WARNING

THE INSTALLATION SHALL BE MADE BY QUALIFIED INSTALLATION PERSONNEL AND SHOULD CONFORM TO ALL NATIONAL AND LOCAL CODES

Hyundai Robot

Hi4aAS071001FMEN3

Hi4a Controller Function Manual

Arc Sensing

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Contents

1 Overview

1.1. Before explaining the functions

Because this function is an optional function not included in the standard package, you need a license key to execute this function.

1.2. Welding line tracking by arc sensing

The welding line tracking function by arc sensing detects the current change during welding in the arc welding system and tracks the welding line. This is a very effective function when used with the tough sensing to detect the starting point.

1.3. Condition to use the arc sensing function

(1) It must be the arc welding including weaving.

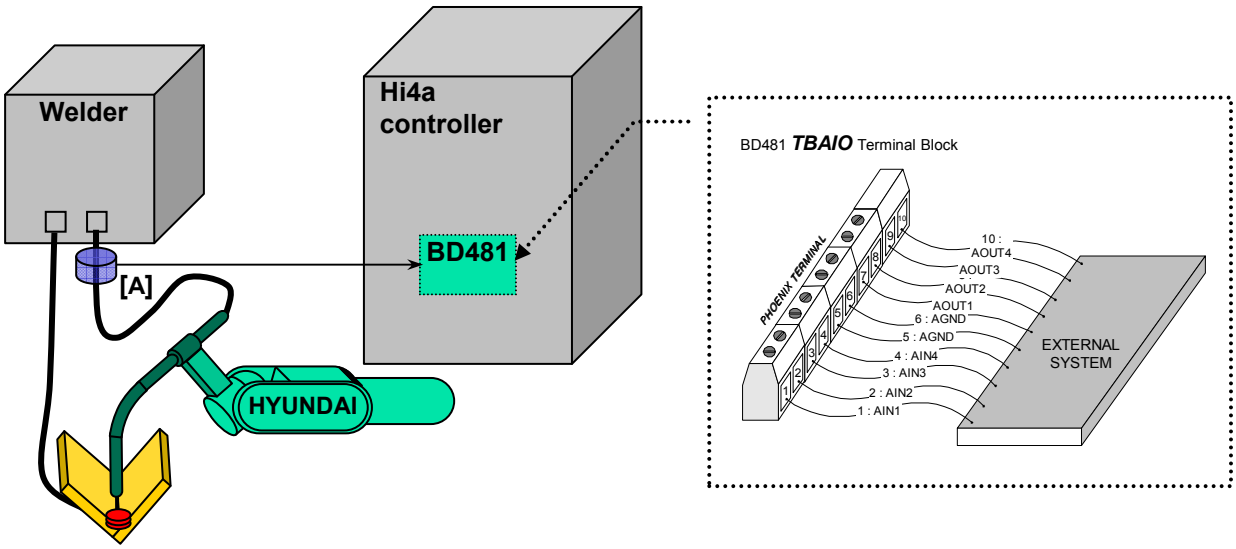
(2) You must have a device to detect the welding current. You can install a device to detect the welding current inside the welder or have a separate unit installed as a separate box. You must have one of the two below current detection device.

- CT(Current Transducer): LF-505S(www.lem.com)
  100[Ω](2W), 150[Ω](2W)
  ±24[V] SMPS
  2[mm^2] X 4[m] x 5 line

- Hole sensor : HC-U200V4B15(www.kohshin-ele.com)
  ±15[V] SMPS
  2[mm^2] X 4[m] x 5 line

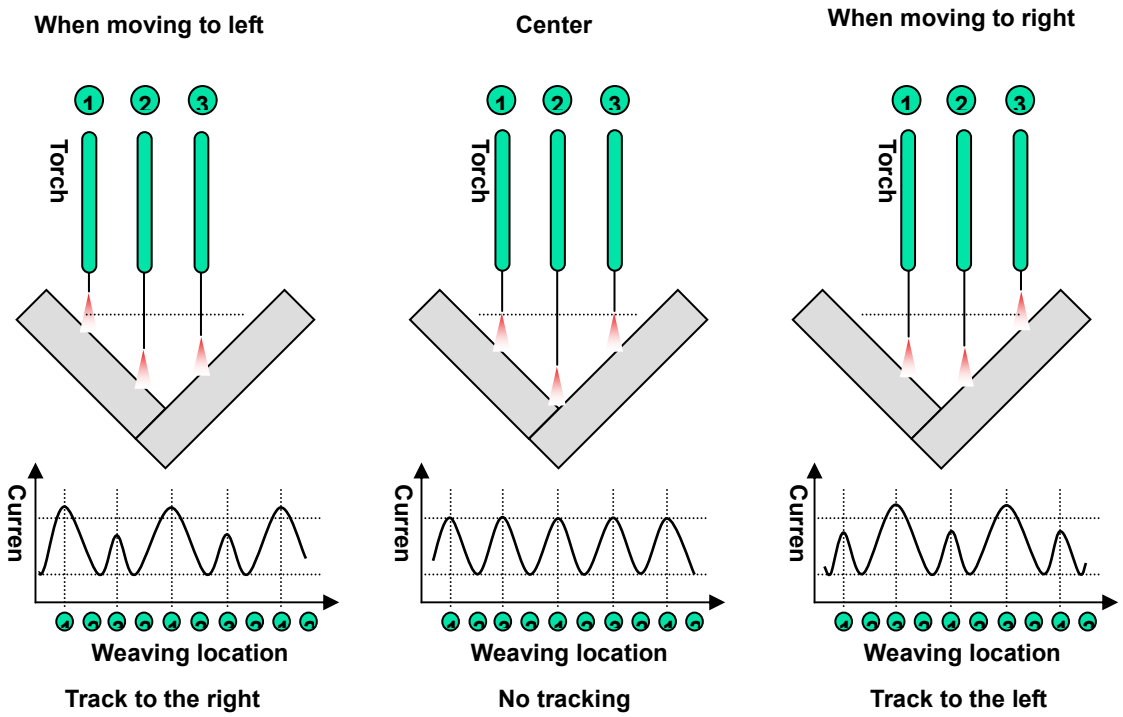
(3) To remove the noise element of the welding current through hardware, you must use a board adjusted with low pass filter of arc welding option board (BD841). The analog input port filter delay time produced by HHI for arc sensing, has No. 3 port fixed to about 240msec and No. 4 port fixed to about 480msec.

