F:%d^1)

**Cause:** Impedance parameters auto tuning to the Z direction could not be completed.

**Remedy:** Correct the error in the following order, and execute the impedance parameters auto tuning again.
1. If there is any vibration source around the robot, stop the vibration source.
2. Desired force might be too small. Increase the desired force by several percents.

### FORC-524 AIT W direction fail (F:%d^1)

**Cause:** Impedance parameters auto tuning to the W direction could not be completed.

**Remedy:** Correct the error in the following order, and execute the impedance parameters auto tuning again.
1. If there is any vibration source around the robot, stop the vibration source.
2. Desired force might be too small. Increase the desired force by several percents.

### FORC-525 AIT P direction fail (F:%d^1)

**Cause:** Impedance parameters auto tuning to the P direction could not be completed.

**Remedy:** Correct the error in the following order, and execute the impedance parameters auto tuning again.
1. If there is any vibration source around the robot, stop the vibration source.
2. Desired force might be too small. Increase the desired force by several percents.

### FORC-526 AIT R direction fail (F:%d^1)

**Cause:** Impedance parameters auto tuning to the R direction could not be completed.

**Remedy:** Correct the error in the following order, and execute the impedance parameters auto tuning again.
1. If there is any vibration source around the robot, stop the vibration source.
2. Desired force might be too small. Increase the desired force by several percents.

### FORC-527 AIT system error (F:%d^1)

**Cause:** Software internal error

**Remedy:** Contact the FANUC service center and report the error status.

### FORC-528 AIT system error (F:%d^1)

**Cause:** Software internal error

**Remedy:** Contact the FANUC service center and report the error status.

### FORC-529 AIT system error (F:%d^1)

**Cause:** Software internal error

**Remedy:** Contact the FANUC service center and report the error status.

### FORC-530 AIT system error (F:%d^1)

**Cause:** Software internal error

**Remedy:** Contact the FANUC service center and report the error status.

### FORC-531 AIT system error (F:%d^1)

**Cause:** Software internal error

**Remedy:** Contact the FANUC service center and report the error status.

### FORC-532 AIT system error (F:%d^1)

**Cause:** Software internal error

**Remedy:** Contact the FANUC service center and report the error status.

### FORC-533 AIT system error (F:%d^1)

**Cause:** Software internal error

**Remedy:** Contact the FANUC service center and report the error status.

### FORC-534 AIT system error (F:%d^1)

**Cause:** Software internal error

**Remedy:** Contact the FANUC service center and report the error status.

### FORC-535 AIT system error (F:%d^1)

**Cause:** Software internal error

**Remedy:** Contact the FANUC service center and report the error status.

### FORC-536 AIT system error (F:%d^1)

**Cause:** Software internal error
**Remedy:** Contact the FANUC service center and report the error status.

### FORC-538 AIT system error (F:%d^1)

**Cause:** Software internal error
**Remedy:** Contact the FANUC service center and report the error status.

### FORC-539 AIT system error (F:%d^1)

**Cause:** Software internal error
**Remedy:** Contact the FANUC service center and report the error status.

### FORC-540 AIT system error (F:%d^1)

**Cause:** Software internal error
**Remedy:** Contact the FANUC service center and report the error status.

### FORC-541 AIT system error (F:%d^1)

**Cause:** Software internal error
**Remedy:** Contact the FANUC service center and report the error status.

### FORC-542 Rotate angle limit (F:%d^1)

**Cause:** Rotation angle exceeded the upper limit during the phase match insertion.
**Remedy:** 1. Make the value of “PhaseMatch Push Force” in Basic data larger than the present value.
2. Check that the clearance of the workpiece and the object might be too small.

### FORC-543 AIT system error (F:%d^1)

**Cause:** Software internal error
**Remedy:** Contact the FANUC service center and report the error status.

### FORC-544 clutch ins. force lim. (F:%d^1)

**Cause:** Force exceeded the limit during clutch ins.
**Remedy:** decrease the amplitude of the search check if the approach point is in a center.

### FORC-545 clutch ins. & tuning (F:%d^1)

**Cause:** tried to make auto tuning for clutch ins.
**Remedy:** auto tuning for clutch ins. is prohibited.

### 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:** 1. When specification of the parent-child relationship was neglected
Before execution, specify the first force control instruction as the parent in a force control parameter of the force control instruction executed second (set the schedule data number of the first force control instruction in parameter 3, "Customize Parent Number", on the performance screen).
2. When two force control instructions are executed independently of each other
When the individual force control instructions are executed independently, it is necessary to make a movement to the position at which force control starts (the approach point) before the second force control instruction is executed. Teach the approach point.

### 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:** 1. 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.

2. When child force control is executed to perform retry operation, the user frame and tool frame of the child force control must be the same as those of the parent, and the specified insertion direction must be opposite to that of the parent. Check the frames and insertion direction on the basic 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 items:

1. Robot is mastered.
2. Force sensor calibration data is loaded.
3. 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-631 Force sensor is abnormal

**Cause:** Force sensor is abnormal.

**Remedy:** Check the following items:

1. Robot is mastered.
2. Force sensor calibration data is loaded.
3. Force sensor cable is connected.

### 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-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:** Too many recorded positions.

**Remedy:** Please reduce total recording time, or increase the the monitoring interval.

### FORC-643 No enough recorded positions

**Cause:** Recording positions not finished, or NO enough recorded positions.

**Remedy:** Please finish recording, or increase total recording time.

### FORC-644 No enough edge points

**Cause:** *i*RVision Debur. Line Output vision process has not been executed or NO enough edge points detected.
**Remedy:** (1) Please finish running *i*RVision Debur. Line Output vision process.
(2) Please check the setting of *i*RVision Debur. Line Output vision process.

