EFFECT OF SURFACE TREATMENT ON THERMAL AND MECHANICAL PERFORMANCE OF JUTE FABRIC REINFORCED ENGINEERING THERMOPLASTIC COMPOSITES

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1. Introduction

Fiber reinforced composite, usually made of glass, aramid, or carbon fiber reinforced with polymer, are being used extensively, because of they are sustainable high mechanical performance. However, they are non-biodegradability, quite expensive materials, and the demands of consumer related to recycling materials [1].

In recent years, many researcher was interested in the thermoplastic composited reinforced with natural fiber. Natural fibers, such as jute, sisal, and hemp can potentially serve as cheap reinforcement of polymer if compounded into polymers without decomposition. Natural fiber reinforced thermoplastic composites have been used widely, because of the combination between natural fiber and thermoplastic composites can produce high performance composites and the development of natural fiber composites has been a subject of interest for the past few years. These natural fibers were low density, low cost, renewable, biodegradability, and environment friendly [2-3].

However, there were two disadvantages of using natural fibers in thermoplastic. The inherent polar and hydrophilic nature of jute fibers and non-polar characteristic of the polymer matrix (hydrophobic) create difficulties in compounding and result composites of poor mechanical performance. Fiber modification, physical modification and chemical modification, which were improved the adhesion between the fiber surfaces and the polymer matrix, which may not only improve fiber surface. It can also increase fiber strength and the mechanical properties were improved [4-5]. Rashed et al studied about jute fiber reinforced polypropylene. The tensile strength was increased after alkalized treated jute fibers [6]. Cao et al reported 13 % improvement in tensile strength, 14 % in flexural strength and 30% in impact strength after fibers were treated with 1 % NaOH solution [7].

Another drawback, the processing temperature of the natural fiber-reinforced thermoplastics is limited due to the potential of fiber degradation at high temperatures. Therefore, polymer matrices that can be used with natural fibers are also limited to low melting temperature thermoplastics such as polypropylene, polyethylene, poly (vinyl) chloride, polystyrene, and poly (lactic acid). However, most of these thermoplastics were inherently weak as compared to high temperature engineering thermoplastics [8]. Sadhan *et al.* attempted to develop wood flour composites with high temperature thermoplastic polymers as the matrix resin. They mixed unsaturated polyester with PPE to reduce the melting temperature of the latter prior to incorporation of wood flour through twin-screw extrusion. The composite exhibited an improvement in mechanical performance since low processing temperatures were used to prevent extensive degradation to the wood flour whereas the matrix itself exhibited high strength and stiffness. Because of thermosetting polymers were among the most important materials in many diverse industries and were being used increasingly in structural engineering applications [9-10].

Polycarbonate (PC) is amorphous thermoplastic and extensively used engineering thermoplastic and characterized by its flame resistance, dimensional stability, transparency, high impact strength, and high heat distortion. However, PC has some disadvantage, which is poor solvent resistance, low fatigue strength, and high melt viscosity. Moreover, it is relative soft and the surface of polymer was poor durable to scratch and shows high notch sensitivity, susceptible to cracking on exposure to various solvent. These drawbacks of PC can improve by the addition of impact modifier or fiber reinforcement [11]. In this study, jute fiber-reinforced composites were fabricated by using high temperature engineering thermoplastics such as polycarbonate (PC) as the matrix resins. The jute mats were treated by thermosetting resin to improve their thermal resistance prior to molding of the composites. The thermal decomposition characteristics of the jute fibers before and after treatment were evaluated by using thermal gravimetric analysis (TGA) while several static mechanical tests were also performed to evaluate the performance of the composites.

2. Experimental

2.1 Materials

The matrix resin used in this study was polycarbonate (PC) (grade S3000) supplied by Mitsubishi Engineering Plastic Corporation, Japan. The melt flow index (MFI at 230 ^{O}C and 2.16 kg) and density of PC were 15 g/10min and 1.2 g/cm^3. Two types of thermosetting resins were used as surface treatments, i.e. epoxy, unsaturated polyester (UP), and Flexible epoxy. Epoxy resin (78% Bisphenol A + 11%Butyl-glycidyl-ether) and the curing agent (diethylene-tri-amine) were supplied by Refinetech Co. Ltd. while the UP resin (Styrene 50-60 %) (grade 150HR BQNTINW) was supplied by Highpolymer Co. Ltd. The curing (methyl-ethyl-ketone-peroxide) agent of UP was supplied by NOF Corporation. Recycled woven jute coffee bags with a thickness of approximately 0.5 mm provided by a coffee company in Japan were used as the reinforcement. The density of jute fiber was 1.52 g/cm^3.

