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Effects of quenching temperature on tempering microstructure and mechanical properties of 30MnB steel

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Abstract. This article presents the effects of quenching temperature on tempering microstructure, mechanical properties and wear resistance of 30MnB steel were studied. The results showed that: The microstructure of 30MnB steel was the tempered martensite and retained austenite after quenching at 840°c-900°c and then tempering at 200°c. the carbide precipitation did not occur when 30MnB steel was tempered at 200°c, only the carbon segregation occurred. Meanwhile, the tensile strength of 30MnB was all above 1350MPa after quenching at 840°c-900°c and then tempering at 200°c, the -40°c ballistic work was above 20J, indicating that it had good low temperature impact toughness. 30MnB had minimum abrasion loss after quenching at 880°c and then tempering at 200°c, the wear morphology was fine wear mark, shallow furrow and ridge augmentation.

1. Introduction
Mn-B steel is a low structure alloy with Mn, B instead of Cr, Ni. The additional trace element B can significantly improve the hardenability of the steel, and significantly improve the wear resistance of the steel after heat treatment. Mn-B steel can be used for the wear part of ploughing machine, grinder and harvester. Güler, H [1] studied the effects of cooling medium and heating times on the microstructure and properties of 30MnB steel, and the results showed that 30MnB heat treated using water quenching process exhibited the best mechanical properties because of the formation of a martensitic microstructure. Yazici, A [2-3] studied the wear resistance of moldboard plowshares produced from 30MnB5 steel that were treated with different mar tempering conditions. The mar tempering process in which the steel was austenite at 960°c for 35 min, held at 350°c for 10 s in salt bath, and then cooled in air produced the best results for decreasing wear loss in laboratory conditions. Dyja, H [4] created the DTTT diagram for the 30MnB4 steel. The effects of conventional quenching temperature on microstructure and properties of 30MnB steel have been studied seldom, so in this paper, the effects of different quenching temperatures on tempering microstructure, mechanical properties of 30MnB were studied, in order to guide the actual production in the future.

2. Material and Experimental Procedures
The chemical composition of the normalizing 30MnB is shown in table 1. The 30MnB steel was austenite at 840°c, 860°c, 880°c, 900°c for 35 min respectively, then cooled in water and held at 200°c for 2 h. The specimens were cut into (10*10*15) mm metallographic specimens, (55*10*10) mm

charpy V-notch impact specimens, tensile specimens with 50mm gauge length, (25*10*10) mm wear specimens by the wire cutting, then tested by the Leica DMI500M metallurgical microscope, 200HRS-150 digital Rockwell hardness tester, JB-30B impact testing machine, INSTRON8802 tensile testing machines respectively. The impact test temperature was 20°c, 0°c, -20°c, -40°c and the strain rate of tensile test was 0.0025s-1. The abrasion test was performed on MMW-1 vertical universal friction wear testing machine. The experimental parameter was the loading force 300N, the pin rotation speed 180r/min, and the loading time 3600s. The abrasion loss ΔG= (W1-W2), W1-the original quality before testing, W2- the quality after testing. Finally the microstructure and wear morphology were observed by Inspect S50 scanning electron microscope.

Table 1. The chemical composition of 30MnB steel

Element	C	Si	Mn	Cr	B	Ti	Ni	Mo	Cu
Wt%	0.299	0.278	1.160	0.318	0.002	0.051	0.052	0.009	0.052

3. Results and discussion

3.1. Effect of quenching temperature on Microstructure of 30MnB steel after tempering

As can be seen from Figure.1, the matrix of the sample was the tempered marten site and retained austenite after heat treatment. The marten site began to decompose, and the internal atomic activity increased, and the degree of supersaturating of carbon in marten site decreased when tempering at 200°c. The lath, lath boundary and grain boundary were the favorable positions for carbide precipitation in the low temperature tempering. But no precipitation of carbides was observed in Fig.2. It was indicated that the carbide precipitation did not occur when 30MnB steel was tempered at 200°c, only the carbon segregation occurred. When the quenching temperature increased from 840°c to 900°c, the size of the lath beam increased gradually, as depicted in Figure.1 and Figure.2. This was because the austenite grain size increased with the increasing of heating temperature when the composition and holding time were fixed.

