HYUNDAI ROBOTICS

WARNING

INSTALLATION SHOULD ONLY BE PERFORMED BY QUALIFIED INSTALLATION PERSONNEL AND MUST CONFORM TO ALL NATIONAL AND LOCAL CODES

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Hyundai Robot

Hi5aSLFC230620FMEN3

Hi5a Controller Function Manual

Sensorless Force Control

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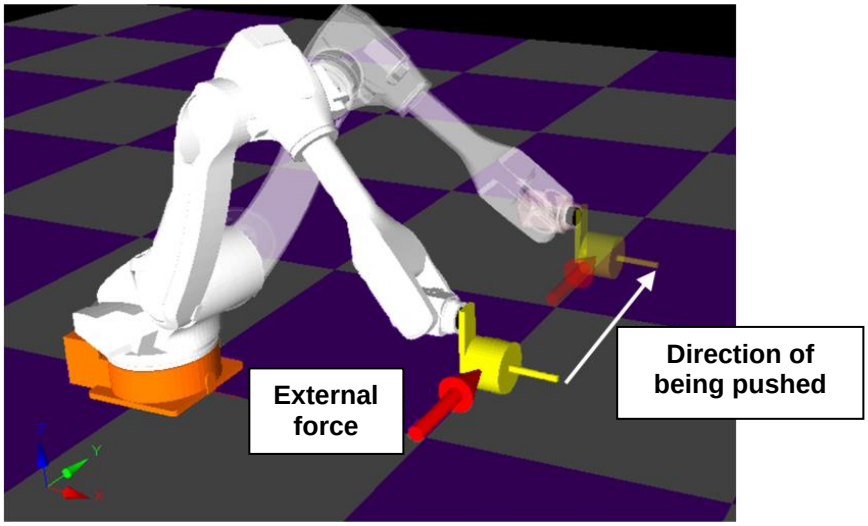
SoftXYZ

1.1. Overview of function



The SoftXYZ function makes it possible to be pushed in the direction of the Cartesian coordinate system for an applied external force. As this function works through a software, there is no need for additional hardware, such as a force/torque sensor, in using it.

1.1.1. Summary of functions

1) A function that makes it possible for individual axes to be pushed based on the Cartesian coordinate system for an applied external force
(Relevant axes will not recover at the original angle even after the external force is removed.)

2) The maximum and minimum distances the robot will move according to the function can be adjusted using the LIMIT command.

3) Only usable for the robot axes

4) Applicable for handling low-speed injection molded bodies, carrying out assembly with a large tolerance or for mechanical works

5) Software version supported: Main V40.01-00 or higher, DSP SV6.07 or higher

1.1.2. Caution

1) For the same LIMIT, sensitivity will decrease as the size of the robot increases, meaning that it is possible to only carry out control for a large external force.
This is because the link weight and friction force will increase as the size of the robot increases.

2) This function only works for the robot axes and not for the additional axes.

3) SoftXYZ cannot be used together with the RHemming, ForceCtrl, OnLTrack, or Convey Sync functions.

4) Required to input tool information through load estimation before using this function

5) When SoftXYZ is on, the robot may move without any external force if there is a disturbance. In order to remove such sensitivity, it is required to set a high threshold value using the LIMIT THR. LIMIT THR needs to be set for individual axes. However, the sensitivity will decrease as the THR value increases, meaning it is only possible to detect a large external force. Accordingly, it is important to find a proper THR through tests.

6) The movement of the robot caused by a disturbance will be limited by LIMIT POS, XnR, or VEL. Set the LIMIT value in a way that does not cause interference with the surrounding environment.

1.2. Methods of Using

1.2.1. Program structure

In order to use the SoftXYZ function, set the LIMIT, then wait for a certain time before activating the function. After the work related to being pushed is completed, deactivate the SoftXYZ function.

