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MECHANICAL CHARACTERIZATION OF HYBRID THERMOPLASTIC MICRO COMPOSITES

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ABSTRACT

Mechanical properties of hybrid composites filled with micro fillers were investigated experimentally. Polyamide 66 and Polypropylene in 80/20 wt. % was used as polymer blend matrix and 10 wt. % of short basalt fiber (SBF) and 10 wt. % of short glass fiber (SGF) were used as reinforcement. The micro fillers used are Polytetrafluroethylene (PTFE), Silicon carbide (SiC) and Aluminium oxide [Al2O3]. These micro composites were prepared by using melt mix method with the help of twin screw extruder. The Tensile strength, Flexural strength, Impact strength and Shore D hardness were determined as per ASTM methods. Experimental results revealed that the effect of fillers decreases mechanical properties of hybrid thermoplastic composites. But the mechanical behaviour was better than blend. The density of studied composites increases due to dense nature of micro fillers. The hardness of blend is increased by 11% by the addition of micro fillers with studied composites. Scanning electron microscope photographs were used to analyse the morphology of fractured surfaces.

Keywords: *Mechanical, Polymer Blends, Hybrid fibers, Micro fillers*

INTRODUCTION

For the last twenty years, advanced polymer composites became very attractive materials for new structures such as automobiles, aerospace and construction [1]. The use of polymers and polymer based composites having a combination of mechanical and tribological properties need to prove themselves as worthy for mechanical industries. It is often found that such properties are not attainable by a homopolymer. This has led to the development of polymer blends. Polymer blends are mixtures of at least two macromolecular species, polymers or copolymers. Blending of polymers or addition of inorganic filler to a polymeric matrix is an elegant and economic way to obtain new materials with improved properties [2-3]. Lot of research has been made to study the effect of micro fillers on polymers. Mcgrath et al [4] studied the mechanical properties of alumina filler filled epoxy composites. They concluded that there was a little effect by the particle size, shape and distribution on mechanical properties. Osman M A et al [5] studied the influence of excessive filler coating on the tensile properties of LDPE-calcium carbonate composite. They observed that by incorporating filler particles into the fiber reinforced composite, synergistic effects may be achieved in the form of higher modulus and reduce the cost of composite accompanied with deceased strength and toughness . Hartikainen et al [6] studied the mechanical behaviour of polypropylene filled with CaCo3. They concluded that the tensile strength and fracture toughness was decreased by the addition of CaCo3 into PP composites. Chen et al [7-9] studied the mechanical properties of PA66/PPS blend reinforced with PTFE particles. They concluded that the addition of PTFE particles was beneficial from friction and wear behaviour point of view but it deteriorates the mechanical properties. Alhareb and Ahmed [10] studied the effect of Alumina (Al2O3) and Zirconium oxide (ZrO2) in PMMA. They concluded that the addition of these fillers improved the fracture toughness, tensile modulus and flexural properties of PMMA composites. Biswas S et al [11] studied the effect of ceramic fillers on mechanical properties of bamboo fiber reinforced epoxy composites. They found that by incorporating particulate fillers, the tensile strength of composites was decreased.

Polyamide 66 is a very high strength engineering polymer with excellent corrosion resistant, wear resistant, self-lubricating property. Polypropylene is also very widely used polymer material with low cost, low density, relatively high thermal stability, easy processing and recyclability characteristics. Very less data are reported on the effect of micro filers on the mechanical characterization of hybrid thermoplastic blends. Keeping this in view, an attempt has been made to investigate the mechanical behaviour of fillers reinforced basalt and glass fibers filled PA66/PP blend hybrid micro composites.

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MATERIALS AND PROCESSING

Materials and their formulations

Materials used in the present investigation and formulation of composites in different weight percentages are tabulated in Table 1 and 2 respectively.

Table 1: Data and properties of the materials used

Material	Designation	Form	Size (µm)	Manufacturer	Density (g /cc)
Polyamide 66	PA66	Granules	----	DuPont Co. Ltd	1.14
Polypropylene	PP	Particles	12	DuPont Co.Ltd	0.96
Short basalt fibers	SBF	Cylindrical	2 - 3 mm	Fine organics , Mumbai	2.4
Short glass fibers	SGF	Cylindrical	2 - 3 mm	Fine organics , Mumbai	2.5
Polytetrafluroethylene	PTFE	Powder	12	DuPont Co.Ltd	2.2
Silicon carbide	SiC	Irregular	5 - 10	Carborundum, India Ltd.	3.21
Alumina	Al_2O_3	Particles	5 - 10	Aldrich, Bangalore	3.95

