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EFFECT OF TEMPERING TEMPERATURE ON MICROSTRUCTURE AND PROPERTIES OF 65Mn STEEL FOR METALLURGICAL SAW BLADE

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The continuous tempering treatment of 65 Mn steel for metallurgical saw blade was carried out in the temperature range of 200-620 °C by means of metallographic observation and mechanical property test. The results show that with the increase of tempering temperature, the strength and hardness of the pattern decrease continuously, and the impact value, section shrinkage and elongation change significantly. The experimental results provide a technical reference for preventing the failure of the saw blade during operation.

Keywords: 65Mn steel, temperature, microstructure, mechanical properties

INTRODUCTION

65Mn is a kind of special saw blade steel produced in Germany. It has high strength, certain toughness and plasticity. Under the same surface state and complete hardenability, the fatigue limit is equivalent to that of alloy spring, but the hardenability is poor. Compared with 65 steel, the strength, hardness and elasticity of 65Mn are better than those of 65 steel. 65Mn can not only manufacture diamond circular saw blade substrate, but also manufacture carbide circular saw blade substrate, and can also manufacture cold-cut circular saw blade, but it has a relatively harsh heat treatment system [1]. At present, the research on 65Mn steel is mostly focused on improving its elastic strength. In order to make it have better mechanical properties and prevent accidental damage in use, it is necessary to analyze the tempering temperature reasonably to explore more potential and lay the foundation for practical application. Therefore, this paper intends to take 65Mn as the experimental object, carry out a series of tempering temperature tests on it, use mechanical performance tests and other methods to determine the temperature points at which brittle transformation is easy to occur, and give its basic mechanical properties at each temperature point.

MATERIALS AND METHODS

The steel plate 65Mn for saw blade imported from Germany was used as raw material, and the supply state was hot rolling. Its chemical composition (mass fraction): C 0,62-0,70 %, Si 0,17-0,37 %, Mn 0,90-1,20 %, S 0,035 %, P 0,035 %, Cr 0,25 %, Ni 0,30 %, Cu 0,25 %. The steel plate was kept at 810-850 °C for 30 min to ensure complete austenitizing, oil quenching and ensuring that the quenching hardness was above 63 HRC, and then tempered in an air furnace for 6h at 200 °C, 290 °C, 380 °C, 450 °C, 520 °C, 570 °C and 620 °C, respectively. The tensile specimen size is 5 mm×30 mm×252 mm, and the impact specimen size is 5 mm×10 mm×55 mm (semi-impact specimen). Three samples were selected from each group and the average value was taken. The polished samples were eroded by 4 % nitric acid ethanol solution and observed and analyzed under Olympus upright metallographic microscope.

EXPERIMENTAL RESULTS AND DISCUSSION

Figure 1 is the rolled structure of 65 Mn steel plate before heat treatment. It can be seen that the steel plate is basically composed of ferrite and pearlite, and the cementite is spotted or discontinuous. Because of its denseness, it shows black in the matrix. The average values of the three mechanical properties of the rolled

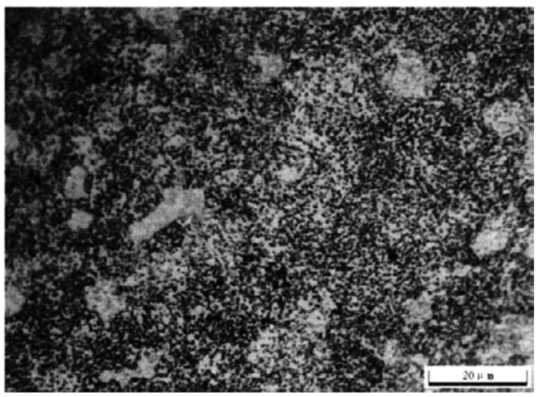

Figure 1 Microstructure of 65Mn rolled steel plate

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steel plate are: R_y = 608 MPa, R_m = 805 MPa, impact toughness A_k = 12,3 J, elongation A = 9,8 %, and section shrinkage Z = 25 %. Through the analysis and mechanical test results of the rolled structure, it can be seen that the structure is relatively uniform, and the yield ratio is about 0,75.

