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Mechanical and Thermal Characterization of Camphor Soot Embedded Coir Fiber Reinforced Nylon Composites

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Abstract: In this study, camphor soot was infused into coir fibers using osmosis technique. Further, modified coir fibers were reinforced in nylon 6 using the melt intercalation method by varying fiber content (0, 3, 6, 9 wt. %) to obtain camphor soot embedded coir fiber reinforced nylon composites (CSCFNCs). The presence of camphor soot infused coir fibers in nylon 6 matrix was confirmed through XRD peaks by forming a single peak for CSCFNCs compared to neat nylon 6. CSCFNCs were characterized for tensile strength, flexural strength, impact strength and density as per ASTM standards. Thermal behaviour of CSCFNCs were also investigated by TGA, DSC, MFI and DMA. Tensile strength, flexural strength and density of the CSCFNCs were enhanced compared to neat nylon 6. On the other hand, impact strength is reduced. MFI and tan δ values for CSCFNCs shows decreased trend due to constrained polymer movement. TGA analysis for CSCFNCs shows increased thermal stability, marginally. DSC analysis revealed two peaks at 228 °C and 468 °C corresponds to the melting point and degradation temperature of CSCFNCs respectively. DMA result shows the storage modulus of 700 MPa for neat nylon 6 and it is enhanced in the case of CSCFNCs. Maximum storage modulus was recorded for 6 wt. % CSCFNCs was 806 MPa. Creep study shows that 6 wt. % CSCFNCs has shown minimum impression depth 0.125 mm compared to neat nylon 6 0.212 mm. SEM reveals that the fibers are uniformly distributed in the matrix and experienced brittle fracture.

Keywords: Camphor soot, Coir fibers, Osmosis, Nylon 6 matrix, Melt intercalation method

Introduction

The rise in prices of plastics, both manufacturing products for commodity and in engineering applications motivates to minimise the dependency on fossil fuels. Growing environmental concerns are convincing researchers to explore sustainable and eco-friendly substitutes for synthetic fibers for the growth of new composites for industries like furniture, and automotive applications [1-3]. Lignocellulose fiber reinforced polymers are biodegradable, environmental friendly and abundant in nature, but natural fibers are increasingly adopted to replace synthetic fibers as reinforcements in thermoplastics for industrial applications [4-6]. As a consequence of growing demand for ecological materials the mechanical properties of plant fibers made these fascinating materials to have global usage in automotive components like headliners, seat backs, panels of door, packaging trays, trunk linings, control panel and internal parts [7,8].

Nowadays, approximately half of an automobiles internal parts are made of polymer composites. In most, advanced countries, the average use of polymer composites in motor vehicles is nearly 110 kg, while usage in other countries is around 105 kg, which accounts for 10-15 % of the entire automobile mass [8, 9]. According to a case study of average fuel economy, the weight of car can be reduced by approximately 10 % to decrease fuel usage by 6-8 % [9]. The reinforcement of relatively low density plant fibers in higher proportions in the engineering plastics can significantly reduce the weight of final components [10]. Among all natural fibers, coir fiber has shown potential in the field of composites. Coir fibers are extracted from the exterior shell of coconuts. Fiber cells are hollow and narrow, comprising dense walls of cellulose. There are two types of coir fibers. White coir fibers are extracted from pre-ripe coconuts. These are smoother and finer and have a white or light brown colour. On the other hand, brown coir is harvested from fully grown coconuts. It is strong and thick and has good abrasion resistance. It is widely used to make brushes, mats and sacking as it contains more lignin and less cellulose than other natural fibers making it stronger and less flexible [11].

Coconut trees are have an astonishing osmosis rate due to their size and so their fibers are highly porous. Coconut fibers are composed of many elementary fibers (in the range of 200) with a lacuna at the centre. The micro elementary fibers are made of two main cell walls comprising bundles of micro fibers aligned at an angle to the fiber axis. Coir fibers have an estimated porosity of about 22-30 % [12]. The porosity of the coir fiber can be used for interfacial alterations by changing their surface topography by reinforcing camphor soot particles with the help of osmosis. Thermal stability of lignocellulosic fibers can be enhanced by surface treatment or additives as by using camphor soot which is a burnt substance with high thermal stability. This can be reinforced in coconut fibers as they have high porosity.

Camphor ($C_6H_{16}O$) is extracted from the cinnamomum camphora tree which is non-toxic and eco-friendly. Camphor is a natural source for both sp^2 and sp^3 covalent bonds with carbon and is considered a fresh nano material vendor.

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Around 0.1 g of carbon nanotubes can be manufactured from 0.5 g of camphor and this is suitable for large scale production of carbon nanotubes [13]. The thermal stability of natural fibers is a crucial factor in polymer processing and the selection of polymer for the manufacturing of bio composites is limited to low melting point plastics like polyethylene and polypropylene. As the melting point of engineering plastics like nylon and polyethylene terephthalate is relatively higher compared to the degradation temperature of lignocellulosic fibers it would lead to the degradation of natural fibers [14].

In the recent past, nylon composites play a vital role in the automobile applications, effectively competing with conventional materials like metals and thermoset resins due to higher resistance to elevated temperatures, light weight, good chemical resistance, decent tensile strength and high modulus, good aesthetics and its part consolidating potential [15]. The use of polyamide as a matrix for lignocellulosic fibers offers excellent advantages like good mechanical properties compared to polyolefins, due to its affinity to the moisture which enhances compatibility between nylon and natural fibers and eliminates the need for a coupling agent or compatibilizer [14]. The objective of this article is to manufacture nylon 6 composites by using camphor soot embedded coir fibers as a reinforcement in nylon 6 through a twin screw extruder makes the developed composites suitable for automotive applications. This article also focuses on effect of increasing in wt. % of modified coir fiber with nylon 6 on the properties of mechanical, thermal and microstructural studies.

