MIXED-MODE INTERFACIAL FATIGUE CHARACTERISTICS OF COMPOSITE/METAL INTERFACE OF BIMATERIALS

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Introduction

The use of composite material is being extended to machine components such as robot and aerospace structures to exploit the benefits of high specific strength and high specific stiffness as well as high damping and good fatigue properties. When composite structures are employed in a large complicated structure or an entire structure, joining of composite structures to other composite or metallic structures is necessary because manufacturing the whole structure using only composites is not technically or economically feasible [1]. For most structural failure in actual machines, fracture often takes place due to a phenomenon called fatigue. So, many studies about the effect of the various mode-mixities on fatigue characteristics have been performed. However, the most of this study is about metal/metal interface [2,3] or delamination [4,5] of composite. Therefore, the purpose of this paper is to study fatigue characteristics of a composite/metal interface. The fatigue experiments were performed using SLB (single-leg bending) specimens bonded with composite and steel using co-cure bonding method. This paper focuses on fatigue characteristics depending on different mode-mixed ratios (G_{II} / G_T) .

Experimental Methods

Materials

In this paper, fatigue experiments were performed using SLB (single-leg bending) specimens [6] bonded with composite that is made by stacking the multiple prepreg (USN 150B, SK chemicals, t=0.146mm) and steel (SM45C, t=1mm) using the co-cure bonding method. As shown in Fig. 1, the geometry and loading condition of the SLB specimen is very simple. Here, the initial crack is made using epoxy release (ER-650, NABAKEM).

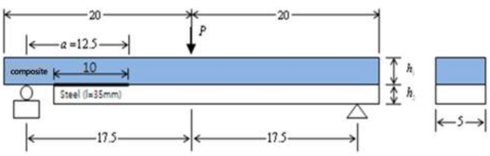

Fig. 1 Shape of SLB(single-leg bending) specimen

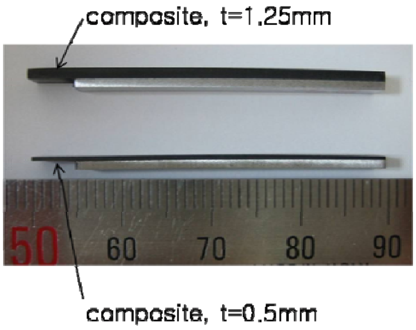

Fig. 2 Actual SLB specimen

Fig. 2 is the actual shape of SLB specimen used in this study that was made by using the co-cure bonding method.

Apparatus and Procedures

In order to perform the 3-point bending test of the SLB (single-leg bending) specimens, the experimental device was prepared as shown in Fig. 3. It moves 10 ㎛ per 1 pulse to the z-axis direction using stepper motor. The displacement is measured using laser displacement sensor (LK-G30, KEYENCE) whose resolution is 0.01 ㎛. The loading is measured using load cell (LCM300, Futex) whose maximum measured load is 223N (50lb). The data of displacement and loading during experiment is stored in computer using LabView program.

The experiments were carried out displacement control and loaded cyclic loading of triangular waveform. Tests were carried out at a displacement ratio $(\delta_{MIN} / \delta_{MAX})$ of 0.1 and a period of 4 sec.

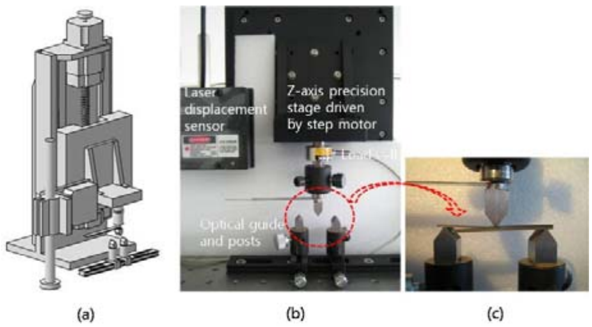

Fig. 3 Experimental device for 3-point bending test;
(a) Schematic diagram, (b) Actual experimental device

