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HDPE- Coir Composites–Fabrication, Process Parameters and Properties

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Abstract: The composites of biodegradable high density polypropylene (HDPE) reinforced with short coir fiber were prepared by melt mixing followed by hot press molding. The effect of fiber addition on some physical and mechanical properties was evaluated. Different process parameters (e.g. mixing time, heating temperature and time, cooling time etc.) were established for good sample preparation The effects of fiber addition on some physical and mechanical properties were evaluated. The mechanical properties were studied via Universal Testing Machine (UTM). The density was increased with the increase of fiber addition. The tensile strength (TS) of fabricated product increased with the increase of fiber addition up to 10% (by wt.) and then decreased continuously. The elongation of fabricated composites was decreased with the increase of fiber addition continuously. The changes in the mechanical properties were broadly related to the accompanying interfacial bonding of HDPE coir composites (HDPECC). To observe the hydrophilicity of the prepared composites was evaluated by the water uptake properties. The interfacial bonding of the fiber and matrix of the coir fiber reinforced composites was studied via scanning electron microscope. It revealed that the introduction of short coir fiber led to a slightly improved mechanical stability of PP- Coir composites.

Keyword: HDPE, Fabrication, Mechanical Properties, Interfacial Bonding, Coir Fiber

1. Introduction

Governmental regulations and growing environmental awareness throughout the world have triggered a paradigm shift towards designing materials compatible with the environment. The use of natural fibers, derived from annually renewable source, as reinforcing fibers in both thermoplastic and thermosetting matrix composites provides positive benefits with respect to ultimate disposability and raw material utilization [1]. Natural fibers such as jute, coir, palm, banana etc. are used as an alternative to synthetic fibers e.g. glass, aramid, carbon, etc. These fibers are used due to their renewable character, acceptable specific strength properties, low cost, enhanced energy recovery, and biodegradability [2]. Natural fiber reinforced polymer combine both good mechanical properties and low specific mass. The coir is widely used as reinforcing agent in thermoplastics like polyethylene (PE), polypropylene (PP) and High Density Polypropylene (HDPE). The use of short coir fibers and their effects on properties are not well documented. The objective of the study is to find out the fabrication process rout, optimization the process parameters and the effect of fiber addition on the properties of coir-HDPE composites. There are currently many types of reinforcing fibers used in composite materials.

A composite may be defined as the combination of two or more substances in various form or composition on a macroscale, having recognisable interfaces with its distinct phases. Composites normaly consist of a (disperse phase) reinforcing material and a continuous phase(matrix phase). The effective method to increase the strength and to improve overall properties is usually by incorporating dispersed phases into the matrix [3]. Disperse phase may be different types of fibers or any other substances and the matrix phases are normally polymer, ceramic or matals. The utilization of

renewable cellulose materials have received increasing attention due to their abundance, low cost, and unique properties, especially the polymer composites with surface modified forms [4, 5]. The low cost glass fibers reinforcing with polymer matrix are the common polymer composites and are used in many high volume applications. The disadvantages of glass fibers are that they have a relatively low modulus and poor abrasion resistance, which decreases its potential strength [1]. Jute fiber has received considerable attention for its diversified use both in academic and industrial research. Biodegradable plastics such as cellulose-based thermoplastics, aliphatic polyester etc. have attracted much attention in recent years from the point of view of environmental protection [6-7]. However, these encounter dimensional changes composites during industrial and house hold use, especially in humid and hot environments; because of jute fiber is highly hydrophilic in nature and is not highly compatible with the hydrophobic organic matrices like epoxy and polyester. A hybrid bio-based composite is a combination of the individual characteristics of at least two different types of natural fiber reinforcements in a single renewable matrix [8, 9] These composites could find their way into many new markets, particularly the electronics, aerospace, and auto motive industries. Fiber reinforcement is an effective way to improve the mechanical properties of thermoplastics. Natural plant based lingo-cellulosic fibers are attractive reinforcing materials than the non degradable fibers like glass fiber, carbon fiber and aramid fiber etc. A number of studies have been carried out on biodegradable thermoplastics reinforced with the fibers have been reported. The presence of hydroxyl and polar groups in various constituents of jute accounts for its high moisture region value, leads to poor adhesion with the polypropylene [10].

