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Processing and Characterization of Areca and Waste Nylon Fiber Reinforced Hybrid Polypropylene Composites

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ABSTRACT: The growing global environmental concern has increased the attention of world's scientific community towards natural fiber reinforced eco-composites. Hybridization of natural fiber with waste synthetic fiber improves the property of the composites as well as provides a better solution to waste management issues. Our Present research investigates the mechanical properties of layered areca and waste nylon fiber reinforced hybrid polypropylene (PP) composites. Composites were manufactured using hot press machine at a constant fiber loading of 10 wt% (areca: nylon=1:1), reinforcing the fibers into 2, 3 and 4 distinct layers. Tensile, flexure, hardness tests and Fourier transform infrared spectroscopic analysis were conducted for the characterization of the composites. Tensile test of composite showed an increasing trend of tensile strength and Young's modulus with increase in number of fiber layers. Similar trend was also observed in case of the flexural strength, flexural modulus and hardness values measurement. The surface morphologies of the tensile fracture surfaces of the composites were studied using scanning electron microscopy (SEM).The thermal stability of the composites were recorded using Thermo Gravimetric Analysis (TGA).

KEYWORDS: Hybrid composites, areca, nylon, polypropylene, mechanical properties.

1 INTRODUCTION

At present the world is shifting rapidly towards a green era of ecofriendly materials for product development because today's consumers are more concerned about the environment friendliness and cost effectiveness of the products. As a result of which natural fiber reinforced composites are getting considerable attention from the world's scientific community because of their characteristic biodegradability, light weight and renewability [1]. Apart from minimizing environment pollution by absorbing CO_2 during their growth, lignocellulosic fibers are attractive because of their easy availability, non-abrasiveness and less energy consumption during processing [2], [3], [4], [5]. The lignocellulosic fibers can be mixed either with thermosetting or thermoplastic polymer matrix to produce composites.

Recent studies has proven that the formation of hybrid composites that is incorporation of a synthetic fiber in addition to natural fiber in polymer based matrix provides a huge 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. Also the concepts of hybridization enable the designer's greater flexibility in tailoring mechanical properties according to the requirement [1]. Using synthetic textile waste fiber for reinforcement in composites creates a new way of recycling those materials which is one of the main concerns of today's industrial world [6].

A large number of studies have been carried out using coir, jute, sisal, flax, hemp as the reinforcement of polymeric materials. Among many other natural fibers, areca fiber is one of the most promising candidate for reinforcement in polymeric materials because it is quite inexpensive, abundantly available and a very high potential perennial crop. It belongs to the species *areca catechu Linnaeus* under the family *Permecea* which grows in much of the tropical Pacific, Asia, and parts

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of east Africa [7]. The tropical region having hot and humid climate is highly suitable for the cultivation of areca nut crops. The areca husk is a hard fibrous material covering the endosperm and constitutes about 60-80% of the total weight and volume of the areca[8].The husk fiber is mainly composed of cellulose with varying proportions of hemicelluloses (around 32.98%) and lignin (7.20%), pectin and protopectin [9].The average filament length of areca husk fiber (4 cm) is too short in comparison to other biofibers[7].The present use of this husk is as a fuel in areca nut processing. On the other hand Nylon fibers are polyamides with recurring amide groups. It has excellent tenacity with high strength to weight ratio. Apart from this the other properties includes high mechanical strength, abrasion resistance, chemical stability, good elasticity and resilience. A large number of thermoplastics are used as matrix in composites. Among many other thermoplastics polypropylene possesses outstanding properties such as low density, good flex life, sterilizability, good surface hardness, abrasion resistance and excellent electric properties [5].

So the objective of this present research is to obtain a balanced combination of mechanical properties by using a natural and a synthetic fiber as reinforcement in polymeric matrix and thus improving the emerging era of green composites in combination with waste fiber recycling. In the present work we have investigated the effect of number of fiber laminate enhancement on the mechanical properties of areca and waste nylon fiber reinforced polypropylene composites. Randomly oriented short fiber contained laminates provides in plane isotropy. So in cases of omni-directional load application, performances of these composites are quite praiseworthy [10].

2 EXPERIMENTAL

2.1 MATERIALS

Commercial grade polypropylene (PP) was used in this study. Polypropylene sheets were collected from the local market. The PP was white in colour having a melting point of 160°C. Waste nylon fibers were collected from a local textile industry and they were chopped in the size of 3-4 mm. The die used to prepare composite was made of aluminum. The die was made by machining aluminum plate to a desired shape.

2.2 EXTRACTION OF ARECA NUT FIBER

The dried areca empty fruit was soaked in water for about seven days. This soaking process loosens the fiber allowing it to be removed from the fruit easily. This process is called retting. The fibers were removed from the fruit. After drying in the room temperature, the fibers were further separated into an individual state using hand.

