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§14. Development of Reliable Miniature-size Fatigue Test Technique for Reduced Activation Ferritic Steels

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Reduced activation ferritic/martensitic (RAFM) steel has been developed as a candidate structural material for a fusion reactor blanket. Since the fusion reactor structural material must support dynamic loads induced by thermal stress and electromagnetic stress under neutron irradiation, the fatigue behavior of the RAFM steel under/after neutron irradiation must be clarified.

Small specimen test technique (SSTT), which is the test technique using a miniature specimen, is essential to evaluate material properties under/after neutron irradiation because volume for material irradiation in test reactor and the IFMIF is very limited. Several types of miniature fatigue specimens were used in previous studies for evaluation of fatigue life. However, these specimens did not always show the same fatigue life as the reference standard specimen. Thus, optimization of the shape and size of miniature fatigue specimen is considered to be a key issue to develop the reliable SSTT of fatigue.

The objective of this study is to clarify the effect of specimen shape on low cycle fatigue life of miniature fatigue specimen of the RAFM Steel.

The reduced activation ferritic/martensitic steel, F82H IEA-heat was employed for the fatigue test in this study. Five kinds of miniature size hourglass specimens shown in Fig. 1 were fabricated. The diameter of the minimum cross-section (φ) was 1.25 mm and 1.85 mm. The specimen shape parameter (φ/ρ) was 0.125, 0.500 and 1.000, where ρ indicates the radius of the curvature of the hourglass type specimen.

Fatigue test was carried out at room temperature in air. A completely reversed push-pull condition was applied and the total strain range was controlled using a triangular wave with an axial strain rate of about 0.04%/s. The axial total strain range ($\Delta\varepsilon_t$) was 1~5%. Fatigue test of the hourglass type specimens was carried out under diametral strain control using an electromotive testing machine with a 2kN load cell fabricated by INTESCO, Japan. The diametral deformation was measured by a laser extensometer. The axial strain range was converted from the diametral strain range using a conversion equation in ASTM E606 Appendix X2.[1)]

Fig. 2 shows the relationship between total strain range and number of cycles to failure in the standard size round-bar specimen (φ3~10 mm) in previous study[2-6)] and the miniature size hourglass specimen (φ1.25 mm) in this study. Effect of specimen shape on the low cycle fatigue life of the miniature size hourglass specimen was almost negligible. All the data from these specimens were ranged in the factor of 2. Fatigue life of the miniature size hourglass specimens was longer than that of the standard size round-bar specimen, especially at relatively high strain range.

Though the specimen shape parameter (φ/ρ) is strongly dependent on the peak stress and stress gradient around the minimum cross-section, which influence the fatigue life generally, almost no effect of specimen shape was observed in the miniature size hourglass specimens in this study. Therefore, the effect of specimen size and the accuracy of the conversion equation[7)] of the ASTM E606 should be investigated in future work to clarify the reason of difference of fatigue life between the standard size round-bar specimen and the miniature size hourglass specimen.

1) ASTM E606, 626-643 (1977).
2) Stubbins, J.F. et al., J. Nucl. Mater. 233-237 (1996) 331-335.
3) Shiba, K.: Fatigue Properties of F82H IEA Heat, 2002.
4) Ishii, T. et al.: J. Nucl. Mater. 258-263 (1998) 1183-1186.
5) Ph.D. thesis of S.W. Kim, Kyoto University, (2007).
6) Ph.D. thesis of D.H. Kim, Kyoto University, (2007).
7) Nogami, S.: Annual Report of NIFS (2007).

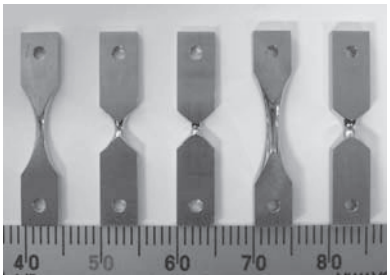

Fig. 1 Photos of the miniature size hourglass specimen ((φ, φ/ρ) = (1.25, 0.125), (1.25, 0.500), (1.25, 1.000) (1.85, 0.125), (1.85, 1.000) from left side)

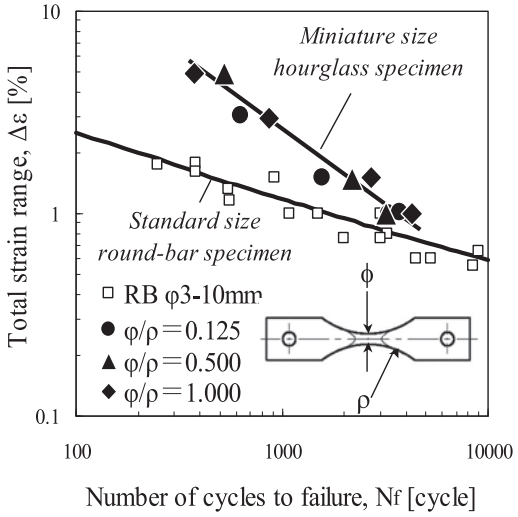

Fig.2 Relationship between total strain range and number of cycles to failure in the standard size round-bar specimen (φ3~10 mm) in previous study[2-6)] and the miniature size hourglass specimen (φ1.25 mm) in this study