Fatigue Crack Growth Rate Behavior of Type 347 Stainless Steel in Simulated PWR Water Environment

Ki-Deuk Min [a*], Dae-Whan Kim [b], Bong-Sang Lee [b], Seon-Jin Kim [a]
[a]*Department of Materials Science and Engineering, Hanyang University, Seoul 133-791, Korea*
[b]*Korea Atomic Energy Research Institute, 989-111, Daedeock-daero, Yuseong-Gu, Daejeon 305-353, Korea*
[*]*Corresponding author: kdmin@hanyang.ac.kr*

1. Introduction

The pressurizer surge line of a Korean standard nuclear power plane uses Nb stabilized type 347 stainless steel. The pressurizer surge line is the pipe connecting the pressurizer and the hot leg line, and the path controlling the pressure and temperature of the cooling system of the nuclear reactor, operated at 316℃ and in a 150atm. The pressurizer surge line operated at high temperature and high pressure receives thermal stress by a temperature change and mechanical stress by a pressure change at the same time, and by being exposed to the high temperature and high pressure cooling water environment of a nuclear power plant, environmental fatigue by stress and corrosion is the main damage instrument[1]. As the effect of environmental fatigue has been reported, through low-cycle fatigue, fatigue life evaluations of austenite stainless steel have been conducted, but evaluations of fatigue crack growth rate to evaluate the soundness are very poor. In this study, evaluated characteristics of fatigue crack growth rate base on a change of dissolved oxygen in a PWR environment.

2. Experimental

The materials used in the fatigue crack growth rate experiment were type 347 stainless steel commensurate with the materials of the pressurizer surge line. Details of the composition of the materials are shown in table 1. The specimen used in the fatigue crack growth rate experiment was a CT type specimen 25.4mm in width and 5mm thick. The experimental environment is shown in table 2. AS shown in table 2, the water chemistry environment had change to 5ppb and 100ppb and temperature was evaluated at room temperature and 316℃ of which is the operating temperature. A fatigue crack growth rate evaluation was conducted by ASTM E647[2]. Since it is hard to directly measure the crack length in a water chemistry environment, a direct current potential drop system was used as an indirect method.

Table 1. 347SS Chemical composition (wt%)

	C	Nb	Cr	Ni
	0.043	0.52	17.08	9.11
ASME Spec.	0.08max	Cx10min 1.0 max	17.0-20.0	9.0-13.0

Table 2. Test conditions

Dissolved Oxygen	5ppb, 100ppb
Dissolved Hydrogen	27cc/kg, 30cc.kg
Temperature	25℃, 316℃
Lode ratio	0.1
Frequency	10Hz

3. Results and Discussion

The mechanical characteristics of type 347 stainless steel are organized in table 3. The mechanical characteristics at 316℃ were decreased compared with those at room temperature, and reduction in elongation was shown with a decreased by DSA.

Table 3. 347SS Mechanical properties

TESTING TEMP. (°C)	YIELD STRENGTH (MPa)	TENSILE STRENGTH (MPa)	UNIFORM ELONG. (%)	TOTAL ELONG. (%)
25	242.52	657.94	62.177	73.370
316	156.2	419.68	21.50	35.0

The fatigue crack growth rate curve by each amount of dissolved oxygen in a PWR environment is shown in Fig 1. The fatigue crack growth rates of dissolved oxygen at room temperature and at 316℃ appeared to be similar. However, 100ppb of dissolved oxygen, was similar to 5ppb at room temperature but at 316℃ showed a decrease in fatigue crack growth rate. Therefore, at 316℃, when the amount of dissolved oxygen increases, the fatigue crack growth rate decreases, which shows that a change of dissolved oxygen has a big effect on the fatigue crack growth rate. Fig. 2 is shows an SEM image of the fracture surface. When viewing the surface, no oxide was observed at room temperature, but each differential sized oxide was observed based on the amount of dissolved oxygen at high temperature. In the case of 5ppb of dissolved oxygen, about 0.1㎛ of oxide was observed while for 100ppb about 1㎛ was observed. In this way, in accordance with the creation of oxide at high temperature, the decreased in the fatigue crack growth rate in 100ppb seems due to the effect of crack closure from the oxide.

Fig. 3 shows the thickness of the oxide film by when observing the fracture surface. The thickness of the oxide film appeared increasing when the amount dissolved oxygen increased. The effect of crack closure is to increase the crack closure stress intensity K_{cl} and decrease effective stress intensity range, thereby resulting in slower crack propagation rates[3].

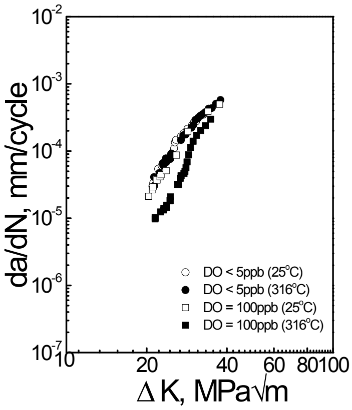

Fig. 1 Fatigue crack growth rate in PWR simulated water

4. Conclusions

1) The fatigue crack growth rate in 5ppb of dissolved oxygen appeared to be identical in room temperature and high temperatures.

2) In 100ppb dissolved oxygen at 316℃, fatigue crack grow rate appeared to decrease.

3) Oxides were generated at the surface of each dissolved oxygen at 316℃ and the size of oxide increased base on the amount of dissolved oxygen.

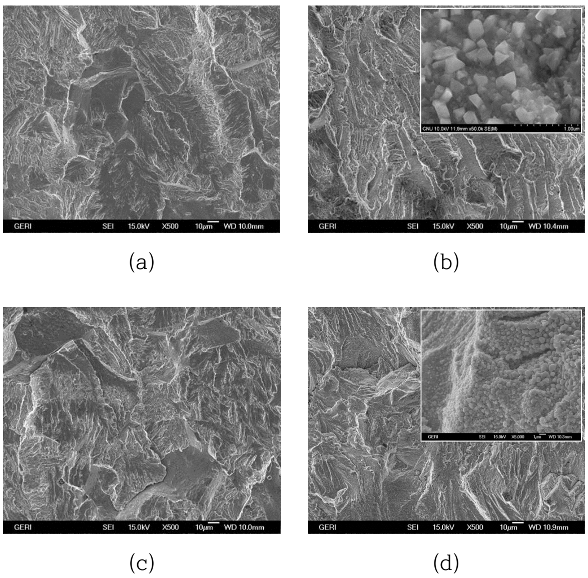

Fig. 2 Fracture surface tested at

(a)DO < 5ppb, 25℃, (b)DO < 5pp, 316℃,

(c)DO=100ppb, 25℃, (d)DO=100ppb, 316℃

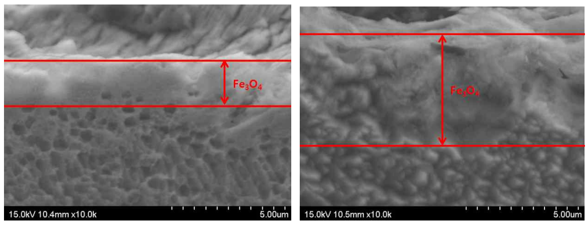

Fig. 3 The cross section of oxide layers in different dissolved oxygen

(a) DO < 5ppb, 316℃, (b) DO=100ppb, 316℃

REFERENCES

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[3] Newman and Elber, Mechanics of fatigue crack closure(1988)