INVESTIGATION ON MECHANICAL PROPERTIES OF SHORT VAKKA FIBER GLASS REINFORCED HYBRID THERMOPLASTIC COMPOSITES

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Abstract

The conventional application of fiber in relation to the technology of synthetic fiber reinforced composites reveal the clue to widen the scope and to adopt the natural fiber composites for industrial applications. In the present work, vakka fiber is incorporated in polypropylene resin matrix hybridized with glass fiber for preparing composite specimens at various fiber weight percentages The developed vakka fiber, glass reinforced hybrid polypropylene composites (VGPP) were then tested for their mechanical properties. To enhance the adhesion between the vakka fiber and the polypropylene matrix, maleic anhydride- grafted polypropylene (MAPP) was used as a compatibilizer for the composites (VGMAPP). It was found that the increase in fiber content reduces the mechanical properties of vakka glass-PP composite. However, VGMAPP composites exhibited better mechanical properties than VGPP composites.

Keywords: *Hybrid Composite, Vakka Fiber, glass Fiber, MAPP*

1. Introduction

Composites consisting lignocellulosic fibers and synthetic thermoplastics have received substantial attention in scientific literature as well as in industry, primarily due to improvements in process technology and economic factor. Natural fiber-based thermoplastic composites are generally lower in strength performance compared to thermoset composites. However, they have the advantage of design flexibility and recycling possibilities.

Hybridization with small amounts of synthetic fibers makes these natural fiber composites more suitable for technical applications such as automotive interior parts. Performance of injection-molded short hemp fiber and hemp/glass fiber hybrid polypropylene composites were analyzed [1]. Results showed that hybridization with glass fiber enhanced the performance properties. Thermal properties and resistance to water absorption properties of the hemp fiber composites were improved by hybridization with glass fibers. Overall studies indicated that the short hemp/glass fiber hybrid polypropylene composites are promising candidates for structural applications where high stiffness and thermal resistance is required. The effect of hybridization on mechanical properties of coir and sisal reinforced polyester composite (CSRP), coir and jute reinforced polyester composite (CJRP), jute and sisal reinforced polyester composite (JSRP) were evaluated experimentally [2]. The results demonstrate that hybridization play an important role for improving the mechanical properties of composites. The tensile and flexural properties of hybrid composites are markedly improved as compare to unhybrid composites. Water absorption behaviour indicated that hybrid composites offer better resistance to water absorption. A hybrid composite materials using Wood Powder, Groundnut Husk and Cashew nut Husk have been developed [3]. The behaviour of composites and hybrid composites of short bamboo and glass fibers in a polypropylene (PP) matrix under hygrothermal aging and under tensile–tensile cyclic load were studied and this hybrid showed better fatigue resistance [4]. Mechanical and physical properties of oil palm empty fruit bunch/glass hybrid reinforced polyester composites were studied and showed hybrid composites exhibited good properties[5]. Different composites based on polypropylene and reinforced with flax and glass fibers have been made and their mechanical properties are measured together with the distribution of the fiber size and the fiber diameter [6]. Maleic anhydride-polypropylene copolymer has shown to be a very effective compatibilizer for lignocellulosic/PP composites [7-11]. The effect of fiber treatments and matrix modification on mechanical properties of flax fiber bundle/polypropylene composites was investigated [12] and the results suggested that matrix modification led to better mechanical performance than fiber surface modification.

The main objective of this work is to determine the suitability of vakka fibers (Scientific name: Roystonea regia) hybridized with glass fiber as reinforcement in the polypropylene matrix for making composites. The effect of the fiber content and the interfacial adhesion on the mechanical properties of VG/PP and VG/MAPP composites prepared by injection moulding process is investigated.

2. Extraction of Vakka Fiber

The source of this fiber is the foliage of the tree, which contains leaves with their stem in the form of a sheath. The sheath which contains fibers is separated from leaves and leaf stem and dried for four to five days in shade. It is then immersed in a water retting tank for 15 days. In the first 15 days, the top layers on either side of the sheath loosen. Then, these layers are removed, washed and immersed in another water retting tank for 3 more days. Later, they are removed, hand rubbed and rinsed in sufficient water. The water retting process takes 18-20 days to extract fibers completely.

3. Fabrication of composite specimen

The extracted fiber, polypropylene pellets, MAPP pellets are dried in an oven at a temperature of 80^0 C for 2 hours to expel the moisture before they were used for injection. The composite samples were prepared in two stages. In the first stage, proper proportions of fibers (0, 5, 10, 15, 20 and 25%) by weight, glass fiber (50% of fiber weight) and polypropylene pellets were properly mixed to get a homogeneous mixture. The mixture was then placed in a 2.5 tonne hydraulic Injection Moulding Machine. At a temperature of 210 ^{0} C and pressure of 1100 kgf/cm^2, composites of different weight fractions of fiber were developed. Five specimens were made for each weight fraction of vakka fiber glass hybridized polypropylene composites.

