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Effect of Wood Filler on Mechanical Properties of Short Carbon Fiber Reinforced Polypropylene Hybrid Composites

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Abstract: The wood filler effect on mechanical behaviour of short carbon fiber (SCF) reinforced polypropylene hybrid composites are investigated in this article. The material systems selected in the study includes: Polypropylene (PP), PP/Short Carbon Fiber (PP/SCF) and PP/SCF/Wood Filler (PP/SCF/WF) and Maleic Anhydride (MA) is used as compatibilizer to enhance the interfacial bonding between the reinforcement phase and the matrix phase. These composites are produced through extrusion process with the help of twin screw extruder and samples were prepared according to ASTM standards by injection molding. The experimentation results revealed that the effect of short carbon fiber has enhanced the aforesaid mechanical behavior of SCF reinforced polypropylene composites. But the effect of wood filler addition has negative effect on flexural and tensile behavior, but enhanced the impact strength and hardness of SCF reinforced wood filler/PP composites. The positive effect on hardness and impact strength is because of synergistic effect of wood filler with the short carbon fiber whereas the negative effect on tensile and flexural behavior is due to poor interfacial bond between wood filler and short carbon fiber.

Keywords: Mechanical Properties; Wood Filler; Carbon Fiber.

1. Introduction

The development of materials in the field of automobile industries is improving day by day. But the weight, weak performance, thermal effects and other abrasion effects are the major causes to inhibit the materials for their effective usage. The effective development of polymer composites is playing the vital role in the place of above said materials due to their light weight, good performance, self-lubrication and multifunctional behavior. The research fraternity observed that the failure percentage of homopolymers is more, since they failure to fulfill the demands rising from both tribological and mechanical situations [1]. It has been noticed that light weight and as well as self-lubrication properties of polymer composites made them suitable for various engineering application [2]. In order to enhance the application of polymer composites, they should be designed to support simultaneously the mechanical and tribological loadings. This is done only through modification of homopolymer. The Polymers are modified through polymer blending, copolymerization, and reinforcing the fibers and/fillers in to polymers [3]. The inclusion of short fibers like carbon fibers, glass fibers and natural fibers as reinforcement plays the vital role in enhancing the mechanical behavior of thermoplastic composites [4]. Further the inclusion of fillers significantly enhanced the properties of hybrid composites. The failure of materials due to wear, fracture and fatigue is very common in today's engineering applications. But the recent research suggests that the effect hybrid fibers can effectively prevent the aforesaid factors. Further the hybrid polymer composites consisting of both fibers and fillers are very promising in enhancing mechanical properties of fiber filled polymer composites. The effect of micro fillers and fibers on the mechanical property of PP were studied [5]. The fracture behavior and structure of PP reinforced with long glass fiber (LGF) and CaCO3 (filler) has been studied. Study reveals that inclusion of CaCO3 into PP/LGF improved the stiffness but the strength and toughness decreased. Further the fracture toughness of the composites was not at all affected by filler addition. The influence of polypropylene grafted maleic anhydride (PP-gMAH) on PP/SCF composites were observed. The E-modulus and tensile strength at the break of the composites were enhanced by increasing the content of carbon fiber and compatibilizer [6,7].

It is observed from the above literature review that the effect of different organic fillers on mechanical behaviour of thermoplastic composites has been studied. But the effect of wood filler on short carbon fiber reinforced polypropylene composites is very rarely reported. Polypropylene is a very good compatible thermoplastic with carbon fibers. Wood filler is one of the most abundant and low cost materials among the natural fibers. Further, wood fillers can establish good interfacial bonding with the thermoplastics.. The development of bio-composites is the present trend in the area of polymer composites. Keeping this in view, the outcome of wood filler on mechanical behaviour of short carbon fiber filled polypropylene composites is studied and systematically presented.

1.1 Processing and Testing of Polymer Composites

The materials used in the compounding of polymer composites are shown in the Table 1. Further, the formulations of composite material systems in weight % has been reported in the Table 2.

Table 1. Details of the materials

Materials	Designation	Size (µm)	Manufacturer	Density (g/cc)
Polypropylene	PP	---	DuPont co.Ltd.	1.14
Short Carbon fiber	SCF	Length: 5 - 6 mm Diameter: 7- 8 µm	Ravago sha Polymers, Bangalore	1.6
Wood filler	WF	Length 500-300µm	Sri Ranga Saw Mills, Hassan	----

Table 2. Formulations and Composition of wood filler composites in weight fraction

Composition	Material ID	PP	SCF	WF	MA
Polypropylene	PP	100	---	---	---
PP/Short Carbon fibers	PP/SCF	88	10	----	2
PP/SGF/Wood filler	PP/SCF/WF	78	10	10	2

