International Journal of Innovation and Scientific Research
ISSN 2351-8014 Vol. 27 No. 2 Nov. 2016, pp. 312-321

http://www.ijisr.issr-journals.org/

Influence of Fiber Content on Mechanical, Morphological and Thermal Properties of Waste Textile Fiber Reinforced Polypropylene Composites

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ABSTRACT: In textile industry, production and consumption of textiles produce huge amount of waste every year, rendering its main conclusion that it is one of the most polluting industry. To counter the problem, reinforcing waste textile fiber with polymeric materials is one of the measures for reducing textile industry's negative contribution towards environment. In the current work, waste textile fiber reinforced polypropylene composites were prepared using hot press machine at different fiber loading (10, 20 and 30 wt%). Mechanical properties of such composites were investigated by tensile, flexural, impact and hardness tests. Generally, their mechanical properties showed a decreasing trend except impact strength that followed increasing trend. Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM) and Thermo Gravimetric Analysis (TGA) were also carried out for the characterization of the composites. The FTIR analysis of the composites showed increase of fiber content. Tensile fracture surface morphology and thermal stability of the composites were examined by SEM and TGA analysis respectively.

KEYWORDS: Fiber, textiles, waste, polypropylene and composites.

1 INTRODUCTION

In the past few decades, higher amount of post industrial fiber waste has been produced because there has been increasing trend in global fiber consumption. In 2007, about 11.9 million tons of textile waste was generated by U.S.A. alone [1]. For the textile industry disposal of huge amount of textile waste is an alarming problem. Burying and land filling will not solve this problem as it is detrimental to the environment [2]. Moreover, a waste management crisis is generated due to the increasing cost of waste disposal [3].

By considering all of these aspects and with growing attention to environmental responsibility towards waste management, textile Industries and research organizations are now looking for applications for various fibrous waste textile products to reduce disposal of post-producer textile waste in landfills [4]. Reinforcing textile fiber with polymeric matrices to produce composite materials is one of the most viable applications of these waste materials [5]. These composite materials are called Polymer matrix composites (PMC) consist of a polymer resin as matrix, with fibers as the reinforcement medium. These materials are used in the greatest diversity of composite applications because of their properties, ease of fabrication and cost [6].

In our research work, waste textile fiber reinforced polypropylene composites consisting of discontinuous and randomly oriented fiber contained within polypropylene matrix. However, the properties of constituent components and the interfacial interactions between the reinforcing agent and the matrix material are the two main factors that influence the properties of such composites [7]. The aim of this work is to compare the mechanical properties of waste textile fiber reinforced polypropylene composites at different fiber loading (10, 20 and 30 wt %). This present research also investigated the effects of fiber content on thermal properties and the morphology of waste textile fiber reinforced polypropylene composites.

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2 EXPERIMENTAL

2.1 RAW MATERIALS AND SAMPLE PREPARATION

Pure polypropylene (pp) sheets and waste textile fiber were collected from local market and textile industry respectively.

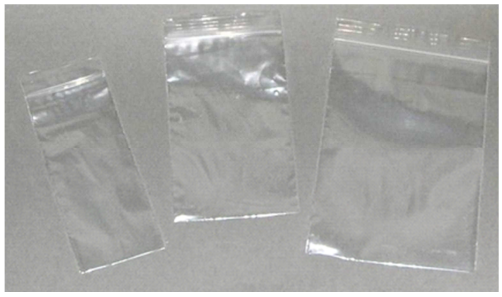

Fig. 1. Polypropylene Sheets

Fig. 1 shows polypropylene sheets.

Fig. 2. Waste Textile Fiber

Fig. 2 shows waste textile fiber.

At first, polypropylene sheets were cut into 150 mm*150 mm size and waste textile fiber was cut into 6-7mm size. Then required amount of fiber and polypropylene were weighed in a balance. To remove the moisture, both fiber and polypropylene were dried in furnace at 70°C for 15 min. Then fiber in different amounts (10, 20 and 30 wt. %) was placed between the polypropylene sheets in a hot pressing die. Hot pressing was then carried out at 30 kN pressure. Temperature initially was raised to 160°C and held there for 10-15 minutes. Then temperature was increased up to 180°C–190°C. After that, sample was cooled to the room temperature by water cooling and after cooling sample was removed from the die.

