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Study of mechanical properties of walnut shell powder filled-glass fiber reinforced vinyl ester hybrid composite

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ABSTRACT

In this article, an experimental investigation has been performed to examine the mechanical behaviour of walnut shell powder filled-glass fiber reinforced vinyl ester composite. The size of walnut shell varied in the range of 80 micron to 120 micron. Glass fiber was reinforced in mat form to provide primary strength to the composite while walnut shell powder (WNP) was used in view of giving value addition to it. Weightage of glass fiber was kept constant at 10 wt. % while WNP was varied as 0, 10, 15 and 20. Composite was fabricated by conventional hand lay-up method and characterized for mechanical propertied such as tensile strength, flexural strength and impact energy. The obtained results revealed that incorporation of WNP has significant influence on the mechanical properties but at higher weightage of WNP, a slight reduction in the properties were observed except flexural strength which showed linear increase with the addition of WNP.

Keywords:

INTRODUCTION

The augmentation of natural waste particularly fillers has become a crucial issue for its disposal after end use [1-3]. Perhaps, its incorporation in various polymer composites can lead to value addition of waste. Various types of natural filler waste for e.g., coconut shell, almond shell fillers, groundnut filler etc., are some of the common fillers extensively reinforced in polymer for properties enhancement [4-7]. The incorporation of such waste not only reduces the overall cost of the material but also decreases the weight of the composite [8-11]. This has become a very common practice in research fraternity to include different types of waste fillers in polymer matrix to fabricate a sustainable composite [12-15]. For instance, modification of epoxy had been performed by incorporation of walnut shell waste filler and found that the thermal properties of epoxy increased with a significant amount as confirmed by the microstructure examination [16]. A combination of three filler waste viz: sunflower, hazelnut and walnut were reinforced in epoxy and found an appreciable increment in mechanical properties at optimum weightage of fillers [17]. To enhance the interfacial bonding of filler and polymer an alkali treatment was performed. The results showed in the study explained the reasons that likely dominated in the improvement of the mechanical bond between the walnut filler and poly lactic acid [18]. Walnut filler treated with perlite have shown noteworthy improvement in the mechanical strength of walnut filler reinforced

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polyurethane composite [19]. The incorporation of walnut shell in polypropylene resulted in decrement in the tensile strength and impact energy. However, the hardness was found to increase a significant amount [20]. The use of walnut filler with a natural fiber or synthetic fiber gives fruitful results leading to its future scope of a substitute hybrid composite reinforcement [21]. The size of the filler has a crucial part to play which varies from 75 micron to 150 micron to have a significant strong bonding with the polymer matrix [22]. Although a lot of work has been done in walnut filler polyester composite. But, till now no such research is available on walnut filler-glass fiber-vinyl ester composite. Therefore, the present article deals with the mechanical properties evaluation of hybrid composite containing glass fiber mat, waste walnut powder filler and vinyl ester resin.

Material and method

Glass fiber in mat form was procured from Amtech Ester Pvt. Ltd Delhi. It was cut in rectangular shape of required dimension of mould. Walnut shell was procured locally from Dehradun which was grounded in the powder form in grinding machine of average mesh size ranging from 80 to 120 micron. Vinyl ester resin with suitable hardener and accelerator was procured from Amtech Ester Pvt. Ltd. Delhi. The reinforcement and matrix images are illustrated in figure1.

(a) (b) (c)

Figure 1. Showing (a) Vinyl esterchemical formula (b) Glass fiber mat and (c) Grounded walnut shell powder as filler

Composite fabrication

The fabrication of composite was carried out by open hand lay-up method as shown in figure 2. Initially the grounded WNP was mixed with vinyl esterin a separate beaker and stirred mechanically to obtain a uniform mixture. Meanwhile, the mould was prepared with setting up mylar sheet above the mould followed by applying silicon spray on it to avoud sticking of prepared composite with the mylar sheet. After this discourse, the mixture prepared in the bekaer was poured over the mould and a measured mat of glass fiber was kept over it. The total mixture of fiber and polymer was covered by mylar sheet at the top. Steel roller was applied over it to remove any moisture. Laslty, the comosition was subjected to static load of 25 kg. The mixture was left to coll for about 12 hours and then the composite was removed from the mould. The process was repeated for different walnut loading as illustrated in table 1.