1.4. System composition



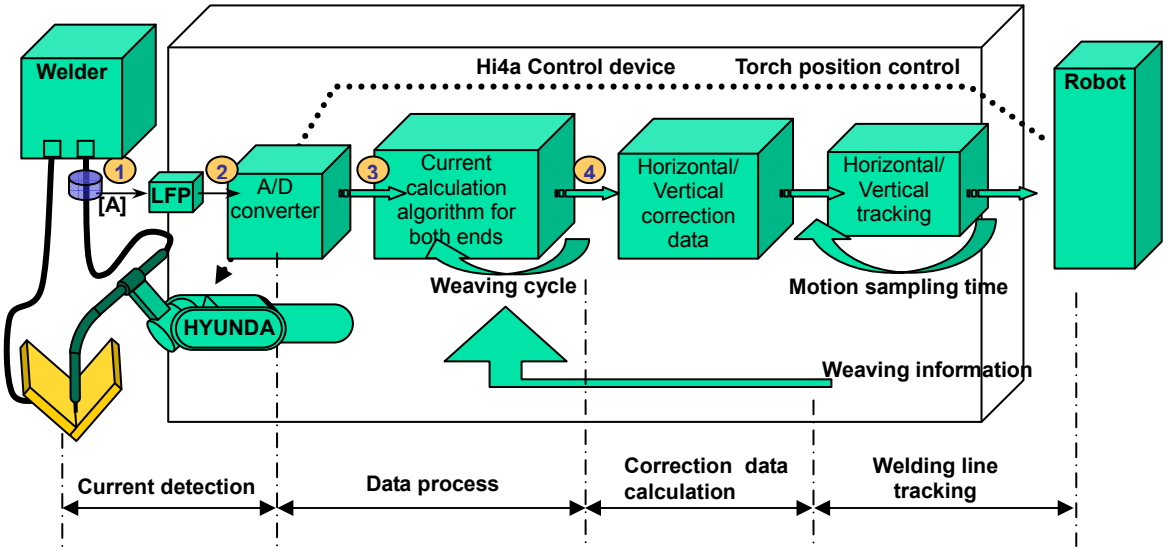
1.5. Principle of arc sensing

The weaving during arc sensing cause the distance between the torch and the work piece to change, causing the resistance to change and current to change. In other words, if you calculate the distance of both ends from current change of weaving zone, you can calculate the calibration in horizontal direction to track the welding line. Also because the starting point of the welding has no error in vertical direction, based on this value you can compare with the average current value of both ends to correct the value.



1.6. Welding line tracking flow

The process of welding line tracking by arc sensing is as follows.



1.7. Arc sensor specification

The welding line tracking function by arc sensing is a function that requires support from HHI technical staff, we cannot support all welding application without the technical support from us. Below specification is the data that went through adequate testing from HHI. If you run on a condition different from below specification, you should contact our technical staff to run a check test of the material and using condition.

1.7.1. Welding condition

- Welding method: CO2, MAG, MIG, FACW
- Applied wire thickness: 1.0~1.6φ (Solid wire, Flux cored wire)
- Maximum welding speed: Depends on welder characteristics
- Applied welding current: 250[A] ~ 300[A]

1.7.2. Work piece condition

- Minimum thickness: 2t
- Maximum tracking performance: Decided by cycle current coefficient value, correction distance per sample and correction distance limit per cycle

1.7.3. Weaving condition

- Frequency range: 0.5~3 Hz
- Amplitude range: Above 2.0 X 2.0 mm
- Weaving method : Simple vibration, ??
- Dwell time: ?.?[sec] ~ ?.?[sec]
- Horizontal unbalanced weaving: ???

1.7.4. Interpolation type

- Straight line interpolation: Possible
- Arc interpolation: Possible
- Positioner synchronization straight line: Possible
- Positioner synchronization arc: Possible

1.7.5. Join type

- Fillet, V-groove
- Maximum permitted gap : Depend on weaving width
- Minimum length of horizontal surface: ???[mm]
- Cylinder fillet : Minimum diameter that can be applied???[mm]

1.7.6. Other functions

- End point detection function
- Sensing path deviation limit function

2
Condition Setting

2.1. Introduction

You must set the following items to use the arc sensing function.

- Welding current input port allocation
- Arc sensing condition setting

2.2. Welding current input port allocation

To detect the arc welding current, you must designate the analog port number to connect the output current form the welding current detection device to the arc welding option board (BD481).

2.2.1. Operation

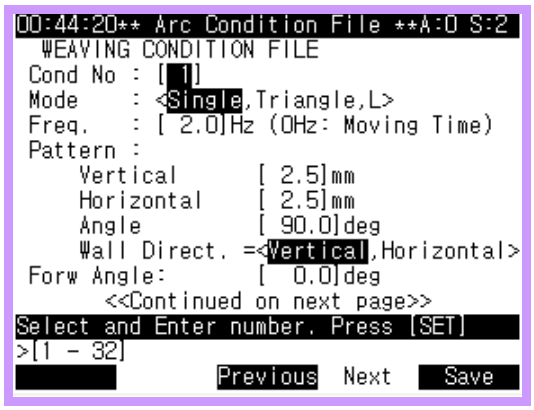
Select 『[PF2]: System』 → 『4: Application parameter』 → 『2: Arc Weld』 from the manual mode and select 『[PF4]: Next』.

You can set the welding current input port using the menu item 13 from above. If the from the above menu. If 『Arc sensing =<Enable>』 from the arc sending condition to be explained later, is allocated to the value of 0, it will indicate an error saying 『E1296 Assign InPORT of weld [A] for TRK.』 and stop.

