Effect of treatment using a silane coupling agent on creep properties of jute fiber reinforced composites

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Abstract

In this study, the effects of surface treatment on the tensile and flexural creep properties of a jute fiber reinforced composite were investigated. The reinforcement was plain woven jute fiber cloth and the matrix was polylactic acid (PLA). The jute fiber cloth and PLA are naturally-derived materials. Therefore, the jute fiber reinforced composites have poor interfacial adhesion. Therefore, the silane coupling agent treatment was used to improve the interfacial adhesion. The alkoxy group of silane is hydrolyzed and changed to the silanol group (Si-OH). In addition, interface adhesion improvement is expected by the covalent bond with the hydroxyl group of the jute fiber surface. As a result, the interfacial adhesion between jute fiber and matrix was improved by the silane treatment and the tensile and flexural creep strains of composite decreased. The creep compliance of the composite was improved by using silane treated jute fiber except for the flexural creep compliance at high temperature.

Keywords: natural fiber, PLA, silane coupling agent, creep, surface treatment.

1 Introduction

Glass fiber reinforced plastics (GFRP) have high specific strength, stiffness and corrosion resistance. GFRP has been used for bathtub and marine applications among others. GFRP has an environmental problem concerning its waste disposal after use. More specifically, GFRP generates CO₂ at disposal processing. In order to solve this environmental problem, new composite materials are required as substitutes to GFRP. Recently, research on natural fiber reinforced plastic (NFRP) that combine natural fibers and biodegradable polymers has been actively conducted [1–4].
NFRP is made of naturally-derived materials, but the latter have poor interfacial adhesion. So, NFRP has low mechanical properties. Poor interfacial adhesion often leads to shortage of impregnation and interfacial de-bonding; thus poor interfacial adhesion affects the material strength.

As a solution to the problem, a variety of chemical methods [5] have been used for NFRP. Lee et al. [6] reported the effect of interfacial adhesion on the tensile and flexural properties of polypropylene-bamboo composites. They treated the bamboo fiber with silane coupling agent. The tensile and flexural properties of the composite using silane treated bamboo fiber were improved by the treatment due to the resulting high adhesion between fiber and matrix. Reid et al. [7] reported the effect of the interfacial adhesion on the bending properties of polypropylene-kenaf composites. They treated the kenaf fiber with alkaline solution and silane coupling agent. The flexural behaviour of the composite was improved by the surface treatment. In spite of many reports on NFRP, there are few reported investigations on their creep behaviour for industrial applications and long term safety.

In this study, the effect of surface treatment on creep properties of jute fiber reinforced plastics was investigated.

2 Specimen and testing method

2.1 Materials

PLA sheets (TERAMAK SS300, Unitika Co.) were used as matrix. The reinforcement was plane woven jute fiber cloths (Kawashima Selkon). The Young’s modulus and the density of jute fiber were 26 GPa and 1.44 g/cm³, respectively. The interfacial adhesion between fibers and matrix was modified using a silane coupling agent (Z-6040, TorayDow Corning Co.).

2.2 Surface modification

In order to improve the interfacial adhesion between fiber and matrix, the jute fiber was modified by using a silane coupling agent. The silane coupling agent treatment was carried out in distilled water with 5% silane coupling content for 1 hour at 25°C. After that, the specimens were dried in the oven for 24 hours at 50°C.

2.3 Composites fabrication

For composite fabrication, the plain woven jute fiber cloth was completely dried at 50°C in an oven. The fiber weight fraction of composite was 35 wt%. The composite was fabricated by the compression molding method with vacuum using a heat press machine. Woven jute fiber cloths and PLA sheets were placed in an aluminum matched-die mold. The molding temperature was 190°C, the pressure was 1.3 MPa, and the holding time was 10 min. Then the mold was cooled down to room temperature (R.T.) by city running water. In this article, the
jute fiber reinforced composite is designated as JFC, and silane coupling agent treated JFC is designated as SJFC.

The dimensions of the specimens for the tensile creep tests were based on the Japanese Industrial Standards (JIS K 7115). The length was 250 mm or more, the width 15 ± 0.5 mm and the thickness 3 ± 0.2 mm. The specimens for the flexural creep tests were based on JIS K 7116. Their length was 80 mm or more, the width 10 mm and the thickness 4 mm.

