EFFECT OF MATRIX ON FATIGUE STRENGTH OF UNIDIRECTIONAL JUTE SPUN YARN/BIODEGRADABLE RESIN COMPOSITE

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Abstract

Natural fiber reinforced biodegradable resin are carbon neutral materials and anticipated for alternative materials of GFRP. In this study, fatigue property of unidirectional jute yarn reinforced ductile biodegradable resin, i.e. PBS, was investigated and compared with the results of jute/PLA composite. The uniaxial tensile fatigue tests were conducted under conditions that the maximum stress was set to 40%-90% of the tensile strength and the stress ratio was set to 0.1. As a result, their fatigue strengths decreased concomitantly with increasing number of cycles, but jute/PBS composite had higher fatigue strength than that of jute/PLA composite. Contrary to jute/PLA composite, no fatigue crack was found in jute/PBS composite. Therefore, fatigue strength of composite was improved by using PBS as ductile matrix.

1 Introduction

Natural fiber reinforced biodegradable resin, which can be carbon neutral materials, have anticipated for alternative materials of GFRP (Glass Fiber Reinforced Plastics). Many papers of natural fiber reinforced biodegradable resin have been reported [1-4].

Natural fiber reinforced biodegradable resin with unidirectional reinforcement have been developed for improvements of modulus and strength [5]. Fatigue property of the unidirectional reinforced biodegradable resin should be investigated to assure the structural integrity.

Author et al. [6] presented the fatigue property and mechanism of unidirectional jute spun yarn reinforced PLA. Fatigue cracks in PLA resin caused the breakage of jute filaments, and the accumulation of the fiber breakage led to the final failure.

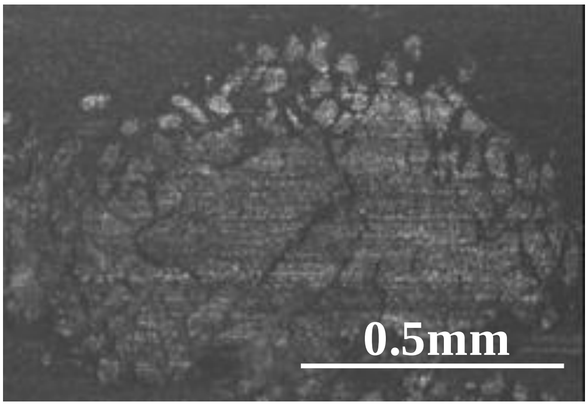
In this study, fatigue property of unidirectional jute yarn reinforced biodegradable resin using ductile matrix was investigated.

2 Materials and specimen

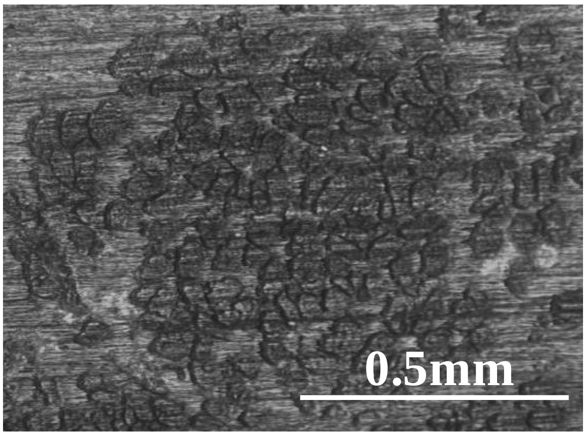
PLA (PL-2000; Miyoshi Oil and Fat Co., Ltd.) and PBS (Bionolle #1020; Showa denko Co., Ltd.) were used as matrix. Jute spun yarn (Asa no himo; BMS Co., Ltd.) was used as reinforcement. Table 1 shows the tensile properties of jute spun yarn and matrix. Alkaline treatment with NaOH5% of jute spun yarn was conducted for 3 hr at room temperature to produce preforms [7]. The alkaline-treated fibers were washed with water, wound around a metallic plate, and dried in a furnace. For jute/PLA composite, the water-dispersible PLA resin was impregnated into the preform and dried for 24 hr at room temperature to produce prepregs. For jute/PBS composite, composite plates were fabricated using the preforms and PBS sheet. Unidirectional composite plates were hot-pressed at 140°C for 20 min. The number of lamination was three. The volume fraction was measured using an optical microscope. The specimen dimensions were 10.0mm wide, 140.0mm long, and 3.5mm thick. The longitudinal direction corresponds to the reinforcement direction. Figure 1 shows cross section of their composite plates. Results showed that PLA and PBS were well impregnated into yarns.

