Study of the influence of heat treatment process on the mechanical performance of wedge shaped components

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Abstract: Mine Splitter is widely used in mining machinery, and wedge assembly components are very important parts of it. In this work, we studied wedge assembly's element content by EDS, and through different heat treatments to improve the performance of wedge assembly components of Mine splitter. The heat treatment process of wedge assembly components is divided into quenching, quenching and tempering to find the changes on microstructure and mechanical properties. It is found that after quenching at 840°C and tempering at 450°C, the structure is tempered Sorbite with the highest strength and wear resistance and the best comprehensive mechanical properties.

1. Introduction

Mine Splitter refers to the equipment for mechanical expansion and splitting of stone. Its working process is as follows: firstly, a hole with a specific diameter and depth is drilled on the split stone, and then the working part of the Minesplitter (an intermediate wedge and two reverse wedges) is put into the hole. Through the action of external thrust, the intermediate wedge moves forward, and the two wedges are propped up and turned into transverse motion. The rock to be split will split in a predetermined direction in a few seconds [1]. Therefore, wedge components are the main parts of the Mine splitter. Wedge components, as the executive part of the Mine splitter, are subjected to tremendous impact. Therefore, wedge components are the first failure parts of the whole Mine splitter. Therefore, it is of great significance for the research of wedge components. In this paper, wedge-shaped components will be studied, and the influence of heat treatment process on the performance of wedge-shaped components will be studied. In this paper, a wedge-shaped component produced by a company is used. Its structure is shown in Figure 1.

![Figure 1. Structural diagram of wedge-shaped components](image-url)
2. Test materials and methods
In order to determine the material element composition of the wedge assembly, EDS was used to detect the structure as shown in Figure 2.

![Figure 2. Material Composition Diagram of Wedge Component](image)

From the data in Fig. 2, we can know the element content of wedge-shaped component material. According to GB/T 2975-1998 "Sampling position and sample preparation for mechanical properties test of steel and steel products", the hardness and metallographic specimens are cut from test rods by wire cutting machine [2]. The heat treatment process and experimental scheme of wedge assembly components of hydraulic splitter are shown in Table 1. The cooling method adopted is Oil cooling.

| Heat treatment                  | Process parameter                              |
|--------------------------------|-----------------------------------------------|
| 1 Quenched                     | 820°CQuenched X30min Oil cooling              |
| 2 Quenched + Tempered           | 840°CQuenched X30min Oil cooling +350°C X1h Tempered (Air cooling) |
| 3 Quenched + Tempered           | 840°CQuenched X30min Oil cooling +400°C X1h Tempered (Air cooling) |
| 4 Quenched + Tempered           | 840°CQuenched X30min Oil cooling +450°C X1h Tempered (Air cooling) |
| 5 Quenched + Tempered           | 840°CQuenched X30min Oil cooling +500°C X1h Tempered (Air cooling) |
| 6 Quenched                     | 860°CQuenched X30min Oil cooling              |

In order to study the mechanical properties of the wedge-shaped component, heat treatment experiments were carried out. Firstly, the wedge-shaped component was intercepted by wire cutting, and the surface of the wedge-shaped component was cleaned. The heat treatment experiments were carried out using high temperature box resistance furnace and programmable box resistance furnace. After heat treatment according to different experimental groups, the cross sections of different test blocks were taken, after grinding, polishing and corrosion with 4% nitric acid and alcohol solution[3].

3. Test results and analysis

3.1. Effect of Quenching Heating Temperature on Microstructure and Hardness of Wedge Component Materials
The mechanical properties of materials with different heat treatment results were compared by heat treatment. Firstly, the samples were quenched, and heated to 820°C, 840°C and 860°C, respectively. After 60 minutes of heat preservation, the samples were discharged from the furnace. Oil-cooled to room temperature. After quenching, the samples were observed by body microscope, and the microstructure was obtained as shown in Figure 3.
In Figure 3(a) (b) (c) are the microstructures of the samples after quenching at 820℃, 840℃, and 860 ℃, respectively. The quenched lath martensite, flake martensite and retained austenite structure of the wedge-shaped assembly sample. From (a) (b) (c) in Fig. 3, it can be seen that the lath martensite bundles increase gradually with the increase of quenching temperature. The reason is that the ferrite in the wedge-shaped assembly material dissolves gradually into austenite, which gradually transforms the material into martensite. At 820 ℃, the grain growth of wedge-shaped components is small. With the increase of quenching temperature, the grain size of wedge-shaped components grows obviously. This is because the austenite grain grows continuously and forms coarse martensite, which reduces the strength and stiffness of materials. After three groups of experiments, it was found that when the heating temperature was 840 ℃, the martensite bundle had larger grain size, and the hardness of the wedge component sample was the highest among the three quenching temperatures [4]. Rockwell hardness values of three groups of samples were shown in table 2.

