Static tensile properties for jute fiber reinforced composite

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Abstract

In fiber reinforced composite, glass fiber reinforced plastics (GFRP) are widely used. But they have a disadvantage from the viewpoint of reuse and recycling. Instead of GFRP, natural fibers such as bamboo, jute, kenaf and hemp fibers are focused upon for environmental friendliness.

In this study, jute fiber is chosen as reinforcement because of the huge market and low cost. Polypropylene and emulsion type biodegradable resins are used as the matrix because of their recycling properties and cost. The tensile properties for Jute Fiber Reinforced Plastics (JFRP) are examined.

There are few reports about strength reduction from the viewpoint of residual strain and damage accumulation. So in this study, cyclic loading (load-unload) tests were conducted for improving the mechanical properties. Heat treatment is also conducted for JFRP to examine the strength.

As a result, the following conclusions are obtained. Young's modulus is improved for load-unload tensile tests. In the case where the load is less than 75% of the ultimate load and the number of cycles is ten, the residual strain has no effect on the tensile strength after load-unload tests. In the case where the load is 82.5% of the ultimate load, the tensile strength decreased. In the case where the load-unload test used 50% and 70% of the ultimate load, the residual strains are 0.12% and 0.40% respectively. There is no effect for tensile strength in the case where heat treatment is conducted to the pre-preg using PLA resin.
Keywords: jute fiber, polypropylene, green composite, tensile strength.

1 Introduction

Fiber Reinforced Plastics (FRP) is widely used for airplanes, automobile parts, fishing rods, bathtubs and many other engineering products. However, recently there have been some environmental problems, especially with the disposal of

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glass fibers that cannot be burned out after use. So, natural fibers such as jute, bamboo, hemp and flax are focused upon as reinforcement [1–5]. In Japan, the fourth international workshop on green composites was held in 2006. More than 60 researchers are interested in this issue. The mechanical properties for some natural fiber reinforced composites (green composites) have been studied. The number of papers for these green composites is greatly increased.

In this study, jute fiber is chosen as reinforcement because of the huge market and low cost. Polypropylene and emulsion type biodegradable resins are used as the matrix because of their recycling properties and cost. The tensile properties for Jute Fiber Reinforced Plastics (JFRP) are examined.

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2 Specimen and experimental procedure

Plain woven jute fabric is used as reinforcement. The directions of jute fibers are parallel and perpendicular to a load direction. Polypropylene sheets (Shin Kobe Electric Inc. PP-N-AN) and emulsion type biodegradable resin (PL-1000 Miyoshi Co.) are used as a matrix. The geometry of specimens is referenced to JIS (Japanese Industrial Standard) 7054 Type B-I. Three sheets of jute fabrics are used for tensile tests of fibers. The molding is conducted using a hot press facility (Toyo Seiki Co.)

A Shimadzu autograph tensile test machine (AG-IS) is used for the static tensile test. An extensometer (MTS Co.) is used for measurement strains. The crosshead speed is 1 mm/min. The test condition is referenced to JIS7054.

3 Results and discussion

3.1 Tensile test for cyclic loading (load-unload test)

Stress–strain curves of jute fabric and PP resin are shown in Figs. 1 and 2 respectively. The strength and failure strain of jute fibers are 112 MPa and 7.4%. The strength is 20.8MPa and strain at the maximum stress is 10.1% for PP resin. The strength and failure strains are used for deciding upon an applied load of cyclic loading tests.

Stress–strain curves for tensile cyclic loading are shown in Fig. 3. PP resin, 50% of the ultimate load (σ=50%), 75% of the ultimate load (σ=75%), 82.5% of the ultimate load (σ=82.5%) tests are conducted. The number of cycles is 10. The static tensile test is named the normal type test. For cyclic tests of PP resin, an applied load is 50% of its ultimate load.

