§10. 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) is essential to evaluate material properties under/after neutron irradiation, which is the test technique using a miniature specimen. 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 (round-bar specimen with a minimum diameter of the cross-section (φ) of about 5–10 mm). 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 and size on fatigue life in the RAFM steel.

The JLF-1 and F82H steel was employed for the fatigue test in this study. The standard-size round-bar specimen (φ = 4–10 mm), miniature round-bar specimen (φ = 1 mm), standard-size hourglass specimen (φ = 6 mm), and miniature hourglass specimen (φ = 1.25 mm) were examined to evaluate the specimen shape and size effect. Fatigue test was carried out at room temperature in air. The axial total strain range was 0.4–5%.

Figure 1 shows the relationship between the total strain range and number of cycles to failure (fatigue life) in the standard-size round-bar, standard-size hourglass, and miniature hourglass specimens of JLF-1. Fatigue life of the standard-size hourglass specimen was shorter than that of the standard-size round-bar specimen at relatively low strain range. This difference was considered to be due to the effect of stress distribution dependent of the specimen shape, which was indicated by the FEA in the previous work [1]. On the other hand, in case of the high strain range conditions, the fatigue life of the standard-size hourglass specimen was longer than that of the standard-size round-bar specimen. The FEA showed no difference of the stress distribution between them [1]. Therefore, the fatigue life difference at relatively high strain range was not due to the effect of stress distribution. Difference of the probability of the crack initiation and propagation between them would be one of the reasons for the fatigue life difference at high strain range. Since effective volume contributing to the crack initiation and propagation in the hourglass specimen would be much smaller than that in the round-bar specimen, fatigue life of the hourglass specimen was considered to be longer than that of round-bar specimen. These trends of the fatigue life in JLF-1 were also observed in F82H tested at room temperature [1].

The effect of specimen size on the fatigue life of JLF-1 was almost negligible in the hourglass specimen as shown in Fig. 1. Moreover, the effect of specimen size on the fatigue life of JLF-1 was almost negligible in the round-bar specimen though the number of the data was relatively limited for the miniature round-bar specimen. Almost no effect of the specimen size was also observed in F82H tested at room temperature.

Based on this study, utilizing the miniature round-bar specimen might be better for the SSTT of fatigue, which showed the same fatigue life as the standard specimen (standard-size round-bar specimen). Thus, database of the fatigue life of the miniature round-bar specimen should be improved in future work.

1) S. Nogami, Y. Sato, A. Tanaka, A. Hasegawa, A. Nishimura, H. Tanigawa, J. Nucl. Sci. Tech. 47-1 (2010) 47-52.

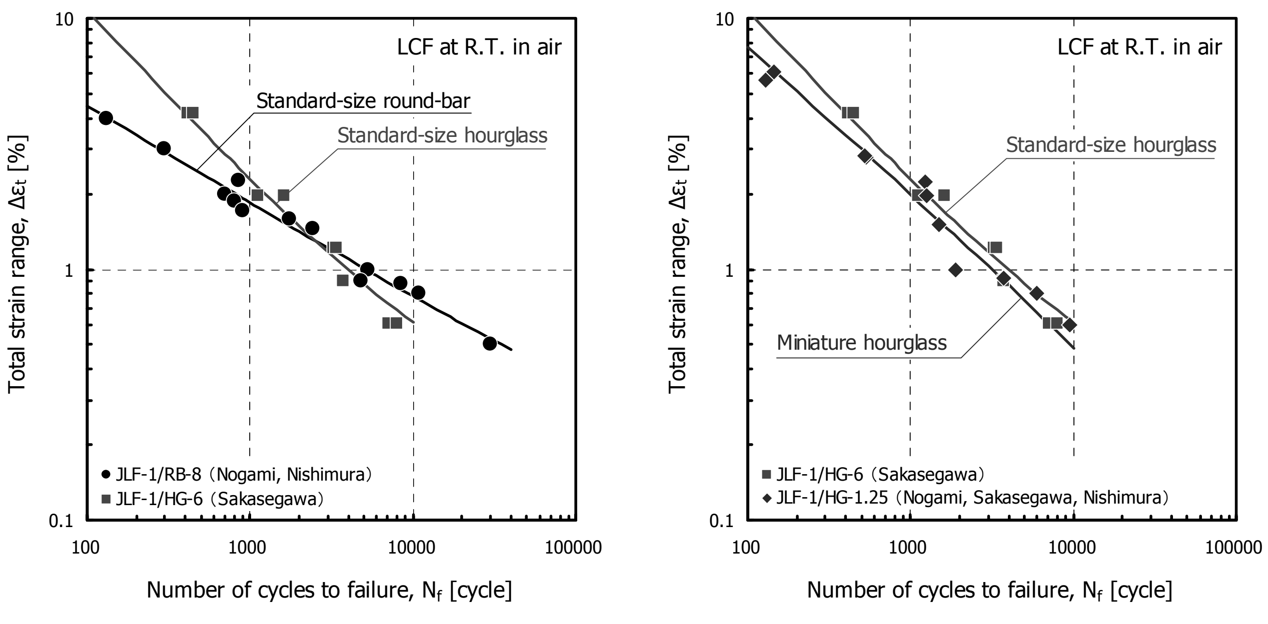

Fig. 1 Fatigue life of JLF-1 with various specimen shape and size