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Characterization of the interlaminar shear strength of angle ply kevlar/glass hybrid composites

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ABSTRACT

In this paper experimental investigation has been carried out on kevlar/glass angle ply hybrid composites to characterize interlaminar shear strength. With the aim of determining the influence that the structure, a reinforcement type and a sort of resin exert upon the interlaminar strength. Hybrid composites are considered materials of great potential for engineering applications. One advantage of hybrid composite materials for the designer is that the properties of a composite can be controlled to a considerable extent by the choice of fibers and matrix and by adjusting the orientation of the fiber. The scope for this tailoring of the properties of the material is much greater, however, when different kinds of fiber orientations are incorporated in the same resin matrix. Three orientations viz 0°/90°, ±45°and 60°/30° were considered for studies. Mechanical properties such as interlaminar strength, interlaminar stiffness, & peak load of the hybrid composites were determined as per ASTM standards. Vacuum bagging technique was adopted for the fabrication of hybrid specimens. It was observed that orientation at 0°/90°showed significant increase in ILSS properties as compared to other orientation.

Introduction

Hybrid composites are manufactured by combining two or more fibers in a single matrix. Hybridization in order to use to tailor the material to exact needs under design [1]. Epoxy resin is used in this hybrid composite because it provides a unique balance of chemical and mechanical properties combined with extreme processing versatility. In all cases, thermoset resins may be tailored to some degree to satisfy particular requirements [2]. Epoxies are one type of thermosetting polymer that are more expensive and have better mechanical properties and resistant to moisture than the polyester and vinyl resin [3]. At present epoxy resins are widely used in various engineering applications, such as electrical industries, and commercial and military aircrafts industries. In order to improve their processing and product performances and to reduce cost, various fillers are introduced into the resins during processing [4].Hybrid laminated composite are prepared by stacking sheets of kevlar/carbon fibers to required orientation to form angle ply laminates. An individual structural glass fibre is both stiff in tensile and compression [5].Interlaminar shear strength (ILSS) of interply woven fabric hybrid composites under the influence of a fluctuating humid environment carried out by S. Mula, B. C. Rayetal [6].They found that the ILSS shows a gradual degradation over a period of time and also ILSS scales inversely with crosshead velocities. Investigated the possibility of using the static ILSS data obtained by testing simple unidirectional laminates to infer the properties of ILS couponby P. Feraboli, etal [7].They found from the detailed shear stress contour it was possible to discover the point of maximum stress in a region within one thickness away from the supporting roller for all three laminates .Experiment carried out on interlaminar shear behavior of typical polymer matrix composites under high strain rate shear loading by N.K. Naik etal [8]. It is observed that the interlaminar shear strength increases with increasing shear strain rate within the range of shear strain rate considered. The classical laminate theory and the higher-order shear deformation theory, are used to predict the interlaminar shear stresses in the cross-ply laminate by C.Y. Lee et al [9].they found that the approach using the higher-order shear deformation theory has improved accuracy for the analysis of thick symmetric laminate over the approach using the classical laminate theory. Investigation on Interlaminar shear strength (ILSS) of traditional glass fiber reinforced epoxy composites multi-walled carbon nanotube (MWNT)–epoxy carried by ZhihangFan et al[10].They found results show the introduction of MWNT into the composite increased the ILSS by up to 33%. The preferential orientation of the MWNTs in the thickness direction was found to contribute to the increase in the interlaminar shear properties. Experimental and finite element analysis of carbon epoxy and carbon epoxy carbon nanotube composites to estimate interlaminar shear strength by P. Rama Lakshmi et al [11]. They found that inferred experiment results are in good agreement with results generated by ANSYS. The superiority of the presence of carbon nanotube in the composite is proved from experimental and finite element technique from the estimated fracture parameters. An approximate method is developed to investigate the interlaminar stresses near the free edges of beam-type composite laminate structures subjected to out-of-plane shear/bending by Taehyoun Kim et al [12]. They found that interlaminar stresses under the shear/bending, particularly those for angle-ply laminates, may exhibit substantially different characteristics than under uniaxial loading or under pure bending. Analytical solution carried out to determine the interlaminar stresses of general cross-ply laminates with

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piezoelectric layers as actuators under transverse mechanical loads by M. Izadi etal [13]. They found numerical results show that this approach can generally predict the behavior of interlaminar stresses. Also, they clearly indicate the singular behavior of interlaminar normal and shear stresses in the boundary region near the edges of the laminate. interlaminar shear strength as well as shear stress values corresponding to the onset of the fibre/matrix-debonding were determined by Stephan Hinz etal [14].They found cross-ply lay-up within the laminate has been interlaminar shear loaded, damage and failure could only be found within the transverse plies. However, the present study focuses on the evaluation of interlaminar shear strength properties of kevlar/glass hybrid laminate.