Although the stress of PP is within the elastic region, residual strain occurs for the 50% specimen. So, the residual strain occurs in JFRP in the case of the region of elastic region for matrix. The fracture occurs at the sixth loading for the 82.5%

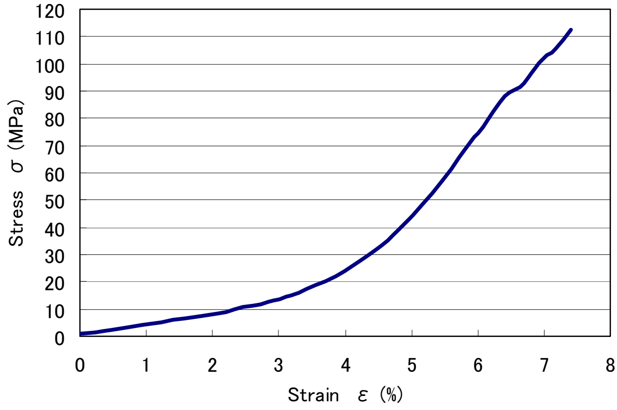

Figure 1: Stress–strain curve for plain woven jute fabric.

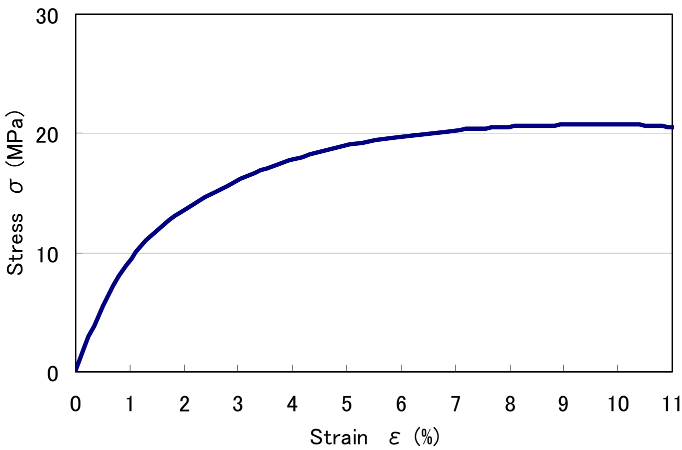

Figure 2: Stress–strain curve for polypropylene (PP).

specimen. At this time, tensile strength and strain decreased 18% and 5% respectively. Therefore, there is a degradation of mechanical properties in the case of the 82.5% loading of ultimate load.

After the cyclic loading test, the static tensile test was conducted for the 75% specimen and the 50% specimen. Figure 4 shows the stress–strain curves. Figure 5 shows the Young's modulus at the first and second cycles in cyclic loadings and static loadings after cyclic loading. At the second loading of the cyclic test, Young's modulus increased 7% for the 50% specimen and 11% for the 75% specimen respectively. At the eleventh loading of the cyclic test, Young's modulus increased 10% for the 50% specimen and 15% for the 75% specimen respectively. This improvement of stiffness seems to be due to pre-loading. In the cyclic test, the Young's modulus of PP does not change, and the residual strain occurs in JFRP, so the residual strain is effective to the improvement of Young's modulus. The strengths for the 50% and 75% specimens after cyclic loading are the same as before the cyclic tests. So, the cyclic test and the residual strain at the cyclic test do not seem to be effective to their strength in the case of the 50% and 75% specimens. However, the strength of the 82.5% specimen decreased. So, there seems to have been damage in the 82.5% specimen.

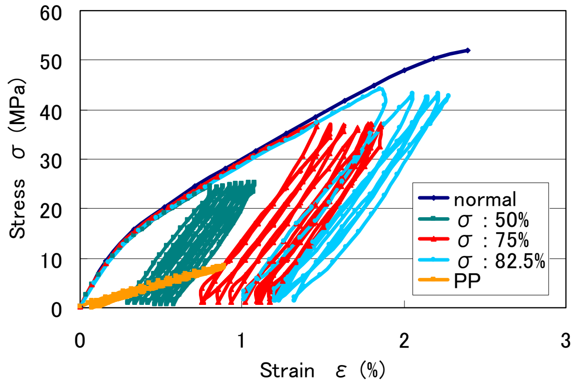

Figure 3: Stress–strain curves for JFRP under tensile cyclic loading.

