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Original Research Paper

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MECHANICAL CHARACTERIZATION OF *Cissus quadrangularis* STEM/GLASS FIBER HYBRID COMPOSITES

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ABSTRACT *Natural fibre reinforced polyester composites are evaluated for strength and performance in order to be a contender for th glass fibre/polyester composites. Hybridization of two different types of fibres is proved to be an effective method to design materials for tailoring the various requirements of the structures. The tensile, flexural, impact and water absorption tests were carried out for Cissus quadrangularis stem fiber (CQSF) reinforced unsaturated polyester composite material. After optimizing CQSF fiber length and weight percentage, the mechanical properties CQSF reinforced composite was enhanced through hybridizing with glass fiber. This study shows that addition of 25 wt.% CQSF along with 25 wt.% of glass fiber in polyester matrix significantly increases the mechanical properties of CQSF composites. Fractured surface morphological analysis using scanning electron microscope shows good interfacial properties.*

KEYWORDS : *Cissus quadrangularis, Polymer-matrix, Composites, Hybrid*

1. Introduction

Natural fibers such as cotton, jute, flax, kenaf, banana, sisal, oil palm and pineapple leaf fibre are being considered as a potential reinforcement for polymer composites in recent years due to its eco-friendly and renewable nature. The major other advantages of natural fibres are its low density, low cost, biodegradability, acceptable specific properties, better thermal and insulating properties along with low energy consumption during processing [1–2]. Natural fibres are known to be neutral with respect to the emission of CO_2, and this feature allows lignocellulosic fibres as a reinforcemnt material in context with the Kyoto protocol [3].

Hybridization is one of the common procedure to obtain properties, which are intermediate between the two originating materials. Hybridization results in a compromise with mechanical properties and cost to meet the specified design requirements. Studies have been performed to prove that the mechanical properties can be tailored using hybridization based on glass laminates with natural fibers [4] and synthetic fibres [5]. Hybrid composites have taken the attention of many researchers as a way to enhance the properties of natural composites [6,7]. The aerospace industry uses hybrid laminates of this kind in very different applications, such as helicopter blades and flaps [8]. Hybrid woven fabrics with interwoven glass, carbon and aramid fibers are also a fine way to combine the best characteristics of those fibers in a unique material [9]. Hybrid composites using lignocellulosic materials are less studied. Reports in the literature are almost related to the use of the natural fiber as a filler to lower the cost or to increase the moment of inertia of the composites cross-section [10], and to a lesser extent as reinforcement [11]. Fabrics interweaving lignocellulosic and glass fibers, as well as fabrics interweaving different cellulosic fibers, are even less studied [12].Hybridizing lignocellulosic fiber with glass fibers will provide the necessary mechanical load bearing capacity. This work attempts to develop a hybrid composite material with Cissus quadrangularis stem fibers (CQSF) and glass fibers bonded by polyester resin. The microstructural and mechanical properties were evaluated to ascertain its potentiality.

2 Methodology

2.1 Preparation of composite specimens

Compression moulding method was adopted in the preparation of the composite specimens. The dried CQSFs were then chopped into strands of 40 mm length. Designed weight percentage of the fiber was taken and placed between two mild steel plates and subjected to a load of 40 metric tons to obtain a CQSF mat with uniform fiber distribution. The obtained chopped glass fiber mats were also separately weighed and taken for reinforcement. In skin-core layup method, glass fiber mat is considered as the skin and the core is the CQSF sheets. These mats were placed in layers inside the mould of 300 mm x 150 mm x 3 mm dimensions. For the matrix, 95% of unsaturated polyester resin along with 2% methyl ethyl ketone (MEKP) and 0.5% cobalt napthanate were mixed together and degassed. The mixture was then applied using a brush after each layer and degassed manually with the help of grooved roller. They were allowed to cure at room temperature under a load of 400 kN. Three set of experiments were done by varying the glass fiber content on weight basis as 0%, 25% and 50%. The total weight percentage of the fiber is maintained constant at 50%, where CQSF is the other reinforcement.

2.2 Material characterization

Three specimens were prepared for each set of experiments and tested under tension using Instron S-Series H25K-S universal testing machine. The gauge length for the tensile specimens were maintained at 100 mm (ASTM D3039M-95). Similarly, three specimens were prepared with a gauge length of 50 mm from each set, to conduct three-point flexural tests (ASTM D790-10). The crosshead speed was maintained at 1 mm/min for both the tests. Energy absorption capacity of the material was estimated by conducting Izod impact test (ASTM D256-10) and the hardness values were determined using a Digital Rockwell Hardness Testing Machine (ASTM D785-98). The water absorption characteristics of the composite were tested as per ASTM D570-98.

2.3 Scanning Electron Microscope

The fractured surface morphology of the composite was examined using a scanning electron microscope (Model EVO 18, Special Edition; ZEISS, Germany) with an electron beam accelerating potential of 10 kV. Since the specimens were nonconductive, they were coated with gold to avoid electron beam charging.

3 Results and Discussion

3.1 Tensile Properties

The variation of the tensile properties of the composites where investigated based on the percentage content of the glass and natural fibers. The total fiber content was maintained constant as 50wt. %. It is obvious, that the composite with only CQSF (50 wt. %) has low tensile strength and modulus, which was found to be at 67.18 ± 3.5 MPa and 1.27 ± 0.2 GPa respectively. The specimen with glass fiber as reinforcement of 50 wt. % gave better property than the CQSF reinforced composite with a tensile strength of 165 ± 4 MPa and a tensile modulus of 1.6 ± 0.25 GPa. These values of glass fiber reinforced composite were in closer proximity with the values reported by other authors [4]. In order to make use of natural fiber for high specific strength than it can provide alone, they were hybridized with glass fiber in 25/25 wt.%. The moderate tensile properties obtained in the hybrid specimen made with glass fiber mats on the top and bottom with random strands of CQSF mat in the middle. The proportions of glass fiber and CQSF reinforcement is maintained as 50/50. The hybrid composite specimens showed a tensile strength of 132.2 ± 3.5 MPa which is 59% higher than the specimen with CQSF alone and is only 20% lower than the specimens with only glass fiber as reinforcement. A similar trend was also observed with the tensile modulus value also as shown in the table 1. The increase in properties can be attributed to the combination of great bonding capabilities of the glass fiber mats and higher strengths of the CQSFs [2].