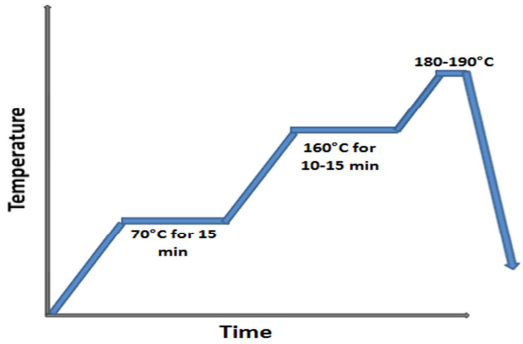

Fig. 3. Thermal Cycle During Hot Pressing

Fig. 3 shows thermal cycle during hot pressing.

2.2 CHARACTERIZATION TECHNIQUES

Fourier Transform Infrared Spectroscopy of the composites was conducted on a SHIMADZU spectrophotometer. In FTIR spectroscopy powdered samples were mixed with potassium bromide (KBr) (at a ratio KBr: Sample=100:1) and KBr acts as a reagent that was mixed with them in a mortar pestle.

Mechanical testing was carried out by tensile, flexural, impact and hardness tests. Tensile and flexural properties of the composites were determined using the universal testing machine of model INSTRON 3369. ASTM D638 and ASTM D 790-98 standard were followed for making the tensile and flexural specimens respectively. The Charpy impact test and hardness test of the composites were conducted by using an impact tester MT 3016 and Bareiss HPE II hardness tester respectively. ASTM D 6110-97 and ASTM D2240 standard were followed for making impact and hardness test specimens.

Tensile fracture surface morphology and interfacial bonding between fiber and polypropylene were analyzed using a Field emission scanning electron microscope (FESEM). Thermogravimetric analysis (TGA) was carried out for determining thermal stability of composites. In our study TGA was carried out in a universal V4.2E TA instruments (TGA Q50 V6.4) at a temperature range was 25˚C- 650˚C and a heating rate of 10˚C/min.

3 RESULTS AND DISCUSSION

3.1 FTIR SPECTROSCOPIC RESULTS

FTIR spectra of 10, 20 and 30 wt% waste textile fiber reinforced polypropylene composites are shown in Fig. 4 to 6. It is observed that absorption peaks at 3433.41 cm-1 (OH stretching vibration), 2962 cm-1, 2918 cm-1, 2840 cm-1 (asymmetric and symmetric C-H stretching vibration), 1456 cm-1 (CH3 asymmetric deformation),1376 cm-1 (CH3 symmetric deformation) and 840.8 cm-1 (C-C stretching, coupled C-H deformation) are the characteristic peaks of pure polypropylene [8], [9]. 1726.35 cm-1 (C=O stretching vibration), 1016.52cm-1, 1099.46cm-1, 1257.63cm-1 (C-O bond vibration) and 726.22cm-1 (aromatic C-H bond vibration) are the characteristic absorption peaks of waste textile fiber because with increasing fiber content these peaks have intensified.

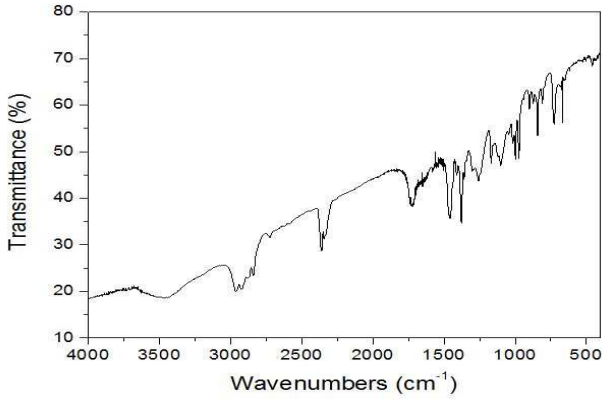

Fig. 4. FTIR Spectra of 10 wt% Fiber Reinforced PP Composite

Fig. 4 shows FTIR spectra of 10 wt% fiber reinforced PP composite.