In this research work it was tried to find out the physic-mechanical properties of coir fiber reinforced HDPE based composites.

2. Experimental Procedure

2.1. Raw Materials

High Density Polypropylene (HDPE) used in this work had a specific gravity of 0.92. Coir was collected from PP and PDC, BCSIR, Dhaka, Bangladesh. Fibers were chopped and kept at 110°C for 24 hours to remove moisture. The length of the fibers was approximately 2-3 mm and sieved with 2 mm sieve (DIN IS03310/1, w=2mm, FRITSCH). Same procedure was also applied to remove moisture from HDPEgranules. HDPEwas also collected from local market. Table 1 shows average chemical composition of coir fibers [11].

Table 1. *Average chemical composition of coir fibers.*

Ingredients	Percentage
Cellulose	43.44%
Hemicellose	0.25%
Lignin	45.84%
Pectin and relaed product	3.00%
Water soluble	5.25%

2.2. Fabrication

The mixtures are taken in a die or mold after using a little amount of mold releasing agent. An initial of 50 KN load was given to top of the mold area then the mold (6"×6") was kept in a Paul-Otto-Weber Press machine. The total heating system was controlled by microprocessor. Heating was done electrically and the temperature was set at 230°C, 245°C, and 260°C. Only 25–30 minutes were required to reach the required temperature. The temperature was kept at that temperature for 20 minutes. After reaching the temperature the final load of 50 KN over the sample area was set to avoid the kind of voids and to have a required thickness. Then pressure was increased up to 100KN and stopped the heating system. Cooling was done by water flow through the outer area of the heating plates. After cooling the specimens were separated from the mold. From these specimens, the samples of different size were cut as per requirement for different tests. All these specimens were collected into ASTM standard.

2.3. Measurement of Properties

2.3.1. Density

The bulk density (BD) of the composites was determined according to ASTM C135-76 by measuring the weight of the samples in the following way [12]:

$$BD=(Wt) / (L*W*H) \quad (1)$$

Where Wt represents weight of the composites, L, W and H represents the length, width and height of the composites respectively.

2.3.2. Water Uptake

Water uptake tests of the jute fibers (about 500 mg) were performed in de-ionized water at room temperature (25°C). Water uptake of the jute fibers was carried out up to 60 min. Jute samples were placed in static glass beakers containing 500 ml of distilled water. At set time points, samples were taken out and dried for 6 h at 105°C and then re-weighed. Similarly, jute/UPR-based composites were treated for water uptake up to 30 days [13, 14].

2.3.3. Tensile Properties

According to ASTM D 638-98 tensiletest were done. Specimens were placed in a chamber at 25°C ± 3°C and 50% ± 6% relative humidity for 24 hours. The specimens were then tested using a HOUNSFIELD–H10KS machine fitted with a 10KN load cell and operating at a cross-head speed of 1 mm/min.

2.3.4. Scanning Electron Microscopic Analysis

Jute fabrics reinforced polypropylene-based composites were examined by high performance scanning electron microscopy (SEM) (JEOL JSM-6490LA Philips SEM) at an accelerating voltage of 20 kV. Fracture side of the composites (after impact tests) was also observed using SEM [15].

3. Results and Discussion

3.1. Temperature, Pressure and Heating Time

These are important parameters to obtain good product. A number of temperatures (230°C, 245°C, and 260°C) have been taken for fabrication. It has found that best samples have been obtained at 245°C. The fiber found to be burnt out for higher temperature and polymerization has not been completed for lower temperature. The incompleteness has been recognized by granule structure of samples. Similarly, the load, heating time are optimized as 20 KN and 30 min.

