Physico-Mechanical Properties of Jute-Coir Fiber Reinforced Hybrid Polypropylene Composites

Salma Siddika, Fayeka Mansura, and Mahbub Hasan

***Abstract*—**The term hybrid composite refers to the composite containing more than one type of fiber material as reinforcing fillers. It has become attractive structural material due to the ability of providing better combination of properties with respect to single fiber containing composite. The eco-friendly nature as well as processing advantage, light weight and low cost have enhanced the attraction and interest of natural fiber reinforced composite. The objective of present research is to study the mechanical properties of jute-coir fiber reinforced hybrid polypropylene (PP) composite according to filler loading variation. In the present work composites were manufactured by using hot press machine at four levels of fiber loading (5, 10, 15 and 20 wt %). Jute and coir fibers were utilized at a ratio of (1:1) during composite manufacturing. Tensile, flexural, impact and hardness tests were conducted for mechanical characterization. Tensile test of composite showed a decreasing trend of tensile strength and increasing trend of the Young's modulus with increasing fiber content. During flexural, impact and hardness tests, the flexural strength, flexural modulus, impact strength and hardness were found to be increased with increasing fiber loading. Based on the fiber loading used in this study, 20% fiber reinforced composite resulted the best set of mechanical properties.

***Keywords*—**Mechanical Properties; Coir, Jute, Polypropylene, Hybrid Composite.

I. Introduction

NOW A DAY'S hybrid composites are receiving considerable attention for its capability of providing designers new freedom of tailoring composites and thus achieving properties that cannot be attained in binary systems containing one type of fiber dispersed in a matrix. It has also provided a more cost-effective utilization of expensive fibers by replacing them partially with less expensive fibers. Hybrid composites provide the potential of achieving a balanced pursuit of stiffness, strength and ductility, as well as bending and membrane related mechanical properties with weight savings, reduced notch sensitivity, improved fracture toughness, longer fatigue life and excellent impact resistance [1].

Increasing environmental awareness has promoted designs that are compatible with environment, non toxic to human body so eco-friendly.

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Natural fiber reinforced composites are inexpensive and could minimize environmental pollution due to their characteristics bio-degradability [2]. Apart from this, the lignocellulosic fibers are lightweight, reduce wear in the equipment used for their production, easily available, renewable, non-abrasive, require less energy for processing, reduce the density of furnished products and absorbed CO_2 during their growth [1]-[9]. The lignocellulosic fibers can be mixed either with thermosetting or thermoplastic polymer matrix to produce composite**s**. The composite using thermosetting polymer shows brittleness and inability to repair. Many of the thermoplastic-based composites offer excellent resistance to impact loading, the possibility of thermoforming and shaping at elevated temperatures and the potential for thermal joining and repair as well as recycling [3].

Among various natural fibers, both coir and jute fibers are widely available and cheap in context to the economic condition of Bangladesh. Coir and jute are lignocellulosic fibers mainly consisted of cellulose, lignin and hemicelluloses. High content of lignin in coir than jute fiber has made it high weather resistant. The coir fiber is relatively water-proof and is one of the few natural fibers resistant to damage by salt water. They absorb water to a lesser extent compared to all the other natural fibers including jute due to its less cellulose content. Both fibers are biodegradable and recyclable. They are renewable resources and. these materials are CO_2 neutral [10]. Furthermore, these fibers are typically less abrasive than glass or carbon fibers. Jute fiber has low density and high mechanical strength. Among different thermoplastics polypropylene possesses outstanding properties such as low density, good flex life, sterilizability, good surface hardness, abrasion resistance and excellent electric properties [4]. Although natural fibers lag behind from the impressive property of synthetic fiber, their eco-friendly nature has made them attractive. The objective of present research is to develop hybrid composite by using two lignocelllosic fibers which are abundant, inexpensive and eco-friendly and improving the new era of green composite.

II. Materials and Methods

A. Materials

A commercial grade polypropylene (PP), coir and jute were used in this study. All of them were collected from the local market. The PP (Fig. 1) was white in colour and granular in form having a melting point of 160^{0}C. Jute fiber (Fig. 2) was extracted from bundles, while coir fiber (Fig. 3) was extracted from coconut and also the. The die used to prepare composite was made of aluminum. The die was made by machining aluminum plate to a desired shape (2.54 cm X 18.8 cm) and depth 0.8cm.