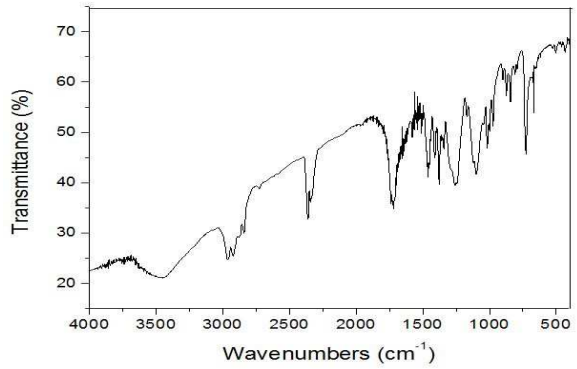

Fig. 5. FTIR Spectra of 20 wt% Fiber Reinforced PP Composite

Fig. 5 shows FTIR spectra of 20 wt% fiber reinforced PP composite.

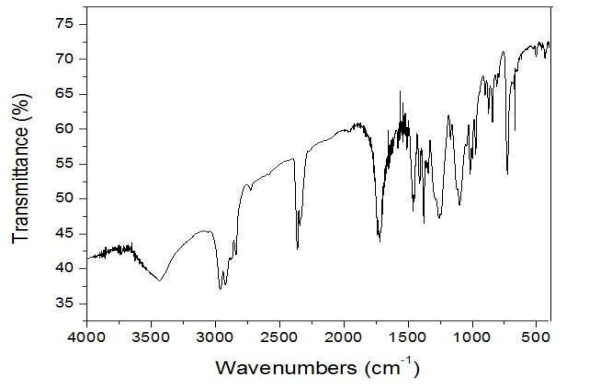

Fig. 6. Spectra of 30 wt% Fiber Reinforced PP Composite

Fig. 6 shows FTIR spectra of 30 wt% fiber reinforced PP composite

3.2 TENSILE PROPERTIES

Tensile properties of the waste textile fiber reinforced polypropylene composites at different fiber loading (10, 20 and 30 wt%) were analyzed with the help of stress-strain curve.

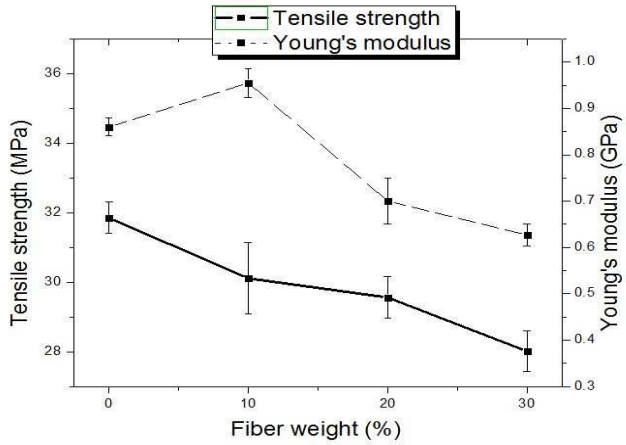

Fig. 7. Variation of Tensile Properties at Different Fiber Loading

Fig. 7 shows variation of tensile properties at different fiber loading.

From the tensile test result it is observed that tensile strength follows decreasing trend with increasing fiber content [9-15]. This behavior can only be explained by the weak interfacial area between fiber and matrix and the number of voids within the composite. Generally the tensile strength depends on the weakest part of the composites. As the fiber content increases number of voids and weak interfacial areas between fiber and matrix increase [9], [15-17].

During tensile loading, partially separated micro spaces are created, which obstructs stress propagation between the fiber and the matrix. As the fiber loading increases, the degree of obstruction increases, which in turn increases the stiffness [14], [15]. On the contrary, in this work young's modulus follows odd pattern with respect to fiber content. Initially young's modulus value increases up to 10 wt% fiber loading. Then its value drops sharply because at higher fiber content micro spaces that are created by tensile loading are filled with fiber, as a result, less obstruction for stress propagation between the fiber and the matrix.

3.3 FLEXURAL PROPERTIES

Flexural properties of the waste textile fiber reinforced composites at different fiber loading (10, 20 and 30 wt%) were analyzed with the help of flexural stress-strain curve. Fig. 8 shows that flexural properties generally follow decreasing pattern with increasing fiber amount. Poor fiber-matrix adhesion which promoted micro cracks formation at the interface as well as non-uniform stress transfer due to fiber agglomeration within the matrix are the main reasons for decrease in flexural properties [18], [19].

