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Application Research about Vertical Welding Technology of Thick Steel Plate

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Abstract: Welding method of vertical seam welding in super thick steel plate (100~120 mm in thickness) is the traditional electroslag welding. The weld mechanical properties are bad and the method is gradually phased out. The emerging monofilament electrogas welding technology of vertical welding in 80 mm below has the high quality advantage. It is a practical technology to expand the electrogas welding technology to the super thick plate in current welding field. In this study, the technical problems faced are analyzed in vertical seam welding of the super thick steel plate. Under the bold innovation, the method and the experimental process by using double electrogas welding method to solve vertical sewing of the super thick steel plate are introduced. Some beneficial experience is summarized. The new technology is a good attempt for exploring high quality and efficient welding method of super thick plate welding.

Key words: Super thick plate welding, electrogas welding technology, high quality and efficiency welding

INTRODUCTION

With the rapid development of China's economic construction, thick plate steel welding in steel structure have widely appeared in metallurgy, shipbuilding, petrochemical, water, nuke industry and other industries. For the thickness of 100~120 mm steel vertical seam welding, traditional electroslag welding and manual electric arc welding are still used. There is not a high quality and efficient welding method and relative equipment. Though electro-slag welding can solve the vertical seam welding problem of the super thick steel plate, there are the following disadvantages. Electro-slag welding method makes heat affected zone of the weld greater, cooling rate of the weld slower (Li *et al*., 2004, Pan *et al*., 2012). As a result, causing weld and its surrounding tissue grain to become coarse, make weld mechanical properties lower than the parent material. The fatal shortcoming makes electro-slag welding face the situation eliminated. So electro-slag welding is now rarely used. It was used only on some occasions when weld quality requirements is not high. Manual electric arc welding also can solve the problem of welding thick steel plate, but it needs the larger weld, the bigger wire filling quantity and the longer welding time. The result is that the welding time is long, the plate deformation is big, the efficiency is low and labor intensity of workers is high. So the method has very little been used.

Electro-gas welding technology overcomes the shortages of electro-slag welding, not only good welding quality, high mechanical performance of the welding seam, simple operation, but its efficiency is higher than the electro-slag welding. Therefore, electro-slag has been replaced by monofilament electro-gas welding in vertical seam welding steel plate whose thickness is below 80 mm (Chen, 2012). But for thicker steel than 100 mm thick steel plate, even the torch swing joined, monofilament electro-gas welding is incapable of action (Changrong, 2012). Welding is a complicated physicochemical process which involves in electromagnetism, heat transferring, metal melting and freezing, phase-change welding stress and deformation and so on. There are some cracks, air holes and residual stress in the parts after welding which will reduce welding strength and welding quality (Rui, 2004). For thicker steel welding than 100 mm thick steel plate, how to ensure welding strength, welding quality, to control effectively welding thermal deformation error and to prevent welding defects are current urgent practical problem in the welding field. For the vertical welding problem of 100 mm thick steel plate, we bold innovation, overcome difficulties and finally develop a pair of electrogas welding technology and some attempts were made, very good results received. The practice has proved, it can completely replace the electroslag welding in solving the quality and efficient automation welding problem of the super thick steel plate vertical seam.

THE KEY TECHNOLOGY IN VERTICAL SEAM AUTOMATIC WELDING OF SUPER THICK ATEEL PLATES

The vertical seam welding of the super thick steel plate is much more complex than the medium thickness

plate. Some special requirements are put forward in the weld groove form, the cooling effect of water circulation system, continuous working time, welding gun swing, electric control system and so on. The technology problems must be solved one by one. In conclusion, the following key techniques need to be solved:

Double wire welding magnetic blow: Double wire welding, because the two wire close to conducting current, will produce a magnetic blow interference. Measures must be taken to eliminate, otherwise normal welding.

Control system: Only one welding trolley completes the whole welding process. Overall control and individual control for the two welding power systems which is composed of two welding power source will be realized by using a set of electric-control system with perfect function.

Special water-cooled torch: Weld line still adopts the narrow gap. The groove is deep, the welding space is small and the temperature above the molten pool is very high. Special water gun is adapted to the welding environment to ensure the weld fusion and penetration.