Example program)

```
S1   MOVE P,S=100mm/s,A=1,T=0
          DELAY 2
          LIMIT XnR,X=50, RY=5
          LIMIT VEL,X=5,RY=0.5
          SoftXYZ ON,CRD=1 'Start Function
S2   MOVE …
          SoftXYZ OFF 'End Function
END
```

Classification	Explanation	Example program
Condition setting	- Designate the direction (XnR) of controlling the robot and the LIMIT of VEL based on the set coordinate system of SoftXYZ. - The direction set for 0 means that the SoftXYZ function is off . - LIMIT XnR,X=30, RY=5 : Limit the movement in the X direction to 30 mm. Limit the movement to RY=5deg. - LIMIT VEL,X=5,RY=0.5 Limit the velocity of being pushed in the X direction to 5 mm/s. Limit the angle velocity of being pushed in the RY direction to 0.5 deg/s.	LIMIT XnR,X=30, RY=5 LIMIT VEL,X=5, RY=0.5
Wait time setting	In order to increase the sensitivity of the robot to an external force, the DELAY command must be used, before turning SoftXYZ on, to keep the robot waiting for about 1–2 seconds.	DELAY 2
Start the function	- Turn on the SoftXYZ function. CRD=1 : Robot coordinate system setting	SoftXYZ ON,CRD=1
End the function	- Turn off the SoftXYZ function.	SoftXYZ OFF

1.2.2. Command statement

1) LIMIT

Explanation	A command statement that is used to designate the distance and velocity of the movement of the robot when controlling the robot by reflecting the increment of the position using the SoftXYZ, RHemming, ForceCtrl, or OnLTrack functions	
Grammar	LIMIT POS,[+X=<+X Distance>],[-X=<-X Distance>],[+Y=<+Y Distance>], [-Y=<-Y Distance>],[+Z=<+Z Distance>],[-Z=<-Z Distance>] LIMIT VEL,[X=<X Velocity>],[Y=<Y Velocity>],[Z=<Z Velocity>], [RX=<RX Velocity>],[RY=<RY Velocity>],[RZ=<RZ Velocity>] LIMIT THR,[S=<S Threshold>],[H=<H Threshold>],[V=<V Threshold>], [R2=<R2 Threshold>],[B=<B Threshold>],[R1=<R1 Threshold>] LIMIT XnR,[X=<X Distance>],[Y=<Y Distance>],[Z=<Z Distance>], [RX=<RX Angle>],[RY=<RY Angle>],[RZ=<RZ Angle>]	
Parameter	POS	▪ Impossible to set the angle when it is similar to XnR ▪ Set the maximum distance the robot can move (X, Y, and Z directions) ▪ A value for limiting the amount of the movement that will take place in accordance with the increment command, regardless of the teaching path
	VEL	▪ Set the maximum velocity of the robot movement (X, Y, Z, Rx, Ry, and Rz directions). ▪ Limiting the velocity of the movement that will take place in accordance with the increment command, regardless of the teaching velocity
	THR	▪ Set the threshold of the individual axes of the robot (S, H, V, R2, B, and R1 axes) ▪ For removing unnecessary movement caused by disturbances ▪ As the value gets larger, the sensitivity will decrease. This means that it is required to set the minimum value.
	XnR	▪ Possible to set the angle when it is similar to POS ▪ Can set the maximum distance and velocity of the movement of the robot (X, Y, Z, Rx, Ry, and Rz) ▪ A value for limiting the amount of the movement that will take place in accordance with the increment command, regardless of the teaching path ▪ Designated values will be evenly applied for the + and – directions. ▪ **The maximum robot operation range will be decided based on the union of POS and XnR**.
Usage example	LIMIT POS,+Z=300 Set the maximum distance to 300 m in the direction of +Z. LIMIT VEL.Z=40 Set the maximum movement velocity to 40 mm/s in the direction of Z. LIMIT THR,H=10 Set the H axis threshold at 10% of the maximum torque. LIMIT XnR,X=200 Set the maximum distance to -200 mm – 200 mm in the X direction.	

