Environmental Effect on the Characteristics of the Structural Materials of the New Advanced Power Plant

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1. Introduction

Fatigue failure has been considered as one of the most important degradation mechanism of the class 1 components of nuclear power plants. 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 in some of the domestic research centers recently. O. K. Chopra, M. Higuchi, I. S. Jeong, C. H. Jang, and H. C. Cho et al. 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 [3,4].

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 type 316LN stainless steel. And the results are compared with abroad test data.

2. System and Conditions of Strain-fatigue Life Test

2.1 Strain-fatigue Life 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.

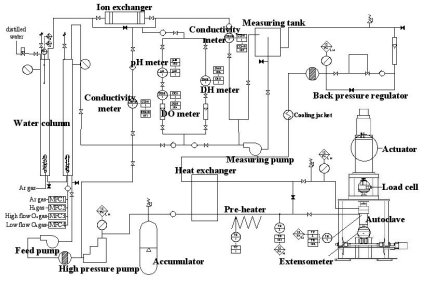

Figure 1. Schematic diagram of fatigue test system.

2.2 Test Specimen and Conditions

The test specimens used in this test are sampled from the SA508 Gr.1a low alloy steel piping material and the type 316LN stainless steel forging material. SA508 Gr.1a low alloy steel piping material is normalized in 920℃ for 10 min. and quenched, and tempered in 650℃ for 130min. in air. The heat treatment of type 316LN stainless steel forging material was conducted at 1065.5℃ for one hour and water quenched.

The chemical compositions of the SA508 Gr.1a low alloy steel (LAS) and type 316LN stainless steel (SS) are presented in Table 1 and the dimension of test specimens is shown in Figure 2 respectively.

Table 1. Chemical composition of test specimens.

	C	Si	Mn	P	S	AL	Cu	Cr	Ni	Mo	V	N	Co
LAS	0.3	0.4	1.35	0.025	0.01	0.04	0.20	0.25	0.40	0.1	0.03	-	-
SS	0.018	0.46	1.84	0.022	0.016	-	0.28	16.37	11.3	2.11	-	0.096	0.1

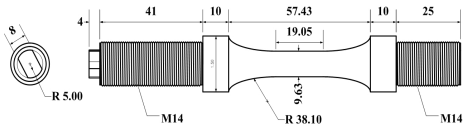

Figure 2. Dimension of test specimens.

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.

Fatigue life (N_{25}) was determined as cycles when load was dropped 75% of maximum load. The low cycle fatigue test conditions are presented in Table 2.

Table 2. Low cycle fatigue test conditions.

Wave Form		Chopping Wave (R = -1)
Strain rate		0.008, 0.04, 0.4 %/s
Strain		0.4, 0.6, 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. Environmental Effect on Fatigue Life

3.1 Fatigue Life in Deoxidized High Temperature Water

The strain-life design curve and test data were presented in Figure 3 and 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 steels are slightly shortened.

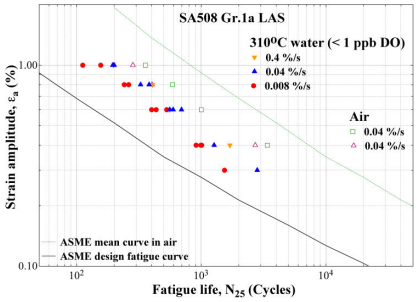

Figure 3. Fatigue lives of SA508 Gr.1a low alloy steel in R.T., 310℃ air, and 310℃ low oxygen-containing water.

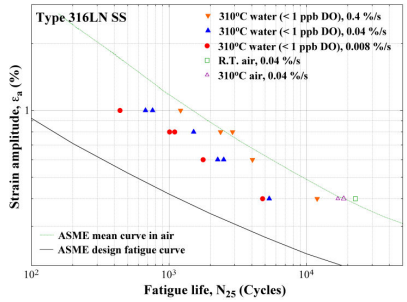

Figure 4. Fatigue lives of type 316LN stainless steel in R.T., 310℃ air, and 310℃ low oxygen-containing water.

3.2 Comparison of Fatigue Life

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, 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 (Higuchi) are the major countries in this area.

Therefore in this study, we compared our test results with those of ANL's and Higuchi's data. As presented in Figure 5 and 6, our test results were very similar to the reference data.

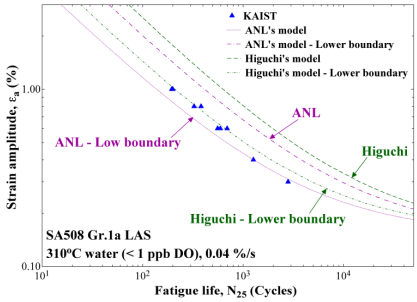

Figure 5. Comparison of the fatigue lives of SA508 Gr.1a low alloy steel.

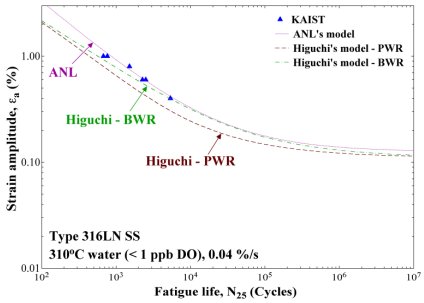

Figure 6. Comparison of the fatigue lives of type 316LN stainless steel.

4. Conclusion

The fatigue life of the SA508 Gr.1a low alloy steel and type 316LN austenitic stainless 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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