Type of groove: Groove form and size is very important, in order to meet the weld fusion weld shape, the smaller the better. For the super thick steel plate, weld can only use X, using double-sided welding, welding sequence is that the face groove is first welded and then the back groove.

To prevent the copper water trapped: When the front groove is welded, it is the key thing how to determine the depth and space of the cooperation between copper water and groove on the back, how to solve the problem of welding copper water not to be caught in the weld.

The circulating cooling system: The mechanical properties of the welded seam is not lower than the parent material. When welding materials is selected in the match with the base metal, heat dissipation of the welding seam and cooling is very important, it is directly related to the weld grain particle size and form and ultimately determines the mechanical properties of weld. Therefore, the circulating cooling system is crucial to the final mechanical properties of weld quality.

The welding torch swing: To ensure that the weld fusion, A set of welding torch swing technique with complete function should be prepared. This will directly relate to the quality of weld fusion weld and fusion depth.

WELDING METHOD

Welding process: For vertical welding of ultra thick plate, because super thick steel plate thickness is large and the groove deep, it is impossible to once shape as the medium thick plate when one-side is welded. The X groove welding method must be used to complete welding, when the side is welded and there is of a triangle type water-cooling block scheduling on the other side.

Welding equipment: Vertical welding of super thick plate is done by double wire double power electro-gas welding apparatus. Vertical welding of super thick plate requires more electric energy (energy) and the much higher filling than the medium one, so the single power supply of single wire has been not meet the weld fusion and filling requirements and we must adopt double welding power supply and a wire feeding machine. This guarantees that the weld has very good fusion. This will improve the welding efficiency.

THECOMPOSITIONS OF DOUBLE WIRE GAS WELDER AND THE PRINCIPLE

The compositions of double wire gas welder: Double wire gas welder is mainly composed of the following parts: two sets of welding power source, two sets of wire feeding machine, a double wire water-cooled torch, a welding dolly, a cooling system, a set of CO_2 supplying system and a set of electric-control system. In which, the welding dolly is the most important component of the double wire gas welder in welding terminal. It is the carrier of the torch, is an execution mechanism in the welding process and electronic-control system terminal also. Its structure is shown in Fig. 1.

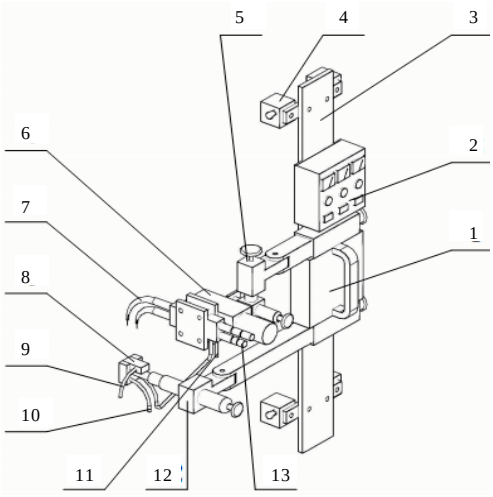

Fig. 1: The structure of a welding dolly

In which, 1-car body 2-welding operation box 3-track 4-magnet 5-adjusting mechanism of welding gun 6-torch swing device 7-double wire water-cooled torch 8-water-cooled slide 9-CO_2 supply pipe 10-a cooling water pipe 11-water-cooled cable 12-adjustment mechanism of the slide 13-wire tube

Working principle of double wire gas welder: When welding begins, a liquid melting zone is formed in the weld points. When wire is high-speed filled, electrical energy is exerted continuously and the torch stir in the weld depth direction, weld pool increases. Under the control of the automatic tracking system, the welding dolly automatically follows the molten pool. At the same time, with the help of continuous cooling through the water-cooled slider and copper water, the weld has been formed. In addition, weld pool burning point can provide adequate protection of CO_2 gas to protect the pool level.