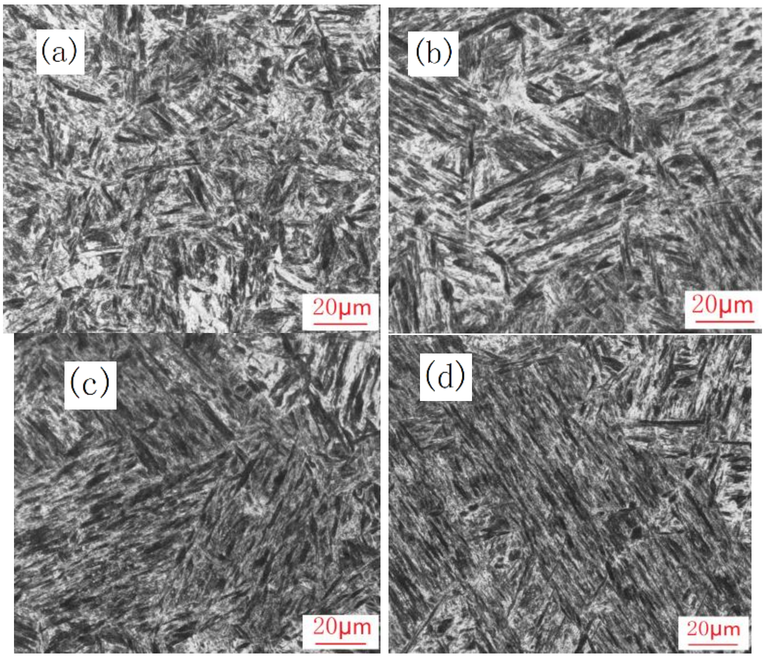

Fig.1 Microstructure of 30MnB with different quenching temperature (a) 840℃; (b) 860℃; (c) 880℃; (d) 900℃

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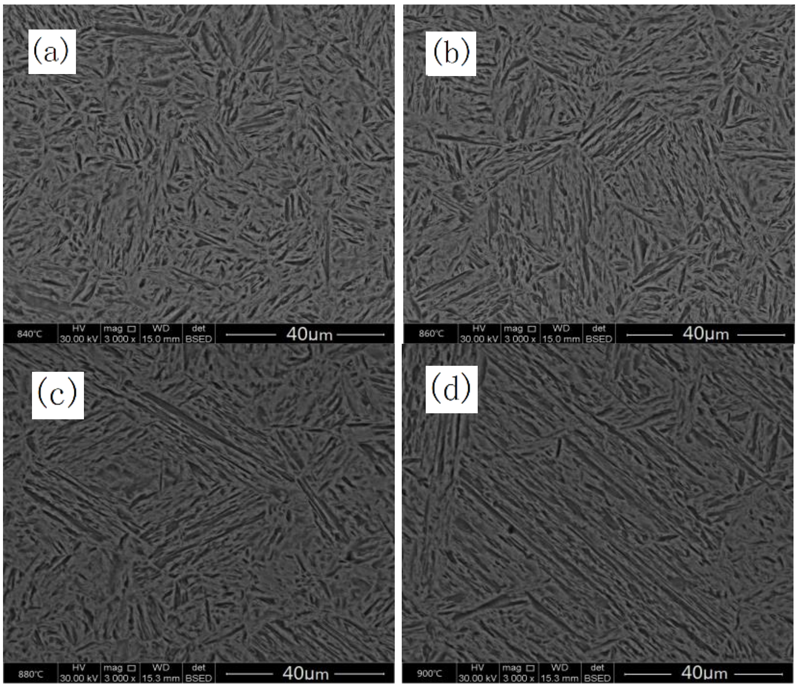

Fig.2 SEM morphology of 30MnB with different quenching temperature

(a) 840℃; (b) 860℃; (c) 880℃; (d) 900℃

3.2. Effect of quenching temperature on mechanical properties of 30MnB steel after tempering

Table 2 gave that 30MnB steel had a very high strength after quenching at 840°c-900°c and then tempering at 200°c. This was due to the existence of high density dislocations in tempered marten site after heat treatment. When 30MnB steel was subjected to external forces, the dislocations were intertwined with each other, which prevented the dislocation from moving, thus increasing the strength. With the increase of quenching temperature, the tensile strength and the yield strength increased first and then decreased, while the elongation and the reduction of cross section area decreased. After quenching at 840°c and tempering 200°c, more retained austenite was existed in steel. Because of the good ductility and low strength of retained austenite, thus it had the lowest strength and the highest elongation and shrinkage after quenching at 840°c and tempering 200°c. With the increase of quenching temperature, the content of retained austenite decreased gradually, which made the strength increase and the elongation and shrinkage decrease; However, when the quenching temperature reached 900 °c, the austenite grains in the steel were obviously thick, the barrier effect of grain boundary dislocations also decreased because of less grain boundary, which resulting in strength decreasing.

