Effect of Fiber Loading on Thermo-Mechanical Properties of Onion Roots and Broom Grass Fiber Reinforced Hybrid Polypropylene Composites

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Abstract

Polymer matrix composites are multi-phase materials, which consist of polymer as the matrix with fibers as the reinforcement resulting in synergistic properties. When they are combined they create a material which is specialized to do a certain job, for instance to become stronger, lighter or resistant to electricity. Hybrid composites are those composites, which contain a combination of two or more reinforcement fibers. In present research, hybrid polymer matrix composites were prepared with polypropylenes as the matrix and onion roots and broom grass as the fibers. Using hot-press technique three composites of different fiber content were prepared. Fiber loading were varied at 5, 10, 15 %wt. Mechanical (tensile, impact, flexural and hardness) tests and thermal characterization (thermo-gravimetric analysis) were subsequently conducted. Tensile strength, Young's modulus, flexural strength, flexural modulus, impact strength and hardness increased, while % elongation decreased with increase in fiber loading. Thermo-gravimetric analysis showed that 15 wt% fiber reinforced hybrid composite had higher thermal stability as compared to other two composites. Based on the fiber loading, composite containing 15 wt% hybrid fiber showed the best set of mechanical and thermal properties.

Keywords: Onion Root; Broom Grass Fiber; Polypropylene Hybrid Composite; Mechanical Properties; TGA

1. Introduction

A composite material can be defined as a combination of two or more materials that results in better properties than those of the individual components used alone. In contrast to metallic alloys, each material retains its separate chemical, physical, and mechanical properties. The two constituents are reinforcement and matrix. The main advantages of composite materials are their high strength and stiffness, combined with low density, when compared with bulk materials, allowing for a weight reduction in the finished part (Campbell 2010). Fiber composites consist of matrices reinforced by short (discontinuous) or long (continuous) fibers. Fibers are generally anisotropic and examples include carbon and aramids. Examples of matrices are resins such as epoxy, metals such as aluminum and ceramics such as calcium–alumino silicate (Kaw 2005). The reinforcing phase provides the strength and stiffness. In most cases, the reinforcement is harder, stronger, and stiffer than the matrix. The reinforcement is usually a fiber or a particulate. The continuous phase is the matrix, which is a polymer, metal, or ceramic. Polymers have low strength and stiffness, metals have intermediate strength and stiffness but high ductility, and ceramics have high strength and stiffness but are brittle. The matrix (continuous phase) performs several critical functions, including maintaining the fibers in the proper orientation and spacing and protecting them from abrasion and the environment.

Thysanolaena is a genus of plants in the grass family, the only genus in the tribe Thysanolaeneae (Shankar et al. 2001). Its only recognized species is Thysanolaena latifolia (formerly Thysanolaena maxima), native to China (Guangdong, Guangxi, Guizhou, Hainan, Taiwan, Yunnan) Bangladesh, Bhutan, Cambodia, India, Indonesia, Laos, Malaysia, Myanmar, Nepal, New Guinea, Philippines, Sri Lanka, Thailand and Vietnam (Liu and Phillips 2013; Subramonium et al. 2016). Tiger grass, Nepalese broom grass, broom grass, broom stick are common names for this plant, jharu in Assamese (Park and Balatinecz 1997; Servais et al. 2002). The flowers of this plant are used as cleaning tool or broom. The waste grass broom fiber has a tensile strength of 297.58 MPa, modulus of 18.28 GPa, and an effective density of 864 kg/m^3 (Ramanaiaha et al. 2012). Although not a true bamboo species, Tiger Grass is a bamboo-like, tropical, ornamental grass with lush arrow shaped foliage that fits a niche for smaller size single storey screens up to 3m tall. It forms a tight upright clump with older stems turning a reddish color in full sunlight making it also perfect as a standalone ornamental. The culms arise centrifugally during the peak growing season (April to July) and bear inflorescence (panicle) on shoot apex at the end of vegetative growth. The inflorescence that is about 30 to 90 cm long resembles a foxtail and used as a broom. This species is common throughout the north-east India. Broom grass is the major crop grown heavily in the Chepurupalli village, Srikakulam District, Arunachal Pradesh. The height of the grass in Chepurupalli is from 4.2 ft. to 5.1 ft. The stems of the broom grass are having high finis (Srinivasababua et al. 2014). Onion roots are natural fibers which does not have any use with food. Thus it is found as waste. It is environment friendly and easily available.