1.2 Processing of Hybrid Wood Filler Composites

The twin screw extruder has five zones for heating the composite material uniformly throughout the extruder barrel to make a fine melt of the materials. The temperature maintained at heating zones are zone1 (170ºC), zone 2 (175ºC), zone 3 (180ºC), zone 4 (183ºC) and die (185ºC) respectively. The screw speed of extruder was set to 100 rpm to get a feed rate of 2 kg/h. A continuous strand of extruded material was quenched in water bath. These long strands were then chopped into pellets by palletizing machine. The pellets thus obtained were again dried in oven at 100^{0}C for 24 hours. Dried pellets were transferred for injection molding to create specimen for mechanical testing according to ASTM methods. The injection molding machine has two zones for heating and the temperature retained at zones 1 and 2 was 200ºC and 250ºC respectively. The temperature maintained at mold was 65^{0}C. The speed of the screw has been set to 10 – 15 rpm and injection pressure of 700-800 bar has been maintained. The injection, cooling and ejection time are 10s, 35s and 2s respectively were maintained for injection molding process.

1.3 Testing of Mechanical Behaviour

The mechanical behavior of wood filler filled PP/SCF hybrid composites have been studied according to ASTM standards. The tensile property was evaluated at 5 mm/min strain rate of according to ASTM D 638 Type 1. The flexural property was evaluated at 1.33 mm/min strain rate according to ASTM D790. Both flexural and tensile tests were conducted by employing Universal testing machine (JJ Lloyd, capacity 1-20 KN). The impact property of the composites has studied by notched izod impact strength by using Izod impact at 3.2 mm/s striking rate in accordance with ASTM D256.

2. Results and Discussion

The outcome of wood filler filled composites on the tensile behavior of 10 wt.% of SCF reinforced PP composites are as shown in figure 2(a). It is noticed that effect of wood filler has enhanced the potential strength of SCF filled polymer composites above neat PP. The tensile strength of SCF filled composite is 34 MPa against 24.62 MPa of neat PP which is 38%

increase. But the inclusion of wood filler in to SCF filled composites has impaired strength to 28 MPa which is 17.6% decrease over SCF filled composite and 13.72% increase over neat PP. The improvement in strength of the SCF filled composites is because of high strength and high modulus carbon fibers.

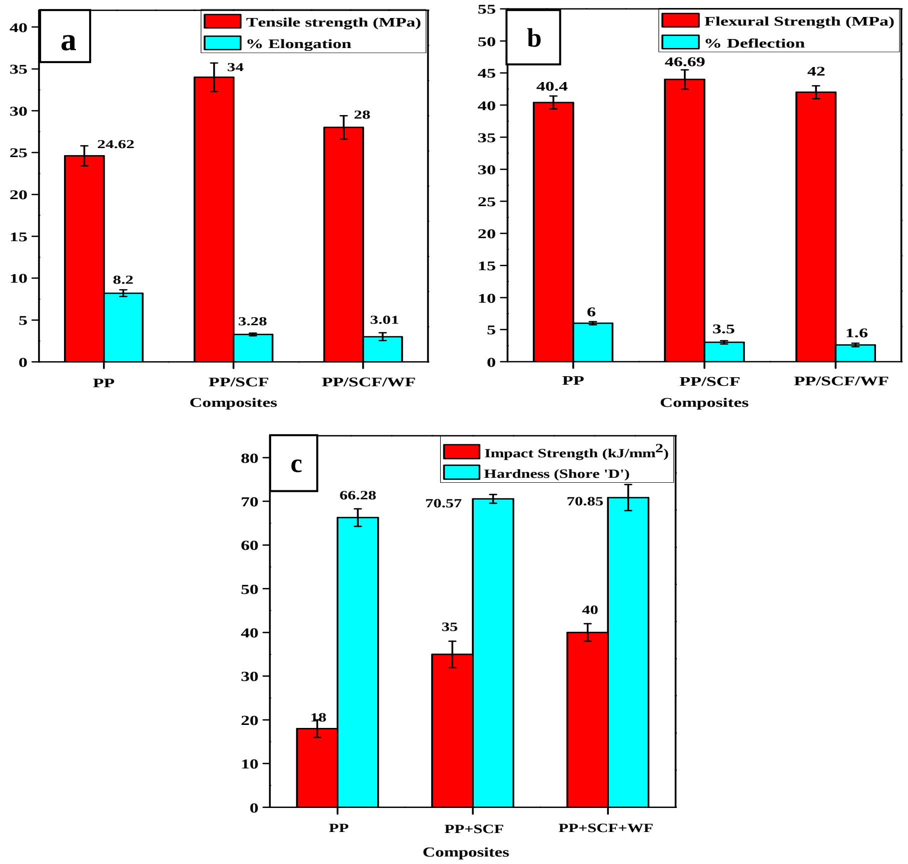

Fig 2. Mechanical Property of PP/SCF/WF hybrid composites: (a) Tensile (b) Flexural and c) Impact Properties