### FORC-645 Too many edge points detected

**Cause:** Too many edge points detected by *i*RVision Debur. Line Output vision process.
**Remedy:** (1) Please check maximum available number of edge points.
(2) Please check the setting of *i*RVision Debur. Line Output vision process.

### FORC-646 Update initial data failed

**Cause:** Failed to update initial data. The real cause is the alarm just below this one in alarm history.
**Remedy:** Please check the alarm history and retry.

### 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:** Please check the alarm history and retry.

### FORC-648 Too many teach points

**Cause:** Too many teach points.
**Remedy:** Please increase values of parameters Distance Threshold, Angle Threshold or Orient Change Thres.

### 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:** Please check the alarm history and retry.

### 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.

### FORC-651 Cannot find matched edge line

**Cause:** Cannot find an edge line detected by iRVision Debur. Line Output vision process matches to that in the initial data.
**Remedy:** Please check the setting of *i*RVision Debur. Line Output vision process.

### FORC-652 Contour Schedule error

**Cause:** The setting of contouring schedule data is wrong.
**Remedy:** Please set contouring schedule correctly.

### FORC-653 Invalid data file

**Cause:** The data file is missing or it is invalid.
**Remedy:** Please check the data file.

# C FORCE SENSOR ATTACHMENT SETTING FUNCTION

## C.1 OVERVIEW

If a force sensor is already attached to a robot wrist with a standard adapter plate (torque wrench needed type) (See section 2.1 “Force Sensor Overview”) when it is delivered from FANUC factory and the sensor attachment position is not changed, the procedures described in this chapter are not necessary.
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.

This function sets the following two items.

- Force sensor attachment
- Sensor frame

On force sensor attachment screen, the setting whether force sensor is attached to the robot wrist or fixed on the working table can be done.
On sensor frame screen, 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.

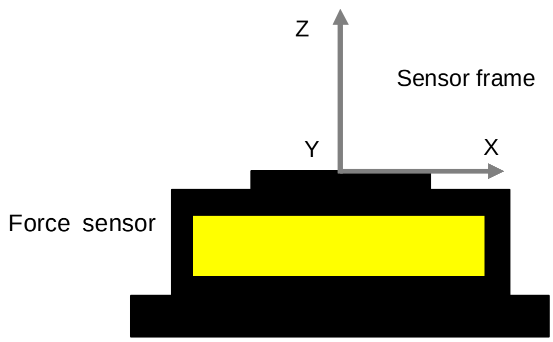
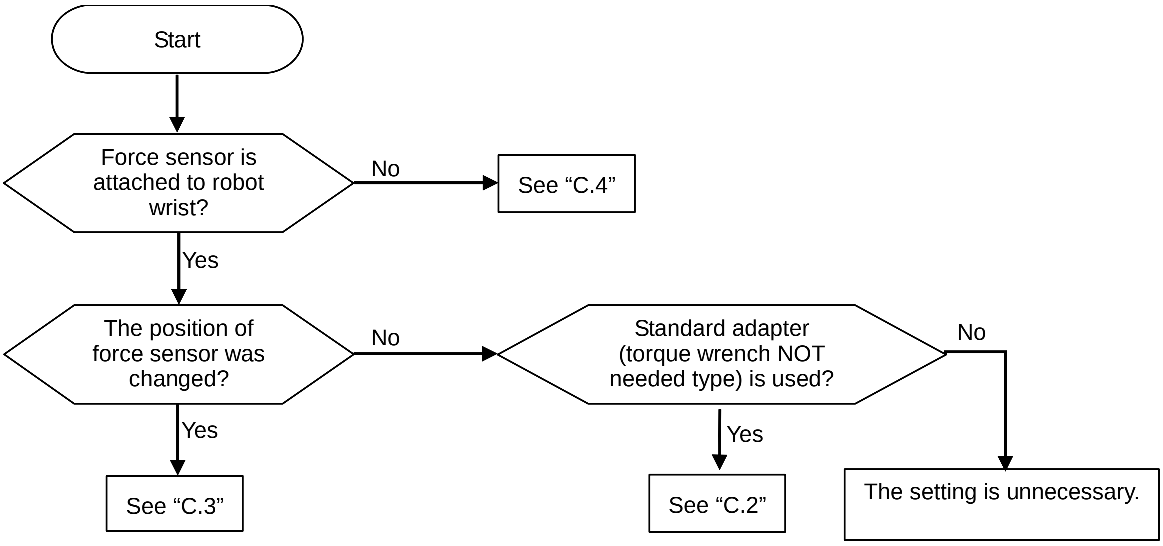



**Fig.C.1 Sensor frame of force sensor**

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).

The standard adapter (torque wrench needed) The standard adapter (torque wrench not needed)

