Induction Hardening Process of G18NiMoCr3-6 Steel

Cai Tang1, 2, *, Bo Chen1, 2, a and Huiji Fan1, 2, b
1 Jiangsu XCMG Construction Machinery Research Institute Ltd., Xuzhou Jiangsu 221004, China
2 State Key Laboratory of Intelligent Manufacturing of Advanced Construction Machinery, Xuzhou Construction Machinery Group, Xuzhou Jiangsu 221004, China
*Corresponding author e-mail: tcxcmg@126.com, *18361333435@163.com, bfanhuiji2009@qq.com

Abstract. The microstructure and properties of G18NiMoCr3-6 steel after medium frequency. Quenching hardening with different process parameters and its heat treatment process optimizing were studied. The results show that the best combination is voltage 420V, cooling water flow 300L/h, moving speed 200mm/min. After medium frequency induction hardening process, the surface of G18NiMoCr3-6 steel generates uniform and small martensite, the strength and wear resistance significantly increases.

1. Introduction
Frequency induction hardening is one of the important processes of heat treatment. It has the characteristics of fast heating speed, energy saving, high production efficiency, no pollution to the environment, easy to realize mechanization and automation. It can be arranged in the production line and the cold processing process simultaneously, with little oxidation. It has an important impact on improving the wear resistance and strength of parts [1-3].

G18NiMoCr3-6 is a structural cast steel that belongs to Cr-Ni-Mo series high strength low alloy cast steel and has good weldability [4]. G18NiMoCr3-6 cast steel has good hardenability and low temperature toughness, due to the addition of alloying elements such as Cr, Ni, Mo, etc. The track shoes can be made of G18NiMoCr3-6 steel, which has high carbon content and high quenching tendency. So it is easy to be damaged if it is subjected to cyclic load during use [5, 6]. In order to improve the defects of steel, intermediate frequency [7-11] can be used. The surface is modified by heating the surface quenching method to improve the comprehensive mechanical properties of G18NiMoCr3-6 steel.

Key words: G18NiMoCr3-6 steel; medium frequency induction hardening; martensite

2. Experimental materials and methods
2.1. Experimental materials
The chemical composition of the G18NiMoCr3-6 test cast steel is shown in Table 1.
### Table 1. Chemical composition of G18NiMoCr3-6t steel (wt%).

| C   | Si  | Mn  | P   | S   | Cr  | Ni  | Mo  |
|-----|-----|-----|-----|-----|-----|-----|-----|
| 0.20| 0.30| 0.85| 0.012| 0.007| 0.51| 0.59| 0.47|

### 2.2. Experimental methods and equipment

A CNC quenching equipment CJC-1000/1500, was used in the medium frequency induction hardening process. Frequency induction hardening process was applied at moving speed of 200mm/min, 230mm/min, 260mm/min, and 290mm/min.

The Vickers hardness was tested with a KB Prutechnik Gmb hardness testing instrument. The cross section of the sample was cut by an automatic cutter, and after grinding, mechanical polishing, and 4% nitric acid solution etching, the microstructure was observed under a DMI5000M inverted metallurgical microscope. Abrasive impact wear of the sample was determined with an experimental MLD-10-type abrasive dynamic load wear tester. Specimen size for abrasive wear testing was 10mm × 10mm × 30mm. The duration of the runs was given as 30min for coarse silica sand under the impact energy of 1.5J. Each test was repeated 3 times for statistical calculation. \( \Delta M \) was determined as the mass loss of standard sample.

### Table 2. Technology parameters of medium frequency induction hardening process.

| Process No. | Cooling water flow/L/h | Voltage/V | Movement rate/mm/min |
|-------------|------------------------|-----------|-----------------------|
| 1           | 300                    | 420       | 200                   |
| 2           | 300                    | 420       | 230                   |
| 3           | 300                    | 420       | 260                   |
| 4           | 300                    | 420       | 290                   |

### 3. Results and discussion

#### 3.1. Microstructures

**Figure 1.** Microstructures for the composite coatings deposited at various moving speed process: (a) 200mm/min; (b) 230mm/min; (c) 260mm/min; (d) 290mm/min.
The microstructure of G18NiMoCr3-6 in different moving speed is shown in Figure 1. It can be seen from Figure 1 that the microstructure of G18NiMoCr3-6 after medium frequency quenching hardening is a martensite, that is, α-Fe of supersaturated carbon. The martensite is uniform and fine.

### 3.2. Hardness and depth of hardened layer

The surface hardness of G18NiMoCr3-6 steel after quenching by medium frequency heating surface of different processes is shown in Table 3. The hardness gradient of the thick plate from the surface to the substrate after induction hardening is tested.

| Process No. | Hardness of surface/HRC |
|-------------|-------------------------|
|             | No.1 | No.2 | No.3 | No.4 | No.5 | Average value |
| 1           | 50.1 | 50.8 | 52.3 | 52.5 | 51.5 | 51.4          |
| 2           | 50.3 | 49.2 | 52.3 | 51.0 | 51.5 | 50.9          |
| 3           | 52.5 | 51.0 | 51.5 | 50.6 | 51.0 | 51.3          |
| 4           | 49.6 | 49.1 | 50.3 | 50.1 | 50.9 | 50.0          |

Figure 2. Microhardness for the composite coatings deposited at various moving speed: (a) 200mm/min; (b) 230mm/min; (c) 260mm/min; (d) 290mm/min.

According to the GB/T 5617-2005 standard, the effective hardened layer depth is the distance from the surface of the part to the hardness value equal to the ultimate hardness, according to the hardness test after induction hardening of G18NiMoCr3-6 steel. It can be seen that the hardness after quenching is between (48~52) HRC. Therefore, this test selects 0.8×48=38.4 as the ultimate hardness. According to the hardness curve of the test, the effective hardened layer depth of G18NiMoCr3-6 induction hardening process is determined as shown in the following table 4. The microhardness of G18NiMoCr3-6 steel after quenching by medium frequency heating surface is show in Figure 2. When
the relative moving speed of the work piece is lowered, the heating time of the sample is prolonged, and the heat can be transferred to a deeper layer, thereby increasing the depth of the hardened layer.

| Process No. | Depth of hardened layer/mm |
|-------------|-----------------------------|
|             | Test 1 | Test 2 | Test 3 | average value |
| 1           | 5.15   | 5.20   | 5.10   | 5.15          |
| 2           | 3.50   | 3.45   | 3.45   | 3.47          |
| 3           | 4.15   | 4.11   | 4.05   | 4.10          |
| 4           | 3.85   | 3.90   | 3.95   | 3.90          |

3.3. Wear test
The wear tests were performed to predict the effect of the different process parameters on the in-service wear behavior of the coated components. The abrasive wear test results are demonstrated in Figure 3. From Figure 3, we can see that when the moving speed is 200mm/min, the corresponding specimen exhibits the smallest mass loss, therefore, it is the most resistant to wear.

**Figure 3.** Variation of mass loss of the G18NiMoCr3-6 steel at various moving speed.

4. Conclusion
In this paper, the effect of technology parameters of medium frequency induction hardening process on microstructure and mechanical properties of G18NiMoCr3-6 cast steel was investigated. The following conclusions can be drawn:

1) When the relative moving speed of the work piece is lowered, the heating time of the sample is prolonged, and the heat can be transferred to a deeper layer, thereby increasing the depth of the hardened layer.

2) The best combination is voltage 420V, cooling water flow 300L/h, moving speed 200mm/min.

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