Table 2. Rockwell hardness values of wedge component samples at different quenching temperatures

| Initial (HRC) | 820℃ (HRC) | 840℃ (HRC) | 860℃ (HRC) |
|---------------|-------------|-------------|-------------|
| 1             | 53          | 55          | 60          | 53          |
| 2             | 54          | 51          | 65          | 47          |
| 3             | 50          | 59          | 59          | 55          |

After three times of testing, the average value of the data is processed and analyzed. The point-line diagram is shown in Figure 4. It can be seen from the diagram that the Rockwell hardness of the wedge-shaped component sample is the maximum value in the three groups of tests after quenching at 840 ℃, and the hardness of the wedge-shaped component sample is 20% higher than that of the original material. From Figure 4, it can be seen that the Rockwell hardness of the wedge-shaped component sample is the maximum of the three groups of tests at 840 ℃.
3.2. Effect of Tempering Temperature on the Microstructure of Wedge Component Materials

In order to study the effect of heat treatment process on the properties of wedge-shaped assembly materials, the quenched samples at 840℃ were divided into four groups, and then air-cooled tempered at 350℃, 400℃, 450℃, and 500℃ for 60 minutes. The changes of structure and properties of samples with tempering temperature were analyzed. The microstructures at four tempering temperatures are shown in Figure 5 below.

Figure 5. Microstructure of Wedge Component Materials at Different Tempering Temperatures: (a) 350℃, (b) 400℃, (c) 450℃, (d) 500℃

Twelve samples treated by oil quenching at 840℃ for 1 h were divided into four groups. Three samples were tempered at 350℃, 400℃, 450℃, and 500℃, and then their metallographic structure was observed by body microscope. It was found that tempered sorbite was obtained by tempering at 350℃ and 500℃. The carbides were mainly flaky and partially granular, and the carbides were small and uniform [5]. The carbides of the structure treated at tempering temperatures of 400℃ and 450℃ are mainly flake-like particles, but when tempering temperatures exceed 450℃, the carbides are flake-needle-like and fine-grained [6].

3.3. Effect of Tempering Temperature on Hardness and Wear Resistance of Wedge Component Materials

The hardness of the wedge-shaped component sample after tempering is measured. In the process of measuring the hardness, the hardness value is measured by means of the average value of several times. The hardness value at different tempering temperatures is shown in Table 3.

Table 3. Rockwell hardness values of wedge component samples at different tempering temperatures

|        | 350℃ (HRC) | 400℃ (HRC) | 450℃ (HRC) | 500℃ (HRC) |
|--------|------------|------------|------------|------------|
| 1      | 53         | 57         | 55         | 48         |
| 2      | 50         | 56         | 59         | 46         |
| 3      | 49         | 54         | 57         | 52         |

According to the hardness value obtained from the experiment, the point-line diagram of the data is shown in Figure 6. By measuring the hardness of the wedge-shaped component sample, it is found that the hardness value of the sample increases with the increase of tempering temperature, but it does not continue to increase. The hardness value of the sample decreases gradually when the tempering temperature exceeds 450℃ degrees. Because wedge-shaped components of Mine splitter not only have certain requirements for hardness in practical work, but also need good wear resistance, so after the experiments of various heat treatment schemes, in order to get the best combination of hardness and impact toughness of wedge-shaped components [7], the wear resistance experiments of wedge-shaped components materials under various heat treatment processes are carried out finally, the results are shown in Figure 7.
Figure 6. The effect of different tempering temperature on material hardness of wedge-shaped components

Figure 7. The effect of different tempering temperature on wear resistance of wedge-shaped components

It is verified by experiments that the best combination of hardness and impact toughness of wedge-shaped component material can be obtained by the heat treatment process of quenching at 840°C and tempering at 450°C.

4. conclusion

(1) It is found that the heat treatment process of wedge component material has certain influence on its performance. The performance of wedge-shaped component material after quenching at 840°C and tempering at 450°C is the best. The hardness of wedge-shaped component material is increased to 57 (HRC), the hardness value is increased by 8% as a whole, and the wear resistance is also improved correspondingly.

(2) By comparing the quenching process of three groups of experiments at 820°C, 840°C and 860°C, it is found that the wedge-shaped component material after quenching at 840°C has larger grain size and uniform distribution, so higher hardness can be obtained.

(3) After 840°C quenching and 450°C tempering, the wedge assembly components has the best mechanical properties combination. The structure of the wedge-shaped component material is flake like particles, the distribution of carbide is uniform, and it shows strong strength, and the wear resistance is also improved correspondingly.

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