It can be seen from Figure 2 that the microstructure characteristics of 65Mn after 6h tempering at different temperatures. Its characteristics are as follows: after tempering at 200 °C, the ferrite structure and pearlite changes from low temperature tempering to strip tempered troostite (Figure 2a); with the increase of tempering temperature, supersaturated carbon atoms gradually precipitate and transform into fine-grained cementite distributed on acicular ferrite matrix, forming tempered troostite structure (Figure 2b). As the tempering temperature continues to increase, the troostite strip characteristics all disappear. When tempered at 620 °C, the carbide spheroidization and growth trend is obvious, and finally it becomes a spherical integrated structure with carbides distributed on the ferrite matrix (Figure 2c). The trend of spheroidization and growth in Figure 2d is more obvious. During the tempering process from low temperature to high temperature, the microstructure of 65Mn steel gradually evolves from typical ferrite and pearlite to tempered troostite and tempered sorbite, which conforms to the general law of ferrite and pearlite tempering [2].

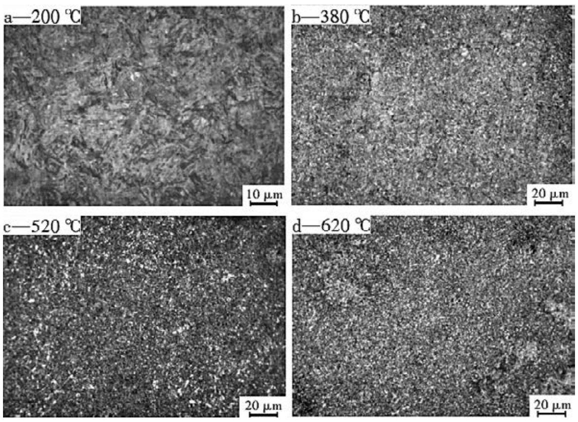

Figure 2 Microstructure of 65Mn steel at different tempering temperatures

During tempering, both tempering time and temperature affect the properties of the material. In general, the best ratio can be obtained by controlling the parameters. The mechanical properties of 65Mn steel at different tempering temperatures are shown in Table 1. In general, with the increase of tempering temperature, the torsional yield strength, torsional strength and hardness of 65Mn steel decrease significantly. When tempered at 200 °C, the C atoms in the quenched martensite are in a supersaturated state, and migrate to the vicinity of dislocations or grain boundaries and form carbides during tempering. At the same time, the dislocation density in the lath martensite is high during low temperature tempering, and the segregation of carbon in the dislocation line will pin the dislocation movement, which hinders the dislocation movement and significantly improves the elastic limit and yield strength of the steel. At this time, due to the low tempering temperature, the carbon content in the α phase matrix is still high, and the interstitial solid solution strengthening of carbon atoms is still the main factor of hardness, so the hardness is also high [3].

After tempering at 380 °C, the martensite decomposes, and the supersaturated C is gradually completely precipitated, resulting in a significant decrease in tempering hardness. At the same time, the ferrite begins to gradually recover, a large number of movable dislocations disappear, and the lower yield strength and torsional strength are improved.

When tempered at 520 °C, the ferrite is further restored and subgrains are formed, and the ferrite size begins to increase, resulting in a decrease in the lower yield strength and torsion resistance. [4]

During the subsequent tempering at 620 °C, the ferrite size further grows, the phase transformation strengthening effect basically disappears, and the hardness of the steel is greatly reduced. At this time, the microstructure is transformed into a spherical granular integrated structure of carbides distributed on the ferrite matrix, namely tempered sorbite [5]. At room temperature, this is an equilibrium structure, and the internal residual stress of the material basically disappears, and the yield strength and torsional strength decrease significantly.

Table 1 **Mechanical properties of 65Mn at different tempering temperatures**

Number	tempering temperature	torsion yield strength	torsional strength	tempering hardness
1	200	1 811	1 985	61,1
2	290	1 486	1 644	54,7
3	380	1 151	1 296	48,2
4	450	950	1 120	43,0
5	520	742	957	37,2
6	570	640	880	32,0
7	620	552	815	26,6

According to the data in Table 1, the mechanical properties change curve is obtained, as shown in Figure 3, which is automatically generated by Origin data processing software. The basic law is that the torsional yield strength and torsional strength curves of 65Mn saw blade steel show a uniform downward trend during tempering.

