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Studying on Adaptive Control System for Moderate-Thick Plate Filled Welding With Variable Groove

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Abstract: An database was developed to for filling the robot welding moderate-thick plate with variable groove based on laser sensor scanning and fitting the section area. The welding section area corresponding to different welding parameters as variables was saved and the least square method was applied to deduce the relationship between the welding area and the welding speed. The system based on groove cross-section variation and changes of adaptive control welding speed could fill the work piece well and solve the problem of welding parameter adjustment on variable groove. It could also use the database language to standardize the management of the knowledge base, and constantly improve the welding database. Taking a 12 mm thick variable groove of moderate-thick plate as a test, the result showed that the welding effect is good and error of groove metal filling volume is small.
Keywords: robot welding; weld seam filler; welding data base; self-adaptive control

I. PREFACE

Moderate-thick plate welding is widely used in vehicles, engineering machinery, machine tools and so on, and it is high requirement of welding quality . It is widely used in the welding of medium and thick plate .When Moderate-thick plate is welded ,it usually gets protect of metal active gas ,which has stable welding process and perfect appearance .With the development of robot technology, robot automatic welding has been widely used in the welding of moderate-thick plate . At the meantime, groove machining and assembly process of work piece both have groove size error. Variable groove filling is a major problem affecting the quality of welding . When the groove size changes ,improper selection of welding parameters can result in the accumulation error of multi layer welding wire ,which affects the surface quality of weld and need more work.

A successful foreign welding filling system, Moon et al[1]. measured groove parameters of laser system , used the adaptive algorithm to control the welding parameters and ensured the weld quality .Sc et al. analyzed the influence of welding current, welding speed and welding speed on the welding speed of low alloy steel structure , and got the calculation formula of the cross section area .

II. GROOVE SIZE DETECTION

The robot can use a small displacement laser sensor to detect groove size . Sensor scanning starting point is the origin .Mobile robot path is X axis. Y axis is perpendicular to the direction of the work piece surface. The Z axis is parallel to the center line of the groove .Finally, the groove section coordinate system is established. Calculate the groove sectional area by using trapezoidal integration method, i.e. S is the groove sectional area; Δt is the laser sensor laser interval; vs is robot scanning speed; hi is data collected of laser sensor scanning the work piece; Hi is the distance of laser sensor and the work piece surface. When the time is small enough, the groove changes can be considered homogeneous linear changes.

$$S = \Delta t v_s \sum_{i=0}^{n} (h_i - H_i) \quad (1)$$

$$S = S_0 + \frac{S_1 - S_0}{Z_1 - Z_0} Z \quad (2)$$

Type: S1, Z0, respectively represent the start end and the end of the cut area; Z1, S0, respectively, represent corresponding to the Z axis coordinate values.

III. SELECTION PRINCIPLE OF WELDING TECHNOLOGY

At the plate multipass welding process, When Groove size change ,the amount of metal filled in the groove will change. Fill the layer with different welding parameters, each road deposited amount is different. Considering the influence of the deposition efficiency, the relationship of welding wire feeding speed and welding speed is below[2,3]. V is welding speed; S is a single weld section; D is wire diameter; η is wire deposition efficiency ; vf is welding wire feeding speed.

$$vS = \pi(d/2)^2 v_f \eta \quad (3)$$

IV. ADAPTIVE CONTROL EXPERT DATABASE

In order to realize the precise adjustment of welding process parameters, the parameter value of the step distance is used to determine the initial value of the skeleton and the parameters of the database .Taking flux cored wire with 1.2 mm diameter as a example, In welding process, welding current range is 180 ～300 A, welding speed is 2.5 ～ 6 mm / s, step distance of welding current calibration is 10A, step distance of speed calibration is 0．5 mm/s .At last, carrying out a series of welding experiments, and getting weld cross section area .Data is as below table 1.