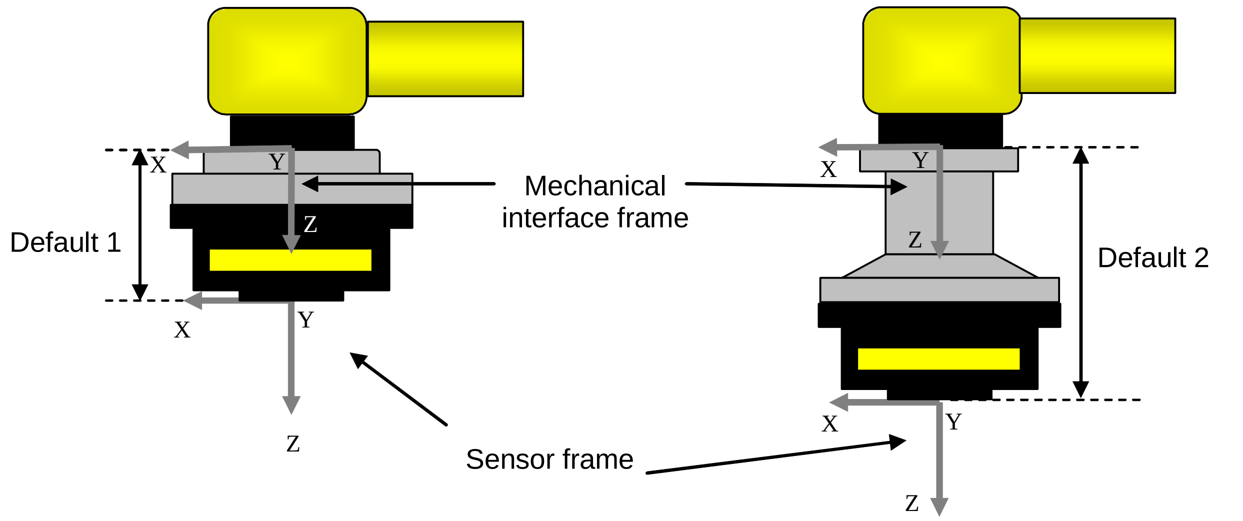



**Fig.C.2 Sensor frame in case of wrist mounted force sensor**

## C.2.1 How to Start the Program

The program for settings of force sensor attachment is executed from the force sensor utilities screen. Refer to Chapter 5 "FORCE SENSOR UTILITIES SCREEN".
To execute the program, select the following.

MENU → 「1 UTILITIES」 → 「Force Sensor」

→ F3 [ 3 Force Sensor Attachment ]

## C.2.2 Setting Force Sensor Attachment

In this screen force sensor attachment type can be set. The force sensor attachment type includes “Fixed” and “Hand”, and the standard setting is “Fixed”. If the screen as shown in Fig.C.2.2(a) is displayed, it is necessary to set “Sensor attachment” to “HAND”. If not, the setting is already set to “HAND” and proceed to “C.2.3 Setting of sensor frame”.

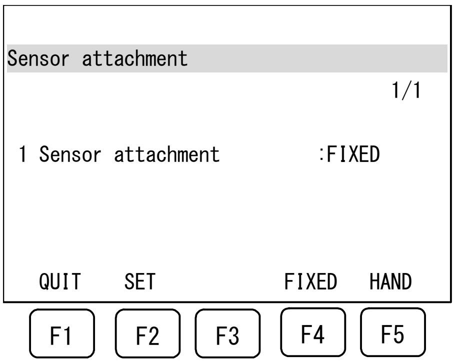



**Fig.C.2.2(a) Force sensor attachment screen 1**

### Function keys

The function keys are displayed as follows.

| Key | Item | 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”. |

### How to set force sensor attachment

- 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.

```
Sensor attachment
                                    1/1

 1 Sensor attachment         :HAND

Set attachment?

                           YES    NO
```

F1 F2 F3 F4 F5

**Fig.C.2.2(b) Force sensor attachment screen 2**

### 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
                                    1/1

 1 Sensor attachment         :HAND

Quit without setting attachment?

                           YES    NO
```

F1 F2 F3 F4 F5

**Fig.C.2.2(c) Force sensor attachment screen 3**

## C.2.3 Setting Sensor Frame

In this screen the setting of sensor frame in case of wrist mounted force sensor can be done.

```
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

**Fig.C.2.3(a) Sensor frame setting screen for hand sensor 1**

## Function keys

The function keys are displayed as follows.

| Key | Item | 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. |
| 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. |

## How to set sensor frame

- In order to set sensor frame for the adapter (torque wrench not needed), press F4 (DEFAULT2). By pressing F4 (DEFAULT2) the message “Set default data?” is displayed on the screen. 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.

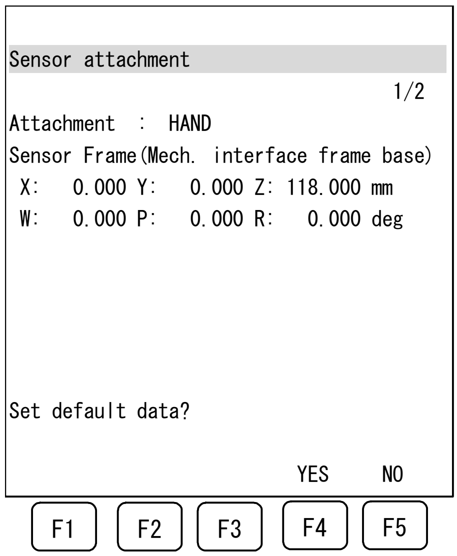



**Fig.C.2.3(b) Sensor frame setting screen for hand sensor 2**

- 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.

```
Sensor attachment
                                             1/2
Attachment  :  HAND
Sensor Frame(Mech. interface frame base)
 X:   0.000 Y:   0.000 Z: 170.000 mm
 W:   0.000 P:   0.000 R:   0.000 deg






Setting Done!! Quit?

                             YES     NO
  F1      F2      F3      F4      F5
```

**Fig.C.2.3(c) Sensor frame setting screen for hand sensor 3**

## How to quit the program

- In order to quit this program, press F1 (QUIT). This program is ended without setting sensor frame.
- By pressing F1 (QUIT) with changing the setting, the message “Quit without setting sensor frame?” is displayed on the screen. If F4 (YES) is selected, quit the program. If F5 (NO) is selected, go back to the current setting screen.

```
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: 8
 2 Offset for Sensor frame   : 15.00 mm

Quit without setting sensor frame?

                             YES     NO
  F1      F2      F3      F4      F5
```

