

Research on Heat Treatment Process for New Low Alloy Steel Structures

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Keywords: Stepping-annealing, Heat treatment, Low alloy steel structure, Mechanical properties, Damping performance.

Abstract. Different annealing process and the same quenching tempering process were used to execute the heat treatment for Q235Ni0.1Zr0.1Y0.1 new low alloy steel structure, and the microstructure of the steel structure was observed and the mechanical properties and damping performance were analyzed. The results show that, compared with 460 °C annealing, the mechanical properties and damping performance of the steel structure reduce after annealed at 600 °C, the tensile strength, yield strength and break elongation is decreased by 7.1% , 12.2% and 9.8% , respectively. As the frequency of 1 Hz, the damping performance is decreased by 71.4%. After stepping-annealing, the tensile strength, yield strength and break elongation of the steel structure is increased by 14.3%, 13.4% and 12.8%, respectively. As the frequency of 1 Hz, the damping performance is increased by 321.4%.

The wide application and continuous improvement of steel structure bring new opportunities and challenges for the development of steel structure materials [1-4]. The existing steel structure materials are often difficult to meet the comprehensive performance requirements of steel structure, especially the damping performance, thermal fatigue performance and other aspects are difficult to meet the market demand [5-9]. Alloying and heat treatment are two effective ways to improve the comprehensive properties of metal materials [10-14]. Therefore, In this paper we studied the heat treatment process of Q235 Ni0.1Zr0.1Y0.1 new low alloy steel structure, which provides corresponding reference for the optimization of the heat treatment process in industrial applications.

Test Materials and Methods

Test Materials

Q235 Ni0.1Zr0.1Y0.1 alloy was smelted in the electric furnace and cast into continuous casting billet. The new low-alloy steel structure samples were obtained for the test by after rolling. The rolling temperature is (1 to 000 + 5) °C when begin rolling, the finishing temperature is (865 + 5) °C, the reduction is 0.6, the finishing thickness is 3 mm. The length and width of the sample are 300 mm and 100 mm. The chemical composition of the samples were analyzed by Q8 direct reading spectrometer and TY2000 trace sulfur-phosphorus analyzer, and the analysis results are shown in table 1.

Table 1. Chemical composition of the sample

C	Si	Mn	S	P	Ni	Zr	Y	Fe
0.168	0.328	1.384	0.025	0.029	0.097	0.096	0.101	Remain

Heat Treatment Process

The heat treatment of the samples is carried out in the sx2-12-12 box resistance furnace. The heat treatment of samples can be divided into three stages: annealing, quenching and tempering. The annealing treatment of samples adopts different technologies, as shown in table 2. The quenching and tempering of samples adopt the same heat treatment system, as shown in figure 1.

Test Method

The microstructure was observed by PG18 Metallographic Microscope (OM) and E-VO18 Scanning Electron Microscope (SEM).

Table.2. Annealing process of the sample

Sample Number	Return Process
Sample 1	460 °C×4 h , Furnace cooling to 200 °C Air cooling
Sample 2	600 °C×4 h , Furnace cooling to 200 °C Air cooling
Sample 3	(600 °C×1 h+460 °C×1 h) , Furnace cooling to 200 °C Air cooling

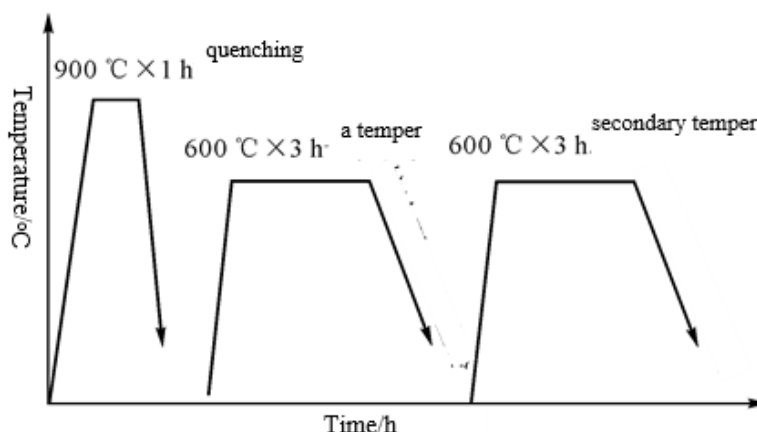


Figure 1. Hardening and tempering process of the sample

Mechanical properties: wd-200d Electronic Universal testing machine was used to test the mechanical properties. The test temperature was room temperature.