2) SoftXYZ

<table>
<tr><td>Explanation</td><td colspan="2">As one of the sensorless force control functions, this function makes it possible to be pushed based on the Cartesian coordinate for an applied external force.</td></tr>
<tr><td>Grammar</td><td colspan="2">SoftXYZ <ON/OFF>,CRD=<REFERENCE COORDINATE SYSTEM>,[<USER COORDINATE SYSTEM NUMBER>]</td></tr>
<tr><td rowspan="2">Parameter</td><td>ON/OFF</td><td>ON: Enable, OFF : Disable</td></tr>
<tr><td>CRD</td><td>▪ Reference coordinate system for the robot to be pushed (0=base, 1=robot, 2=tool, 3=U, and 4=Un)
▪ If the reference coordinate system is U and UN (=3 and 4), the user coordinate system number needs to be inputted.</td></tr>
<tr><td>Usage example</td><td colspan="2"><u>(Example 1) A case of making it possible to be pushed in the X, Y, and RY directions to carry out assembly in the Z direction</u>
:Based on the robot coordinate system (CRD=1), carry out setting in a way that makes it possible to be pushed within -50 – +50 mm in the X and Y directions at the maximum velocity of 5 mm/s and within -3 – +3 degrees at the maximum velocity of 3 deg/s.

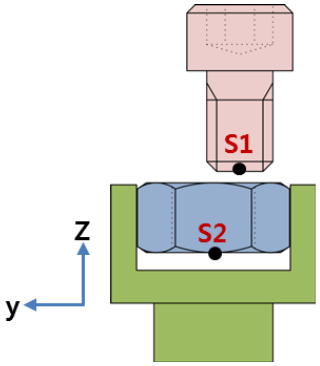
S1 MOVE P,S=100mm/s,A=1,T=0
DELAY 2
LIMIT XnR,X=50, Y=50,RY=3
LIMIT VEL,X=5,Y=5,RY=3
SoftXYZ ON,CRD=1 ‘Start Function
S2 MOVE …
SoftXYZ OFF ‘ End Function
END

<u>(Example 2) Handling an injection molded body</u>
: A case of setting in a way that makes it possible to be pushed, based on the robot coordinate system (CRD=1), to the maximum distance of only 300 mm in the +Y direction
at the maximum velocity of 200 m/s Set in a way that makes it possible to be only pushed when a torque of 10% or more of the maximum torque is applied on the S, H, and V axes
through the LIMIT THR command.

S1 MOVE P,S=100mm/s,A=1,T=0
DELAY 2
LIMIT POS, +Y=300
LIMIT VEL,Y=200
LIMIT THR,S=10, H=10, V=10
SoftXYZ ON,CRD=1
S2 WAIT …
SoftXYZ OFF
END</td></tr>
</table>

1.3. Example program

Peg-in-hole work




```
Robot:HA006A-02, 6axes, 2steps
S1  MOVE L,S=100mm/s,A=1,T=1
    LIMIT XnR,X=50,Y=50,Z=0,RX=0,RY=3,RZ=0
    LIMIT VEL,X=5,Y=5,Z=0,RX=3,RY=3,RZ=0
    LIMIT THR,S=0,H=0,V=0,R2=0,B=0,R1=0
    DELAY 2
    SoftXYZ ON,CRD=1
S2  MOVE L,S=50mm/s,A=1,T=1
    SoftXYZ ON,CRD=1
    END
```

Movement of the robot	▪ Moving to S1 that is close to the hole ▪ Moving to S2, which is the point of completing the assembly, after the SoftXYZ function is turned on ▪ The function is turned off as the assembly is completed
Position record	▪ S1: Positioning the peg close to the hole ▪ S2: Position of the tool end for the assembly of the peg to be completed
Limit setting	Required to set the value by differentiating between the direction that requires alignment against the recorded position and the direction that does not require such alignment. In case of the peg-in-hole work, as shown in the example, positional errors could occur in the X, Y, RX, and RY directions. It is required to control the force in relevant directions. ▪ XnR: Set the movement distance necessary for work in the X, Y, RX, and RY directions. Set 0 for the Z and RZ directions to prevent any response to an external force from taking place. ▪ VEL: Set the maximum velocity for movement that will take place through force control in the X, Y, RX, and RY directions. Set 0 for the Z and RZ directions to prevent any response to an external force from taking place. ▪ THR:Set a threshold for individual axes in order to prevent any unnecessary movement caused by a disturbance from taking place. Use a small value considering that sensitivity will get lower as the value gets higher.

