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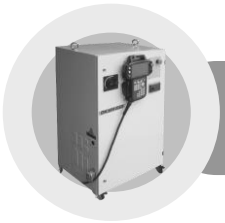

Hi5 Controller Function Manual

Load Estimation

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1 Introduction

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1.1. Introduction

Load estimation is a function for calculating the weight and the weight center of a load attached to the end of a robot. In order to control the robot based on dynamics models, it is required to secure dynamics parameters both for the main body of the robot and for the load attached to the robot all together. In relation to that, as the load that is to be attached to the robot will be different, depending on the situations of the individual sites and the difficult in calculating their data at sites, there is a need for a function that will allow a robot controller to estimate the data automatically.

- **Load Estimation coordinate: Tool coordinate**

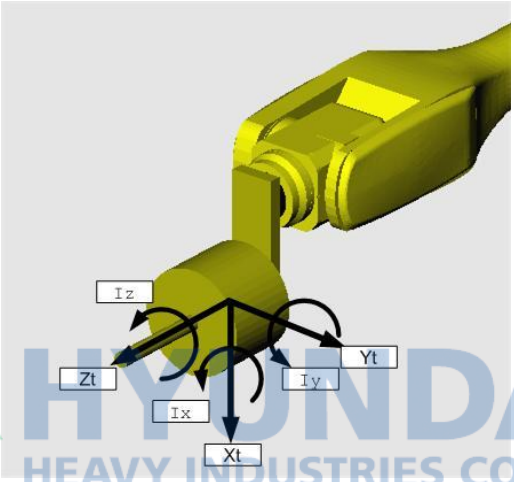

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Figure 1.1 Tool coordinate

※ The load estimation function is for helping a robot operate smoothly. It would be inappropriate to use the function to measure weight with precision.

※ The load estimation function can be used only when the robot is installed on the ground.
In other words, the load estimation function will not be supported for a robot if it is installed on a wall or onto a ceiling.

※ As the physical properties (weight, weight center, and inertia) of a tool get smaller, the estimation error will get larger
If the physical properties of a tool are small, it is recommended for the user to enter the tool data manually.

※ If there are tools, which are to be attached to a robot and works that are to be handled by the tools, it is required to register the tool data for individual conditions first before using them. Load estimation should be performed for individual working conditions of (tools) and (tools + works).

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Load Estimation Results

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2.1. Weight

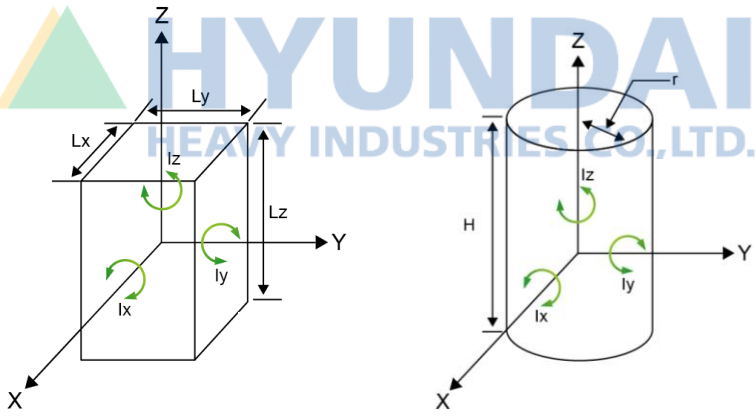
This is the total weight of the load assembled to the end of the robot. The unit is kg.

2.2. Center (Weight center)

As the distance from the end of the robot to the location of the weight center in x, y and z direction, and the unit is mm.