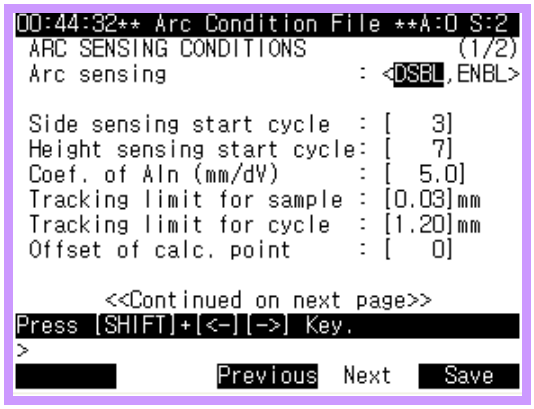
2.3. Arc sensing condition setting

2.3.1. Operation

(1) Because arc sensing basically includes weaving, it is included in the weaving condition file. You can see the weaving condition file, as shown below, by locating the cursor to the {WEAVON WEV#=?} command and pressing the [QuickOpen] key.

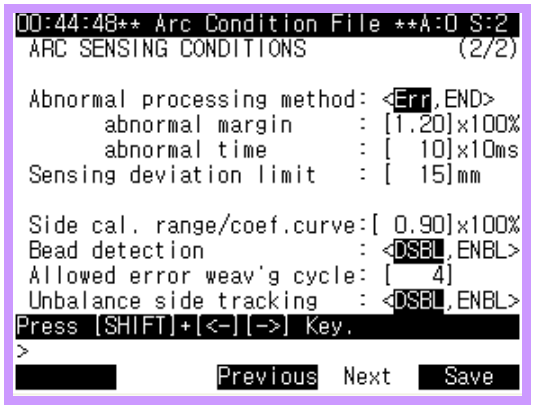


(2) Press 『[PF3]: Next』 twice from the above screen to see the following arc sensing condition.



Reference) The value shown in the screen is default value.

(3) If you press the 『[PF3]: Next』 from the above screen, you can see the additional condition as shown below.



2.3.2. Item explanation

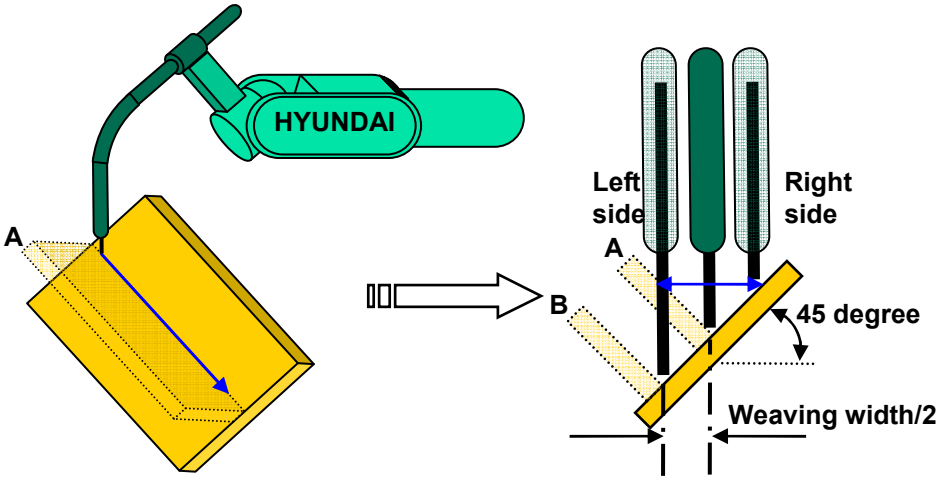
- Arc sensing: <Disable, Enable >
  This sets whether to enable or disable the arc sensing function.

- Side sensing start cycle: [0~9]
  Arc sensing is divided into horizontal and vertical sensing based on the weaving surface. This sets from which weaving cycle to start the horizontal sensing. Generally it is recommended to skip 2 or 3 cycles when starting the arc welding because the welding current is unstable.

- Height sensing start cycle: [1~9]
  This sets the starting cycle of the vertical sensing and because the reference value for vertical sensing has to be set, it must be a higher value than the horizontal sensing. Generally because the current change when starting the welding is unstable, this value should be set to about 7 cycles so that the vertical sensing is done based on the current value from the start cycle of the horizontal sensing to right before the vertical start cycle.

- Coef. of ampare: [0.0~25.5]
  This value is used for calculating the corrected distance from the welding current input value. It is calculated based on the formula 『Corrected distance = Amplitude of analog input voltage (0~12) × Current coefficient』. This value can slightly differ depending on the type of current detection device, input range and using current. Therefore you should get the appropriate value through a simple measurement during site installation.

  ① Calculating the current coefficient



For the down looking weaving, tilt the plate of the work piece by 45 degrees. Assume that there is A and teach the weaving program of joining the two work pieces. Measure the current value of left and right side to calculate the current coefficient. (Refer to data collection function of engineering material). In other words, in the above example, because there is no A, the wire length on the left side is long than that on the right, and there exists a current change reciprocal to this value. At this time because the distance the robot must move is the same as the when there is a work piece on B location, the robot must move by a distance of weaving wide/2. Therefore you can calculate with the formula 『Current coefficient =(Weaving width /2)/Different in current value』.

Ex) 500[A] welder, welding current = within 300[A], side calculation of arc sensing condition is 0.9, current detection device is CT and ±24V SMPS, connect to 100[Ω] resistance. Set the weaving width to 3X3[mm] and operate the robot to collect the data.
If actual robot moves 3.82[mm] and collected value of the analog input voltage in horizontal direction is 6.046/5.871[V], and because the voltage difference is 0.175[V], 『Current coefficient = (Weaving width /2)/Voltage difference =(3.82/2)/0.175 =10.9』.

- Tracking limit for sample: [0.00~2.55]mm
  This sets the maximum value of tracking the horizontal/vertical correction distance calculated from the current coefficient per each weaving cycle by the motion sampling cycle. This value is calculated by actual weaving width and moving speed as shown below.