In present research, onion roots and broom grass reinforced hybrid polypropylenes composites were prepared using hot-press technique. Fiber loading were varied at 5, 10, 15 %wt. Mechanical and thermal testing of prepared composites were subsequently conducted.

2. Materials and Methods

2.1 Materials

Polypropylene (PP) of commercial grade was collected to be used as the matrix. It was white in color and granular shaped. Onion roots and broom grass were used as fibers. All of these materials were collected from market. The dirt and other unwanted materials were removed from the fibers. The die used for hot press technique was made of aluminium.

2.2 Preparation of Composites

Hot press technique was used to prepare composites of polypropylene (PP) and onion roots and broom grass fiber. Fiber (short and randomly arranged fibers) loading was varied at 5, 10 and 15 wt%. The fibers were initially cut to a length of 3-5 mm. Then desired amount of polypropylene and fibers were taken after measuring with a balance. The die was first sprayed with silicone spray. PP was then stacked as the first layer in the die. Then the mixture of onion roots and broom grass fibres were stacked. That is, the second layer was of fibers. Then the third layer of PP was stacked at last. The die was then covered with the other part and put in the hot press machine. The application of heat (much below the melting point of PP) enables the fibers to adhere with the PP granules, since no additional adhesive had been used. The fiber-matrix mixture was allowed to press at 30KN at 160℃ for 20 minutes and at 180℃ for 10 minutes in a hot press machine. The die was then cooled to room temperature. The composite was then withdrawn from the die.

2.3 Mechanical Testing

Tensile, flexural, impact and hardness tests were conducted. For each test and fiber loading of composite, five specimens were tested and the average values are reported. Tensile test was carried out according to ASTM D 638-01 using an Instron machine (system Id3369J8567, maximum capacity 50 KN). The three point flexural test was carried out according to ASTM D 790-07 using the same Instron machine. Impact test of the composite was conducted using an impact tester MT 3016 and Specimen was prepared according to ASTM D 6110-97. Hardness was measured using Shore durometer in its D scale.

2.4 Thermogravimetric Analysis

Thermo gravimetric analysis was carried out in a thermo gravimetric analyzer of model TGA Q50 W/FMC. Temperature range of 25ºC to 500ºC and a constant heating rate of 10ºC/min were used in present research.

3. Results and Discussion

3.1 Tensile Properties

Tensile tests were conducted following ASTM D 638-01 and each test was performed until tensile failure took place. Tensile strength, Young's modulus and elongation values of onion roots and broom grass fiber reinforced polypropylene composites for different fiber loading (5, 10, 15 wt%) were determined and plotted in Figure 1. It was found that with the increase in fiber content, both tensile strength and Young's modulus increased. With increase in fiber loading, the strong interaction area between the fiber and matrix increases and fibers act as dislocation points. These dislocation points work as barriers to the crack movement. As a result, with the increase in fiber content, tensile strength increased. Young's modulus increased because the composite became more brittle with the increase in fiber amount and as a result the stress-strain curves became steeper. Elongation (%) reduced considerably increase in fiber content (Figure 1 (c)). Both onion roots and broom grass fiber was stiffer than polypropylene matrix. Thus they had a lower percentage of elongation at break than the polypropylene matrix. As a result, the elongation decreased with increase in fiber content of the PP composites.