**Fig.C.2.3(d) Sensor frame setting screen for hand sensor 4**

# 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

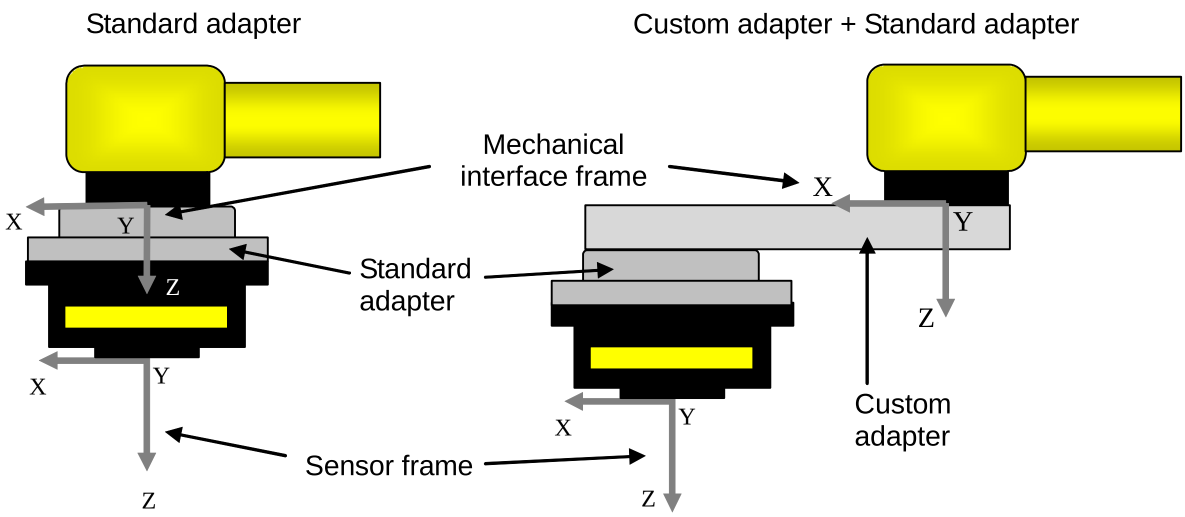



**Fig.C.3 Sensor frame in case of wrist mounted force sensor**

## 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. Here, 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.

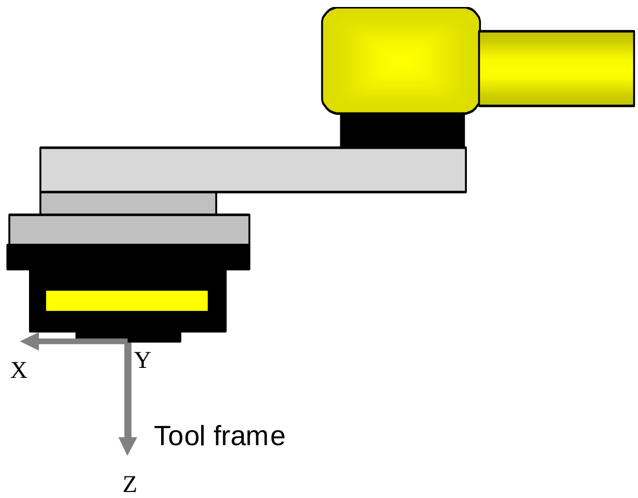



**Fig.C.3.1(a) An example of teaching tool frame1**

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. Here the tip is on the central axis of force sensor. Teach Tool frame on the tip of the jig, where Z-axis of tool 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 tool frame and the length of the jig are needed. After setting sensor frame, this tool frame is not necessary any more.

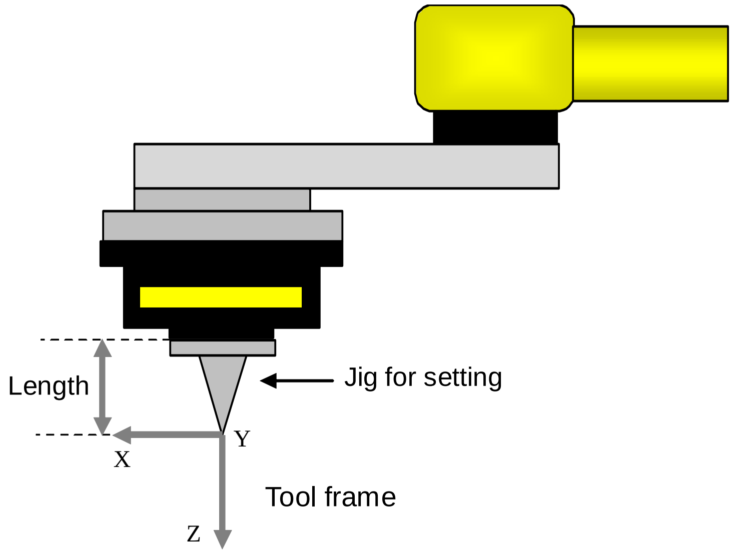



**Fig.C.3.1(b) An example of teaching tool frame2**

## C.3.2 How to Start the Program

The program for settings of force sensor attachment is executed from the force sensor utilities screen. Refer to Chapter 5 "FORCE SENSOR UTILITIES SCREEN".
To execute the program, select the following.

MENU → 「1 UTILITIES」 → 「 Force Sensor 」

→ F3 [ 3 Force Sensor Attachment ]

## C.3.3 Setting Force Sensor Attachment

In this screen force sensor attachment type can be set. The force sensor attachment type includes “Fixed” and “Hand”, and the standard setting is “Fixed”. If the screen as shown in Fig.C.2.2(a) is displayed, it is necessary to set “Sensor attachment” to “HAND”. If not, the setting is already set to “HAND” and proceed to “C.3.4 Setting of sensor frame”.

