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Improvement in Mechanical Properties of SA508 Gr.1a Piping Material by Modifying Microstructure

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1. Introduction

Applying LBB (Leak-Before-Break) concept to the design of nuclear piping system provides a lot of benefits, because an assumption of large guillotine break can be eliminate from the design of components and structures of nuclear power plant (NPP)[1]. Thus, recently, it is attempted to apply LBB concept to the design of secondary piping systems, such as main-steam line and feed-water line. But, for obtaining sufficient margin in LBB analysis for these piping systems, it is necessary to reduce the applied loads by improving structural design and to employ piping material with higher toughness and strength than existing piping materials such as SA106 Gr.C and SA106 Gr.B carbon steels. SA508 Gr.1a ferritic steel has been used for the reactor coolant system (RCS) piping in KSNP (Korea Nuclear Power Plant) and is known to have good toughness and strength as well as weld ability [2]. Such characteristics provide a sufficient margin in the LBB analysis for RCS piping. Based on SA508 Gr.1a piping material, thus, this study attempts to obtain a further improved piping material by modifying microstructure of SA508 Gr.1a without change of chemical composition.

2. Experiment

2.1 Material and Specimens

This study attempts to obtain a piping material whose mechanical properties are improved by modifying microstructure of SA508 Gr.1a ferritic piping material. SA508 Gr.1a ferritic piping material used in experiment is an archive material of RCS piping with a diameter of 1075.4mm and a thickness of 102.6mm. The chemical composition of SA508 Gr.1a piping material is listed in Table 1. SA508 Gr.1a piping was manufactured by forging and was heat-treated; normalized at 920^{o}C for 10min. followed by water quenching and tempered at 650^{o}C for 170min. As shown in Fig. 1(a), as-received SA508 Gr.1a piping material has typical ferrite and pearlite microstructures.

Table 1 Chemical composition of SA508 Gr.1a (CMTR)

C	Mn	P	S	Si	Ni
0.223	1.27	0.009	0.0047	0.225	0.242
Cr	Mo	V	Al	Cu	
0.118	0.026	0.003	0.024	0.200	

Tensile and J-R fracture toughness tests were conducted on as-received and modified SA508 Gr.1a piping materials. Round-bar specimens with a diameter of 5mm and a gage length of 25mm were used in tensile test. 1T-CT specimens with a thickness of 25.4mm were used for J-R test. The specimens for J-R test were 20% side-grooved. Tensile specimens were machined from the pipe in longitudinal direction, and 1T-CT specimens were machined in L-C direction.

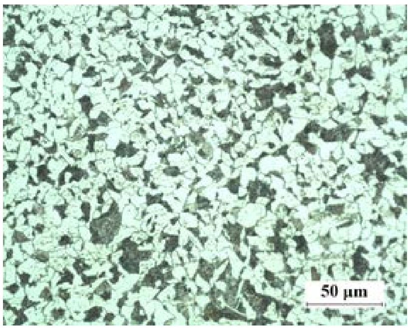
2.2 Experimental Procedure

In this study, heat-treatment for modifying microstructure of SA508 Gr.1a piping material was performed at air environment using box furnace. Microstructures were examined using optical microscope (OM). The specimens for OM examination were etched using 3% nital etchant. To evaluate mechanical properties of modified SA508 Gr.1a piping material, tensile and J-R tests were conducted at RT and 316^{o}C. Motor-driven universal testing machine with a load-cell of 50kN capacity and servo-hydrolic dynamic testing machine with a load-cell of 100kN capacity were used in tensile and J-R tests, respectively. Strain of specimen in tensile test and load-line displacement in J-R test were measured by using high-temperature extensometer and COD guage, respectively.

