Research on Arc Spot Welding of T12 Steel

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Abstract. This paper mainly studied the microstructure change and hardness change of manual arc spot welding of T12 steel before and after post weld heat treatment. The experiment results showed the weld microstructure of J422 and J506 electrodes, which were common structural steel electrodes, were similar under different welding current. The weld microstructure of D256 wear resistance electrode were significantly different from those of structural steel electrodes. The hardness of spot weld before heat treatment had little change except for wear resistance electrode. The hardness of wear resistance electrode was the highest under different welding current before heat treatment. After quenching, the microstructure of spot weld were changed, the dendritic crystal disappeared and the hardness were generally improved. The microstructure and hardness of structural steel electrodes and wear resistance electrode before and after heat treatment were greatly different, which were caused by the different content of carbon and alloying elements of electrodes.

1. Introduction
Arc spot welding was a kind of welding method which melts two pieces of superposition weldment to form spotty weld using arc heat source. T12 steel was a kind of carbon tool steel which was used to manufacture cutting tool and measurement tool. The weldability of T12 steel was bad but it also need weld in some cases. In this paper T12 steel thin plates had been welded by manual arc spot welding. The microstructure and hardness of lap joint were studied. The change of microstructure and hardness of T12 steel spot-welded joint were studied under different electrode and different welding current. T12 steel spot-welded joints were post-weld quenching heat treated. The change of microstructure and hardness of T12 steel spot-welded joint were studied before and after heat treatment. The research of this paper had large practical meaning [1-4].

2. Experimental scheme and process
The base metal was T12 steel and its plate thickness was 0.5mm. T12 steel was common carbon tool steel and high carbon steel. The chemical composition of the base metal was shown in Table 1. T12 steel was not suitable for long distance continuous welding and can be welded by spot welding operation because of the bad weldability of T12 steel. This paper used manual arc welding to spot weld T12 steel. Four electrodes were used which were acid electrode J422Φ2.5×350, acid electrode J422Φ3.2×350, basic electrode J506Φ3.2×350 and wear resistance electrode D256Φ4.0×350. The chemical composition of electrodes were shown in Table 2. Welding equipment was ZXE1-400 welding machine. The experiment used dc welding power source and lap joint. The welding operation...
was that two pieces of T12 steel base metal were piled on together to form lap joint. The electrode was 90° upon the base metal. The electrode knocked or rubbed on the arc striking plate. After arc striking success, the arc was moved on the T12 steel lap joint maintaining one or two second and quickly moved away. The lap joint welds were cut out from the base metal as experimental sample after all welding currents were welded. Sample number and welding parameter were shown in Table 3.

Table 1. Chemical composition of T12 steel.

| C (%) | Si (%) | Mn (%) | P (%) | S (%) |
|-------|-------|--------|-------|-------|
| 1.15-1.24 | ≤0.35 | ≤0.40 | ≤0.035 | ≤0.030 |

Table 2. Chemical composition of electrodes.

| Electrode grade | C(%) | Mn(%) | Si(%) | S(%) | P(%) | Other element amount (%) |
|-----------------|------|-------|-------|------|------|-------------------------|
| J422            | ≤0.12 | 0.4   | ≤0.15 | ≤0.035 | ≤0.05 |
| J506            | ≤0.12 | 0.8-1.4 | ≤0.07 | ≤0.035 | ≤0.04 |
| D256            | ≤1.1  | 11-16 | ≤1.3  |       | ≤5   |

Table 3. Sample number and welding parameter.

| Sample number | Welding parameter | Electrode type |
|---------------|-------------------|---------------|
| 1             | 80A               | J422 Φ2.5×350 |
| 2             | 100A              | J422 Φ2.5×350 |
| 3             | 120A              | J422 Φ2.5×350 |
| 4             | 80A               | J422 Φ3.2×350 |
| 5             | 100A              | J422 Φ3.2×350 |
| 6             | 120A              | J422 Φ3.2×350 |
| 7             | 80A               | J506 Φ3.2×350 |
| 8             | 100A              | J506 Φ3.2×350 |
| 9             | 120A              | J506 Φ3.2×350 |
| 10            | 80A               | D256 Φ4.0×350 |
| 11            | 100A              | D256 Φ4.0×350 |
| 12            | 120A              | D256 Φ4.0×350 |

The microstructure and hardness of T12 steel weld were studied under welded condition before heat treatment. And then these samples were quenched. The initial temperature was 25 ℃ and temperature rising time was 85 minutes. The maximum temperature was 900 ℃, holding time was 3 minutes and cooling mode was water cooling. The microstructure and hardness of twelve samples were studied after quenching heat treatment.

3. Weld microstructure before heat treatment

The microstructure of T12 steel base metal was shown in Figure 1. The microstructure was pearlite and secondary cementite and the cementite presented network distribution along original austenite grain boundary. The weld microstructure of 12 samples were shown in Figure 2 ~ 5 before heat treatment.
The weld microstructure was solidification and crystallization microstructure after the mixed melting of J422 electrode and T12 steel base metal. The base metal which melted into weld was less because of spot welding. Weld transformation structure of sample 1～3 were the mixed structure of ferrite, pearlite, bainite and martensite. The weld microstructure grain size increased with the increase of welding current. The weld microstructure of sample 3 was massively dendritic when the welding current was 120A.