Damping performance: DMAQ800 Dynamic Mechanical thermal analyzer was used to test the damping performance. The test temperature was room temperature and the strain frequency was 1.2 Hz, the strain amplitude range is $0 \sim 1 \times 10^{-2}$.

Test Results and Discussion

Microstructure

Before quenching and tempering, the picture which the microstructure OM after annealing is shown in figure 2, which sample 1~ sample 3 of Q235 Ni0.1Zr0.1Y0.1 new-type low-alloy steel structure with different annealing processes. Figure 3 shows the SEM pictures of the microstructure of samples after different annealing processes. As can be seen from figure 2 and figure 3, the annealing process is different, and the annealing microstructure of Q235 Ni0.1Zr0.1Y0.1 new low-alloy steel structure is obviously different. Compared with the sample 1 of annealing process with 460 °C, the microstructure of sample 2 with 600 °C annealing process was obviously coarsening; the microstructure of sample 3 with graded annealing process was significantly refined, and the carbide changed from reticular distribution to dispersed granular distribution.

Mechanical Properties

The mechanical test results of Q235 Ni0.1Zr0.1Y0.1 new-type low-alloy steel structure samples are shown in figure 4 with different annealing processes, the same quenching and tempering processes. It can be seen that the mechanical properties of the new low-alloy steel structure samples are different with different heat treatment processes. Compared with the sample 1 of 460 °C annealing process has been adopted, the mechanical properties of the sample 2 with 600 °C annealing process is reduced, the tensile strength from 523 MPa decreased to 486 MPa, reduced by 7.1%; The yield strength decreased from 337 MPa to 296 MPa by 12.2%. The elongation after fracture decreased from 29.7% to 26.8% by 9.8%. The mechanical properties of sample 3 with graded

annealing process were improved, which the tensile strength increased from 523 MPa to 598 MPa by 14.3%; the yield strength increased from 337MPa to 382MPa, an increase of 13.4%; the elongation after fracture increased from 29.7% to 33.5%, an increase of 12.8%.

Damping Performance

The damping properties of Q235 Ni0.1Zr0.1Y0.1 new-type low-alloy steel structure samples with different annealing processes and the same quenching and tempering processes are shown in figure 5. It can be seen that the damping properties of the new low-alloy steel structure specimens are obviously different with different heat treatment processes. When strain amplitude was less than 10^{-3} , with 460 °C annealing process (sample 1)、600 °C annealing process (sample 2) and hierarchical annealing process (sample 3) have very low damping values, which the three of damping performance curve were basically overlapped; However, when the strain amplitude was more than 10^{-3} , the damping properties of samples 1~sample3 were significantly different. When the strain amplitude is 10^{-2} , the damping property of sample 2 decreases from 0.036 to 0.023, which is 36.1% lower than that of sample 1; Compared with sample 1, the damping performance of sample 3 increased from 0.036 to 0.091, an increase of 152.8%. FIG. 6 shows the variation of damping performance for sample 1~ sample 3 with the frequency change. As can be seen from figure 6, with the increase of frequency, the damping performance of Q235 Ni0.1Zr0.1Y0.1 new low-alloy steel structure decreases gradually, but the damping performance of each sample decreases significantly. In addition, it can be seen from figure 6 that the damping properties of each sample are obviously different at the same frequency. When the frequency of 1 Hz, compared with the sample 1 of 460 °C annealing process, the damping performance of sample 2 with 600 °C annealing process reduced from 0.014 to 0.004, reduced by 71.4%; the damping property of sample 3 with graded annealing increased from 0.014 to 0.059 by 321.4%. It can be seen that the damping performance of the new low-alloy steel structure Q235 Ni0.1Zr0.1Y0.1 can be significantly improved by the appropriate heat treatment process.