Table 1 Welding parameters database

welding current(I/A)	Welding speed(mm .s-1)	Weld section area(S/ mm2)
180	2.5	42.83
180	3	35.40
…	…	…
300	6	29.21

Because the welding speed and the area of the weld seam are nonlinear, there are a variety of commonly used curve fitting algorithm .And in order to facilitate the programming, using the least square method .By curve fitting, the function relation between the section area and the welding speed is obtained.

According to formula (3), the weld and welding speed is inversely proportional to the cross-sectional area, because the change of welding speed will cause the change of deposition efficiency. In order to improve the precision, we should increase welding speed correction in the function. So the method of least squares curve fitting formula is as below formula (4). Combined with the variation of the groove sectional area, simultaneous formula (2) and formula (4), the function relation between the welding speed V and the Z coordinate value is obtained.

$$S = \frac{a}{v+b} \quad (4)$$

$$v = \frac{a}{S_0 + \frac{S_1 - S_0}{Z_1 - Z_0} Z} - b \quad (5)$$

In the process of welding robot, we could use formula (5) the function to adjust the welding speed, to complete the change of groove filling. According to formula (4) available: v =a/s— b ,if y = v， x = 1 / s，then y = ax — b. Calculate the a, b by the least square method. The basic idea of the least square method is to find the "closest" n observation points of a straight line[5].

$$a = \frac{n\sum_{i=1}^{n} x_i y_i - (\sum_{i=1}^{n} x_i Y_i)\sum_{i=1}^{n} y_i}{n\sum_{i=1}^{n} x_i^2 - (\sum_{i=1}^{n} x_i)^2}$$

$$b = \frac{(\sum_{i=1}^{n} x_i) y_i \sum_{i=1}^{n} x_i y_i - (\sum_{i=1}^{n} x_i^2)\sum_{i=1}^{n} y_i}{n\sum_{i=1}^{n} x_i^2 - (\sum_{i=1}^{n} x_i)^2}$$

The function relation between the cross section area and the welding speed is obtained .The function relationship between variable groove welding speed and welding length is also obtained.

V. SOFTWARE IMPLEMENTATION

The system's overall structure includes two modules. A module is groove detection module, which mainly processes the data collected by laser sensor. The other welding plate is variable groove welding database ,making the planning of the weld cross-sectional area according to the major groove size and change rules, calling the welding parameter database to complete the selection of welding parameters and adaptive adjustment by data reasoning.

The module is mainly to record robot scanning speed vs and laser sensor transmission interval △t. The data collected by the laser sensor is stored in array .The surface of the work piece can be recognized when the recorded data is changed little by little .At the time ,hi=Hi. The data of adjacent value changes when the recorded data of the laser sensor can be identified clearly. Scanning has entered the groove surface and the distance between the sensor and the work piece surface Hi is the distance from the sensor to groove boundary point. calculate the groove cross-sectional area by type (1) , as shown in figure 1.

Record the scanning section's location and the cross section of the sectional area .Get change rules of groove cross-sectional area by type (2).The database mainly includes the process knowledge database and the welding parameter database. The working principle can be described in this way .The welding speed is assigned to y and the value of the weld cross-sectional area is assigned to the x through the reciprocal operation .Dynamic array data number is assigned to n, calculate a, b by least squares calculation ,and go into the type (5).The function relation of welding speed and welding path is obtained at last.