Fig. 1. Extracted Areca Nut Fiber

Figure 1 shows the extracted areca nut fiber.

Fig. 2. Commercial Nylon Fiber

Figure 2 shows the fiber commercial nylon fiber

2.3 MANUFACTURING OF COMPOSITES

Hybrid composites of polypropylene matrix reinforced with areca and waste nylon fibers were manufactured using hot press technique in a 150×150×5 mm die. Composites were prepared incorporating 10 wt% areca and nylon fiber in a ratio of (1:1) in polypropylene matrix. Three types of composites were prepared in which the fiber percentages were reinforced by dividing into 2, 3 and 4 distinct layers. A hydraulic type machine having maximum load of 35 kN and maximum temperature of 300 °C was utilized. Fibers were cut into 3-5 mm length. Firstly, required amount of fiber and PP were weighed in a balance. In order to allow the removal of moisture, fibers and polypropylene sheets were dried in an oven at 80 °C for 20 minutes before preparing each composite. In 2 layered fiber reinforced composite, properly weighed fiber percentage was divided into two equal halves and the PP sheets were divided into three equal plies. After that placing of one ply of PP sheets and one fiber layer one above another inside the die, the composite lamina was prepared. Both the fibers were premixed in order to ensure better distribution of both fibers into the matrix. The fiber-matrix mixture was allowed to press at 30 kN pressure. The temperature was initially raised to160 °C and hold there for around 12-15 minutes, after that the temperature was raised to (180-185) C depending on the thickness required. The die was cooled to room temperature, pressure was released and the composites were withdrawn from the die. The composites reinforced with 3 and 4 layers of fibers were prepared in the same way.

2.4 FTIR SPECTROSCOPY

In present research infra-red spectra of areca, waste nylon fiber and the hybrid composite were recorded on a SHIMADZU spectrophotometer. Firstly, some powdered samples were collected by scratching of the composite by a knife. Then potassium bromide (KBr), which acts as a reagent, was mixed (at a ratio KBr: Sample=100:1) with them in a mortar pestle. The mixture was then taken into a dice of specific dimensions (13 mm dia). The pellet was formed by pressing (mechanical presser at 8 tons of pressure) and was placed on the sample holder and the spectroscopy was carried out.

2.5 SCANNING ELECTRON MICROSCOPY (SEM)

The morphology of the tensile fracture surface of areca-waste nylon fiber reinforced hybrid PP composites and interfacial bonding between the filler and the PP matrix was examined using a Field emission scanning electron microscope (FESEM). The samples were viewed perpendicular to the fractured surfaces. The micrographs were taken at a magnification of 100 and 200.

2.6 TGA ANALYSIS

In In our study TGA was carried out in a universal V4.2E TA instruments (TGA Q50 V6.4) at a temperature range of 25-800ºC, with a constant heating rate of 10ºC/sec.

2.7 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 ASTMD 638-01 [11] using a Instron universal testing machine at a crosshead speed of 4 mm/min. Each test was continued until tensile failure. Static flexural tests were carried out according to ASTM D 790-00 [12] using the same testing machine mentioned above at same crosshead speed. The hardness of the composite was measured using a shore hardness testing machine.

3 RESULTS AND DISCUSSIONS

3.1 FTIR SPECTROSCOPIC ANALYSIS

- The FTIR spectrum of the untreated areca fibers and waste synthetic fibers between around 450 cm^{-1} and 4000 $cm^{-1}$are shown in figure 3 and figure 4. The characteristic infrared absorption frequencies that dominates in the FTIR spectrum of areca fiber are at 3421.72 cm^{-1} which indicates the hydroxyl group and bonded OH stretching,1045.42 cm^{-1} which indicates C-O stretching vibrations. The peak at 1737.86 cm^{-1} represents ester and other crosslinks between cellulose and lignin or cellulose and hemicelluloses [8]. Furthermore, the peak of C=C stretching of the aromatic ring of the guaiacyl unit is found at 1631.78 cm^{-1}[5]. The peaks observed between 1100-1600 cm^{-1} showed the presence of hemicellulose in the fiber. The peak at 1379.1 cm^{-1} is referred to alcohol group of cellulose. The peak at 1512.19 cm^{-1} corresponds to the lignin and lignocelluloses (aromatic skeletal).
- The characteristic infrared absorption frequencies of the waste nylon fiber includes peak at 1739.79cm^{-1} which represents C=O stretching, 3425.58 cm^{-1} corresponds to amine N-H stretching, The peaks at 3500-3700 cm^{-1} represents amide N-H stretching. All these characteristic peaks are quite conspicuous at the FTIR of composite (figure 5) also the peak in the range of ~2900-2880 /cm is due to C-H vibration of – (CH_2) - group of PP [13].