Fig. 1 Image of polypropylene (PP) granules

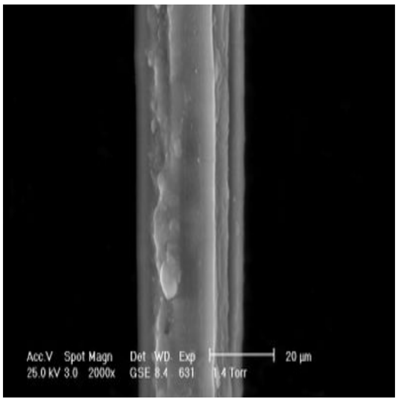

Fig. 2 SEM image of jute fiber [11]

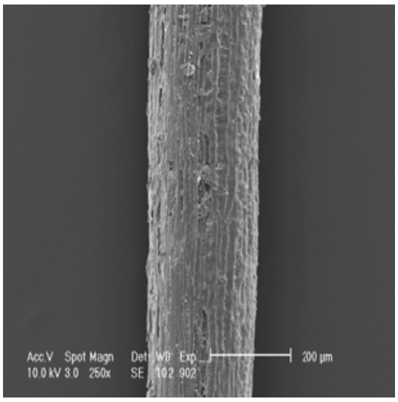

Fig. 3 SEM image of coir fiber [11]

B. Manufacturing of Composites

Hybrid composites of polypropylene matrix and varying amount of coir and jute fiber were manufactured using hot press technique in a 2.54 cm X 18.8 cm X 0.8 cm die as mentioned in the previous section. A hydraulic type machine having maximum load of 35 kN and maximum temperature of 300^{0}C was utilized. The fiber loading was varied at 5, 10, 15 and 20 wt% with the ratio of jute to coir of 1:1. Fibers were cut to 3-5 mm length. Firstly required amount of fiber and PP were weighed in a balance. Then to allow the removal of moisture, fibers and polypropylene were dried in an oven at 80^{0}C for 20 minutes before preparing each composite. In some cases they were mixed properly in a container by applying heat from a hot plate. The application of heat (much below the melting point of PP) during mixing enables the fibers to adhere with the PP granules, since no additional adhesive had been used. The fiber and PP mixture was then placed inside the die. The fiber-matrix mixture was allowed to press at 30kN pressure. The temperature was initially raised to 160^{0}C and hold there for around 12-15 minutes, after that the temperature was raised to $(180\text{-}185)^{0}$C depending on the thickness required. The die was cooled to room temperature, pressure was released and the composites were withdrawn from the die. Since the compression temperature was higher than the melting point of PP (160^{0}C), the matrix melted but the fibers (melting point > 220^{0}C) remained intact.

C. Mechanical Testing

Tensile, impact and hardness tests were carried out. In each case, five samples were tested and average values were reported. Tensile tests were conducted according to ASTM D 638-01 [12] using a universal testing machine at a crosshead speed of 4mm/min. Each test was continued until tensile failure. Static flexural tests were carried out according to ASTM D 790-00 [13] using the same Testing Machine mentioned above at same crosshead speed. The dynamic charpy impact test of the composite was conducted using an impact tester MT 3016 according to ASTM D 6110-97 [14]. The hardness of the composite was measured using a shore hardness testing machine.

D. Scanning Electron Microscopy (SEM)

The interfacial bonding between the fibers and PP matrix in manufactured composites and tensile fracture surfaces of the same composites were examined using a Scanning Electron Microscope (Philips XL 30). The micrographs are presented in the Results and Discussion section.

III. Results and Discussion

A. Tensile Properties

Tensile properties (Young's modulus and tensile strength) of the composite samples were measured for each fiber content (5, 10, 15 and 20 wt%) with the help of stress/strain curves. The tensile strength of raw coir and jute fiber reinforced hybrid polypropylene composites at different fiber loading is shown in "Fig. 4". The tensile strength decreased with an increase in fiber loading [6]-[10]. As the fiber loading increased, the interfacial area between the fiber and matrix increased, which was weak because of worsening interfacial bonding between cellulose based hydrophilic filler (jute and coir) and hydrophobic matrix. This consequently decreased the tensile strength [7]. The same trend was also observed by other researchers [15]-[18].