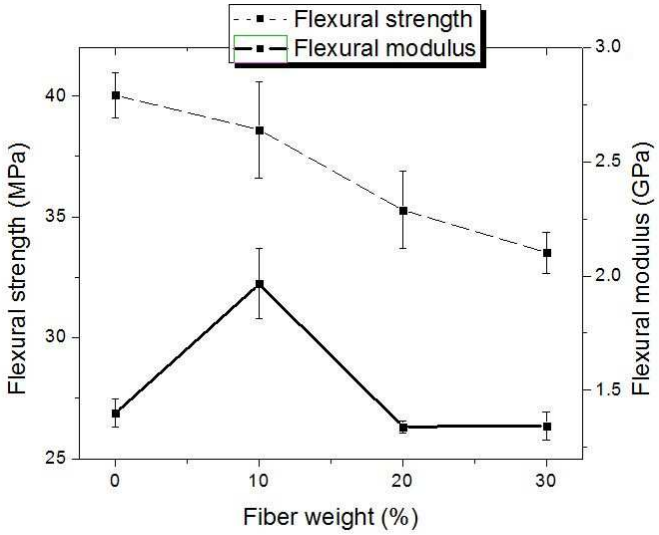

Fig. 8. Variation of Flexural Properties at Different Fiber Content

Fig. 8 shows variation of flexural properties at different fiber content.

There is an increase in flexural modulus up to a certain fiber loading, then decreases sharply. This increase in the flexural properties is primarily attributed to reinforcing effect imparted by the fibers, which allowed a uniform stress distribution from continuous polymer matrix to dispersed fiber phase [18].

3.4 IMPACT STRENGTH AND HARDNESS TEST RESULTS

Impact strength of composites increased with increasing fiber loading. The same trend was also observed by other researchers [13], [14], [15], [20]. The entanglement of fiber and matrix, rendering its main conclusion, that that fiber is capable of absorbing energy. With increase in fiber loading, stronger force was required to pull out the fibers from the matrix, as a result, impact strength increased [15], [20].

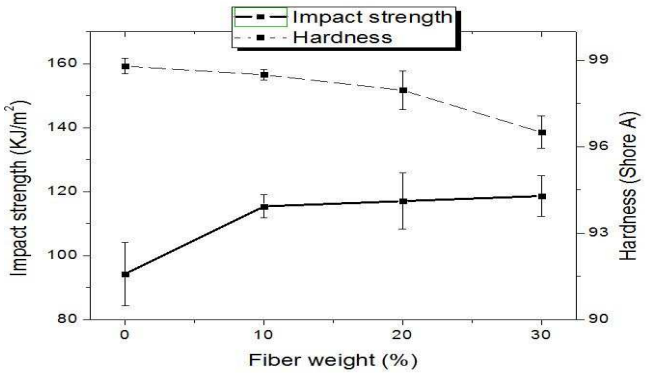

Fig. 9. Variation of Impact Strength and Hardness at Different Fiber Content

Fig. 9 shows variation of impact strength and hardness at different fiber content.

Distribution of fiber into the matrix is a main factor of hardness of a composite [15]. However, the hardness decreased with increasing fiber content due to the poor dispersion of fiber into the polypropylene matrix [21]. From the above hardness curve, hardness of the composites more or less similar and higher standard deviation of hardness for a particular composite provides its main conclusion that fiber into the matrix is not uniformly dispersed.

3.5 SEM MORPHOLOGY

Fracture surface morphology of the composite sample was analyzed for different fiber content (10, 20 and 30 wt%) with the help of SEM micrographs shown in Fig. 10 to 12. SEM micrograph of tensile fracture surface in Fig. 10 indicates occurrence of fiber pullout in composite.

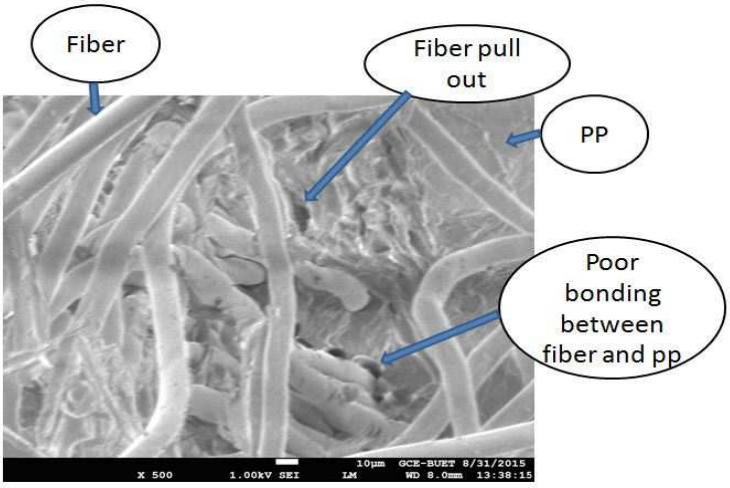

Fig. 10. SEM Micrograph of Tensile Fracture Surface of 10% Fiber Reinforced PP Composite

Fig. 10 shows SEM micrograph of tensile fracture surface of 10% fiber reinforced PP composite.

