Effect of heat treatment process on microstructure and properties of T8 steel

Kunyu Li *
Department of Materials Science and Engineering, Jiamusi University, Jiamusi, Heilongjiang Province, 154007, China
*Corresponding author’s e-mail: kunyuli@126.com

Abstract. The most suitable heat treatment process for T8 steel was studied by testing T8 steel under different heat treatment processes. The metallographic structure of T8 steel after heat treatment was observed by metallographic microscope. The hardness of T8 steel under different heat treatment processes was studied by Rockwell hardness tester as a reference for mechanical properties. The results show that the quenching of T8 steel at 860°C is the optimum quenching temperature of T8 steel, and the temperature should not be too high or too low. If the temperature is too high, the original austenite grains in the steel will become coarse, which will further affect the quenching. The martensite needle makes it coarse; the optimum tempering temperature after quenching of T8 steel is 200°C, and the hardness of the tempered T8 steel sample reaches the maximum at this temperature. When the tempering temperature is increased from 100°C to 400°C, the tempered structure of the sample is sequentially transformed into tempered martensite, tempered torsite and tempered sorbite.

1. Introduction
T8 steel is one of the commonly used steel grades in the machinery manufacturing industry. The carbon content is 0.75%~0.90%, and the hardness after heat treatment is 60~63HRC. T8 steel has excellent mechanical properties, high hardness and wear resistance, but low hardness at low temperature, low deformation plasticity and low strength. Because of its low production cost, good cold and hot processing performance, simple heat treatment process, and high hardness and wear resistance after heat treatment, there are many applications in processing and production [1-8]. In this paper, the T8 steel samples were quenched and tempered at different temperatures to study the heat treatment process of T8 steel. The effects of quenching and tempering on the mechanical properties of T8 steel and microstructure changes and laws were observed by hardness test. Trying to find the optimum process temperature for T8 steel provides a theoretical reference for industrial heat treatment.

2. Experiments and Materials

2.1. Materials
The bar used in the experiment was a T8 steel bar with a diameter of 12 mm. The chemical composition of T8 steel is C: 0.75% to 0.84%, Si: ≤ 0.35%, Mn: ≤ 0.40%, P: ≤ 0.035%, and S ≤ 0.030%.
2.2. Methods for Testing

In this experiment, a T8 steel bar with a diameter of 12 mm was used, and the bar was cut into a cylinder having a length of 30 mm using a cutter, and a total of 9 pieces were cut. The samples were numbered 1-9 and marked with a mark.

After thermal deformation treatment of T8 steel, in addition to granular pearlite and a small amount of polygonal ferrite, there are some modified layered pearlite structures, and after spheroidizing annealing, almost all spheroidized structures are obtained. In order to prevent the sample from cracking during the quenching process, the annealing process is first carried out, heated to 770°C for 1 h, then slowly cooled to 660°C for 2 h, and the furnace is cooled to 200°C for air cooling.

Sample No. 1 was the original sample without any treatment, and Sample No. 2 was only subjected to spheroidizing annealing.

Table 1. Quenching samples No. 3-5

| Sample number | quenching process                                      |
|---------------|--------------------------------------------------------|
| No. 3         | spheroidizing annealing, water quenching at 800 °C, holding for 30 min |
| No. 4         | spheroidizing annealing, water quenching at 860°C, holding for 30 min |
| No. 5         | spheroidizing annealing, water quenching at 920°C, holding for 30 min |

By testing the hardness and observing the metallographic phase, it is concluded that 860 °C is the theoretical optimum quenching temperature.

Table 2. Tempering samples No. 6-9

| Sample number | Tempering process                                      |
|---------------|--------------------------------------------------------|
| No. 6         | Water quenching at 860 °C, holding for 30 min, tempering at 100 °C for 2 h, air cooling. |
| No. 7         | Water quenching at 860 °C, holding for 30 min, tempering at 200 °C for 2 h, air cooling. |
| No. 8         | Water quenching at 860 °C, holding for 30 min, tempering at 300 °C for 2 h, air cooling. |
| No. 9         | Water quenching at 860 °C, holding for 30 min, tempering at 400 °C for 2 h, air cooling. |

3. Results and Analysis

3.1. Hardness test

Table 3 shows the hardness data obtained after different heat treatments of samples No.1-5. Sample No.1 is an untreated sample, No.2 is a sample after spheroidizing annealing, and steel after spheroidizing annealing. The hardness of the piece has a certain degree of decrease because the cementite in the pearlite changes from a sheet to a sphere. The sample No.3-5 is the hardness of quenching at different temperatures. It can be seen that the hardness of the quenched T8 steel reaches a maximum at 800 °C, and the quenching hardness gradually decreases with increasing temperature.

