Effect of Different Heat Treatment Methods on Microstructure and Properties of 40Cr Steel

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Abstract. In this paper, the properties of 40Cr steel were studied by heat treatment. Different kinds of temperature quenching combined with tempering at different temperatures were used to study the influence of different heat treatment methods on the microstructure and properties of the samples, and find the optimal solution. The 40Cr steel samples were subjected to 850 °C oil quenching, respectively, and then tempered at 240 °C and 440 °C respectively, and then compared with the oil quenched parts which were not tempered. It can be known that the hardness of the quenched workpiece at 40 °C at the same quenching temperature of 850 °C is higher than that of the medium temperature tempering at 440 °C. When 40Cr steel is tempered at low temperature, the obtained structure is tempered martensite, and at the medium temperature tempering, the tempered tortite is obtained, the tempered martensite particles and the layered tempering hullite are fine. The hardened steel is organized from tempered martensite to tempered tortoise as the tempering temperature increases. 850 °C quenching + 240 °C tempering is the best solution.

1. Introduction
With the continuous development of industry in recent decades, people's demand for materials is not only limited, but also constantly improved and problems in use have been continuously solved. Especially in the era of science leadership, the requirements for material properties are not only demanding and diversified, but also require good performance and economical requirements. Every material needs to be used to its full potential. This requires understanding of each material, his composition, content ratio, hardness, toughness and other physical properties. The corresponding properties obtained by different heat treatment of the materials should be correctly grasped. Only when the experimental data is constantly updated, our understanding will continue to improve, and we can turn different materials into different tools.

This paper is a heat treatment method for quenching and tempering of 40Cr steel at different temperatures to transform austenite into martensite, and then tempering at different temperatures to obtain the corresponding hardness, fatigue and toughness of 40Cr steel. The use of steel in different fields. The effects of different quenching processes on the microstructure and properties of 40Cr steel were investigated by observing the shape, distribution and size of the microstructure martensite.

2. Experiments and Materials
2.1. Materials
The selected material is 40Cr Steel. Its chemical composition (mass fraction) is, C: 0.37 to 0.45, Mn: 0.49 to 0.80, Si: 0.16 to 0.36, Cr: 0.80 to 1.11, S: ≤ 0.034, P: ≤ 0.034, Ni: ≤ 0.33, and Cu: ≤ 0.30.

2.2. Experimental.

First, the box-type resistance furnace was heated to the required temperature of 850 ° C, and two sets of samples were placed in a box-type resistance furnace for heat preservation, and the time was started for 40 minutes. Secondly, the first set of samples was taken out and placed in a quick-displacement oil and cooled to room temperature. Then, it was placed in a box-type resistance furnace at 240 ° C for 2 hours, and then taken out and cooled to room temperature in air. Third, the second set of samples was also carried out. After the oil was cooled to room temperature, it was placed in a box-type resistance furnace at 440 ° C, and after 2 hours of heat preservation, it was taken out and cooled to room temperature in the air.

The 40Cr bearing steel specimens observed by microstructure were coarsely ground from 200 mesh, 400 mesh and 800 mesh with different thickness of sandpaper, then finely ground with 1200 mesh and 1500 mesh sandpaper respectively, and then mechanically on the metallographic sample polishing machine. For the polishing operation, the polished sample is etched with 4% nitric acid, rinsed with water and then etched with alcohol, and finally blown dry with a hair dryer. Then use a metallographic microscope to magnify the 40Cr steel samples to be observed 500 times respectively, select the appropriate eyepiece and objective lens, first turn the coarse focus to turn the spiral wheel, so that the height of the stage is reduced to the appropriate one. The downward side of the sample is close to the objective lens; then the coarse focus spiral is turned back, the stage is raised to the appropriate position, and slowly turned to the eyepiece to observe the blurred image. Finally, slowly turn the fine-focusing wheel until the observed image becomes clearest, take a picture of the tissue and save it.

3. Results and Analysis

3.1. Analysis of hardness test results of the 40Cr steel after different tempering temperatures

The sample was heat-treated according to the above scheme, and the treated 40Cr steel sample was taken for testing, and the hardness was tested by a Rockwell hardness machine. Three sets of data need to be measured for each set of samples. Three different points need to be found, and the average value is calculated to obtain the data as shown in Table 1.

| process                  | 240 ° C tempered | 440 ° C tempered | not tempered |
|--------------------------|------------------|------------------|--------------|
| Oil quenching at 850 ° C | 38.5HRC          | 34.2HRC          | 48.5HRC      |

From the Rockwell hardness data in Table 1, it can be seen that the Rockwell hardness of the 40Cr steel is slightly improved after being treated by different refining processes. First, at the same quenching temperature of 850 ° C, the hardness of the sample that has not been tempered is significantly higher than that of other tempered treatments, and the hardness of the tempering temperature of 240 ° C is higher than the tempering hardness of 440 ° C. Second, in the case where the tempering temperature is the same but the quenching temperature is different. The hardness of the workpiece becomes lower as the quenching temperature increases. Third, the steel parts that have not been tempered, although the quenching temperature is higher, the hardness is not much different. Finally, we can see from the table that the hardness of tempering at 240 ° C is the highest at 850 ° C. This process is the best process.