2.3. Inertia (Momentum)

This is the inertia moment of the load itself. Assuming that the 3 axes, x, y, and z, are rotating based on the center, this refers to the sum of the each weight distributed on the load times the distance from the rotating axis cubed. The inertia will be decided according to the weight distributed on the circumference of a shaft. Its value will become larger as the mass of the load is distributed more distantly from the rotating shaft. The unit to be applied for the x, y, and z axes is kgm^2.



$$lx = \frac{(Ly^2 + Lz^2)}{12} \times W$$
$$ly = \frac{(Lx^2 + Lz^2)}{12} \times W$$
$$lz = \frac{(Lx^2 + Ly^2)}{12} \times W$$

Inertia calculation for rectangular tool

$$lx = ly = \frac{(3r^2 + H^2)}{12} \times W$$
$$lz = \frac{r^2}{2} \times W$$

Inertia calculation for cylinder type

Figure 2.1 Inertia calculation

3

Load Estimation Menu Description

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Execute the Load Estimation from 『[F2]: System』→『6: Automatic constant setting』→『4: Load estimation function』

※ When selecting the 『4: Load Estimation function』 menu, the motor will be in 'On', For Load Estimation motion operation, the motor will automatically be in 'Off'.

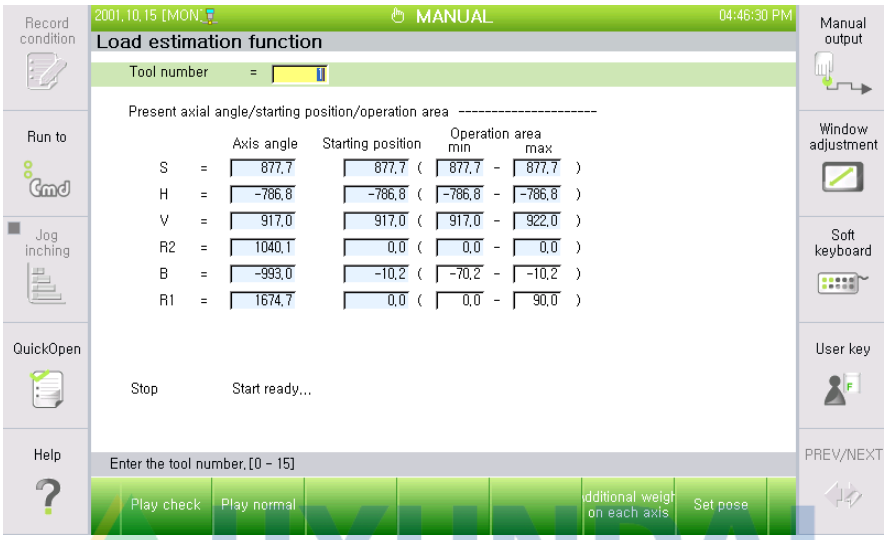

Figure 3.1 Load Estimation function screen

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3.1. Tool number

This declares the number to represent the tool to use. When the declared number is applied to the tool number of the teaching program, the robot will operate based on the properties of the calculated load. The tool numbers can be declared in the range of "0~15".

3.2. Operation area

This shows the operation area of individual axes for the load estimation motion. 『Axial angle』 presents the information of individual axes of a robot. 『Start pose』 displays the information of initial pose from which load estimation will start. The 『min』 and 『max』 items of the 『operation area』 present the minimum and maximum values that are to be used for the load estimation motion. In case of axes B and R1, their minimum and maximum operation areas can be set. The following shows the basic conditions of their operation areas:

[Basic operation area]
- Axis B operation area (min) : (60 degrees – Angle for axis H – Angle for axis V)
- Axis B operation area (max) : (120 degrees – Angle for axis H – Angle for axis V)
- Axis R1 operation area (min) : 0 degree
- Axis R1 operation area (max) : 90 degrees

In some specific wrist axis operation area setting conditions, there can be physical properties that cannot be estimated. For such cases, the user needs to enter the physical properties manually.