Experimental

Materials

Nylon-6 as 3 mm granules was supplied by Colam traders Coimbatore, and had a density of 1.13 g/cm^3. Coconut fibers were purchased from SKT textile services India Pvt. Ltd. The apparent density of raw coir fibers was found to be 0.79 g/cm^3. Camphor soot was prepared by burning camphor tablets and collecting the soot on a glass plate. The apparent density of camphor soot was 0.3 g/cm^3.

Processing of Composite Materials

Fabrication of camphor soot embedded coir fiber reinforced nylon composites was carried out in two steps. First the processing of coir fibers was followed by reinforcing the processed coir fibers in nylon. Manufacturing of camphor soot embedded coir fibers was carried out through the osmosis technique. Figure 1 shows interfacial alteration of the coir fibers. Ripened coir fibers with a uniform diameter were selected and subjected to prewash in clean water. Subsequently moisture in the raw fibers was removed using a hot air oven at 50 °C for an hour and the initial weight of fibers was recorded. Dried raw fibers were then immersed in a camphor soot water solution prepared with the aid of ultrasonication method to disperse camphor soot particles uniformly. It had different weight fractions for different timespans and temperature.

As the coir fibers are highly porous and act as a semipermeable membranes camphor soot particles of around 40-50 nm tend to diffuse in to the fibers by osmosis. Further,

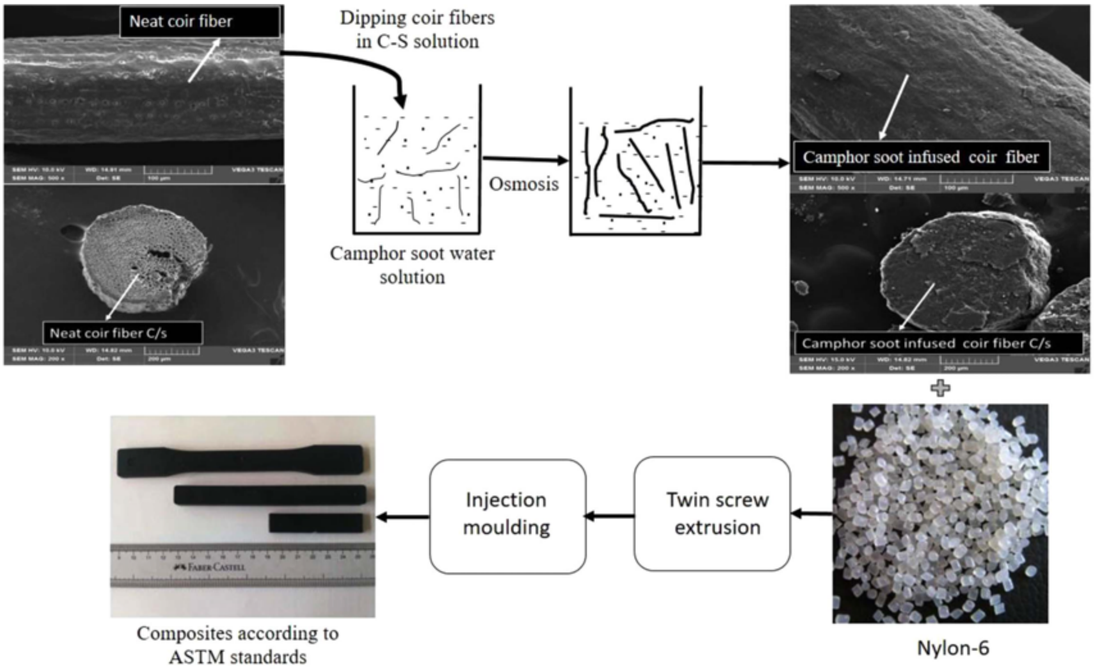

Figure 1. Manufacturing of camphor soot embedded coir fiber reinforced nylon composite.

the modified fibers were taken out from the container and moisture was removed and their final weight was recorded. The fiber preparation and parameter optimization is discussed in detail in the paper [16]. The processed coir fibers were chopped approximately 1 mm length and were reinforced in nylon using the melt intercalation method. First, processed coir fibers and nylon-6 granules were dried in a hot air oven for 3 hours to remove moisture. Composites with varied processed coir fiber reinforcement (0, 3, 6, 9 wt. %) was prepared using segmented twin screw extruder with an L/D ratio of 40. The screw speed was 75 rpm and temperature range was between 210 °C to 280 °C. The extrudate was cooled through a water bath, pelletized and moisture was removed using a hot air oven over the night. Further, the composite granules were injection moulded in accordance with ASTM standards in the temperature range of 230-250 °C at an injection pressure of 90 bars.

Characterization of Composites

Tensile test was done according to ASTM D-638, under room temperature and pressure with the aid of a kalpak computerised horizontal testing machine, having a load cell of 2 kN and cross head speed 10 mm/min. The stated values of tensile strength are the average of three measurements.

Flexural test was performed according to ASTM D-790 with a cross head speed of 1 mm/min in ambient conditions using a TINIUS-OLSEN universal testing machine. The impact test was conducted according to ASTM D-256 with a hammer force of 6.5 joules and v notch on the specimen using an IZOD impact tester. The density of the composites was determined by ASTM D792. The samples were weighed both in air and water and density was determined using standard equations.

The rheological behaviour of nylon composites was examined using a melt flow index (MFI) tester, manufactured by Veekay test labs at 235 °C and 2.16 kg load. Extrudate timer was set to 30 s and the MFI was calculated. XRD was carried out using PANalytical X'Pert Pro MPD with Cu-Kα radiation, with a scanning speed of 2 ° min^{-1}, and scan angles (2θ) ranging from 5 to 80 °.

