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RESEARCH ARTICLE

HYBRIDIZATION EFFECT ON FLEXURAL PROPERTIES OF EPOXY BASED WOVEN CARBON/GLASS AND KEVLAR/GLASS COMPOSITES

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ABSTRACT

Hybrid composites possess unique features that can be used to meet differentdesign requirements with respect to strength, stiffness and flexuralbehavior. Akey parameter in hybrid composite structures is the arrangement offibers within the hybrid. It was reported that the hybrid design strongly affects avariety of properties such as flexural strength, modulus, fatigue behavior, andimpact performance of hybrid composites based on high performance fibers. In this paper, the flexural properties of composite materials based on two types of hybrid composites such as Carbon/glass& Kevlar/glass reinforced with epoxy resin are investigated under quasi-static loading conditions. Hybrid laminates based on carbon/glass fiber and Kevlar/glass was then manufactured using a hand lay-up technique and tested. Hybridising the carbon/glass and Kevlar/glass fibre composites in thismanner combines the strength and stiffness of the fibres system with the excellent flexural resistance of the hybrid composite. These specimens were then tested in the three point bend configuration in accordance with ASTM D790-07. The failure modes were examined under fractographs, and the results show that the dominant failure mode is fiber matrix interface cracking. The flexural modulus, flexural strength and strain to failure were recorded. It is seen that flexural modulus decreases with carbon/glass hybrid and increases in Kevlar/glass hybrid composite system.The experimental evidence suggests that hybrid composites based on combinations of Kevlar/ glass fibre reinforced with epoxy resin as matrix offer better flexural properties for use in a number of engineering sectors such as the automotive, aerospace, and marine and other various industries.

INTRODUCTION

Hybrid composites are manufactured by combining two or more fibers in a single matrix. Hybrid composites can be made from artificial fibers, natural fibers and with a combination of both artificial and natural fibers [1]. Hybrid composites can help us to achieve a better combination of properties than fiber reinforced composites. The constituent fibers in a hybrid composite can be altered in a number of ways leading to variation in its properties. In an effort to develop a superior,but economical composite, natural fibres can be combined with synthetic fibres in the same matrix material totake the best advantage of both. It is also possible to combine different kinds of fibres to form either an interply or an intraply hybrid laminate. An interply hybrid laminate consists of different kinds of fibres in different laminas,whereas an intraply hybrid laminate consists of two or more different kinds of fibres interspersed in the samelamina Mallick [2] *et al* investigated the tensile, flexural and compressive properties of coir–silk fibre-reinforced composites, and Venkata Subba Reddy *et al*[3] evaluated the tensile properties of glass and bamboo fibre-reinforced polyester hybrid composites. The importance for the development of hybrid composites was discussed by Jarukumjorn and Suppakarn [4].They investigated the effect of glass fibre hybridization on the physical properties of sisal–polypropylene composites. Sabeel Ahmed and Vijayarangan [5] studied the effect of stacking sequence on the mechanical properties of woven jute– coir hybrid composites and they suggested that the glassplies at the extreme end has good mechanical strength. Geethamma *et al.* [6] investigated the mechanical properties of short coir–rubber composites and suggested the economical composites using coir fibres. Structural characteristics and mechanical properties of coir fibre/polyester composites were investigated by Monteiro [7]. He analyzed variation of the flexural strength with the mass fraction of coir fibres and molding pressure. Mishra *et al* [8] studied the effect of glass fibres addition on tensile, flexural and izod impact strength of pine apple leaf fibre (PALF) and sisal fibre-reinforced polyester composites. Pavithran *et al* [9] evaluated the enhancement in the properties of coir–polyester composites by incorporating glass as intimate mix with coir. Harish *et al* [10] investigated the mechanical properties of randomly oriented coir composites mixed with epoxy resin and suggested for low load applications. Woven coir–glass hybrid polyester composites were developed and their mechanical properties were evaluated for different stacking sequences by S.Jayabal [11] *et.al.* Scanningelectron micrographs of fractured surfaces were used for a qualitative evaluation of interfacial properties of woven coir–glass hybrid polyester composites. They indicated that coir–glass hybrid composites offered the merits of both natural and synthetic fibres. From the above literature, it is very evident that the much of the work have been focused on hybridization of natural and synthetic fibers and their characterization. However, the present study focuses on the evaluation of flexural properties of interply woven glass/carbon hybrid laminate and Kevlar/glass hybrid laminate.

EXPERIMENTAL METHODS

Materials

Woven fabric Carbon fibres (T-300 PAN based, High Strength), E-glass (FGP, RP-10) of density 360 GSMand epoxy adhesive (Bisphenol A type, Ciba-Geigy LY 556 araldite, hardener HY- 951) were used to fabricate composite laminates.

