C.F. ZHANG, K.X. CUI, L.S. YI, J.J. WANG

ISSN 0543-5846
METABK 63(3-4) 360-362 (2024)
UDC – UDK 669.14.018:786.9-621.771:621.785:620.18:620.17=111

EFFECT OF TEMPERING TEMPERATURE ON MICROSTRUCTURE AND PROPERTIES OF 45 STEEL PIANO STRING

Received – Primljeno: 2024-02-01
Accepted – Prihvaćeno: 2024-03-30
Original Scientific Paper – Izvorni znanstveni rad

The effect of tempering temperature on microstructure and properties of 45 steel was studied. The string of 45 steel was tempered in the temperature range of 820°C-880 °C by means of metallographic observation and microstructure performance test. The results show that with the increase of tempering temperature, the hardness and yield strength of the sample increase first and then decrease, the tensile strength increases, the impact toughness jumps, and the elongation and reduction of area show an upward trend. The experimental results provide theoretical guidance for 45 steel in the process of making piano strings.

Keywords: 45 steel, piano string, tempering temperature, microstructure, mechanical properties

INTRODUCTION

High-quality strings are mainly made of 45 steel. 45 steel is a high-quality carbon structural steel containing 0,45 %. It is cheap, widely available, high strength, and easy to heat treat. It is suitable for manufacturing shaft parts, molds, strings, etc. It is also widely used in automobile, machinery and other industries in the rod, bolts and other parts, the processing process is very complicated, usually turning, hot forging, cold heading, heat treatment and other processes, the surface quality and mechanical properties of circular steel pipe have high requirements [1]. This project will take 45 steel as the research object. Through a series of tempering temperature tests and mechanical property tests, the temperature points at which the material is prone to performance transformation are obtained, and the basic mechanical properties of the material are given at each temperature point.

MATERIALS AND METHODS

45 hot rolled steel was used as raw material. Its chemical composition (mass fraction): C 0,42-0,50 %, Cr ≤0,25 %, Mn 0,50-0,80 %, Ni ≤0,25 %, P ≤0,035 %, S ≤0,035 %, Si 0,17-0,37 %. The experimental steel was tempered by STM-1-10 box-type resistance furnace. The tempering temperature was 820, 840, 860, 880 °C, the holding time was 2 h, and then air cooling was carried out. The microstructure of 45 steel was observed by metallographic microscope, and the corrosive agent was 3 % nitric acid alcohol solution. The mechanical properties of 45 steel plates in different states were tested on 5105 microcomputer controlled electronic universal testing machine.

C.F. Zhang, K.X. Cui, Harbin University. L.S. Yi, Shenyang Conservatory of Music. J.J. Wang (wangjiajun@stu.cpu.edu.cn), Heilongjiang Taiqi Tertiary Education Training Institute Co. Ltd, Heilongjiang, Haerbin, China.

EXPERIMENTAL RESULTS AND DISCUSSION

Figure 1 shows the microstructure of the tested steels tempered at 820, 840, 860 and 880 °C. The results show that after quenching and tempering at 820 °C, the microstructure of the experimental steel is composed of flaky ferrite phase (white) phase precipitation, and mainly flaky pearlite. When the heat treatment temperature was increased to 840 °C, a large number of white flake ferrite appeared, and fine lamellar structure appeared, in which the cementite was short rod-shaped. The results show that clear white lamellar ferrite phase and lamellar pearlite phase appear in the alloy at 860 °C [2-3]. When the temperature rises to 880 °C, the distribution of pearlite and flaky ferrite at high temperature is more uniform, and the arrangement between them is closer.