Thermogravimetric analysis was conducted in the presence of nitrogen atmosphere. The specimens were heated gradually from room temperature to 650 °C at a heating rate of 10 °C/min with the flow rate of nitrogen gas having 60 m*l*/min. DSC was measured with the help of a DSC 6000-Perkin Elmer apparatus. The operating temperature was from room temperature to 350 °C at a heating rate of 10 °C/min with the nitrogen gas flow rate being maintained at 20 m*l*/min.

The storage modulus and tan δ of neat nylon and CSCFNCs has been studied by DMA. The DMA was conducted using NETZSCH DMA 242 instruments in dual cantilever mode from 25 °C to 180 °C. The testing frequency was 15 Hz and the heating rate was 5 °C/min in nitrogen atmosphere. The creep resistance of the neat and CSCFNCs are studied in air atmosphere using tungsten carbide indenter of 1mm diameter. The constant load of 12.5 kg was applied at temperature of 70 °C, the impression depth as a function of time is measured using LVDT having accuracy of 1 μm as shown in Figure 1. Dispersion of the processed coir fibers in nylon-6 matrix, thermal degradation and fracture analysis of tensile specimen were examined using a scanning electron microscope. The specimens were gold sputtered and observed in a Tascam Vega 3 microscope having an electron beam acceleration of 20 kV voltage.

Results and Discussion

Mechanical Characterization

Tensile behaviour of neat nylon 6 and nylon 6 reinforced modified coir fibers with varying fiber reinforcement (0, 3, 6, 9 wt %) was accomplished by a tensometer at ambient temperature and pressure. Figure 2(a) depicts the tensile behaviour of neat nylon 6 and CSCFNCs and 2(b). Shows the tensometer setup and fractured tensile samples. It is seen that neat nylon 6 exhibits elastic behaviour with a tensile strength of 50.3 MPa. All the composites reinforced with modified coir fibers showed a brittle fracture and enhanced tensile properties compared to neat nylon. Tensile strength for modified coir fiber reinforced composites was enhanced gradually up to 6 wt. %, highest tensile strength observed was 59.84 MPa for 6 wt. % and declined marginally for 9 wt. % (58.6 MPa) fiber loads these findings agree with literature [8].

Enhanced tensile strength for CSCFNCs compared to neat nylon is attributed to good compatibility between modified coir fiber surface and the matrix due to the hydrophobic nature of both nylon matrix and camphor soot which results in good adhering property. Other reason for enhanced tensile property could be uniform distribution of the modified coir fibers in the nylon matrix which helped to distribute the load uniformly throughout the matrix. However tensile strength of CSCFNCs was found almost similar in comparison with glass fiber reinforced nylon composites [17]. These results revealed that glass fiber reinforced nylon composites can be replaced by CSCFNCs.

Moreover, density of glass fiber being higher than density of all most all natural fibers. Hence, it offers better alternative when weight reduction is concerned for automotive applications. On the other hand, 9 wt % fiber loaded composites experienced diminished tensile strength compared to the 6 wt % fiber loads due to agglomeration of fibers in the matrix. Other reasons could be the processing temperature of nylon 6 in the twin-screw extruder of around 280 °C which made the coir fibers fry and become brittle, leading to the partial degradation of coir fibers resulting in a decrease in the tensile strength of high fiber loaded composites [24].

The effect of different fiber loads in the nylon-6 with

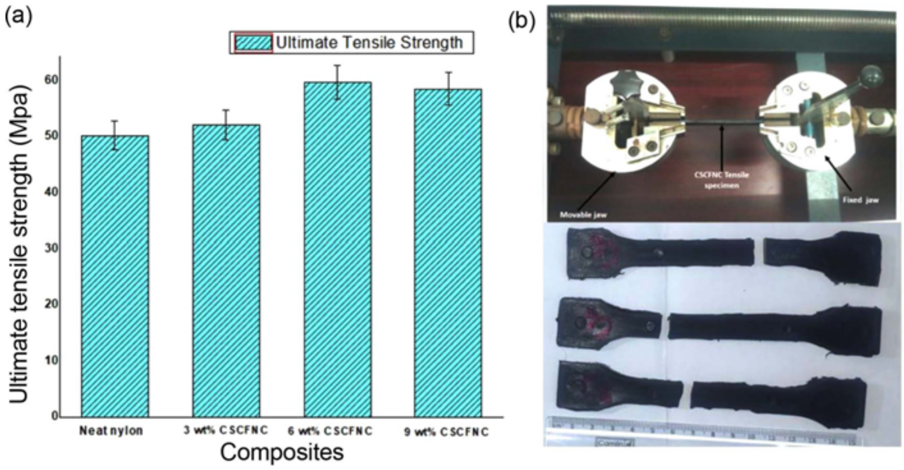

Figure 2. (a) Tensile behaviour of neat and modified coir fiber reinforced nylon 6 composites and (b) tensometer setup and fractured specimens.

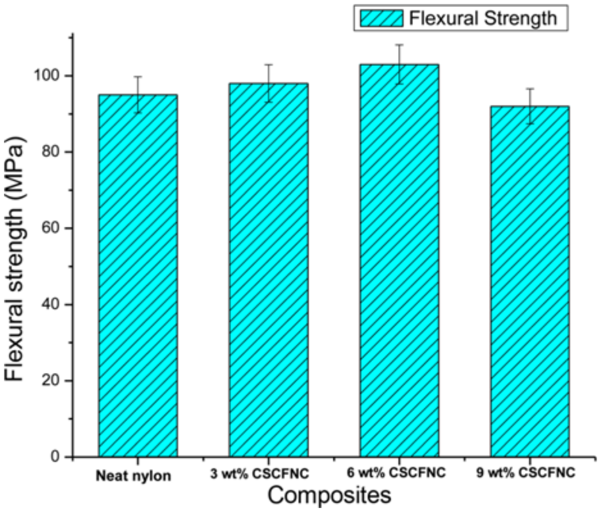

Figure 3. Flexural strength of neat and CSCFNCs.