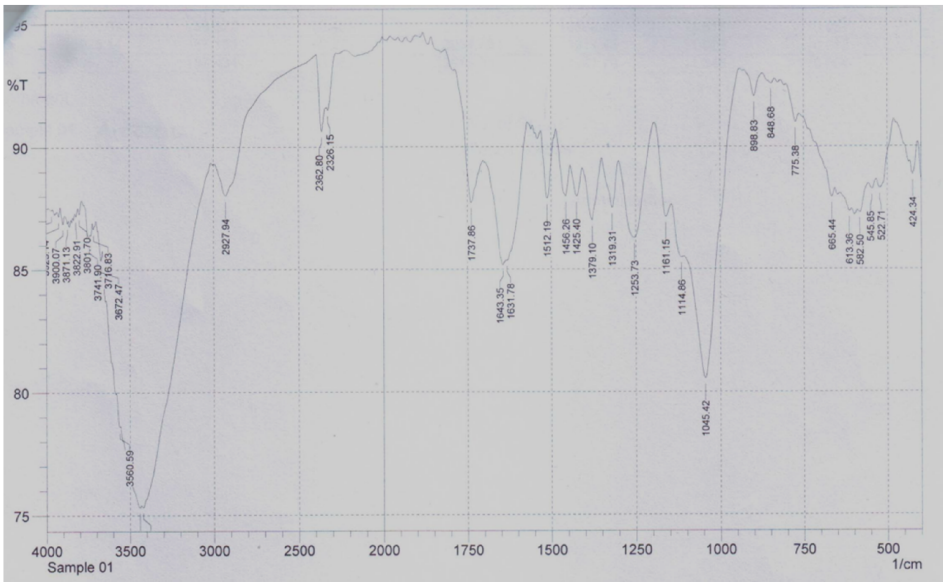

Fig. 3. FTIR Spectrum of Areca Nut Fiber

Figure 3 shows FTIR spectrum of areca nut fiber.

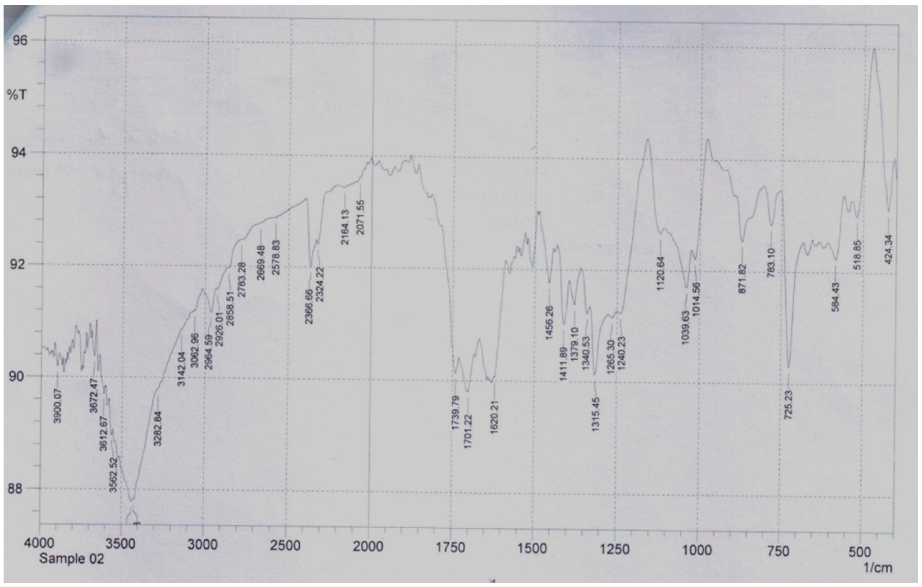

Fig. 4. FTIR Spectrum of Waste Nylon Fiber

Figure 4 shows FTIR Spectrum of waste nylon fiber.