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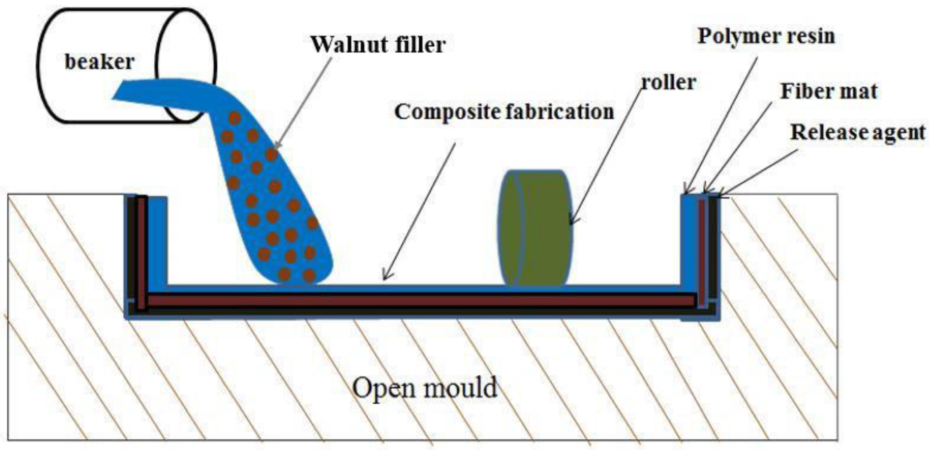

Figure 2. Lay out of fabrication of hybrid composite

Table 1. weightage of reinforcement and polymer

Designation	Vinyl ester (wt. %)	Glass fiber (wt. %)	Walnut filler (wt. %)
VGW0	90	10	0
VGW1	85	10	5
VGW2	80	10	10
VGW3	75	10	15

Composite characterization

The composite samples were characterized for various mechanical tests. Samples were sharpened, polished and cut in the required dimension as per ASTM standards. Tensile test was performed in accordance with ASTM D 3039 standard. The specimen size was selected as 150mm×15mm×4mm placed under the UTM machine of maximum load capacity of 4 KN at cross head speed of 3 mm/m^{-1}. The flexural test was conducted on the same UTM machine in compliance with ASTM D790-07 standard. The specimen size of 125mm×15mm×4mm was cut and placed in the UTM under the cross-head speed of 3 mm/m^{-1}. The span to width ratio was kept at 24:1. The impact energy was measured by using impact testing machine AIT D on a sample having dimension of 55mm×10mm×4mm with a deep notch of 2 mm maintain an angle of 45^o.

Results and discussion

The outcomes of the tensile testing are shown in figure 3. As per the figure 3, it was discovered that inclusion of WNP has noteworthy influence on the tensile strength of the Glass fiber vinyl ester composite. Although, glass fiber itself is capable of enhancing the tensile properties but by including WNP waste, a decent increase in the tensile strength was observed. With an inclusion of 5 wt. % of WNP, the improvement of 10.4 % was obtained for the tensile strength.

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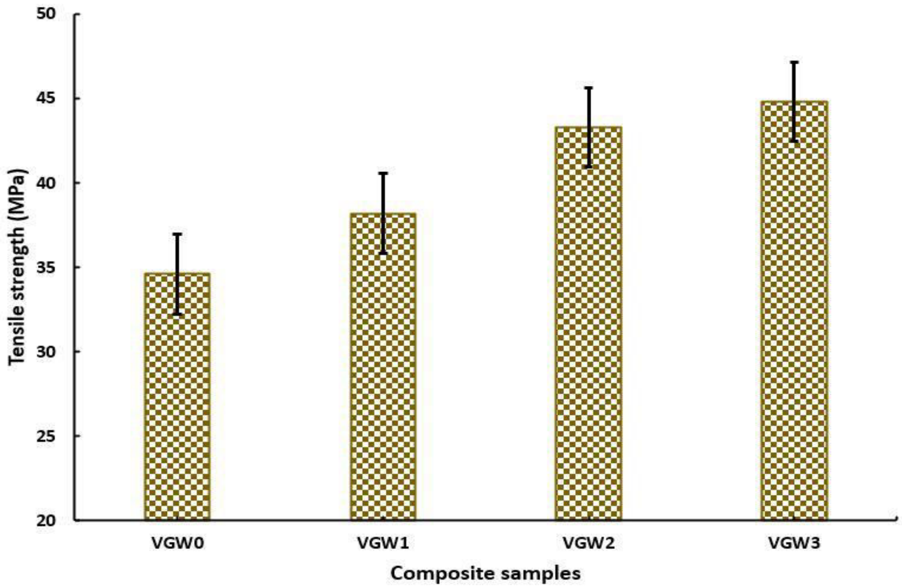

Figure 3. Tensile strength of composites

Upon further adding WNP (10 wt. %), the properties relative to VGW1 enhanced by a factor of 13.3 % as expected due to good mechanical bonding among the fiber-polymer and WNP. At 15 wt. % of WNP addition, the enhancement was observed relatively low of 3.4 %, obviously due to the agglomeration of WNP causing the higher stress intensity at one region leading to early fracture. Nevertheless, being a waste WNP its influence was found to be fruitful as per tensile enhancement. Similar results for increase in tensile strength with the inclusion of waste were reported in literature [20, 21, 23].

