Influence of Strength Match on WELDOX960 Steel Weld Microstructure

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Abstract. WELDOX960, as low-alloy high-strength steel in new generation, is widely used in construction machinery and other heavy-duty field. In the paper, mixed gas shielded arc welding is adopted for multi-pass welding on low alloy high strength steel WELDOX960. Different intensity match methods are adopted for respectively preparing six groups of samples. Microstructure of weld joint is tested and analyzed after welding. The result shows that micro-structure in filling welding of six groups of samples is basically similar to cosmetic welding, which is composed of acicular ferrite and carbides. Backing weld micro-structure of samples 50-80, 50-85 and 50-90 are essentially the same. Their microstructures are basically composed of a small amount of pearlite, proeutectoid ferrite and acicular ferrite.

Introduction

With continuous increase of weight lifted by truck cranes at home and abroad, the demand of high-end boom is continuously increasing, in order to realize high strength and high reliability of the boom, meanwhile, reduce the weight of boom frame as possible as it can, and be convenient for suspension and loading, the strength of steel materials used by the boom is higher and higher [1]. In order to guarantee that the toughness of high-end boom welding joint meets the design of high strength and high reliability and application requirement, most of the booms of existing big-size tonnage cranes use WELDOX960 series high strength steel produced by Swiss OXELOSUND Company.

As for welding line metal made of high strength steel, the higher the strength is, the lower the realizable toughness level is, which is always lower than toughness level of base metal. So far, in order to have good toughness in welding structure with great rigidity, the strength of welding fine strength is always sacrificed, using low matchable welding material[2]. This method can guarantee the toughness of welding line, however, bearing ability of the component is reduced, which reduces the capacity of the crane significantly. During welding high strength steel, there is very rare study in practical production application that low strength solder wire backing welding technique is used in backing welding line section with the most stress concentration, and the match of the solder wires in different intensities is studied to optimize strength match, in order to provide references for the study on welding strength toughness of high strength steel[3].

Considering that backing welding is the most important technique process in multi-layer and multi-channel welding, which has significant impact to joint performance, therefore, this paper studies one kind of new strength match welding method, i.e. with WELDOX960 high strength steel plate material as subject, Ar + CO_2 mixed gas is used for welding, the changing law of joint microstructure matching different intensities is studied by changing strength matching method of welding joint.

Testing Method

Testing base metal uses 300mm×150mm×12mm low alloy high strength plate material, with the type of WELDOX960, and its tensile strength is about 980～1150 MPa under ambient temperature. The oil dirt should be cleaned with acetone before welding, and then sand paper is used to grind its front and back sides to eliminate oxides on its surface. MAG welding is used, with protective gas of 86%Ar+14%CO_2, and joint form is butt-joint, and the form of welding line is 60°V slope mouth, and the gap between slope mouths is 2.5mm. There are 3 layers of welding channels, which are backing layer, filling layer and cladding layer. Preheating temperature before welding is 75℃, and the temperature between the layers is 80～85℃, and the energy of welding line is 10～12KJ/cm. This test uses 4 kinds of solder wires with different intensities, whose brands are: ER50-6、T union GM100、T union GM110、T union GM120.

There are 6 groups in this test, and 6 groups of steel plates with the specification of 300mm×302.5mm×12mm welded by 6 pairs of WELDOX960 steel plates with the specification of 300mm×150mm×12mm, each of which uses different kinds of strength matches for welding, with specific strength matching forms seen in table 1. In 48 hours after welding, the sample should be milled to level, and tensile and impact samples of welding joint should be prepared.

Table 1 Strength matching forms of 6 groups of welding lines

Category	50-80	80-80	50-85	85-85	50-90	90-90
Solder wire of backing welding	ER50-6	Tunion GM100	ER50-6	Tunion GM110	ER50-6	Tunion GM120
Solder wire of filling and surfacing welding	Tunion GM100	Tunion GM100	Tunion GM110	Tunion GM110	Tunion GM120	Tunion GM120

As samples in group 50-80 shown in table 1, backing welding uses ER50-6 solder wire with tensile strength of 525MPa (hereafter referred to as solder wire 50), and filling welding and surfacing welding use Tunion GM100 solder wires with the tensile strength of 840MPa (hereafter referred to as solder wire 80); in the group 80-80, backing welding and surfacing welding both use solder wire 80; in the group 50-85, filling welding and surfacing welding both use Tunion GM110 welding wire with tensile strength of 880MPa (hereafter referred to as solder wire 85), and so on, and the last group uses Tunion GM120 solder wire with yield strength of 950MPa(hereafter referred to as solder wire 90). Thus, we can get 6 groups of welding lines with decreased strengths, i.e. 50-80、80-80、50-85、85-85、50-90、90-90.