  ① Correction distance per sample = (Actual weaving width /2) / (Number of motion sampling per weaving cycle)
  For example, if actual weaving width = 3.82[mm]
  Weaving frequency = 2[Hz]
  Welding speed = 60[cm/min],
  Number of motion sampling per weaving cycle = 1 / (2[Hz]) /20msec = 25,
  Therefore, correction distance per sample = 3.82/2/25=0.0764mm

  The calculated value above is a theoretical value and it is not recommended to track half of the weaving width during 1 cycle of actual weaving. Therefore set it to a slightly smaller value than the calculated value. If this value is too high, the bead is not being smooth and if this value is too low, the tracking angle will be smaller.
  If the value calculated from the current coefficient is higher than the distance to reach within 5 weaving cycles due to the limitation of correction distance per sample, 『E1194 Arc sens'g error(Side range over)』 or 『E1195 Arc sens'g error(Height range ov.)』 can occur.

  Reference) For example, correction distance per sample = 0.05[mm],
  Weaving frequency = 2[Hz],
  Welding speed = 60[cm/min],

  ② Correction distance per weaving cycle
  = Correction distance per sample X Cycle time / Sampling time
  = 0.05[mm] X 1 / (2[Hz]) / 20[msec]
  = 0.05[mm] X 500[msec] / 20[msec]
  = 1.25[mm]

  ③ Movement per cycle
  = Welding speed X Cycle time
  = 60[cm/min] X 1 / (2[Hz])
  = 60 × 10[mm] / 60,000[msec] X 500[msec]
  = 5[mm]

  ④ Tracking angle range
  = tan-1(Correction distance per weaving cycle / Movement per cycle)
  = tan-1(1.25[mm] / 5[mm])
  ≒ 14[deg]

- Tracking limit for cycle: [0.00~2.55]mm
  The highest value of the corrected distance from the current coefficient per cycle, is limited. The maximum of this value is half of actual weaving width but as described in correction distance per sample, it is recommended that the value be lower than the theoretical value.

Reference) For example, correction distance limit per cycle = 1.2[mm],
Weaving frequency = 2[Hz],
Welding speed = 60[cm/min]

① Movement per cycle
= Welding speed X Cycle time
= 60[cm/min] X 1 / (2[Hz])
= 60 X 10[mm] / 60,000[msec] X 500[msec]
= 5[mm]

② Tracking angle range
= tan-1(Correction distance per cycle / Movement per cycle)
= tan-1(1.20[mm] / 5[mm])
≒ limited to 13.5[deg].

- Offset of calc. point: [-9~9]
  HHI's arc sensing sets the zone starting from the center of the weaving and going around the end points, and calculates the current values of the end points. This set value is for the horizontal shift function (negative=past direction) based on the center of the weaving. And this function deals with the case when the response speed of the welding current detector is different. Generally it is set to 0.

- Abnormal processing method: <Err,END>
  This sets the method to process the current value when it is abnormal. If you set it to 『Error』, and the number of cases when the input current exceeds the 『abnormal margin』 exceeds 『Decision number』, it generates an error saying 『E1192 Arc sensing error([A] range over)』. But if you set it to 『End 』, error will not be generated in the above case and moves to the end point. Then it stops and executes the next command. Generally the next command is {ARCOF}, which processes crater from the detected location.

  ① abnormal margin: [1.00~1.50] X 100%
  This sets the margin to decide the abnormal current. The abnormal current is decided by the past 5 data based on the following criteria.

  Top value of abnormal decision = Average of past 5 × Abnormal decision margin,
  Bottom value of abnormal decision
  = (Average of past 5 ×2)– Top value of abnormal decision

  ② abnormal time: [3~200] X 10msec
  This sets the time to decide whether it is abnormal when the input current exceeds the『abnormal margin』. This value is to decide how fast to recognize the end point, but if set too low, there is a possibility that robot will make a judgment that it is the end point even when it is not. Therefore you must set it according to the environment and it is generally recommended to set to about 10 (0.1 second).

- Sensing deviation limit: [0(disable)~200]mm
  This sets the limit to generate an error and stop the robot when the welding line tracking distance by arc sensing exceeds a specific distance. You can utilize this value to set the robot to not deviate from the set path taught by several welding related causes.

- Side cal. range/coef.curve : [-1.27~0.00]
  You can set the algorithm and the value to calculate the side current.

① Arithmetic average algorithm
If this value is greater than 0, use the average value to calculate the side current. The meaning of this value is to decide and use the average of how much current based on the center of the weaving zone of side. In other words, it set to 0.9, it takes the plus and minus 45% average of the current value based on the end point to calculate the side current.

② Curve fitting algorithm
If the above value is set to 0 or negative, it uses the curve fitting algorithm and the value means the curve sensitivity. In other words, it decides the constant of the 2^{nd} term. If this value is 0, it means that it is a surface condition not distinguishing between end point and center point. If this value is negative, the bigger the value the sharper the curve of the end point than the center point. When detecting the bead, it is effective to set the value to -0.02~-0.1.

Reference)
Generally it is recommended to use the arithmetic algorithm because the welding current changes abruptly.

- Bead detection: <Disable, Enable>
This function is only valid when the side current calculation method is using curve fitting algorithm. This function is set to make a decision with the bead when you are not satisfied with the curve shape. If disabled, the time when you cannot forecast the current at the end point exceeds the 『Allowed error weav'g cycle』, it generates an error 『E1192 Arc sensing error([A] range over)』. But if this function is enabled, in the above situation it will not be processed as an error but recognizes with the bead and stops the movement to execute the next command. Generally the next command is {ARCOF}, which processes crater from the detected location.

- Allowed error weav'g cycle : [1~9]
This value is also valid when the side current calculation method is curve fitting algorithm, and is used for the following.

① For the initial correction distance calculation, you cannot calculate the correction distance if the end point current cannot be estimated. In this case it just moves to the next operation and if it reaches a fixed number of times an error is generated saying 『E1192 Arc sensing error ([A] range over)』.

② This limits the number of accumulated times when you cannot get the end point current of both left and right side. Number of accumulated times refers to number which increases as an error occurs and decreases when it does not occur. In other words, if continuously normal, it will maintain 0 until en error is generated.
If it reaches the number set here, you will see an error 『E1193 Arc sens'g error(Too unstable [A])』. You can check the detail error item in the error screen. But if this process is set to enable the bead detection function, it decides with the bead and processes as it is an end point.