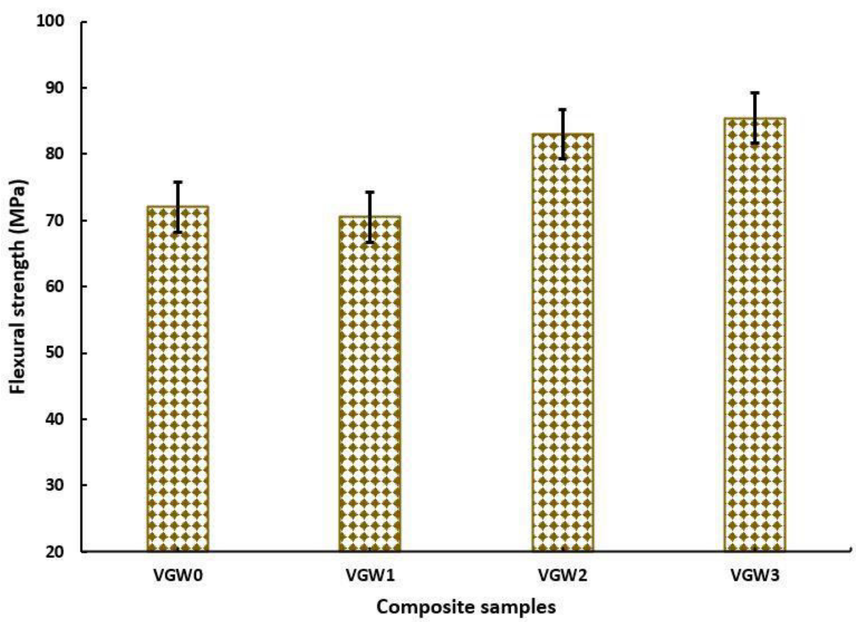

Figure 4. Flexural strength of composites

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The influence of WNP (as shown in figure 4) on the flexural strength is quite interesting and fascinating as per values are concerned. At low reinforcement of WNP (5 wt. %), a reduction in flexural strength of near about 2 % was noticed. Thereafter, a healthy improvement of 17.7 % relative to VGW1 was obtained at 10 wt. % of WNP. Upon loading 15 wt. % WNP, a 2.9 % improvement with respect to VGW2 was obtained. WNP interaction with fiber and matrix caused the strong inter mechanical bond and improved load bearing capability with enhanced stress transfer mechanism. Similar trends for flexural strength with increased waste content were reported in literature [17, 24, 25]

The impact energy capability of composite enables it to perform better in situation where it is subjected to dynamic load. This requires high deformability of internal bonds. WNP seems to play a similar role as required for high energy capability material. The results were seemed to be continuous increasing with the addition of WNP at every % of reinforcement. The WNP filled the gaps as present between the glass fiber and vinyl ester matrix to allow easy stress transfer among the bonds leading to higher energy absorption capability of the composites. The lowest was found to be 6.2 J at 0 wt. % reinforcement while highest was obtained as 7.6 J at 15 % of WNP reinforcement. The observed ascending trend of impact energy values with increased waste content is in good agreement with the published research [17, 25].

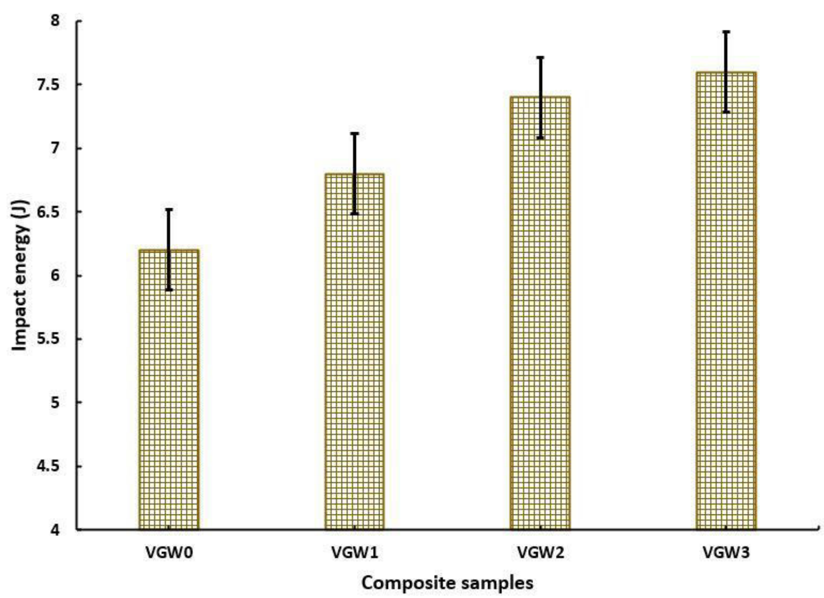

Figure 5. Impact energy of composites

Conclusion

The hybrid composite with the variation in WNP was successfully fabricated by open hand lay-up method. The composite was homogenized by proper mixing of resin and WNP before pouring into the mould. The results obtained were quite satisfactory with enhanced tensile, flexural and impact behaviour. The properties were continuous increasing with the addition of WNP except in the case of flexural strength. Still, at higher % of WNP, the flexural strength overall increased. The present work can be extended for higher % of WNP with natural fiber and biopolymer to bring a complete bio family of composite material in one single composite. The work can also be subjected to tribological behaviour to expands its reach in wear applications.

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