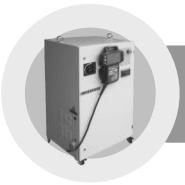
HYUNDAI
HEAVY INDUSTRIES CO.,LTD.

WARNING

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

Hyundai Robot

Hi5AS100601FMEN1



Hi5 Controller Function Manual

Arc Sensing

HYUNDAI
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1 Introduction

1.1. Before function description

This function is an optional function not included in the standard component and requires a License Key to execute the function.

1.2. Welding line tracking by arc sensing

The welding line tracking function by arc sensing is the function to track the welding line by detecting the change in welding current from the arc welding system including the weaving function, and is effective when used with the touch sensing function to detect the starting point.

1.3. Condition to use arc sensing function

(1) Must be arc welding with weaving function

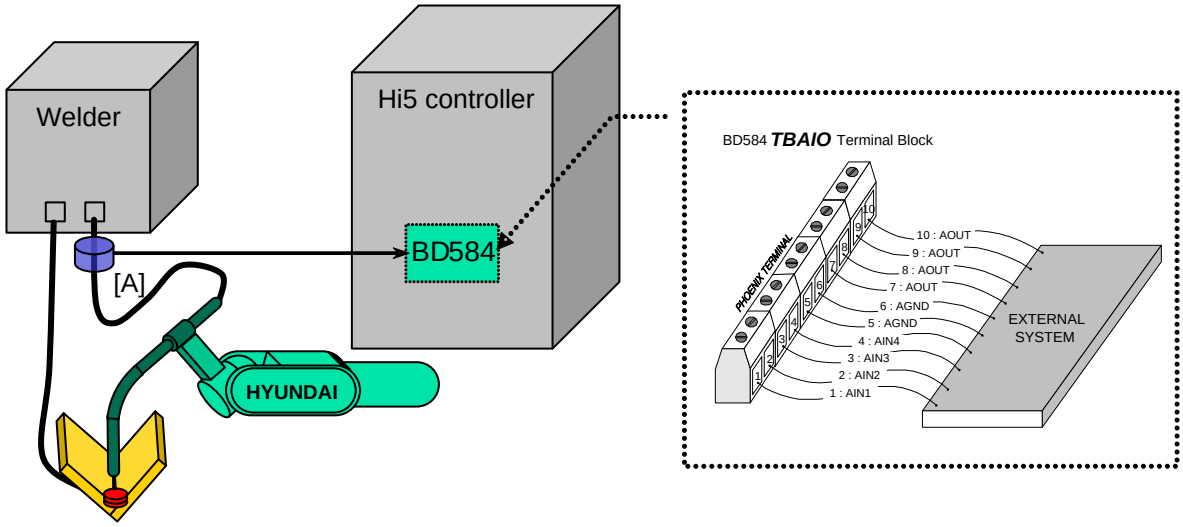
(2) Device to detect welding current for arc sensing must exist. Device to detect the welding current can be installed inside the welder or can be configured as a separate box, and must be configured as one of the two types of current detection device.

- 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

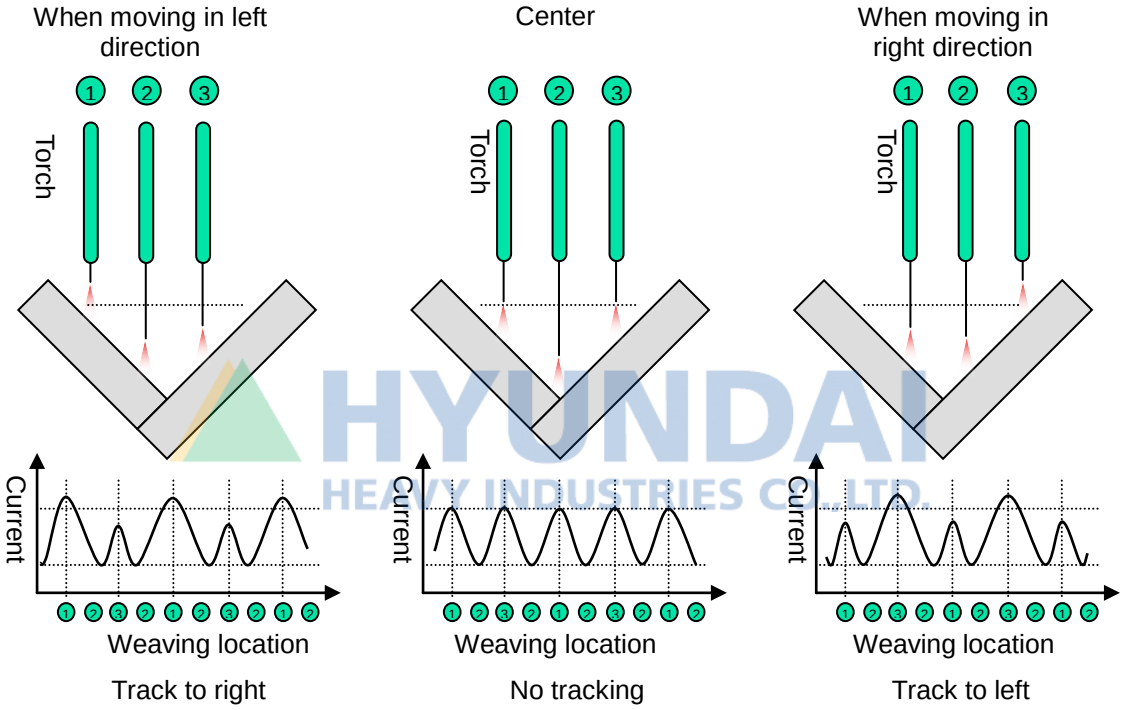
(3) For the digital arc welder, the sensing can be enabled using the welder transmitted data when the welding transmits the current and voltage. (Please consult with the engineer of Hyundai Heavy Industries for more detail.)

