Fatigue Crack Growth Rate of Type 347 Stainless Steel at the PWR Environment

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1. Introduction

Materials used in nuclear power plants are low alloy steel, stainless steel, and superalloy steel. Understanding the characteristics of these materials is important in the develop ment of nuclear power plant related technology.

Nb-stabilized Type 347 stainless steel is used for the coolant pressurizer surge line of Korea Standard Nuclear Power Plant (KSNPP). Surge line of PWR nuclear reactor are damaged by thermal fatigue due to thermal gradient during heat-up and cool-down, mechanical fatigue due to mechanical stress, and corrosion fatigue due to nuclear reactor water environment. Fatigue is an important factor which limits the life of structure. Fatigue crack growth rate curves in nuclear reactor environment are needed to evaluate the integrity of nuclear reactor structure but that result is not sufficient.

In this study, fatigue crack growth rates at nuclear reactor environment are produced to evaluate integrity of nuclear power plant.

2. Experimental

The material used in an experiment is Type 347 commercial stainless steel. Its chemical composition is in Table 1. The specimen geometry is the thickness 5mm and width 25.4mm CT type specimen. The test environment 150atm, 316℃, dissolved hydrogen(DH) 30cc/Kg, dissolved oxygen(DO) 5ppb, PH 5~7 and load ratio was 0.1, frequency was 10Hz. Fatigue crack growth rate tests were conducted under load control. The crack length was measured by Direct Current Potential Drop method.

Table 1. chemical composition of the steel (wt%)

	C	Nb	Cr	Ni
	0.044	0.36	17.17	9.22
ASME	0.08max	Cx10min 1.0 max	17.0- 20.0	9.0-13.0

3. Results and Discussion

3.1 Microstructure

Microstructure before test was shown in Fig. 1. Grain size was 34μm. Small precipitates were observed in the matrix from SEM. They were identified as NbC of NaCl structure (space group: F4/mb32/m).

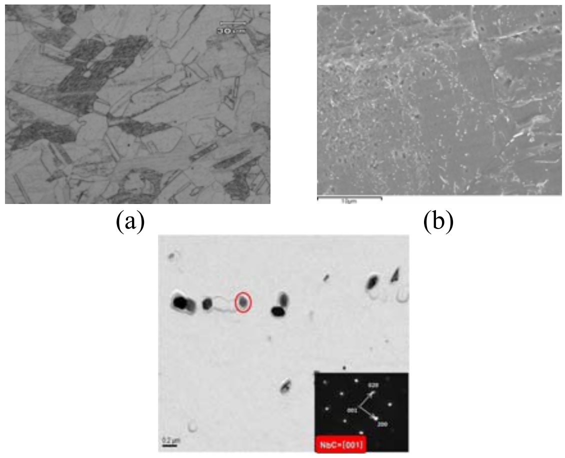

Fig. 1 Microstructure of Type 347 stainless steel :
(a) Optical (b) SEM (c) TEM

3.2 Tensile Properties

Tensile properties of Type 347 stainless steel were shown in Fig. 2. Stress-strain curve is shown in Fig. 3. Yield strength, tensile strength and elongation ratio decreased with temperature. Serration was observed at 316℃ but not observed at 167℃. In the Type 316 stainless steel, the temperature range of serration was 250℃~700℃[1]. Serration temperature for Type 347 stainless steel was consistant with that of Type 316 stainless steel.

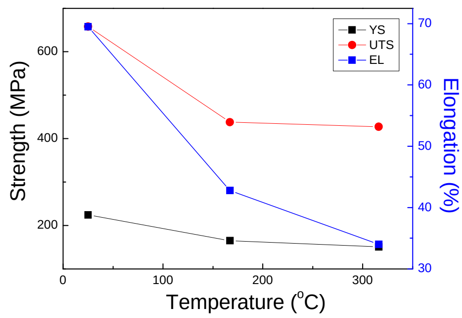

Fig.2 Tensile properties of Type 347 stainless steel

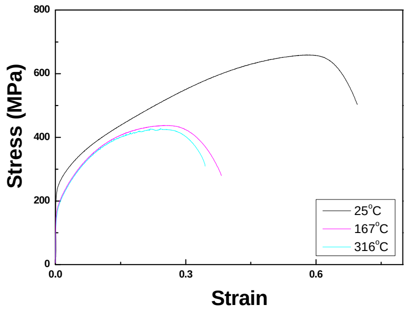

Fig. 3 Stress-Strain curves of Type 347 stainless steel

3.3 Fatigue Crack Growth Rate

Crack length is shown with cycles in Fig. 4. Crack lengths at the same cycles were larger in PWR environments than in air. Fatigue crack growth rates are shown in Fig. 5 for PWR environments. Fatigue crack growth rate in PWR environments was almost the same as fatigue crack growth rates in air. Fatigue crack growth rates increased when DO decreased. Low cycle fatigue life decreased when DO decreased[2,3]. This result is consistent with the results of fatigue crack growth rates of this study. Fatigue crack growth rates with temperature in PWR environments are shown in Fig. 6. Fatigue crack growth rates were not changed with temperature.

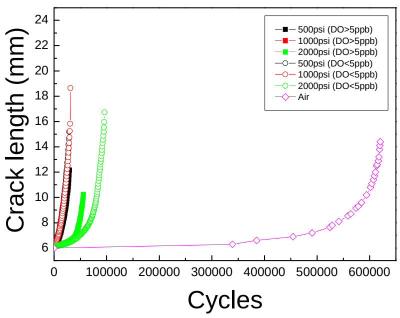

Fig. 4 Crack length with cycles at PWR environment and air condition

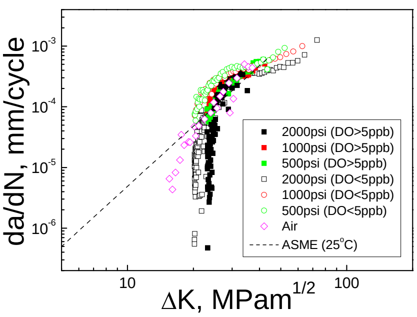

Fig.5 Fatigue crack growth rate at PWR environment and air condition

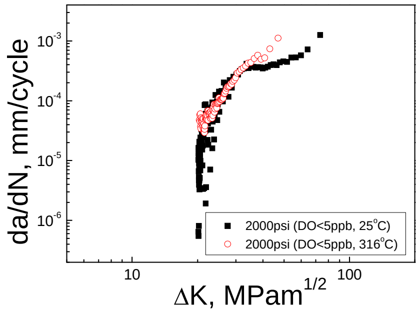

Fig. 6 Fatigue crack growth rate with temperature at PWR environment

4. Summary

The tensile strength, YS, and elongation ratio decreased as temperature increases. Serration was observed at 316℃. Crack length at same cycle was larger in PWR environment than in air. Fatigue crack growth rate increased when DO decreased. Fatigue crack growth rate was not changed with temperature.

REFERENCES

[1] S. L. Mannan, K. G. Samuel, P. Rodriguez, Trans. Ind. Inst. Metals, Vol. 36, pp313, 1983
[2] O. K. Chopra, NUREG/CR-5702, ANL-98/31, 1999.
[3] M. Higuchi, K. Tsutaumi, A. Hirano, and K. Sakaguchi, J. Pressure Vessel Technology, 125 (2003) 403.