3.2. Observe and analyze the microstructure

Figure 1 shows the microstructure of the sample 40Cr steel which was tempered at 850 ° C for 40 min without tempering, 240 ° C tempering for 2 h, 440 ° C tempering for 2 h, and then polished to a magnification of 500 times under a Zeiss metallurgical microscope. It can be observed from Fig. 3-
2(a) that the sample 40Cr steel is kept at 850 °C for 40 min, its metallographic structure: fine needle martensite + lath martensite + a small amount of retained austenite; It can be seen from a) that the oil-hardened structure at 850 °C is mostly composed of fine-needle martensite accompanied by lath martensite, while the part of acicular martensite and platy martensite exists. It is considered to have been hardened. Figure (b) is tempering at 850 °C + 440 °C tempering, the metallographic structure is mainly tempered tortite and a small amount of tempered sorbite, from the ferrite that has not recrystallized and the distribution of the minimum Carbide composition. Since the ferrite has not recrystallized at this time, the morphology of the original old martensite remains. The tempering tortuosite has a high elastic limit. When martensite is formed, the martensite is decomposed in the first tempering, and the carbon is desolvated in the form of excessive carbide. At this time, extremely fine carbide flakes are dispersed in the solid solution matrix. Complex phase organization. The metallographic structure is characterized by the distribution of fine-grained cementite on the matrix of acicular ferrite with certain toughness. Figure (c) is tempered at 850 °C + 240 °C, and its metallographic structure is tempered martensite composed of carbide and martensite. Since the tempering has a certain degree of carbide segregation, the whole is black needle-like under the microscope. The unstable structure after quenching of steel is that martensite and a small amount of retained austenite coexist, and there is a tendency to change to stable structure due to instability. However, due to the low temperature in the room, the atomic activity is limited, resulting in a slower speed. However, as the tempering temperature rises gradually, its activity capacity gradually increases from the original slowly, and then the organizational transformation will proceed at a faster rate. Because the temperature is changing, the internal organization also changes accordingly, the performance of the steel. Corresponding changes have also taken place.

By comparing and analyzing Fig. 1(a) and Fig. 1(c), we find that the structure in Fig. (a) is martensite, which is bright in the metallographic microscope, and the tempered martensite in Fig. (c) It is black and is a product of low temperature tempering of martensite. At low temperature tempering,
the supersaturated carbon in martensite is desolvated to form carbides, but the whole remains in the original martensite orientation. The difference is martensite single phase, tempered martensite complex phase, and tempered martensite maintains high hardness and wear resistance, greatly reducing brittleness and quenching stress.

4. Conclusions
In this paper, several different heat treatment methods are applied to 40Cr steel. The quenching process is used to convert supercooled austenite into martensite in 40Cr steel. The tempering process greatly increases the wear resistance, hardness and strength of steel. Performance. The conclusions are as follows. First, the optimal heat treatment process for 40Cr steel in this experiment is 850 °C quenching for 40 min and tempering at 240 °C for 2 hours. The 40Cr steel carbide treated by this method is compared with other undissolved carbides. More uniformity and distribution are more diffuse. Second, the austenite grain size of 40Cr steel oil-hardened at 850 °C is not only small but also uniform. Third, 40Cr steel at the same quenching temperature, the hardness of the quenched workpiece at 850 °C at a low temperature tempering 240 °C is higher than the hardness of the medium temperature tempering 440 °C. When 40Cr steel is tempered at low temperature, the obtained structure is tempered martensite, and at the medium temperature tempering, the tempered tortite is obtained, the tempered martensite particles and the layered tempering hullite are fine. The function is to reduce the internal stress and brittleness of the quenching under the condition that the hardness of the quenched steel is constant or slightly reduced, and stabilize the structure to avoid cracking or premature failure during use. Finally, we found that the quenched steel is organized from tempered martensite to tempered tortoise as the tempering temperature increases.

Acknowledgement
It is a project supported by Innovation and Entrepreneurship Training Program for College Students (201910222041); Jiamusi University President Innovation and Entrepreneurship Fund Project (XZYF2019-12); Heilongjiang Provincial Education Department Youth Talent Innovation Plan Project (UNPYSCT-2018115) and (UNPYSCT-2017146); Jiamusi University Science and Technology Surface Project(L2013-078); Basic Research Funds Basic Research Project of Heilongjiang Education Department (2016-KYYWF-0567) of China.

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