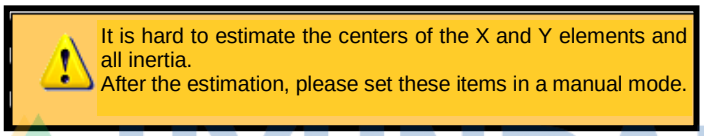

Figure 3.2 Warning for the conditions in which the center of gravity (Cx, Cy) and the inertia cannot be estimated

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The following shows the conditions that are needed for estimating all the physical properties:

[Operation area conditions for estimating all the physical properties]
- Axis B operation area: (40-H-V) ~ (140-H-V)
- Axis B between min. and max. 20 degrees or larger
- Axis R1 between min. and max. 60 degrees or larger

3.3. Play check

'Play check' takes place at a lower speed (about 50–200m/s) than the 'Play normal' in order to check for any interference. No estimation will occur if Play check takes place.
As load estimation is for gaining load information after operating a robot on a specific pattern, it is required to pay attention to any interference with surrounding environment and the robot itself. That is why it is required to check for any interference through 'Play check' before 'Play normal'. If there is a risk of collision, the 『Emergency stop』 button should be pushed or the 『Enable switch』 should be turned off to stop the robot. If the robot stops operating before the 'Play check' is completed, the load estimation menu needs to be executed again.

[Execution condition]

- Robot controller : Manual mode
- Enable Switch : On

3.4. Play normal

This is the menu to execute the Load Estimation. Because this is done in fast speed, this must be executed after checking any interference from the 'Play check'.

[Execution condition]

- Robot controller : Manual mode
- Enable Switch : On

3.5. Axis additional weight

Move to the Axis Additional menu. In order to calculate load accurately, it is required to enter the additional weight information (weight, x axis weight center, and z axis weight center) of each axis. The additional weight includes plates, signal boxes, and cables installed to the frame.

The following shows the coordinates for entering the additional weight of 3 axes

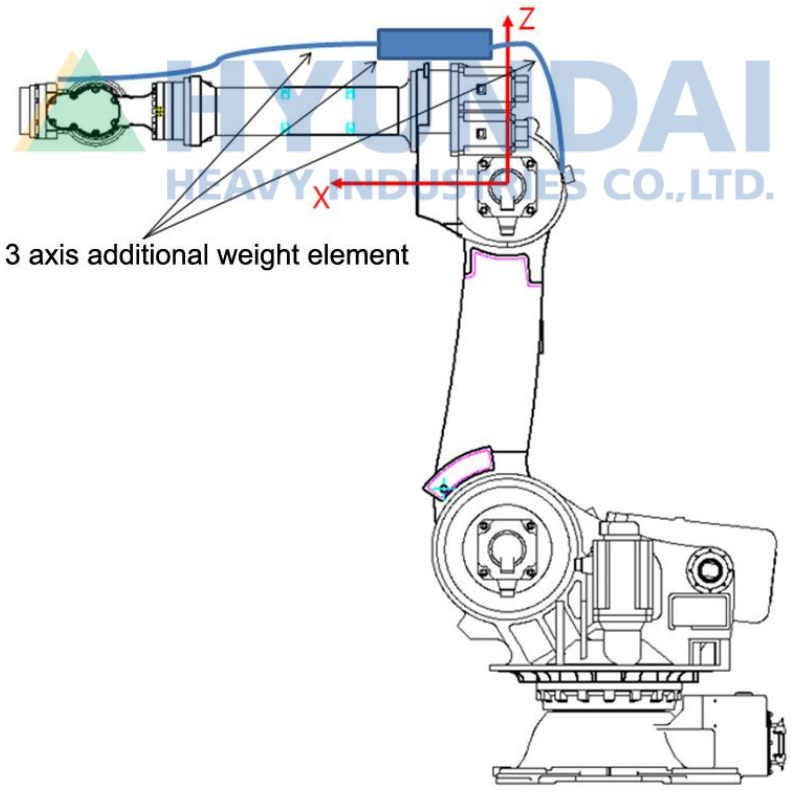

Figure 3.3 Additional weight elements and coordinates of 3 axes

3.6. Position designation

This designates the starting position of the estimated motion. After the user moves the basic axis of the robot to the location avoid any interference of the robot or tool, press the 『[F7]: Set pose』 key to designate the starting position.
There is no restriction in setting a pose for the axis S. In case of axes H and V, the frame angle of the axis V of the robot needs to be set at ±60 degrees at least against the ground. In order to perform estimation well, it is recommended to set the angle to be near 0 degree as much as possible. If the user presses the『[F7]: Set Pose』 key while exceeding ±60 degrees, a message, 『Angle of V axis must be -60 degrees or more.』, will be displayed

① Current value
This displays the position of the main axis (S, H, V) in the current position of the robot.

