Research on Butt Joint of Ultrafine Grained Steel of Manual Arc Welding

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Abstract. 400Mpa grade ultrafine grained steel was welded by manual arc welding with J506 electrode and I type grove butt welding. The microstructure and hardness change of welded joints were also studied. The welded joints were quenching heat treated and the change of microstructure and hardness were studied before and after heat treatment. The result showed that the microstructure grain size in the weld zone and overheated zone increased with the increase of current. Both the weld zone and the overheated zone were coarse ferrite and pearlite, and the weld zone was dendritic morphology. The weld zone had the highest hardness in the welded joint, followed by the overheated zone, the normalized zone and the base metal. The weld joints did not soften. After heat treatment, the microstructure of welded joints were the mixed structure of low carbon martensite, pearlite, ferrite and bainite. The hardness of welded joints were all improved.

1. Introduction
Ultrafine grained steel is new steel. The grain size is micron or submicron which can improve strength and toughness of steel. Compared with other equal strength steel, chemical composition of ultrafine grained steel is low carbon content which is beneficial to the improvement of weldability. Micron ultrafine grained steel is one of structural materials which is widely used in production practice. The study of its weldability is very hot[1-6].

2. Experimental material and parameter
Experimental materials were 4 mm thickness ultrafine grained steel, J506 electrode used in butt welding and J422 electrode used in tack weld. Chemical composition of ultrafine grained steel was shown in Table 1. Manual arc welding has been adopted and welding current of four test blocks was increased gradually. Welding parameters were shown in Table 2. The four samples were quenching heat treated. These samples were heated to 920°C, and heat preservation time was 15 minutes. And these four samples were cooled by water. The change of microstructure and hardness were studied before and after heat treatment.

Table 1. Chemical composition of ultrafine grained steel.

| C  | Si  | Mn  | P   | S   |
|----|-----|-----|-----|-----|
| 0.150 | 0.213 | 0.800 | 0.015 | 0.004 |
Table 2. Welding parameters.

| Sample number | 1 | 2 | 3 | 4 |
|---------------|---|---|---|---|
| Welding current (A) | 95 | 110 | 120 | 130 |
| Average welding speed (cm/s) | 0.6 | 0.8 | 0.89 | 1.2 |

3. Experimental result and analysis

3.1 Welded joint before heat treatment

The microstructure of base metal and welded joint of sample 1～4 was observed by 500 times metalloscope. Base metal microstructure of sample 1～4 was similar and was fine ferrite and pearlite which was showed in Figure 1. Welded joint was divided into weld zone, overheated zone and normalized zone. The microstructure of weld zone, overheated zone and normalized zone of sample 1～4 were shown in Figure 2～5.

Figure 1. Base metal before heat treatment.

(a) Weld zone (b) Overheated zone (c) Normalized zone

Figure 2. Welded joint of sample 1 before heat treatment.
From Figure 2~5, we can know that grain size of weld zone and overheated zone increased with the increase of welding current. From Figure 2(a)~5(a), we can know that there were elongated grains...
and equiaxed grains in the weld zone. The microstructure of weld zone showed dendritic. The carbon content of weld zone was low, so the microstructure of weld zone were ferrite and pearlite which began precipitating from boundary of austenite and so their grains were coarse. From Figure 2(b)~5(b), we can know that the microstructure of overheated zone were obviously coarse ferrite and pearlite because this zone was overheated by welding thermal cycle. From Figure 2(c)~5(c), we can know that the normalized zone of sample 1~4 was similar and was finer ferrite and pearlite than base metal.

The hardness of welded joint reflected the microstructure of welded joint. It was important index of harden quenching tendency of ultra-fine grain steel. The microstructure distribution of welded joint were uneven, so the hardness distribution of welded joint were uneven. The hardness of welded joint before heat treatment were shown in Table 3. From Table 3, we can know that the hardness distribution of welded joint were uneven. The hardness of weld zone was the highest in all samples. The hardness of overheated zone was higher than normalized zone. The hardness of normalized zone was higher than base metal. The welded joint did not soften.

Table 3. Hardness of welded joint before heat treatment (HV).

| Sample number | Base metal | Normalized zone | Overheated zone | Weld zone |
|---------------|------------|-----------------|-----------------|-----------|
| 1             | 170.74     | 174.58          | 185.80          | 196.82    |
| 2             | 156.25     | 157.03          | 190.22          | 191.23    |
| 3             | 162.17     | 163.42          | 177.49          | 217.49    |
| 4             | 163.67     | 167.12          | 178.70          | 203.70    |

3.2 Welded joint after heat treatment

Metallograph were shown in Figure 6~9.

Figure 6. Microstructure of sample 1 after heat treatment.
After quenching heat treatment, base metal, heat affected zone and weld zone of sample 1~4 were observed by 500 times metallographic microscope. From Figure 6~9, we can know that the
microstructure of base metal, heat affected zone and weld zone were all the mixed structure of low carbon martensite, ferrite, pearlite and bainite after quenching heat treatment. The microstructure of base metal was more uniform.

The hardness of sample 1～4 after heat treatment were shown in Table 4.

| Sample number | Base metal | Weld zone | HAZ     |
|---------------|------------|-----------|---------|
| 1             | 380.54     | 236.14    | 236.45  |
| 2             | 331.73     | 268.13    | 325.69  |
| 3             | 212.89     | 304.95    | 335.82  |
| 4             | 356.02     | 205.04    | 353.96  |

From Table 4, we can know that the hardness of base metal, heat affected zone and weld zone were all increased after quenching heat treatment. The increase of base metal hardness was the highest and secondly heat affected zone (HAZ).

4. Conclusion
(1) Welding current and postweld heat treatment were main factors of the quality of welding joint.
(2) Before heat treatment, grain size of weld zone and overheated zone increased with the increase of welding current. The microstructure of weld zone and overheated zone were all coarse ferrite and pearlite and the organization form of weld zone was dendritic. The hardness of weld zone was the highest followed by overheated zone, normalized zone and base metal.
(3) After heat treatment, the microstructure of base metal, heat affected zone and weld zone were all the mixed structure of low carbon martensite, ferrite, pearlite and bainite. The hardness of base metal and welded joint were obviously improved. The increase of base metal was the most.

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