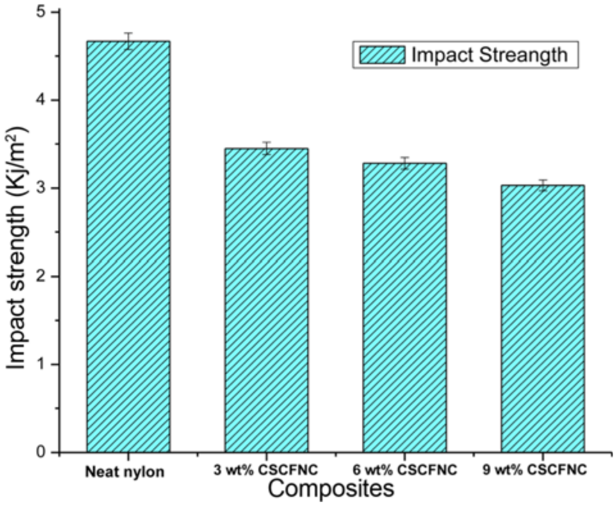

Figure 4. Impact strength of nylon-6 and CSCFNCs.

respect to flexural strength is shown in Figure 3. Neat nylon-6 revealed a flexural strength of 95 MPa. The flexural strength was increased with increased fiber content up to 6 wt. % (103 MPa) this is attributed to a good interface between fiber and nylon matrix that allows better stress transfer from nylon to coir fibers. It is also felt that camphor soot being hydrophobic leads to strong adhesion with the matrix. The earlier literature found that the flexural strength also increased with the inclusion of alpha cellulose [18].

On the other hand, flexural strength was decreased marginally in 9 wt. % of coir fiber loads due to agglomeration of the fibers. The other reasons may be processing at high temperature (280 °C) which makes fibers brittle and causes partial degradation resulting in decreased flexural strength. Decreased flexural strength also may be influenced by Camphor soot due to the slipping nature of graphite particles present in the camphor soot as it is an amorphous graphite made up of many layers, as seen in pencil tip.

Impact strength of the composites is mainly depends on the amount of filler loads and type of test and samples are notched and un-notched. Impact strength of the neat nylon 6 and CSCFNCs was conducted with notched Izod impact tester at ambient conditions. Figure 4 shows the impact strength of neat nylon and nylon reinforced with processed coir fibers. The impact strength of the composites decreased with the infusion of coir fibers in the nylon 6 matrix. The decrease in impact after addition of natural fibers was also reported in the earlier literature [18]. Attributed to increase in the fiber loading in the matrix resulting in more interfacial regions which cause the crack propagation. From the figure

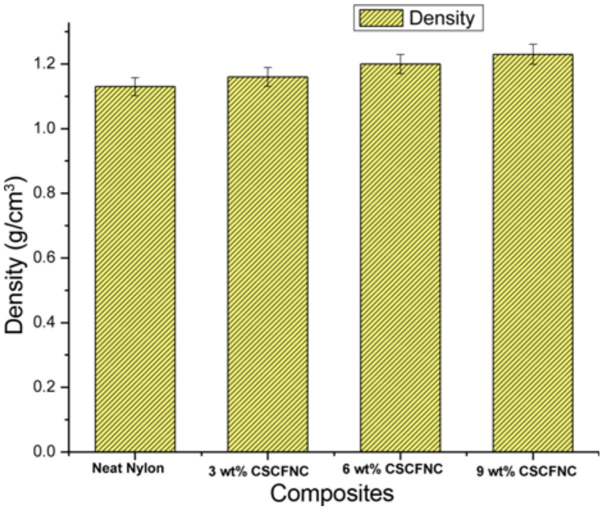

Figure 5. Density variations of neat nylon and CSCFNCs.

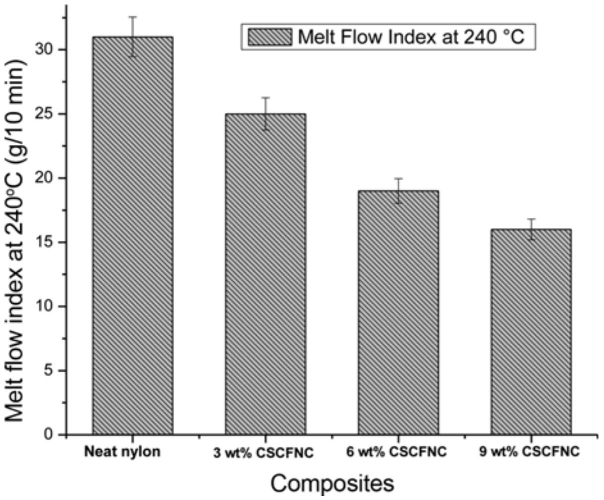

Figure 6. Melt flow index of nylon-6 and its composites.

it is clear that neat nylon shown highest impact strength of 4.67 Kj/m^2 and gradually decreases as the fiber content increases, and lowest impact strength was observed in case of 9 wt. % (3.03 Kj/m^2) fiber reinforced composites.

Figure 5 demonstrates the density of neat and processed coir fiber reinforced nylon-6. Incorporating the processed coir fibers into nylon increased the density of the composites gradually, as the fiber reinforcement increased, compared to neat nylon. Increased density was marginal as the inherent density of coir fibers is (~ 1 g/cm^3) lower than the density of nylon (~ 1.13 g/cm^3). From this we conclude, that natural fibers provide better reinforcement compared to synthetic fibers like glass fibers having (2.5 g/cm^3) and also compared to natural fibers which accounts for the natural fiber reinforced composites reducing weight of the final parts in automobiles, as automobile industries are concentrating on reducing weight and fuel consumption in vehicles [19].