3.2 Flexural behaviour

The flexural properties of the specimens showed a similar trend like the tensile properties. Lower value was recorded for the CQSF reinforced composite specimens whereas the highest was recorded for the glass/polyester composite. However, the effect of hybridization is well embossed in the flexural properties also.

Table 1. Mechanical properties of raw and hybrid composites.

Fiber Composition CQSF/GF wt. (%)	Tensile Stress (MPa)	Tensile Modulus (GPa)	Tensile Strain (%)	Flexural Stress (MPa)	Flexural Modulus (GPa)	Impact strength (J/cm^2)	Hardness (HRRW)
0/50	165	1.60	5.37	170	3.10	10.50	94
25/25	132.2	1.48	6.46	143.9	2.25	12.87	98
50/0	67.18	1.27	5.25	81.75	1.62	7.84	84

The CQSF reinforced specimens gave a flexural strength of 81.75 ± 4.2 MPa and flexural modulus of 1.62 ± 0.22 GPa where the hybrids showed 43% higher flexural strength and flexural modulus of 2.25 ± 0.2 GPa. The glass fiber reinforced specimen had higher flexural properties with a strength of 170 ± 2.5 MPa and modulus of 3.1 ± 0.4 GPa (Table 1).

3.3 Impact behaviour

The impact properties of the specimens further stressed the importance of hybridizing the natural fiber with glass fiber in composite materials. The impact strengths of the CQSF reinforced specimen was low were at 7.84 ± 0.3 J/cm^2 in comparison with the glass fiber reinforced specimens which gave an impact strength of 10.5 ± 0.25 J/cm^2. However the highest value was recorded for 50/50 hybrid specimen which gave an impact strength of 12.87 ± 0.23 J/cm^2, which may be due to the combination of glass fiber mats on the sides sandwiched with random oriented CQSF in the middle layer.

3.4 Water absorption study

Fig. 1 shows the water absorption properties all three polymer composites. The specimens were immersed in three aqueous environments, namely distilled water (pH 7), seawater (pH 8.3), and acidic solution (pH 5.6).

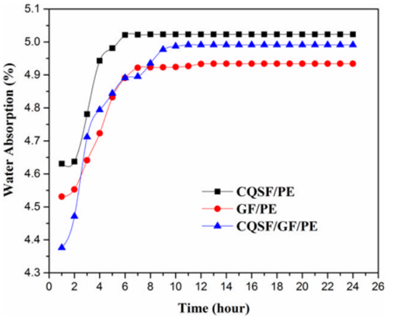

Fig. 1. Water absorption properties of composites

The maximum moisture absorption capacity of the given CQSF/glass hybrid polymer composite material is approximately 5% in all aqueous environments, which is lower than the moisture absorption percentage of other natural fiber reinforced unsaturated polyester matrix composites reported [13].

3.5 Fractography study

The study of the fractured section of the specimens shows the details of the fiber bonding with the resin. Lower bonding leads to failure of material at lower strength, which demands fractographical study of specimen. The SEM images show the fractograph of the specimens in detail (Fig. 2).

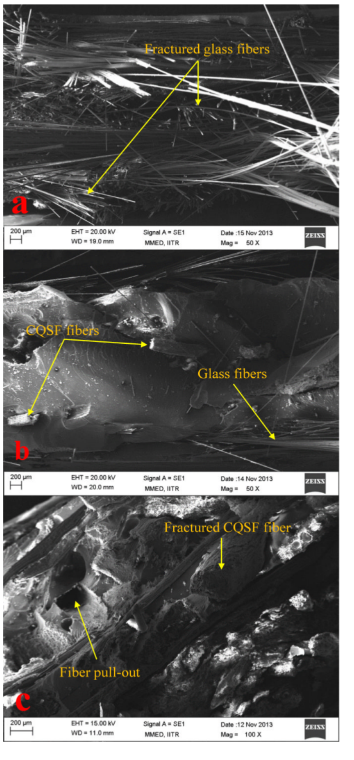

Fig.2. (a) Glass fiber/PE, (b) Glass fiber/CQSF/PE, (c) CQSF/PE

It is noted that there is extensive debonding leading to matrix breakage in case of CQSF reinforced composite and the fiber pull-out is also quiet prominent, which is due to the hydrophilic nature of the natural fiber. The presence of glass fiber mats on both the top and bottom surface of the material increase the bonding characteristics leading to high strength for the hybrid composite. It is interesting to note a phenomenal decrease in debonding and resin breakage in the glass fiber composite, which yields better mechanical strength.

4 Conclusion

Despite of the fact that, some natural fibers have mechanical properties comparable or even higher than some artificial fibers, while the hydrophilic nature of the natural fibers leads them down. The study on the effect of hybridization in this paper reveals that CQSF reinforced specimen gave low mechanical properties. However, the hybridized composites at 50/50 proportion showed tremendous increase in properties. The increase in properties upon hybridization was as high as 59% and 43% for tensile and flexural strength respectively in comparison with CQSF/polyester composites. The results indicates that the incorporation of CQSF fiber with GFRP improves the properties CQSF fiber reinforced composite, which can tailored as per the need of the structure.

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