Effect of surface and heat treatment on tensile properties of jute fiber reinforced composites

K. Takemura

Kanagawa University, Japan

Abstract

In this study, the tensile properties of fiber reinforced plastics using natural fibers were investigated. Jute fibers were chosen as reinforcement. Polypropylene was used as the matrix. Jute fiber reinforced plastics were laminated using a conventional hot press facility. Surface treatment using the astringency of persimmon was performed on the jute fibers before molding. Surface treatment using heat treatment on jute fibers in an oven was also conducted. The static tensile and creep properties of jute fiber reinforced composites were investigated. As a result, the following conclusions were drawn: (1) the treatment using the astringency of persimmon is effective in improving the interfacial strength between jute fiber and the matrix and it decreases the initial elastic strain in a creep test; (2) in a static tensile test, the treatment using the astringency of persimmon increases the initial stiffness; the improvement ratio decreases as the applied load increases; (3) the treatment involving the heating of fibers before molding has an effect to the extent of increasing the tensile strength and initial stiffness, because the treatment improves the interfacial strength between the fiber and the matrix; (4) the effect of heat treatment is highest in the case when the temperature is 120°C and the treatment duration is half an hour.

Keywords: green composite, jute fiber, polypropylene, tensile properties, creep, surface treatment, heat treatment.

1 Introduction

Glass fiber reinforced plastics (GFRP) have been popular for use in many mechanical parts. Because of their superior advantages, such as durability, high specific strength, stiffness, GFRPs have replaced metals in many applications. Recently, there has been a waste disposal problem concerning fishing boats and

other items made of GFRP. The glass fiber has a high chemical stability and it is also difficult to be burned out. Thus, GFRP composite materials, particularly those manufactured using thermoset resins, are almost impossible to be recycled or reused. As a solution to such problems, there has been a lot of interest in developing green composites. These green composites are characterised by fully sustainable, biodegradable, environment friendly and renewable fibers, which are called natural fibers.

Recently, there have been some studies on manila hemp, bamboo fibers as reinforcement in green composites. The Manila hemp fiber reinforced composite has a high strength which is above 350 MPa [1, 2]. However, it has the problems of high cost and a small market. For the bamboo fiber reinforced composite, there are a lot of studies regarding their mechanical properties [3–5]. Many researchers who participated in the 5th International Workshop for Green Composites, held in 2008 in Japan, were interested in this issue [6, 7].

Currently, the focus has been on jute from the viewpoint of cost. Moreover, it is easy to get jute fibers from the general market, therefore jute fiber reinforced plastics (JFRP) are considered in this study. Static tensile tests on this composite are conducted in order to examine its strength and stiffness. Natural fibers have been used in fishing nets for a long time in Japan. Many chemical treatment methods have been applied to these natural fibers. Among them, the astringency of a persimmon has been used for improving the surface of natural fibers. Therefore, surface treatment is applied to the jute fiber using the astringency of a persimmon. Surface treatment of jute fibers using heat treatment in an oven is also applied. Subsequently, the static tensile test and creep properties of JFRP are investigated.

2 Specimen and experimental procedure

2.1 Specimen

Plain woven jute fabric was used as reinforcement. The directions of jute fibers are parallel and perpendicular to the load direction. Polypropylene resin sheet (Shin Kobe Electric Inc. PP-N-AN) was used as a matrix. The plate of the composite was molded with a conventional hot pressing technique (Toyo Seiki Co., Mini Test Press MP-WCL). To process the composite, jute fabric sheets were put into the metallic mold. The mold with material was vacuumed with a heat resisting film bag in the process.

The geometry of specimens was based on JIS (Japanese Industrial Standard) 7054. The length of the specimen was 200 mm. The breadth and thickness were 10 mm and 2.5 mm, respectively.

2.2 Surface treatment using the astringency of a persimmon

For a surface treated specimen, the plain woven fabric was laid in the solution of astringent persimmon. The density of the solution was 25%. After absorbing the solution, the fabric was dried in an oven for five hours.