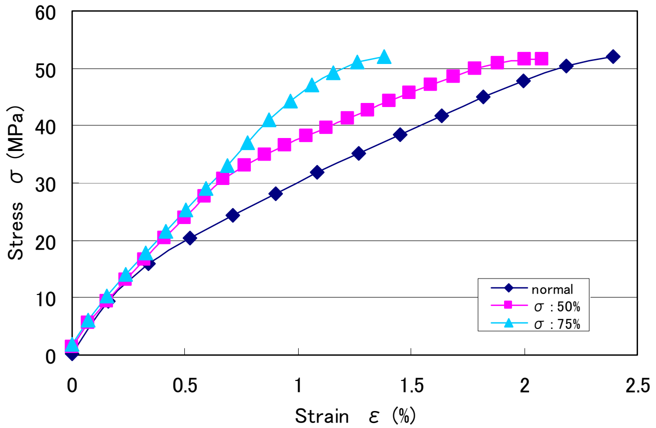

Figure 4: Stress–strain curves for JFRP (σ:50% and σ:75% specimens).

The matrix has visco-elastic properties. So, the residual strains for the 50% specimens and the 75% specimens are examined after cyclic loading. These tests were conducted under no loading condition. Figure 6 shows the residual strain and time curves. The residual strains decreased 30% for the 50% specimen and

25% for the 75% specimen respectively. But the permanent residual strains are 0.12% and 0.40% respectively. So, it is understood that there are a permanent residual strains under these cyclic loading conditions.

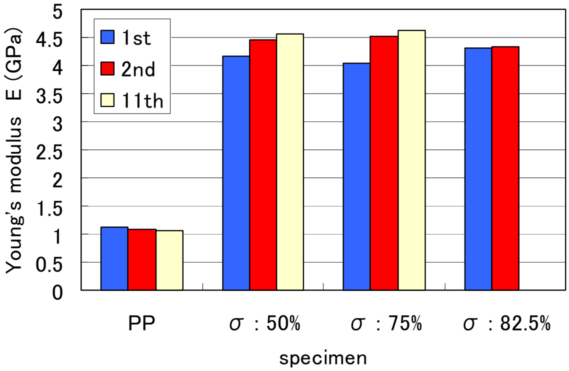

Figure 5: Young's modulus (σ:50%, σ:75% and σ:82.5% specimens).

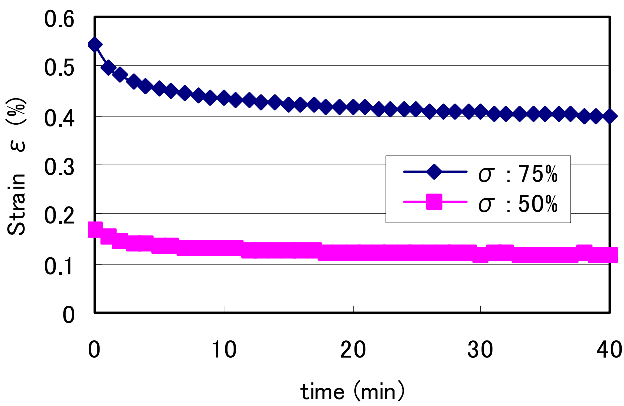

Figure 6: Residual strain (σ:50% and σ:75% specimens).

3.2 Tensile test after heat treatment of fibers

Figure 7 shows the stress–strain curves for JFRP whose fiber was heat treated for 1 hour before molding. The temperatures of heat treatment are 100, 120, 140 degrees centigrade. At the 120 degrees centigrade environment, the mechanical properties are most improved. At this condition, the tensile strength and stiffness were improved by 6% and 25% respectively. The reason is thought to be that the moisture has been removed during drying process at this condition. At 140 degrees centigrade, the tensile strength decreases. This is because heat resolution occurs at a high temperature and so the strength of fibers decreases.

Figure 8 shows stress–strain curves at the 120 degrees centigrade environment. The treatment times are 0.25, 0.5, 0.75 and 1.0 hours. Figure 9 shows the comparisons of tensile strength at this condition. The tensile strength improved 20%, 19%, 17% and 5% at 0.25h, 0.5h, 0.75h and 1 hour conditions respectively. The tensile strength is measured using PLA resin. Heat treatment is conducted under pre-preg conditions. The heat treatment temperature is 120 degrees centigrade. The heating time is 0.5 hour, which is decided from the mentioned JFRP test. Figure 10 shows stress–strain curves for JFRP and JGC. JGC means Jute Green Composite. The strength and Young's modulus of JFRP improve 37% and 19% respectively. On the other hand, they are not changed in the case of JGC. This is because there is a surface film during the process of making pre-preg, and it prevents drying pre-preg of JGC.