Experimental Methods

Materials:

Woven fabric Kevlar fibers (K-29, High Strength), E-glass (FGP, RP-10) of density 360 GSM and epoxy adhesive (Bisphenol A type, Ciba-Geigy LY 556 araldite, hardener HY-951) were used to fabricate composite laminates.

Preparation of Specimens:

E-glass fibre grade 360GSM & diameter of glass fibre is 0.25 mm diameter is tailored with kevlar 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 ($0^0/90^0$), ($60^0/30^0$) & ($\pm$ 45^0) composites. For ($0^0/90^0$) glass fibre placed at 90^0 kevlar fibre at 0^0, for ($60^0/30^0$) glass fiber is placed at 60^0 and kevlar fibre at 30^0, & ($\pm$ 45^0) glass is placed in + 45^0& kevlar at -45^0. 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 ASTM D 2344 standard as shown in fig1.

ILSS Testing of Hybrid Laminates

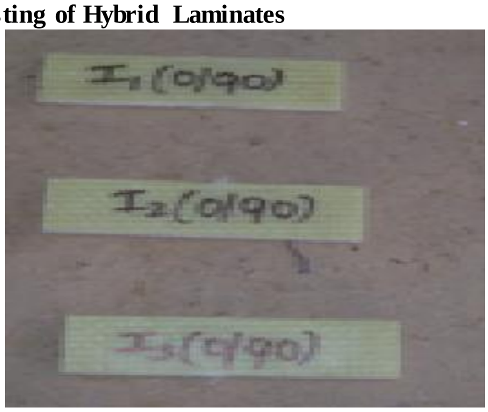

Fig 1 Kevlar /Glass ILSS specimens

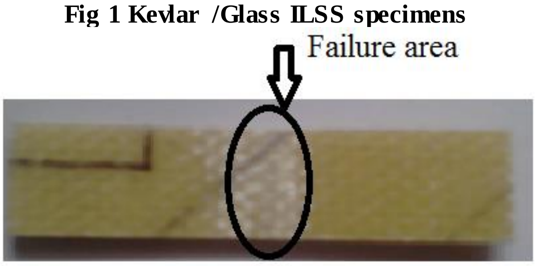

Fig. 2 Kevlar /Glass failure specimen

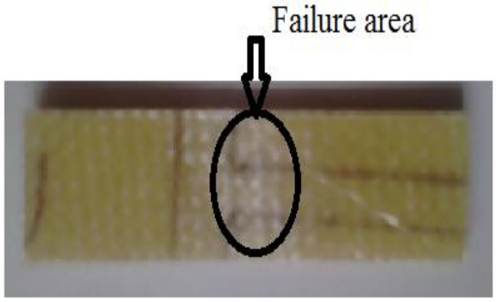

Fig. 3 Kevlar /Glass failure specimen

Fig – 4 ILSS testing of hybrid laminates

Interlaminar shear strength analysis was carried out at room temperature through three-point bend testing as specified in ASTM D 2344, using BIS Model Bi-10-101of capacity 15 KN universal testing machine as shown in Fig 5. The speed of the crosshead was 2 mm/min. Three composites specimens were tested for each sample interlaminar shear strength was calculated from

Eq. (1) $\tau = \dfrac{3P}{4bd}$ -------------------------- (1)

Where, $\tau =$ interlaminar shear strength(Mpa), P = Max load at a given point on the load deflection curve (N),b = width(Specimen) (mm), d =depth(specimen) (mm)

Eq. (2) specific strength = $\dfrac{\tau}{\rho}$ ------------- (2)

Where, τ = stiffness strength (Gpa/ (gm/mm^3), ρ = mass density of specimen (gm/mm^3)

Results & Discussions

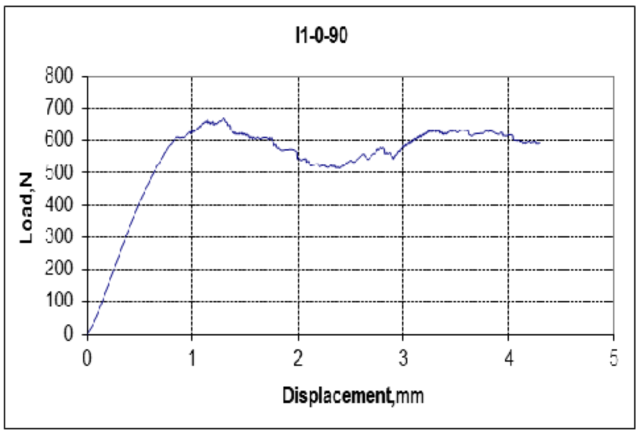

Fig – 5 kevlar/Glass Hybrid laminate (0°/90°)

