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Procedia Engineering 31 (2012) 515 – 519

Procedia Engineering

www.elsevier.com/locate/procedia

International Conference on Advances in Computational Modeling and Simulation

Study on the Cooling Capacity of Different Quenchant

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Abstract

Heat treatment is one method to improve mechanical properties of metal, but each heat treatment method has its advantages and disadvantages, therefore, different requirements regarding size, shape, and properties with respect to different heat treatment processes should be considered. The traditional liquid quenchant are clear water and quench oil. Gas quenching is a relatively new process with several important advantages, such as minimal environmental impact, clean products, and ability to control the cooling locally and temporally for best product properties. To meet the high cooling rates required for quenching, the cooling gas must flow at very high velocities, but still the cooling capacity of gas is weakness. In order to increase the cooling capacity of gas, the spray water is added during gas quenching. In this paper, the GCr15 steel is as the research object, the cooling capacity of clear water, quench oil, nitrogen and nitrogen-spray water are studied through comparison of temperature difference and cooling velocity of the specimen.

Keywords: Cooling capacity; Quenching; Nitrogen-spray water; Cooling velocity; Temperature difference.

1. Introduction

Heat treatment is a process of heating and cooling a solid metal to obtain the desired properties. Typically, the heat treatment of steels can be classified into normalizing, quenching, tempering and annealing. Quenching is used to increase the surface hardness by martensite phase transformation. The

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doi:10.1016/j.proeng.2012.01.1061

quenching process is classified into liquid quenching and gas quenching. The cooling capacity differs with different quenchant. The traditional liquid quenchant are water and oil. Gas quenching is becoming increasingly important in industry with the improvement of gas-quenching equipment. During the gas-quenching process, the component is first heated to the solution temperature and then rapidly cooled by gas. The use of gas instead of liquid as quenchant has environmental, product quality, process control, safety and economic advantages[1-3], but the cooling capacity of gas is less than water and oil.

The gas quenching can be classified into vacuum high pressure gas quenching and ordinary pressure high velocity gas quenching[4-6]. The vacuum high pressure gas quenching has more requirements for equipment and cost. The ordinary pressure high velocity gas quenching may have wider applications. CHENG et al. [5] designed the equipment of ordinary pressure high velocity gas quenching by themselves and it has the same quenching effects as vacuum quenching. The common gas quenching media are hydrogen, helium, argon, nitrogen and air. The nitrogen is safe, abundant, cheap and inertia, so the nitrogen is used during gas quenching in this paper. In short, clear water, quench oil, ordinary pressure high velocity nitrogen and nitrogen-spray water quenching are experimentally studied in this paper. The continuous cooling curves during quenching were obtained, and the experimental results are analyzed.

2. Experiment process

The metallic specimen is shown as Fig. 1. It is a GCr15 steel cylinder whose material chemical composition (wt%) is presented in Table 1. The cylinder was heated to 30-50℃ higher than austenitic temperature, then austenized for 20 min, and quenched using different quenchant. The change in temperature during quenching was measured by thermocouples, experimental data were recorded by computer data equipment. The experimental conditions is shown in Table 2.

Table 1. Chemical composition of GCr15 steel (wt%)

C	Si	Mn	Cr	P	S
1.02	0.22	0.35	1.55	⩽0.025	⩽0.030

Table 2. The experimental conditions

No.	Specimen	Material	Quenchant	Velocity (m/s)
1	Cylinder ϕ 20×60mm	GCr15	Quench oil	—
2	Cylinder ϕ 20×60mm	GCr15	Clear water	—
3	Cylinder ϕ 20×60mm	GCr15	Nitrogen	86
4	Cylinder ϕ 20×60mm	GCr15	Nitrogen-spray water	86

3. Experimental results and analysis

The curves of temperature-time during different quechant quenching can be seen in Fig. 2. Fig. 2 shows that the time used when the specimen was cooled from heated temperature to room temperature using nitrogen quenchant is longest, oil quenchant the second, water and nitrogen-spray water the third, and nitrogen-spray water quenchant is closely with water quenchant.

The internal-external temperature difference during different quenchant quenching is shown in Fig. 3. Fig. 3 shows that the internal-external temperature difference of the specimen during water quenching is largest, nitrogen-spray water the second, oil the third, nitrogen the fourth. Which means that the corresponding thermal stress and the thermal deformation of the specimen during water quenching is largest, nitrogen-spray water the second, oil the third, nitrogen the fourth.

The internal average cooling velocity during different quenchant quenching is shown in Fig. 4. Fig. 4 shows that the internal average cooling velocity of the specimen during nitrogen-spray water quenching is fastest, water the second, oil the third, nitrogen the fourth.

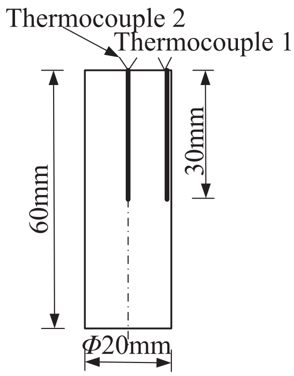

Fig. 1. Specimen and position of thermocouples.