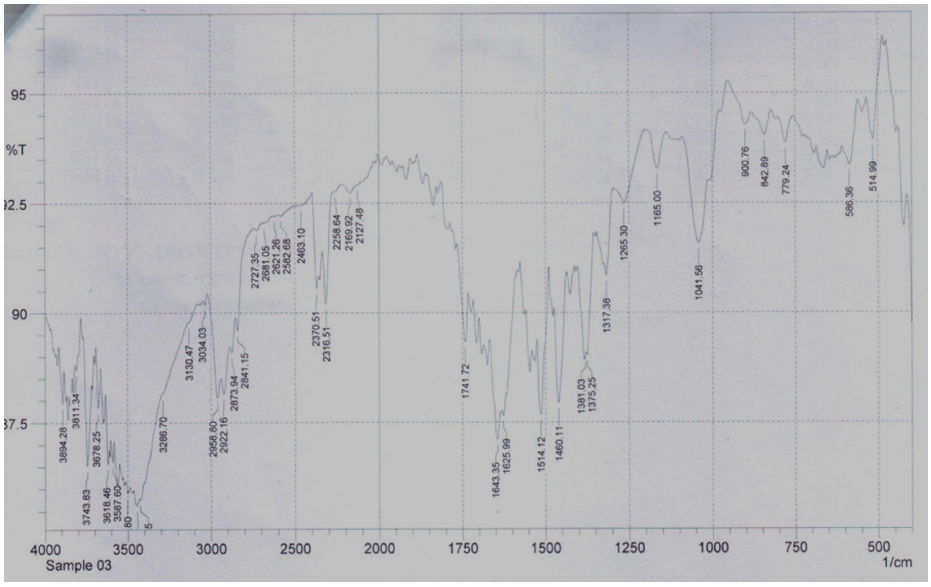

Fig. 5. FTIR Spectrum of 3L Areca and Waste Nylon Fiber Reinforced PP Composite

Figure 5 shows the FTIR spectrum of 3L areca and waste nylon fiber reinforced PP composite.

3.2 TENSILE PROPERTIES

Tensile properties (Young's modulus, tensile strength and elongation at break) of the 2 layered (2L), 3 layered (3L) and 4 layered (4L) 10 wt% areca and waste nylon fiber (areca: nylon=1:1) reinforced composite samples were measured with the help of stress/strain curves. The tensile strength, young's modulus and elongation at break values of areca and waste nylon fiber (areca: nylon=1:1) reinforced hybrid polypropylene composites are shown in Figure 6, 7 and 8 respectively.

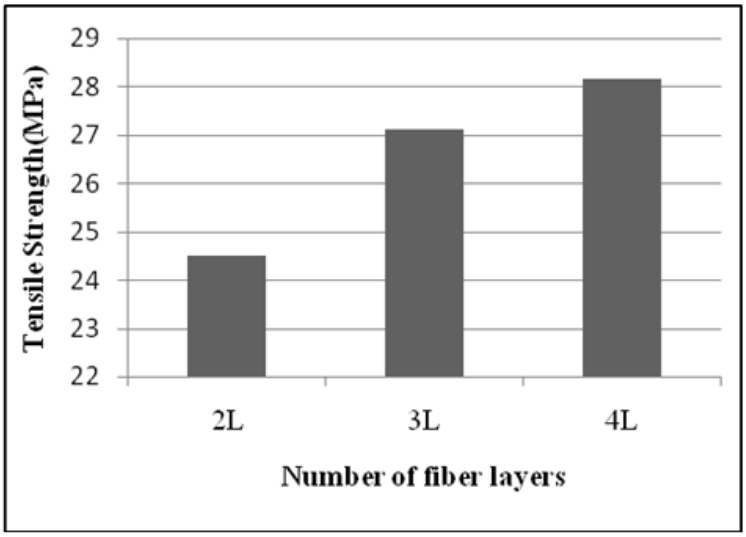

Fig. 6. Variation of Tensile Strength with Number of Fiber Layers

Figure 6 shows variation of tensile strength with number of fiber layers.

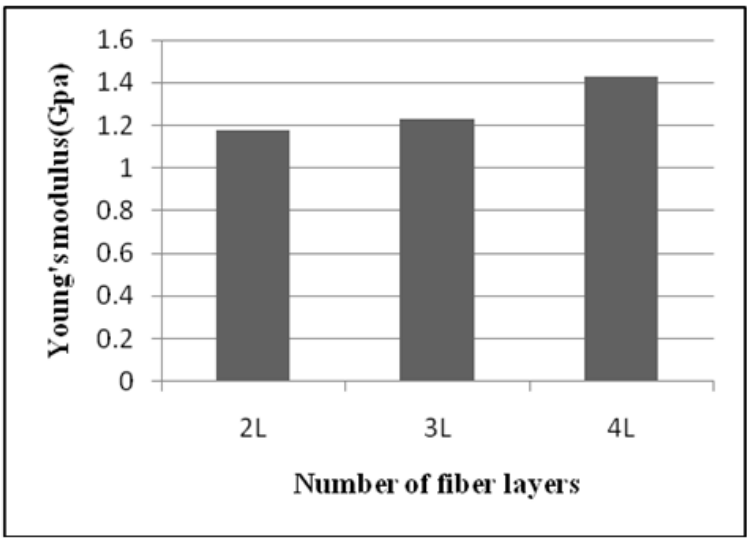

Fig. 7. Variation of Young's Modulus with Number of Fiber Layers.

Figure 7 shows variation of Young's modulus with number of fiber layers.

The tensile strength increased with an increase in number of fiber layers. As the number of fiber layers increases, the fibers become uniformly dispersed into the matrix. So the interaction between the fibers are limited which constraints the formation of voids [15, 16]. This consequently increases the tensile strength. The same trend was also observed by other researchers [17, 18]. It is observed that the Young's modulus increased with an increase in number of fiber layers. High stiffness is related to the fine dispersion of individual fiber so that good materials contact is created [15], [16], [17], [18], [19].

