Effect of Weight Fractions of Jute Fiber on Tensile Strength and Deflection Temperature of Jute Fiber/Polypropylene Composites

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Abstract. Jute is one of eco-friendly natural fiber with relatively low cost and high volume production. This study aimed to determine the effect of weight fractions of jute fiber as a reinforcement in polypropylene (PP) to obtain an optimum properties of PP/jute fiber composites. Jute fiber was pre-treated through alkalization. The PP was initially produced by extrusion process, followed by fabricated the composites by compiling the PP matrix and jute fibers into lamina using a hot-press method. The results of tensile test and heat deflection temperature test showed that the addition of 40 wt% jute fiber to the PP increased the tensile strength about 19.7 % up to (38.2±4.9)MPa, the Young modulus about 79.8 % up to (3.20±0.26)GPa, and the heat deflection temperature about 143% up to (143.3±1.14)°C compared to pristine PP. Based on Scanning Electron Microscopy observation on the fracture surfaces, it was shown that the mode of failure on the composites failure surfaces was "fiber pull-out", which due to the poor interface bond between the fiber and the matrix.

1. Introduction
Over the last few years the application of natural fibers in composites is increasingly used in various fields like the automotive, furniture and packaging [1]. Natural fibers have several advantages compared to synthetic fibers, such as relatively low cost, relatively low density, renewable and biodegradable. In addition, natural fibers showed a tendency to replace glass fiber reinforced polymer composites. One of the reasons is that natural fibers have a comparable strength and a similar specific modulus with fiber glass [1]. The strength of natural fibers depends on the fiber structure. The properties of natural fibers are influenced by the location, climatic conditions, age of the plants and extraction methods that are used. More over, natural fibers generally have a composition of cellulose, hemicellulose, lignin, pectin and waxy substance that allows absorption of water from the environment, and these substances will form a poor interface bonding with the matrix [2]. One of the plant fibers that is often used as reinforcement in composites is jute. As one of the cheapest natural fiber with the highest volume production, jute shows the advantages to produce material with relatively low production costs and high availability [3].

Compatibility between the hydrophilic nature of natural fibers and hydrophobic nature of polymer matrix is a major problem. Incompatibility between natural fiber and polimer caused poor interface...
bonding, that decrease composite strength. Therefore, natural fiber modifications such as chemical treatment, coupling agent and acetylation are considered in modifying the fiber surface properties to improve their adhesion with different matrices. Natural fiber modification improves the interface and wettability between the matrix and fiber; and at the end to improve mechanical properties of composites [4]. In this study, alkalization of fiber with a 5% solution of sodium hydroxide (NaOH) was performed before the fiber used as reinforcement in composites. Furthermore, the tensile strength and the influence of heat on the mechanical properties of PP/Jute composites were investigated by adding various fractions of jute fiber.

2. Experimental

2.1 Materials
Materials used for this study were jute fiber, 5% NaOH and homopolymer PP types cosmoplene FY3012E from The Polyolefin Company (Singapore) Pte. Ltd.

2.2 Alkali treatment
Jute fiber was prepared in ± 20 cm long for alkalization. Jute fiber bundle soaked in 5 % NaOH solutions for 60 min with a weight ratio of fibers in a solution 1:15 at a temperature of 30 ± 2°C. Then, the jute fiber in the bundle were rinsed with distilled water until the fiber was rough. The drying process was conducted in 48 hours at room temperature and then at 100°C for 6 hours until the sample was completely dry. The dried fibers were stored in airtight containers to keep the humidity of the sample. Single fiber test was conducted before and after alkali treatment.

2.3 Sample Preparation
Continuous directionally aligned PP reinforced composites with a variation of jute fibers compositions were manufactured by hot-press method. The compositions of the jute fiber were 30, 40 and 50 wt%. The composites were made by preparing the jute fiber in parallel direction between PP sheets. Jute and PP were prepared and placed in a steel die. The dies, that was pre-cleaned by a mold released agent, were closed by applying force of 40 barr by hot-press machine at 190 °C for 5 minutes to produce a single mat of 3-4 mm. Thickness the composites were then cooled and the specimens were cut to the required size based on ASTM D638 Type 4 for tensile testing and standard ISO 75 type 2 for Heat deflection Temperature (HDT) testing.