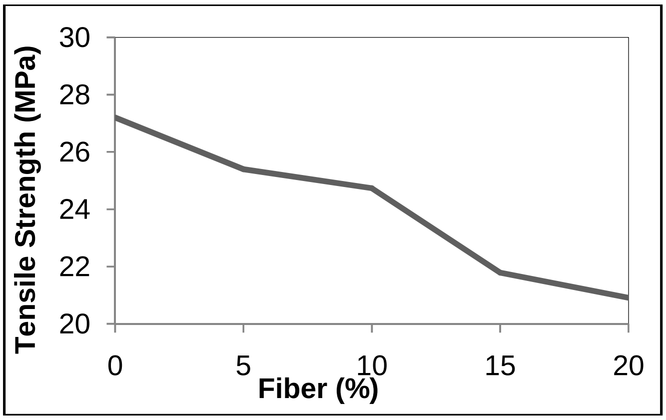

Fig. 4 Variation of tensile strength at different fiber content.

The Young's modulus values of coir fiber reinforced polypropylene composites for different fiber loading are shown in "Fig.5". It is observed that the Young's modulus increased with an increase in fiber loading [6]-[9]. This is because with an increase in fiber content, the brittleness of the composite increased and stress/strain curves becomes steeper. Poor interfacial bonding creates partially separated micro spaces which obstruct stress propagation between the fiber and the matrix [17]. As the fiber loading increases, the degree of obstruction increases, which in turn increased the stiffness.

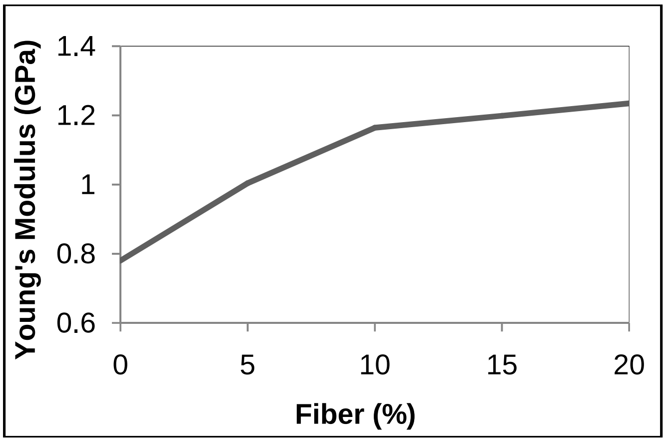

Fig. 5 Variation of Young's modulus at different fiber content.

B. *Flexural Properties*

Flexural properties (Flexural strength and flexural modulus) were measured for samples of each fiber content (5, 10, 15 and 20 wt %) with the help of flexural stress/strain curves and respective equations. The flexural strength of raw coir and jute fiber reinforced hybrid polypropylene composites at different fiber loading, is shown in "Fig. 6". The flexural strength increased with an increase in fiber loading which was in agreement with the findings by other researchers [8, 9, 16]. This may be due to the favourable entanglement of the polymer chain with the filler which has overcome the weak filler matrix adhesion with increasing filler content [18].

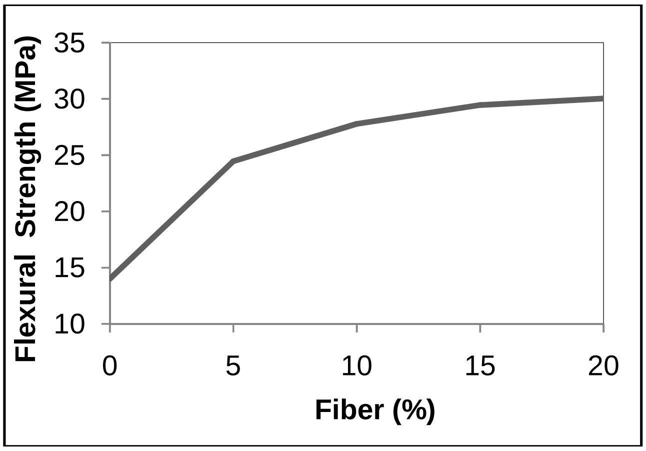

Fig. 6 Variation of flexural strength at different fiber content.

The flexural modulus values of raw coir and jute fiber reinforced hybrid polypropylene composites at different fiber loading is shown in "Fig. 7" the flexural modulus increased with an increase in fiber loading [6]-[8],[16]. Since both coir and jute are high modulus material, higher fiber concentration demands higher stress for the same deformation [18]. So the incorporation of the filler (rigid coir and jute) into the soft polypropylene matrix results into the increase in the modulus.