1.4. System configuration



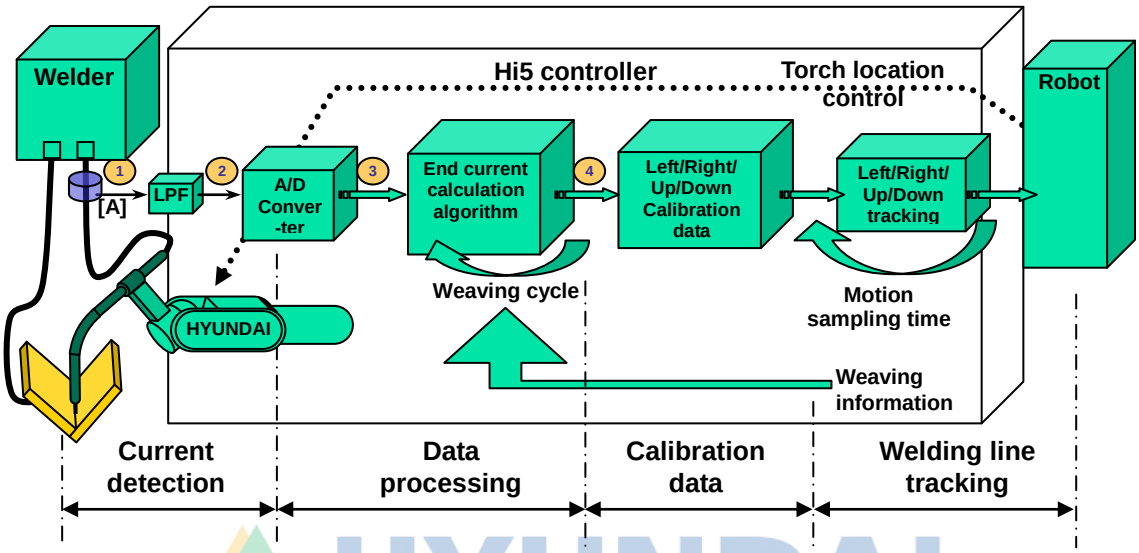
1.5. Principle of arc sensing

In case of weaving during arc sensing, the distance between the torch and base material exists and the resistance changes as much as the distance to change the current. That is, when the distance of the two ends is calculated from the current change in the weaving interval, the calibration in left/right direction can be calculated to track the welding line. Also because the welding start location does not have any error in up/down direction by the touch sensing, the average currents of both ends are compared based on this value to calibrate in up/down direction.



1.6. Welding line tracking flow

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



1.7. Arc sensor specification

Because the welding line tracking function by arc sensing is the function that requires technical support of Hyundai Heavy Industries, all applied functions of the welding cannot be supported without the technical support of Hyundai Heavy Industries. The following specification shows the data based on sufficient testing by Hyundai Heavy Industries. Conditions other than the following specification must be communicated to Hyundai Heavy Industries and requires testing for actual material and using condition.

1.7.1. Welding condition

- Welding method : CO2, MAG, MIG, FCAW
- 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. Workpiece condition

- Minimum thickness : 2t or above
- Maximum tracking performance :
- Decided by current coefficient value, calibrated distance by sample and limitation of calibrated distance by cycle

1.7.3. Weaving condition

- Frequency range : 0.5 ~ 10.0 Hz
- Amplitude range : 2.0 X 2.0 mm or above
- Weaving form : Simple harmonic oscillation
- Dwell time : 0.0[sec] ~ 2.0[sec]

1.7.4. Interpolation type

- Linear interpolation : Possible
- Arc interpolation : Possible
- Positioner synchronized linear : Possible
- Positioner synchronized arc : Possible

1.7.5. Joint type

- Fillet, V-groove
- Maximum permitted gap : Differs by weaving width

1.7.6. Other function

- End point detection function
- Sensing trace deviation limit function

2

Basic Setting

2.1. Introduction

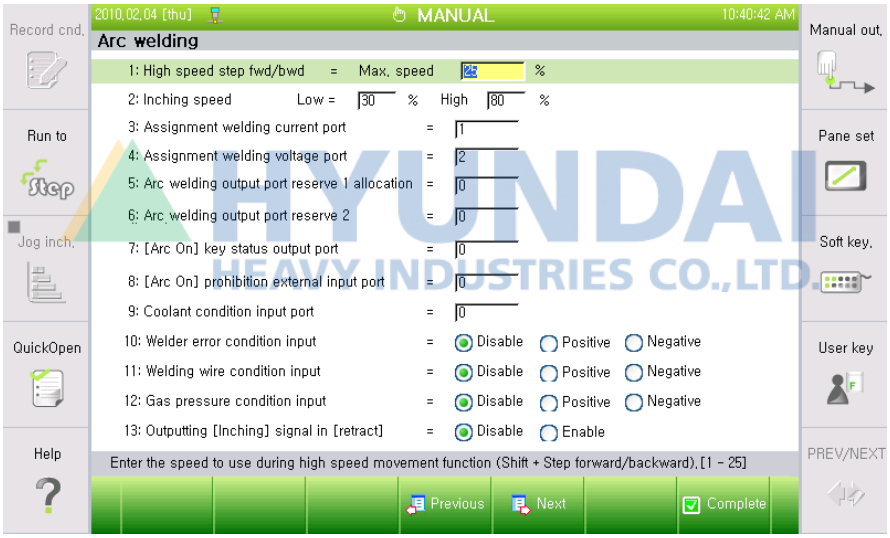
Items to be set to use the arc sensing function are as follows.

- Welding current input port assignment
- Arc sensing condition setting

2.2. Welding current input port assignment

To detect the current during arc welding, the analog port number connected to the arc welding option board (BD584) for the output current from the welding current detection device must be designated.

(1) Select 『[F2]: System』 → 『4: Application parameter』 → 『2: Arc welding』 from manual mode.

