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

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Abstract

In this study, effects of surface treatment on tensile and flexural creep properties of jute fiber reinforced composite were investigated. The reinforcement was plain woven jute fiber cloth and matrix was polylactic acid (PLA). The jute fiber cloth and PLA are naturally-derived materials. So, the jute fiber reinforced composites have a 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 by silanol group (Si-OH). And interface adhesion improvement is expected by 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 composite was improved by using silane treated jute fiber except for 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, marine applications and so on. GFRP has an environmental problem about waste disposal after use. However, GFRP generates CO_2 at disposal processing. In order to solve this environmental problem, new composite materials were required instead of GFRP. Recently, the researches on natural fiber reinforced plastic (NFRP) that combines the natural fibers and biodegradable polymer were actively conducted [1–4].

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NFRP is naturally-derived materials, but it has a poor interfacial adhesion. So, NFRP has low mechanical properties. Poor interfacial adhesion often leads to shortage of impregnation, interfacial deboning and poor interfacial adhesion affect 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 tensile and flexural properties of polypropylene-bamboo composites. They treated the bamboo fiber with silane coupling agent. The tensile and flexural properties of composite using silane treated bamboo fiber were improved by the treatment for the high adhesion between fiber and matrix. Reid *et al*. [7] reported the effect of the interfacial adhesion on bending properties of polypropylene-kenaf composites. They treated the kenaf fiber with alkaline solution and silane coupling agent. The flexural property of the composite was improved by surface treatment. In spite of many reports on NFRP, there is a few report of the creep property for industrial application and long term safety.

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

2 Specimen and testing method

2.1 Materials

PLA sheet (TERAMAK SS300, Unitika Co.) was used as matrix. The reinforcement was plane woven jute fiber cloths (Kawashima Selkon). Young's modulus and the density for jute fiber were 26 GPa and 1.44 (g/cm^3) 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 interfacial adhesion of fiber and matrix, the jute fiber was modified by using silane coupling agent. Silane coupling agent treatment was carried out in distilled water with 5 % silane coupling content for 1 hour at 25^{o}C. After that, the specimens are dried in the oven for 24 hours at 50^{o}C.

2.3 Composites fabrication

For composite fabrication, the plain woven jute fiber cloth was completely dried at 50^{o}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^{o}C, pressure was 1.3 MPa, and holding time was 10 min. Then the mold was cooled down to room temperature (R.T.) by city running water. In this study, jute fiber reinforced composite is called as JFC, and silane coupling agent treated JFC is called as SJFC.

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

2.4 Tensile and flexural creep test

The tensile creep test was also referred to JIS K 7115. Creep tester 100LER (Toyo Seiki Seisaku-sho Co.) was used for testing machines. In the tensile creep test, the constant load was 300N (it is about 10% of the tensile strength). The maximum test time was 100hours, and 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 for testing machines. In the flexural creep test, the constant load was 40N (it is about 25% of the bending strength). The maximum test time was 50hours, and environment temperatures were R.T., 40 and 60°C.

3 Results and discussion

3.1 Tensile and flexural creep behavior

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

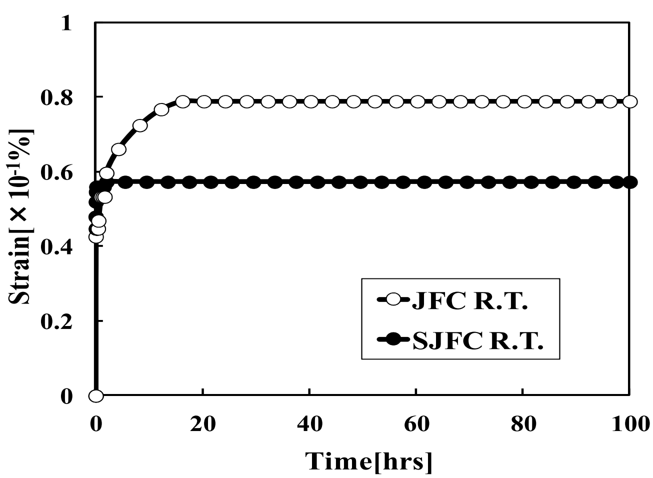

Figure 1: Tensile creep behavior of JFC and SJFC at R.T.

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them. However, it can be confirmed that the creep rates of JFC and SJFC decrease at 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 silanol group (Si-OH) [8]. The interfacial adhesion is improved by covalent bond with the hydroxyl group of jute fiber surface. It leads to the enhancement of creep behavior.