Table 2. The tensile properties of 30MnB with different quenching temperature

Quenching temperature/℃	Room temperature mechanical properties			
	R_m/MPa	$R_{p0.2}$/MPa	A%	Z%
840	1383	1235	11.5	46.0
860	1529	1367	9.5	36.5
880	1703	1573	8.0	28.5
900	1687	1528	6.5	21.5

30MnB steel had high room temperature ballistic work after heat treatment, as shown in Figure.3. The reason is that there was a 10nm thick austenite film between the tempered marten site positions, which can hinder the crack propagation [5]. Along with the increase of quenching temperature, the ballistic work of 30MnB steel decreased gradually. The ballistic work of 30MnB after quenching at 840°c ,860°c and tempering at 200°c declined slowly between 0°c and -20°c, which indicated that the ballistic work was insensitive to temperature between 0°c and -20°c. When the impact test temperature reaches -40°c, the ballistic work of 30MnB steel after heat treatment was still above 20J, which showed that 30MnB had good low temperature impact toughness.

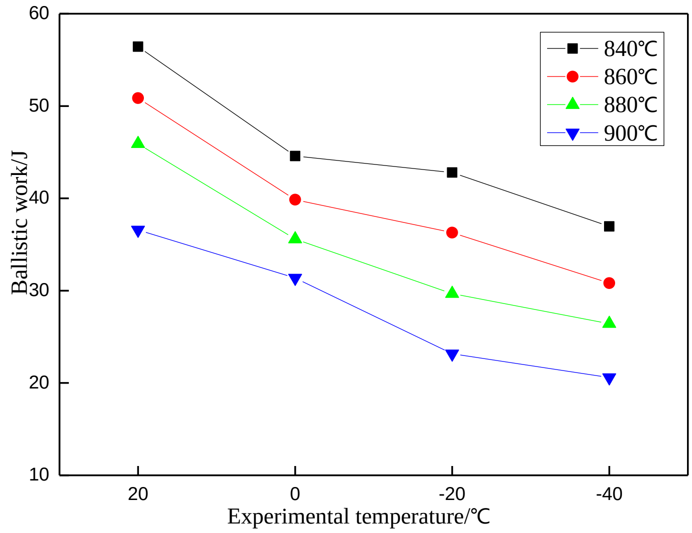

Fig.3 The ballistic work of 30MnB steel with different quenching temperature.

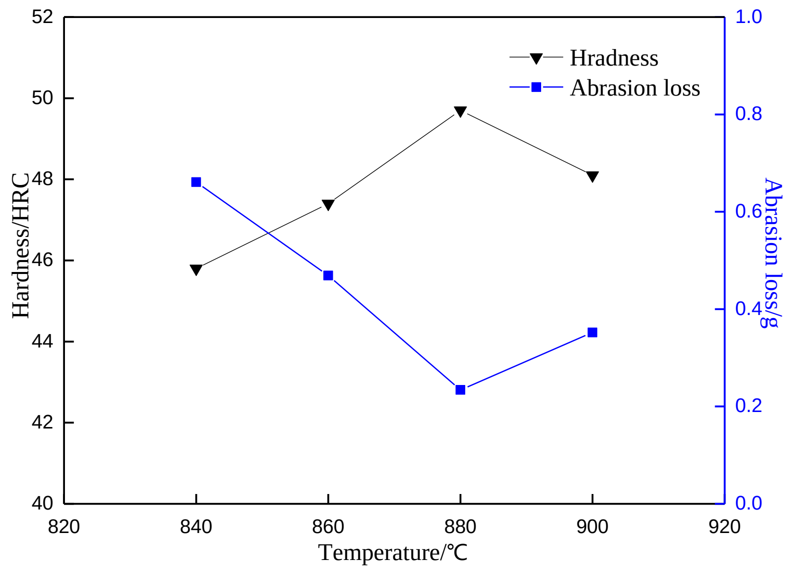

Fig.4 Relationship between hardness and wear resistance of 30MnB steel with different quenching temperature

3.3. Effect of quenching temperature on wear resistance of 30MnB steel

The relationship between hardness and abrasion loss of 30MnB steel was illustrated in Figure.4. It can be seen from figure 4 that the abrasion loss decreased with the increase of hardness. This was due to the wear resistance of the material directly proportional to the hardness of the material. The formula can be expressed as [6-7]:

$$W^{-1}=K\times H \tag{1}$$

K- Coefficient; H- hardness; W-1- wear resistance. It can be obtained the higher the hardness of 30MnB steel, the better its wear resistance from the formula.