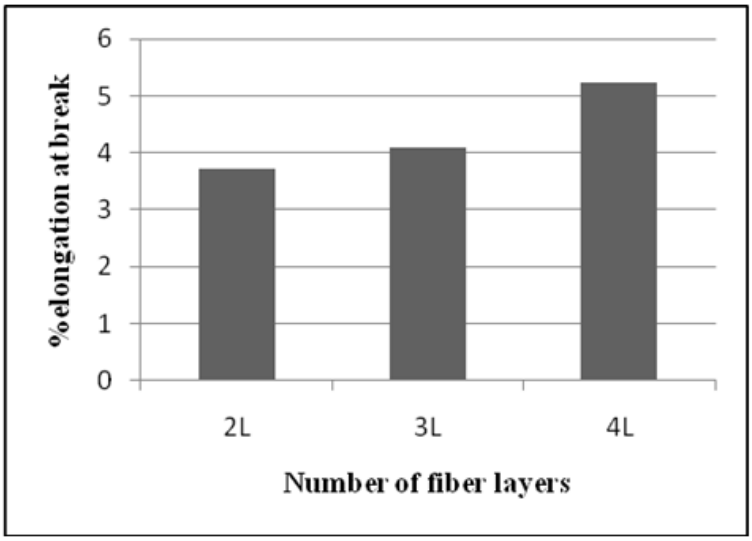

Fig. 8. Variation of %Elongation at Break with Number of Fiber Layers.

Figure 8 shows variation of % elongation at break with number of fiber layers.

Percentage elongation at break increased with the enhancement of number of fiber layers. This is due to the uniform dispersion of fibers that restrict the interference of fibers in the mobility or deformability of the matrix, which results in the enhancement of elongation at break of the composite [20].

3.3 FLEXURAL PROPERTIES

Flexural properties (Flexural strength and flexural modulus) of the 2 layered (2L), 3 layered (3L) and 4 layered (4L) 10 wt% areca and waste nylon fiber (areca: nylon=1:1) reinforced composite samples were measured with the help of flexural stress/strain curves and respective equations. The flexural strength and flexural modulus of areca and waste nylon fiber (areca: nylon=1:1) reinforced hybrid polypropylene composites are shown in Figure 9 and 10 respectively.

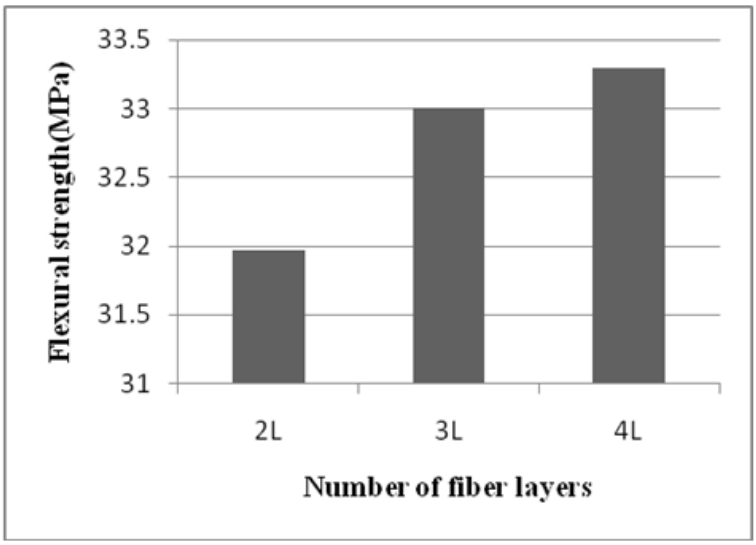

Fig. 9. Variation of Flexural Strength with Number of Fiber Layers.

Figure 9 shows variation of flexural strength with number of fiber layers.

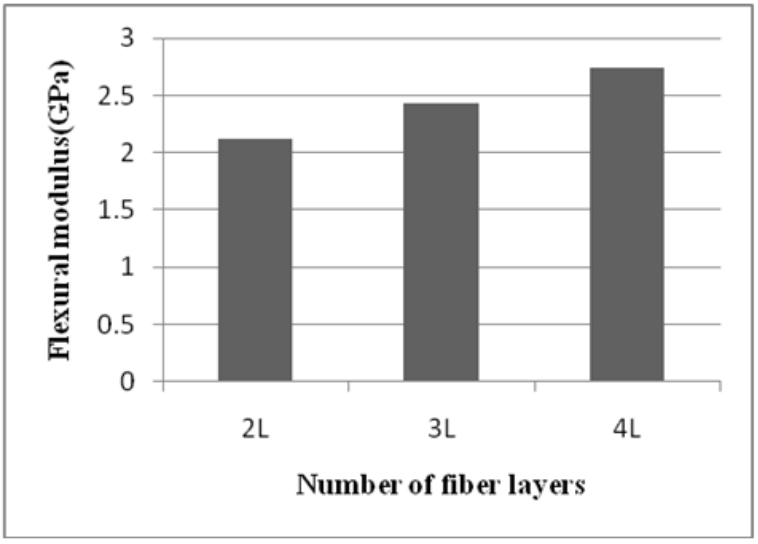

Fig. 10. Variation of Flexural Modulus with Number of Fiber Layers.