3.2. Physical and Mechanical Properties of HDPE-Coir Composites

3.2.1. Density

Figure 1 shows the effect of fibber addition on density of composite materials. With the increase of fiber addition the density increases and follows the mixture rule [16].

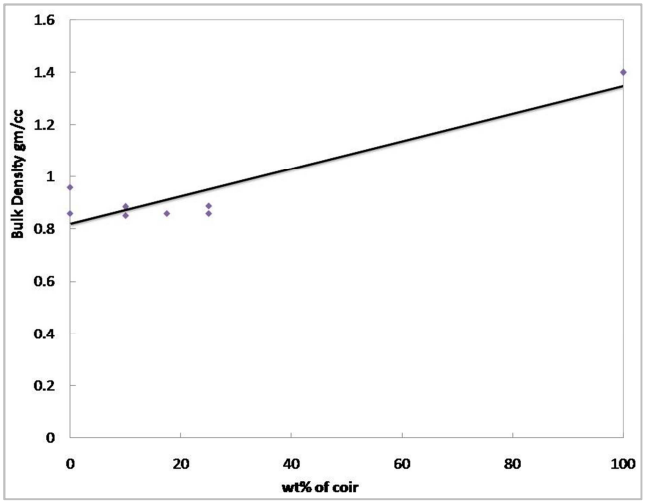

Figure 1. *Effect of coir addition on density of HDPE-coir composites.*

Similar effect was found by Kuriger and Alam [17, 18]. The density of HDPE product without addition of fiber was 0.91 whereas it was 0.96 found in literature. It revealed that the density of fabricated product was slightly lesser than that of actual density. The liner relationship between Bulk Density and percentage of coir fiber addition is:

$$BD = 0.8224+0.0053 \text{ (percentage of coir)} \quad (2)$$

It happened due to the presence of voids in fabricated product.

3.2.2. Tensile Properties

Figure 2 shows the effect of fiber (coir) addition tensile strength of HDPE-coir composites. It revealed that the tensile strength of fabricated product increased with the increasing of fiber addition up to 10% (wt.) and then decreased continuously. Up to this composition the fiber and polymer were well distributed.

Up to 10% fiber addition both the fiber and matrix bore the load and fibers made resistance to slip as in the case of age hardening of metals [19]. After that, fibers were present as bundle of fibers and fiber–fiber bonding strength was lesser. Moreover, these also acted as stress concentrator. Consequently, after 10% fiber addition the tensile strength was decreased. The tensile strength of the fabricated product (100% PE) was 8.0 MPa, which was less than that of literature value, 11 MPa [18]. It was due to lower density of the fabricated product.

