Comparison between Oil Quenching and Gas Quenching

Yasuhiro Nakadai[1]

[1]*Technical Solution Department, Industrial Merchant Division, AIR LQUIDE Japan G.K, Yokosuka 239-0847, Japan*

In the quenching process, oil is mainly used. At this time, we done the gas quenching after LPC to compare the results with oil quenching. We used nitrogen and hydrogen for gas quenching. As a result, when the quenching gas pressure was 0.8 MPa, the use of hydrogen, a gas with a high heat transfer coefficient, resulted in the same level of hardness and metallurgical structure as the oil quenching.

Keywords: *oil quenching, gas quenching, hydrogen*

1. Introduction

The quenching process, which hardens steel, is an important process in the manufacture of various parts.
As a coolant used for quenching, there is a method using a liquid such as water or oil, or a gas such as nitrogen. In Japan, oil is mainly used for quenching. This is because Japanese local regulations make it difficult to use gases above 1 MPa for quenching, and oil is best suited to meet the heat treatment characteristics of the product. However, with oil quenching, it is difficult to reduce production time, reduce CO2 emissions, and meet the demand for products with low distortion, which are issues in the heat treatment process. The use of gas quenching has the potential to solve these issues. In addition, by using hydrogen[1)], which has good cooling efficiency, it is possible to meet the heat treatment characteristics even with a gas of 1 MPa or less.
Therefore, in this paper, after low pressure carburizing, oil quenching, nitrogen gas quenching, and hydrogen gas quenching were performed, and the hardness and metallurgical structure after each quenching were compared.

2. Experiment

2.1 Furnace

Figure 1 shows a schematic diagram of the furnace used in the experiment. The furnace consists of a heating chamber, a gas quenching chamber, and an oil quenching chamber. After low pressure carburizing in the heating chamber, the furnace can be quenched with oil or gas.

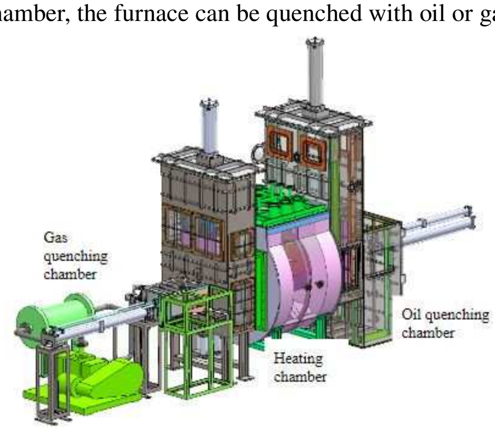

Figure 1 Furnace schematic

2.2 Samples

A round bar sample of 19 mm in diameter and 40 mm in length was used to compare heat treatment properties. The material used for the samples was SCr420H, which is typically used for carburizing in Japan. The chemical composition of the samples used is shown in Table 1.

Table1 Chemical compositions of selected steel (weight %)

Grade	C	Si	Mn	P	S
SCr420H	$21*10^{-2}$	$19*10^{-2}$	$67*10^{-2}$	$21*10^{-2}$	$22*10^{-2}$
Grade	Cu	Ni	Cr		
SCr420H	$12*10^{-2}$	$6*10^{-2}$	$96*10^{-2}$		

2.3 Experimental method

2.3.1 Heat treatment

The sample was charged into a heating chamber heated to 1203 K, the pressure was reduced to 50 Pa, 10 L of C2H2 was fed every 180 s for 3600 s, the sample was carburized for 1200 s in vacuum, the temperature was lowered to 1153 K, the sample was held for 1200 s, the oil temperature was kept at 393 K for 600 s for oil quenching, and the pressure in the gas quenching chamber was increased to 0.8 MPa for gas quenching. After the thermometer installed in the gas quenching chamber was below 328 K, the sample was removed after holding for 600 s. Tempering was performed at 453 K for 3600 s.

Figure 2 shows a thermal cycle diagram.

