Discussion on the welding performance of automatic welding of industrial robot and manual welding

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Abstract. Since the introduction of industrial robots and their widespread application in manufacturing, the production quality and efficiency of manufacturing have been affected their automated welding performance directly. In this paper the author provides a useful basis for improving welding quality and promoting production efficiency through the analysis of industrial robot automatic welding technology standards and welding performance.

Keywords: automated welding, plat butt welding, tensile test for deposited metal, microstructure analysis

1. Introduction
Welding is a widely used processing technology in the manufacturing industry, with the advantages of low cost, good performance of connection and easy operation, etc. The introduction of industrial robots undoubtably injected fresh blood into the manufacturing industry although the global manufacturing industry continues to fall now, and the quality of manufacturing products is affected by the level of welding technology directly. As technology continues to evolve, automated welding techniques are becoming more sophisticated, but there are still questions about whether the welding performance of automated welding is sufficient to meet needs of production. In the process of cooperation and exchange with XuZhou Construction Machinery Group, the author compares the tensile strength test of welded plates, the tensile and impact tests of deposited metal and the structural analysis of T-joint welds to compare the performance strength of robot welding and manual welding.

2. Technical standard of industrial robotic automatic welding
2.1. Principles of industrial robot automatic welding
At present, most of the intelligent positioning techniques of welding robots use wire contact positioning, and some welding robots use nozzle contact positioning [1].
The robot contact positioning circuit is a normally open circuit. When the welding wire or nozzle contacts the workpiece, the open circuit is closed and the built-in relay of the robot is closed, then the processor records the position information of the contact point. During the positioning process, the deviation between the actual position of the workpiece surface reference point and the programmed position can be determined and the corresponding welding procedure is corrected. When the welding contact positioning has an error, the position of the weld automatically corrected by the robot will also change [2].

2.2. Methods and standards for automated welding
2.2.1. Two smooth polished samples which have a 60° slope is reserved for the butt assembly of the workpiece are placed and fixed on the tooling table with a clamp. Make sure there are no people and foreign objects in the robot’s working range. Run the clearing program to check whether the robot’s TCP point deviates and the dry elongation is between 18 and 22 mm after the reduction of the wire. If the TCP point deviates, check if the contact nozzle is worn and the torch, clamp holder, and sway bar are deformed. After correcting the TCP point, the cleaning procedure should be debugged to ensure that the gun is safe and reliable during the cleaning process, and the dry extension is between 18 and 22 mm after the gun is cleaned and the wear is reduced.

2.2.2. Turn on the wire signal, pull the wire with a needle-nosed pliers and check if the wire-clamp system is reliable. If the wire clamping system is not reliable, check the air supply line for leaks, whether the wire-clamp solenoid valve is reliable, and whether the cylinder for wire-clamp is dirty.

2.2.3. Turn on the mixed gas signal, check if the mixture gas pressure is between 0.4±0.05MPa, and adjust the mixture flow to 20~25 L/min.

2.2.4. The welding line must be accurately added to match the TCP point and a reasonable program running speed shall be selected.

2.2.5. When programming the welding procedure, the assignment range should be accurately determined, and repeated assignments are strictly prohibited.

2.2.6. After the programming is completed, the programmed welding procedure shall be simulated. The simulation adopts the single-step operation mode and the running speed of the program should be less than 75%.

2.2.7. After the simulation is completed, check whether the water circulation, air supply, and wire feeding system are normal. After confirmation above without error then enter into the automatic mode for automatic welding [3].

3. Analysis of tensile properties of plat butt welding
According to the GB/T228-2002 metal material tensile test method at room temperature, the CSS-44300 electronic testing machine is used for stretching, and the tensile test was carried out using a rectangular cross-section sample of 14.40x10.20 mm, and the stretching speed was 3 mm/min. Sample No. A is a welding wire for ESAB welding wire; sample No. B is a manual welding of the cohesive welding wire; and No. C is a automatic welding of the cohesive welding wire.
Figure 1. Schematic diagram of sampling position of plat butt welding tensile specimen

The welding sampling position is shown in Figure 1, the tensile test results are shown in Table 1, Figure 2, Figure 3, and Figure 4 show the sample of the tensile tests of samples A, B, and C:

