

§24. Fatigue Life Evaluation of Reduced Activation Ferritic Steel using Small Specimen

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1. Introduction

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

Development of the fatigue life evaluation method using small specimen is necessary for evaluating the neutron irradiation effect on it. Though the small fatigue specimen with several shapes such as round-bar, hourglass and flat-plate has been used in previous studies, verification was not enough whether these small specimens showed the same fatigue life as the standard specimen, which was the round-bar specimen with a minimum diameter of a few millimeters. Authors ¹⁾ have reported the difference of the fatigue life between the standard specimen and the small hourglass specimen, which has been the standard small fatigue specimen in Japan to evaluate the fatigue life of RAFM steels. On the other hand, the small round-bar specimen showed almost no difference of the fatigue life from the standard specimen ¹⁾.

The objective of this study is to expand the database of the fatigue life of the small round-bar specimen, to develop its reliable regression formula, and to clarify the validation of utilizing the small round-bar specimen for evaluation of the fatigue life.

2. Experimental

The reduced activation ferritic/martensitic steel, F82H IEA-heat was employed for the fatigue test in this study. The diameter of the minimum cross-section and the gauge length of the small round-bar specimen (RB-1) in this study were 1 mm and 3.4 mm, respectively.

Low cycle fatigue tests were carried out at room temperature in air under axial strain control using an electromotive testing machine with a 1 kN load cell fabricated by Kobe Material Testing Laboratory, Japan. A completely reversed push-pull condition was applied, and the total strain range was controlled using a triangular wave ($R = -1$) with an axial strain rate of about 0.1%/s. The axial strain was measured by an extensometer attached directly to the specimen. The total strain range ($\Delta\epsilon_t$) was 0.6–1.2%. The fatigue life (N_f) was defined as the number of cycles at which the tensile peak stress drops to 75% from the extrapolated line of the cyclic softening trend.

3. Results

Relationship between total strain range ($\Delta\epsilon_t$) and fatigue life (N_f) in the RB-1, RB-4, RB-7, and RB-10

specimens of F82H IEA-heat at room temperature in air is shown in Fig. 1. ¹⁾ RB-4, RB-7, and RB-10 specimens are the standard round-bar specimen with diameter of the minimum cross-section of 4 mm, 7 mm and 10 mm, respectively. The solid line in Fig. 1 is the Manson-Coffin type regression formula ¹⁾ for the RB-4, RB-7, and RB-10 specimens obtained as

$$\Delta\epsilon_t = 105N_f^{-0.66} + 0.80N_f^{-0.07}. \quad (1)$$

The first term was related to the plastic strain range ($\Delta\epsilon_p$) and the second one to the elastic strain range ($\Delta\epsilon_e$). Though the number of the data was limited and there was relatively large scatter for the RB-1 specimen, difference of the fatigue life between the standard specimens (RB-4, -7, and -10) and the RB-1 specimen from 10^3 to 10^4 cycles level was almost negligible at room temperature. Generally, too small number of the grains across the specimen diameter (thickness) could cause the difference of strength and life from the standard specimen. The average grain size (average prior austenitic grain size) of the F82H IEA-heat in this study was about 60 μm . Therefore, number of the grains across the specimen diameter in the RB-1 specimen of F82H IEA-heat, which was larger than 18, was considered to be so enough that no significant effect of specimen size on the fatigue life appeared.

In order to develop the reliable regression formula of the RB-1 specimen and to clarify the validation of utilizing the small round-bar specimen for evaluation of the fatigue life, it is necessary to expand the database of its fatigue life in future work.

- 1) S. Nogami, T. Itoh, H. Sakasegawa, H. Tanigawa, E. Wakai, A. Nishimura, A. Hasegawa, J. Nucl. Sci. Tech., 48-1 (2011) 60-64.

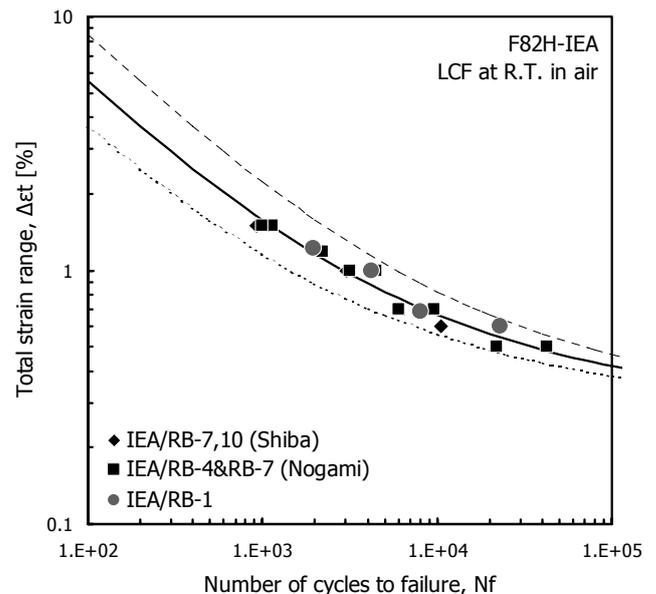


Fig. 1 Relationship between total strain range ($\Delta\epsilon_t$) and fatigue life (N_f) in the RB-1, RB-4, RB-7, and RB-10 specimens of F82H IEA-heat at room temperature in air ¹⁾.