③ When you cannot calculate the end point current, you can separately manage the number of accumulated times in left and right side. When it exceeds this number, you will get an error saying 『E1193 Arc sens'g error(Too unstable [A])』. You can check the information on which side in the error screen. But if this process is set to enable the bead detection function, it decides with the bead and processes as it is an end point.

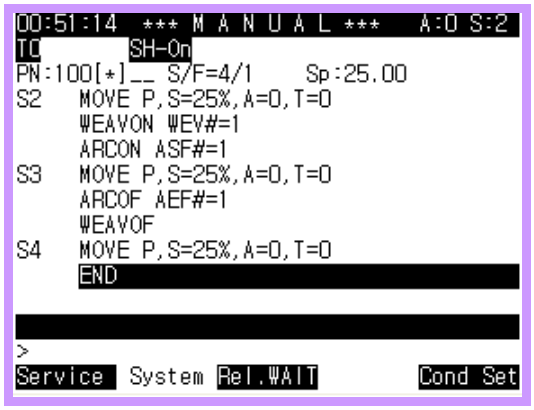
Caution) In case of tag welding to fix the work piece within the welding zone, you must set the number of times to ignore the tag.

- Unbalance side tracking: <Disable, Enable >
  This function is enabled when needed for imbalance sensing w hen the left and right welding bead width are different. Horizontal imbalance sensing is executed based on the initial imbalance level.

3
Work Programming

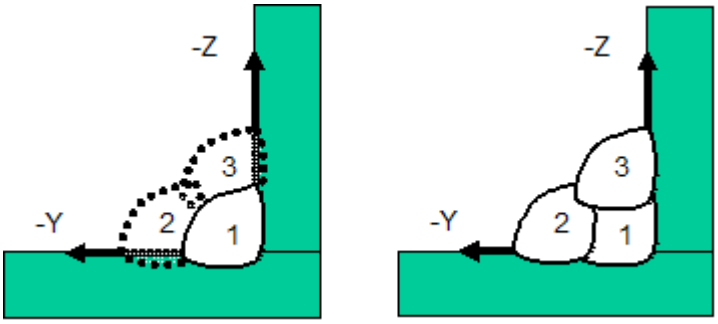
3.1. Introduction

Because arc sensing function is included in the WEAVON command, refer to the 『Arc Welding function manual』.



3.2. Multi-pass welding using path save function

This function is used when required angle in rear plate arc welding is too wide for one welding or when the volume is too large requiring several weldings.
Generally due to the characteristics of the arc sensing, layers other than the root path which is the initial layer can be unstable. Therefore only track the welding line for the initial layer and then save the tracking path. Shift the saved path and create a path for 2 or more layers.



You can designate the sensing path using the following “TRJLOG” command and you can use the saved path in HRBASIC.

TRJLOG ST=<Start/End>,SC=<Sampl'g cycl>,
LSP=<Record start pose parameter >,
LCV=<LV% number for record number exchange >

Explanation) Index explanation
SC : 1=Path record start, 0=Path record end
SC : 0=Path step save option (currently not supported)
1~100=Sampling weaving cycle
LSP: Record start pose parameter number (Max of 999)
LCV: Designate/check LV% parameter number of record number
If you set it to maximum value before command execution, it will decrease by 1 every time you record.

The work programming is as follows.

```
~~~~~~~1st layer welding: Arc sensing and path saving ~~~~~~~~~~~~~~~~~~~~~~~~~~
            LV3%=200                          'Designate maximum number of saves
            WEAVON WEV#=1                     'Arc sensing including weaving
            ARCON ASF#=1                      'Arc welding start
            TRJLOG ST=1,SC=5,LSP=100,LCV=3 'Path save start
      S2    MOVE L,S=40cm/min,A=0,T=0
            TRJLOG ST=0                       'Path save end
            ARCOF AEF#=1                      'Arc welding end
            WEAVOF                            'Arc sensing end
            V5%=200-LV3%                      'Number of saves with path
~~~~~~~Omitted ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
```

Based on the saved path, you can prepare a work program to do multi-pass welding as follows.

2nd layer path : Shift the 1st layer path by 3mm to –Y direction and rotate 10 degrees in RX direction
3rd layer path : Shift the 1st layer path by 3mm to –Y direction and rotate -10 degrees in RX direction

```
~~~~~~~2nd/3rd Welding program ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
            IF V2%=2 THEN                     '2nd layer welding?
            LR1=(0,-3,0,10,0,0)R              'Y=-3, RX=10 degree
            ELSE V2%=3 THEN                   '3rd layer welding?
            LR1=(0,0,-3,-10,0,0)R             'Z=-3, RX=-10 degree
            ENDIF
    S4  MOVE L,P20,S=20%,A=0,T=0              'P20 is start point.
            WEAVON WEV#=1
            CONTPATH 1                        'Continuous pass start
            ARCON ASF#=1
            FOR V1%=0 to V5%                  'V5% is saved number
            LP1=P[100+V1%]+LR1                'LR1 is shift value for applicable layer
    S5  MOVE L,LP1,S=40cm/min,A=0,T=0
            NEXT                              'Move to saved location path
            ARCOF AEF#=1
            CONTPATH 0
            WEAVOF
~~~~~~~Omitted ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
```

4

Troubleshooting

Code	E1192 Arc sensing error([A] range over)
Cause	The detected welding current is in excess of the range. Namely, the frequency in excess of End point judging margin is more than the items of judgment.
Action	1. Inspect the welding current detecting circuit. 2. In case of end point, set the end point detecting function as Enable. 3. In case of no end point, adjust the end point judging margin or items.

Code	E1193 Arc sens'g error(Too unstable [A])
Cause	The detected welding current is in excess of the range. Namely, the frequency in excess of End point judging margin is more than the items of judgment.
Action	1. Inspect the welding current detecting circuit. 2. In case of end point, set the end point detecting function as Enable. 3. In case of no end point, adjust the end point judging margin or items.