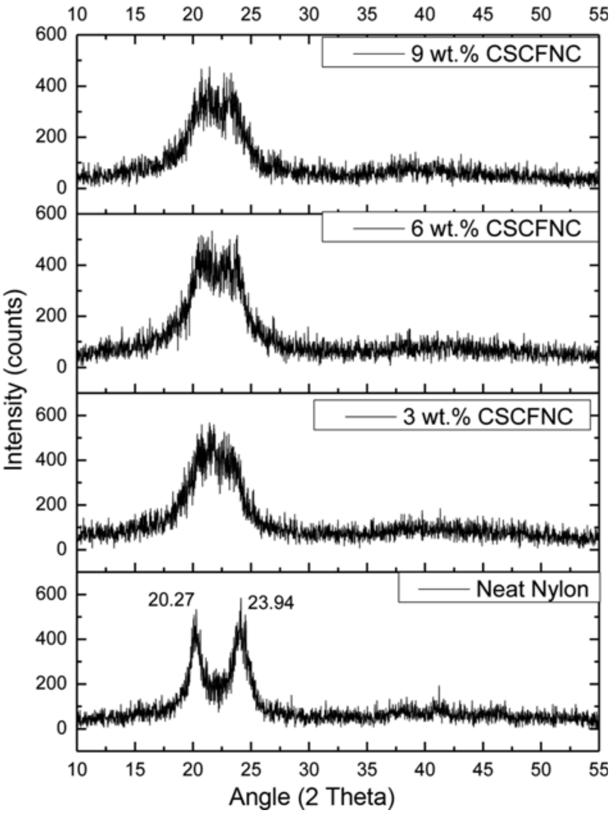

Figure 7. XRD patterns of neat and modified coir fiber reinforced nylon composites.

Melt flow index (MFI) of a polymer is a key factor governing the desirable properties of composites. MFI is a reverse measure of the melt viscosity and is a valuation of average molecular mass. Figure 6 shows the MFI values of nylon 6 and CSCFNCs. The MFI value of neat nylon 6 (32 g/10 min) reduced to (17 g/10 min) by increasing the reinforcement of fiber content in nylon 6 matrix. This is attributed to the decreased fluidity of the neat nylon due to the fiber reinforcement which causes immobility in the nylon 6 matrix. MFI also play a vital role in processing composites in injection moulding machine as the fiber loading increases in the matrix, it is difficult to process fibers in injection moulding as there will be fluctuation in fluidity, which accounts for higher injection pressure.

XRD Analysis Neat Nylon 6 and CSCFNCs

XRD graphs of the pure nylon 6 and nylon reinforced with modified coir fibers of different wt. % are shown in Figure 7. The graph of pure nylon 6 revealed two intense peaks at 20.27 ° and 23.94 °. These peaks correspond to characteristic basal reflections of polyamide which is in α-crystalline form [20]. On the other hand, aforementioned peaks disappeared

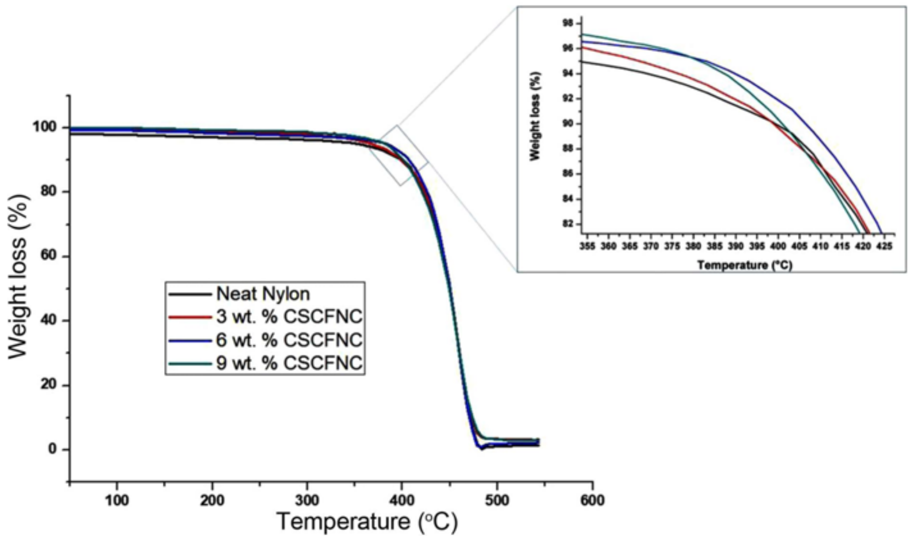

Figure 8. TGA analysis of neat nylon and CSCFNCs.

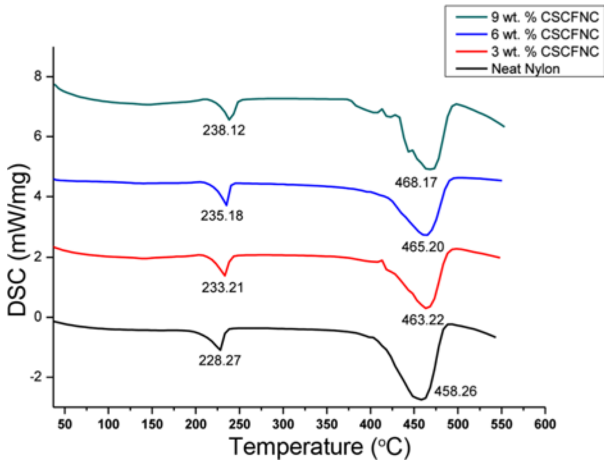

Figure 9. DSC study of nylon and camphor soot embedded coir fiber reinforced nylon composites.

and merged to form a broadened peak in the case of camphor soot embedded coir fiber reinforced nylon 6 composites. This is ascribed to crystalline graphite in 002 plane, and these peaks also represents the semi crystalline nature of the coir fibers. The coir fiber comprised of cellulose interface among hydroxyl and carboxyl groups [21].