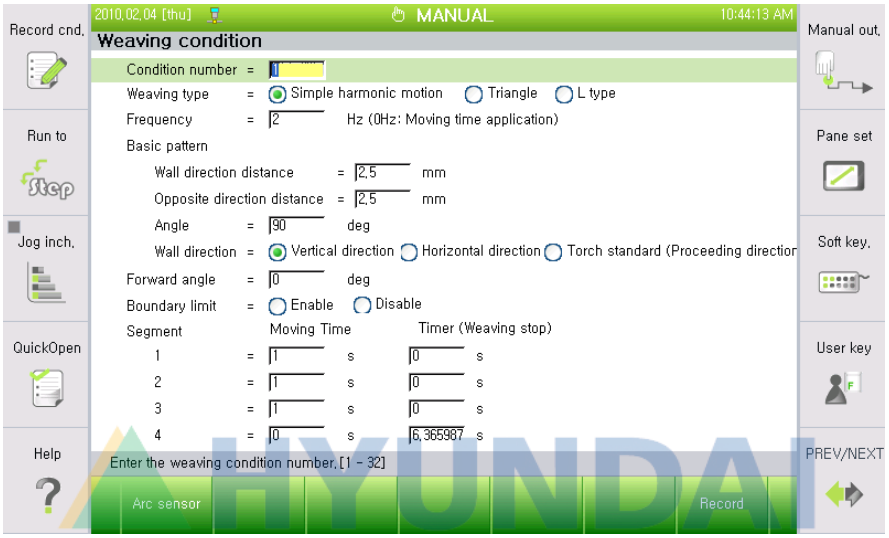


(2) You can set the welding current input power with item #13 from the above menu. If 『Arc sensing = <Enable>』 in the arc sensing condition to be described later and the assigned value is 0, then 『E1296 Allocate welding current input port.』 will be displayed and the unit will stop with an error.

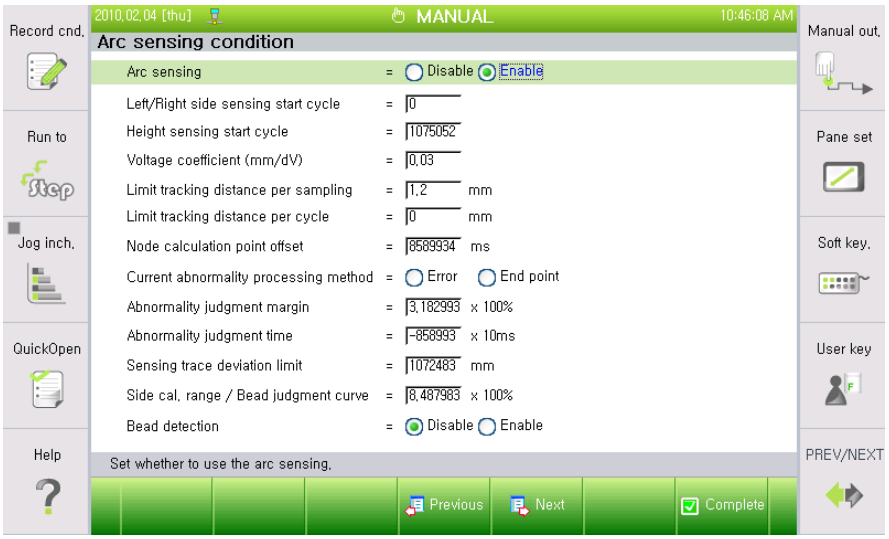
2.3. Arc sensing condition setting

2.3.1. Operation

(1) Because arc sensing basically includes the weaving, it is included in the weaving condition file, and the weaving condition file is displayed in the following screen when you locate the cursor on the {WEAVON WEV#=?} command and press the [QuickOpen] key.



(2) When you press 『[F1]: Arc sensor』 from the above screen, the arc sensing condition will be displayed as shown in the following screen.



2.3.2. Item description

- Arc sensing: <Disable, Enable>

  Set whether to enable or disable arc sensing.

- Left/Right side sensing start cycle: [0~9]

  Arc sensing is done in left/right direction and up/down direction based on the weaving surface, and this value sets from which weaving cycle to start the left/right direction sensing. Generally when starting the arc welding, it is recommended to skip 2-3 cycles as the initial welding current is unstable.

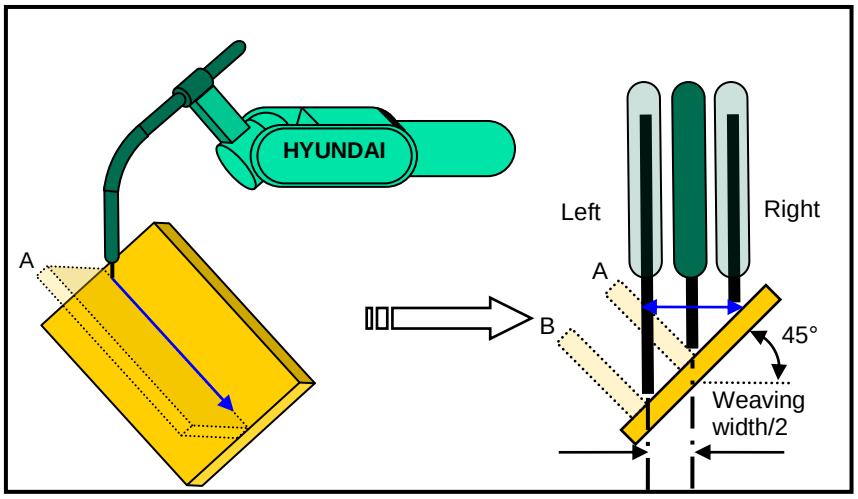
- Height sensing start cycle: [4~10]

  This sets the up/down direction sensing start cycle, and because the reference value for up/down direction must be set, this must be higher than the left/right sensing value. Generally, if this value is set to about 7 cycle as the current change at the start of the welding is unstable, the up/down sensing is done based on the current value from left/right sensing start cycle to before the up/down sensing start cycle internally.

- Voltage coefficient (mm/dV): [-12.5~12.5]

  This value is applied when calculating the calibration distance based on the input value of the welding current, and is calculated based on the equation of 『Calibration distance = Analog input voltage variance (0~12) × Current coefficient』. For current sensing '+' value is entered and for voltage sensing '-' value is entered. This value can differ by the type of current detection device, input range and used current. Therefore, the appropriate value must be calculated based on simple measurement for on-site installation.