Table 2: Formulations of composites in weight percentage

Composition	Material ID	Weight Percentage						
		PA66	PP	SBF	SGF	PTFE	SiC	Al_2O_3
Blend (PA66/PP)	1 T	80	20	---	---	---	---	---
Blend/SBF/SGF	2 BG	80	20	10	10	---	---	---
Blend/SBF/SGF/PTFE/SiC/ Al_2O_3	2 L	80	20	10	10	5.0	2.5	2.5

Compounding and Sample preparation

The thermoplastic polymers (PA66, PP), short fibers and fillers with proper weight percentage as per table 2 were dried at 850C for 48 hours to avoid plasticization, hydrolyzing effects from humidity and to obtain good homogeneity. The selected materials were mixed and mixture was extruded using Barbender co-rotating twin-screw extruder (Make: CMEI, Model: 16CME, SPL, chamber size 70 cm3). The processing details of composites using extrusion method was discussed elsewhere [12].

MEASUREMENT OF MECHANICAL PROPERTIES

The tensile behaviour of composites was measured by conducting tensile test. The tensile strength and elongation at yield were measured using Universal testing machine (JJ Lloyd, London, United Kingdom, capacity 1– 20 kN) in accordance with ASTM D 638 as per the specimen shown in Fig. 1a. Tests were performed at constant strain rate of 5 mm/min. The flexural strength and flexural modulus were determined at a rate of 2 mm/min as per ASTM D 790 (Fig. 1b). The Izod impact strength was determined using ASTM D 256 by using Izod impact testing machine at a strike rate of 3.2 mm/s. The specimen for impact test is shown in Fig. 1c. The density and hardness (Shore D) of composites were determined as per ASTM D792 and ASTM D224 respectively.

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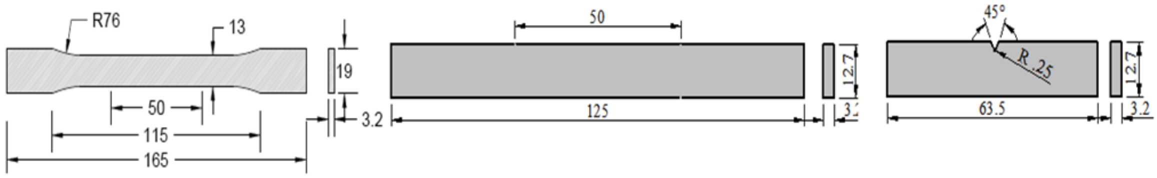

Figure 1: Specimen standards :(a) Tensile Test (b) Flexure Test and (c) Impact Test

RESULTS AND DISCUSSIONS

Effect of micro fillers on Density

The effect of micro fillers on density of hybrid thermoplastic composite is shown in fig. 2. Addition of fillers to hybrid thermoplastic composite improves the density by 6.7 % against 2BG composites. This can be attributed due to dense nature of fillers and fibers. The density of 2L composite was increased by 18.5 % due to filler effect against blend. Addition of fillers to PA66/PP blend enhanced the density of micro composites [tiim, bvl 13] .