Figure 10 shows variation of flexural modulus with number of fiber layers.

The flexural strength increased with an increase in number of fiber layers, which is in agreement with the findings by other researchers [Reference required]. This may be due to the lower amount of clustering of fibers which results due to the non- uniform dispersion of fibers with increasing/ decreasing fiber layers. Clustering affects the effective load transfer and reduces the flexural strength [16]. Also properly arranged high modulus fiber causes the enhancement of flexural modulus.

3.4 HARDNESS PROPERTIES

Hardness of a composite depends on the uniform distribution of the filler into the matrix [2, 21].Hardness is enhanced when the flexibility of matrix is lowered. The presence of a rigid fiber material into the pp matrix results into more rigid composites. Due to the decrease of flexibility of respective composite the hardness of areca waste nylon fiber reinforced hybrid PP composites showed a slight increasing trend with an increase in the number of fiber layers [2].

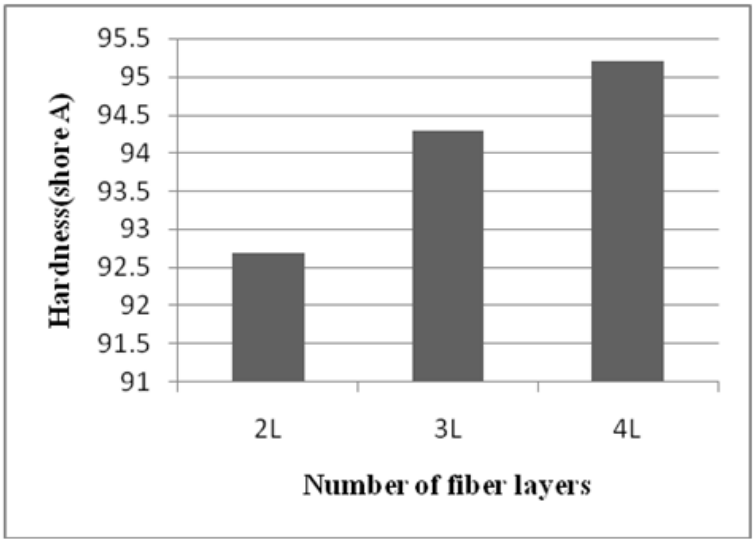

Fig. 11. Variation of Shore Hardness with Number of Fiber Layers.

Figure 11 shows variation of shore hardness with number of fiber layers.

3.5 TGA ANALYSIS

The TGA curves of 3 layered(3L) and 4 layered(4L) 10 wt % areca and waste nylon fiber reinforced polypropylene (PP) composites are shown in figure 12 and Figure 13.In both cases the obtained TGA curves represents a one-stage decomposition and therefore represents the thermal stability limit of the composite. From Fig 11 it can be seen that in case of 3 layered fibers reinforced composite thermal degradation starts at around 280 ºC and the decomposition starting temperature does not differ much in case of 4 layered fiber reinforced composite without slight enhancement. From this it can be concluded that the composites have lower thermal stability then pure polypropylene which starts to decompose in around 350 ºC [23] and this occurs due to the presence of less thermally stable fibers. However, around 2.5% residual products remains in 4 layered fiber reinforced composite, the amount is slightly higher in case of 3 layered fiber reinforced composites[22],[23].