  Voltage coefficient calculation method



For the following weaving case, the base material is inclined by 45° as shown in the picture. Assuming that A exists, you can calculate the current coefficient by measuring the left/right current value while implementing the actual welding work after teaching the weaving work program that joins the two type of base material. (Refer to data collection function of engineering data). That is, as shown in the above picture, there is no work piece A, and the length of the left wire is longer than that of the right, showing inverted current change. In this case, because the distance for the robot to move due to the current change is the same as when base material existed on location B, the robot must move only by weaving width/2. Therefore you can calculate the 『Current coefficient =(Weaving width/2)/Current value difference』.

Ex) Configure the system to be 500[A] welder, welding current = Within 300[A], side calculation range of arc sensing condition is 0.9, current detection device is CT and ±24V SMPS and resistance of 100[Ω] to collect the data while operating the robot by setting the weaving width of 3X3 [mm].
When the robot actually moves by 3.82 [mm] and the collected value of analog input voltage of left/right direction is 6.046/5.871[V], the voltage difference is 0.175[V] and the 『Current coefficient = (Weaving width/2)/Voltage difference =(3.82/2)/0.175 =10.9』.

- Limit tracking distance per sample: [0.00~2.55]mm

Set the maximum value to track in the left/right/up/down direction in the motion sampling cycle for the left/right/up/down calibration calculated based on the current coefficient for each weaving cycle. This value is calculated from the actual weaving width and moving speed as follows.

① Limit tracking distance per sample = (Actual weaving width/2) / (Number of motion sampling per weaving cycle)
For example, 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, the calibration distance per sample = 3.82/2/25=0.0764mm.
The above calculated value is a theoretical value and it is not ideal to actually track half of the weaving width in one cycle. Therefore set the actual value lower than the calculated value. The effect of this value is that when it is high, the bead will not be smooth and when low, the tracking angle will be reduced.

If the value calculated based on current coefficient is higher than distance that can be reached in 5 cycles due to the calibration distance limitation per sample, the 『E1194 arc sensing error (Left/Right sensing range exceeded)』 or 『E1195 arc sensing error (Up/Down sensing range exceeded)』.

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

② Calibration distance per weaving cycle
= Calibration distance by sample × 1 cycle time / Sampling time
= 0.05[mm] × 1 / (2[Hz]) / 20[msec]
= 0.05[mm] × 500[msec] / 20[msec]
= 1.25[mm],

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

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

- Limit tracking distance per cycle: [0.00~2.55]mm
This limits the upper value calculated based on the current coefficient per each weaving cycle. Though the maximum of this value is about half of the actual weaving width, it is recommended to have a slightly lower value than the theoretical value described in the calibration distance per sample.

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

① Movement per cycle
= Welding speed × 1 cycle time
= 60[cm/min] × 1 / (2[Hz])
= 60 × 10[mm] / 60,000[msec] × 500[msec]
= 5[mm],
② Tracking angle range
= tan-1 (Calibration distance per cycle / Movement per cycle)
= tan-1(1.20[mm] / 5[mm])
≒ 13.5[deg] limited to.

- Node calculation point offset: [-9~9]

Arc sensing of Hyundai Heavy Industries sets the interval from the central weaving point to the TOP point and calculate the current value of the TOP point, and this function shifts the point of judgment in left and right direction based on the central weaving point depending on the setting (Negative=Past direction). This is the function to respond to the different response speed of the welding current detector. Generally set this to 0 for use.

- Current abnormality processing method: <Error, End point>

This sets the processing method for abnormal current. If the 『Error』 is set, the 『E1192 arc sensing error (Current range exceeded)』 error occurs when the current input that exceeds the 『Abnormality judgment margin』 exceeds the 『Abnormality judgment time』. But when set as the 『End point』, the error does not occur in the above condition and is processed as the end point to stop the movement, and then the next command is executed. Generally the next command is {ARCOF}, and the unit executes crater process from the detected location.

① Abnormality judgment margin: [1.00~1.50]x100%
This sets the margin to judge as abnormal current. Judgment of abnormal current is done based on the past 5 data points.
Upper limit of abnormal judgment = Average of past 5 data points × Abnormal judgment margin,
Lower limit of abnormal judgment = (Average of past 5 data points × 2)– Upper limit of abnormal judgment

② Abnormality judgment time: [3~200]x10msec
This sets the time to judge as abnormal when the input current exceeds the 『Abnormal judgment margin』. Though this value is an element that decides how fast to judge the recognition of end point, if this is set too low, there is a possibility of judging non-end points as end points. Therefore this must be set accordingly to the environment and generally 10 (0.1 sec) is recommended.

- Sensing trace deviation limit: [0 (disable)~200]mm
This sets the limit value to stop the robot when the welding line tracking by arc sensing exceeds a certain distance. By utilizing this value, you can set the robot not to deviate more than a certain distance from the taught trace from several causes of the welding system.

- Side cal. range / Bead judgment curve: [-1.27~0.00]
This sets the algorithm and value to calculate the side current.

① Arithmetic average algorithm
If this value is set higher than 0, the average value is used for side current calculation, and the value decides how much current to use for the average based on the center of the side weaving interval. That is, if set to 0.9, 45% of the current value of before and after the TOP point is averaged to calculate the side current.

② Curve fitting algorithm
If the above value is set to 0 or a negative number, the curve fitting algorithm is used, and the value decides the sensitivity of the curve. That is, this decides the constant of the 2^{nd} factor. When set to 0, this value means the surface condition without any distinction between the TOP and central point, and when this value is set to negative, this refers to the curve in which the TOP point is sharper than the central points. If you set to -0.02~-0.1 when detecting the bead, you can effectively detect the bead.

Reference) Generally the variance of welding current is high and therefore the use of arithmetic average algorithm is recommended.

- Bead detection: <Disable, Enable>
This function is only valid when using the curve fitting algorithm to calculate the above side current and if the curve form is not satisfied, this sets the operation of the function to judge with bead. If disabled, 『E1192 arc sensing error (Current range exceeded)』 occurs when the number of accumulation exceeds 『Permitted cycle exceeding reference value』 when the TOP current cannot be projected based on the input current. But when this function is enabled, the error is not processed in the above condition. The bead is recognized to stop the movement and then the next command is executed. Generally the next command is {ARCOF}, and the unit executes crater process from the detected location.

