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微小き裂成長挙動に基づく低放射化フェライト鋼の疲労寿命予測手法の開発

Development of Fatigue Life Prediction Method based on Crack Growth Behavior in Reduced Activation Ferritic/Martensitic Steel

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1. Introduction

Reduced activation ferritic/martensitic (RAFM) steel has been developed as a candidate structural material for a fusion reactor. Since a fusion reactor material must support dynamic loads induced by thermal and electromagnetic stresses under neutron irradiation, the fatigue life assessment method under irradiation should be developed to ensure the reliability and economy of a fusion reactor.

Since the fatigue life is generally composed of micro-crack initiation, crack propagation, and final fracture stages, the fatigue life assessment is considered to be improved by evaluating not only the fatigue life but also the micro-crack growth behavior at those individual stages.

The objective of this study is to investigate the micro-crack growth behavior of the unirradiated and irradiated RAFM steel under low cycle fatigue and to discuss the predictability of the fatigue life based on the crack growth behavior to develop a reliable fatigue life assessment method.

2. Experimental

The material used in this study was F82H-IEA. The neutron irradiation was carried out using BR-2 in Belgium. The maximum neutron fluence and irradiation temperature was 0.275 x 10^{20} n/cm^2 (~0.055 dpa) and 118ºC, respectively. The helium implantation was carried out using Cyclotron accelerator of Tohoku University. The helium concentration and implantation temperature were 350 appm and 470ºC, respectively.

Fatigue tests were carried out at room temperature in air. The total strain range and strain rate were 0.4–1.5% and 0.01–0.06%/s, respectively. The measurement of surface crack length was carried out for evaluating the micro-crack growth behavior. A replica of the specimen surface obtained by periodically stopping the fatigue test was used for the measurement.

3. Results and Discussion

The relationship between surface crack length (2*a*) and number of cycles (*N*) in the unirradiated and helium-implanted F82H-IEA was described by the following equation under all the test conditions of this study:

$$2a = \mathrm{A}\cdot\exp(\mathrm{B}\cdot N) \qquad (1)$$

where A and B were constants dependent on the total strain range. The relationship between the surface crack length (2*a*) and life fraction (N/N_f) in the unirradiated and helium-implanted F82H-IEA is shown in Fig. 1. This relationship was described using one equation. Therefore, based on this evaluation, it was possible that the residual life (N_f–N) of F82H-IEA could be estimated using the surface crack length, independent of the total strain range regardless of the helium implantation.

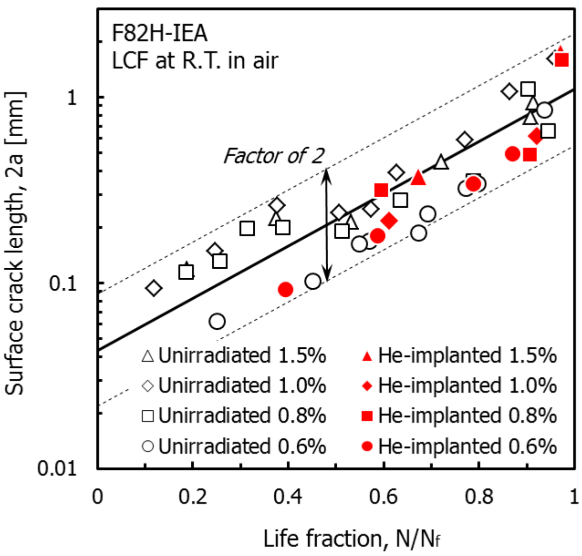

Fig. 1 Relationship between surface crack length (2*a*) and life fraction (N/N_f) in the unirradiated and helium-implanted F82H-IEA tested at R.T. in air