A cryogenic treatment system for treating large rolls

Guo Jia, Chen Liubiao, Gu Kaixuan, Wang Junjie

Key Laboratory of Cryogenics, Technical Institute of Physics and Chemistry, CAS, Beijing 100190, China

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Introduction

- Cryogenic treatment refers to improve the microstructure and mechanical properties of materials by keeping the workpiece in a controlled low-temperature environment.
- Cryogenic treatment is a supplementary process of traditional heat treatment which has been acknowledged for many decades as an effective method for increasing wear life, dimensional stability and mechanical properties such as yield strength, hardness et al.
- The traditional cooling approaches for cryogenic treatment mainly include carbon dioxide cooling (the available lowest temperature is -70 ℃) and liquid nitrogen mixed with n-propanol cooling (the available lowest temperature is -90 ℃).
- In this paper, a cryogenic treatment system for treating large rolls has been designed, built and tested. A 453Mo roll with the size of Ø260 mm has been cryogenically treated in this developed system.

Description of the cryogenic treatment system

- It includes two deep-cryogenic furnaces, control system, hydraulic system and transmission system of liquid nitrogen.
- This system is cooled by liquid nitrogen; and the advanced technologies of temperature control and liquid nitrogen dispersion have been employed. Liquid nitrogen vaporizes first, and then the cold nitrogen is exchange heat with rolls under the action of rotation fan.
- In order to reduce the wastage of liquid nitrogen, a high vacuum transport tube has been employed.
- The two deep-cryogenic furnaces can be pre-cooled by each other and they can also work independently.
- The temperature of this system can be controlled from -180 ℃ to the room temperature with a temperature control accuracy of ±3 ℃. The temperature uniformity of the chamber is ±3 ℃ and the cooling rate is ±5 ℃/min.
- The maximum size of the rolls that can be treated in this system is Ø500 × 4300 mm and the maximum load capacity is 6000 kg.

System simulation and test

- The temperature uniformity is very important for the rolls, as they will be deformed or even cracked because of the stress caused by the uneven temperature distribution.
- The boundary conditions set as follows: the power of fan is 15 kW, the flow rate is 7200 m³/h, and the pressure is 1100 Pa. In order to make the model more practical, a roll with the size of Ø450 × 3000mm was added into the model; the total weight of this roll is about 3000 kg.

Effects of cryogenic treatment on roll

- A 9Cr1Mo roll with the size of Ø260mm has been cryogenically treated in this developed system. The roll was quenched at 900 ℃ first and tempered after a process of cryogenic treated at -120 ℃.
- The amount of residual austenite can be reduced after cryogenic treatment.
- The depth of hardened layer has been thicker and the hardness of the roll has been improved.
- The distribution of stress has been improved and the residual stress has been reduced.
- Cryogenic treatment is a supplementary process of conventional heat treatment to improve the microstructure and mechanical properties of metals. To cool down the rolls after quenching to below its MF point further, most of the residual austenite changed into martensite, thus the hardness and dimensional stability improved.

Conclusions

- A cryogenic treatment system for treating large rolls has been designed, built and tested. Liquid nitrogen has been employed to provide cooling capacities; and the temperature can be controlled from -180 ℃ to the room temperature with an accuracy of ±3 ℃ by the developed temperature controller.
- A 9Cr3Mo roll with the size of Ø260 mm has been cryogenically treated in this developed system. The test results showed that most of the residual austenite would be changed into martensite after cryogenic treatment, which contributed to the improved hardness and dimensional stability.

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