The working principle and welding process of double wire electro-gas welder is similar to monofilament electro-gas welding. Double wire electro-gas welder also uses a set of electronic control system to control the whole welding process. But the difference is this set of electric control system will control the two welding power system composed of two sets of welding source. It is not only responsible for opening and closing the total control of the two sets of welding system, but also can realize the regulation of each welding system respectively. Two gun nozzles of double wire water-cooled torch are arranged on before and after in the weld depth direction of the weld line. This will not only greatly improve the fusion environment in the weld depth direction, but also provide effective security for improving the quality of weld fusion and avoiding adverse fusion by aid of the welding gun swing.

The "X" form is adopted as vertical seam grooves of thick plate. The depth of positive weld groove is slightly larger than the back. First positive groove is welded and then back groove. When positive groove is welded, water slide block is arranged in the outer mouth of the weld, triangular copper water is deeply installed in the internal mouth of the weld from back weld. Welding is still executed from the bottom to the top.

THE GROOVE FORM OF WELD LINE AND WELDING PROCESS PARAMETERS

Weld groove form: Two pieces of test plates adopted, each 600 mm long, 150 mm wide and 100 mm thick, material for Q235. The weld cross section type and size of weld groove by combining two pieces of test plates are shown in Fig. 3. No matter what is the plate width, the outer mouth width after combining just reaches 18 mm, the internal mouth width 6 mm.

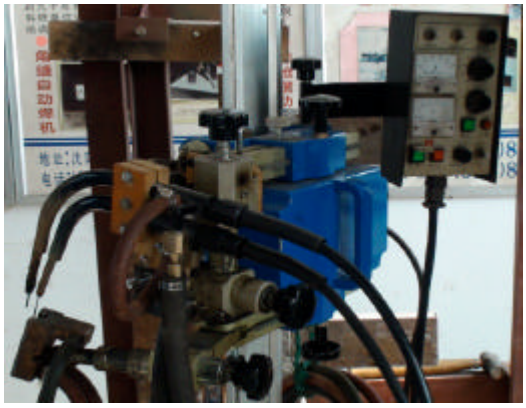

Fig. 2: Double electrogas welding car prototype

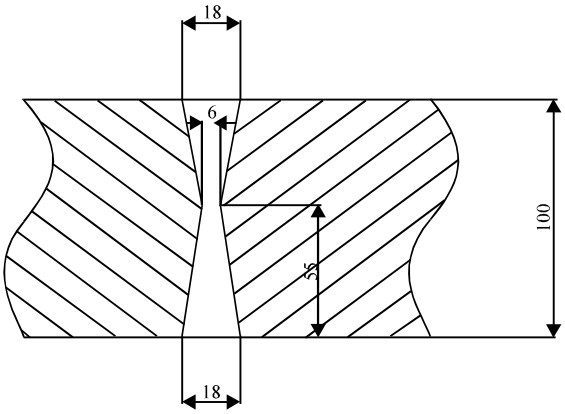

Fig. 3: Cross section type and size of the weld groove

Table 1:Welding process parameters

Two welding power source:	
Lincoln DC-600	Welding grade: 43G (diameter φ 1.6)
The welding current: 480~550A	Gas flow rate: 25 L min^{-1} CO2
Welding voltage: 38 ~ 40V	Cooling water flow rate: 130 L min^{-1}
Welding speed: adaptive	Test plate material: Q235

Welding parameters: Welding process parameters have been shown in Table 1.

RESULYS ANALYSIS

The super thick steel plate vertical welding experiments are done in the case of no torch swing. Even so, the weld fusion is still good. Through the use of dual electrogas welding of 100 mm and 120 mm thick steel plate welded plate experiment, the followings are shown from the macro:

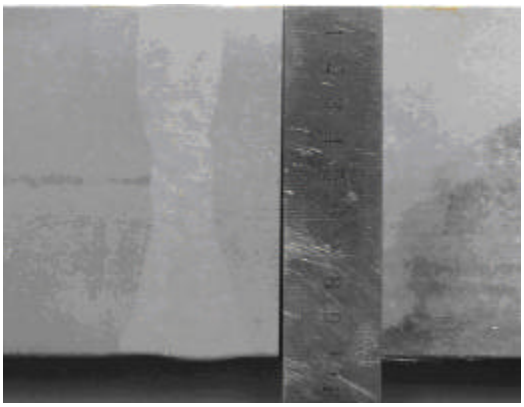

Fig. 4: The cross section of weld specimen in the test plate (100 mm)