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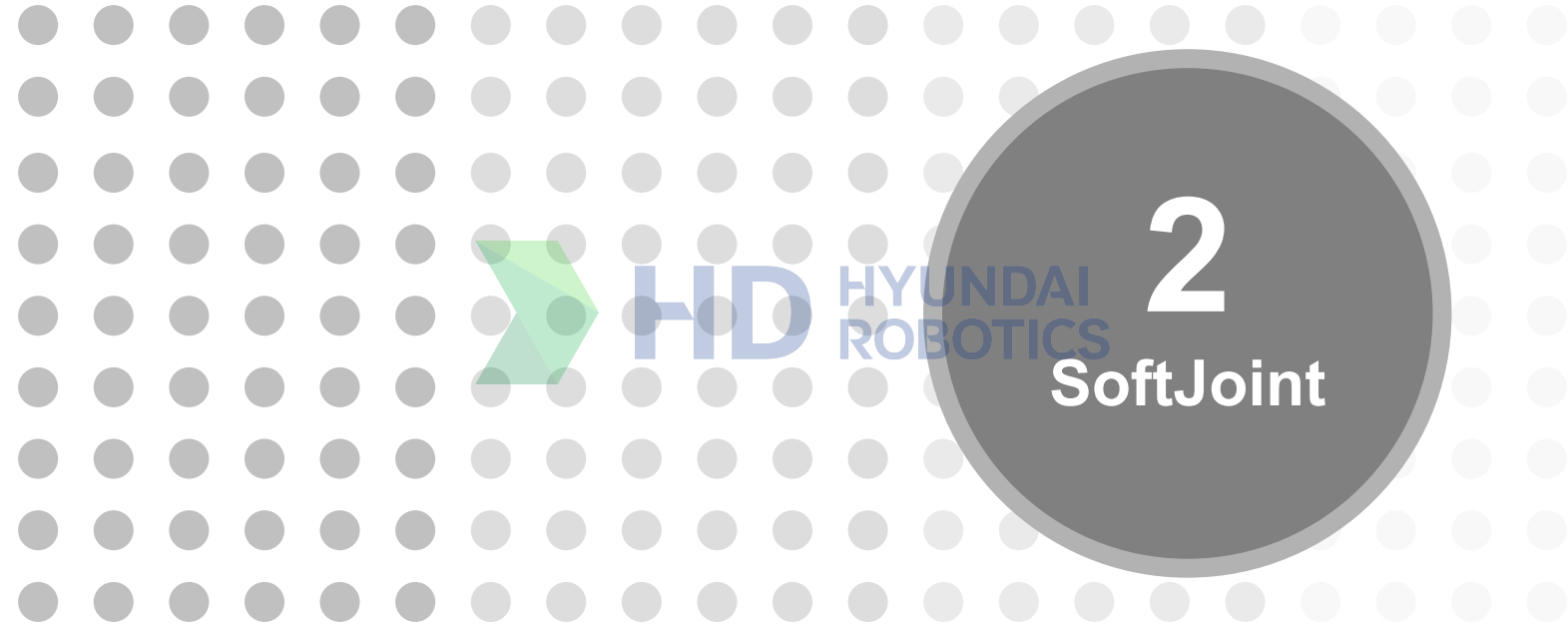
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2
SoftJoint

2.1. SoftJoint program structure

The SoftJoint function makes it possible for individual axes of the robot to work like a virtual spring for an external force applied on the robot. As this function works through software, there is no need for additional hardware, such as a force/torque sensor, in using it.

2.1.1. Summary of functions

1) A function that makes it possible for individual axes of the robot to work like a virtual spring for an external force
(When the softness is set low enough, relevant axes will not be recovered at the original angle even when the external force is removed.)