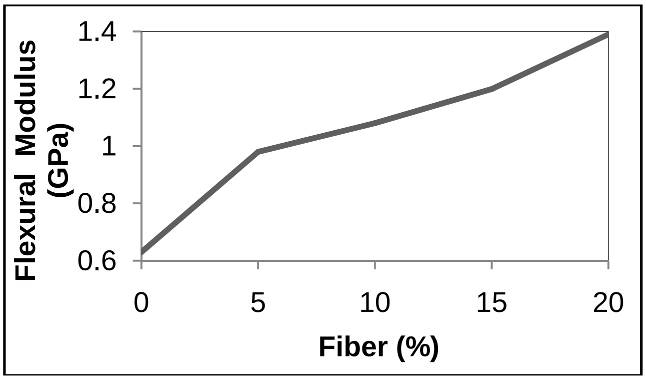

Fig. 7 Variation of flexural modulus at different fiber content.

C. *Impact Strength*

Variation of the Charpy impact strength with fiber loading for coir and jute fiber reinforced hybrid composite is shown in "Fig. 8". Impact strength increased with fiber loading [10], [15], [17], [19]. Impact strength of a material provides information regarding the energy required to break a specimen of given dimension, the magnitude of which reflects the materials ability to resist a sudden impact. The impact strength of the fiber reinforced polymeric composites depends on the nature of the fiber, polymer and fiber–matrix interfacial bonding [20]. As presented in the figure, impact strength of all composites increased with fiber loading. This result suggests that the fiber was capable of absorbing energy because of favourable entanglement of fiber and matrix. Fiber pull out is found to be an important energy dissipation mechanism in fiber reinforced composites [21]. One of the factors of impact failure of a composite is fiber pull out. With the increase in fiber loading, stronger force is required to pull out the fibers. This in turn increased the impact strength.

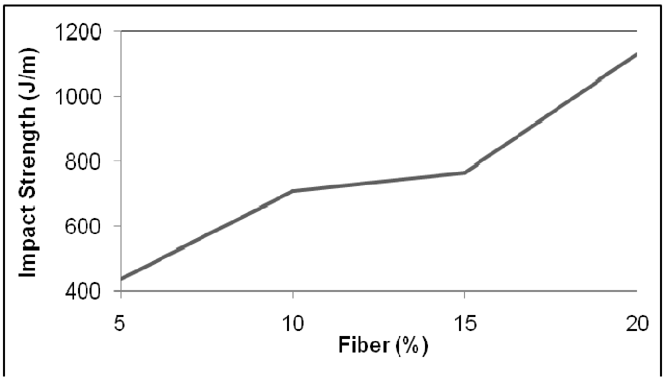

Fig. 8 Variation of impact strength at different fiber content

D. Hardness

Hardness of a composite depends on the distribution of the filler into the matrix [2],[15]. Usually the presence of a more flexible matrix causes the resultant composites to exhibit lower hardness. As shown in "Fig. 9", incorporation of fiber into the PP matrix has reduced the flexibility of the matrix resulting in more rigid composites. Due to the increase of stiffness of respective composite the hardness of jute coir hybrid PP composites showed a slight increasing trend with an increase in the fiber content [2]. Better dispersion of the filler into the matrix with minimization of voids between the matrix and the filler also enhanced hardness [22].

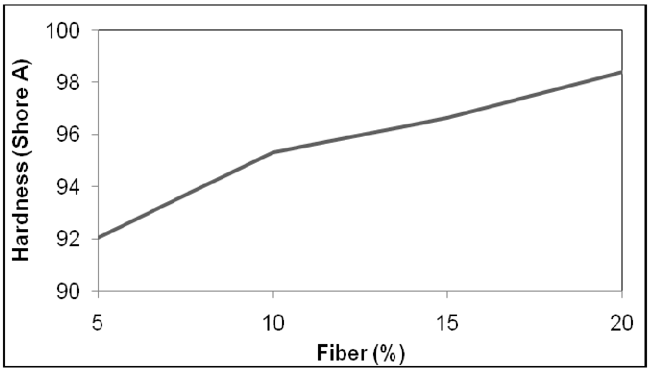

Fig. 9 Represents Variation of hardness at different fiber content

E. Surface Morphology

Tensile fracture surface of 5, 10, 15 and 20 wt% coir-jute fiber reinforced hybrid polypropylene composites are shown in "Figs. 10 to Fig -13" respectively. All the figures show presence of both coir (comparatively larger diameter) and jute (comparatively smaller diameter) fiber in polypropylene composite. According to scanning electron micrographs, 20% fiber reinforced composites ("Fig. 13") shows favourable entanglement between the fiber and the matrix. As a result 20% fiber composites yielded best set of mechanical properties compared to other composites.