From Figure 3, we can know that weld microstructure of sample 4～6 were the mixed structure of ferrite, pearlite, bainite and martensite. The weld microstructure grain size increased with the increase of welding current.
From Figure 4, we can know that weld microstructure of sample 7~9 were the mixed structure of ferrite, pearlite, bainite and martensite. The weld microstructure grain size increased with the increase of welding current. The contents of bainite and martensite of J506 weld were higher than J422 weld.

![Figure 5.](image)

(a) sample 10  (b) sample 11  (c) sample 12

Figure 5. Weld microstructure of D256 Φ4.0 × 350 under different welding current before quenching.

From Figure 5, we can know that weld microstructure of sample 10~12 were the mixed structure of austenite and martensite. D256 electrode was high Mn electrode and Mn element can enlarge austenite phase area. A3 point decreased below freezing and single phase austenite was generated at room temperature when the content of Mn exceeded 13%. The weld microstructure of D256 was the mixed structure of austenite and martensite under the welding condition which was unbalanced cooling. From Figure 5, we can know that the content of melt base metal in weld increased with the increase of welding current and then the content of Mn in weld decreased. So the content of austenite decreased and the content of martensite increased when the welding current increased.

The carbon content of T12 steel was 1.2% and it was hypereutectoid steel. The carbon content of common structural steel electrode was low and the composition of base metal in the weld was less because of spot welding. The composition of weld was mainly made of the electrode metal and the carbon content of weld was hypoeutectoid steel. The Mn content of wear resistance electrode was 16% and it was high alloy steel. Mn element promoted the generation of austenite. The weld microstructure of common structural steel electrode and wear resistance electrode were greatly different. The weld microstructure of common structural steel electrode were the mixed structure of ferrite, pearlite, bainite and martensite. The organization form and proportion and grain size changed when the welding current changed. The weld microstructure of wear resistance electrode were the mixed structure of austenite and martensite. The weld microstructure of J506 electrode and J422 electrode were similar but the microstructure proportion was different. The contents of bainite and martensite of J506 weld were higher than J422 weld. Compared with J506 and J422, the weld microstructure of D256 was completely different.

4. Weld microstructure after heat treatment
The weld microstructure after quenching of sample 1~12 were shown in Figure 6~9.

![Figure 6.](image)

(a) sample 1  (b) sample 2  (c) sample 3

Figure 6. Weld microstructure of J422Φ2.5×350 under different welding current after quenching.
5. Weld hardness before and after heat treatment

The weld hardness before quenching heat treatment were shown in Table 4.

| Electrode type | Weld hardness under 80A | Weld hardness under 100A | Weld hardness under 120A |
|----------------|-------------------------|--------------------------|--------------------------|
| J422 φ 2.5×350 | 215.8HV                 | 252.8HV                  | 218.5HV                  |
| J422 φ 3.2×350 | 234.6HV                 | 220.8HV                  | 205.2HV                  |
| J506 φ 3.2×350 | 221.3HV                 | 241.5HV                  | 214.0HV                  |
| D256 φ 4.0×350 | 240.3HV                 | 316.0HV                  | 572.3HV                  |

From Table 4, we can know that the hardness change of common structural steel electrode was very small and the hardness change of wear resistance electrode was very large when the welding
current changed. The hardness of J422 $\phi 2.5 \times 350$ and J506 $\phi 3.2 \times 350$ firstly increased and then decreased with the increase of welding current and the hardness reached maximum when the welding was 100A. The hardness of J422 $\phi 3.2 \times 350$ little decreased with the increase of welding current. The hardness of D256 $\phi 4.0 \times 350$ greatly increased with the increase of welding current and reached maximum when the welding was 120A. The weld hardness of wear resistance electrode D256 was the highest under different electrodes and different welding currents before heat treatment.

The weld hardness after quenching heat treatment were shown in Table 5.

| Electrode type | Weld hardness under 80A | Weld hardness under 100A | Weld hardness under 120A |
|---------------|------------------------|--------------------------|-------------------------|
| J422 $\phi 2.5 \times 350$ | 326.0HV | 325.6HV | 332.0HV |
| J422 $\phi 3.2 \times 350$ | 368.5HV | 317.8HV | 286.9HV |
| J506 $\phi 3.2 \times 350$ | 272.7HV | 219.4HV | 343.5HV |
| D256 $\phi 4.0 \times 350$ | 254.3HV | 612.6HV | 357.4HV |

From Table 5, we can know that the hardness change of common structural steel electrode was not large and the hardness change of wear resistance electrode was very large when the welding current changed. Compared with the weld hardness before quenching, the weld hardness after quenching commonly increased except two hardness values.

### 6. Conclusion

(1) The weld microstructure of common structural steel electrodes were greatly different from wear resistance electrode. The weld microstructure of common structural steel electrodes were the mixed structure of ferrite, pearlite, bainite and martensite before quenching. The weld microstructure of wear resistance electrode were the mixed structure of austenite and martensite before quenching. The weld microstructure of common structural steel electrodes were the mixed structure of low carbon martensite, pearlite and ferrite after quenching. The weld microstructure of wear resistance electrode were the mixed structure of austenite, martensite and precipitated carbide after quenching.

(2) The hardness change of common structural steel electrode was very small and the hardness change of wear resistance electrode was very large when the welding current changed. The quenching heat treatment can improve the weld hardness of T12 steel.

### References

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