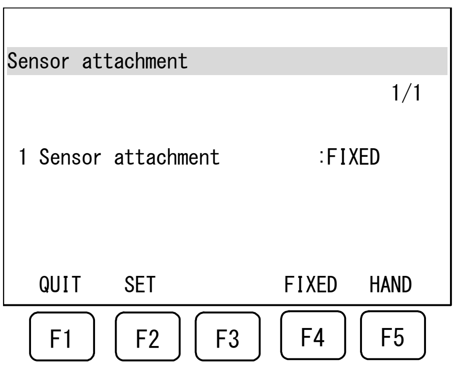



**Fig.C.3.3(a) Force sensor attachment screen 1**

### Function keys

The function keys are displayed as follows.

| Key | Item | 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”. |

## How to set force sensor attachment

- 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.

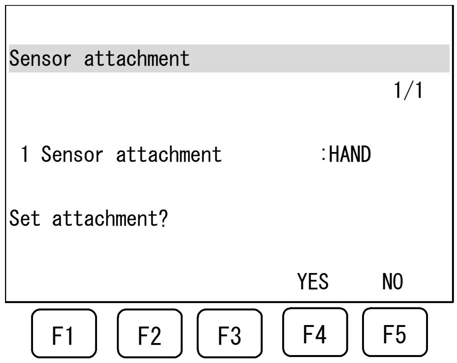



**Fig.C.3.3(b) Force sensor attachment screen 2**

## 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.

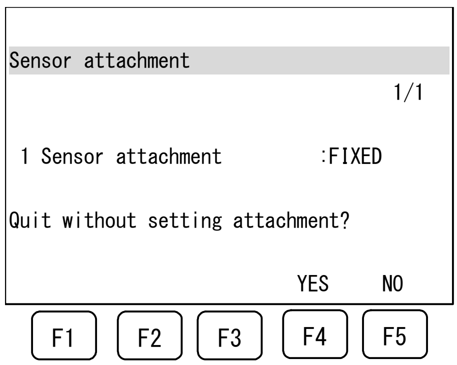



**Fig.C.3.3(c) Force sensor attachment screen 3**

## C.3.4 Setting Sensor Frame

In this screen the setting of sensor frame in case of wrist mounted force sensor can be done.

```
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




   QUIT    SET  DEFAULT1 DEFAULT2
    F1      F2     F3      F4      F5
```

**Fig.C.3.4(a) Sensor frame setting screen for hand sensor 1**

### Function keys

The function keys are displayed as follows.

| Key | Item | 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. |

### Parameters

The setting parameters are displayed as follows.

| Parameter | Default | Description |
|---|---|---|
| Tool Frame No. for Sensor frame | 1 | This parameter specifies tool frame number for teaching sensor frame. |
| Offset for Sensor frame | 0.00 mm | This parameter specifies the difference between sensor frame and tool frame in Z direction. |

### How to set sensor frame

- Set the parameters. If the jig for setting tool frame is used, set the length to the parameter ”Offset for Sensor frame”. If not, set “0” to that.
- By pressing F2 (SET) the message “Set Sensor frame?” is displayed on the screen. If F5 (NO) is selected, go back to the current setting screen. If F4 (YES) is selected, a sensor frame confirmation screen such as Fig.C.3.4(c) is shown.

```
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: 8
 2 Offset for Sensor frame    : 15.00 mm

Set Sensor frame?

                           YES    NO
   F1    F2    F3    F4    F5
```

**Fig.C.3.4(b) Sensor frame setting screen for hand sensor 2**

- Move the robot in X,Y,Z direction of the Tool Frame which is shown in Fig.C.3.4(c), and confirm that the Tool Frame has a same direction as a Sensor Frame. If the direction is correct, press F4 (CONFIRM). If the direction is not correct, press F5 (CANCEL) and set the Tool Frame again.

```
Sensor attachment

Attachment  :  HAND
Parameter for setting
 1 Tool Frame No. for Sensor frame UT:8
 2 Offset for Sensor frame    : 15.00 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
```

**Fig.C.3.4(c) Sensor frame setting screen for hand sensor 3**

- Force data are shown just like Fig.C.3.4(d). Follow the instructions in this screen and confirm the output of the force sensor. After the confirmation is completed, press F4 (OK). A new sensor frame is set. If the force sensor output is not correct, press F5 (CANCEL). The sensor frame is not updated. Check the Tool Frame and force sensor calibration data.

```
Sensor attachment

Force Data(Mech. interface frame base)
 X:  32.287 Y:  -9.012 Z: -24.031 N
 W:  33.123 P:   0.541 R:  14.204 N*m

Press the sensor in the direction of +X
and +Y on the Mech. interface Frame.
And check the changes of output.
If it is not correct,
please set the Senser Frame again.


                           OK    CANCEL
  F1     F2     F3     F4     F5
```

**Fig.C.3.4(d) Sensor frame setting screen for hand sensor 4**

- 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.

```
Sensor attachment
                                      1/2
Attachment  :  HAND
Sensor Frame(Mech. interface frame base)
 X: 323.315 Y:   3.214 Z: 143.498 mm
 W:  89.845 Y:  -0.715 R:   0.312 deg





Setting Done!! Quit?

                           YES     NO
  F1     F2     F3     F4     F5
```

**Fig.C.3.4(e) Sensor frame setting screen for hand sensor 5**

## How to quit the program

- In order to quit this program, press F1 (QUIT). This program is ended without setting sensor frame.
- By pressing F1 (QUIT) with changing the setting, the message “Quit without setting sensor frame?” is displayed on the screen. If F4 (YES) is selected, quit the program. If F5 (NO) is selected, go back to the current setting screen.

```
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: 7
 2 Offset for Sensor frame    : 20.00 mm

Quit without setting sensor frame?

                           YES     NO
  F1    F2    F3    F4    F5
```