Figure 2 shows tensile creep behavior of JFC and SJFC at 40 and 60°C. The creep strain decreases by silane treatment at each temperature. There is no significant difference in 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, tensile creep strain of JFC at 60°C became big. Nevertheless, the use of the silane coupling agent modification was noticeably reduced the creep strain at the 60°C.

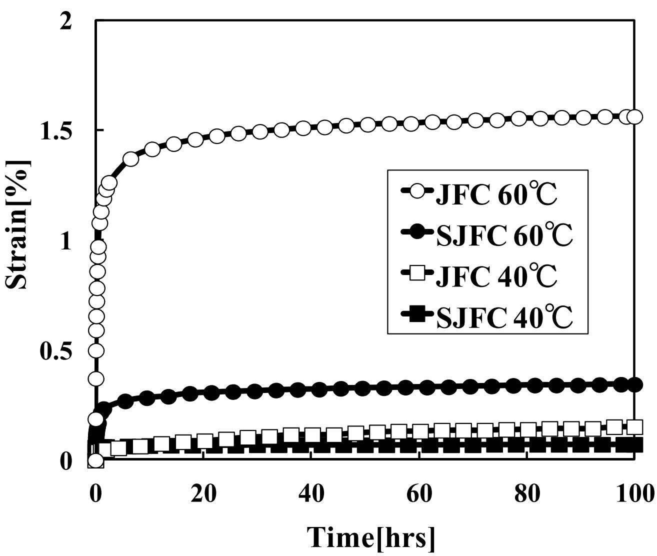

Figure 2: Tensile creep behavior of JFC and SJFC at 40, 60°C.

Figure 3 shows flexural creep behavior of JFC and SJFC at R.T. Figure 4 shows 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. Creep strains of JFC and SJFC at 60°C increased to failure due to glass transition temperature.

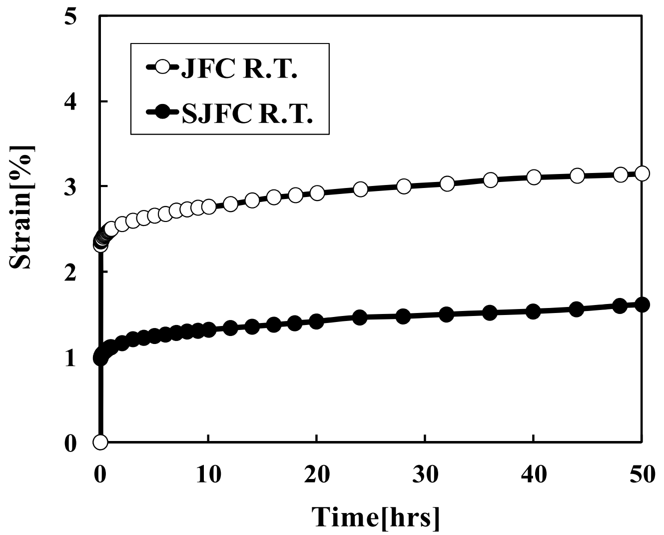

Figure 3: Flexural creep behavior of JFC and SJFC at R.T.

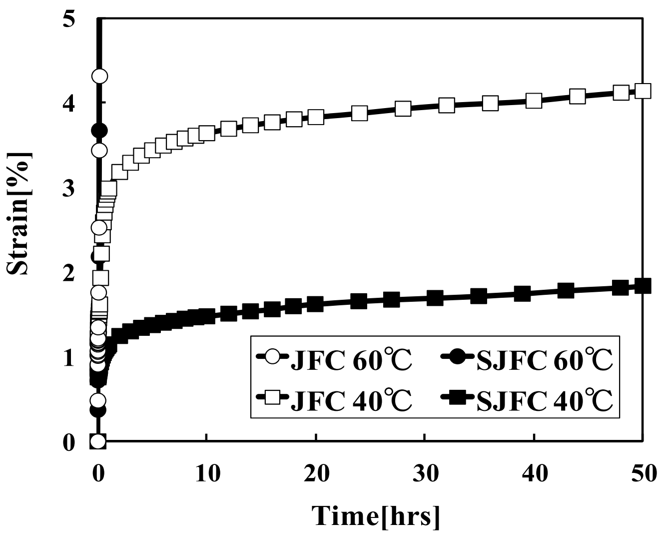

Figure 4: Flexural creep behavior of JFC and SJFC at 40, 60^{o}C.