Code	E1194 Arc sens'g error(Side range over)
Cause	It occurs when the calculated left/right follow-up is not available for a certain cycle.
Action	Adjust the left/right current or maximum distance of interpolation per sample.

Code	E1195 Arc sens'g error(Height range ov.)
Cause	It occurs when the calculated up/down follow-up is not available for a certain cycle.
Action	Adjust the up/down current or maximum distance of interpolation per sample.

Code	E1196 Shift limit over
Cause	Shift volume is in excess of shift limt value of system/shift limit item
Action	Reduce the shift volume or readjust the limit value.

Code	E1295 Set Weav'g mode=single for Track'g
Cause	It occurs when weaving type of weaving condtion is not Single.
Action	Change the weaving type to Single.

Code	E1353 Over allowed max. dist. deviation.
Cause	Aberrant distance from trace(locus) by tracking is in excess of allowable value.
Action	Adjust a teaching position, or adjust the allowable averrant distance.

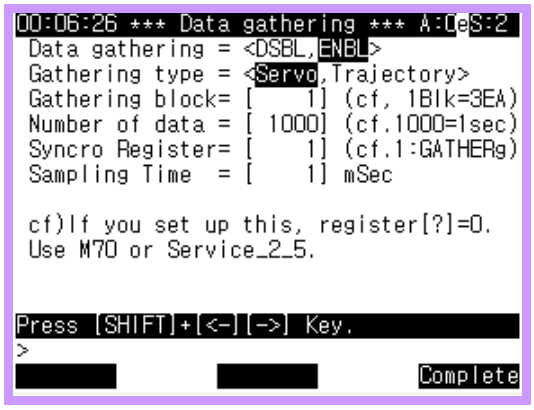
5

Detail Tuning Method (For Engineer)

This part is for the engineer and if the data is incorrectly entered to the controller, it can be very dangerous. Extra care is needed for this operation.

5.1. Information collection file creation

Enter the R4571[SET] in engineering mode and you will see the data collection environment screen as follows.

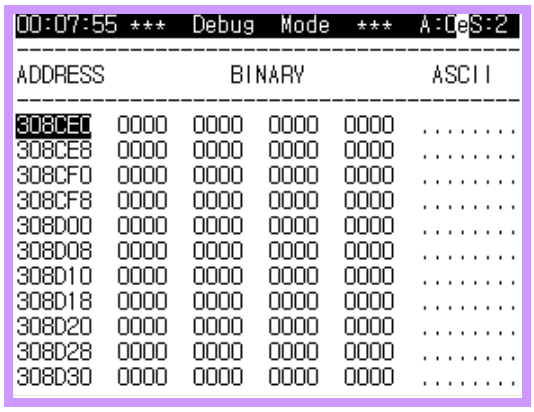


Enter the data as required from the above screen and press 『[PF5]: Complete』 key. It will create a data collection file (ROBOT.GT0). Set it up as explained in the next section and start the arc sensing to collect the data related to arc sensing. Collect data number, from above, is not 1000=1 sec but 1 per 10msec. Therefore it is 1000/(1000/10)=10 sec.

File created this way can be opened in the PC using HRView and use the Microsoft Excel tool to graphically diagnose the status.

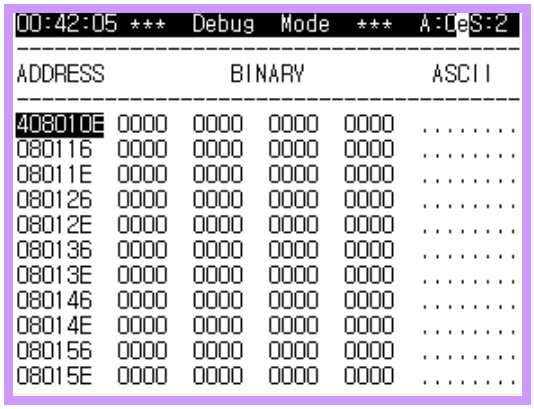
5.2. Arc sensing information collection environment setting

(1) When the engineering code is entered, press the [SHIFT]+[FWD] key to see the following debug mode.

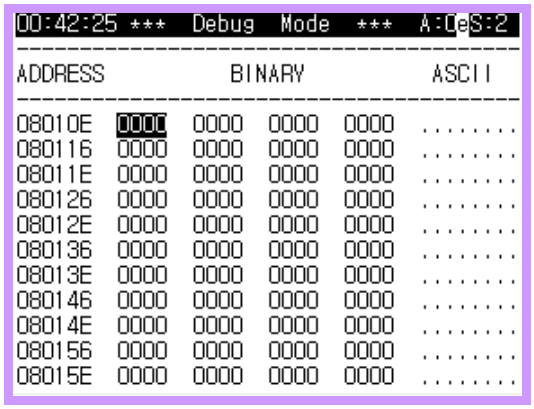


(2) Enter 4080010E (Refer to below A~F input method) and press the [SET] key. You can see the screen change as follows.

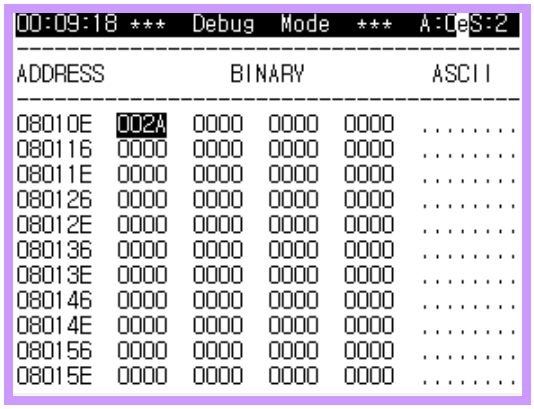
Reference) A~F entry method
A=([SHIFT]+[4]),B=([SHIFT]+[5]),C=([SHIFT]+[6]),
D=([SHIFT]+[7]),E=([SHIFT]+[8]),F=([SHIFT]+[9])



(3) Press the cursor [=>] key to see the following screen.