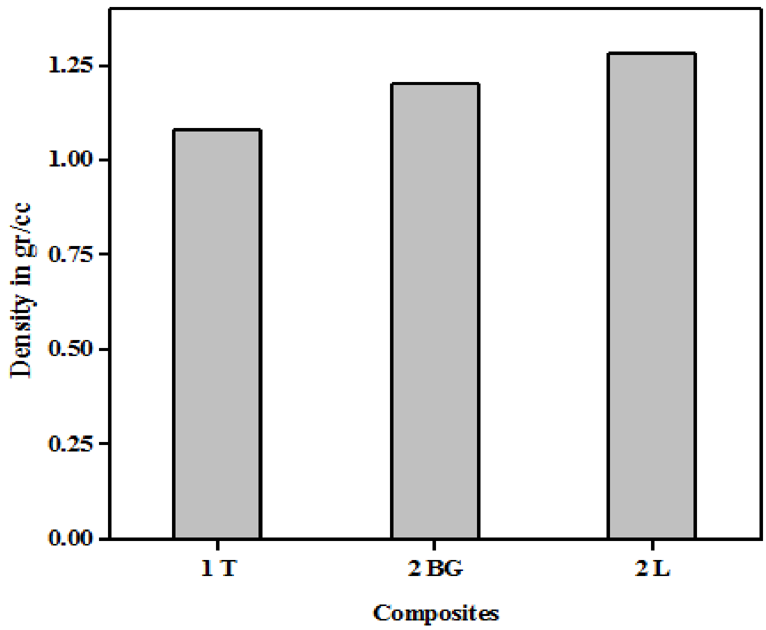

Figure 2: Density of composites

Effect of micro fillers on Tensile behaviour of hybrid thermoplastic composite

The tensile behaviour of studied micro composites are reported in fig. 3(a, b). The effect of micro fillers on tensile behaviour of hybrid thermoplastic composites is not appreciable. The tensile strength of neat blend PA66/PP was 39.78 N/mm2. But the reinforcement effect of hybrid fibers improved the tensile strength by 77%. This is purely attributed to the balanced mechanical properties of hybrid fibers. The interfacial bonding between the blend and fibers is very promising in improving the mechanical behaviour of hybrid thermoplastic composites [11]. The silane coated hybrid fibers exhibited better adhesion due to compatibilizing effect. But the effect of micro fillers on hybrid thermoplastic composites was not appreciable. The decrease in tensile strength by 32.3% was noticed due to hybrid fillers effect. This is due to the increase in porosity of micro composites. Further, the effect of micro fillers transformed the ductile material to brittle nature introducing more number of voids. This may initiate the early development of cracks which will weaken the strength of material. On the other hand, the non contact zone of resin which is occupied by fillers and fibers acts as void for the material. Among the studied composites, 2BG composite possess very good tensile strength.

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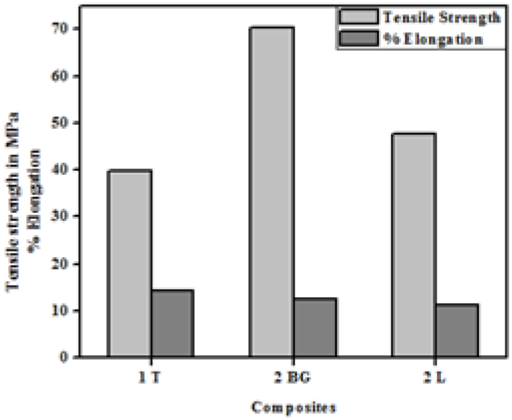
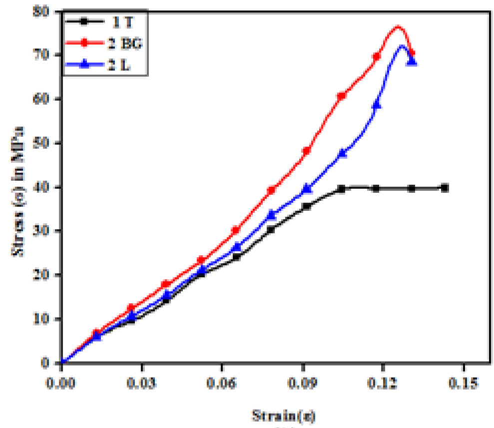


(a)



(b)

Figure 3: Tensile Behavior of Composites: (a) Tensile strength and % Elongation (b) Stress Strain Curve

Effect of micro fillers on Flexural behaviour of hybrid thermoplastic composite

The effect of micro fillers on flexural behaviour of hybrid thermoplastic composite is plotted in fig. 4(a, b). The flexural strength of pure PA66/PP blend is 55 N/mm2. After the addition of Hybrid fibers, the flexural strength was increased to 115 N/mm2, which is around 52 % increase. This is purely attributed to the slenderness ratio of hybrid fibers. The compatibility exhibited by fibers and blend totally contributed towards the improvement of flexural strength. Further, addition of fillers into hybrid composite showed the flexural strength of 79.7 N/mm2, which is around 30% decrease against hybrid composite. The reduction in flexural strength is due to hard and brittle nature of fillers. This is in good agreement with the work of Hui et al [14].