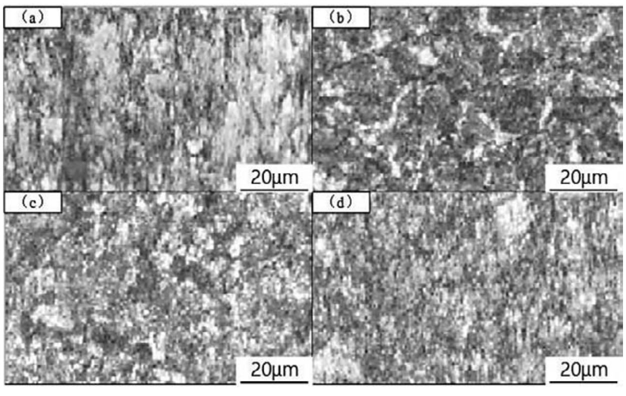

Figure 1 Microstructure of 45 steel at different tempering temperatures

During the tempering process, the tempering time and temperature affect the properties of the material. In general, the best ratio can be obtained by controlling the parameters. The change of mechanical properties of 45 steel at different tempering temperatures is shown in Table 1.

Table 1 **Mechanical properties of 45 steel at different tempering temperatures**

Number	Tempering temperature	Hardness/ HRC	R_V/MPa	R_m/MPa	Elonga-tion/%
1	820	19,5	373,9	634,6	20,0
2	840	58,7	565,1	642,7	21,1
3	860	50,3	275,8	648,1	22,9
4	880	39,8	193,8	650,3	24,0

After tempering at 820-880 °C, the hardness of 45 steel increases first and then decreases, and there is a peak at 840 °C, as shown in Figure 2. If the tempering temperature of 45 steel is too low, it has not been completely austenitized, and there will be some untransformed ferrite residues. After the tempering, the ferrite will continue to stay in it. Due to the low hardness of the ferrite region, the hardness after tempering cannot meet the requirements, and has a certain impact on other mechanical properties. If the re-melting temperature of 45 steel is too high, obvious austenite grains will be produced, which will affect the properties of 45 steel after tempering. Therefore, Ac3 + (30-50 °C) should be selected when quenching 45 steel in order to maintain a finer austenite morphology while ensuring complete austenitizing.

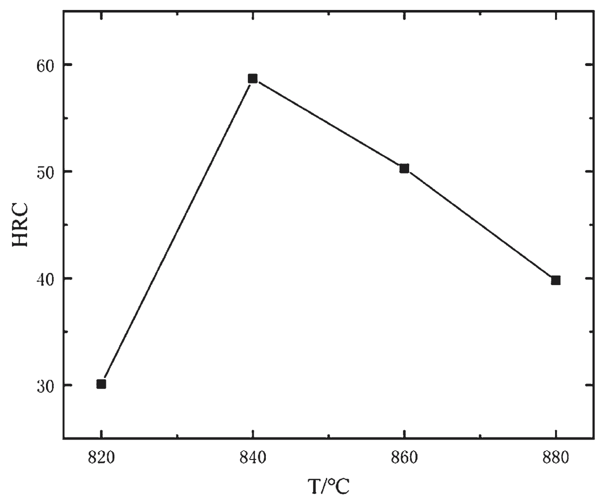

Figure 2 Effect of tempering temperature on hardness of 45 steel

The results show that the yield strength of 45 steel has been greatly improved after tempering treatment, and it also has good wear resistance. After tempering treatment, the toughness and plasticity of 45 steel are improved, the internal stress is eliminated, but the hardness is reduced. When the tempering temperature is 820-880 °C, the microstructure is mainly tempered troostite, with high yield strength, large elasticity and high toughness. After tempering treatment, the comprehensive mechanical properties are better. In Figure 3, the change of yield strength at various tempering temperatures is shown.