② Designation
This displays the position of the main axis (S, H, V) designated robot in degrees to calculate the load. When you press the 'Play check' or 'Play normal' button, the robot position will change to the designated position.

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4

Load Estimation Operation area

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The motion of the Load Estimation differs for 6 axis robot (HX165, HS165, HS200, HA006, HA020 etc.) and 4 axis palletizing robot (HP160).

4.1. 6 axis robot

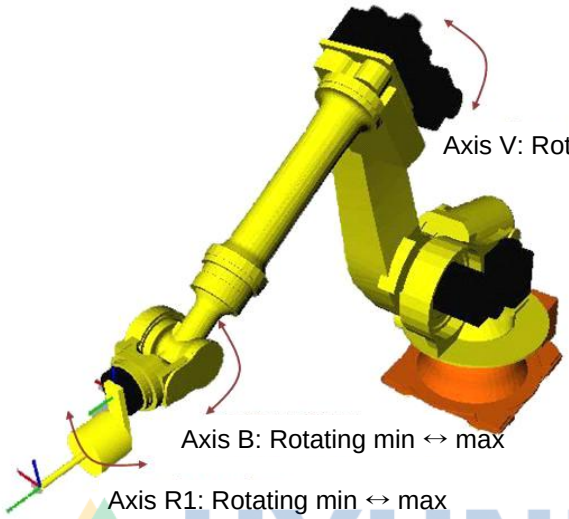

Figure 4.1 Load Estimation motor area (6 axis robot)

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4.2. 4 axis palletizing robot

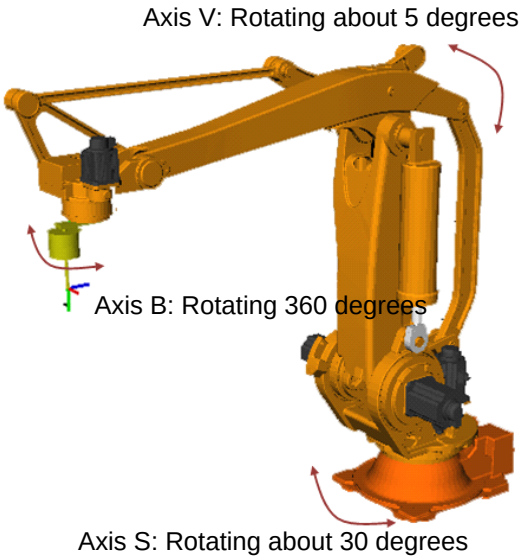

Figure 4.2 Load Estimation motion area (4 axis palletizing robot)

5

Load Estimation Result Application Method

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5.1. Load Estimation result application

After pressing the ‘End’ button from the window to check the Load Estimation result, click on “Yes” to apply to controller when asked to “Reflect estimated result to tool data?”, and the calculated load information is saved to the designated tool number. On the other hand, when you press “No”, it will not be saved.

Figure 5.1 Load estimation result displayed

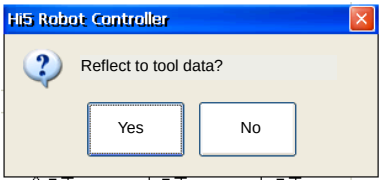


Figure 5.2 Window to reflect result to Load Estimation

Thus saved tool data makes it possible to select them from the teaching program and apply them for operating the robot and executing functions. Accordingly, when a tool needs to be changed or when a tool is handling a work, the information related to the tool data that shows the current situation should be used as the tool data of the teaching program.

5.2. Load Estimation result check and edit

The calculated load information can be checked and edited from 『[F2]: System』 → 『3: Robot parameter』 → 『1: Tool data』 menu. The calculated result at the entered tool number (0~15) is displayed.