**Fig.C.3.4(f) Sensor frame setting screen for hand sensor 4**

## How to set default value

- In order to set default value to sensor frame, press F3 (DEFAULT1) or F4 (DEFAULT2). By pressing F3 (DEFAULT1) or F4 (DEFAULT2) the message “Set default data?” is displayed on the screen. If F4 (YES) is selected, sensor frame for the normal adapter is set. If F5 (NO) is selected, go back to the current setting screen. By setting default data the original setting of sensor frame is deleted. Be sure to set carefully.

```
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






Set default data?

                           YES     NO
  F1    F2    F3    F4    F5
```

**Fig.C.3.4(g) Sensor frame setting screen for hand sensor 5**

- 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.

```
Sensor attachment
                                        1/2
Attachment  :  HAND
Sensor Frame(Mech. interface frame base)
 X:    0.000 Y:    0.000 Z: 170.000 mm
 W:    0.000 P:    0.000 R:    0.000 deg




Setting Done!! Quit?

                           YES     NO
   F1     F2     F3     F4     F5
```

**Fig.C.3.4(h) Sensor frame setting screen for hand sensor 6**

# 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

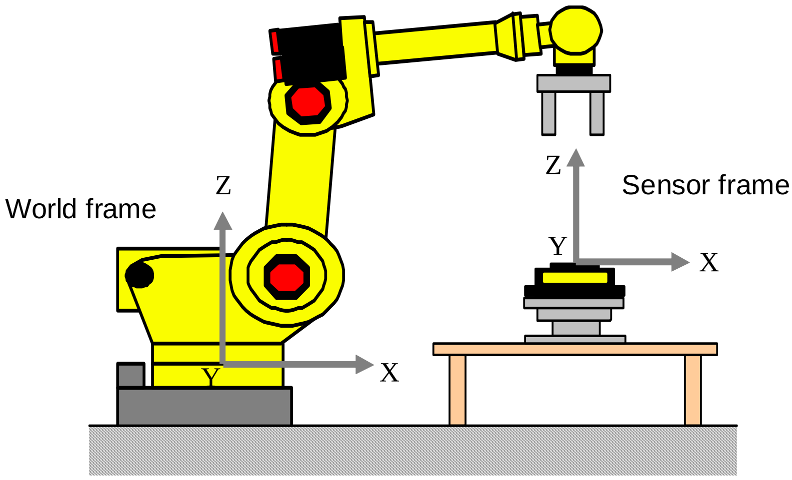



**Fig.C.4 Sensor frame for fixed sensor**

## 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.

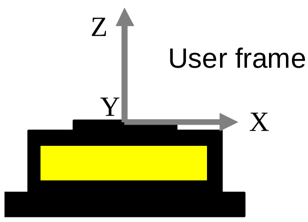



**Fig.C.4.1(a) An example of teaching user frame1**

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-10iA | A05B-1407-K001 |
| Frame setting jig, for FS-40iA | A05B-1407-K101 |
| Frame setting jig, for FS-100iA | A05B-1407-K201 |
| Frame setting jig, for FS-250iA | 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.

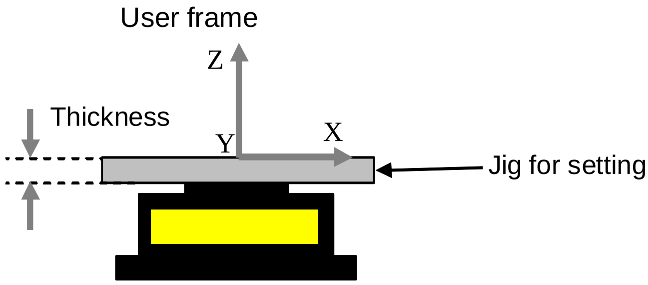



**Fig.C.4.1(b) An example of teaching user frame2**

## C.4.2 How to Start the Program

The program for settings of force sensor attachment is executed from the force sensor utilities screen. Refer to Chapter 5 "FORCE SENSOR UTILITIES SCREEN".
To execute the program, select the following.

MENU → 「1 UTILITIES」 → 「 Force Sensor 」

→ F3 [ 3 Force Sensor Attachment ]

## C.4.3 Setting Force Sensor Attachment

In this screen force sensor attachment type can be set. The force sensor attachment type includes "Fixed" and "Hand", and the standard setting is "Fixed".

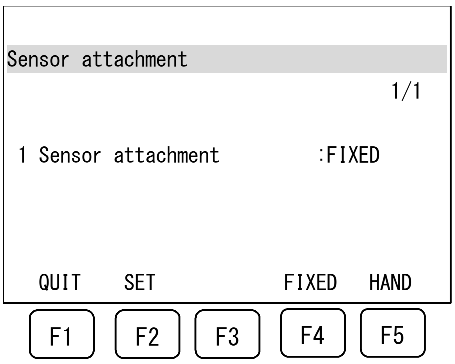



**Fig.C.4.3(a) Force sensor attachment screen 1**

## Function keys

The function keys are displayed as follows.

| Key | Item | 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”. |

## How to set force sensor attachment

- 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 of sensor frame”.) If F5 (NO) is selected, go back to the current setting screen.

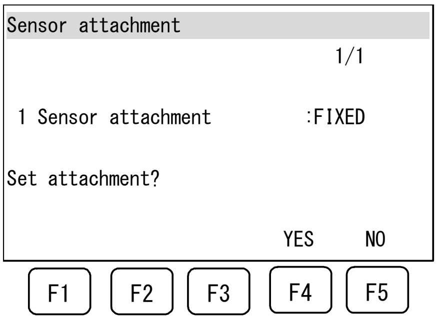



**Fig.C.4.3(b) Force sensor attachment screen 2**

## 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.

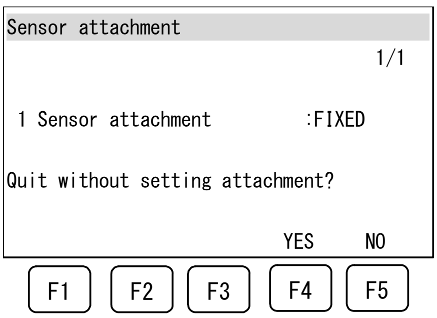



**Fig.C.4.3(c) Force sensor attachment screen 3**

# C.4.4 Setting Sensor Frame

In this screen the setting of sensor frame in case of remotely fixed force sensor can be done.

