J-R Fracture Resistance of SA533 Gr.B-Cl.1 Steel for Reactor Pressure Vessel

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1. Introduction

The reactor pressure vessel (RPV) is a key component in most nuclear power plants (NPPs) and since it is usually considered to be impossible to replace, its operating life can therefore determine the lifetime of the NPPs [1]. The PRVs in Westinghouse type NPPs in Korea (Kori unit 2, 3, 4 & Hanbit unit 1, 2 were made from SA533 Gr.B-Cl.1 hot rolled plate. A rolled plate might show different mechanical behaviors from a forging, even though they contain same chemical compositions. Furthermore, it is known that the fracture behavior of a rolled plate is very sensitive to material orientation comparing to a forging [2].

In this study, the J-R fracture resistances of SA533 Gr.B-Cl.1 plate were measured at reactor operating temperature and the material orientation sensitivity was discussed.

2. Experimental

2.1 Material and Specimen

SA533 Gr.B-Cl.1 test block with dimension 150 mm x 150 mm x 225 mm manufactured by Kawasaki Steel Co. After rolling, the plate was heat treated normalizing at 900°C, quenching from 800°C and tempering at 665°C for 12 hours, then stress relieving at 620°C for 40 hours. The chemistry of the material is listed in Table 1.

Table 1. Chemistry of SA533 Gr.B-Cl.1 test block.

	C	Si	Mn	P	S	Cr	Ni	Mo	Cu
wt%	0.18	0.25	1.39	0.017	0.003	0.12	0.83	0.51	0.14

The compact tension type specimens with thickness of 1 inch (1T-C(T)) were used for J-R fracture resistance. The specimens were oriented such that T-L or L-T orientation. The specimens were precracked by fatigue and side grooved by 10% on each side before the testing.

2.2 J-R Fracture Resistance Testing

The J-R curves were determined by using the single specimen unloading compliance technique. The tests were conducted at a reactor operating temperature (288°C) and room temperature using a servo-hydraulic test machine in general accordance with ASTM Standard E1820-13. The specimen temperature was controlled within ±1°C by using PID controller.
Fig. 1 shows the test system for J-R fracture resistance testing at an elevated temperature.

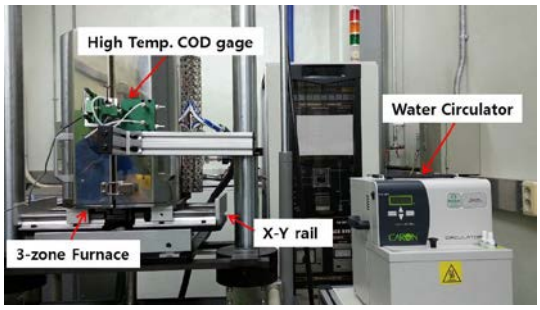

Fig. 1. Elevated temperature J-R fracture resistance testing system.

3. Results & Discussion

3.1 Effect of Temperature on J-R Fracture Resistance

J-R curves of the specimens with T-L orientation at reactor operating temperature (288°C) and room temperature are presented in Fig. 1. The fracture resistance of SA533 Gr.B-Cl.1 steel was lowered by about 25% at 288°C comparing to that at room temperature as shown in Fig. 2.

The decrease of fracture resistance of this kind of low alloy steel at an elevated temperature is known as the effect of dynamic strain aging (DSA) [3].

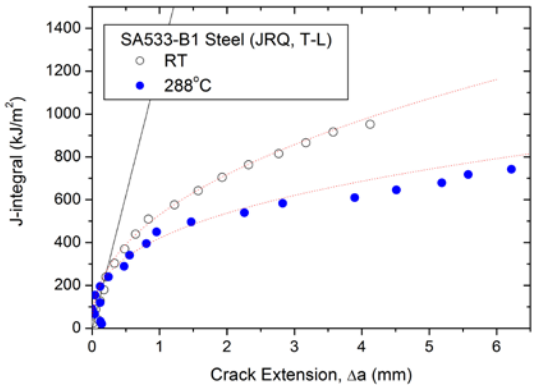

Fig. 2. J-R curves of the specimens with T-L orientation at reactor operating temperature (288°C) and room temperature.

3.2 Effect of Material Orientation

A comparison of J-R curves for specimens with T-L orientation and L-T orientation is shown in Fig. 3 for reactor operating temperature (288°C) and in Fig. 4 for room temperature. The fracture resistance of a specimen with T-L orientation was lower than that with L-T orientation by about 25% at 288°C. It was attributed to that the carbides and grains elongated to primary rolling direction, so that the aspect ratio of carbides and grains in the specimen with T-L orientation is larger.

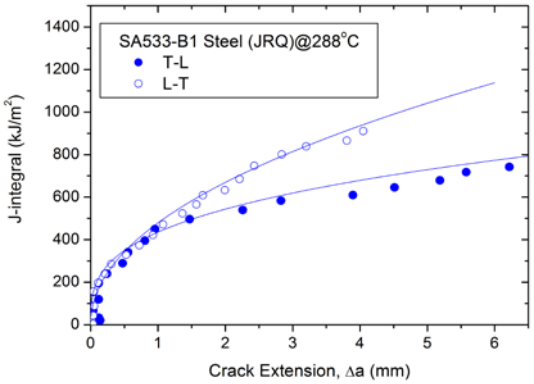

Fig. 3. A comparison of J-R curves for specimens with T-L orientation and L-T orientation taken from SA533 Gr.B-Cl.1 plate, obtained at 288°C.

3.3 Microstructural Inhomogeneity

It has been believed that the fracture toughness of specimen with L-T orientation was higher than that with T-L direction. However, a specimen with L-T orientation showed unstable crack propagation at room temperature after ~0.6 mm crack extension as shown in Fig. 4.

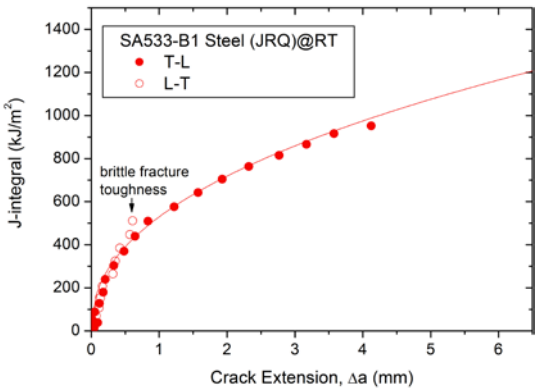

Fig. 4. A comparison of J-R curves for specimens with T-L orientation and L-T orientation taken from SA533 Gr.B-Cl.1 plate, obtained at room temperature.

It might be due to the microstructural inhomogeneity in SA533 Gr.B-Cl.1 steel. Generally, the hard second phase could take a roll of trigger point of unstable fracture. It is needed that the fracture surfaces of the tested specimens to be examined profoundly.

REFERENCES

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