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Preparation of Specimens

E-glass fibre grade 360GSM & diameter of glass fibre is 0.25 mm diameter is tailored with carbon fibre 0.25 mm diameter to prepare bi-woven clothes. The thickness of the cloth is 0.3mm which are stacked layer by layer about 10 layers to attain required thickness. During preparation of laminated required orientation of fibre is carried out for 0°/90° orientation with Epoxy resins, also known as polyepoxides, grade LY556 HY951 resin used. It consists of monomers or short chain polymers with epoxide group at its end. Which contain epoxide groups co-reactants are often referred to as hardeners or curatives, and the cross-linking reaction is commonly referred to as curing. Laminates are prepared by hand-layup process using vacuum bag technique. After preparation of laminates it is cured in a reheating furnace to 100^0 C up to 2hrs. After curing specimens are fabricated as per the standard procedure as shown in Fig 1, and Fig 2.

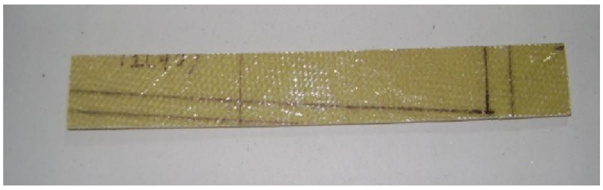

Fig. 1. Flexural Specimen – Kevlar/Glass

Fig. 2. Flexural Specimen – Carbon/Glass

Flexural Testing of Hybrid Laminates

Flexural analysis was carried out at room temperature through three-point bend testing as specified in ASTM D 790, using Instron Model 5582 universal testing machine as shown in Fig 3.

Fig. 3. Flexural testing of hybrid laminates

The speed of the crosshead was 2 mm/min. Three composites specimens were tested for each sample. Flexural strength was calculated from Eq. (1)

$$\sigma = \frac{3PL}{2bd^2} \text{ ------------- (1)}$$

Where, P = peak load at a given pointonthe load deflection curve (N),L = support span (mm), b =width of the samples (mm), d = thickness of the samples (mm) Flexural modulus was calculated from Eq. (2)

$$E_f = \frac{L^3 m}{4bd^3} \text{ --------------- (2)}$$

Where, L = support span (mm), b =width of the samples (mm), d = thickness of the samples (mm), m= slope of the tangent to the initial straight-line portion of the load deflection curve (N/mm).

RESULTS AND DISCUSSIONS

Table 1 & 2 indicates the results of flexural properties evaluated on two hybrid laminates for 0°/90° orientation. Table 2indicates that Kevlar/glass hybrid combination offer higher flexural properties as compared to Carbon/glass composites for the same glass content. Similarly, the Kevlar/glass combination hybrid offers a higher stiffnessas can be seen from Table 2. However, it has been reported that for carbon/glass hybrid laminatepossess higher tensile delamination strength as compared to Kevlar/glass hybrid laminate. Tensile delamination strength is the strength at which delamination occurs under tension. Visual examination of the fracturedspecimen showed that on the upper and lower surfaces were subjected to compression and elongation of fibers respectively.The failed specimens showed very different failure modes. The three primary modes of failure observed in fracture of a hybrid specimen are fiber separation, fiber breakage, and ply delamination. The total failure of hybrid laminate can occur by any combination of these three modes. Fig 6 indicates the presence of voids in carbon/glass epoxy hybrid laminates. Fig. 7 shows cracking in the carbon layers while none is seen on the glass layers. This took place because the carbon fibers are brittle while the glass fibers are ductile and expand morethan carbon fibers. The cracks started at the interface between the carbon and glass layers and developed inwardly to the interface of carbon layers.These cracks then propagate into the specimen and cause rupture.

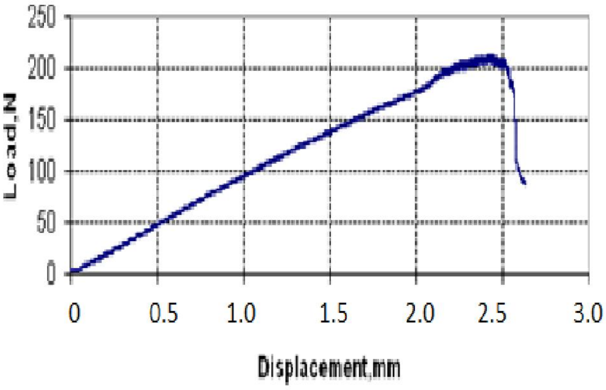

Fig. 4. Carbon/Glass Hybrid laminate (0°/90°)