	Young's modulus (GPa)	Tensile strength (MPa)	Failure strain (%)
Jute spun yarn	8.6	242	3.5
PLA	0.8	13	1.6
PBS	0.8	40	>100

Table 1. Tensile properties of jute spun yarn and matrix.



(a) PLA.



(b) PBS.
Figure 1. Cross sections.

3 Experiment method

3.1 Quasi–static tensile testing

Tensile tests were conducted to measure Young's modulus and ultimate strength according to JIS K 7164. The cross-head speed was 1.0 mm/min. Strain gauges and an extensometer were both used for measuring strain. The volume fraction of jute/PLA composite was 41%, and that of jute/PBS composite was 43%.

3.2 Fatigue testing

The fatigue tests of composite specimens were conducted using a hydraulic servo testing machine. The maximum stress was set to 90% ~ 40% of the ultimate strength and the stress ratio was set to be 0.1. The volume fractions of jute/PLA composite were 34%, 41% and 42%, and that of jute/PBS composite was 43% and 49%. Scattering was not intended; it resulted from using the hand lay-up method.

4 Results and discussion

4.1 Quasi–static tensile testing

Figure 2 shows typical stress - strain curves. Table 2 shows the tensile property of composites. Note that jute/PLA composite always failed at the corner of an aluminum tab. Thus, the tensile strength of jute/PBS composite was higher than that of jute/PLA composite because higher ductility of PBS prevented the initiation of crack.

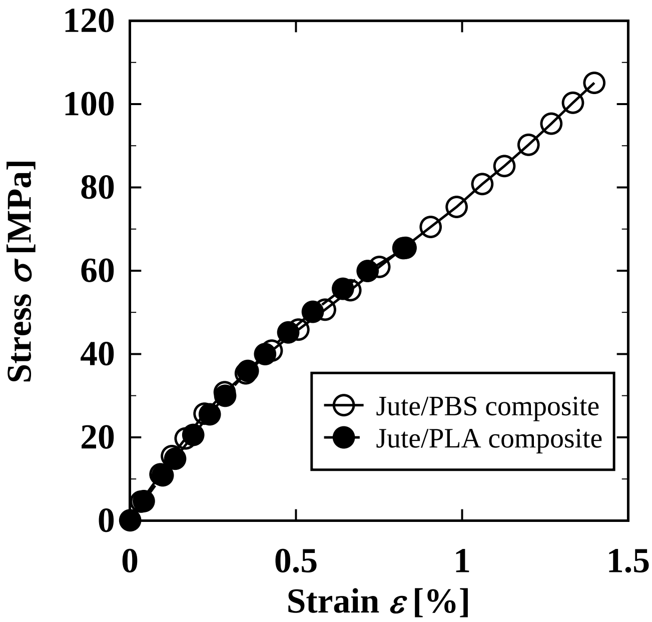


Figure 2. Stress – strain curves.

Matrix	Young's modulus (GPa)	Tensile strength (MPa)	Failure strain (%)
PBS	11	110	1.7
PLA	10	70	1.0

Table 2. Tensile properties of materials.

4.2 Fatigue testing

Figure 3 shows the S-N diagram of composites. The fatigue resistance of composite using PBS was higher than that of jute/PLA composite. The fatigue strength of these composites decreased with increasing the number of cycles. Their fatigue life at 10^6 cycles is around 55% of the ultimate strength. Figure 4 shows macroscopic fractures of jute/PLA composite. Figure 5 shows macroscopic fractures of jute/PBS composite. Cracks perpendicular to the loading

