§20. Evaluation of Fatigue Damage Formation and Growth in SiC/SiC Composite

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1. Introduction

Silicon carbide (SiC) fiber reinforced SiC matrix composite (SiC/SiC composite) has been developed as a candidate structural material for an advanced fusion reactor blanket. Since the fusion reactor structural material must support dynamic loads induced by thermal and electromagnetic stresses, the fatigue properties of the SiC/SiC composite should be clarified. Because the damage formation process under the mechanical loadings of the SiC/SiC composite is significantly complicated, the definition of the fatigue life and the prediction method of it have not been established. The objective of this work is to clarify the fatigue damage formation and growth processes of the SiC/SiC composites.

2. Experimental

Material used in this work was SiC/SiC composite fabricated by a chemical vapor infiltration (CVI) process. The reinforced fiber of this composite was Tyranno SA 3rd. The interface between the matrix and fiber was SiC/C multilayer. The small round-bar specimen with test section diameter of 1.7 mm and test section length of 3.4 mm was examined. The end-connection of this specimen was a modified button head type. By using this type of end-connection, it is relatively easy to reduce bend strain applied to the specimen caused by the gap between the positions of both up and down bodies of fixture. As a consequence, probability of the buckling could be reduced.

Fatigue tests up to about 10^5 cycles 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 tension-compression (T-C) loading condition ($R = -1$), the tension-tension (T-T) loading condition ($R = 0.14$), and the compression-compression (C-C) loading condition ($R = 7$) were applied and the total strain range was controlled using a triangular wave with an axial strain rate of 0.01%/s. The axial strain was measured using an extensometer with gauge length of 2 mm, which was attached directly to the specimen. The total strain range was 0.06% and 0.12%. The peak stress was below the proportional limit stress (PLS) for the total strain range of 0.06% and above that for the total strain range of 0.12%. The fatigue tests were stopped at about 10^5 cycles before any visible fracture and failure of the specimens.

3. Results

In the case of the C-C tests at the total strain range of 0.12%, the hysterisis curve was relatively smooth and showd almost no change through the test up to 10^5 cycles. On the other hand, in the case of the T-T tests at the total strain range of 0.12%, a pseudoplastic-like and a elastic-like deformations were observed for the 1st cycle and after the 2nd cycle, respectively.

Fig. 1 shows the normalised modulus change during the T-C, T-T and C-C tests at the total strain range of 0.06% and 0.12%, which was the slope of the elastic region of the hysteresis curves. According to the open literatures, the modulus change had a strong correlation with the damage formation (crack initiation, propagation and deflection etc.).

In the case of the C-C tests at the total strain range of 0.06% and 0.12%, no change of the modulus was observed through the test up to 10^5 cycles. Therefore, no significant damage formation was considered to occur under the C-C tests regardless of the peak stress. On the other hand, in the case of the T-T tests at the total strain range of 0.12%, the signisficant reduction of the modulus at the 1st cycle and the slight reduction from the 2nd cycle up to 10^5 cycles were observed. Therefore, relatively large and/or a lot of defects formed at the 1st cycle and their growth after the 2nd cycle was considered to be induced by the cyclic loading. Based on the change of the hysteresis curve and the modulus, no significant damage formation, which induced the macroscopic pseudoplastic-like deformation, was considered to occur from the 2nd cycle up to 10^5 cycles in the case of the T-T tests at the total strain range of 0.12%.

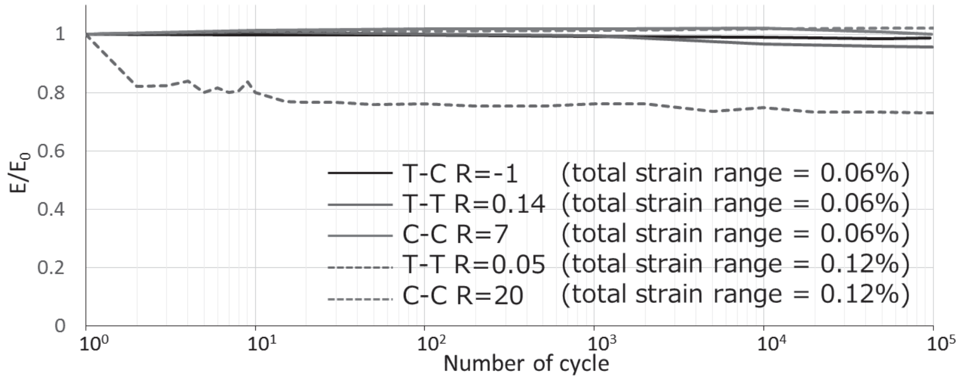

Fig. 1. The normalised modulus change during the T-C, T-T and C-C tests at the total strain range of 0.06% and 0.12%.