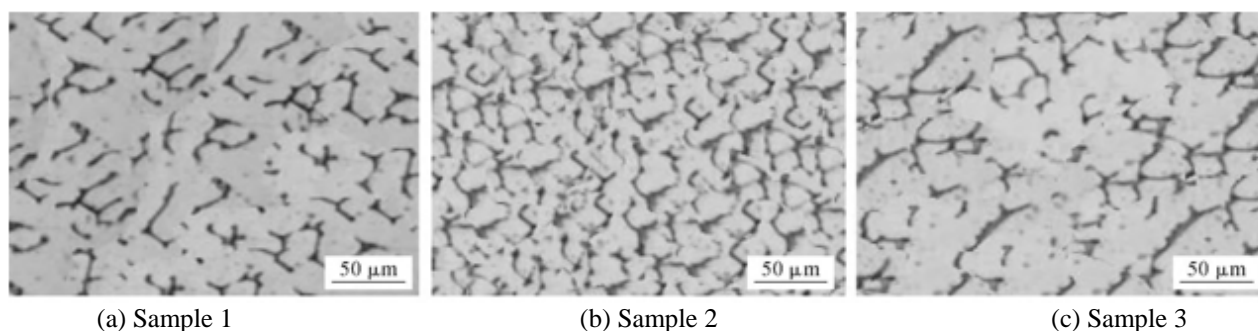


Figure 2 The OM microstructure of the samples after annealing

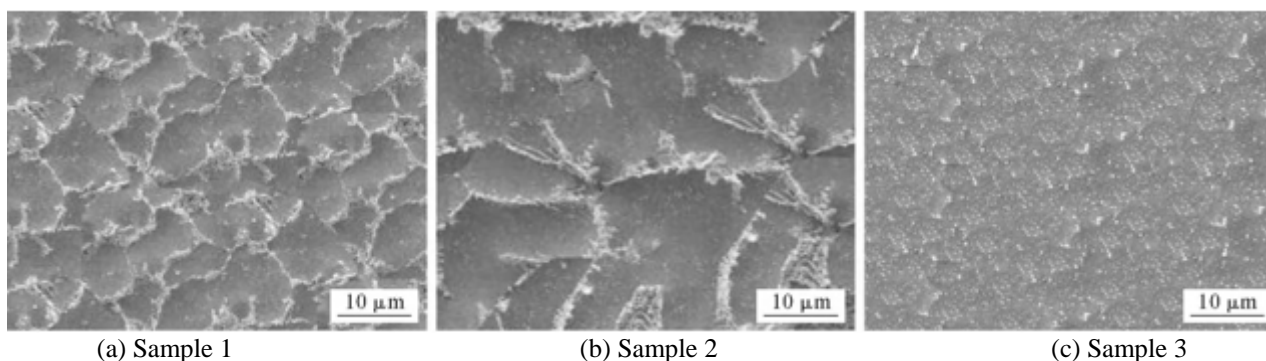


Figure 3. The SEM microstructure of the samples after annealing

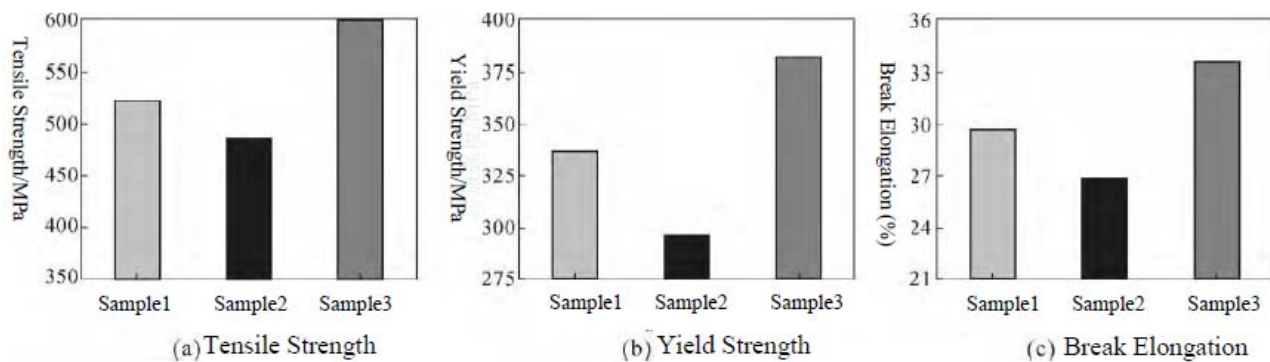


Figure 4. The mechanics properties test results of the samples

Above all, compared to the sample 1 with 460 °C annealing process, the microstructure of the sample 2 with 600 °C annealing process coarsening, reduced mechanical properties and damping performance, which mainly because the higher annealing temperature is easy to cause the grain coarsening and difficult to get the fine microstructure, so as to make the deterioration of mechanical properties and damping performance [15]; the microstructure of sample 3 with graded annealing process was obviously refined, the carbide distribution changed from reticular distribution to fine dispersion distribution, and the mechanical properties and damping properties of the material were obviously improved. From raising the mechanical properties and the damping properties of Q235 Ni0.1 Zr0.1 Y0.1 new low alloy steel structure, so the annealing process optimization is the classification annealing process of 600 °C x 1 h + 460 °C x 1 h.

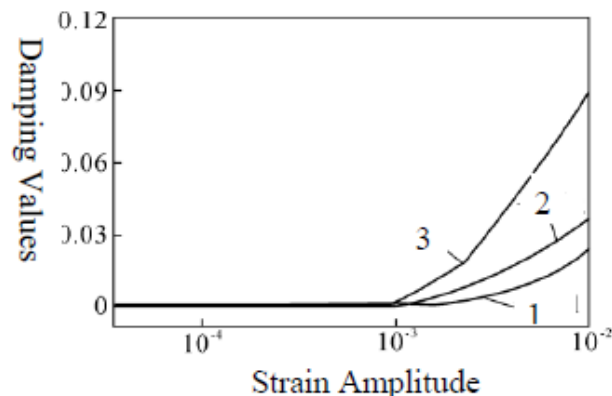


Figure 5. The change of damping performance of the samples with strain amplitude

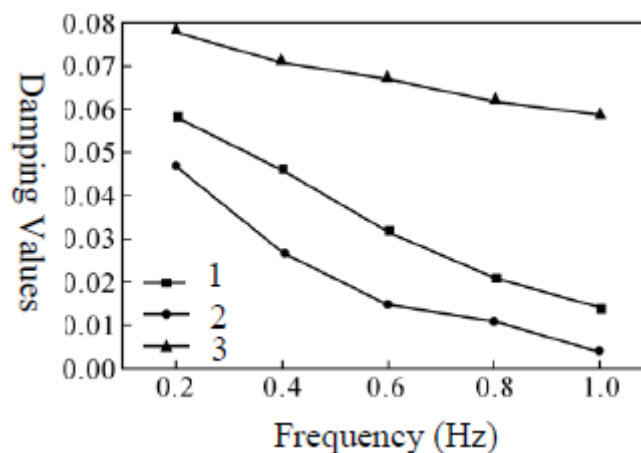


Figure 6. The change of damping performance of the samples with frequency

Conclusion

(1)The annealing microstructure of the Q235Ni0.1Zr0.1Y0.1 new low alloy steel structure is obviously different by different annealing process , same quenching and tempering process.