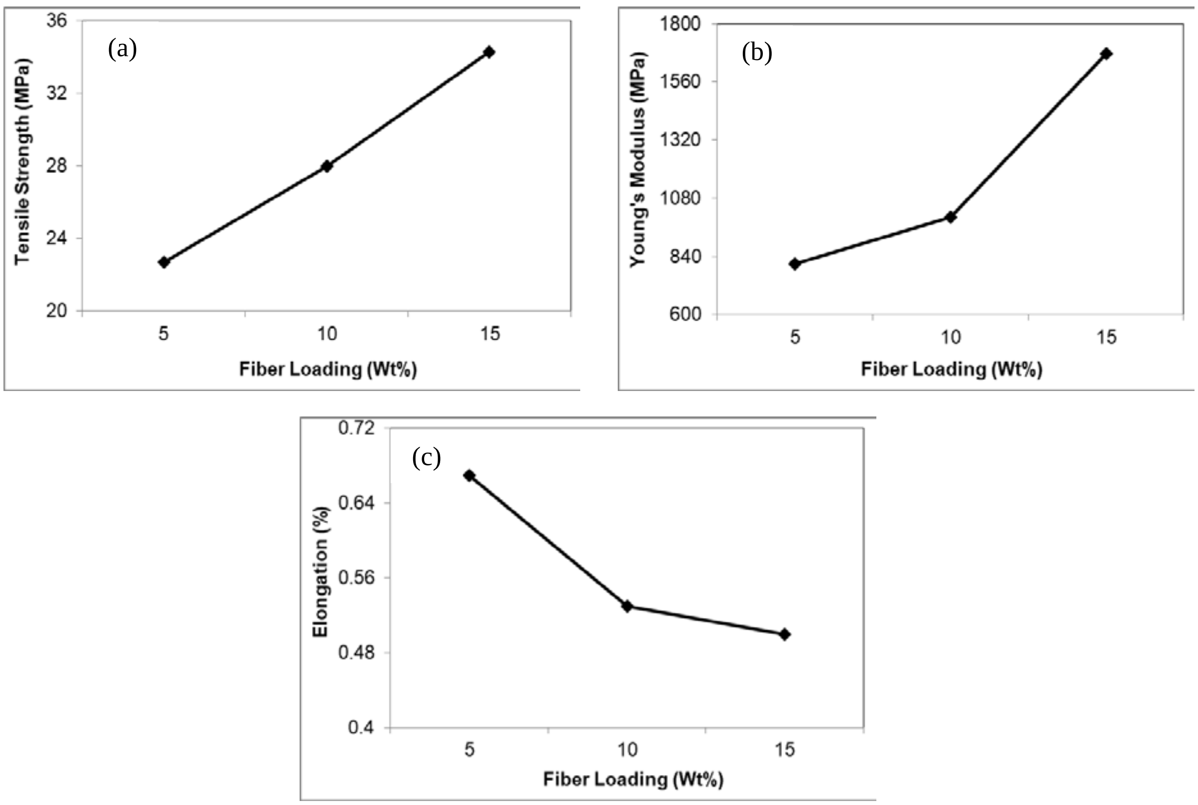

Figure 1: Variation of (a) tensile strength, (b) Young's modulus and (c) elongation against fiber loading.

3.2 Flexural Properties

Flexural test was carried out following ASTM D 790-07. Using flexural stress/ flexural strain curve, the values of flexural stress and flexural modulus were measured for each of the three composite samples. Variation of flexural strength and flexural modulus is shown in Figure 2. Both flexural strength and flexural modulus increased with increase in fiber loading. The increase in flexural strength may be due to the favourable entanglement of the polymer chain with the filler, which has overcome the weak filler matrix adhesion with an increasing filler content (Rahman et al. 2009). Since both onion roots and broom grass are high modulus materials, a higher fibre concentration demands higher stress for the same deformation. So the incorporation of the filler (rigid onion roots and broom grass) into the soft polypropylene matrix results in an increase in the flexural modulus (Rahman et al. 2009).