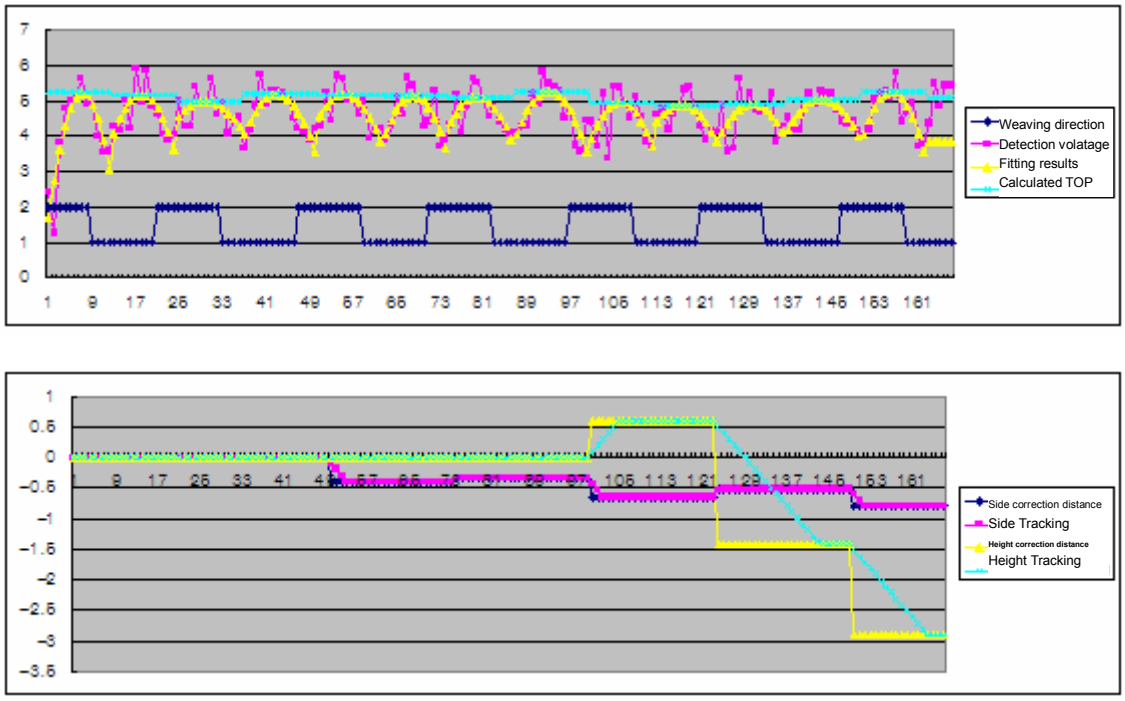
(4) Enter [2][A][SET] to complete the setting.



Caution)
This value is not deleted even after turning the power Off. The arc sensing information is newly created from WEAVON command execution to WEAVOF command execution. Therefore, enter “R357: History display clear” when you want to finish the data collection to clear the setting.

5.3. Arc sensing information data explanation

HHI's arc sensing function is uses the curve fitting method to reinforce immunity to arc noise and you can obtain the internal processing information as shown below from the arc sensing information data.



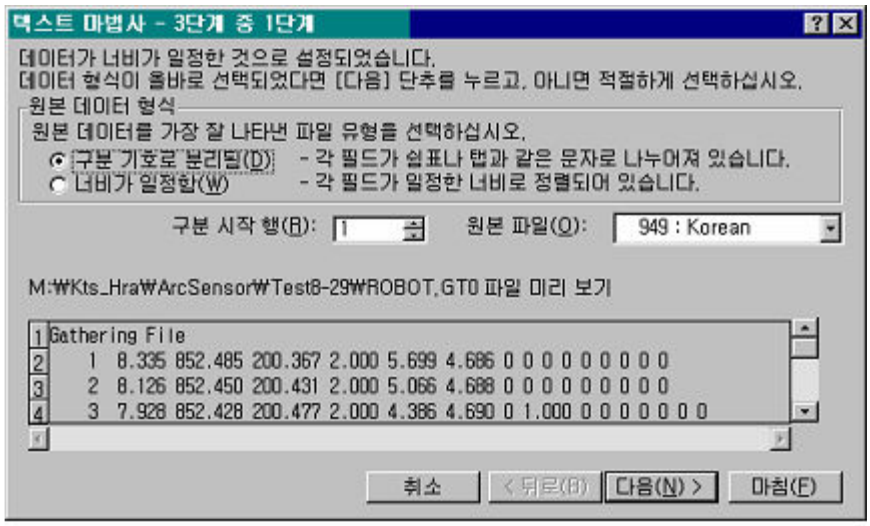
5.3.1. Arc sensing information data file content

The arc sensing information data file is composed of the following content in each line.

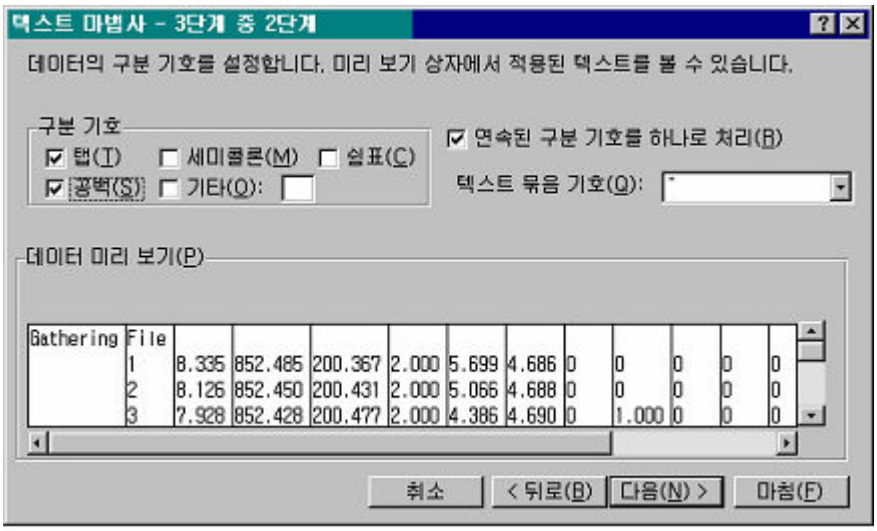
B. Save number: 1~
C. Current robot location X value
D. Current robot location Y value
E. Current robot location Z value
F. Weaving information: 1=Moving in left direction, 2=Moving in right direction
G. Analog voltage value entered from welding current detection device [V]
H. Curve Fitting results
I. Averaging result or end point calculated by Curve Fitting (TOP)
J. Debugging information (Maximum permitted current value, minimum permitted current value, weaving counter, 2^{nd} factor, ..., 0^{th} factor, 1^{st} factor, 2^{nd} factor are repeatedly saved for more than 10 times.
K. Side correction value
L. Side tracking distance: Value reflected to motion
M. Height correction value
N. Height tracking distance : Value reflected to motion

