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Effect of heat treatment process in SA508 Gr.3 for a Small Modular Reactor application

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1. Introduction

The small modular reactors (SMRs) are being developed worldwide in order to increase the safety and usability of nuclear power plants, and innovative SMRs are being developed in Korea with the goal of operating in 2033. SMR has the advantage that actual nuclear power plant components can be manufactured in a factory in module units and transported to the site for installation. It is necessary to reduce the weight of components through the application of high-strength materials in order to facilitate the transportation of the reactor pressure vessel. Currently, SA508 Gr.3 Cl.1 low-alloy steel is used for the reactor pressure vessel, but the application of SA508 Gr.3 Cl.2 low-alloy steel having higher strength is being considered. According to ASTM Code [1], minimum tempering temperature of SA508 Gr.3 Cl.1 and Cl.2 is different.

In this study, SA508 Gr.3 Cl.2 heat treatment process was applied to the RPV material, which is SA508 Gr.3 Cl.1, and the effect on strength and toughness of the material was evaluated.

2. Methods and Results

2.1 Materials and heat treatment

In this study, heat treatment was carried out using SA508 Gr.3 steel to improve the mechanical properties of material. The small blocks with size of 130mm (L) ×190mm (W) ×35mm (T) were taken from the archive materials of RPV. Tempering was performed at the different temperature of 660 °C and 630 °C for 7 h. For convenience, these samples are referred to as A (660 °C) and B (630 °C)

2.2 Microstructure

The L-T surfaces were mechanically polished and etched with a 3% nital solution. The microstructure were investigated by an optical microscope (OM, Eclipse-MA200, Nilon, Japan). Several SEM images were selected to analyze the precipitates. Then that size of the precipitates were quantified using an image analyzer. The images are shown in Figure 1. The microstructure of A and B is tempered upper bainite. Size of precipitates of B is slightly smaller than that of A owing to the lower tempering temperature as shown in Figure 2.

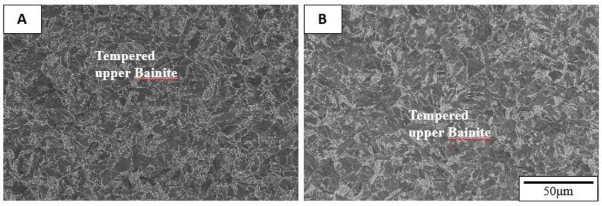

Fig. 1. SEM images of SA508 Gr.3 steel performed different tempering temperature

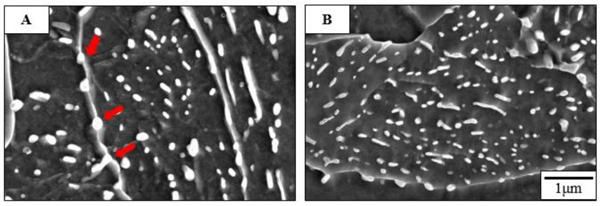

Fig. 2. The precipitates images of SA508 Gr.3 steel .

2.3 Mechanical testing

Tensile tests were performed using rod-type tensile specimens (gauge length 25 mm, diameter 6.25 mm) prepared in the longitudinal direction according to ASTM E8M[2]. The tensile tests were conducted at room temperature at a strain rate of 5.2×10^{-4}/s using a MTS universal testing machine (MTS 810.24 MTS Systems Corporation, USA). The tensile properties (yield strength, tensile strength, and total elongation) were determined from the each stress-strain curves. The yield strength was determined by the 0.2% offset method. Tensile properties were summarized in table 1. The yield strength and tensile strength increased as the tempering temperature decreased.

Table 1. Tensile test results of SA508 Gr.3

RT			
	YS (MPa)	TS (MPa)	T.El (%)
A	470	588	30.6
B	499	618	26.8

Charpy impact test was performed using a standard specimens (10 mm × 10 mm × 55 mm, transverse-longitudinal (T-L) orientation). The test conducted using a DTI-603A testing machine with a capacity of 500 J in the temperature range from -120 °C to 100 °C, according to ASTM E23 [3]. Hyperbolic tangent curve fitting was done for the absorbed impact energy data to obtain the characteristic temperatures [4]. The Ductile-Brittle Transition Temperature (DBTT) of B was better than that of A. It is because B had smaller precipitates than A.

Pre-cracked Charpy V-notch (PCVN) test was performed using a standard specimen (10 mm × 10 mm × 55 mm, transverse-longitudinal (T-L) orientation) according to E1921 standard test method [5] to evaluate fracture toughness in the transition region. The reference temperature (T_0) of B is -32°C lower than that of A.

3. Conclusions

In this study, effects of tempering temperature on mechanical properties of SA508 Gr.3 steels were analyzed. Both specimens are composed of tempered upper bainite. As the tempering temperature decreased, the formation of large precipitates are reduced. Thus, yield strength increased and DBTT decreased. This is because size of precipitates decreased as tempering temperature decreased.

REFERENCES

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