2.2 Sample preparation methods

Jute mats were dried at 80 °C for 24 hours in the vacuum oven prior to being immersed in epoxy or UP resin. The ratio of the resin and its curing agent was determined in weight ratio of 100:1. The concentrations of curing agent were varied 10 wt% for epoxy resin where as the concentrations of curing agent of UP resin were 1.0 wt%. After immersion, the jute sheets were hung up and allowed to cure at room temperature for 12 hours. Post curing of the jute sheets was done in an oven set at 100 °C for 2 hours. The thickness of the resin treatment was determined to be approximately 0.8 mm.

2.3 Processing

2.3.1 Heat treatment of jute fiber

The single jute fibers were subjected to heat treatment at 200 ºC by using hot dry air in a furnace for 0, 15, 30, 45 and 60 minutes. At least 5 single jute fibers were used for heat treatment for each condition.

2.3.2 Jute fiber reinforced composites

The composites consist of a layer of jute mat sandwiched between the matrix sheets of PC. The size of matrix sheets was 150 mm long ×150 mm wide ×1 mm thick whereas the jute sheets were 150 mm long ×150 mm wide ×0.5 mm thick. The composites were prepared by compression molding. The molding temperature was set at 270 °C. Compression molded was pressed under a constant pressure of 100 kgf/cm^2. The molding time was varied at 1.5, 3, 4.5 and 6 minutes.

2.4 Characterizations

2.4.1. Single jute fiber

TGA measurements were carried out on the treated jute fibers by using a thermo gravimetric analyzer (TGA) (TA Instrument 2950) over temperature range of 40 to 600 ºC, at a heating rate of 50 ºC/min. Measurements were performed in air. And tensile test was conducted on single jute fiber. Tensile test were performed by using an Instron 4206 universal testing machine at an extension rate of 5 mm/min. At least five single jute fibers were test for each condition.

2.4.2. Jute fiber reinforced composites

The specimens were cut into strips in order to perform 3-point flexural test (ASTM D790) by using an Instron 4206 universal testing machine at 28 ºC. The flexural tests were conducted at a crosshead speed of 1 mm/min. Span length was set at 40 mm. Tensile test was carried out with an Instron 4206 machine at 28 ^{O}C, according to ASTM D 3039, at a crosshead speed of 1 mm/min. At least five composite specimens were test for each

condition. The fracture surfaces of the composites were observed by using an optical microscope (Keyence VH-S30).

3. Result and discussion

3.1 Influence of Surface Treatment on Thermal Degradation Resistance of Jute Fiber

Fig. 1 and table 1 present the result of TGA of the untreated and treated jute fibers. It can be seen that untreated jute fibers started to degrade considerably after 270 ºC. In the case of UP and epoxy resins, the onset degradation temperatures were 372 and 362 ºC, respectively, which were significantly higher than that of jute fibers. Therefore, the jute fibers treated with UP or epoxy resin would exhibit higher degradation temperatures at 345 and 324 ºC, respectively. Hence, the thermal degradation resistance of the jute fibers can be improved by treatment of the thermoset resins.

3.2 Effect of heat treatment on strength of untreated and treated single jute fiber

The strength of jute fiber was determined by tensile testing. Fig. 2 presents the effect of heat treatment on strength of single jute fiber without and with thermosetting treatment. Tenacity of jute fiber decreased significantly when subjected to heat treatment at 200 °C for long time. It was due to degradation of jute fiber after heat treatment. Declination of tenacity after heat treatment of untreated jute fiber was lower than treated jute fiber. It was due to stiffness of untreated jute fiber was higher than the fiber after surface treatment.