- Reference value exceeding permitted cycle : [1~9]
  Permitted cycle that exceeds the reference value is used as follows.

  ① When you cannot calculate the current of the end point when calculating the initial calibration, the calibration cannot be calculated and move onto the next operation repeatedly. When a specific number of times is reached, the 『E1193 arc sensing error (Detected current value too unstable)』.

  ② When the TOP current of left and right side cannot be calculated, the number of accumulation is limited. The number of accumulation is the running number of errors from the initial error, which increases by one for each occurrence of the error. But if the calculation is normal after that, it decreases by one. That is, when it is continuously normal, it will maintain 0 and the accumulative management starts when the error occurs. When this reaches the set number of times, the error of 『E1193 arc sensing error (Detected current value is too unstable)』 occurs. You can check the detail error item from the record screen. But, this process judges based on the bead when the bead detection function is enabled and processes as the end point.

  ③ When the TOP current cannot be calculated as described above, the number of accumulation in the left and right direction is managed separately. When this reaches the set number of times, the error of 『E1193 arc sensing error (Detected current value is too unstable)』 occurs. You can check the information on which side the error is from based on the record screen. This process judges based on the bead when the bead detection function is enabled and processes as the end point.

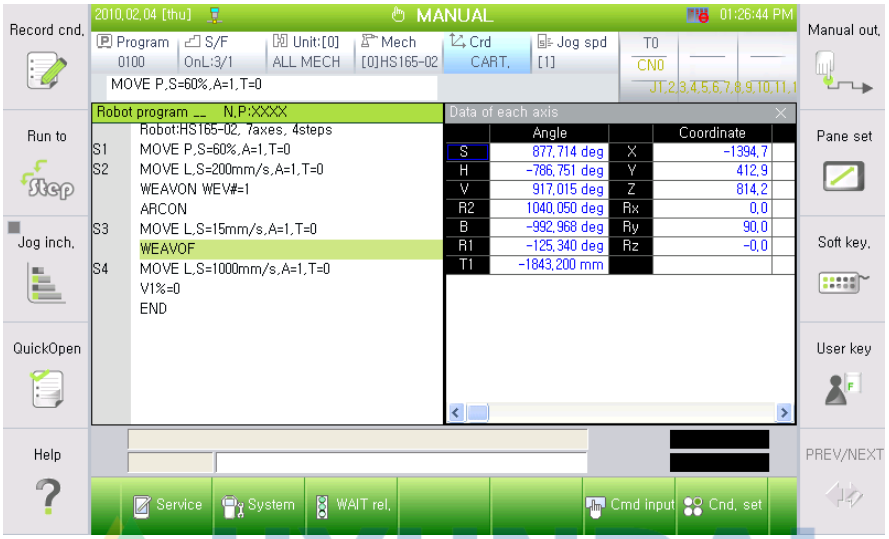
  Caution) If there is tag welding to fixate the base material within the welding interval, you must set the number of times to skip the tag in order to ignore the tag.

- Left-right unbalance sensing ratio : <Disable, Enable>
  This is used for tracking the welding line when the welding bead width of left and right sides are different, and set to Enable when you imbalance sensing is required. Left/Right imbalance sensing will proceed based on the degree of initial imbalance.

3 Work Programming

3.1. Introduction

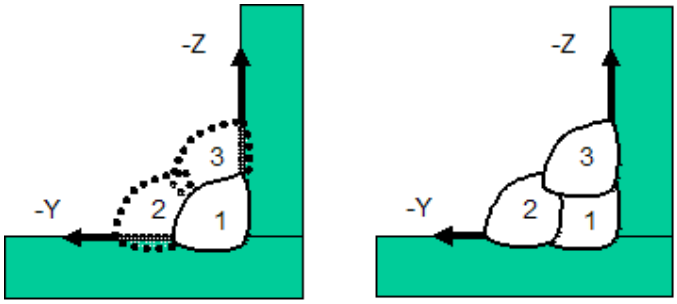
As the arc sensing function is included in the WEAVON command, refer to the 『Arc welding function manual』.



3.2. Multi-path welding using trace save function

This function is used when the required angle in the rear board arc welding is too wide to be welded in one welding or when the volume to fill with welding is too large and requires multiple welding repeatedly.

Generally due to the characteristics of the arc sensing, the sensing can be unstable except for the initial layer, root path. Therefore use the arc sensing only for the initial layer tracking the welding line. And then save the tracking trace and generate the path by shifting the saved path by more than 2 layers.



The sensing trace can be saved using the following “TRJLOG” command, and the saved trace can be used from HRBASIC.

TRJLOG ST=<Start/End>,SC=<Sampling cycle>,
LSP=<Record start pose variable>,
LCV=<LV% number for record count exchange>

Description) Description of element

ST: 1=Trace record start, 0=Trace record end
SC: 0=Path step save option (Currently not supported)
1~100=Sampling weaving cycle
LSP: Record start pose variable number (Maximum of 999)
LCV: Record count designation/check LV% variable number
Before executing the command, save the maximum record value and reduce 1 for every recording.

Prepare the work program as follows.

```
~~~~~~~1st layer welding: Arc sensing and trace save ~~~~~~~~~~~~~~~~
            LV3%=200                    'Designate maximum number of records to save
            WEAVON WEV#=1               'c
            ARCON ASF#=1                'Start arc welding
            TRJLOG ST=1,SC=5,LSP=100,LCV=3 'Start trace saving
        S2  MOVE L,S=40cm/min,A=0,T=0
            TRJLOG ST=0                 'End trace saving
            ARCOF AEF#=1                'End arc welding
            WEAVOF                      'End arc sensing
            V5%=200-LV3%                'Number of traces saved
~~~~~~~Omitted ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
```

The work program to weld multiple paths based on the saved trace is as follows.