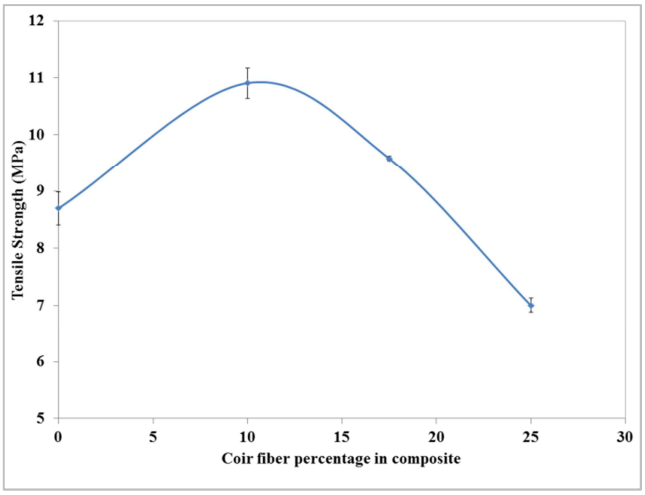

Figure 2. *Tensile stength of coir fiber reinforced HDPE based composites.*

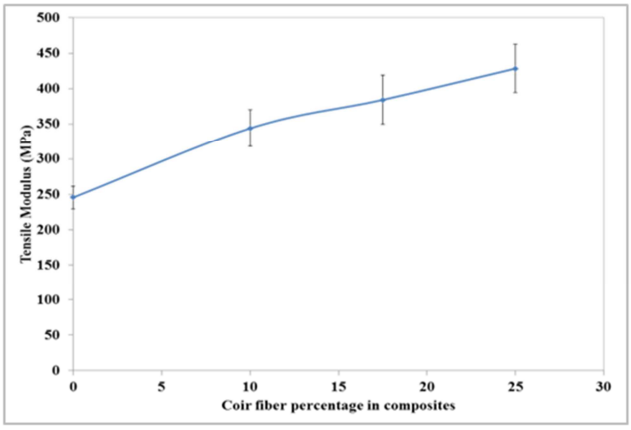

Figure 3. *Tensile Modulus of coir fiber reinforced HDPE based composites.*

The tensile modulus (TM) of the coir fiber reinforced HDPE based composite was evaluated. With the addition of fiber to the matrix material, the TM was increased. Minimum TM of the matrix, HDPE was only 245 MPa and the maximum TM of the fiber reinforced composites was 400 MPa. This increment was due to the addition of fiber to the matrix as the TM of the matrix was much higher than the matrix materials. The effects of the fiber addition in the composites is shown in figure 3.

Figure 4 shows the effect of coir addition elongation of HDPE-coir composites. It revealed that the elongation of fabricated product decreased continuously with the increase of fiber addition. The presence of fiber restricts the slip resulting in lesser ductility and consequently the % of elongation decreased continuously with the increasing of

fiber addition. The figure shows that the % of elongation of the fabricated product was lesser than that of literature value. It was also due to lower density.

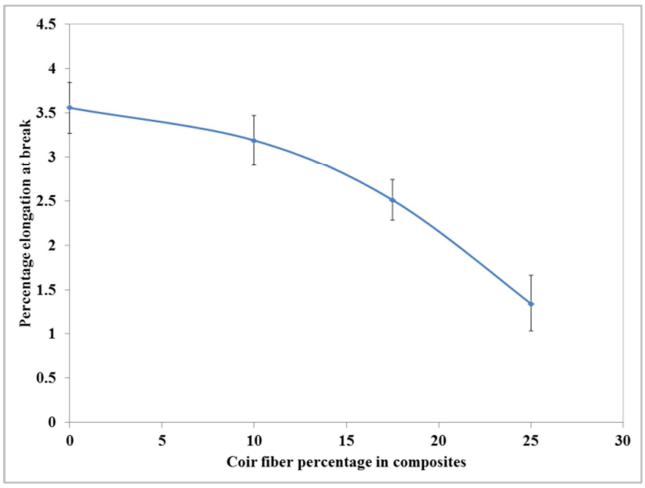

Figure 4. *Percentage elongation at break of coir fiber reinforced HDPE based composites.*

3.3. Water Uptake

Water uptake was measured by soaking the samples of coir fiber reinforced HDPE based composites. Figure 5 shows the water uptake propertiesof the prepared composites. The composites absorbed water in a regular increasing manner up to 60 minutes. In 60 minutes the composite absorbed 3.4% water. Then the water uptake property was remained more or less constant. In this research work, we tested the composite for 120 minutes. After 60 minutes there was no significant change in water uptake. This carried a good evidence of slightly hydrophilic property of prepared composite. As the matrix material, synthetic polymer, HDPE was hydrophobic and the reinforcing material, cellulose containing coir fiber was hydrophilic material. The combination of these two materials made the prepared composites slightly hydrophilic.