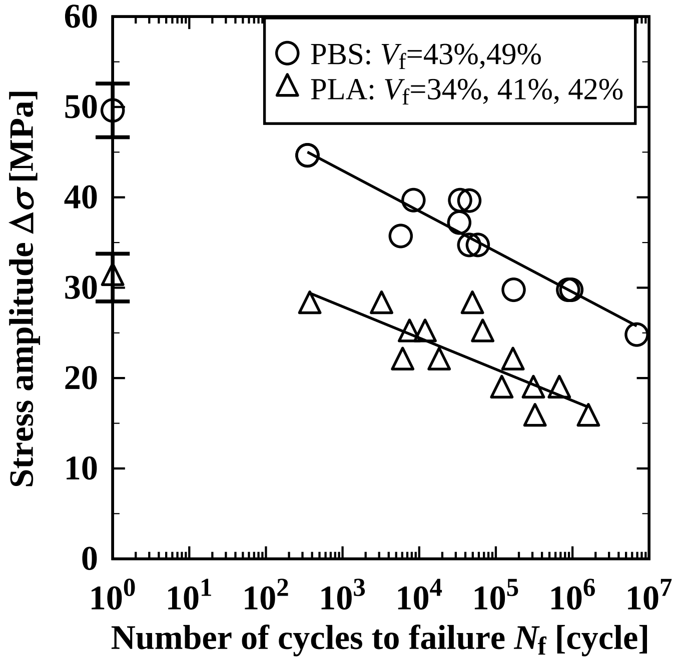
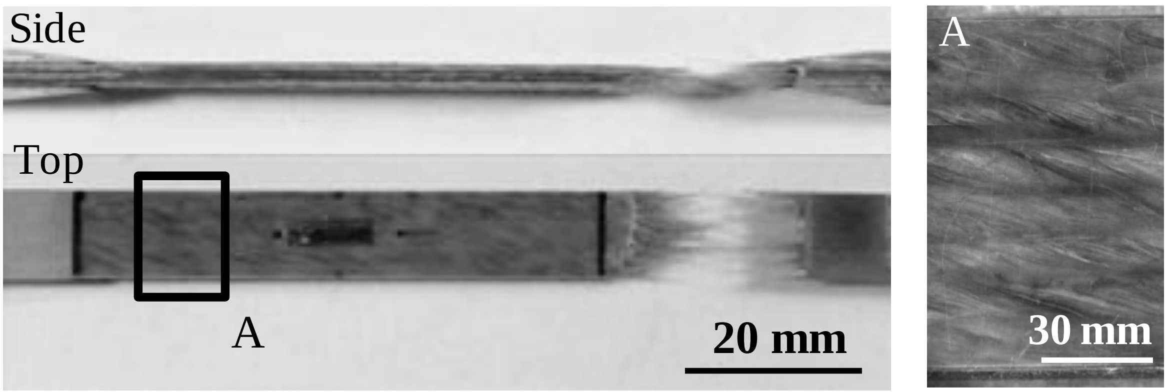
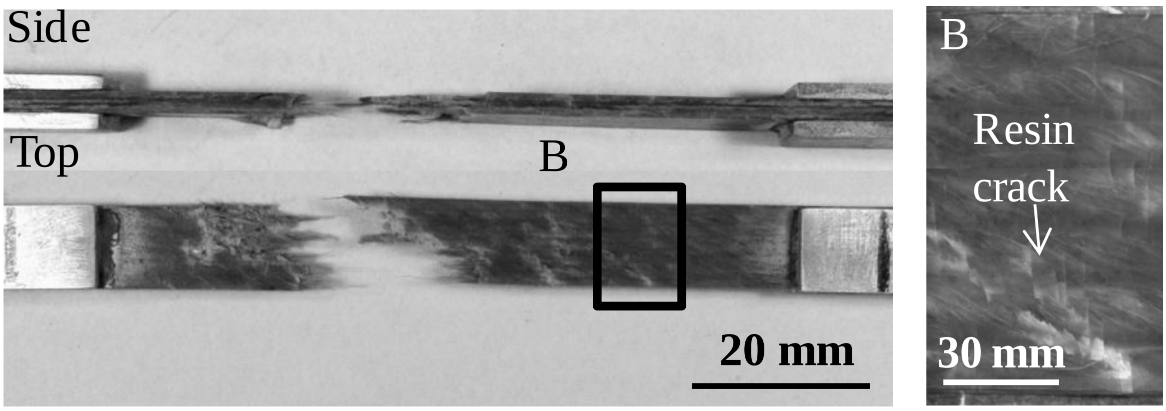