3.2 Effect of Molding Time on Mechanical Properties of Composites

Fig. 3-4 shows the tensile modulus and flexural modulus of untreated and treated jute fiber reinforced polycarbonate composites at molding temperature of 270 °C with molding time of 1.5, 3, 4.5 and 6 minutes. It was observed that molding time did not affect the tensile modulus and flexural modulus of untreated and treated jute fiber reinforced composite. Moreover, the moduli of treated jute fiber reinforced composites were higher than untreated jute fiber reinforced composites. It could due to the epoxy and UP can be improved the stiffness of the jute fiber.

Fig. 5-6 shows the tensile modulus and flexural modulus of untreated and treated jute fiber reinforced polycarbonate composites at molding temperature of 270 °C with molding time of 1.5, 3, 4.5 and 6 minutes. For untreated and treated jute fiber, longer molding times would cause significant deterioration in mechanical properties. This indicates that the longer molding times caused more void at interface area and also reduce fiber-matrix interfacial strength, as show in Fig 7.

Mechanical properties of untreated jute were higher than both UP and epoxy treated jute. It can be observed the delamination between jute fiber and polycarbonate of UP and epoxy treated specimens due to polycarbonate cannot impregnate into the thermoset coated jute fiber, as show in Fig 8.

4. Conclusions

This study established that both the epoxy and UP treatments were able to improve the thermal degradation resistance of jute fibers. The UP resin was especially effective in enhancing the thermal resistance of jute thermoset can improve the thermal resistance of jute fibers. Heat treatment at 200 °C has been an effect on degradation of jute fiber both without and with surface treatment. Declination of tenacity after heat treatment of untreated jute fiber was lower than jute fiber with epoxy and UP treatment.

Thermal degradation analysis results suggest that the epoxy and UP surface treatments were effective in improving the thermal degradation resistance of the jute fibers. This allowed the processing of jute fibers with high temperature engineering thermoplastics. However, short molding times, i.e. less than 3 minutes, should be used to avoid excessive heat transfer that could lead to deterioration of the jute fibers as well as interfacial adhesion strength.

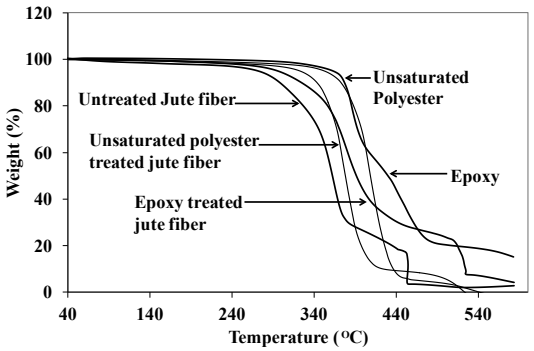

Fig. 1: TGA of jute, thermoset resin, thermoset impregnate in jute at 50 ºC

Table 1: Onset temperature of specimen

Materials	Onset degradation temperature (ºC)
Untreated jute fiber	270
Epoxy	362
Epoxy treated jute fiber	324
Unsaturated polyester	372
Unsaturated polyester treated jute fiber	345

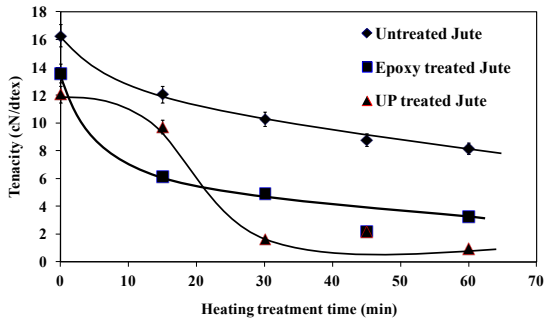

Fig. 2 Tenacity of jute fiber after heat treatment at 200 °C for 0, 15, 30.45 and 60 min of Untreated, Epoxy treated and UP treated jute fiber.

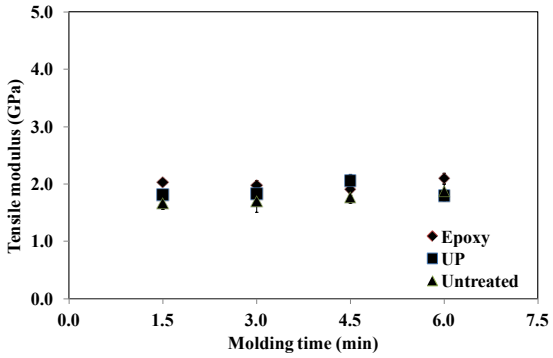

Fig. 3 Effect of molding time of untreated and treated jute fiber reinforced composites on tensile modulus.