and (c) Specimen in position under loading

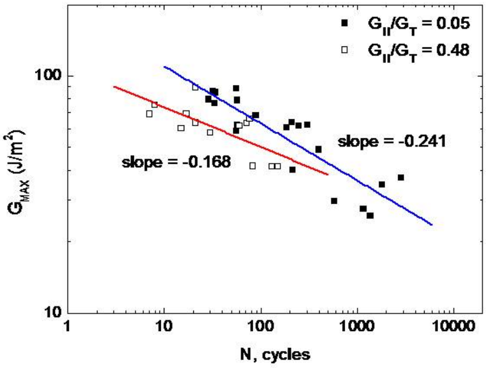

Fig. 4 G_{MAX} -N (onset of crack growth) curves

Results and Discussion

First, it is studied about the relation between the maximum energy release rate and the number of cycles up to the onset of crack growth using SLB specimen of two groups that the mode-mixed ratio is different.

As shown in Fig. 4, it can be represented by straight lines to draw the relation between the maximum energy release rate and the number of cycles up to the onset of crack growth in coordinates of log-log scale. The relation is expressed as eq. (1) in the mode-mixed ratio 0.05 and eq. (2) in the mode-mixed ratio 0.48.

$$G_{MAX} = 191.364 \times N^{-0.241} \quad (1)$$

$$G_{MAX} = 108.775 \times N^{-0.168} \quad (2)$$

It is found that the value of slope in straight lines was -0.241 with the mode-mixed ratio 0.05 whereas that with the mode-mixed ratio 0.48 was -0.168. In comparison, the straight line of the mode-mixed ratio 0.48 is more lying than that of mode-mixed ratio 0.05. This suggests that the changes in the number of cycles up to the onset of crack growth for the changes of the maximum energy release rate is larger in the mode-mixed ratio 0.48 than in the mode-mixed ratio 0.05.

Second, it is studied about the relation between the crack propagation rate and the maximum energy release rate using SLB specimen of three groups that the mode-mixed ratio is different. The crack propagation rate data which is calculated by Incremental Polynomial Method are correlated with the corresponding maximum energy release rate for each over G_{II} / G_T mode ratio, as shown in Fig. 5. It is expressed as eq. (3) in the mode-mixed ratio 0.05, eq. (4) in the mode-mixed ratio 0.48, and eq. (5) in the mode-mixed ratio 0.78.

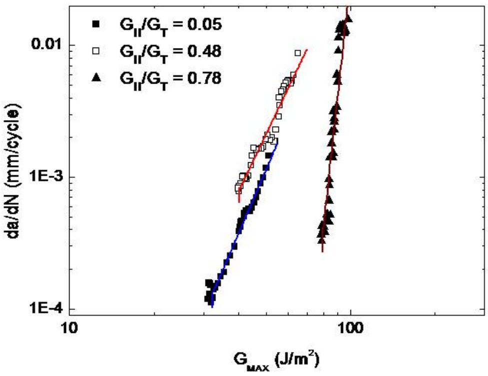

Fig. 5 Crack propagation rate- G_{MAX} curves

$$da / dN = 4.38E - 12 \times (G_{MAX})^{4.95} \quad (3)$$

$$da / dN = 5.98E - 11 \times (G_{MAX})^{4.44} \quad (4)$$

$$da / dN = 1.69E - 41 \times (G_{MAX})^{19.65} \quad (5)$$

It is found that the value of the exponent in a power-law relationship was 4.95, 4.44, and 19.65 with the mode-mixed ratio 0.05, 0.48, and 0.78, respectively. The threshold energy release rate with the mode-mixed ratio 0.05, 0.48, and 0.78 came out approximately 31 J / m^2, 40 J / m^2, and 78 J / m^2, respectively. Overall, result obtained in this study show that the crack propagation rate increases with the mode Ⅱ loading component.

Conclusion

In this paper, it has revealed the fatigue characteristics in a composite/metal interface depending on different mode-mixed ratios. The results are considered very useful in the prediction of fatigue crack propagation life as well as the product development and selection of materials.

References

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