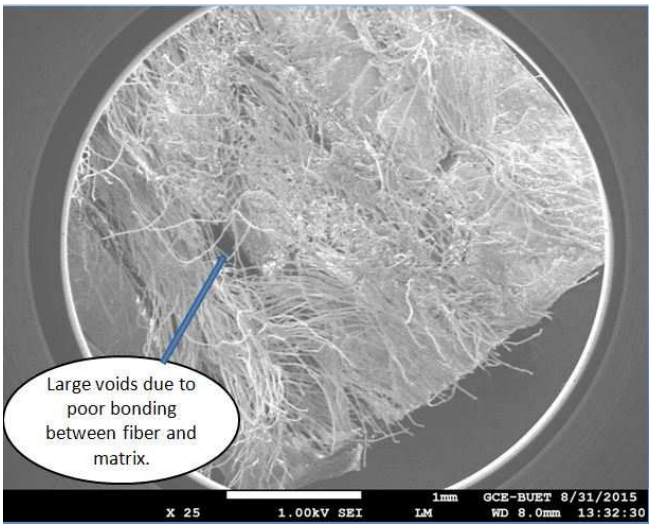

Fig. 11. SEM Micrograph of Tensile Fracture Surface of 20% Fiber Reinforced PP Composite

Fig. 11 shows SEM micrograph of tensile fracture surface of 20% fiber reinforced PP composite.

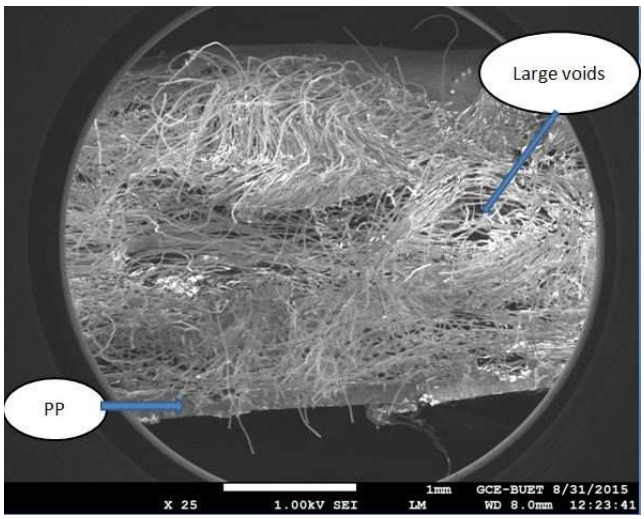

Fig. 12. SEM Micrograph of Tensile Fracture Surface of 30% Fiber Reinforced PP Composite

Fig. 12 shows SEM micrograph of tensile fracture surface of 30% fiber reinforced PP composite.

Why mechanical properties of the composites decreased with increasing fiber content can be understood by the SEM micrographs of the fracture surface. With increasing fiber volume fraction, number and size of voids within the composite increases, due to the poor interfacial bonding between fiber and matrix.

3.6 TGA ANALYSIS

In order to observe the thermal stability of composites, TGA analysis was performed at different fiber loading (10, 20 and 30 wt%). The specimens showed thermal stability at the range of 0-210°C. Three TGA curves shown in Fig. 13 to 15 are two stage decomposition curves.