2) The softness of individual axes can be adjusted by using the “AXIS axis number.Softness” command.
Example 1) Set the softness of the axis 1 at 10% of its capacity. AXIS1.Softness=90
Example 2) Set the softness of the axis 7 at 80% of its capacity. AXIS7.Softness=20

3) Can be used for the robot axes and additional axes

4) Software version supported: Main V40.03-00 or higher, DSP SV6.08 or higher

2.1.2. Caution

1) For the same softness, the spring stiffness will get higher as the size of the robot increases. This is because the link weight and friction force will get higher as the size of the robot increases. The increase of the spring stiffness means that more force is needed to push at the same angle.

2) Required to input tool information through load estimation before using this function

3) AXIS.Softness = 0 is equivalent to the function being turned off,
and in case of AXIS.Softness = 100, the sensitivity to the external force will get the highest.

4) Caution in turning off the function (SoftJoint Off)
When the SoftJoint Off is executed, the mode will instantly shift to the position control mode, meaning that updating the final command to the current position must be processed. If not, abnormal operation of abruptly recovering to the final command could take place.

Program example)
AXIS5.Softness=90
SoftJoint ON
MOVE P,S=50mm/s,A=0
P1=P* **← Must save the current position**
MOVE P,P1,S=100%,A=7 **← Must insert the command for movement to the current position before the SoftJoint Off takes place**
SoftJoint OFF

5) **Take precautions against possible dropping of the axis when SoftJoint On takes place in the following cases.**
- When wrong tool information is inputted:
  (Example) 0 kg is inputted while the actual tool is 100 kg
- Input a very large value for AXIS.Softness:
  (Example) In order to prevent the axis from dropping, the AXIS.Softness should be 70 or lower. However, 80 is inputted for AXIS.Softness.

2.2. Methods for using

2.2.1. Program structure

In order to use the SoftJoint function, set the softness for individual axes first. After the work related to being pushed is completed, deactivate the SoftJoint function.

Classification	Explanation	Example of setting
Condition setting	- Set the softness for individual axes. - When the softness is set as 0 for an axis, it means that the SoftJoint function is off for the axis. - When the softness is set as 10 for an axis, it means that 90% of the capacity of the axis is used. - When the softness is set as 100 for an axis, it means that 0% of the capacity of the axis is used.	AXIS5.Softness=10 AXIS8.Softness=100
Start the function	- Turn on the SoftJoint function.	SoftJoint ON
End the function	- Turn off the SoftJoint function. - When SoftJoint Off is executed, the softness for all axes will be reset as 0.	SoftJoint OFF

2.2.2. Command statement

The commands used in the SoftJoint function include the 'AXIS.Softness' Command statement, which is for setting the softness, and the 'SoftJoint' command statement, which is for activating and deactivating the SoftJoint function

1) AXIS.Softness statement

Explanation	A command statement for setting the softness of individual axes to be used for the SoftJoint function	
Methods of inputting	『[F6]: Input Command』 → 『[F7]: Assign』 → 『PREV/NEXT』 → 『[F7]: AXIS』 → 『Relevant Axis Number』 → 『.』 → 『[F2]: Softness』 → 『ENTER』 → 『Softness Value』 → 『ENTER』 → 『ENTER』	
Grammar	AXIS<Axis Number>.Softness=<Softness Value>	
Parameter	Axis number	The number of the axis for which the SoftJoint function will be used
	Softness value	Input a value ranging 0–100 (use of 100%–0% of the axis capacity)
Example of use	AXIS5.Softness=90 AXIS10.Softness=80	Set the softness of the B axis as 90 (10% of the capacity of the axis) Set the softness of the B axis as 80 (20% of the capacity of the axis)
For information	▪ Before SoftJoint On is executed, the AXIS .Softness command must be used to set the softness for the axis that is to be pushed. ▪ AXIS.Softness=0 is equivalent to the function being turned off. (Use of 100% of the capacity of the axis) ▪ The increase of the softness means that less force is needed to push at the same angle.	