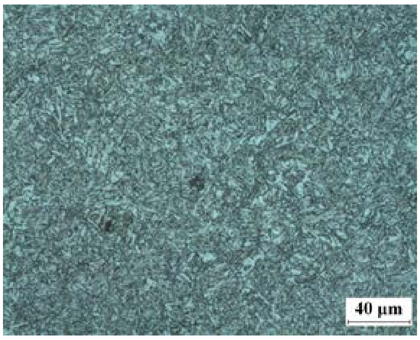
3. Result and Conclutions

3.1 Modifying Microstructure

As shown in Fig. 1(a), as-received SA508 Gr.1a piping material has a typical ferrite-pearlite microstructure, even though it was normalized and water-quenched. In order to obtain a modified microstructure, thus, this study simply heat-treated again SA508 Gr.1a piping material at the same heat-treatment condition that had been employed in the fabrication of SA508 Gr.1a piping material. Fig. 1(b) shows the microstructures of SA508 Gr.1a modified by heat-treatment. The microstructure is composed of the homogeneous mixture of fine-grained ferrite and bainite. This is different from that of as-received SA508 Gr.1a. This difference is associated with different size of object to be heat-treated. This shows that SA508 Gr.1a piping material has a microstructure with fine-grained ferrite and bainite mixture, which provides good toughness and strength [2], if it is properly heat-treated.



(a) SA508 Gr.1a

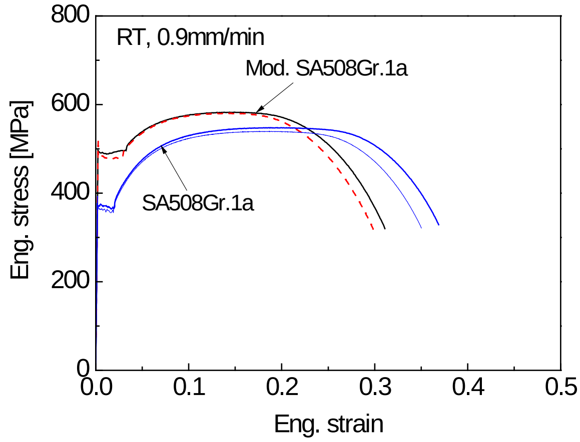


(b) Modified SA508 Gr.1a

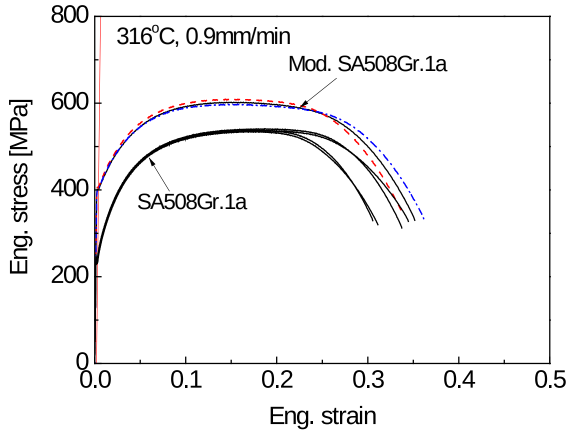
Fig. 1 Microstructures of as-received SA508 Gr.1a and modified SA508 Gr.1a pipe materials.

3.2 Mechanical Properties

Tensile and J-R tests were conducted using specimens machined form modified SA508 Gr.1a piping material given by heat-treated, and the results were compared with those tested from as-received SA508 Gr.1a piping material. Fig. 2 presents the engineering stress-strain curves tested at RT and 316°C. At RT modified SA508 Gr.1a shows higher strength and lower elongation compared to as-received SA508 Gra.1a. At 316°C, however, both strength and elongation of modified SA508 Gr.1a are higher than those of as-received SA508 Gra.1a. The results of J-R tests showed that J-R curve of modified SA508 Gr.1a is almost the same as that of as-received SA508 Gr.1a at RT. But, at 316°C J-R curve of modified SA508 Gr.1a is much higher than that of as-received SA508 Gr.1a piping material. This indicates that the mechanical properties of SA508 Gr.1a piping material at operating temperature of NPP are much improved by modifying microstructure that is simple achieved by heat-treatment.



(a) RT



(b) 316°C

Fig. 2 Engineering stress-strain curves of as-received SA508 Gr.1a and modified SA508 Gr.1a piping materials.

AKNOWLOGEMENT

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REFERENCES

[1] USNRC, "Evaluation of Potential for Pipe Breaks," NUREG-1061, Vol.3, 1984.

[2] B.S. Lee, et.al, 2000, "J-R fracture properties of SA508-1a ferritic steels and SA312-TP347 austenitic steels for pressurized water reactor's(PWR) primary coolant piping," Nucl. Eng.& Design, Vol. 199, pp.113-123.