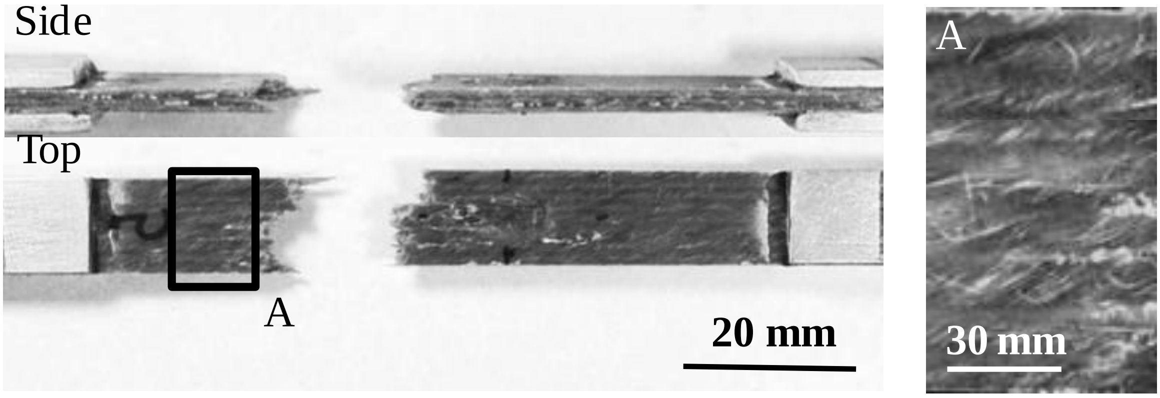
Figure 3. S-N diagram.



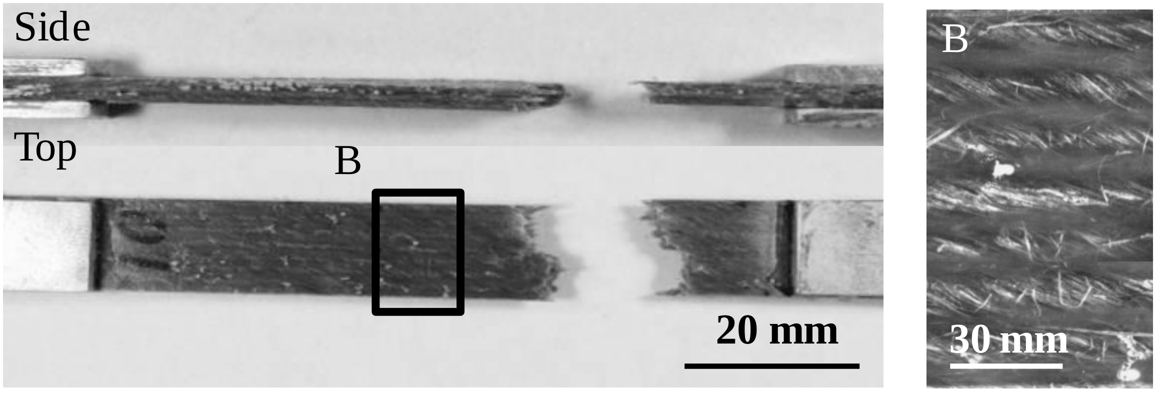
(a) Quasi-static tensile test.



(b) Fatigue test (σ_{max}=0.6σ_B).
Figure 4. Macroscopic fractures (Matrix: PLA).



(a) Quasi - static tensile test.



(b) Fatigue test (σ_{max}=0.6σ_B).
Figure 5. Macroscopic fractures (Matrix: PBS).

direction occurred in PLA during cyclic loading. On the surface of jute/PBS composite, no fatigue crack was found because PBS matrix has higher ductility. Therefore, fatigue strength of composite was improved by using PBS as ductile matrix.

5 Conclusions

In this study, the fatigue property of unidirectional jute yarn reinforced biodegradable resin was investigated. As a result, it was found that the fatigue property of jute yarn reinforced composite was improved by using ductile matrix.

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