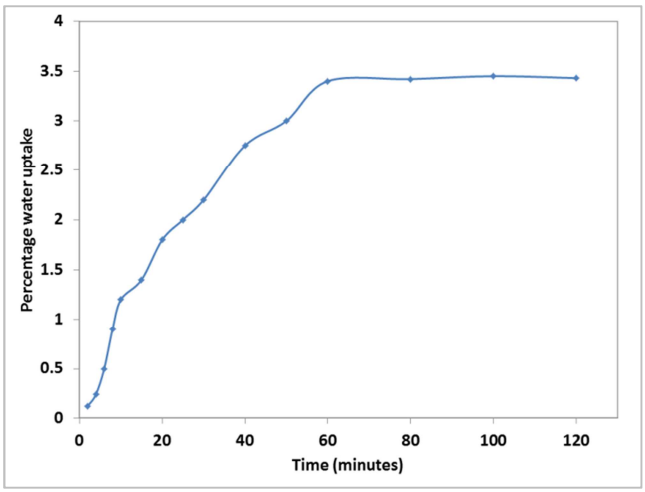

Figure 5. *Water uptake of coir fiber reinforced HDPE based composites.*

3.4. Scanning Electron Microscopic Image

SEM investigation of the fracture surface of the coir based composites was performed to study interfacial properties between jute fiber and HDPE matrix. Fractographic observation suggested that the fracture behavior was brittlein nature. SEM images of the fracture surface of Coir/HDPE basedcomposites are shown in Figures 6. From the figure it can be said that the fiber-matrix adhesion is very good on the fracture surface. That is the main reason to increase the tensile properties of fiber reinforced composites. There also some void space in the composites. When the fiber percentage was increased the void spaces were increased. That is why, with the increment of fiber percentage at a certain level, the mechanical properties were also increased. Then the mechanical properties were decreased with the increment of fiber percentage. At the 10% fiber contain, the void space was minimum that is why we observed maximum tensile strength. The elongation at break was decreased all through the increment of fiber percentages. The tensile modulus increased with the increment of fiber percentage.

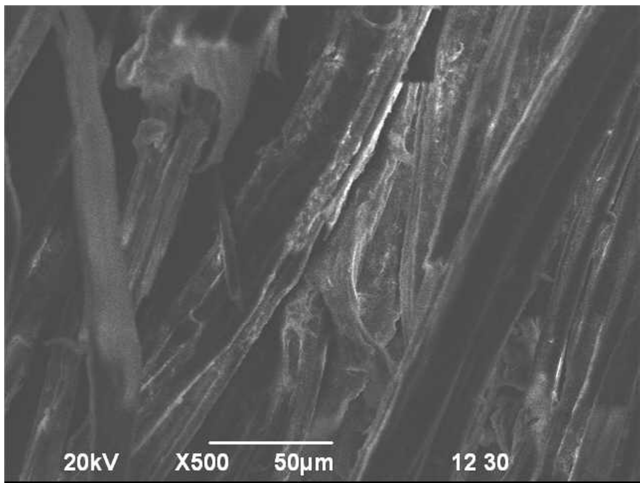

Figure 6. *Fiber reinforced composites.*

4. Conclusion

The density increased with the increase of fiber addition. The tensile strength of composite product increased with the increase of fiber addition up to 10% (wt.) and then decreased. Up to 10% the short fibers were finely distributed, fibers made resistance to slip as in the case of dispersion hardening of metals and in this regions both the fibers and matrix bore the load. After that fibers were coagulated as bundle of fibers, bundle of fibers fractured during load to slips and did not make resistance to slip. Consequently strength decreased. The tensile strength of composite product decreased with the increase of fiber addition. Water intake increased with increase of dipping time. The interfacial bonding was very good between the fiber and matrix.

Conflict of Interest Statement

All the authors do not have any possible conflicts of interest.

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References

[1] Natural Science Foundation of China (NSFC) (Key project, Grunt 29734120), the Natural Science Foundation Guangdong province (Team project, grunt 015007), the key strategic project of Chiness Academy of Science (grunt KJCX2-206B).