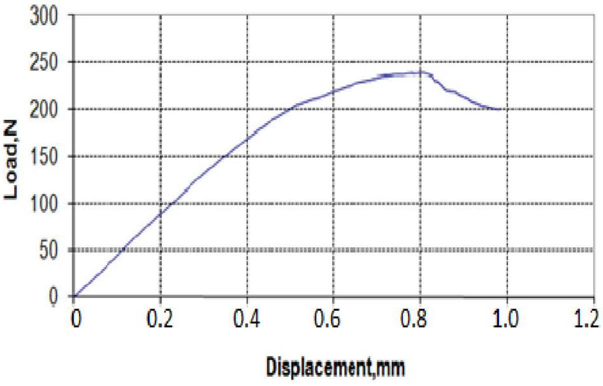

Fig.5. Kevlar /Glass Hybrid laminate (0°/90°)

Table 1. Carbon/Glass hybrid – Flexural Test results

Speci- -men	Load (N)	Average Load (N)	Flexural Strength (MPa)	Average Flexural Strength (MPa)	Flexural Modulus (GPa)	Average Flexural Modulus (GPa)	Flexural Stiffness (N/mm)	Average Flexural Stiffness (N/mm)
1.	220	190.67	293.3	254.2	189.6	173.7	112.5	101.43
2.	162		216.0		185.7		102.7	
3.	190		253.3		149.7		88.23	

Table 2. Kevlar/Glass hybrid – Flexural Test results

Speci- -men	Load (N)	Average Load (N)	Flexural Strength (MPa)	Average Flexural Strength (MPa)	Flexural Modulus (GPa)	Average Flexural Modulus (GPa)	Flexural Stiffness (N/mm)	Average Flexural Stiffness (N/mm)
1.	240	242.6	320.0	323.6	737.4	775.3	388.9	408.9
2.	240		320.0		790.1		416.7	
3.	248		330.6		798.4		421.0	

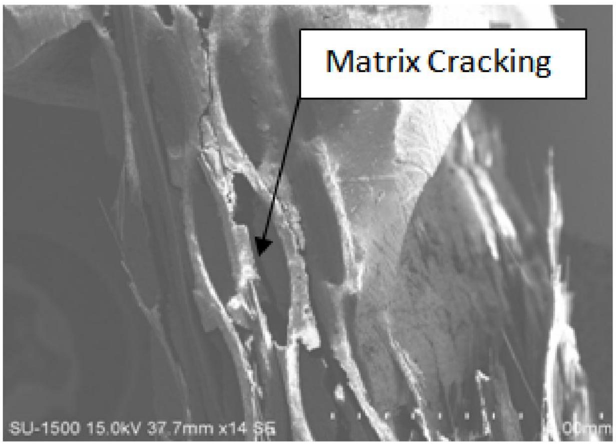

Fig. 6. Matrix cracking in carbon/glass epoxy hybrid laminates

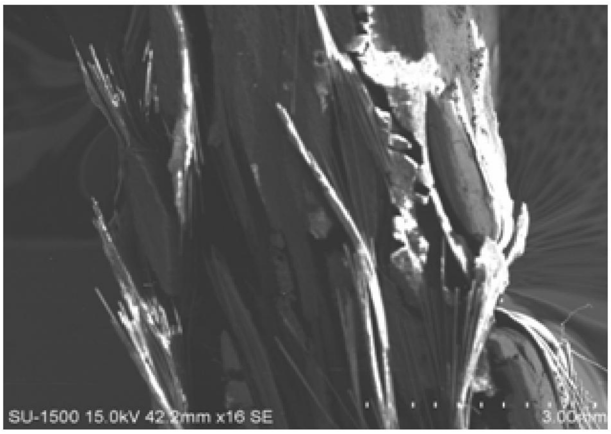

Fig. 7. Fiber pull out on the fractured carbon/glass epoxy hybrid laminate

Conclusions

- Experimental evaluation of flexural properties of carbon/glass epoxy and Kevlar/glass epoxy hybrid specimens have been attempted and it is observed that the flexural strength, flexural modulus and stiffness are significantly increasing in Kevlar/glass hybrid as compared to carbon/glass for the same glass content.
- A simple three point bend test was adequate to evaluate the flexural properties of hybrid laminates successfully and agree with analytical solutions.
- Finally, it can be concluded that in hybrid composite system, Kevlar/glass hybrid laminate can withstand more load and improved flexural strength as compared to carbon/glass hybrid system for the same glass content.

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