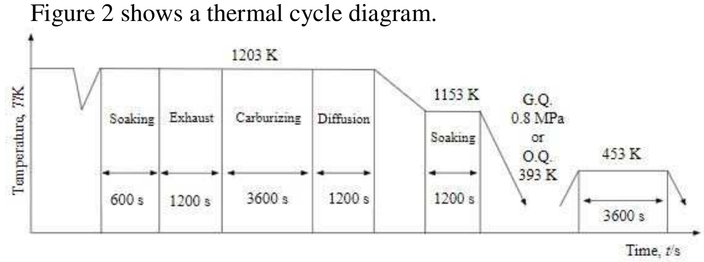

Figure 2 Thermal cycle diagram

2.3.2 Heat treatment characteristics inspection

The center of the treated sample was cut, embedded in thermosetting resin, and mirror-polished. The hardness distribution was measured using a Micro Vickers Hardness Tester (Model: HR-400) manufactured by Mitsutoyo, and the microstructure of the etching sample using Nital 5% was performed using an inverted microscope (Model: ECLIPSE MA 100N) manufactured by Nikon.

3. Results

3.1 Hardness profile

Figure 2 shows the results of hardness profile measured using a micro-Vickers hardness tester. The load was measured at 300 gf.

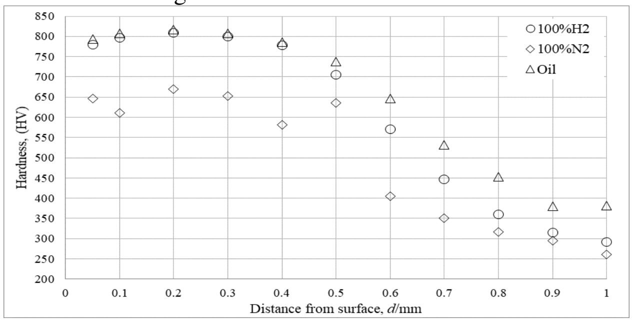

Figure 2 Cross-sectional hardness profile after carburizing.

The effective case depths (HV 550) were 68*10-2 mm for oil quenching, 54*10-2 mm for nitrogen gas quenching, and 62*10-2 mm for hydrogen gas quenching.

3.2 Metallurgical microstructure

Figure 3 shows the metallographic structure of each samples.

The microstructure of oil quenching is martensite and retained austenite, hydrogen gas quenching is martensite, retained austenite, and some bainite, and nitrogen gas quenching is martensite, retained austenite, and bainite.

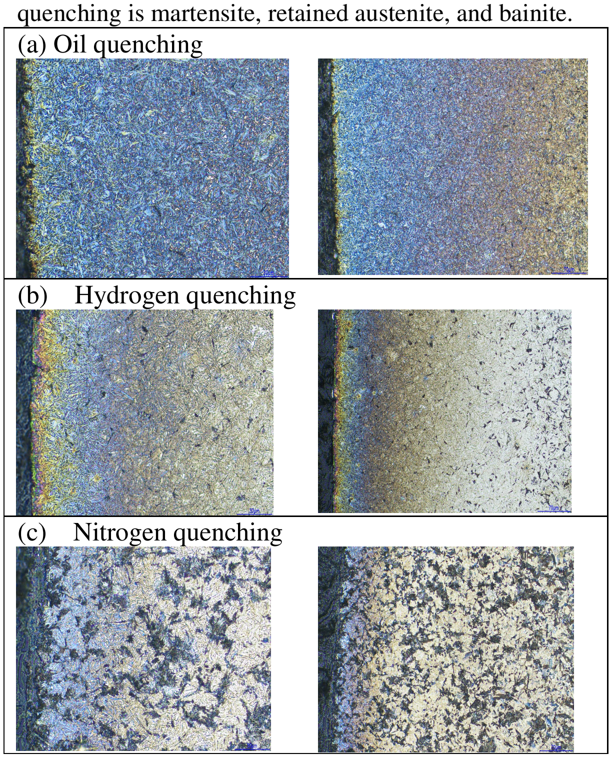

Figure 3 Cross-section microstructure after quenching.

4. Discussion

The hardness and microstructure results mentioned above may suggest that the nitrogen gas quenching results in a decrease in hardness due to the slow cooling rate and the presence of more residual austenite near the surface. Since oil quenching and hydrogen gas quenching do not show the same hardness reduction near the surface as nitrogen gas quenching, and martensitic microstructure is obtained, hydrogen gas quenching has the potential to be used as a quenching method in place of oil quenching.

In order to establish the conditions for hydrogen gas quenching in the future, it will be necessary to increase the number of samples and examine the difference in heat treatment characteristics depending on the location and whether quenching of large, heavy samples is possible.

5. Conclusion

The test results show that quenching at a pressure of 1 MPa or less is possible at the same level as oil quenching by using hydrogen gas, which has good cooling efficiency.

6. Reference

1) Robert Hill Jr.: HEAT TREATING PROGRESS **6** (2006) 30-32