[2] Khan, A., Joshi, S., Ahmad, M. A. and Lyashenko, V. (2015) Some Effect of Chemical Treatment by Ferric Nitrate Salts on the Structure and Morphology of Coir Fibre Composites. Advances in Materials Physics and Chemistry, 5, 39-45.

[3] Aguele, F. O., Madufor, C. I. and Adekunle, K. F. (2014) Comparative Study of Physical Properties of Polymer Composites Reinforced with Uncarbonised and Carbonised Coir. Open Journal of Polymer Chemistry, 4, 73-82.

[4] Kong, D. and Wilson, L. (2018) Structural Study of Cellulose-Iron Oxide Composite Materials. Journal of Materials Science and Chemical Engineering, 6, 65-77.

[5] Crini, G. (2005) Recent Developments in Polysaccharide-Based Materials Used as Adsorbents in Wastewater Treatment. Progress in Polymer Science, 30, 38-70.

[6] Doi, Y.; Fukuda, K. In Biodegradable, Plastics and Polymers. Proceedings of the Third International Scientific Workshop on Biodegradable Plastics and Polymers, Osaka, Japan, November 9-11, 1993, Elsevier; Amsterdam, 1994.

[7] Vert, M,; Feijen, J,; Albertsson, A.; Choellini, E. Biodegradable Polymers and Plastics; The Royal Society of Chemistry, London, 1992.

[8] Adekunle, K. F. and Skrifvars, M. (2015) Processing of Lyocell Fiber Mat: An Alternative Renewable Reinforcement in Composite Manufacturing. Green and Sustainable Chemistry, 5, 47-54.

[9] Adekunle, K. F., Patzelt, C., Kalantar, A. and Skrifvars, M. (2011) Mechanical and Viscoelastic Properties of Soybean Oil Thermoset Reinforced with Jute Fabrics and Carded Lyocell Fiber. Journal of Applied Polymer Science, 122, 2855- 2863.

[10] Ranna, A. K.; Basak, R. K.; Mitra, B. C.; M.; Banerjee, A. N. J Appl Polym Sci 1517.

[11] htp://www.karan-carpets.com.

[12] ASTM Designation C134-76, Standard Test Methods for Size and Bulk Density of Refractory Brick.

[13] Md. SahadatHossain, A. M. SarwaruddinChowdhury&Ruhul A. Khan (2017) Effect of disaccharide, gamma radiation and temperature on the physico-mechanical properties of jute fabrics reinforced unsaturated polyester resin-based composite, Radiation Effects and Defectsin Solids, 172: 5-6, 517-530, DOI: 10.1080/10420150.2017.1351442.

[14] A. K. Mohanty, Mubarak A. Khan, S. Shaoo, G. Hinrichen, Effect of chemical Modification on the performance of Biodegradable jute yarn-Biopol composites, J. Material Science 35 (2000)2598.

[15] Md. Sahadat Hossain, Muhammad B. Uddin, Md. Razzak, A. M. Sarwaruddin Chowdhury & Ruhul A. Khan (2017) Fabrication and characterization of jute fabrics reinforced polypropylene-based composites: effects of ionizing radiation and disaccharide (sucrose), Radiation Effects and Defects in Solids, 172: 11-12, 904-914, DOI: 10.1080/10420150.2017.1417409.

[16] D R Askeland, The Science and Engineering of Materials, Alternate Ed., p.381.

[17] RJ Kuriger, and M Khairul Alam, Thermal properties of Carbon Fiber reinforced Polypropylene, BSME-ASME Int. Conf. on Thermal Engineering 31 Dec.2001-2 Jan. 2002.

[18] RA Higgins, Properties of Engineering materials, 2nd ed. p.285.

[19] RA Higgins, Properties of Engineering materials, 2nd ed. p.364.