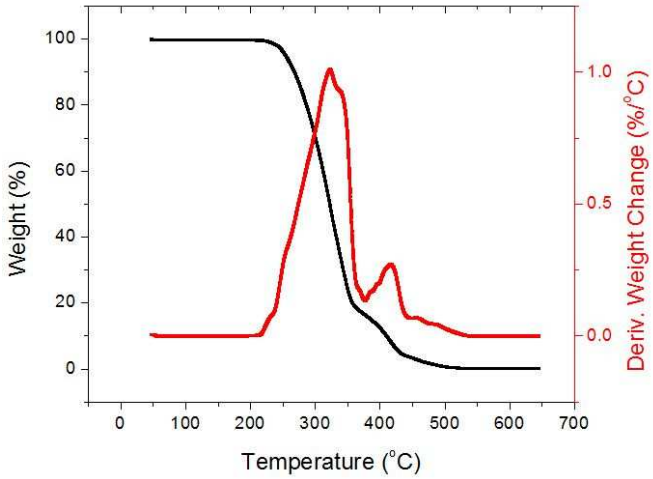

Fig. 13. TGA Curve of 10 wt% Waste Textile Fiber Reinforced PP Composite

Fig. 13 shows TGA curve of 10 wt% waste textile fiber reinforced PP composite.

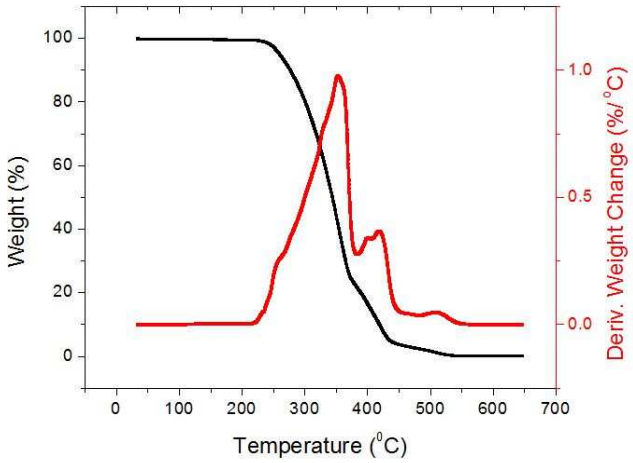

Fig. 14. TGA Curve of 20 wt% Waste Textile Fiber Reinforced PP Composite

Fig. 14 shows TGA curve of 20 wt% waste textile fiber reinforced PP composite.

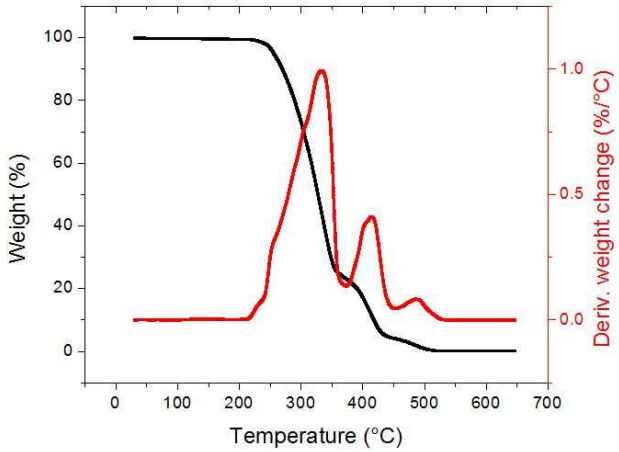

Fig. 15. TGA Curve of 30 wt% Waste Textile Fiber Reinforced PP Composite

Fig. 15 shows TGA curve of 30 wt% waste textile fiber reinforced PP composite.

No significant difference was observed between these three curves except second stage derivative weight change increases with increasing fiber volume fraction and first stage derivative weight change remains same with fiber loading. So, polypropylene starts to decompose first and then fiber starts to decompose. From these three TGA curves, composites start to decompose at approximately 230°C and on the other hand, polypropylene starts to decompose at 350°C [22]. As a result, composites have lower thermal stability than polypropylene.

4 CONCLUSION

The present research investigated the effects of fiber content on mechanical, thermal properties and the morphology of waste textile fiber reinforced polypropylene composites. Composites were manufactured using hot press machine at three levels of fiber loading (10, 20 and 30 wt%). Generally, mechanical properties show a decreasing trend with fiber volume fraction except impact strength that shows increasing trend. FTIR analysis of the composites at different fiber loading (10, 20 and 30 wt %) showed increasing of fiber content from 10% fiber reinforced to 30% fiber reinforced composite. SEM showed that poor adhesion between matrix and fiber and TGA suggested slightly lower thermal stability of composites than that of pure polypropylene.

ACKNOWLEDGMENT

First and foremost the authors would like to express their utmost gratitude to Department of MME and Department of GCE of Bangladesh University of Engineering and Technology (BUET) for technical and financial support during the work.

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