2.3 Heat treatment before molding

Jute fabrics were laid in an oven and they were dried before molding. Four lengths of time 0.25 h, 0.5 h, 0.75 h and 1.0 h were used. Also, four levels of heat temperature 80, 100, 120 and 140°C were used.

2.4 Static tensile and creep tests

The Shimadzu autograph tensile test machine (AG-IS) was used for the static tensile tests. The test condition was referenced to JIS7054. The crosshead speed was 1.0 mm/min.

The Creep Tester 100LER (Toyo Seiki. Co.) was used for creep tests. This test is referenced to JIS7087. The test is continued until the failure of the specimen. When a specimen does not fail, the creep test stops after 100 hours. Three specimens can be tested simultaneously in this test machine. Creep strains were measured throughout the test. Before the test, the surfaces of the composite were observed using Scanning Electron Microscope (SEM) to confirm the effect of the treatments.

3 Results and discussion

3.1 Tensile creep properties for surface treatment

Fig. 1 shows the tensile creep curves when the applied loads are 200 N, 300 N and 400 N. In this figure, U means untreated data and K means treated data using

Figure 1: Comparison of untreated (U) and surface treated (K) JFRPs.

the astringency of a persimmon. When the applied loads are 300 N and 400 N, the curves have a transient creep region and a steady creep region, and the specimens do not fail. On the other hand, when the applied load is 400 N, they also have an accelerating creep region, and the specimens fail several hours after the test started. When the applied load is 400 N, the treated specimen fails faster than the untreated specimen. When the applied load is 300 N, there is no distinct difference between either curve. On the other hand, the strain of treated specimen is smaller than that of an untreated specimen when the applied load is 200 N. The treatment especially affects the elastic strain. So, when the applied load is relatively low, the effect of surface treatment is emerging.

3.2 Static tensile properties for surface treatment

Fig. 2 shows the stress-strain curves for untreated and surface treated JFRPs. Table 1 shows the Young’s modulus when the strain is 0.05 and 2.0 percent. From this figure and table, the initial stiffness for treated JFRP can be seen to be bigger than that of untreated JFRP. As the strain increases, the difference in stiffness decreases.

Figure 2: Stress-strain curves for untreated (U) and surface treated (K) JFRPs.

Table 1: Young’s modulus of JFRP with surface treatment.

Strain		0.05%	2.0%
Young’s modulus (GPa)	Treated	2.39	0.67
	Untreated	2.03	0.66

So, this surface treatment is effective in increasing the initial stiffness. In the creep test which is already mentioned, when the applied load is low, the effect of the surface treatment is distinct. This phenomenon of initial stiffness is thought to be the reason for the difference in creep strains.

3.3 Observation of jute fibers after surface treatment by SEM

Figure 3(a), (b) show the SEM photographs of untreated and treated jute fibers. From the photographs, it is understood that the untreated fibers do not make fiber bundles, but the treated fibers can make fiber bundles. Astringent persimmon has tannin which makes a skin layer on the fiber surface, so the surface of fibers is thought to be sticky. This is thought to be the reason of the initial stiffness increase.

Figure 3: SEM photographs of jute fibers with surface treatment.

3.4 Tensile properties of JFRP using heat treated jute fiber

Figs. 4(a)–(d) show the stress-strain curves for heat treated and untreated JFRP. Table 2 shows the tensile strength and stiffness. When the heating temperatures are 80, 100, 120°C, and heating times are 0.25, 0.5, 1.0 hours, the tensile strength and stiffness are improved by heat treatment. Among these cases, the case when the heating time is 0.5 hour, the effect is large. On the other hand, when the heating temperature is 140°C, the effective case is only when the heating time is 0.5 hour. In this case, the effect is smaller than that for 120°C. The strength of bamboo fibers and manila hemp fibers decreases due to heat resolution above 140 and 160°C, respectively. The strengths of both fibers decrease by 60% at 200°C. The strength of jute fiber is thought to decrease at around 140°C. So, the decrease in strength of JFRP is due to a heat resolution around 140°C. Under this temperature condition, the effect is the highest when the heat time is 0.5 hour. When the heating time is longer than 0.5 hour, there is no effect. This is because that heat resolution is dependent on the heating time in the conditions.