Thermogravimetric Analysis of Neat and Modified Coir Fiber Reinforced Nylon 6 Composites

Figure 8 displays the thermogravimetric analysis of neat nylon 6 and CSCFNCs respectively. The first stage starts below 100 °C due to the volatilization of stored water in nylon 6 as nylon is a good absorber of moisture. TGA graphs also show that pure nylon 6 and surface modified coir fiber reinforced nylon 6 experienced typical one step degradation during thermal analysis in the presence of nitrogen due to the unsystematic scission of polyamide chains as the dominant decomposition process. Pure nylon 6 underwent initial decomposition at approximately 4-5 wt. % at a temperature around 370 °C and then underwent rapid decomposition with a maximum weight loss at 430 °C due to the polyamide backbone decomposition. Meanwhile, nylon reinforced with different fractions of modified coir fibers showed higher thermal stability in case of (6 wt. %) followed by (9 wt. %) of around 10 °C compared to neat nylon 6, due to the presence of camphor soot in the coir fibers is having much higher degradation temperature compared to the nylon.

The camphor soot is a burnt substance which can sustain higher temperature and also protects coir fibers from degradation. Moreover the nylon 6 reinforced with 9 wt. % modified coir fiber shown lower thermal stability compared to 6 wt. % fiber reinforced composites due to the high fiber content in the nylon matrix which resulted in agglomeration of fibers. The agglomeration of fibers resulted in more fiber-fiber interaction caused the partial degradation of the coir fibers further declined the thermal stability of the higher fiber content composites. On the other hand 3 wt. % fiber reinforced composites also shown lower thermal stability compared to other composites due to the adequate absence of camphor soot filled coir fibers in the composites.

DSC Analysis of Nylon 6 Composites

DSC study was carried out to access the effect of camphor soot embedded coir fiber content in the nylon 6 matrix with varying proportions as shown in Figure 9. DSC heating curves clearly reveal that strong endothermic peak with an average value of around 228 °C is visible in case of neat nylon, which is associated with the melting of the crystalline

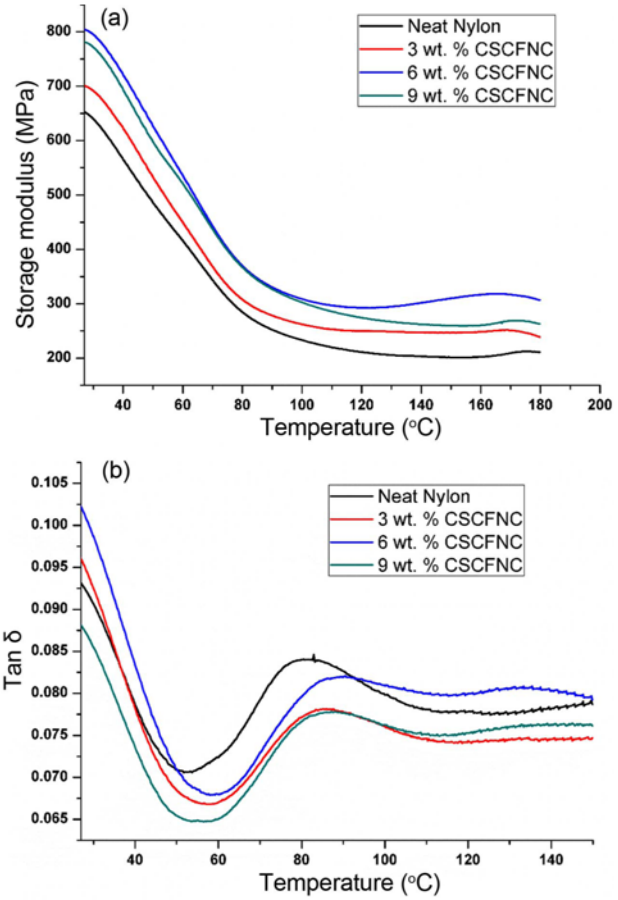

Figure 10. (a-b) DMA analysis of neat nylon and CSCFNC's; (a) storage modulus and (b) tan δ.

domains of the polymer chains in nylon 6. However, melting temperature of nylon 6 slightly increased with the incorporation of modified coir fibers for all the composites from 228 °C to 238 °C. This is due to dispersion of the modified coir fibers in the matrix leads to lower mobility of the nylon 6 polymer chains contributing to a higher melting point in nylon 6 composites.

On the other hand camphor soot particles dispersed and act as filler in the nylon 6 matrix while processing in the twin-screw extruder also influenced in higher melting point. Heating curves also reveal another peak around 458 °C which corresponds to the degradation point of the nylon 6 polymer chains where the liquid phase converts to gas. It is clear from the heating curves that the degradation temperature of the CSCFNC's increased marginally as the fiber reinforcement increases, due to the presence of camphor soot in coir fibers which accounts for higher degradation temperature compared to neat nylon 6.

DMA Analysis of Neat Nylon 6 and CSCFNC's

DMA was performed to study viscoelastic behaviour and relaxations in plastic materials. It provides revealing information like loss modulus, storage modulus and tan δ. To measure the viscoelastic behaviour of the material tan δ is one of the important parameter [22] Tan delta is the ratio of loss to the storage and is called damping. It is a measure of the energy dissipation of a material. It tells us how good a material will be at absorbing energy. Basically tan delta can be used to characterize the modulus of the material. Figure 10(a-b) shows the storage modulus and tan δ for neat nylon and CSCFNC's at varying fiber content. Figure clearly reveals that storage modulus for neat nylon was 650 MPa and it was increased in case of CSCFNC's. Highest storage modulus observed for 6 wt. % coir fiber reinforced nylon 6 composites is 806 MPa. The glass transition temperature (T_g) of the polymers is one of the most important factor, T_g value for neat nylon was found to be 80 °C. On the other hand CSCFNC's experienced enhanced T_g value from 80 °C to 87 °C due to the presence of modified coir fibers and 6 wt. % fiber reinforced composites shown a increment of 7 °C compared to neat nylon 6.

