Effect of Strain Rate 0.04 to 0.004%/sec on Environmental Fatigue of CF8M stainless steel

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1. Introduction

The fatigue life reduces remarkably with reduction in strain rate in pressurized water reactor (PWR) water[1-4]. To estimate the effect of strain rate on fatigue life of cast stainless steel CF8M in the environment of PWR, low-cycle fatigue test have been conducted by Korea Electric Power Research Institute (KEPRI).

2. Test Methods and Results

2.1 Test Rig and Specimen

The test rig was locally fabricated, and is shown in Figures 1 and 2. The rig simulates PWR operating conditions by controlling dissolved oxygen, pH, and conductivity with a high pressure and high temperature water loop. Design parameters of the test rig and loop are as follows:

- Maximum temperature: 350 ^{o}C
- Maximum pressure: 17 MPa
- Dissolved oxygen: < 5 ppb
- Conductivity: < 30 μS/cm
- Autoclave: 6 liters, electrical heating
- Load Frame assembly: 50 kN
- Servo electric actuator: 50 kN, 30 mm stroke

Figure 3 depicts the features of the cylindrical solid fatigue specimens used inside the autoclave. Test specimen blocks were manufactured conservatively with a ferrite content of 25 wt.% based on a review of CMTR (certified material test report) for a domestic power plant. Test specimens were fabricated according to ASTM E 606-92[5]. Table 1 tabulates the chemical composition of the material.

Fig. 1. Low cycle fatigue test rig

Fig. 2. Test Loop

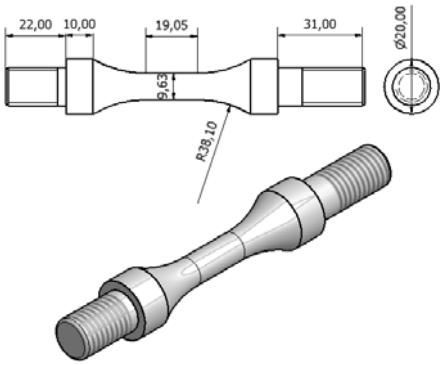

Fig. 3. Cylindrical solid fatigue test specimen

Table. 1. Chemical composition of cast stainless steel CF8M

C	Mn	Si	Cr	Ni	Mo	S	P
0.04	0.79	1.35	19.0	9.3	2.4	0.013	0.02

2.2 Test Conditions and Procedures

Low cycle environmental fatigue test conditions defined in terms of strain rate, strain amplitude, load ratio (R), temperature, pressure and dissolved oxygen are shown in Table 2. Fatigue loading by a strain controlled method was imposed. Fatigue life was determined based on the number of cycles where the first 25% fatigue tension load was reduced[6].

Table. 2. Test Conditions

Load Ratio (R)	-1 (tensile/compress)
Strain Rate	0.004%/s
Strain Amplitude (ε_a)	0.4%, 0.6%, 0.8%

Temperature	315℃
Pressure	15MPa
DO (dissolved oxygen)	< 5ppb

2.3 Result and Discussions

The result of low cycle fatigue test of CF8M stainless steel under the environment of PWR water is shown in table 3. The result of this test shows the decrease in fatigue life as the strain amplitude increases with strain rate unchanged. To evaluate the effect on fatigue life respect to strain rate, this result was compared to the previous research test result, with 0.04%/sec of strain rate, of CF8M SS under the same condition. Just as it is shown in figure 4, as the strain rate decreases with unchanged strain amplitude the fatigue life decreases. The decrease in fatigue life due to the change of strain rate became more excessive with higher strain amplitudes. Figure 5 shows the relationship of fatigue life with strain rate.

Table. 3. Result of low cycle fatigue test in PWR water

	Strain amplitude (%)		
	$\varepsilon_a = 0.4$	$\varepsilon_a = 0.6$	$\varepsilon_a = 0.8$
Strain rate (%/s)	0.004	0.004	0.004
Frequency(Hz)	0.0025	0.00167	0.00125
Fatigue life(cycles)	2786 2434	2194	153

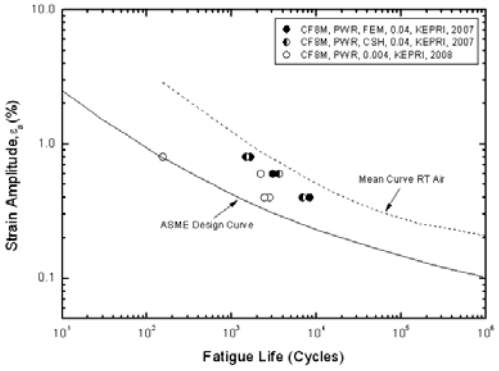

Fig. 4. Relationship of strain amplitude to fatigue life for CF8M in PWR water

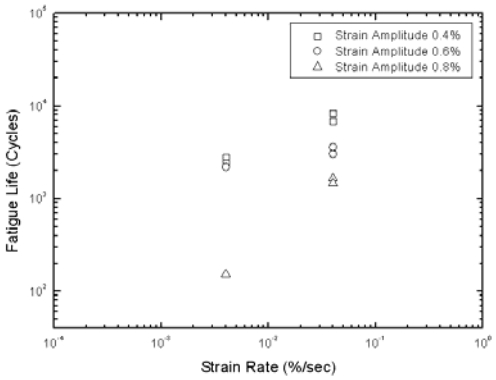

Fig. 5. Relationship of fatigue life to strain rate for CF8M in PWR water

3. Conclusions

This research provides the data of low cycle fatigue life for CF8M SS under the environment of PWR water. In addition, the effect on fatigue life due to the change of strain rate was evaluated by comparing with previous research results. As it is known, this research has confirmed that the fatigue life of CF8M SS decreases as the strain rate decreases. While there are a lot of data on low cycle fatigue life respect to strain rate for carbon steel, low alloy steel, stainless steel, there are almost none for CF8M SS. With additional data under various conditions, the results of this research will be applied in researches developing the curve line of environmental fatigue life evaluation.

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