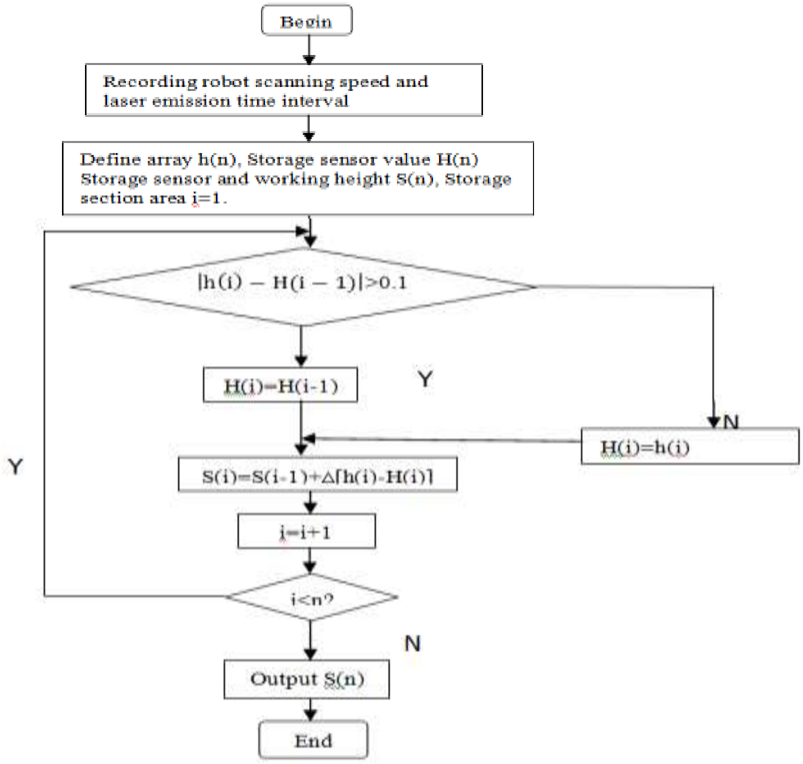

Figure.1 Flow chart of sectional area calculation

I. TEST

The thickness is 12 mm .Plate groove length is 120 mm . According to the detection of laser sensor, variable groove cross-sectional area of the starting is 83 mm^2, the end is 179 mm^2. According to the planning of welding process knowledge base and table 2, at a bottom of the work piece, the welding current is 210 A, the filling layer of welding current is 280 A, the cover layer of welding current is 240 A. The backing layer, a filling layer and a covering layer height are 6, 4, 3 mm. The number of channels per layer is 1.

Table 2 Each bead parameter programmed by database

	welding current(I/A)	Deep(h/mm)	Starting end area(S0/ mm2)	Termination area (S1/mm2)
Bottom layer	210	6	20.8	56.8
Fill layer	280	4	36.9	60.9
Cover layer	240	2	32.4	50.4

Then according to the data reasoning ,the values of the function coefficient a and b are obtained by formula (5). Respectively as: 136.56，0． 38; 165. 46，0. 26; 149． 73，0.36.The relationship between the welding speed and the welding length in the bottom layer is respectively below.

Table 3 Welding speed rules of each layer

	Functional relation
Bottom layer(v1/mm.s-1)	$v_1 = \frac{136.56}{20.8+0.32z} - 0.38$

Fill layer(v2/mm.s-1)	$v_2 = \frac{165.76}{36.9+0.2z} - 0.26$
Cover layer(v3/mm.s-1)	$v_3 = \frac{149.73}{32.3+0.2z} - 0.26$

Type: z is the distance between a real-time welding position and the arc point . The test showed that variable groove work piece weld high is uniform. Before and after welding, the groove section is scanned ,whose distance is respectively 30, 60, 90 mm. The weld cross-sectional area and the actual weld cross-sectional area error is smaller, the maximum is only 1.52%

II. CONCLUSION

(1) Develop plate break variable adaptive control system .Scan groove section by using a laser displacement sensor . Calculate the cross-sectional area of the groove and get variation of groove cross-sectional area at last.

(2) Set up welding database. According groove size ,it can plan the cross-sectional area of each weld and the cross-sectional area change rules.

(3) Through a lot of welding experiments, the welding current and welding speed were recorded, and the function relationship between the welding speed and the area of the weld is fitted by using the least square method. Combining with the changes of groove cross-sectional area ,the function relation of welding speed and welding length is finally obtained .By the robot program , the welding speed can be adjusted on the relation of the function. The test of welding groove show that the welding effect is good and error of groove metal filling volume is small.

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