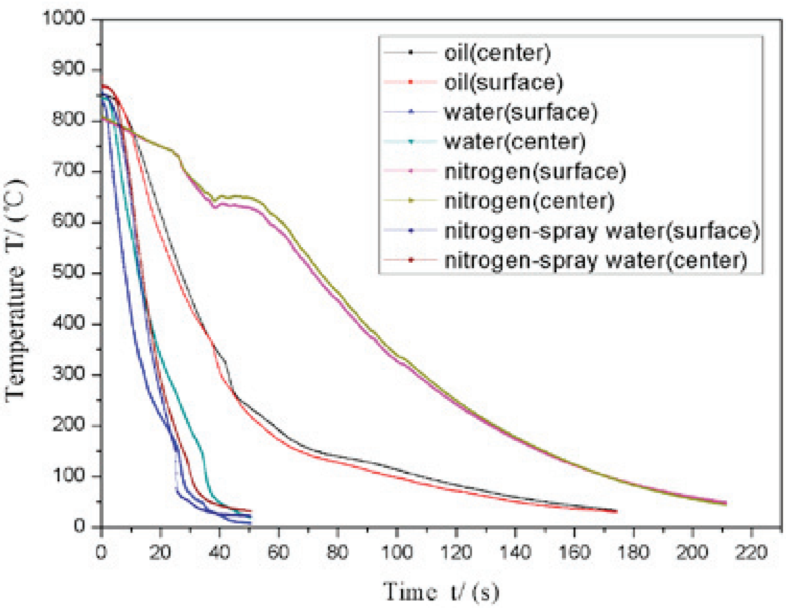

Fig. 2. Continuous cooling curves of GCr15 during different quenchant quenching.

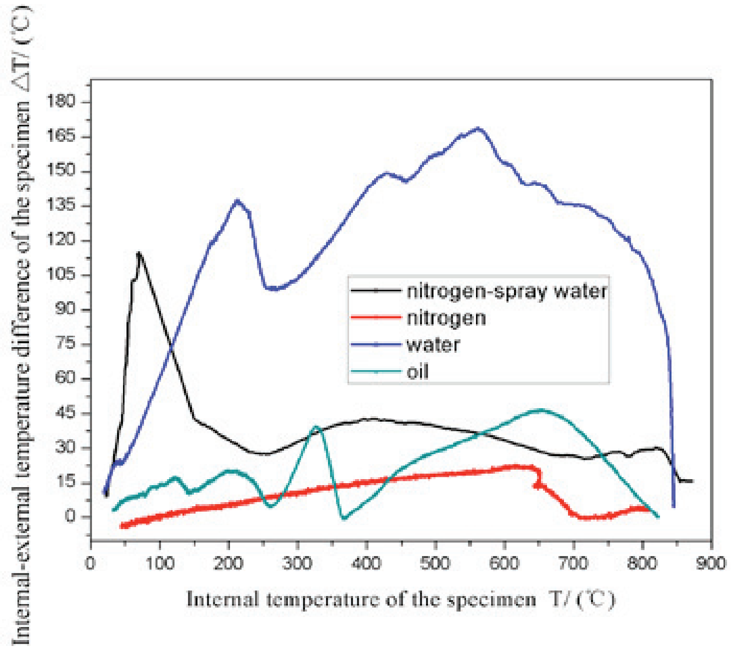

Fig. 3. Internal-external temperature difference of GCr15 during different quenchant quenching.

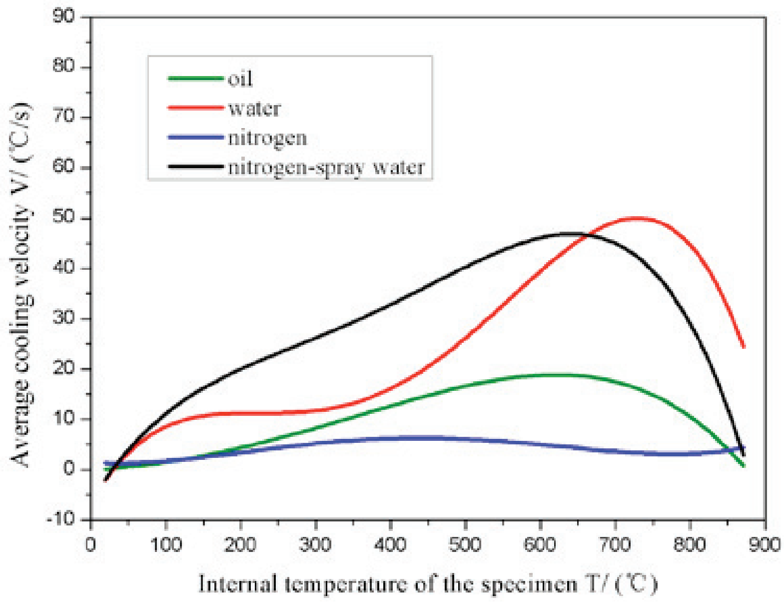

Fig. 4. Internal average cooling velocity of GCr15 during different quenchant quenching.

4. Conclusion

The different quenchant quenching of GCr15 steel is studied experimentally, and the results show that the different quenchant showing different cooling performance. The cooling velocity of the nitrogen-spray water is faster than the water, but the internal-external temperature difference of the specimen during nitrogen-spray water quenching is smaller than the water. Which means that the thermal stress and the thermal deformation of the specimen during nitrogen-spray water quenching is smaller than the water at same cooling velocity. The cooling velocity of nitrogen is slowest, and the internal-external temperature difference of the specimen during nitrogen quenching is smallest. Which means that the thermal stress and the thermal deformation of the specimen during nitrogen quenching are smallest.

Based on above conclusions, in order to increase the physical properties of the metallic material through quenching, the proper quenchant can be choosed.

Acknowledgements

This project has been supported by the Province Natural Science Foundation of Yunnan (2007A00152) and the Youth Natural Science Foundation of Kunming University of Science and Technology (2006-33).

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