§21. 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.

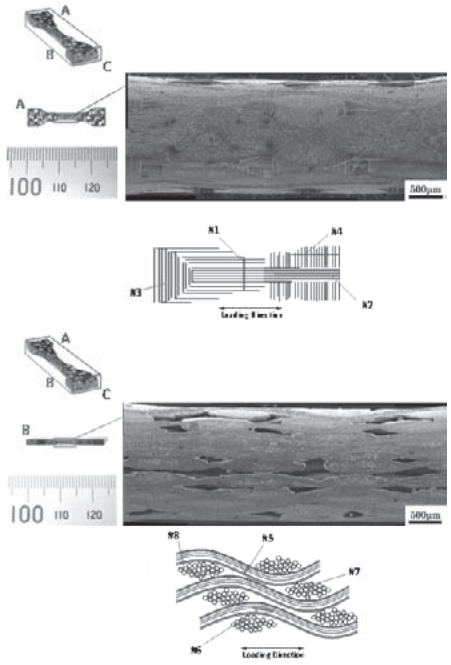

Fig. 1 Schematic illustration of the crack initiation sites

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 (TC) loading condition ($R = -1$), the tension-tension (TT) loading condition ($R = 0.14$), and the compression-compression (CC) 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%. The peak stress was below the proportional limit stress (PLS) in all the test conditions. The fatigue tests were stopped at about 10^5 cycles before any visible fracture and failure of the specimens. After the fatigue test up to about 10^5 cycles, the cracks of the specimen surface were observed using a scanning electron microscope (SEM).

3. Results

The fatigue tests of SiC/SiC composite under all the test conditions were successfully performed. It was clarified that the fatigue test method using the small round-bar specimen and the test equipment of this work was suitable for the completely reversed tension-compression test of the SiC/SiC composite. Relatively smooth hysteresis curves and the change in peak stresses were obtained throughout the fatigue test. The slight change in the average stress occurred during the fatigue test exceeding 10^4 cycles. This might be due to the slippage of the extensometer during the fatigue test. This technical issue would be solved by optimizing the condition to fix the extensometer.

Though the fatigue tests were performed below the PLS, several open cracks were observed at the specimen surface regardless of the test conditions. The schematic illustration of the crack initiation sites and the typical cracks of the specimen surface under the CC loading condition are shown in Fig. 1 and Fig. 2, respectively. Based on the SEM observation, surface crack initiation occurred at 8 sites. As shown in Fig. 2, crack initiation from the pore, which was created during the CVI fabrication process, was observed especially under the CC loading condition. This might indicate that the possibility of the crack initiation from the stress concentration region of the edge of the pore was relatively high under the CC loading condition. Therefore, the systematic investigation of the effect of the loading condition and the pore will be carried out in 2014.

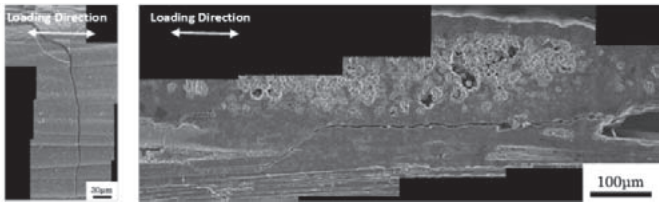

Fig. 2 Typical SEM observation of the surface crack of the SiC/SiC composite under the CC loading condition