Fig. 5: The cross section of weld specimen in the test plate (120 mm)

- The weld appearance shape is smooth, apart from the adverse fusion at arc beginning. In follow-up part of the weld line, the fusion and transition between welding meat and parent material are free of defects
- The test plate is 600 mm long; the positive weld time is in 7.5 minutes. This fully shows double wire for electro-gas welding gas electric welding technology has high efficiency advantage

Through cutting and sampling in the welding seam of the welding test plate, processing analysis, the followings have microcosmical been obtained:

- The weld fusion test case of 100 mm and 120 mm steel weld cross section are shown in Fig. 4 and 5. It shows the fusion and transition between welding meat and parent material is very good. This also shows that the line energy provided by the double welding power source is enough

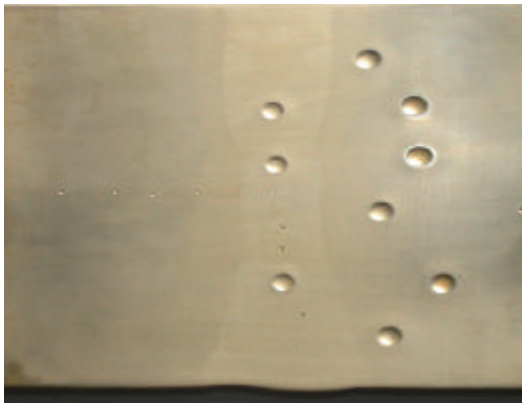

Fig. 6: Weld specimen hardness measuring icon (100 mm)

Table 2: Brinell hardness

The name	Three point average indentation Diameter (mm)	Hardness (HB)
Weld line	ϕ 4.35	192
The point near to the weld line	ϕ 4.86	153
The point far away from the weld line	ϕ 5.00	142

Table 3: Rockwell hardness

The name	Distance away from the fusion line(mm)	Hardness (HRC)
Weld line	0	88.5
Spot 1	9	87.5
Spot 2	18	84.5
Spot 3	26	82
Spot 4	36	82

On the above table, spot 1-4 are on the parent material

- Hardness testing has been done with electronic Brinell hardness apparatus (HB-3000C) on the test plate specimen. Measuring point distribution has been shown on the right in Fig. 6. The measured data are shown in Table 2.

Hardness testing has been done with Rockwell hardness apparatus (HR-150) on the test plate specimen. Measuring point distribution has been shown on the left in Fig. 2. The measured data are as shown in Table 3.

Two groups of hardness measurement data have shown, the mechanical strength of the weld line is higher than the base material. Its hardness is higher than the base material affected by heat and slightly higher than the base material away from heat. This can prove that heat affected zone has a normalizing effect.

- The width of the front and back of the groove of the test plate before the welding is all 18 mm. and the forming width in front of weld line welding is 28~30 mm, forming width in the back of weld line is 23~25 mm. The forming width in both sides of weld line is not the same. There are two reasons: one is in the

process of welding, the welding gun in the groove depth is in different locations; the two is, different current and voltage value used will also affect the weld forming width.

CONCLUSIONS

- Double wire for electro-gas welding includes advantages of monofilament electro-gas welding and has some innovation also. The new technology lays a good foundation for exploring high quality and efficient welding method of super thick plate welding
- The mechanical properties of zone affected by heat are not less. The expected effect has been achieved
- Reliable fusion of 100 mm thick steel plate and vertical seam can been achieved without welding gun swing. The thickness of the plate welded will be greater by aid of welding gun swing
- Using double wire for electro-gas welding technology to weld super thick steel plate is feasible and successful
- In addition, the use of air-cooled is the cooling mode of circulating cooling water in the experiment. If the refrigeration equipment with Freon replaces air-cooled, strengthen heat dissipation, the mechanical properties of the zone affected by the heat in weld line will be better improved
- The above conclusions have been obtained by only studying on welding principle and feasibility and the significant progress has been made only in the welding method. But the study on the welding mechanism is far from enough. To improve the double wire for electro-gas welding of thick steel plate vertical seam welding technology, further research is not only needed, but a lot of welding process test need doing also.

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