Tan δ plots reveal that neat nylon experienced highest (0.084) molecular mobility. However CSCFNC's show the lower tan δ peaks as reinforced modified coir fibers hindered the damping of neat nylon. Thus storage modulus was found

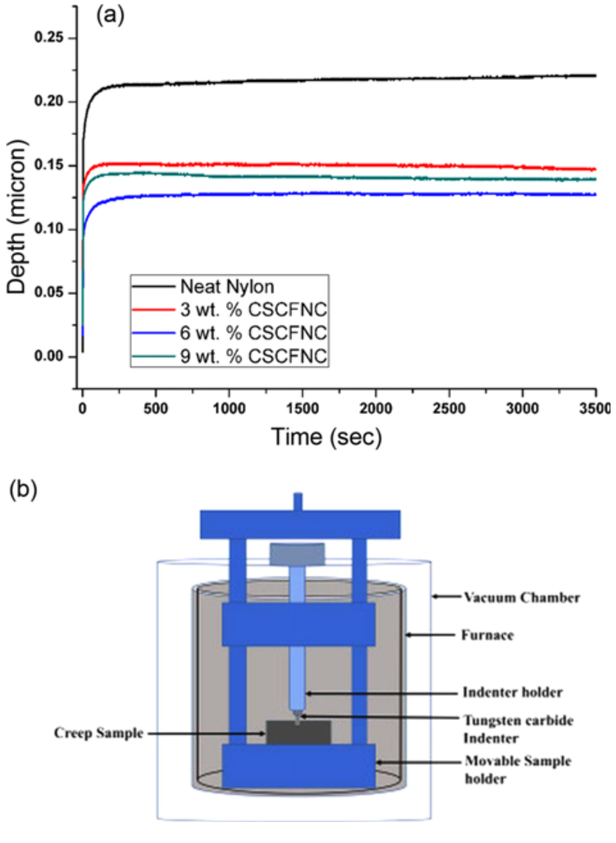

Figure 11. (a) Creep behaviour of neat nylon and CSCFNC's and (b) creep experimental setup.

greatly influenced by the addition of modified coir fibers in nylon matrix. On the other hand CSCFNC's tan δ value was reduced which shows the uniform distribution of fibers which resulted in the constrained polymer movement.

Creep Study Analysis of Neat Nylon 6 and CSCFNC's

Impression creep test was carried out for neat nylon 6 and nylon 6 reinforced with modified coir fibers with varying fiber content as shown in Figure 11(a) and creep experimental