Figure 4 shows the relationship between tempering temperature and tensile strength. The basic law is that the tensile strength curve of 65Mn steel shows a uniform downward trend during tempering. By comparing with the yield strength curve in Figure 3, it can be seen that their yield ratio is very large, which is calculated to be 0,96-0,99. The strength decreased from 1 700 MPa at

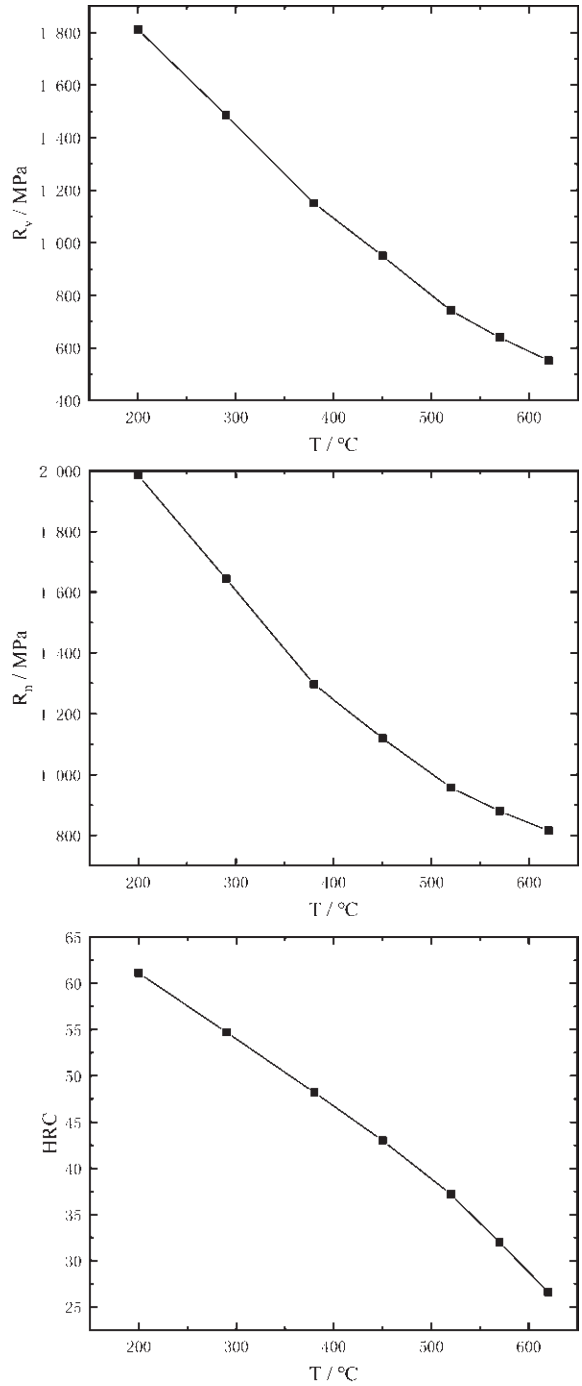

Figure 3 Effect of tempering temperature on properties of 65Mn steel

200 °C to about 1 200 MPa at 620 °C, and the curve was basically concave, only slightly beating at 450 °C.

Figure 5 is the relationship between tempering temperature and impact toughness. The basic law is : 65Mn saw blade special steel in the tempering process, the impact toughness of the overall increase in the tempering temperature and rise, in line with the general law of tempering. However, at 520 °C, the impact brittleness value is only about 25J, which is much lower than 37 J at 380 °C, indicating that the temper brittleness occurs at this temperature. Considering the jump of strength value, this is more obvious.

Figure 6 is the effect of tempering temperature on reduction of area and elongation. It can be seen that with the increase of tempering temperature, the two parameter values gradually increase, although there is some fluctuation, but the range is not large. At 520 °C, the reduction of area is about 11 % and the elongation is 4,5 %. Compared with the adjacent data, the value decreases, but the reduction of area changes more obviously. Considering the data reflected in Figure 5, it corresponds to the index of impact toughness, that is, the toughness decreases, the reduction of area and the elongation decrease.