In the second stage, to improve fiber matrix adhesion, MAPP is added and VGMAPP composites of same fiber weight fractions were prepared with mixture of polypropylene pellets, vakka fibers and the glass fibers. The percentage of added MAPP is 0.5 % of fiber weight. Five specimens were made for each weight fraction of VGMAPP composites.

4. Characterization of composites

4.1. Tensile properties

A 2 ton capacity - Electronic Tensometer, METM 2000 ER-I model was used to find the tensile and flexural properties of the composite specimens. Dog bone shaped tensile test specimens were made in accordance with ASTM-D 638M to measure the tensile properties. The samples were tested at a crosshead speed of 1 mm/min and the strain was measured with an extensometer. The sample specimen after tensile testing is shown in Fig.1.

Fig.1: Tensile Specimen

4.2. Flexural properties

Three point bend tests were performed in accordance with ASTM D790M test method I, Procedure A to measure the flexural properties. The samples were 98mm long by 10mm wide by 4mm thick. In three point Bending test, the outer rollers are 64mm apart and the samples were tested at a strain rate of 1mm/min. The flexural strength and flexural modulus of the composites are determined.

The flexural modulus, $E_B = L^3 m /4bt^3$

The flexural strength, $S = 3PL/2bt^2$

Where L is the support span (64mm), b is the width and t is the thickness, P is the maximum load and m is the slope of the initial straight line portion of the load-deflection curve. The sample specimen after flexural testing is shown in Fig.2.

Fig: 2. Flexural Specimen

4.3. Impact properties

Izod impact test specimens were prepared in accordance with ASTM D256-97, to measure the impact strength. The specimens are prepared to dimensions of 64 x 12 x 9 mm width. A V-notch is provided having an included angle of 45^0 at the centre of the specimen, and at 90^0 to the sample axis. The depth of the specimen under the notch is 10.16 ± 0.05 mm. Five identical specimens were tested for each composition. The samples were fractured in a plastic impact testing machine and the impact toughness was calculated from the energy absorbed and the width of the sample. The sample specimen after impact testing is shown in Fig.3.

Fig.3: Impact Specimen

The Impact strength is given by

$I = EI/T$ Joules/m

EI = Impact Energy in joules

T = Thickness of the sample used

5. RESULTS AND DISCUSSION

5. 1 Tensile properties

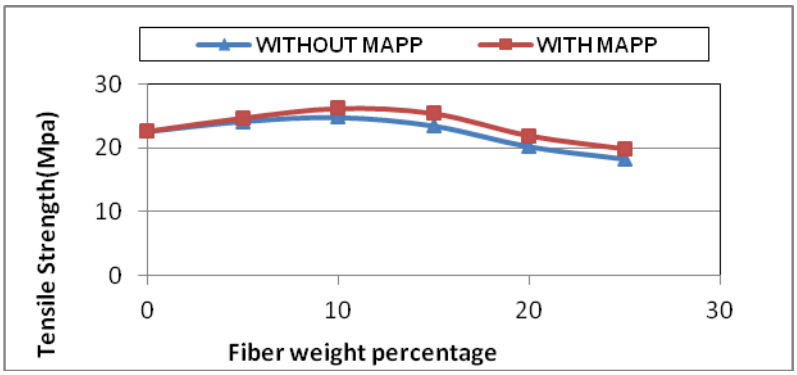

Fig.4: Maximum Tensile strength Vs fiber weight percentage

The tensile strength of the VGPP composites and VGMAPP composites at different fiber loading is shown in Fig.4. The tensile strength is found to be increasing up to 10% fiber (by weight) and then decreases. The tensile strength of the pure polypropylene is calculated as 22.63 MPa. A tensile strength of 24.83 MPa is noted at 10 weight % of VGPP composite without MAPP which is 9.72 % higher than PP matrix. The incorporation of fibers into thermoplastics leads to poor dispersion of fibers due to strong inter fiber hydrogen bonding which holds the fibers together. Improper adhesion hinders the considerable increment of tensile strength [13]. Thus, as fiber percentage increases, gathering of fibers takes place instead of dispersion and melted polypropylene cannot wet them properly due to non entrance of melt through the adjacent two fibers. Since no adhesion is present between the fibers and fibers are also not bonded with matrix, failure occurs before attaining the theoretical strength of composite.