2) SoftJoint statement

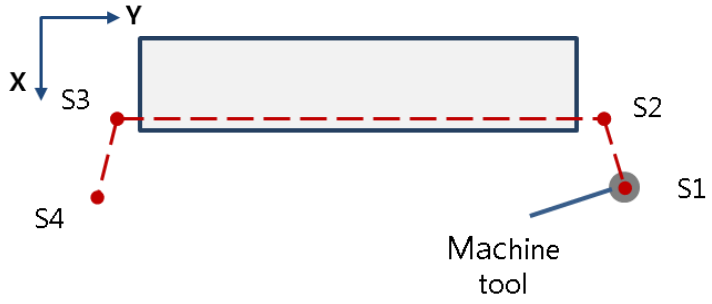
<table>
<tr><td>Explanation</td><td colspan="2">A command statement for activating (on) or deactivating (off) the SoftJioint function</td></tr>
<tr><td>Methods of inputting</td><td colspan="2">『[F6]: Command input』 → 『[F1]: Motion,I/O』 → 『PREV/NEXT』 → 『PREV/NEXT』 → 『PREV/NEXT』 → 『[F6]: SoftJoint』 → 『ON or OFF』 → 『ENTER』</td></tr>
<tr><td>Grammar</td><td colspan="2">SoftJoint <ON/OFF></td></tr>
<tr><td rowspan="2">Parameter</td><td>ON</td><td>Activating the SoftJoint function</td></tr>
<tr><td>OFF</td><td>Deactivating the Softjoint function</td></tr>
<tr><td rowspan="4">Example of use</td><td colspan="2">When turning off the function while the final command angle and the current angle are same</td></tr>
<tr><td>AXIS5.Softness=90
SoftJoint ON
MOVE P,S=50mm/s,A=0
SoftJoint OFF</td><td>Setting the softness of the B axis as 90
Function On
External force applied while moving
Function Off</td></tr>
<tr><td colspan="2">When turning off the function while the final command angle and the current angle are different</td></tr>
<tr><td>AXIS5.Softness=90
SoftJoint ON
MOVE P,S=50mm/s,A=0
P1=P*

MOVE P,P1,S=100%,A=7

SoftJoint OFF</td><td>Setting the softness of the B axis as 90
Function On
External force applied while moving
Right before the function is switched off, save the current angle in P1.
Updating the final command by using the MOVE command statement
Function Off</td></tr>
<tr><td>For information</td><td colspan="2">▪ When turning off the function while the final command angle and the current angle are different, the relevant axis may
suffer from a collision while recovering at the final command angle.
▪ In order to prevent such problems, use P* and the MOVE command to update the command
before SoftJoint Off is executed.
▪ For this, P* should be set as the current value.
(『[F2]: System』 → 『1:User Environment』 → 『8: Select P*=Current value』)</td></tr>
</table>

2.3. Example program

Chamfering work




```
Robot:HA006A-02, 6axes, 4steps
S1  MOVE L,S=100mm/s,A=0,T=0
S2  MOVE L,S=100mm/s,A=0,T=0
    AXIS4,Softness=80
    AXIS5,Softness=90
    SoftJoint ON
S3  MOVE L,S=50mm/s,A=0,T=0
    SoftJoint OFF
S4  MOVE L,S=100mm/s,A=0,T=0
    END
```

Movement of the robot	▪ Move from S1 to S2, which is the point of starting the processing ▪ After the SoftJoint is turned on, the robot will carry out chamfering while moving to S3. ▪ Move to S4 after the SoftJoint function is turned off.
Position recording (S2–S3)	As the SoftJoint makes it possible to be pushed for an external force, the teaching point should be placed inside the workpiece to secure the effect of applying a force onto the workpiece
Axis.Softness	▪ Set the softness by taking in consideration the direction of working, the material of the workpiece, and the level of machining. ▪ In the example shown above, as the robot will be pushed in the +X direction based on the robot coordinate system while moving in the –Y direction, it is needed to set the softness for the R2 and B axes

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