2.4 Tensile creep test

The tensile creep test was also referred to JIS K 7115. Creep tester 100LER (Toyo Seiki Seisaku-sho Co.) was used as the testing machine. In the tensile creep test, the constant load was 300 N (this is about 10% of the tensile strength). The maximum test time was 100 hours, and the environment temperatures were R.T., 40 and 60°C.

2.5 Flexural creep test

The flexural creep test was also referred to JIS K 7116. Creep tester (ADVSNCE FS-620P) was used as the testing machine. In the flexural creep test, the constant load was 40 N (this is about 25% of the bending strength). The maximum test time was 50 hours, and the environment temperatures were R.T., 40 and 60°C.

3 Results and discussion

3.1 Tensile and flexural creep behavior

Fig. 1 shows the tensile creep behavior of JFC and SJFC at R.T. When the initial strains of JFC and SJFC are compared, there is not much difference between

![Figure 1: Tensile creep behavior of JFC and SJFC at R.T.](image-url)
them. However, it can be confirmed that the creep rates of JFC and SJFC decrease 10 hours after the start of the test. The tensile creep strain of SJFC was approximately 30% lower than that of JFC. This behavior can be directly related with the interfacial adhesion. The alkoxy group of silane is hydrolyzed and changed to silanol group (Si-OH) [8]. The interfacial adhesion is improved by the covalent bond with the hydroxyl group of jute fiber surface. This leads to the enhancement of creep behavior.

Fig. 2 shows the tensile creep behavior of JFC and SJFC at 40 and 60°C. The creep strain decreases by the silane treatment at each temperature. There is no significant difference at 40°C between JFC and SJFC. The tensile creep strain of SJFC was approximately 80% lower than that of JFC at 60°C. The glass transition temperature of PLA used in this study is about 58°C. The PLA was rapidly softened above the glass transition temperature. The stiffness of composite can be decreased. Therefore, the tensile creep strain of JFC at 60°C became large. Nevertheless, the use of the silane coupling agent modification noticeably reduced the creep strain at 60°C.

![Figure 2: Tensile creep behavior of JFC and SJFC at 40 and 60°C.](image)

Fig. 3 shows the flexural creep behavior of JFC and SJFC at R.T. Fig. 4 shows the flexural creep behavior of JFC and SJFC at 40 and 60°C. The flexural creep strain of SJFC was approximately 50% lower than that of JFC at R.T. This behavior can be directly related with the interfacial adhesion. The creep strain of SJFC was approximately 60% lower than that of JFC at 40°C. The creep strains of JFC and SJFC at 60°C increased to failure due to glass transition temperature.
3.2 Creep compliance

Fig. 5 shows the relationship between creep compliances and time for three test temperatures. In the case of tensile and flexural creep tests at R.T. and 40°C, the creep compliances of SJFC were lower than those of JFC. In particular,
Figure 5: Relationship between creep compliance and time.
the tensile creep compliance of SJFC at 60°C was noticeably lower than that of JFC at 60°C. However, the flexural creep compliance of SJFC at 60°C was similar to that of JGC at 60°C. Their results implied that interfacial adhesion was affected by the visco-elastic behavior of PLA. Therefore, the tensile creep compliance of the composite was improved by using silane treated jute fiber, and the flexural creep compliance strongly improved except for the test temperature of 60°C.

4 Conclusions

In this study, the effects of surface treatment on tensile and flexural creep properties of jute fiber reinforced composite were investigated. As a result, the following conclusions were reached.

(1) The interfacial adhesion between jute fiber and PLA was improved by the silane treatment. The tensile creep strain of the composite using silane treatment decreased. The result implied that the silanol group (Si-OH) was effective in covalent bond with the hydroxyl group of the fiber surface.

(2) In the case of flexural creep tests under R.T., 40 and 60°C, the flexural creep strain of the composite using silane treatment was approximately lower than that of the untreated composite. The PLA as matrix was rapidly softened at high temperature above the glass transition temperature, and the flexural creep strain decreased. This behavior can be directly related with the interfacial adhesion.

(3) In the case of tensile creep compliance under R.T. and 40°C, the tensile creep compliance of composites using silane treatment was lower than that of the untreated composite. In particular, the tensile creep compliance of the composite using the silane treatment at 60°C was noticeably lower than that of the untreated composite. However, the flexural creep compliance of the composite using the silane treatment at 60°C did not change.

References


