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Environmental Effect on the Characteristics of the Low Cycle Fatigue of SA508 Gr.1a Low Alloy Steel

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1. Introduction

For the class 1 components of nuclear power plants, fatigue failure has been considered as one of the most important degradation mechanisms. The researches concerned with the fatigue life test under the high-temperature and water chemistry condition mainly have been performed in the United States and Japan and were in the process in some of European and domestic research centers recently. O.K. Chopra, M. Higuchi, I. S. Jeong, C. H. Jang, and H. C. Cho et al. is have produced the results of fatigue life test at home and abroad.

The fatigue curve test results for carbon steel, low alloy steel, and austenitic stainless steel by O.K. Chopra have presented the model to predict the fatigue life [1,2]. M. Higuchi suggested that the fatigue life correction factors for carbon steel, low alloy steel and austenitic stainless steel from his research results.

In this study, by using the low cycle test system which is composed of an autoclave and a water circulation loop, the fatigue life test considering environmental effected factors were performed for SA508 Gr.1a low alloy steel and the results compared with abroad test data.

2. System and Conditions of Fatigue Test

2.1 Fatigue Test System

The low cycle test system used in this test is the servo-electric and dynamic fatigue test machine which is composed of an autoclave and a water circulation loop as shown in Figure 1. In this system, the DO content is controlled under 1.0 ppb by two water columns quickly and conveniently. And fatigue life was defined as a number of cycles, i.e. N_{25}, achieved before the load dropped 25% from the peak value.

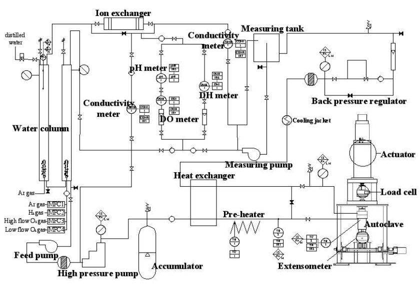

Figure 1. Schematic diagram of fatigue test system.

2.2 Test specimen and Conditions

The test specimen used in this test is sampled from the SA508 Gr.1a low alloy steel piping material which is normalized in 920℃ for 10 min. and quenched, and tempered in 650℃ for 130min. in air. The chemical composition and the microstructure of the SA508 Gr.1a low alloy steel is presented in Table 1 and 2 respectively.

Table 1. Chemical composition of SA508 Gr.1a.

C	Si	Mn	P	S	Al	Cu	Cr	Ni	Mo	V
0.300	0.400	1.35	0.025	0.0100	0.040	0.200	0.250	0.400	0.100	0.030

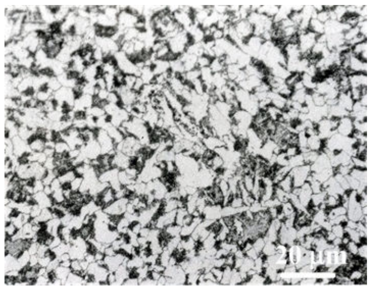

Figure 2. Microstructure of SA508 Gr.1a low alloy steel.

Low cycle tests are carried out in strain control mode with fully reversed chopping wave form in 310℃ and under the low DO water condition. In this test, strain rates considered 3 cases such as 0.008, 0.04, and 0.4%/s for the strain amplitudes of 0.4, 0.6, 0.8, and 1.0%. The electric conductivity of the steel was controlled below 0.1 ㎲/cm.

Table 2. Low cycle fatigue test conditions.

Wave Form		Chopping Wave (R = -1)
Strain rate		0.008, 0.04, 0.4 %/s
Strain		0.3, 0.4, 06, 0.8, 1.0 %
Test Condition		RT, 310℃ Air Condition, 310℃ Water Chemistry
Water Chemistry Factors	DO	< 1 ppb
	Conductivity of Electricity	< 0.1 μ S/cm

3. Fatigue Life and Stress Behaviors

3.1 Cycle Stress Response

The cyclic stress behavior of the SA508 Gr.1a low alloy steel in 310℃ and under the low DO water condition is illustrated in Figure 3. As shown in this figure, the strain hardening according to the reduction of strain rate is decreased and negative strain rate sensitivity is observed in the specific narrow ranges of fatigue cycles. Considered the results observed in this work, the cyclic hardening behavior of the steel might be related with the dynamic strain aging.

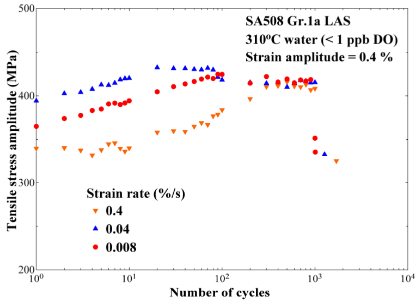

Figure 3. Cyclic stress response of SA508 Gr.1a low alloy steel with various strain rates.

3.2 Fatigue Life in Water Chemical Conditions

The cyclic stress behavior of the SA508 Gr.1a low alloy steel under the DO water chemistry and the air conditions of 310℃ is presented in Figure 4. To compare the results of this test with the ASME fatigue curve, the average curve of their conditions are illustrated in a diagram. The fatigue life of the SA508 Gr.1a low alloy steel in 310℃ and under the low DO water condition is shorter than that in air condition. And in 310℃ and under the low DO water condition, the fatigue life of the steel is slightly shortened.

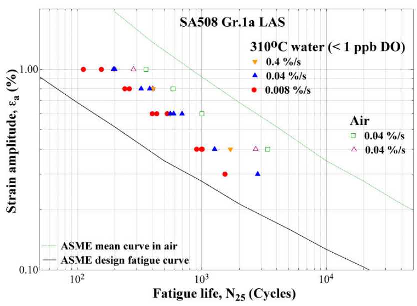

Figure 4. Fatigue lives of SA508 Gr.1a low alloy steel in R.T., 310℃ air, and 310℃ low oxygen-containing water.

For the material of structure components such as pipes and reactor vessel, the fatigue life was decreased in the operation condition of nuclear power plants in general. It was generally known that this reduction of fatigue life was dependent on the factors of strain rate, strain, temperature, Do content, sulfur content and so on. The quantitative study for these factors is progressing now in domestic country and overseas, especially the United States (Argonne National Laboratory) and Japan are the major countries in this area. Therefore in this study, we compared our test results with those of the ANL and the Higuchi as presented in Figure 5.

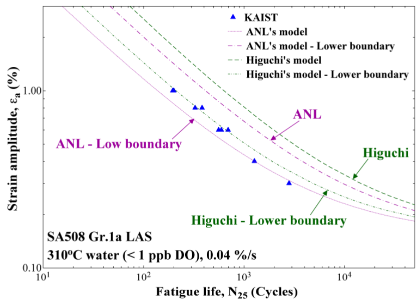

Figure 5. Comparison of the fatigue lives of SA508 Gr.1a low alloy steel.

4. Conclusion

The fatigue life of the SA508 Gr.1a low alloy steel in 310℃ and under the low DO water condition was shorter than that in air condition and dependent on the water chemical factors. Compared with the test results, we have found that our test results were very similar to those of the ANL and the Higuchi. Therefore we also showed that our fatigue life test performed in this study had reliability in terms of accuracy.

REFERENCES

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