3.2 Creep compliance

Figure 5 shows relationship between creep compliances and time under three temperatures. In case of tensile and flexural creep tests under R.T. and 40^{o}C, creep compliances of SJFC were lower than those of JFC. In particular, tensile

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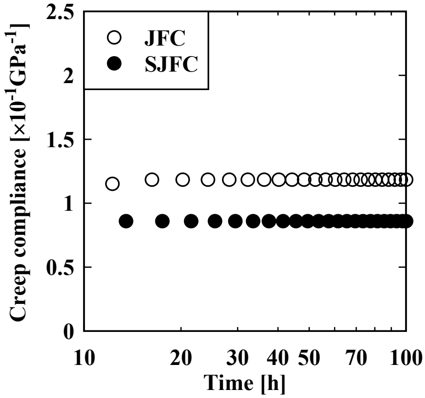
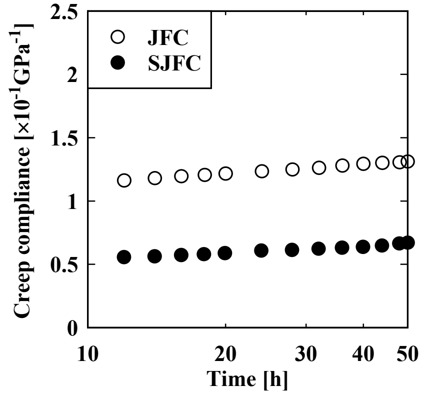
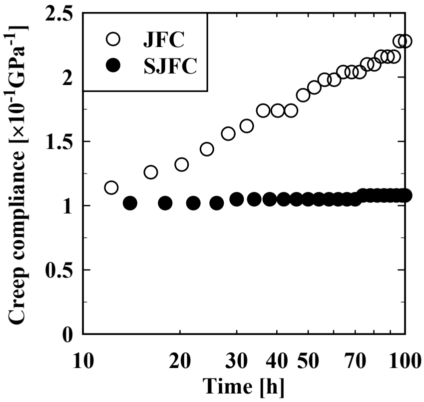


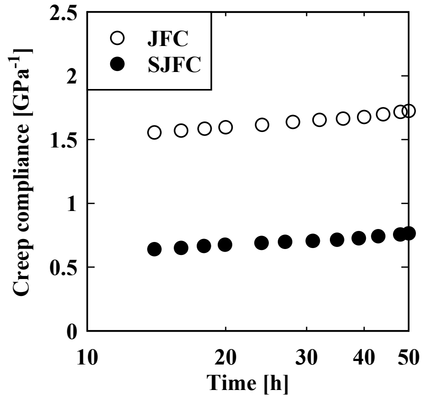
(a) Tensile test at R.T.



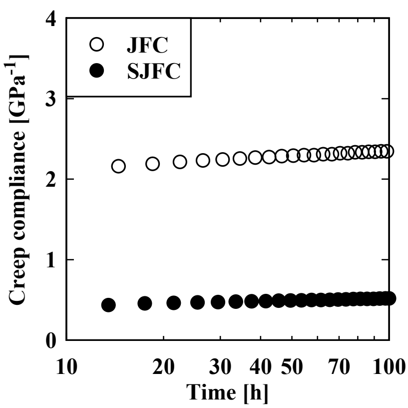
(b) Flexural test at R.T.



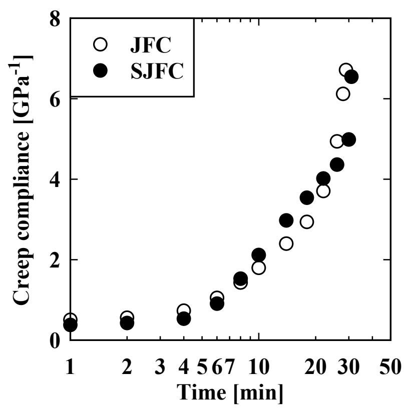
(c) Tensile test at 40^{o}C.



(d) Flexural test at 40^{o}C.



(e) Tensile test at 60^{o}C.



(f) Flexural test at 60^{o}C.

Figure 5: Relationship between creep compliance and time.

creep compliance of SJFC at 60°C was noticeably lower than that of JFC at 60°C. However, 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 visco-elastic behavior of PLA. Therefore, tensile creep compliance of composite was improved by using silane treated jute fiber, and the flexural creep compliance strongly improved except for 60°C.

4 Conclusions

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

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

(2) In case of flexural creep test under R.T., 40 and 60°C, the flexural creep strain of composite using silane treatment was approximately lower than that of virgin composite. The PLA as matrix was rapidly softened in 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 case of tensile creep compliance under R.T. and 40°C, tensile creep compliances of composites using silane treatment were lower than that of virgin composite. In particular, tensile creep compliance of composite using silane treatment under 60°C was noticeably lower than that of virgin composite. However, flexural creep compliance of composite using silane treatment at 60°C did not change.

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