3. Results and discussion

3.1 Tensile Test Results
Jute fiber tensile test results showed that the tensile strengths before and after alkalization were about 24.3 MPa and 132.2 MPa. It was clear that alkalization increased the tensile strength value of the jute fiber. This occurred because the alkalization removed the lignin and waxy substances but the cellulose which is the main content of the jute physically was not affected by the NaOH solution [2,9]. Tensile test results of pristine PP and PP/Jute composites are shown in Figures 1 and 2. As shown in Figure 1, the tensile strength and Young's modulus of the PP/40wt% jute composites increased up to 19.7 % and 79.8 % compared to the pristine PP. The tensile strength and Young’s modulus were then decreased when the jute content was 50 wt%. This indicates the poor interface bonding between the fiber and the matrix. This lead to the formation of poor interface, which resulted in poor mechanical properties of the composite [10]. The strain at break of the composites, as exhibited in Figure 2, decreased along with increasing weight fraction of jute. This showed that the composite was more brittle than pristine PP which was highly elastic.

Tensile strength on composites increases when fibers and matrix are well bonded, where the load transfer from matrix to fibers spread out well on entire surface of composite fibers and causes resistance of composite is increased against a given load. In composites with low weight fraction, the composite strength will be lower than composites with high weight fraction [5]. Therefore, the addition of weight
fraction in composite will increase tensile strength until the optimum value, so the load transfer from matrix to fibers in the composite will be more evenly distributed. Despite the addition of fiber can increase the tensile strength of composite, the tensile strength will be decreasing when it reach optimum value. Weight fraction of fibers that exceed a certain value will make it does not bond perfectly with the matrix, it because the fibers are not fully wetted by the matrix as a filler in the composite which ends up causing a lot of voids that will decrease the tensile strength of the composite [5].

Figure 1. Tensile strength and Young modulus vs weight fraction of jute fiber.

Figure 2. Strain at break vs weight fraction of jute fiber.

By using a modification of the matrix and different methods from this study, the tensile strength of PP/Jute is 34-73 MPa [6]. The same result on this study is also showed by using 2 wt% MAHgPP as a matrix modification of the PP/jute yarn composite. By using injection molding method, the tensile strength of PP/30wt% jute yarn composite were about 48 MPa [7].

a. Heat Deflection Temperature Test Result
Figure 3 shows the heat deflection temperature of pristine PP and PP/Jute composites. The highest heat deflection temperature value was obtained in the PP/40 wt% jute composites, which was (143.3 ± 1.14)°C. This value increased significantly of about 143% compared to pristine PP. Based on previous study [10], the best result of deflection temperature was 134°C belong to a PP/jute composite. This difference is influenced by dissimilar PP used in the two studies.

Figure 3. Deflection temperature vs weight fraction of jute fiber on PP/jute composite.

b. SEM Observation Result
Figures 4 (a) and (b) show the SEM images before and after tensile test of PP/40wt% jute composite surfaces. The SEM images before tensile test of PP/40wt% jute composite surface shows a clear
difference layer between the matrix and fiber. This indicated imperfect wettabiliy between the fibers and the matrix that causing poor bonding interface. Moreover, the poor interface bonding between the fiber and the matrix also caused by the existence of a void on the composite surface. Figure 4(a) shows the existence of void on PP/40wt% jute composite. Large concentration of void on the composite surface caused poor interface bonding between the fiber and the matrix and resulted low mechanical properties. Figure 4(b) shows the matrix cracks and the fiber pull-out of PP/40wt% jute composite. High damage due to the load of tensile test showed by fiber pull-out on the composite surface breakage occurs when the fiber on composite can not longer hold the applied load.

Figure 4. SEM images (a) PP/40 wt% jute before tensile test, (b) PP/40 wt% jute after tensile test.

4. Conclusion
The best mechanical and thermal properties of PP composite reinforced jute was obtained in the PP/40 wt% jute composites. Tensile strength, Young's modulus and heat deflection temperature of PP/40 wt% jute composite were (38.2 ± 4.9) MPa, (3.20 ± 0.26) GPa, and (143.3 ± 1.14)°C respectively. These values increased up to 6%, 50.2% and 143.0% respectively compared the pristine PP. Fiber pull-out occurs on all composite samples after the tensile test. This mode of failure showed a poor interface bonding between jute and PP.

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