Table 4 shows the hardness value data obtained by quenching at 860 °C after quenching at 860 °C. It can be seen that the increase in tempering temperature leads to a decrease in hardness. The hardness does not decrease drastically under low temperature tempering because the martensite structure does not change much at this time, but the hardness is reduced due to the elimination of internal stress.
during quenching, when the temperature rises to 300 °C. At this time, it was moderate temperature tempering, and the hardness at this time had a certain decrease. This proves that the structure at this time has changed, and the hardness has a greater decrease at 400 °C.

Table 3. Hardness of T8 steel after quenching at different temperatures

| frequency | No. 1  | No. 2  | No. 3  | No. 4  | No. 5  |
|-----------|--------|--------|--------|--------|--------|
| the hardness /HRC | 15.14  | 10.82  | 66.49  | 66.37  | 65.39  |

Table 4. Hardness of T8 steel after tempering at different temperatures

| frequency | No. 6  | No. 7  | No. 8  | No. 9  |
|-----------|--------|--------|--------|--------|
| the hardness /HRC | 60.2   | 62.8   | 52.8   | 44.6   |

3.2. Observe and analyze the microstructure

As shown in Figure 1, the T8 steel of the original sample and the metallographic structure after spheroidizing annealing are shown. It can be seen that the cementite in the original T8 steel is coarse and unevenly distributed, and T8 can be seen through spheroidizing annealing. The original cementite body in the steel tends to be spheroidized and becomes fine. Spheroidizing annealing can improve the appearance of the carbide and uniform structure. Because of this, the hardness of the T8 steel after spheroidizing annealing is reduced, but the toughness is improved at this time. In this paper, an optical metallographic microscope was used, after heat treatment, the samples were lapping and polishing, then corroded with 4% ethanol. After etching, the magnification is 200 times and 500 times respectively under optical microscope.

![Figure 1](image_url)

(a) The original sample  (b) spheroidized annealed sample

Figure 1. Original sample and microstructure after spheroidizing annealing

As shown in Figure 2, the quenching hardness at 800 °C is extremely different from that before quenching, which means that austenite to martensite transformation has occurred at this time. However, at this time, the martensite structure is fine and the martensite does not exhibit needle-like characteristics, and the carbide distribution is dense. This tissue is called cryptocrystalline martensite. When the temperature is further increased, the T8 steel is quenched at 860 °C. At this time, the microstructure is martensite M+, and retained austenite Ar, and a large amount of undissolved cementite Fe3C. At this time, the martensite structure is needle-like. When the temperature is raised to 920 °C, the microstructure is martensite M+ at this time, and the retained austenite, undissolved cementite is less than 860 °C. From this, it is understood that the undissolved cementite starts to dissolve in a large amount at 860 °C. The microstructure after quenching at 920 °C is lath martensite + retained austenite and a small amount of extremely fine undissolved carbide. The undissolved
carbide should be (VxNb1-x) C. It is this high-melting carbide that exists at the grain boundary and acts to hinder grain boundary migration, so even if quenched at a higher temperature, the grain size is still small.

4. Conclusions
The test mainly studied the theoretical optimum quenching temperature and tempering temperature of T8 steel. The mechanical properties of T8 steel are improved by a suitable heat treatment process. Spheroidizing annealing can refine the crystal grains to make the eutectoid carbides in the original T8 steel structure more uniformly and finely distributed in the steel structure. And fully spheroidize the carbide. A suitable quenching temperature of T8 steel is 860 °C, and a structure of martensite M+, retained austenite, and a small amount of undissolved cementite can be obtained. The tempering temperature of T8 steel is the highest at 200 °C. After quenching of T8 steel, the tempering temperature has little effect on the hardness of T8 steel. Tempering mainly improves the stress state inside the steel and reduces the brittleness and internal stress of the steel.

References
[1] Xiaoli Li, Wenfeng Zhang, Minggang Shen: Journal of Welding Technology Vol. 37(2014), p.138-143, in Chinese.
[2] LI Tian-sheng, WANG Fu-ming, LI Chang-rong, et al. Carbide evolution in high molybdenum Nb-microalloyed H13 steel during annealing process[J]. Steel Journal of Iron and Steel Research, International, 2015, 22 (4):330.
[3] Ghassemi-Armaki H., Maa R., Bhat S P, et.: Journal of Acta Materialia, 2014, 62: 197—211.
[4] Hailing Cao, Zhanling Zhang, Jiewu Zhou et.: Journal of Hot working process Vol. 16(2007), p.19-21, in Chinese.
[5] Shuqin Shi, Baoqi Wang, Yuanzhong Gu et.: Journal of Journal of iron and steel research Vol. 18(2006), p.39-41, in Chinese.
[6] Jianxun Gong, Jianzhong Lei: Journal of Bearing Vol. 09(2015), p.35-37, in Chinese.
[7] Qiang Han, Zongchang Liu, Yonglin Ma: Journal of Hot working process Vol. 41(2012), p.119-121, in Chinese.
[8] Yuanzhe Kou: Journal of Gansu science and technology Vol. 23(2007), p.98-100, in Chinese.