5.3.2. Arc sensing shape drawing

(1) Open the “ROBOT.GT0” file from Microsoft Excel,

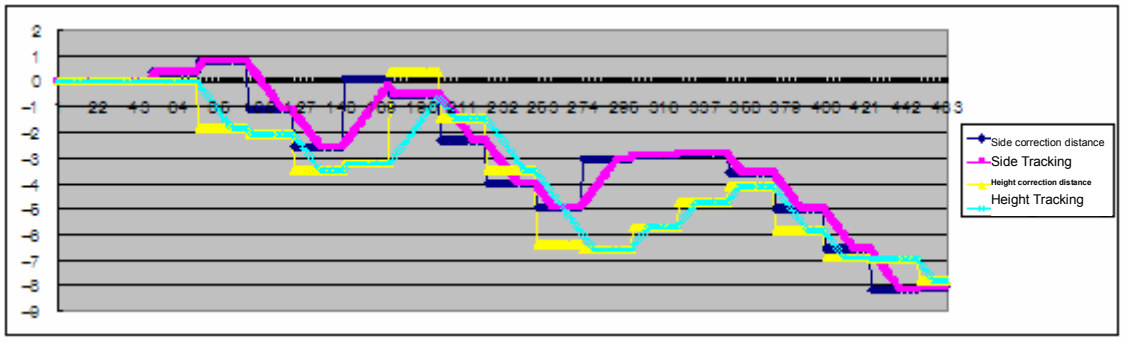


(2) Select delimited and click on [Next] to see the following screen.



(3) Select the empty space and click on [Finish]
Drag the cells 2-F,G,H,I with the mouse and with the [Shift] key down press the [End][Down] to select all. Click on [Chart wizard] to select the ‘Line graph” and click on [Finish] or press [Enter]. You can now draw the first picture. In the same method, you can draw the second picture in cells K, L, M and N.

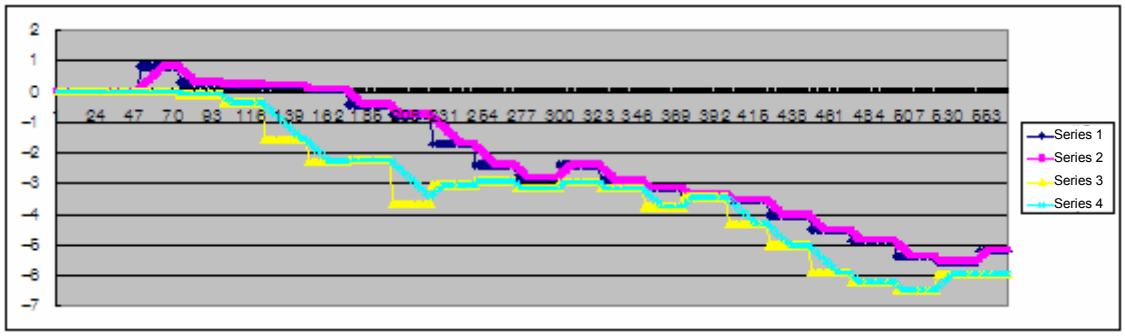
5.3.3. Example-1



① Current coefficient setting : You can see that there is a vibration in tracking due to the current coefficient of horizontal/vertical sensing being set too high.

② Maximum correction distance per sample: It is well set because the function is tracking the correction distance generated by every waving cycle almost in one cycle.

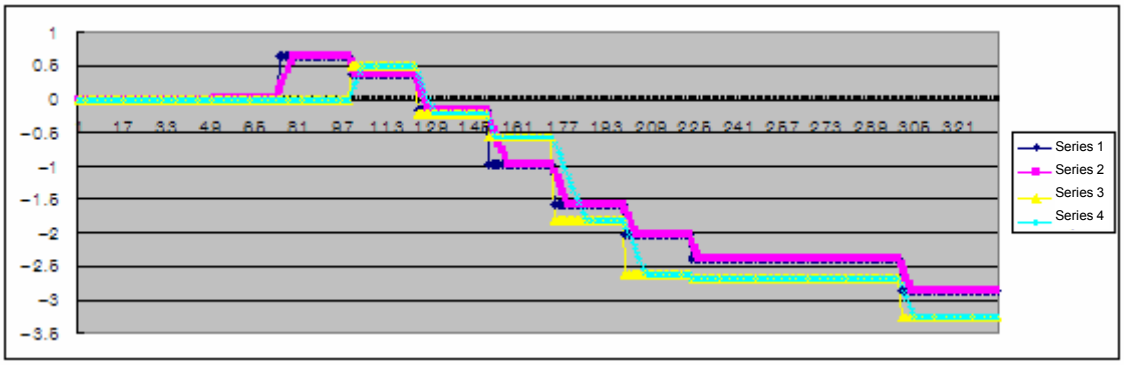
5.3.4. Example -2



① Current coefficient: It is well set because there is no vibration in the correction distance generated every weaving week.

② Maximum correction distance per sample: It is well set because the function is tracking the correction distance generated by every waving cycle almost in one cycle.

5.3.5. Example-3



① Current coefficient: It is well set because there is no vibration in the correction distance generated every weaving week.

② Maximum correction distance per sample : Because it is tracking the correction distance very fast generated by every weaving week, so the current set value can be lowered. But unless you have an issue with the bead type, it is recommended to keep it as it is. This is because the correction distance can increase from actual location error.

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