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

```
~~~~~~~2nd /3rd layer welding program ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
            IF V2%=2 THEN               '2nd layer welding?
            LR1=(0,-3,0,10,0,0)R        'Y=-3, RX=10 degrees
            ELSE V2%=3 THEN             '3rd layer welding?
            LR1=(0,0,-3,-10,0,0)R       'Z=-3, RX=-10 degrees
            ENDIF
        S4  MOVE L,P20,S=20%,A=0,T=0'P20 is starting point.
            WEAVON WEV#=1
            CONTPATH 1                  'Start continuous pass
            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 Error Description

Code	E1192 Arc sensing error (Current range exceeded)
Detail	This error occurs when detected welding current exceeds the range. That is, “Abnormal judgment margin” is exceeded for “Abnormal judgment time”.
Action	1. Check welding current detection circuit. 2. For end point, set to “Current abnormal processing method = <End point>”. 3. For non-end point, adjust “Current abnormal judgment margin” and “Current abnormal judgment time”.

Code	E1193 Arc sensing error (Current detection too unstable)
Detail	This error occurs when the number of weaving that cannot be fitted to the curve from the detected current value in arc sensing using the curve fitting algorithm exceeds “Permitted cycle exceeding reference value”.
Action	1. Check welding current detection circuit. 2. Adjust the “Bead judgment curve” value slightly higher in – value. 3. Stop location is bead and when the bead detection function is used set to “Bead detection = <Enable>”.

Code	E1194 Arc sensing error (Left/Right sensing range exceeded)
Detail	This error occurs when left/right tracking cannot be done for a certain period (5 cycles).
Action	Adjust the current coefficient or maximum calibration distance by sample.

Code	E1195 Arc sensing error (Top/Bottom sensing range exceeded)
Detail	This error occurs when left/right tracking cannot be done for a certain period (5 cycles).
Action	Adjust the current coefficient or maximum calibration distance by sample.

Code	E1296 Allocate welding current input port
Detail	This occurs when the welding current input port for arc sensing is not set.
Action	Assign the input port for “13: Welding current input port assignment” in arc welding parameter (System > 4: Application parameter > 2: Arc welding).

Code	E1295 Arc sensing only supports weaving shape=simple harmonic motion.
Detail	This occurs when the weaving type of weaving condition is not simple harmonic oscillation.
Action	Change the weaving type of weaving condition to simple harmonic oscillation.

Code	E1353 Exceeded the permitted trace deviation distance.
Detail	This occurs when the trace deviation distance by tracking exceeded the permitted value.
Action	Edit the teaching location or adjust the permitted trace deviation distance.

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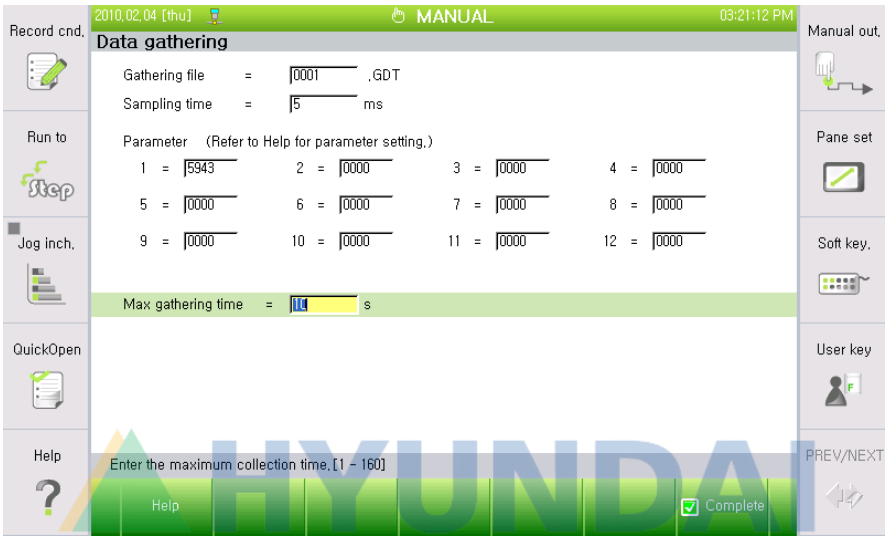
5

Detail Tuning Method (For Engineer)

This item is the description for the engineer, and when the data is entered incorrectly, it can result in very high risk. Therefore it must be operated prudently and carefully

5.1. Information gathering file preparation

(1) First the data collection must be set up to collect the information. Enter the message box through 『[F1]: Service』 → 『16: Data gathering』.



(2) For arc sensing, '5943' must be entered in #1 input box of parameter item to indicate data collection for arc sensing. During arc sensing, parameter setting from 2 to 16 is ignored.

(3) Other setting item is as follows.

- Gathering file
  This file is set to save the data collection results. When you press the [F7: End] key, the data collection file of set number will be newly created.

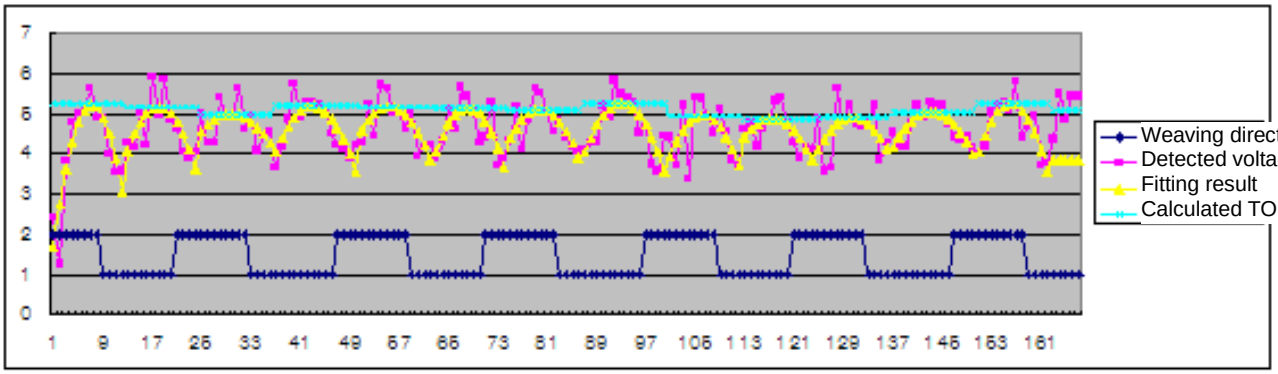
- Sampling time
  This setting is not used for arc sensing.