Table – 1 KEVLAR/GLASSS HYBRID –0/90 ILSS Test result

Sl no	Load (N)	Avg Load (N)	Shear strength (Mpa)	Avg Shear strength (Mpa)	Shear stiffness (N/mm)	Avg Shear stiffness (N/mm)	Specific Strength ($Gpa/gm/mm^3$)	Avg Specific Strength ($Gpa/gm/mm^3$)
1	680		11.33	11.33	909.10		8.10	
2	670	680	11.17		1000	914.14	7.98	
3	690		11.50		833.33		8.21	8.10

Table – 2 KEVLAR /GLASSS HYBRID – ± 45 ILSS Test result

Sl no	Load (N)	Avg Load (N)	Shear strength (Mpa)	Avg Shear strength (Mpa)	Shear stiffness (N/mm)	Avg Shear stiffness (N/mm)	Specific Strength ($Gpa/gm/mm^3$)	Avg Specific Strength ($Gpa/gm/mm^3$)
1	416		6.93		350		4.95	
2	402		6.70		375		4.78	
3	400	406	6.67	6.77	353	359.3	4.76	4.83

Table – 3 KEVLAR /GLASSS HYBRID –60/30 ILSS Test result

Sl no	Load (N)	Avg Load (N)	Shear strength (Mpa)	Avg Shear strength (Mpa)	Shear stiffness (N/mm)	Avg Shear stiffness (N/mm)	Specific Strength ($Gpa/gm/mm^3$)	Avg Specific Strength ($Gpa/gm/mm^3$)
1	550		9.17		600		6.55	
2	540		9.0		666.67		6.43	
3	520	537	8.67	8.95	575	613.9	6.19	6.39

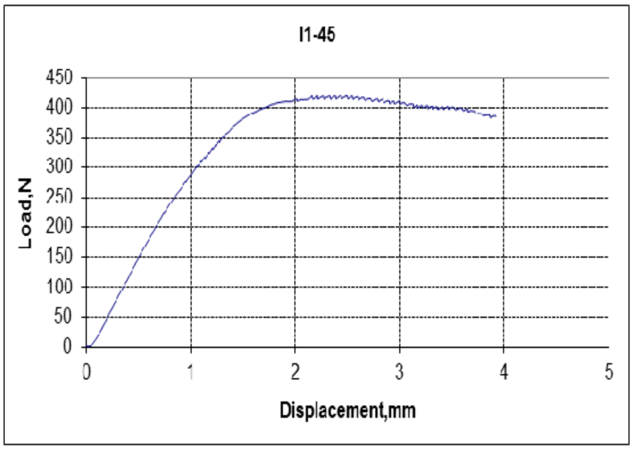

Fig –6 kevlar/Glass Hybrid laminate (± 45^0)

Fig 2 & Fig3 shows the failure of hybrid specimens, it is observed in Fig2 & Fig3 that white coloured line shows the failure area of specimen. Table 1, 2 & 3 indicates the results of interlaminar shear strength properties evaluated on kevlar/glass hybrid laminates for three different orientation i.e.0°/90°, ±45^0& 60°/30°. Table 1 indicates that 0°/90° orientation offer higher interlaminar strength, higher stiffness and Specific Strength as compared to ±45^0 & 60°/30°orientation composites. However, it has been reported that for kevlar/glass hybrid laminate with 0°/90° orientation possess higher shear delamination strength as compared to ±45^0 & 60°/30° orientation hybrid laminate.

Conclusions

Experiments were conducted on kevlar fibre/glass fiber/Epoxy resin hybrid angle ply laminates with different fibre orientation to characterize the ILSS properties. The following conclusions were drawn and recorded:

(a) The glass fibers fail quickly than the kevlar fibers. The five layers of glass plies at front opposed the applied load greater than the five layers of glass plies at back in woven kevlar/glass hybrid composites.

(b) Incorporation of woven kevlar/glass in extreme plies of composites enhances the improved mechanical properties of hybrid composites.

c) The mechanical properties of composite materials depend upon the structure of the material, and also depend on the volume fraction, interfaces between components.

d) A simple three point bend test was adequate to evaluate the ILSS properties of hybrid laminates successfully and agree with analytical solutions.

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