(a) 80°C

(b) 100°C

(c) 120°C

Figure 4: Stress-strain curves of JFRP with heat treatment.

Figure 4: Continued.

Table 2: Tensile properties of JFRP with heat treatment.

		0.25h	0.5h	0.75h	1.0h
Tensile strength (MPa)	80°C	32.9	33.6	33.2	32.2
	100°C	32.3	33.4	32.4	32.6
	120°C	36.0	36.7	35.7	32.2
	140°C	30.5	33.3	30.5	29.5
	Untreated	30.5			
Young's modulus (GPa)	80°C	2.13	2.30	2.30	2.30
	100°C	2.14	2.47	2.27	2.22
	120°C	2.80	2.83	2.78	2.14
	140°C	2.06	2.31	2.16	2.03
	Untreated	2.03			

3.5 Observation of jute fibers after heat treatment

Figs. 5(a), (b) show the SEM photographs of untreated and heat treated jute fibers. The treatment condition was that the heating temperature was 120°C and heating time was 0.5 hour. From these photographs, it is understood that untreated fibers have not formed a fiber bundle and treated fibers formed a better bundle. Natural fibers have many voids in them and, as a consequence, they can absorb moisture. Under heating treatment, the moisture in jute fiber evaporates. So the resin can penetrate between fibers during molding. Thus, the strength and stiffness is thought to be increased by heat treatment. The reason why the effect of heat treatment increases as treatment temperatures increase is because the vaporization is more strongly activated under high temperature conditions. As a result, the strength at the interface between fibers and matrix is thought to be

high. Furthermore, the reason the effect for a 0.5 hour treatment is bigger than that for 0.25 hour, is also the water vaporization in jute fibers.

Figure 5: SEM photographs of jute fiber with heat treatment.

4 Conclusions

As a result of this investigation, the following conclusions are drawn:

- (1) The treatment using the astringency of persimmon is effective in improving the interfacial strength between jute fiber and matrix and it decreases the initial elastic strain in a creep test.
- (2) In a static tensile test, the treatment using the astringency of persimmon increases the initial stiffness. The improvement ratio decreases as the applied load increases.
- (3) The treatment involving the heating of the fibers before molding has the effect of increasing the tensile strength and initial stiffness because the treatment improves the interfacial strength between fiber and matrix.
- (4) The effect of using heat is the highest in the case when the temperature is 120°C and the treatment time is half an hour.

References

- [1] Ochi, S., Development of high strength biodegradable composites using manila hemp fiber and starch-based biodegradable resin. *Composites Part A: Applied Science and Manufacturing*, **37**(11), pp.1879-1883, 2006.
- [2] Ochi, S., Takagi, H. & Tanaka, H., Tensile properties of manila hemp reinforced cross-ply “green” composites. *Journal of the Society of Materials Science*, **52**, pp. 916-921, 2003.
- [3] Lee, S. & Wang, S., Biodegradable polymers/bamboo fiber biocomposite with bio-based coupling agent. *Composites Part A: Applied Science and Manufacturing*, **37**, pp. 80-91, 2006.
- [4] Takagi, H. & Takura, R., The manufacture and mechanical properties of composite boards made from starch-based biodegradable plastic and bamboo powder. *Journal of the Society of Materials Science*, **52**, pp. 357-361, 2003.

- [5] Takagi, H. & Ichihara, Y., Effect of fiber length on mechanical properties of “green” composites using a starch-based resin and short bamboo fibers. *JSME International Journal Series A Solid Mechanics and Materials Engineering*, **47(4)**, pp. 551-555, 2004.
- [6] Tanaka, K., Masabe, Y. & Katayama, T., Mechanical properties of jute fabric reinforced PLA nonwoven sheet composite. *Proc. of 5th Int. Workshop on Green Composites*, pp. 37-41, 2008.
- [7] Takagi, H. & Hagiwara, Y., Microfracture behavior of hemp fiber-reinforced green composite. *Proc. of 5th Int. Workshop on Green Composites*, pp. 23-26, 2008.