From the results of Fig.4, it is observed that all composites have shown a moderate increase in tensile strength with the addition of MAPP. MAPP improves the adhesion between fiber and matrix by chemically bonding to available OH groups on the fiber surface and then adhering to the matrix through molecular chain entanglement. With the addition of MAPP, the tensile strength has increased by 18.52 percent compared to that of pure polypropylene at 10 weight % fiber load and its value is 26.82MPa.

Fig.5 shows the variation in tensile modulus with respect to fiber weight fraction. It is observed that the tensile modulus which is an indication of load bearing capacity increases with fiber weight fraction. As fiber is the stiffer component in the composite, resistance towards deformation increases with increase in fiber content,

this consequently increases the stiffness of the composite. The tensile modulus of the pure polypropylene is calculated as 0.14 GPa. The tensile modulus for VGPP composites is 0.2 GPa which is 42.86 % higher than pure PP and 0.212 GPa for VGMAPP composites which is 51.43 % higher than pure PP. For both the composites higher tensile modulus value is observed at 25% fiber weight fraction.

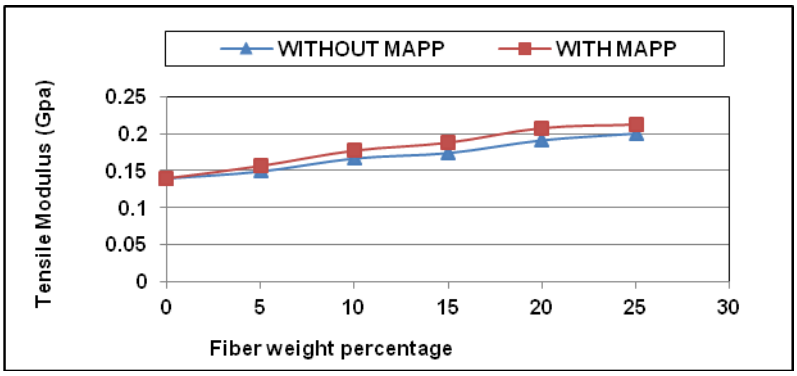

Fig. 5: Tensile Modulus Vs fiber weight percentage

5.2. Flexural properties

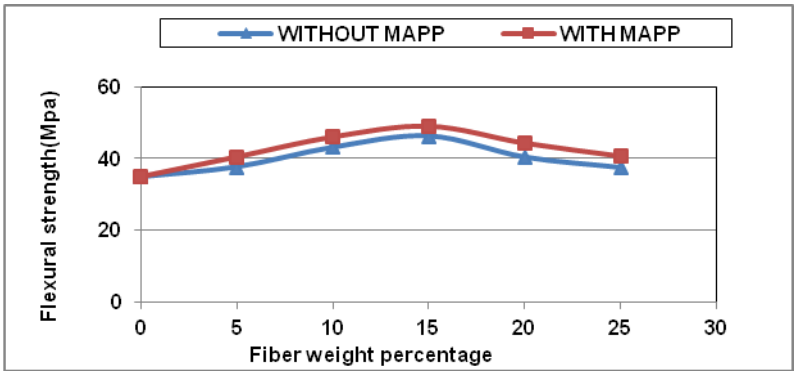

Fig.6:Flexural strength Vs fiber weight percentage

Flexural strength of VGPP and VGMAPP composites at different percentages of fiber loading is shown in Fig.6. The flexural strength increased with fiber loading up to 15% weight fraction of the fiber, and there was a decrement after 15% fiber loaded composites. The reasons for the lower flexural properties at higher fiber fractions are possibly due to the lower fiber to fiber interaction, void and poor dispersion of fiber in the matrix [14]. The flexural strength of the pure polypropylene is 34.77MPa. The maximum flexural strength of the VGPP composite is 46.26 MPa and for VGMAPP composite is 48.95 MPa, occurring at 15% fiber fraction. There was a moderate increase in the flexural strength values due to the addition of MAPP. The percentage increase in the flexural strength values when compared to pure polypropylene is 33.05% for VGPP composites and 40.78% for VGMAPP composites.

Fig.7 shows the Flexural Modulus as a function of % weight fraction of the fiber for VGPP and VGMAPP composites. The flexural modulus increases with the fiber loading. Since, higher fiber concentration demands higher stress for the same deformation due to increase in the degree of obstruction, the modulus values has increased with the fiber content. Increased fiber–matrix adhesion provides increased stress transfer between them. Again the higher modulus values of the MAPP treated composites compared to the composites without MAPP provide evidence of homogeneous distribution of the fiber particles into the matrix and better fiber–matrix interaction. So, there is an increase in stiffness in the MAPP treated composites compared to the composites without MAPP. Flexural test on pure polypropylene specimen exhibited a modulus

of 0.77 GPa. The flexural modulus for VGPP composites is 1.53 GPa which is 98.7 % higher than pure PP and 1.74 GPa for VGMAPP composites which is 126 % higher than pure PP. For both the composites higher flexural modulus value is observed at 25% fiber weight fraction.