Figure.5 showed the relationship between the friction coefficient and the time of 30MnB steel. It can be found that the friction coefficient decreased with the increase of hardness. When materials rubbed together, the deep pit produced on the surface of the low hardness object, thus blocking friction. The friction coefficient increases with the increase of wear time, this is due to the occurrence of wear behavior, more and more wear debris generated, the wear debris were along the sliding direction and the sample surface friction, resulting in an increase in friction coefficient. The friction coefficient fluctuated in the whole test, which was also due to the mutual adhesion between the chip and the friction surface, and the shearing plough [8].

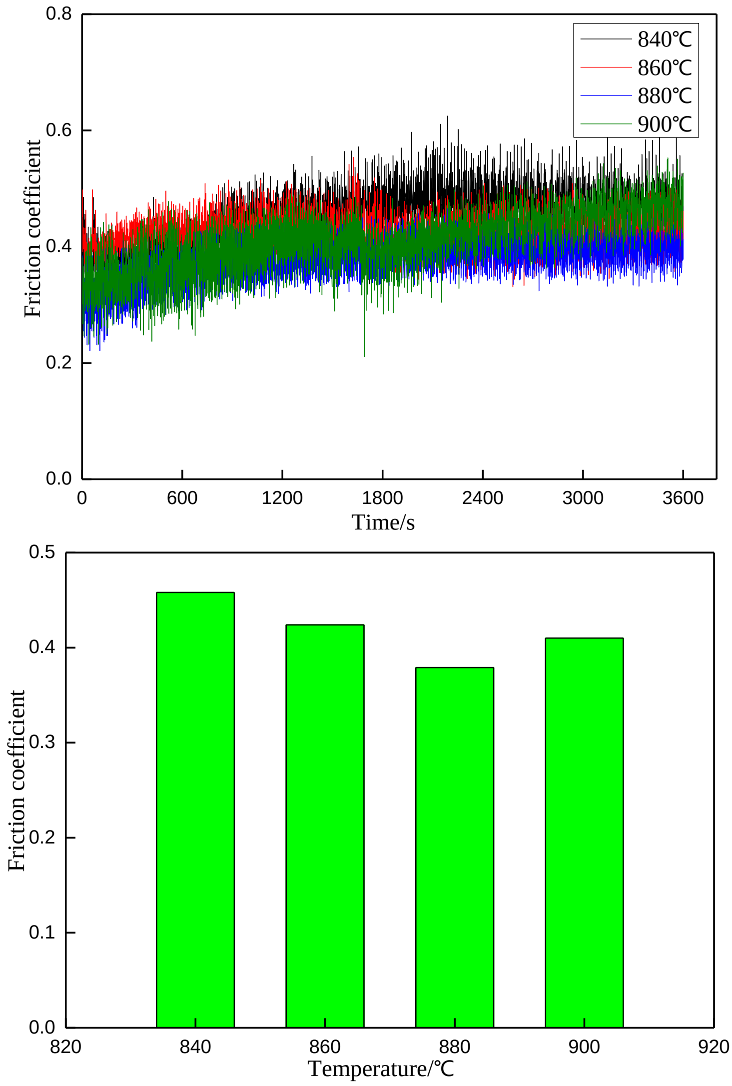

Fig.5 Relationship between friction coefficient and time of 30MnB steel with different quenching temperature

We can find that the wear morphology of 30MnB steel with four kinds of heat treatment showed a long furrow and ridge from figure.6. The gtinding crack of 30MnB was obvious, and it had deep furrow and ridge augmentation after quenching at 840°c and tempering at 200°c, also there were massive spalling in some areas because of its relatively low hardness. Hardness reflected the ability of a material to resist the pressure of other objects, a deep pit produced on the surface of low hardness object when materials rubbed together, with the extension of friction time, the temperature of the friction surface rose, and the hardness of the contact surface of the 30MnB steel was softened, therefore the 30MnB was easy to flake off. The furrows and ridges long became shallow, and there was no massive exfoliation because of the hardness improvement of 30MnB with quenching at 860°c and tempering at 200°c. 30MnB had high hardness with quenching at 880°c, 900°c and tempering at 200°c, the wear morphology was fine wear mark, shallow furrow and ridge augmentation.