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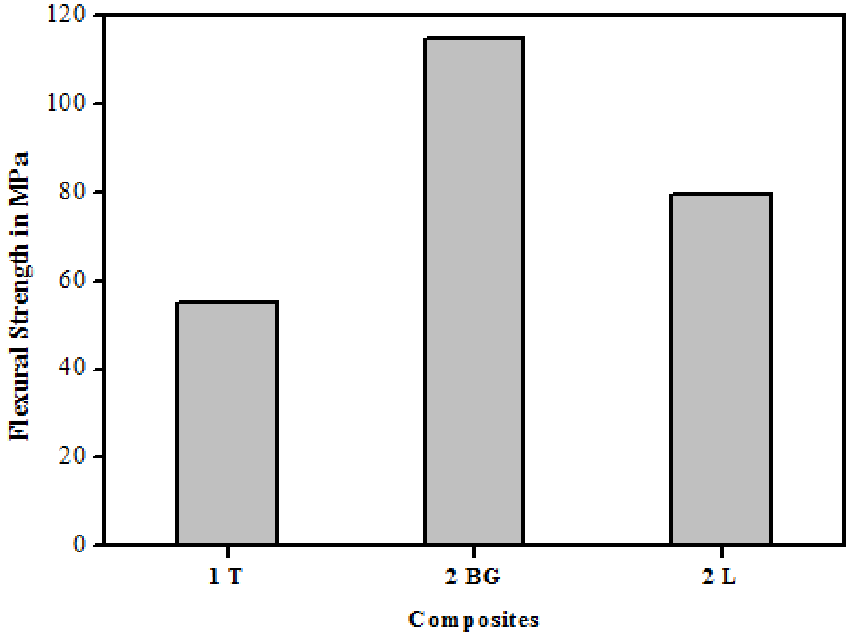
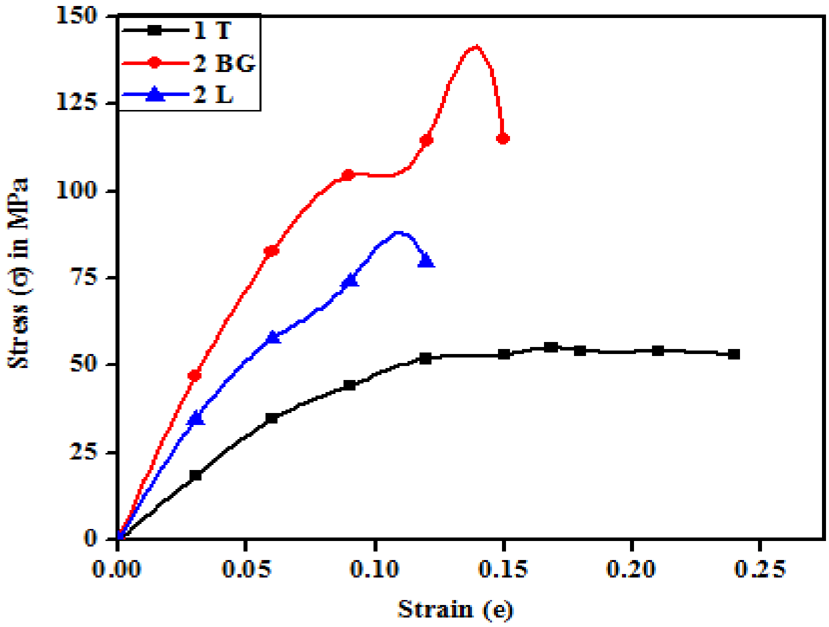


(a)



(b)

Figure 4: Flexural Behavior of Composites: (a) Flexural strength (b) Stress Strain Curve

Effect of micro fillers on Impact behaviour of hybrid thermoplastic composite

The effect of hybrid fillers on impact strength and hardness of hybrid thermoplastic composites are shown in the figure 5. The impact strength of neat blend (1T) was 60 Kj/m2. But the effect of hybrid fibers deteriorated the impact strength of hybrid composites. The decrease of 27% impact strength was noticed due to hybrid fibers effect against neat blend (1T). Further, decrease in impact strength (58.3%) was noticed due to the effect of fillers against blend. This is purely attributed to the brittle nature of composite materials after the addition of fibers and fillers. Fillers further worsened the impact strength of the composites. Among the studied composites,

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blend (1T) exhibited the better impact strength. The hardness of hybrid micro composites was presented in the same figure. The hardness of blend was increased due to the hybrid fibers effect which is around 11%. This is due to the hard nature of fibers. Also the hybrid composites possess good resistance against the load due to hard fibers. This is the reason to increase the hardness of composites. Further, addition of micro fillers into hybrid thermoplastics has not altered the hardness of composites. This shows that the effect of micro fillers was not so appreciable than the fibers on hardness of composites. Due to increase in hardness of composites, impact strength of the same was deteriorated. This is due to the fracture to fibers in the direction of impact. Among the studied composites, blends (1T) possess better impact strength and micro composites possess appreciable hardness.