Compared with 460 °C annealing, the microstructure of 600 °C annealing was coarsening and the microstructure of fractional annealing was markedly refined and the carbide was changed from reticular distribution to dispersion particle distribution.

(2) The Q235Ni0.1Zr0.1Y0.1 new low alloy steel structure which after the different annealing process and the same quenching and tempering process. The 600 °C annealing material for tensile strength, yield strength and break elongation decrease by 7.1%, 12.2% and 7.1% respectively, which compare to 600 °C annealing. The material for tensile strength and yield strength and elongation after fracture increased by 14.3%, 13.4% and 12.8% respectively by the classification of annealing.

(3) The Q235 Ni0.1Zr0.1Y0.1 new low-alloy steel structure with different annealing processes and the same quenching and tempering processes has no significant difference in damping performance when the strain amplitude is less than or equal to 10⁻³. When the strain amplitude more than 10⁻³, the damping performance of material with 600°C annealing which compared to 460°C annealing decreased 36.1%; and the damping performance of grading annealing material increased 152.8%. When the frequency for 1 Hz, compared with 460 °C annealing, the damping performance of 600 °C annealing reduces 71.4%, classification of annealing damping performance increased 321.4%.

(4) From raising the mechanical properties and the damping properties of Q235 Ni0.1 Zr0.1 Y0.1 new low alloy steel structure, so the annealing process optimization is the classification annealing process of 600 °C x 1 h + 460 °C x 1 h.

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