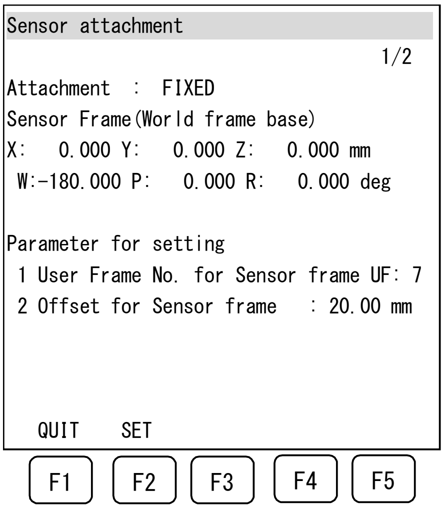



**Fig.C.4.4(a) Sensor frame setting screen for fixed sensor 1**

## Function keys

The function keys are displayed as follows.

| Key | Item | Description |
|---|---|---|
| F1 | QUIT | Quit this program. |
| F2 | SET | Set sensor frame using parameter. |

## Parameters

The setting parameters in case of remotely fixed force sensor are displayed as follows.

| Parameter | Default | Description |
|---|---|---|
| User Frame No. for Sensor frame | 0 | This parameter specifies user frame number for teaching sensor frame. |
| Offset for Sensor frame | 0.00 mm | This parameter specifies the difference between sensor frame and user frame in Z direction. |

## How to set sensor frame

- Set the parameters. If the jig for setting user frame is used, set the thickness to the parameter ”Offset for Sensor frame”. If not, set “0” to that.
- By pressing F2 (SET) the message “Set Sensor frame?” is displayed on the screen. If F5 (NO) is selected, go back to the current setting screen. If F4 (YES) is selected, a sensor frame confirmation screen such as Fig.C.4.4(c) is shown.

```
Sensor attachment
                                    1/2
Attachment  :  FIXED
Sensor Frame(World frame base)
 X:   0.000 Y:   0.000 Z:   0.000 mm
 W:-180.000 P:   0.000 R:   0.000 deg

Parameter for setting
 1 User Frame No. for Sensor frame UF: 7
 2 Offset for Sensor frame   : 20.00 mm

Set Sensor frame?

                           YES     NO
```

```
 F1   F2   F3   F4   F5
```

**Fig.C.4.4(b) Sensor frame setting screen for fixed sensor 2**

- Move the robot in X,Y,Z direction of the User Frame which is shown in Fig.C.4.4(c), and confirm that the User Frame has a same direction as a Sensor Frame. If the direction is correct, press F4 (CONFIRM). If the direction is not correct, press F5 (CANCEL) and set the User Frame again.

```
Sensor attachment

Attachment  :  FIXED
Parameter for setting
 1 User Frame No. for Sensor frame UF: 8
 2 Offset for Sensor frame   : 15.00 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
```

**Fig.C.4.4(c) Sensor frame setting screen for fixed sensor 3**

- Force data are shown just like Fig.C.4.4(d). Follow the instructions in this screen and confirm the output of the force sensor. After the confirmation is completed, press F4 (OK). A new sensor frame is set. If the force sensor output is not correct, press F5 (CANCEL). The sensor frame is not updated. Check the User Frame and force sensor calibration data.

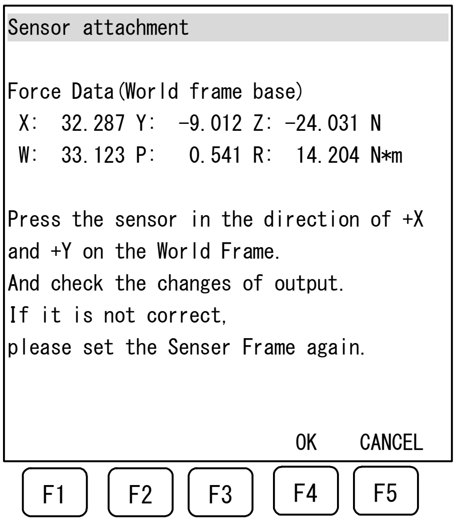



**Fig.C.4.4(d) Sensor frame setting screen for fixed sensor 4**

- 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.

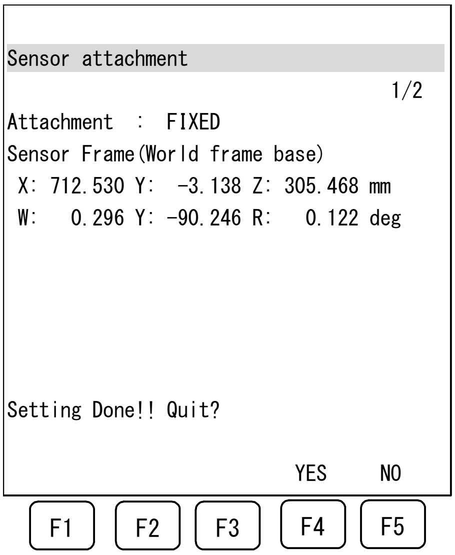



**Fig.C.4.4(e) Sensor frame setting screen for fixed sensor 3**

## How to quit the program

- In order to quit this program, press F1 (QUIT).
- By pressing F1 (QUIT) with changing the setting, the message “Quit without setting sensor frame?” is displayed on the screen. If F4 (YES) is selected, quit the program. If F5 (NO) is selected, go back to the current setting screen.

```
Sensor attachment
                                      1/2
Attachment  :  FIXED
Sensor Frame(World frame base)
 X:   0.000 Y:   0.000 Z:   0.000 mm
 W:-180.000 P:   0.000 R:   0.000 deg

Parameter for setting
 1 User Frame No. for Sensor frame UF: 7
 2 Offset for Sensor frame   : 20.00 mm

Quit without setting sensor frame?

                           YES    NO
```

F1 F2 F3 F4 F5

**Fig.C.4.4(f) Sensor frame setting screen for fixed sensor 4**

# 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 force sensor utilities screen. Refer to Chapter 5 "FORCE SENSOR UTILITIES SCREEN".
To execute the program, select the following.