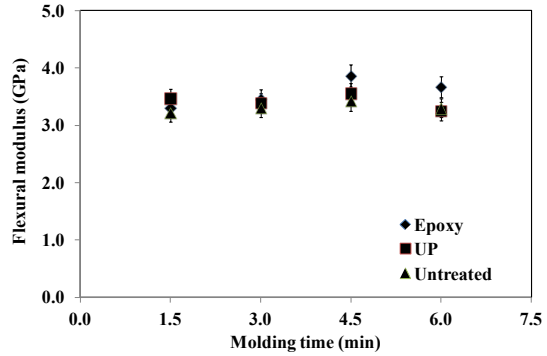

Fig. 4 Effect of molding time of untreated and treated jute fiber reinforced composites on flexural modulus.

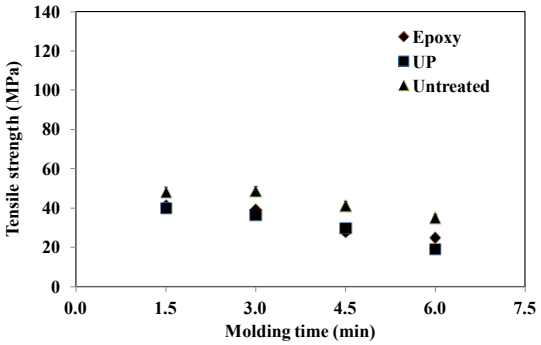

Fig. 5 Effect of molding time of untreated and treated jute fiber reinforced composites on tensile strength.

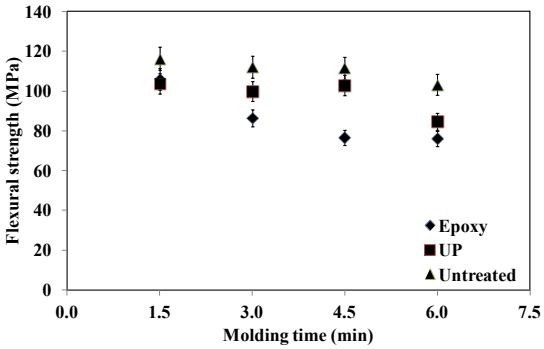

Fig. 6 Effect of molding time of untreated and treated jute fiber reinforced composites on flexural strength.

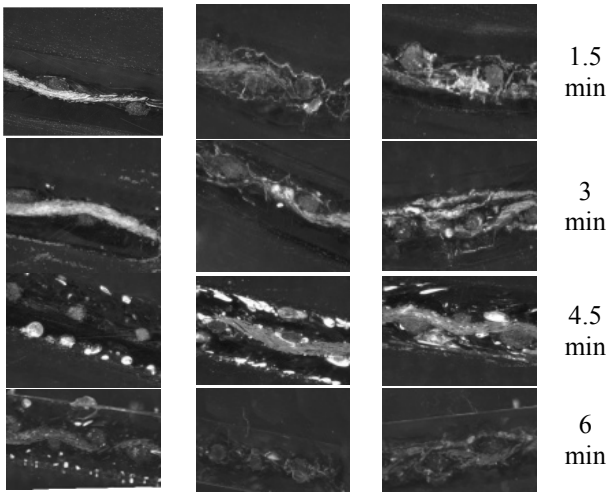

Fig. 7 The fracture surface of untreated and treated jute reinforced composite after flexural testing at several molding times.

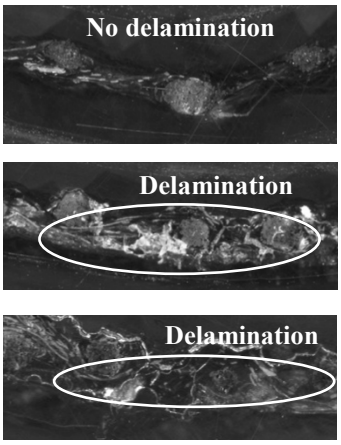

Fig. 8 The Cross-section of untreated and treated jute reinforced composite after flexural testing, Molding time at 1.5 minutes

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