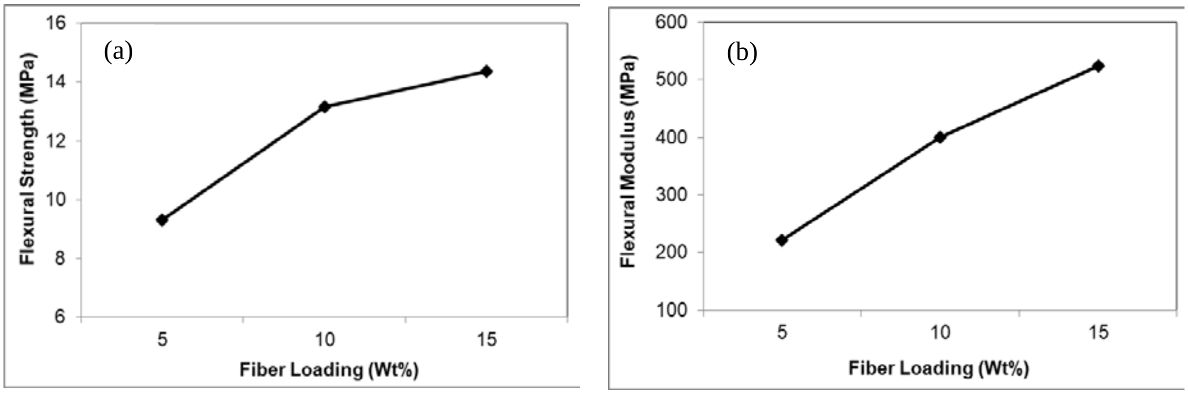

Figure 2: Variation of (a) flexural strength and (b) flexural modulus against fiber loading.

3.3 Impact Strength

Impact strength is the capacity of the material to withstand a suddenly applied load and is expressed in terms of energy. The Charpy impact test was performed for the three composites with different fiber content. Resulta are shown in Figure 3. Impact strength decreased steadily with increase in fiber loading. Fiber-matrix interface is actually weak due to fiber pull-out in composites. There are two mechanisms by which fibers can reduce the impact strength of the composite: fibers tend to inhibit deformation and ductile mobility of polymer molecules, which lowered the ability of the composite to absorb energy during crack propagation and fiber also created high stress concentration regions that required less energy to initiate a crack (Park and Balatinecz 1997). Such regions might occur at fiber ends, areas of poor interfacial adhesion and regions where fibers contact each other. For good impact strength, an optimum bonding level is necessary (Servais et al. 2002).

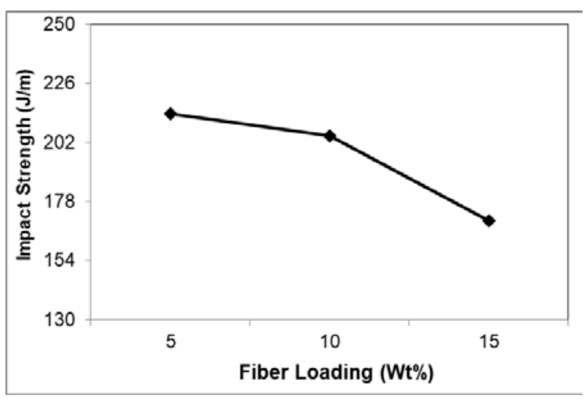

Figure 3: Variation of impact strength against fiber loading.

3.4 Hardness Properties

Figure 4 shows the hardness of composites prepared at different fiber loading. The shore hardness increased with increase in fiber loading. The hardness value of a composite depends on the distribution of the filler into the matrix. The hardness increases when the resistance of the materials to the deformation increases. This happens when more filler is added; the composite becomes harder and the materials' hardness improves. The layer of the filler gives better resistance to the plastic deformation in the transverse direction of the filler.

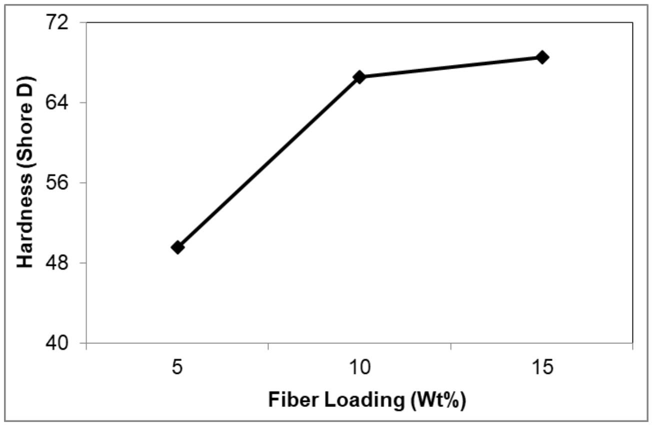

Figure 4: Variation of hardness against fiber loading.