Table 1. Tensile test results of plat butt welding

| No.  | Yield Strength MPa | Tensile strength MPa | Elongation δ 5% | Reduction of area Ψ% | Break position | Remarks               |
|------|--------------------|----------------------|-----------------|----------------------|----------------|-----------------------|
| A1   | ——                | 503.5                | 25.8            | 55.8                 | Base metal     | Yield is not obvious  |
| A2   | 345.3             | 506.3                | 27.2            | 58.6                 | Base metal     |                       |
| A3   | ——                | 506.9                | 27.2            | 59.7                 | Base metal     | The yield is not obvious |
| Average value | 345.3 | 505.6 | 26.7 | 58.0 |                     |                       |
| B1   | 342.5             | 499.5                | 26.8            | 60.5                 | Base metal     |                       |
| B2   | ——                | 497.7                | 26              | 58.4                 | Base metal     | The yield is not obvious |
| B3   | 342.1             | 499.5                | 27              | 58.0                 | Base metal     |                       |
| Average value | 342.3 | 498.9 | 26.6 | 59.0 |                     |                       |
| C1   | 356.6             | 493.2                | 30.0            | 58.0                 | Base metal     |                       |
| C2   | 335.9             | 502.8                | 29.6            | 56.6                 | Base metal     |                       |
| C3   | 344.6             | 489.9                | 30.0            | 57.3                 | Base metal     |                       |
| Average value | 345.7 | 495.3 | 29.9 | 57.3 |                     |                       |
The qualification standard for the normal temperature tensile test is that the tensile strength of the welded joint is not lower than the lower limit of the specified value of the tensile strength of the base metal, and the elongation of the weld metal is not less than 80% of the specified value of the parent metal [4]. The tensile test value mainly depends on the welding material and process, and is less affected by the welder's skill. Comparing the values in Fig. 2, Fig. 3, Fig. 4 and Table 1, it is not difficult to find that in the automatic welding, the tensile properties of the plate butt welding are in compliance with the requirements and is not too much different from the artificial welding.

4. Specimens of Deposited metal tensile and impact

According to the national standard GB/T228-2002 metal material tensile test method at room temperature, the CSS-44300 electronic testing machine is used for stretching, and the tensile test is carried out with Φ10×50mm sample, and the stretching speed is 3mm/min. The impact test uses a standard sample, sample No. 1 is a cohesive wire robot welding; sample No. 2 is a cohesive wire artificial welding. The sampling position of the deposited metal tensile and impact samples is shown in Figure 5:
Figure 6. Schematic diagram of the sampling position of the deposited metal tensile and impact specimens

Results of the tensile test and impact test are shown in Table 2, and Figure 6 is a graph of specimen of the deposited metal tensile test and the impact test:

Table 2. Tensile metal tensile test results

| No. | Yield Strength MPa | Tensile strength MPa | Elongation δ % | Reduction of area Ψ% | Impact work J | Remarks |
|-----|--------------------|----------------------|----------------|----------------------|---------------|---------|
| 1   | 401.3              | 523.6                | 31.8           | 73.0                 | 147           | Unbroken |
| 2   | 466.8              | 573.9                | 29.4           | 43.8                 | 108           | Unbroken |

The test results of the two sets of tensile specimens were compared by Table 2, and the two groups were unbroken. Through the macroscopic analysis of the fracture morphology of Figure 6, both groups have obvious plastic deformation, and the fracture location is characterized by brittle fracture. According to the above test, the performance of the deposited metal of the automatic welding and the manual welding is not much different.

5. Weld microstructure analysis of T-joint

Figure 7 and Figure 8 show the macroscopic feature of the T-shaped weld seam. We use a cohesive welding wire and take two samples. The number of the cohesive welding wire samples is A and B, where A is robot welding and B is manual welding with an average penetration depth of 2.98 mm.
Figure 7. cohesive welding wire samples A

Figure 8. cohesive welding wire penetration sample B

The welding depth of the cohesive welding wire is 3mm, 2.7mm, 2.6mm, 3.6mm, and the form of weld seam is basically the same, which is the base metal, the incomplete crystallization zone, the complete crystallization zone (normalized zone), and the coarse grain zone, fusion zone, weld seam zone. Below is the microstructure of each sample.

A sample microstructure

A base metal 200 times

A incomplete crystallization zone area 200 times

A complete crystallization area 200 times

A coarse grain area 200 times

A fusion zone 200 times

A weld zone 200 times

B sample microstructure

B base metal 200 times

B incomplete crystallization

B complete crystallization
Analysis of sample microstructure characteristics:
The base material of the sample is ferrite and pearlite which is distributed in strips and is the same as the rolling direction of the sheet. In the incomplete crystallized area, a part of the structure undergoes a phase change which becomes fine ferrite and pearlite, and a part of it is the same as the base material. In the complete crystallization zone, the normalized zone, uniform and fine ferrite and pearlite, equivalent to the normalized structure during heat treatment [5]. In the coarse-grained zone, the superheated zone, the grain grows, there is Wei's structure, and the mechanical properties are poor. In the fusion zone, the upper part is the weld columnar crystal, and the lower part is the coarse crystal zone, which has a great influence on the welded joint and shaping. In the weld zone, columnar crystals.

Results of sample analysis:
It can be known from the hardness curve that the hardness of the samples A and B remained unchanged. In addition, it can be seen that the pearlite content in the area is increased compared with the base material, and the hardness of the weld bead is higher than that of the base material. On the one hand, it is the main reason of high carbon content. On the other hand, observing the structure of the weld beam we can know that there are columnar crystals inside, which is the main reason of the hardness.

6. The conclusion
The author compares the welding performance of automatic welding with manual welding by tensile test, impact test and microstructure analysis of welded plates, and it is worthwhile to determine the welding performance of automatic welding. However, if there is no suitable structural form, mature welding process, stable point quality, and excellent personnel quality, it cannot obtain the ideal welding quality even with the advanced welding technology. In the actual plate welding, a human-machine combination method can be adopted, which can control the welding cost and ensure the welding quality, and has certain engineering value.

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