Further, the SCFs have very good compatibility with the thermoplastic [8,9]. But the addition of wood filler slightly decreased the strength of SCF filled composites. This is because of the improved degree of brittleness because of the addition of wood filler. But the good compatibility between the wood filler and carbon fibers enabled the SCF filled composites to exhibit high strength than neat PP. This is because the maleic anhydride strongly associates with the hydroxyl groups on the wood filler surface and improves the adhesion between fiber and filler. The wood filler is chemically strong to interact with the thermoplastic [9, 10]. But their effectiveness was weakened because of the presence of fibers in the polymer composites. The flexural strength of SCF filled composites is shown in the figure 2 (b). The flexural strength of 46.69 MPa has been presented by SCF filled composites which is 15.56 % increase over the neat PP (40.4 MPa). The effect of SCF reinforcement is more dominant in matrix is due to fine surface treatment of SCF. Carbon fibers could able to transfer the load through them to the matrix effectively due to excellent interface bonding between matrix and fibers. Further, SCFs are epoxy coated [8]. Epoxy is a good coupling agent which establishes the bonding layer across the materials. The fibers at the outer layer were under tension and are subjected to severe tensile load [9]. But the adhesive strength between the fibers and the matrix was good so that they can resist the bending load this may be due to the addition malice anhydried. But the flexural strength of the PP/ SCF/WF composites has reduced because of inclusion of wood filler. The flexural strength of 42 MPa has been responded against 40.4 MPa and 46.69 MPa of neat PP and PP/SCF composites respectively. This contributed to the brittle phase of composites [11]. The impact strength of 35 kJ/m^2 has been exhibited by SCF filled composites which is 95% increase over neat PP (18 kJ/m^2). But the inclusion of wood filler in to PP/SCF composites has further improved the impact strength of PP/SCF/WF composites to 40 kJ/m^2 due to increase in stiffness and brittleness of composites (figure 2(c)). The hardness of 70.57 has been reported against 66.28 of neat PP. Further, the hardness of 70.85 has been exhibited by the composites after the addition of wood filler in to PP/SCF composites (figure 2(c)). This is because the compatibilizer plays a major role in binding the filler with fiber and matrix.

SEM images of the failure surface during tension of PP/SCF/WF hybrid composites are depicted in figure (a). Excellent bonding between the filler and fiber with the matrix are shown in the figure. Fiber pull out and fracture are common mechanisms observed in image. The stability of PP/SCF/WF composites has been changed due to the addition of wood filler. This is clearly witnessed in the figure. The bending fractured surface presents impressions of fiber misalignment, fracture and pull-out. This is shown in figure 3 (b). More matrix deformation is appeared in the figure. The impact failure of PP/SCF/WF is shown in the figure 3 (c). The ductility loss is clearly shown. This is witnessed by the appearance of deep cracks and voids in composite system. The fiber pullout is more in the image. Severe deformation of matrix with wood fillers is shown in the image

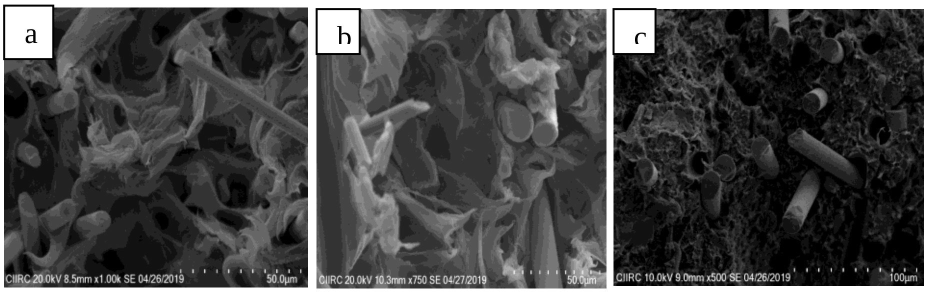

Fig 3. SEM images of 10 wt% SCF and 10 wt% WF filled PP a) Tensile, b) Flexural and c) Impact fractures

3. Conclusions

The following facts were drawn during the investigation on the effect of wood filler on tensile and flexural properties of SCF reinforced Polypropylene composites.

- The reinforcement effect of short carbon fibers has improved the flexural and tensile behaviour of PP/SCF composites.
- The addition of wood filler impaired the tensile and flexural behavior of PP/SCF/WF composites.
- The negative outcome of wood filler on these properties of PP/SCF/WF composites is because of higher degree of agglomeration and also higher degree of stress concentration as an effect of inclusion of wood filler.
- The inclusion of wood filler has significantly enhanced the impact behaviour of hybrid thermoplastic composites.
- The inclusion of wood filler impaired the hardness value of hybrid composites.

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