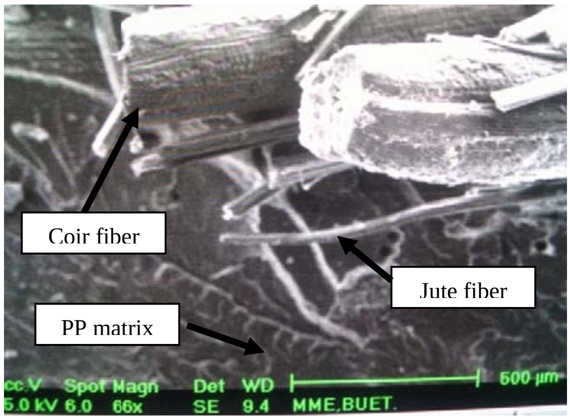

Fig. 10 Tensile fracture surface of 5% jute-coir fiber reinforced hybrid polypropylene composite

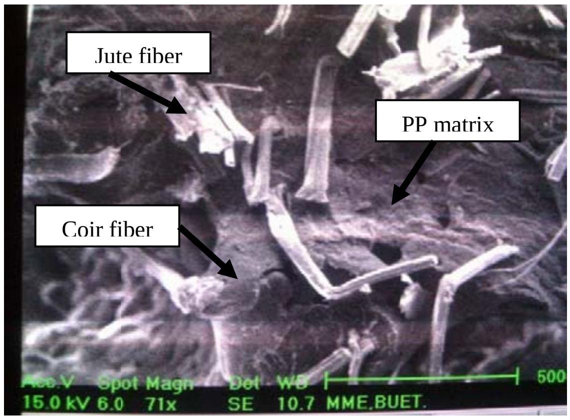

Fig. 11 Tensile fracture surface of 10% jute-coir fiber reinforced hybrid polypropylene composite

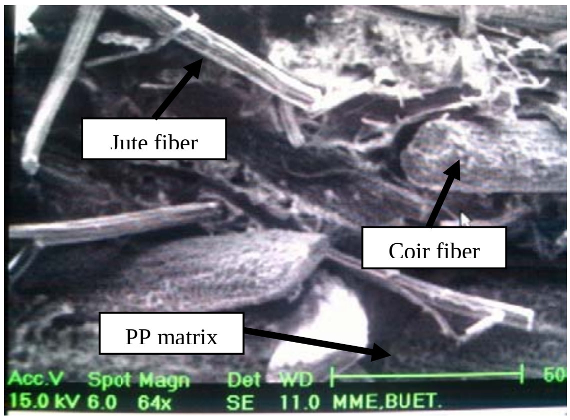

Fig. 12 Tensile fracture surface of 15% jute-coir fiber reinforced hybrid polypropylene composite

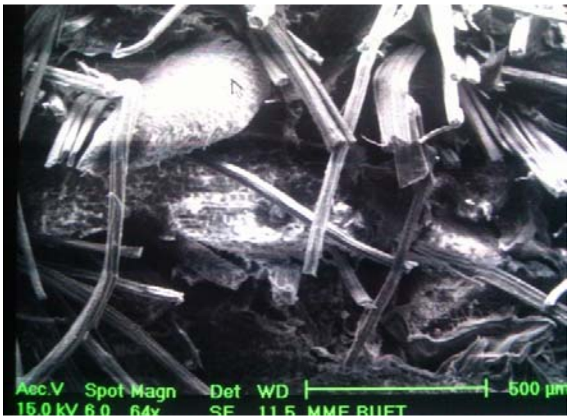

Fig. 13 Tensile fracture surface of 20% jute-coir fiber reinforced hybrid polypropylene composite

IV. Conclusions

In the present work, jute and coir hybrid fiber reinforced PP composites were manufactured using hot press machine. The level of fiber loading was varied at 5, 10, 15 and 20 wt% with jute coir ratio of 1:1. The tensile strength of the composites decreased with an increase in fiber loading. Whereas, the Young's modulus increased with fiber loading. Flexural strength, flexural modulus, charpy impact strength and average hardness values increased with an increase in fiber loading. Scanning electron microscopic analysis indicated strongest adhesion between the fiber and matrix when 20% fiber was reinforced into polypropylene polymer. As a result 20% fiber composite yielded the best set of mechanical properties compared to other composites. Basically these composite can be further modified by treatment of the fiber and improving fiber matrix interbonding.

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