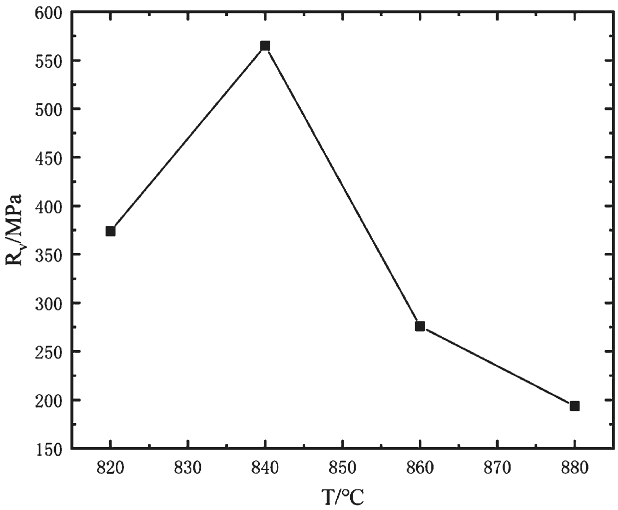

Figure 3 Effect of tempering temperature on yield strength of 45 steel

Figure 4 shows the relationship between tempering temperature and tensile strength. The basic law is as follows: during tempering, the tensile strength curve of 45 steel shows a trend of uniform increase. Compared with the yield strength curve shown in figure 3, the yield ratio is slightly smaller, between 0,30 and 0,59. The strength at 880 °C increased from 634,6 MPa at 820 °C to 650,3 MPa. According to the relevant specifications, the tensile strength of 45 steel should not be less than 540 MPa during rolling. The law conforms to the standard.

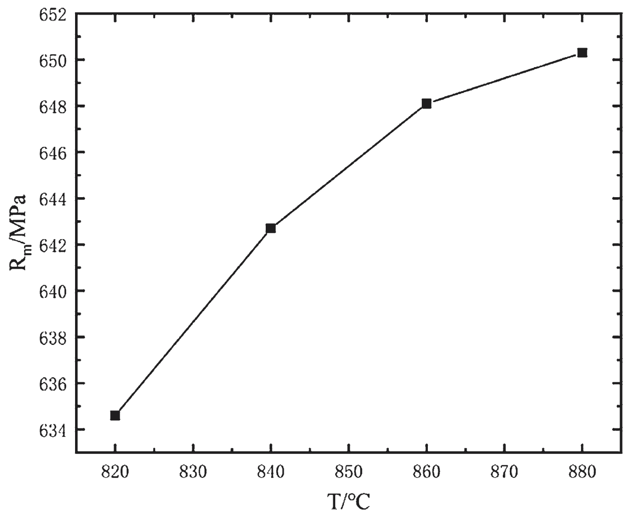

Figure 4 Effect of tempering temperature on tensile strength of 45 steel

The impact energy reflects the ability of the material to resist deformation and failure under impact load, and its size reflects the impact toughness of the material. As shown in Figure 5, after tempering heat treatment, the internal stress in the sample has been completely removed, and the α solid solution gradually transforms to

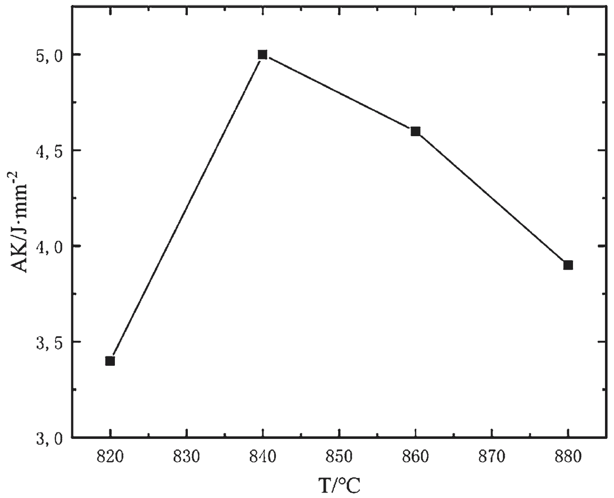

Figure 5 Effect of tempering temperature on impact toughness of 45 steel

the equilibrium content of ferrite, thus realizing recovery and recrystallization, so that the strength and toughness of 45 steel are reduced, and the plasticity and toughness are further improved.