MENU → 「1 UTILITIES」 → 「 Force Sensor 」

→ F3 [ 3 Force Sensor Attachment ]

## C.5.2 Setting Force Sensor Attachment

In this screen force sensor attachment type can be set.

```
Sensor attachment
                                      1/1

 1 Sensor attachment        :FIXED




  QUIT    SET          FIXED    HAND
```

F1 F2 F3 F4 F5

**Fig.C.5.2(a) Force sensor attachment screen 1**

## Function keys

The function keys are displayed as follows.

| Key | Item | 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”. |

## Sensor attachment

The sensor attachment setting is displayed as follows.

| Description | Default |
|---|---|
| The sensor attachment setting specifies the setting of force sensor attachment. Choose from “Fixed” and “Hand”. | FIXED |

## How to set force sensor attachment

- After choosing attachment type from 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. If F5 (NO) is selected, go back to the current setting screen.

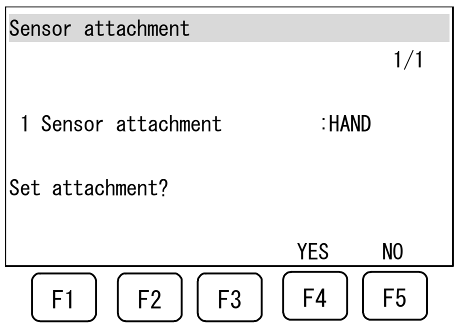



**Fig.C.5.2(b) Force sensor attachment screen 2**

# 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.

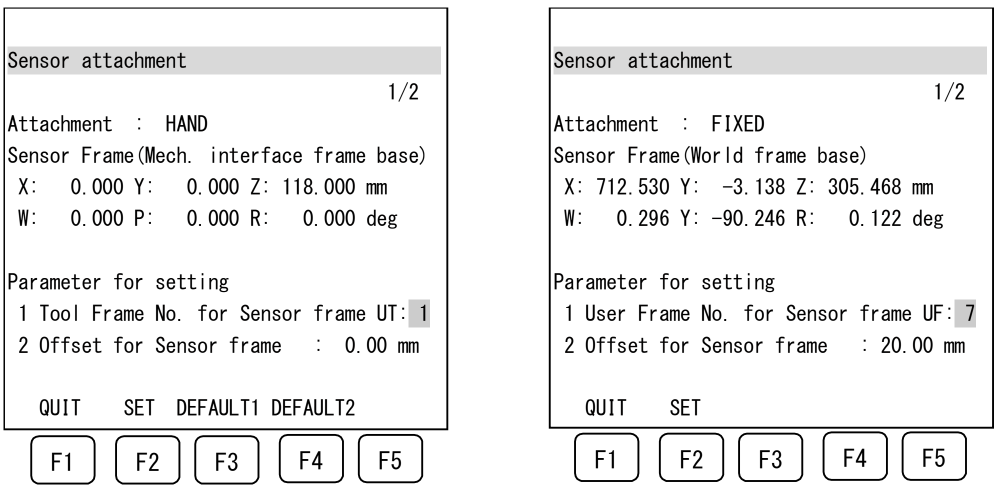



**Fig.C.5.3(a) Sensor frame setting screen 1**

## How to quit the program

- In order to quit this program, press F1 (QUIT). This program is ended without setting sensor frame.
- By pressing F1 (QUIT) with changing the setting, the message “Quit without setting sensor frame?” is displayed on the screen. Select F4 (YES) to quit this program.

```
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: 8
 2 Offset for Sensor frame   : 15.00 mm

Quit without setting sensor frame?

   QUIT    SET  DEFAULT1 DEFAULT2
   F1      F2     F3      F4      F5
```

```
Sensor attachment
                                   1/2
Attachment  :  FIXED
Sensor Frame(World frame base)
 X: 712.530 Y:  -3.138 Z: 305.468 mm
 W:    0.296 Y: -90.246 R:    0.122 deg

Parameter for setting
 1 User Frame No. for Sensor frame UF: 8
 2 Offset for Sensor frame   : 15.00 mm

Quit without setting sensor frame?

   QUIT    SET
   F1      F2     F3      F4      F5
```

**Fig.C.5.3(b) Sensor frame setting screen 2**

# D SYSTEM FILES OF FORCE SENSOR/FORCE CONTROL

There are following system files for force sensor/force control.
These files are saved to external memory on Teach Pendant’s File screen.

| File name | description |
|---|---|
| SYSFSCDL.SV | Force control schedule data are stored. |
| SYSFSCB2.SV | Calibration data for 6-axis force sensor (FS-15iA, FS-40iA, FS-100iA, FS-250iA) are stored. |
| SYSFSCB3.SV | Setting data for 3-axis force sensor (FS-15iAe) 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. |

# INDEX

# REVISION RECORD

| Edition | Date | Contents |
|---|---|---|
| 02 | Aug.,2015 | • Addition of Contouring new functions, threading, 4D graphic<br>• Applied to R-30*i*B Mate. |
| 01 | Dec.,2012 | |

**B-83424EN/02**

* B - 8 3 4 2 4 E N / 0 2 *