Test results and analysis

Microstructure analysis of filling welding and cosmetic welding. Microstructures of filling welding and cosmetic welding are shown in Fig. 1, wherein Fig. 1 (a) shows microstructure (hereafter referred to as 50-80) with 50 welding wire for backing welding and 80 welding wire for filling and cosmetic welding. Fig. 1 (b) shows micro-structure with complete 80 welding wire for welding (hereinafter referred to as 80-80). Fig. 1 (c) shows micro-structure with 50 welding wire for backing welding and 85 welding wire for filling and cosmetic welding (hereinafter referred to as 50-85); Fig. 1 (d) shows the micro-structure with complete 85 welding wires for welding

(hereinafter referred to as 85- 85), and so on. Fig. 1 (e) shows micro-structure with 50 welding wire for backing welding and 90 welding wire for filling and cosmetic welding; Fig. 1 (f) shows micro-structure with complete 90 welding wire for welding.

The figure shows that welding micro-structures of both 50-80 and 80-80 groups are composed of acicular ferrite. This acicular ferrite belongs to product of $\gamma \rightarrow \alpha$ phase transformation in the medium temperature zone, which is also known as bainitic ferrite, there is no unified view of its formation mechanism. It is generally considered that acicular ferrite may be based on oxide-nitride as nuclear site with radial growth. Micro-structures in (c) and (d) are not as thick as 50-80 and 80-80. Although the whole micro-structure is still composed of acicular ferrite, its length and width are prominently shorter than that in the former two groups. Carbide is the black part among ferrites in the Figure. Microstructures in Fig. 1 (c) and (d) are similar substantially. It is obvious that different backing welding has little influence on micro-structure of filling and cosmetic welding. Welding micro-structure of 50-90 and 90-90 groups is composed of acicular ferrite + carbide, and the micro-structures of the two groups are finest.