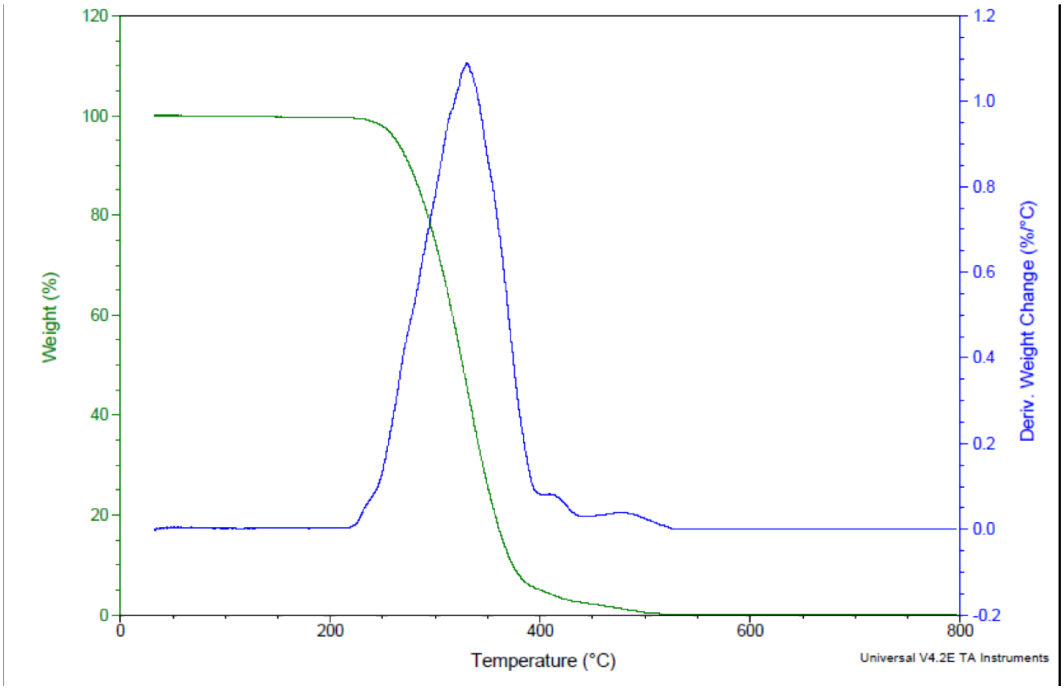

Fig. 12. TGA curve of 3L 10 wt% areca waste nylon fiber(areca:nylon=1:1) reinforced PP composites.

Figure 12 shows TGA curve of 3L 10 wt% areca waste nylon fiber(areca:nylon=1:1)reinforced PP composites.

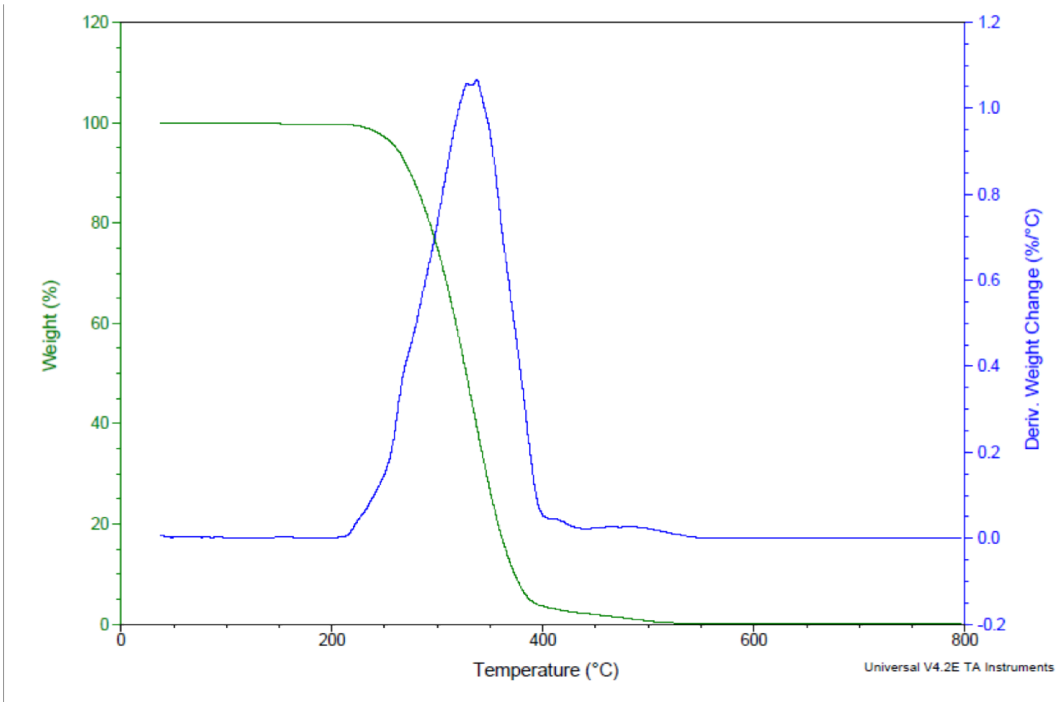

Fig. 13. TGA curve of 4L 10 wt% areca waste nylon fiber (areca:nylon=1:1) reinforced PP composites.

3.6 SEM MORPHOLOGY

The tensile fracture surface morphologies of 2L,3L,4L areca and waste nylon (areca: nylon=1:1) fiber reinforced hybrid polypropylene composites are shown in figure 14,15 and 16 respectively. From The morphology of the fracture surface the phase information can be understood. It reflects the reasons why the mechanical properties of the composites fabricated with more number of fiber layers is better than others. The SEM micrograph of the 2L areca and waste nylon fiber reinforced composites shows weak interfacial bonding of fiber and matrix as well as agglomeration of the fibers in polypropylene matrix. In the SEM images of 3L fiber reinforced PP composites a number of pullout traces of fiber with smooth other hand 4L fiber reinforced PP composites show better dispersion of the filler into the matrix as clearly seen in the micrograph (figure 16) both surfaces are quite conspicuous. These clustering of fiber suggest non uniform dispersion of fibers in matrix [24]. On the fiber pull-out traces and the agglomeration of the fibers in the matrix is substantially reduced in this one. The outcome of the better dispersion of fiber in the matrix is reflected by the improvement of the mechanical properties of the 4L fiber reinforced composites.