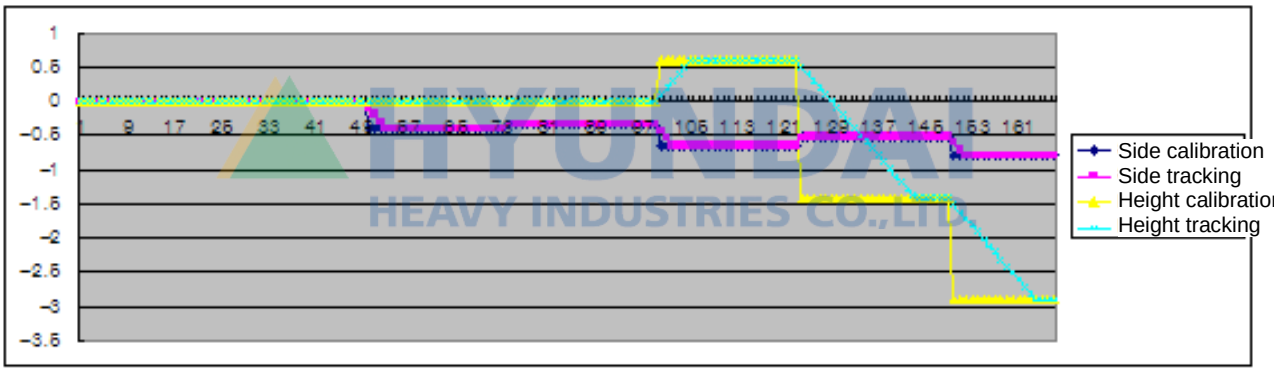
- Max. gathering time
  This sets the time to collect the arc sensing data. Arc sensing function saves the data as much as the time set from this item prior to the end point of arc sensing to the gathering file.

  The file created based on this setting can be exported to the PC using HRView and the condition can be diagnosed graphically using the Microsoft Excel tool.

5.2. Arc sensing information data description

Arc sensing function of Hyundai Heavy Industries uses the curve fitting method to reinforce the resistance to the arc noise, and can obtain the internal processing information as shown below from the arc sensing information data.





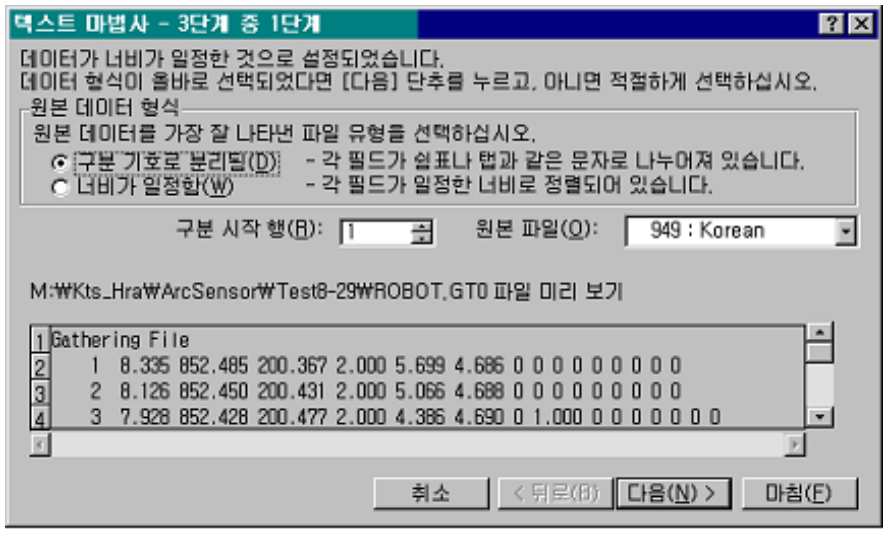
5.2.1. Arc sensing information data file detail

The arc sensing information data file saves the detail as shown below.

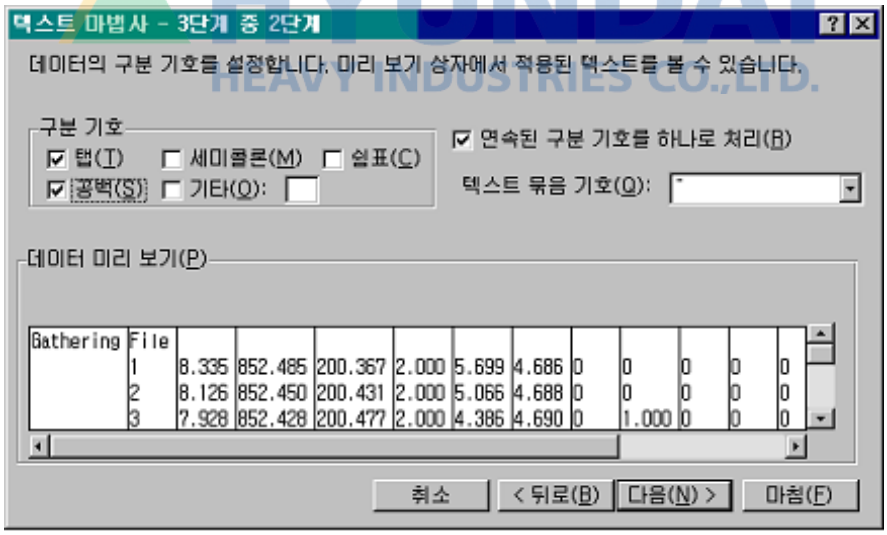
A. Saving number : 1~
B. Current robot location X value
C. Current robot location Y value
D. Current robot location Z value
E. Weaving information : 1=Moving to left direction, 2=Moving to right direction
F. Entered analog voltage value entered in welding current detection device [V]
G. Maximum permitted current
H. Peak point (TOP) calculated based on average result or curve fitting
I. Debugging information (Maximum/Minimum permitted current for curve fitting, weaving counter, 2^{nd} factor, ..., 10 times 0^{th} factor, 1^{st} factor, 2^{nd} factor are repeatedly saved.)
J. Side calibration
K. Side tracking : Value reflected to motion
L. Height calibration
M. Height tracking : Value reflected to motion