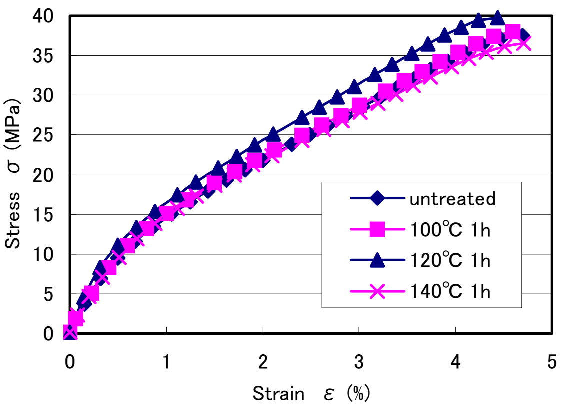

Figure 7: Stress–strain curves for heated JFRP (1h).

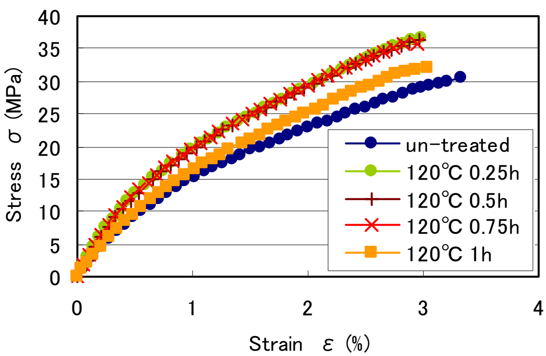

Figure 8: Stress–strain curves for heated JFRP (120℃).

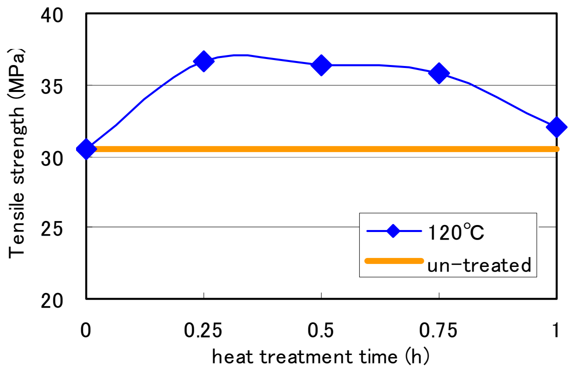

Figure 9: Tensile strength of heated JFRP (120℃).

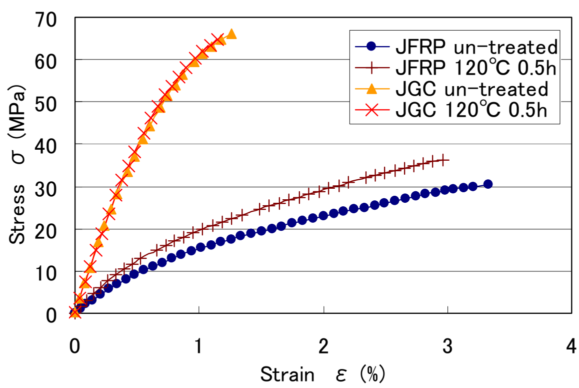

Figure 10: Stress–strain curves for JFRP and JGC.

4 Conclusions

In this study, the static properties of jute fiber reinforced composite are examined. As a result, the following conclusions are obtained.

(1) Young's modulus is improved after load-unload tensile tests.
(2) In the case that the load is lower than 75% of the ultimate one and the number of cycles is ten, the residual strain has no effective on the tensile strength after load-unload tests.
(3) In the case that the load is 82.5% of the ultimate load, the tensile strength decreased.
(4) In the case that the load-unload tests are conducted using 50% and 70% of the ultimate load, the residual strains are 0.12% and 0.40% respectively.
(5) There is an effect of heat treatment on strength and stiffness using JFRP.

(6) There is no effect for tensile strength in the case that heat treatment is conducted to the pre-preg using PLA resin.

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