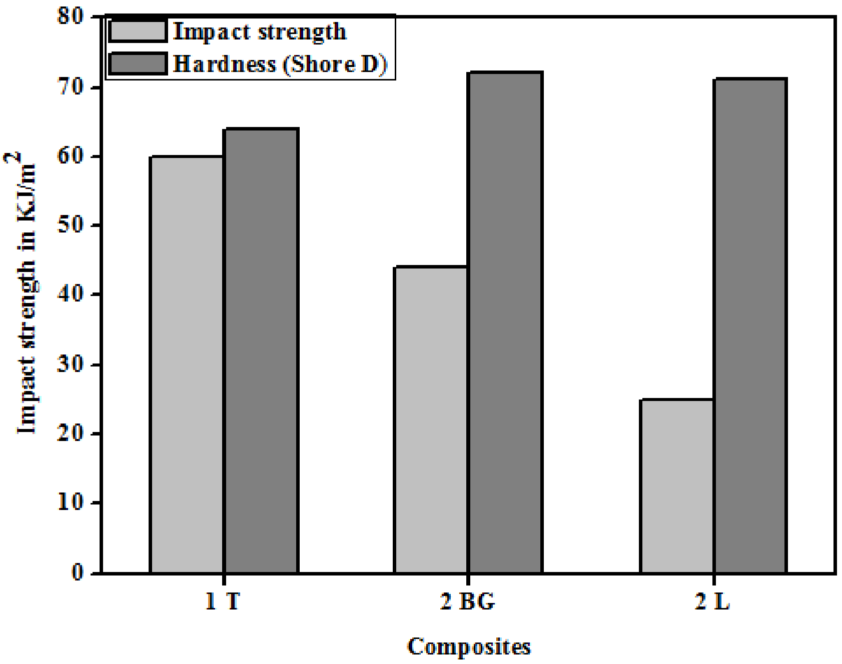

Figure 5: Impact strength and Hardness of composites

Failure Analysis Using Sem

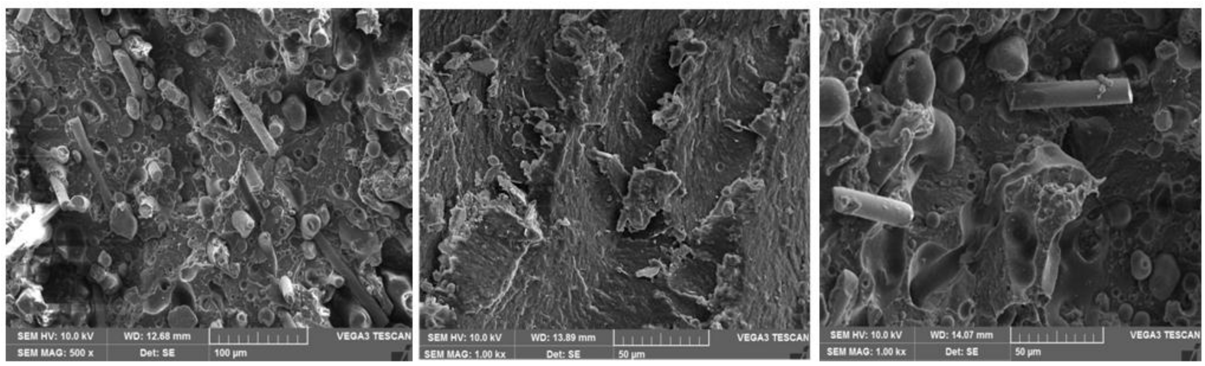

Figure 6: SEM photographs of fractured surfaces: (a) Tensile (b) Flexure and (c) Impact test

The SEM micrographs of fractured surfaces of hybrid composites as a result of mechanical test are presented in figure 6. The fractured surface of tensile test of micro hybrid composite is shown in figure 6 (a). The SEM photographs clearly show the good compatibility between the blend and fibers. Fiber pull out and their impressions were seen in the image. The voids as a result of filler addition are also exhibited by the images. Deformation of surface as a result of pull out is also seen. The matrix phase has deformed much when compared to filler phase. The flexural failure of surface as a result of flexural test is shown in the SEM micro graphs (Fig

6b). This image shows the severe plastic deformation of matrix during bending. The combined action of both fillers and fibers of blend contributed to the betterment of flexural strength, this is clearly shown SEM photograph. The SEM images after impact strength of micro composites are shown in figure (6c). SEM picture evidenced about the fiber fracture. The fiber pull out was very less. But more number of voids was witnessed by this figure. Thus the impact strength of material was less.

CONCLUSION

The hybrid fiber filled thermoplastic composites are class of materials for structural applications. But the micro fillers filled hybrid thermoplastic composites are not promising for better mechanical performance. The following are conclusions emerged from the experimental investigation of micro composites:

- PA66/PP blend proved to be the best matrix for structural applications
- The hybrid composites exhibited better tensile and flexural properties but poor impact strength
- The hybrid fillers deteriorated the strength of hybrid composites
- The hardness of micro composites was appreciable due to filler addition
- Fiber pull out and fiber fracture are the mechanisms observed for the failure of materials

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