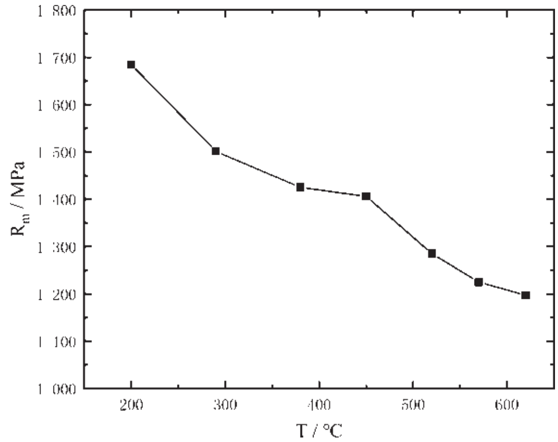

Figure 4 Effect of different tempering temperature on tensile strength

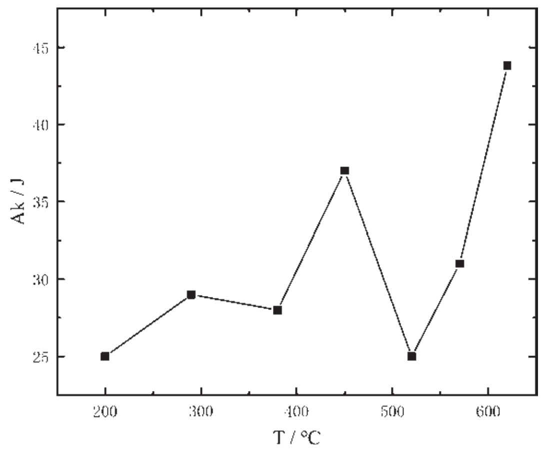

Figure 5 Effect of tempering temperature on toughness

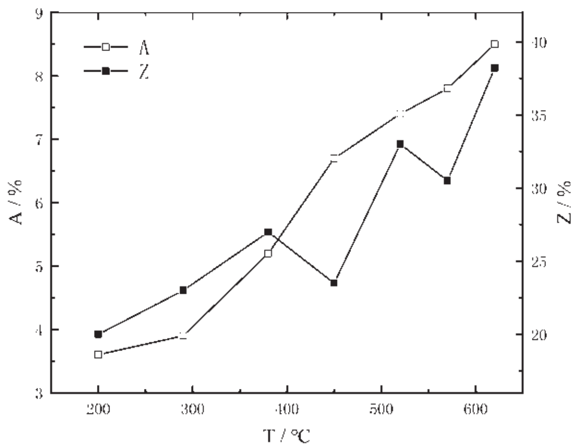

Figure 6 Effect of tempering temperature on reduction of area and elongation

From the results of this experiment, it can be seen that the impact toughness of tempering does not increase monotonously with the increase of tempering temperature, and tempering brittleness occurs at 520 °C. In general, the tempering brittleness of steel within 400 °C is the first type of tempering brittleness, and it is high temperature tempering brittleness above 450°C. Temper brittleness of 65Mn appears near 520 °C, which belongs to high temperature temper brittleness [6-7]. The reason may be that Ni, Cr, Mn and other elements in the experimental steel coexist with impurity elements (P, S, etc.). When the content of impurity elements is constant, the more such elements, the more serious the embrittlement. When two or more elements exist at the same time, the embrittlement is greater. Therefore, it may be that 65Mn steel conforms to the above reasons at 520 °C, which makes the hardness increase slightly and the toughness decrease.

The mechanism of temper brittleness of 65Mn saw blade steel needs further experimental research to clarify the internal mechanism of its formation. It should be noted that in the actual use of the process, because the blade is generally very thin, but also requires the blade has a higher stiffness and impact, therefore, to meet the use of the premise as far as possible under low temperature tempering, taking into account the experimental results, should avoid tempering at about 520 °C.

CONCLUSION

The microstructure of rolled 65Mn steel for metallurgical saw blade is typical ferrite and pearlite, and the fracture of local cementite flake is dotted distribution. With the increase of tempering temperature, the microstructure of 65Mn steel plate gradually evolved into tempered troostite and tempered sorbite. At the same time, the strength decreases, the plasticity and toughness increase, and the temper brittleness appears at 520 °C, which is between the commonly considered high temperature temper brittleness.

Acknowledgments

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Note: The responsible translator for English language is S.Y. Sui -North China University of Science and Technology, China.