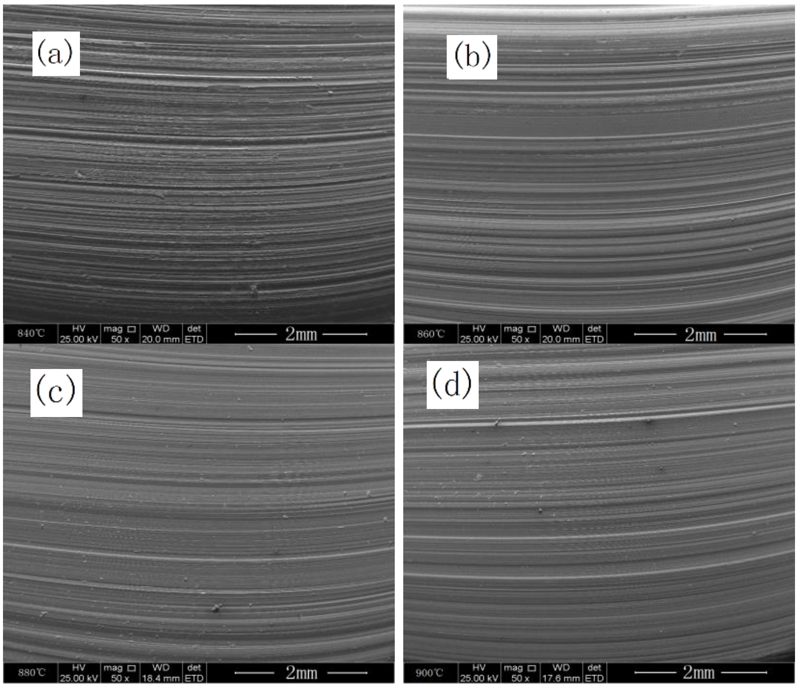

Fig.6 The worn surface morphology of 30MnB steel with different quenching temperature

(a) 840℃; (b) 860℃; (c) 880℃; (d) 900℃

4. Conclusion

1) The microstructure of 30MnB steel was the tempered martensitic and retained austenite after quenching at 840°c-900°c and then tempering at 200°c. The carbide precipitation did not occur when 30MnB steel was tempered at 200°c, only the carbon segregation occurred.

2) The tensile strength of 30MnB was all above 1350MPa after quenching at 840°c-900°c and then tempering at 200°c, the -40°c ballistic work was above 20J, indicating that it had good low temperature impact toughness.

3) 30MnB had minimum abrasion loss after quenching at 880°c and then tempering at 200°c, the wear morphology was fine wear mark, shallow furrow and ridge augmentation.

References

[1] Güler,H. Ozcan,R. Yaunz,N. Comparison of the mechanical and microstructural properties of heat-treated boron steel in different cooling media. [J] Materialwissenschaftund

Werkstoffechnik. 2014, 45 (10): 894-899.
[2] Yazici,A. Investigation of the wear behavior of martempered 30MnB5 steel for soil tillage[J]. Transactions of the ASABE. 2012, 55(1): 15-20.
[3] Yazici,A. Cavdar, U. AStudy of Soil tillage Tools from Boronized Sintered Iron.[J]. Metal Science & Heat Treatment. 2017, 58(11/12): 753-757.
[4] Dyja, H. KoczurkiewiczZ, B. Laber, K. et al. Physical simulation of microstructure evolution of the specimens made of 30MnB4 steel.[J]. Metallurgical & Mining Industry. 2015, 11:148-153.
[5] Thomas G. Retained austenite and tempered martensite embrittlement[J]. Metallurgical Transactions A, 1978, 9(3): 439-450.
[6] Modi O P, Mondal D P, Prasad B K, et al. Abrasive wear behavior of a high carbon steels: effects of microstructure and experimental parameters and correlation with mechanical properties [J]. Materials Science and Engineering, 2003, A343: 235-242.
[7] Sevim I, Eryurek I. Effect of fracture toughness on abrasive wear resistance of steels [J]. Materials and Design, 2006, 27(10): 911-919.
[8] Feng Ai-xin, Chen Feng-guo, Pei Shao-hu, et al. Effects of laser cladding on friction and wear properties of 304 stainless steel[J]. Transactions of Materials and Heat Treatment, 2015, 36(8): 223-228.