Figure 6 is the effect of tempering temperature on elongation and reduction of area. It can be seen that with the increase of tempering temperature, the reduction of area and elongation show an upward trend. At 840 °C, the reduction of area is about 33 % and the elongation is 21,1 %. Compared with the adjacent data, the value decreases, but the change of the reduction of area is more obvious.

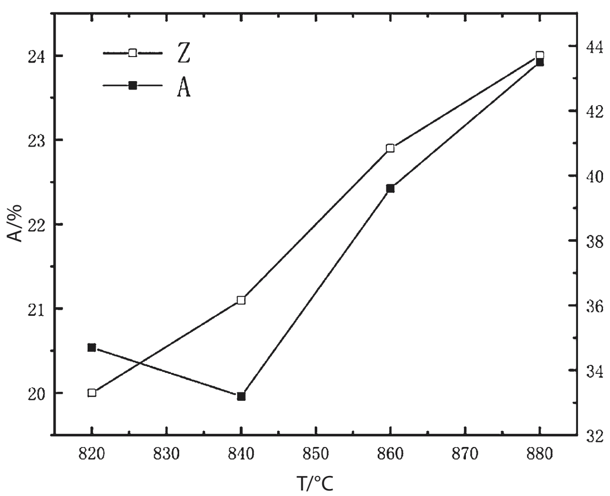

Figure 6 Effect of tempering temperature on elongation(A) and reduction of area(Z) of 45 steel

It can be seen from the test results that the impact toughness after tempering does not increase monotonously with the increase of tempering temperature, but temper embrittlement occurs at 840 °C. Generally, tempering brittleness below 400 °C belongs to tempering brittleness, and tempering brittleness above 450 °C belongs to tempering brittleness. The temper brittleness of 45 steel occurs at about 840 °C, which is a higher temperature temper brittleness [4]. The reason is mainly due to the coexistence of nickel, chromium, manganese and other elements as well as phosphorus, sulfur and other impurity elements in the test steel. In the same case, the number of these elements increases and is prone to embrittlement. When two or more elements coexist, the brittleness increases. The results show that the hardness of 45 steel increases and the toughness decreases at 840 °C.

CONCLUSION

The results show that the hardness and yield strength of 45 steel increase first and then decrease with the increase of tempering temperature, and the hardness and yield strength decrease after 840 °C. If the tempering temperature is too low, the austenitizing of 45 steel occurs, and the residual ferrite will remain in the tempered structure, which not only reduces the hardness after quenching, but also has an adverse effect on other mechanical properties. If the recycling temperature of 45 steel is too high, it will lead to the obvious coarsening of austenite grains and affect its tempering performance. Therefore, in 45 steel, the best tempering temperature is 840 °C, that is, sufficient austenite can be obtained while retaining fine austenite grains. Therefore, the analysis of the microstructure and properties of 45 steel provides a theoretical analysis for the manufacture of strings.

REFERENCES

[1] F. Chen, X.D. Wang, Y.G. Shi, et al. Discussion on the mechanical properties of 45 steel[J]. Shanxi Metallurgy, 44 (2021)06,89-90+93.

[2] W.Z. Li, Y.P. Sun, S.J. Chen. Influence of Heat Treatment Conditions on Microstructures and Mechanical Properties of 45 Steel [J]. Foundry Technology, 36(2015)05, 1092-1094.

[3] Y. Cai. Effect of heat treatment process on microstructure and properties of 45 steel was analyzed[J]. Modern Manufacturing Technology and Equipment, (2016)10,125-126.

[4] W.D. Wang, X. Han, Y.C. Cao, et al. Effect of Heat Treatment Temperature on Mechanical Properties of 45 Steel for High Strength Bolt[J]. Science & Technology Vision, (2017)20,37-38+74.

Note: The responsible translator for English language is C.F. Zhang - Harbin University, China.