3.5 Thermogravimetric Analysis Results

Three samples of mass .0025 gm from the three different composites each were taken for performing TGA analysis. The TGA analysis was carried out to determine the thermal stability of each of the composite. The data taken from the analysis were plotted in the graph. It was found that the thermal degradation of composites containing 5, 10, 15 wt% fiber content started at temperature 233.9°C, 236.8°C and 238.3°C respectively. From this observation it can conclude that with the increase of fiber content, thermal stability of the composites increased.

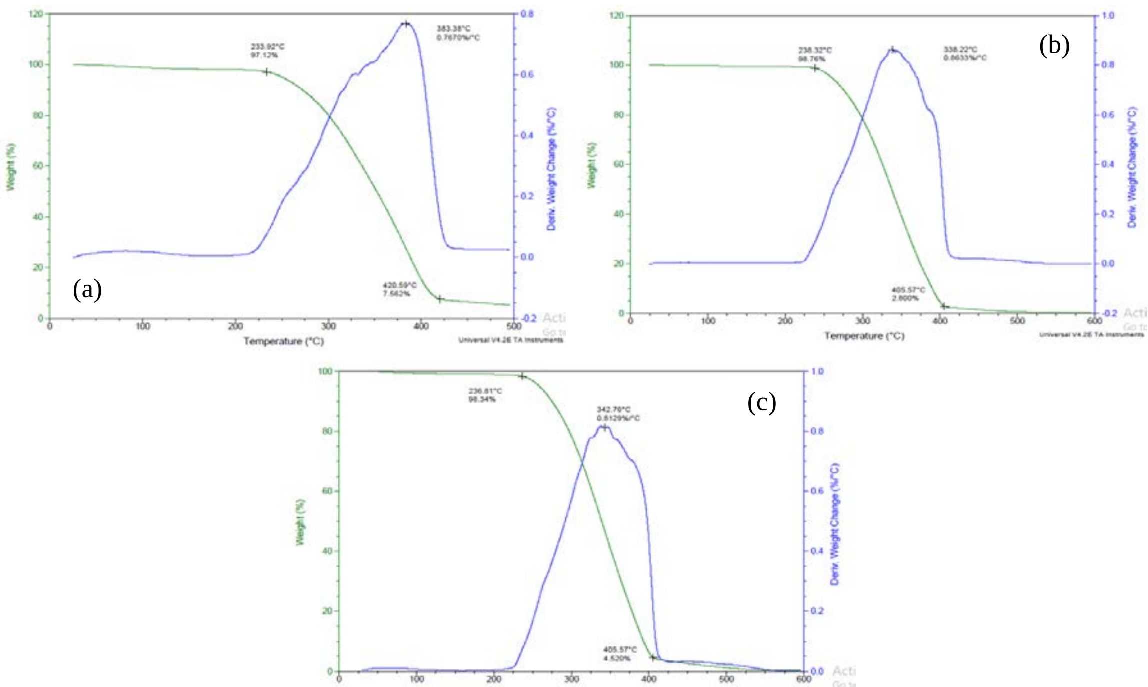

Figure 5: TGA curves of (a) 5, (b) 10 and (c) 15 wt% onion roots and broom grass fiber reinforced hybrid PP composites.

4. Conclusion

In present research, onion roots and broom grass fiber reinforced hybrid polypropylene composite were prepared using the hot press technique. The level of fiber loading was varied at 5, 10 and 15 wt%. The tensile strength, Young's modulus, flexural strength, flexural modulus and hardness of the composite increased with an increase in fiber loading. Conversely, elongation and impact strength decreased with fiber loading. Thermogravimetric analysis showed that thermal resistance increased with increase in fiber loading. Thus, 15% fiber reinforced composite yielded the best set of mechanical and thermal properties as compared to other composites. A further modification can be implemented by treatment of the fiber and improving the fiber matrix interfacial bonding.

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Acknowledgement

Authors are grateful to Department of Materials and Metallurgical Engineering, Bangladesh University of Engineering and Technology for their support during the work.

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