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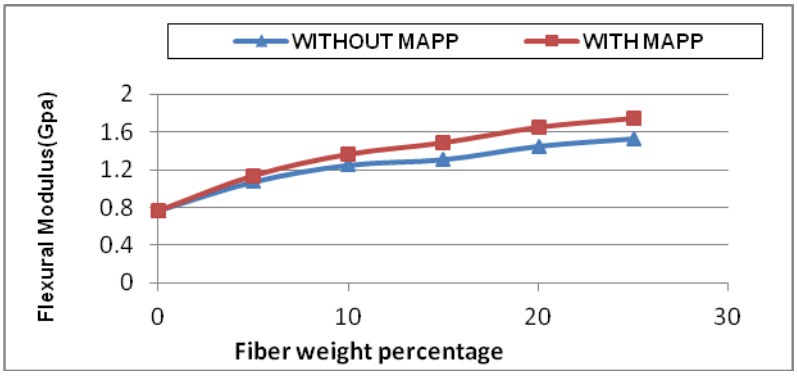

Fig.7: Flexural modulus Vs fiber weight percentage

5.3. Impact properties

Impact strength is the ability of a material to resist the fracture under applied load. The fibers play a very important role in the impact resistance of the composite as they interact with the crack formation in the matrix and act as stress transferring medium. The variation of impact strength with fiber loading for VGPP and VGMAPP composites is shown in Fig. 8. The impact strength of the pure polypropylene is 27.77 J/m.

It is observed that the impact strength increases with the increase in the fiber content upto 20% weight fraction of fibers and then decreases. Impact strength of 48.66 J/m is noted at 20 weight % of VGPP composites which is 75.23 % higher than PP matrix. The impact strength of VGMAPP composites has increased by 112.03 % than pure polypropylene at 20 weight % fiber load and its value is 58.88 J/m. The energy dissipation mechanisms operating during impact fracture are matrix and fiber fracture, fiber–matrix debonding and fiber pull out. Fiber fracture dissipates lesser energy compared to fiber pull out and is the common mechanism of fracture in fiber reinforced composites. As the main failure mechanism in these composites are fiber pull out, impact strength increases with fiber loading. High fiber content increases the probability of fiber agglomeration which results in regions of stress concentration requiring less energy for crack propagation [15]. This results in lower energy dissipation and hence impact strength decreases.

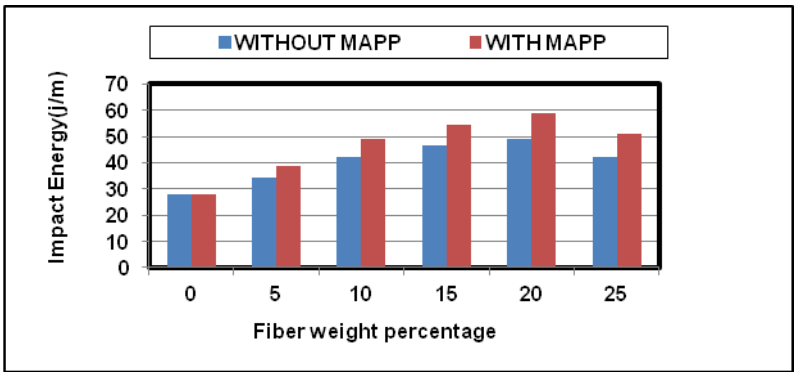

Fig.8: Impact Energy Vs fiber weight percentage

6. Conclusions

The incorporation of vakka fiber hybridized with glass fiber into the polypropylene matrix has shown a moderate improvement in the tensile, bending and impact properties of the composite. 10% fiber weight fraction composites exhibited maximum tensile strength and maximum flexural strength is observed for 15 % fiber weight fraction composites. Maximum Impact strength is observed in 20 % fiber weight fraction composites. Tensile and Flexural Modulus values increased with increase in fiber weight fraction and higher values are observed in 25% fiber weight fraction composites. Addition of MAPP resulted to an increase in both strength and modulus of all composites at different fiber weight fractions. The composite can be regarded as a useful light weight engineering material and also the manufacturing cost of the composite can be reduced considerably by adding Vakka fiber hybridized with glass fiber to the matrix.

7. References

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