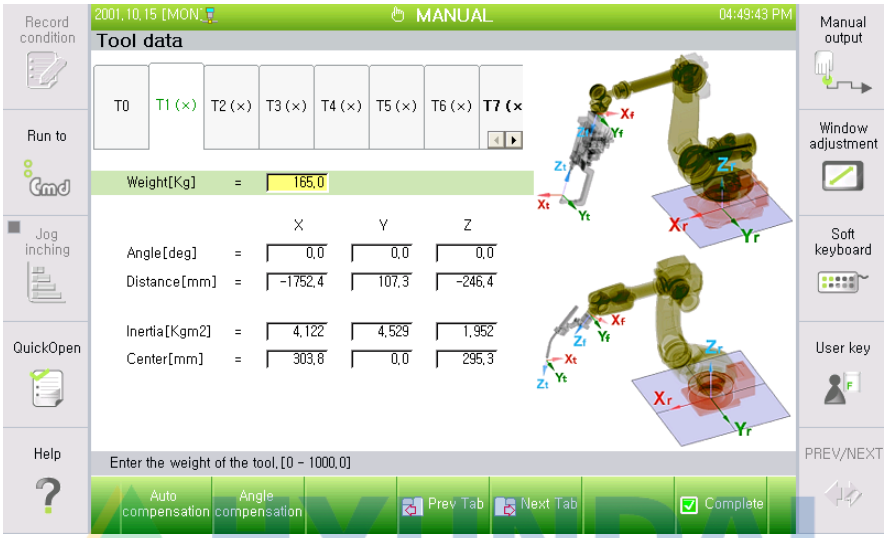


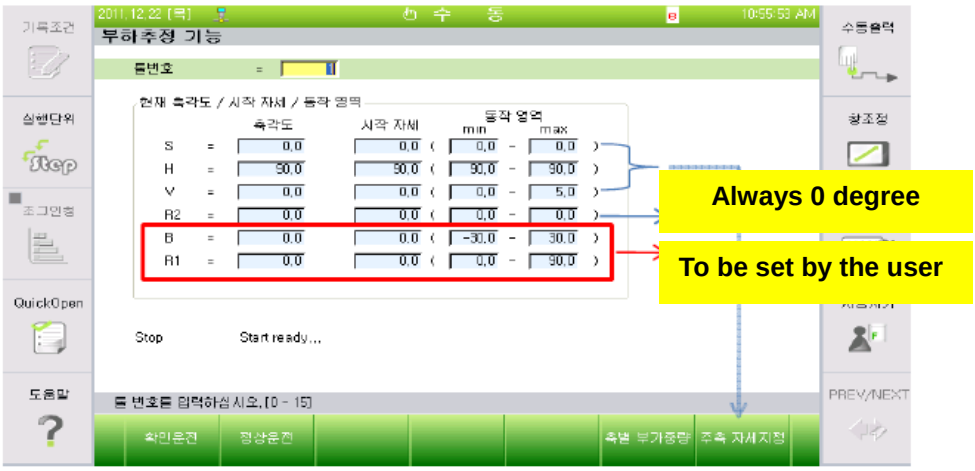
Figure 5.3 Tool data screen

※ In case of the inertia, the estimation result is about the weight center of a load.
If the inertia toward a specific direction is small, the estimation result can be displayed as 0

< Appendix >

Hi5 Controller Load Estimation Simple Procedure

1	**Load estimation function menu**	『[F2]: System』 → 『6: Automatic constant setting』 → 『4: Load estimation]
2	**Additional weight input check**	『[F6]: Additional weight on each axis』
3	**Main axis estimation pose designation**	Designate estimation pose for main axes (S, H, and V) (『[F7]: Set pose』)
4	**Wrist axis motion range input**	Operation area input for axes B and R1 (There can be variables that cannot be estimated depending on the conditions of operation areas)
5	**Play check**	『[F1]: Play check』 Check for interference while in low-speed motion
6	**Tool number input and play normal**	Tool number input, (『[F2]: Play normal』)
7	**Reflect estimation results**	Check whether the estimation result is reflected.



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