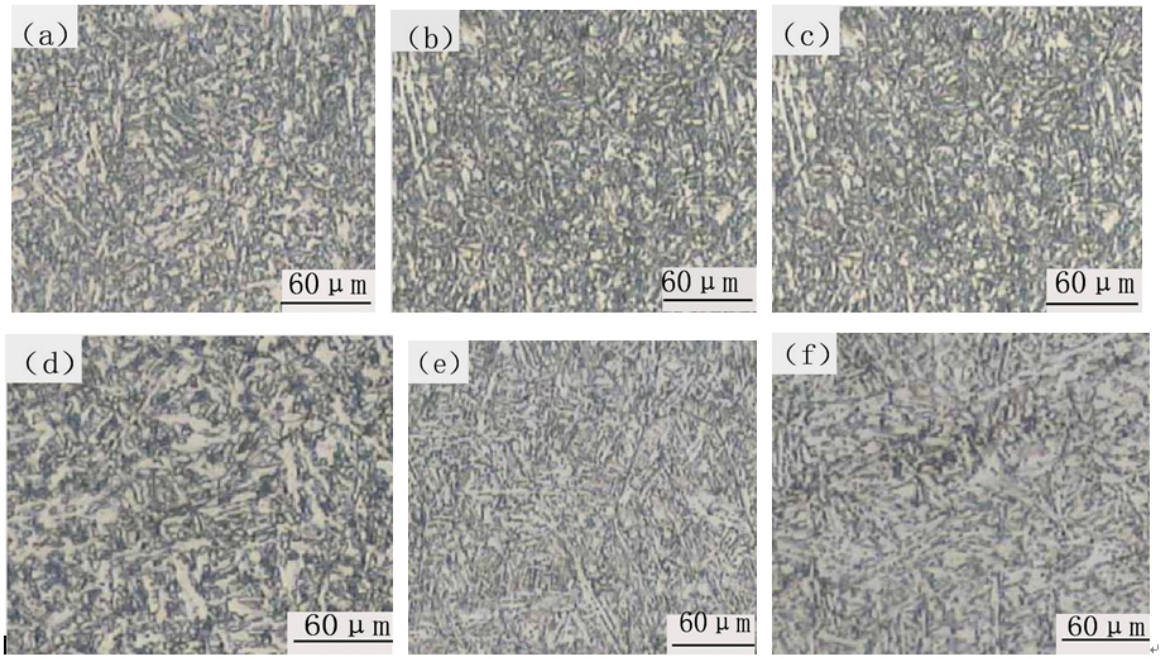

Figure 1 Microstructure of filling and cosmetic welding

(a) 50-80 (b) 80-80 (c) 50-85 (d) 85-85 (e) 50-90 (f) 90-90

Micro-structure analysis of backing welding. Compared with micro-structures of filling and cosmetic welding, two completely different variation rules are shown in backing welding: microstructure change is in line with changing rule of typical welded microstructure aiming at weld joint with 50 welding wire for backing welding. The shape of backing welding micro-structure is similar to the micro-structure of filling and cosmetic welding aiming at weld joints of complete 80, complete 85 and complete 90 welding wires.

Weld micro-structure of sample 50-80, 50-85 and 50-90 backing welding is basically similar, therefore only weld joint micro-structure of sample 50-80 is provided in fig. 2. Fig. 2 (a) shows micro-structure on the joint between filling welding and backing welding. Filling welding of 80 welding wire is shown on the upper part, and micro-structure of backing welding of 50 welding wire is shown on the lower part. It is obvious in the figure that the granule on the joint between the two is coarse. However, course granules are mainly discovered on the 50 welding wires for backing

welding. White lumpy micro-structure belongs to ferrite. The granules of filling welding with 80 welding wire on the upper part are prominently fine, which belongs to fine acicular ferrite. Fig. 2 (b) shows microstructure of backing welding. Black microstructure belongs to pearlite with low quantity. White micro-structure belongs to polygonal ferrite and certain amount of acicular ferrite with fine micro-structure. Peak temperature in the area is between 1200℃ and melting point, and surrounding proeutectoid ferrite is nucleated in original austenite grain boundaries, which is expanded in a strip shape. Many granules are mutually connected and distributed along the boundaries. Granule shape of original austenite can be basically formed. In Fig. 2 (b) microstructure in original austenite granule is composed of acicular ferrite.

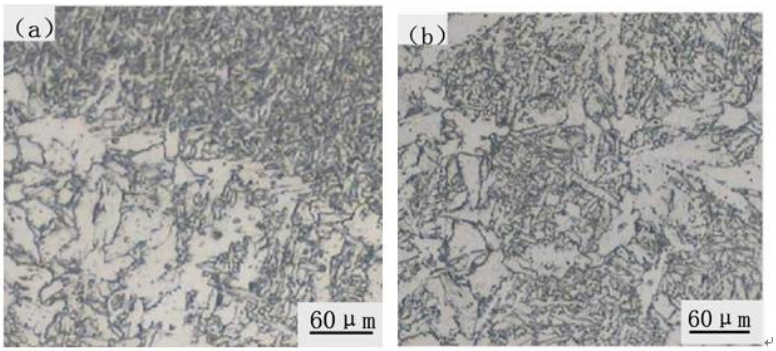

Fig.2 Micro-structure of 50-80 and 80-80 backing welding; (a) Joint of 50-80 filling welding and backing welding (b) 50-80 backing welding

Conclusion

(1) Microstructures of filling and cosmetic welding in 50-80, 80-80, 50-90 and 90-90 samples are basically similar, which are composed of acicular ferrite + carbide. The micro-structures of the later two groups are much fine than the former two groups in comparison. Micro-structures of filling and cosmetic welding in 50-85 and 85-85 are different from that in the other four groups, which are composed of ferrite + carbide in irregular shapes. Granule dimensions are larger.
(2) Microstructures of samples 50-80, 50-85 and 50-90 are basically the same, which are composed of a small amount of pearlite, proeutectoid ferrite and acicular ferrite.

References

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