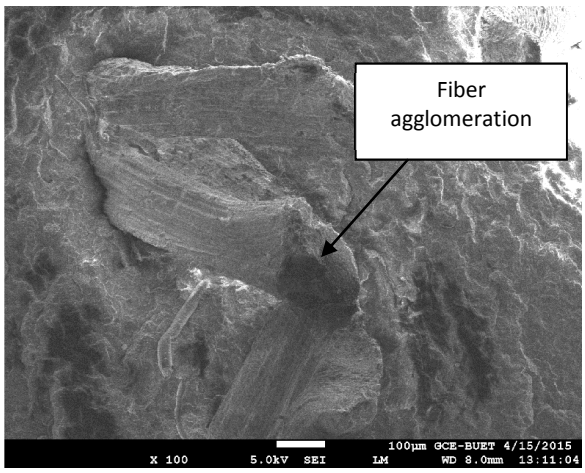

Fig. 14. SEM micrograph of tensile fracture surface of 2L 10 wt% areca waste nylon fiber(areca: nylon=1:1)fiber reinforced PP composite.

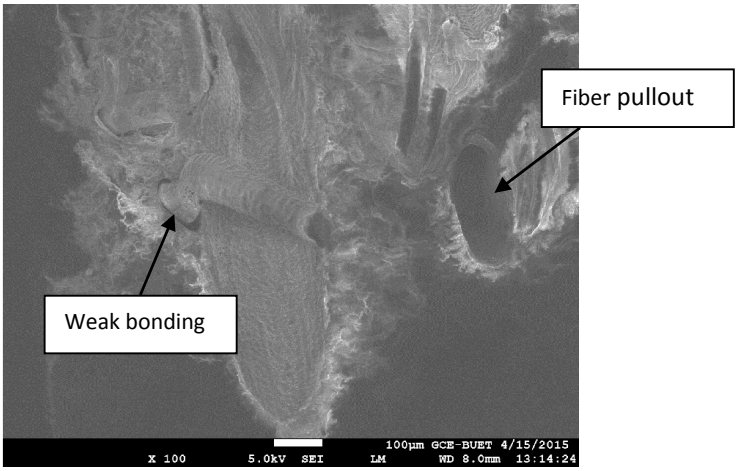

Fig. 15. SEM micrograph of tensile fracture surface of 3L 10 wt% areca waste nylon fiber (areca: nylon=1:1) fiber reinforced PP composite.

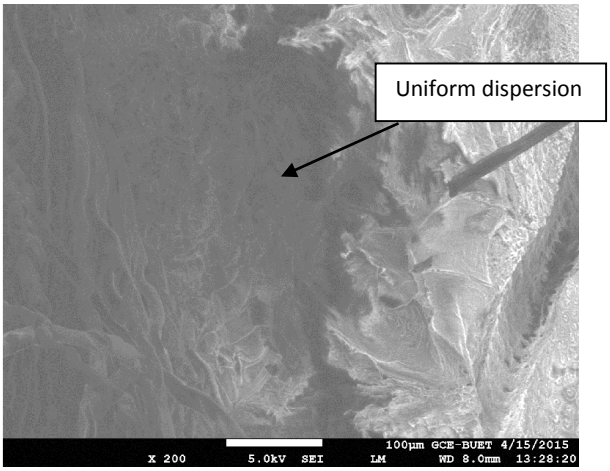

Fig. 16. SEM micrograph of tensile fracture surface of 4L 10 wt% areca waste nylon fiber (areca: nylon=1:1) fiber reinforced PP composite.

4 CONCLUSION

The present study reveals that areca and waste nylon fiber could be successfully used as reinforcing fillers in polypropylene composites. In the present work, mechanical properties of layered composites were studied.. Three composites of 10 wt% areca and waste nylon fiber (areca: nylon=1:1) has prepared changing reinforcing condition of fiber in 2, 3 and 4 layers. The tensile strength of the layered composites enhanced with an increase in number of fiber layers. The change of young's modulus and % elongation at break also reveals the similar trend. Flexural strength, flexural modulus and hardness values increased with an increase in number of fiber layers. FTIR spectroscopic analysis of areca, nylon and both fiber reinforced composites shows characteristic peaks of hemicelluloses and lignin. SEM micrograph reveals the reason of better mechanical property of 4 layered fiber reinforced composites compared to 2 and 3 layered composites. TGA curves indicated that composites have lower thermal stability then pure polypropylene and it varies only slightly with changing number of fiber layers.

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