5.2.2. Drawing arc sensing wave form

(1) Select “ROBOT.GT0” from Microsoft Excel,

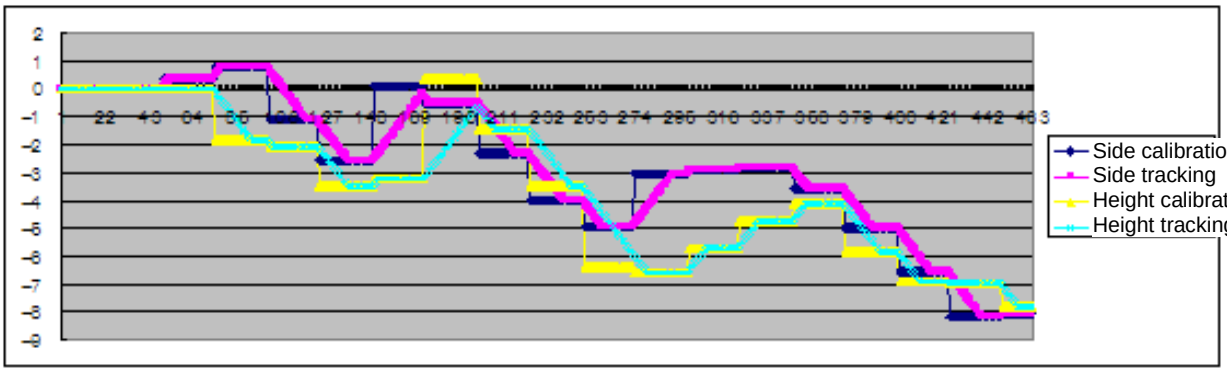


(2) Select “Delimited” and click on [Next].



(3) Select space and click on [Finish].
Drag cells 2-F, G, H and I and with the [Shift] key pressed, press the [Finish] and [Down] key to select all. Click on [Chart Wizard] and select ‘Line’, and then click on [Finish] or press the [Enter] button to draw the first graph of this chapter. In the same method, you can draw the second graph of this chapter by selecting cell K, L, M and N in the same method.

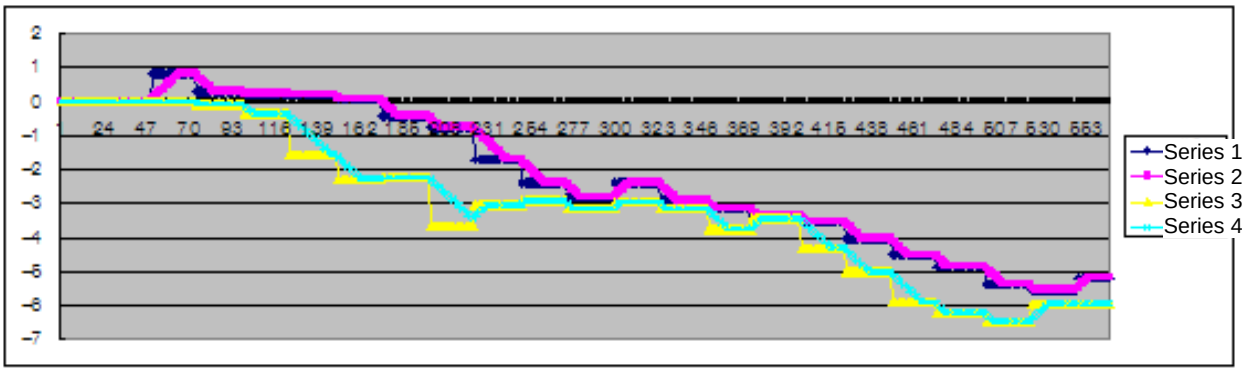
5.2.3. Utilization example-1



(1) Current coefficient setting
The left/right/up/down sensing current coefficient value is set too high and the vibration in the tracking can be checked.

(2) Maximum calibration distance by sample
Because the calibration is tracked for almost each cycle by the weaving cycle, it is well set.

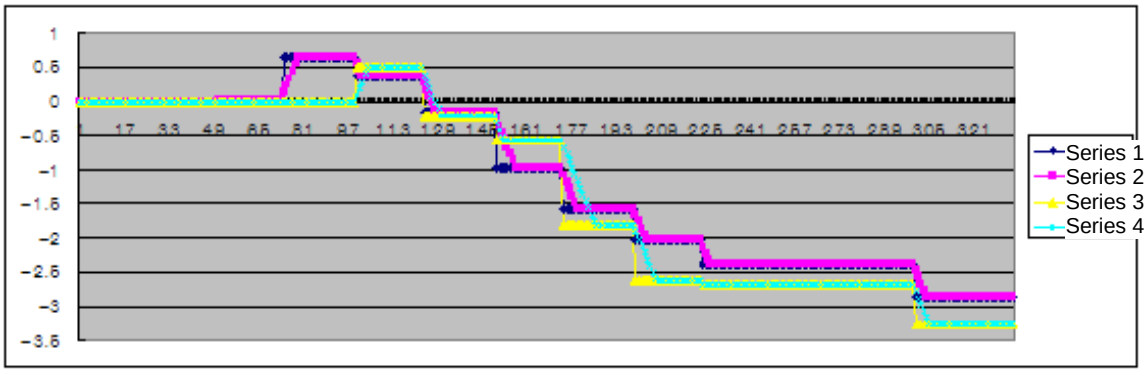
5.2.4. Utilization example-2



(1) Current coefficient
Because there is no vibration in the calibration for each waving cycle, it is well set.

(2) Maximum calibration distance by sample
Because the calibration is tracked for almost each cycle by the weaving cycle, it is well set.

5.2.5. Utilization example-3



(1) Current coefficient
Because there is no vibration in the calibration for each waving cycle, it is well set.

(2) Maximum calibration distance by sample
Because the calibration for each weaving cycle is tracked at high speed, it can be less than the current value, but it is recommended to use as current condition if there is no issue with the bead form. This is because it can generate higher calibration depending on the actual location error.

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