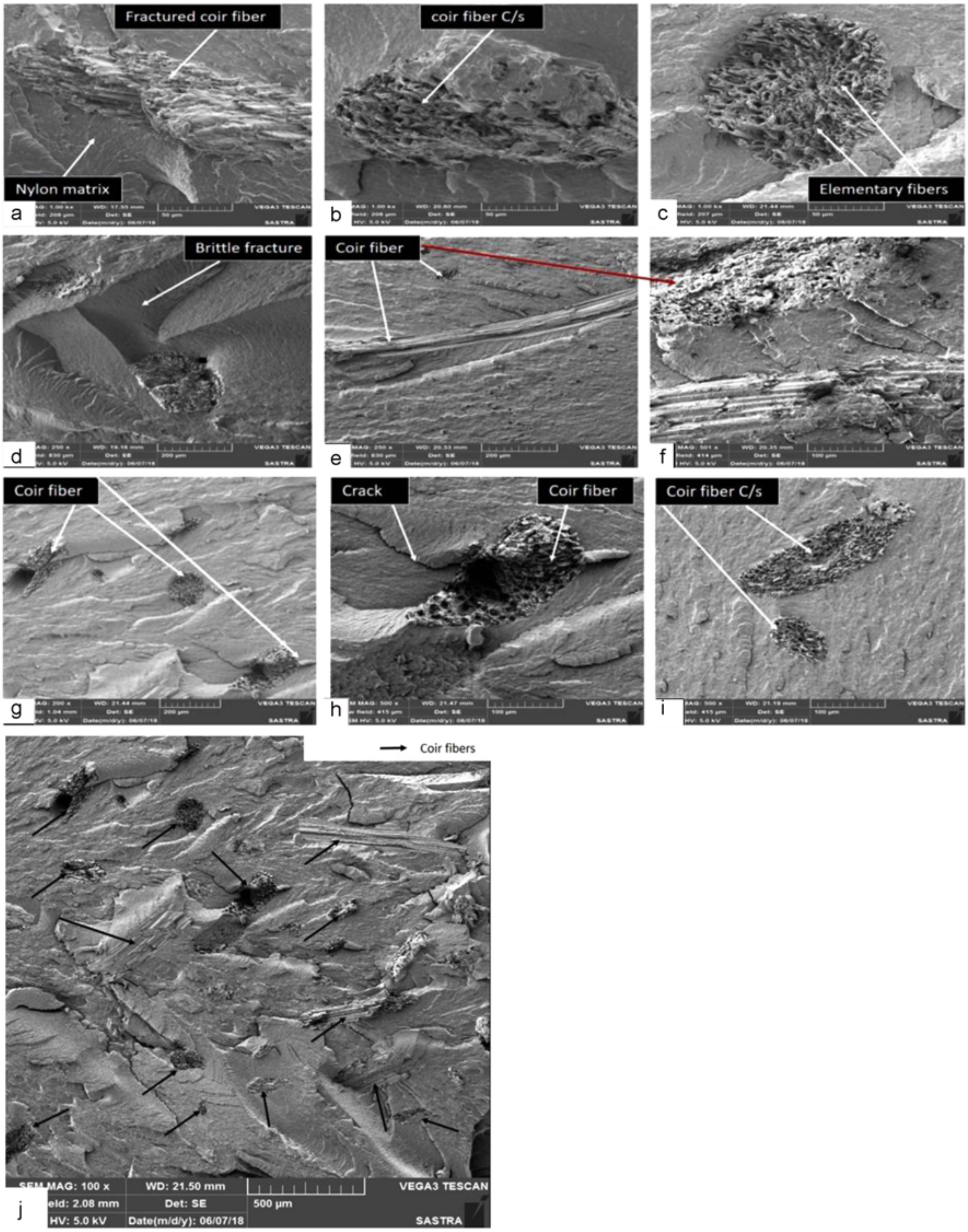

Figure 12. Fracture analysis of CSCFNCs; (a-c) 3 wt. % fiber loading, (d-f) 6 wt. % fiber loading, (g-i) 9 wt. % fiber loading, and (j) uniform distribution of coir fibers.

setup is shown in Figure 11(b). A constant load of 12.5 kg was applied at a temperature of 70 °C (i.e. below glass transition temperature of nylon 6). The impression depth was measured continuously as a function of time, and using data, a plot of impression depth against time was measured.

From the creep plots it is clear that creep curves shown short primary creep and then all the curves experienced a prolonged secondary creep where depth was amplified linearly with time. The tertiary stage of the curve is not recorded as the load is compressive and necking and fracture were absent [23,24]. Among all composites, 6 wt. % coir fiber reinforced composite had a minimum impression depth of 0.125 compared to other composites. This is due to the uniform distribution of the modified coir fibers and camphor soot in nylon matrix which resulted in good compatibility between nylon and camphor soot and hence enhanced the hardness of the composites. Neat nylon 6 experienced maximum impression depth of 0.212 mm is ascribed to free mobility of the polymer chains due to increase in temperature which results in decreased dimensional stability of the neat nylon as nylon has poor dimensional stability at higher temperatures.

Fracture Analysis of Camphor Soot Embedded Coir Fiber Reinforced Nylon 6 Composites

The morphology of the tensile fracture surfaces of nylon 6 composites with varying proportions of modified coir fibers are shown in Figure 12(a-i). It is clear that all the composites have undergone brittle fracture. Figure 12(a-c) shows that 3 wt. % fiber reinforced composites clearly reveals that the fibers are uniformly distributed in the matrix with perfect registry between fiber and matrix. Also the fiber and nylon matrix experienced brittle fracture, due to camphor soot dispersed in the matrix being a crystalline graphite which acts as a lubricant between camphor soot particles in the matrix during tensile load.

On the other hand, coir fiber loading in the nylon matrix at a higher temperature in twin screw extruder followed by injection moulding results in the partial degradation of the coir fibers which become brittle, which could be another reason for the brittle fracture of the composites. Figure 12(d-f) and 12(g-i) correspond to 6 and 9 wt. % fiber loads respectively. Figure 12(j) shows the uniform distribution of modified coir fibers in nylon matrix. The uneven orientation of the fibers in the matrix is the prime reason for enhancing the mechanical properties. Also more fibers are seen in higher fiber loads. In all SEM micrographs fiber pulling is not seen, we thus conclude that all the composites experienced brittle fracture due to the camphor soot and partial degradation of the coir fibers during processing in the twin screw extruder.

Conclusion

In this study low cost and environmental friendly composites like camphor soot embedded coir fiber reinforced nylon 6 were prepared with varying fiber loads. The composites were prepared using melt compounding using twin screw extruder. Mechanical, thermal and morphological properties were investigated. Tensile strength, flexural strength and density of the nylon 6 composites were enhanced with the modified coir fiber reinforcement compared to neat nylon 6. On the other hand, impact strength and MFI properties decreased after the inclusion of the modified coir fibers in nylon 6.

The presence of camphor soot infused coir fibers in nylon 6 matrix was confirmed through XRD peaks by forming a single peak for CSCFNCs compared to neat nylon 6. TGA results reveal that thermal stability of nylon 6 composites is enhanced marginally compared to neat nylon 6 due to the presence of camphor soot particles in coir fibers. DSC analysis shows that heating curves experienced two sharp peaks one at approximately 228 °C corresponding to the melting point of polymer converting from solid to liquid state. Another peak at approximately 458 °C related to degradation temperature where the liquid state converted to a gaseous state rapidly. DMA result shows storage modulus for neat nylon was around 700 MPa at 25 °C and it is enhanced in the case of modified coir fiber reinforced composites. Maximum storage modulus was recorded for 6 wt. % fiber reinforced nylon composites is around 806 MPa. Tan δ plot for neat nylon possess highest value (0.084) revealing higher degree of molecular mobility on the other hand tan δ values for CSCFNCs shows decreased trend due to constrained polymer movement.

Creep study indicates that 6 wt. % coir fiber reinforced composite has shown minimum impression depth of 0.125 mm compared to neat nylon 6 depth of 0.212 mm. Fracture surface of the tensile specimens morphology was inspected using SEM, revealed that fibers are uniformly distributed in the matrix and all composites experienced brittle fracture due to the presence of camphor soot and partially degraded coir fibers. Overall, we can thus conclude that camphor soot embedded coir fiber reinforced nylon composites showed enhanced mechanical and thermal properties. Also as the materials used for reinforcement are freely available and environmental friendly, these composites are promising replacements for synthetic fibers reinforced nylon composites. As the density of coir fiber is very low these composites can be effectively used in air and fuel intake manifold in automobiles.

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