Morphological Study of the Flexural Behaviour of the Jute/Kevlar Reinforced Epoxy Hybrid Composite

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Abstract— Hybrid composites are one of the most prominent materials that are being extensively used and is gaining momentum due to factors like flexibility in design and higher strength to weight ratio. The new materials are on the anvil and are developing day by day. Natural fibre composite like jute has become more attractive due to its improvement in properties. Mixing of the jute with kevlar is finding its way for the new sort of research. The present study deals with the flexural strength of jute-kevlar composites which is fabricated by simple hand layup technique as per ASTM standards. The interfacial properties, internal cracks and internal structure of the fractured surfaces are evaluated using the Scanning Electron Microscope (SEM). The results indicate that the incorporation of kevlar to the jute has led to the improvement in bending property.

Keywords— **Jute, kevlar, epoxy, hybrid polymer composites, flexural property**

I. INTRODUCTION

Fiber Reinforced Polymer (FRP) is a composite material made of a polymer matrix reinforced with fibers. The most widely used synthetic fibers till date are glass, carbon, aramid and Kevlar. Over the recent years, FRP composites have become increasing popular for its structural applications in aerospace, marine, automobile and construction industries due to their higher mechanical performance. In the aerospace industry, applications are being from wall, floor panels to the fuselage [1, 2]. Now a days natural fibres such as jute reinforced composites are replacing the glass and carbon fibres due to their ease of availability and ease of cost [3]. The use of natural fibres has improved day by day due to the fact that the field of application is in use especially in automative industries. Silva et al [4] developed the natural fibre / castor oil polyurethane composites and tested for the fracture toughness which led to the best out of performance [4]. Cicala et al [5] have studied the properties of various hybrid glass/ natural fibre composites for the application in curved pipes. Most of the studies on natural fibres deal only with single reinforcement.

The addition of natural fibre to the kevlar fibre can make the composite hybrid by improving the properties. Panthapullakkal and sain [6] studied the mechanical properties of hemp/glass fibre polypropylene composite materials. They observed improvement by the use of hybrid composite material by increasing the flexural and impact properties. They also observed the addition of glass fibre into Hemp-PP composites resulted in improvement in thermal properties and the water resistance of the composites. The addition of natural fibre with GFRP improves the tensile, flexural and impact strength of the materials [7] and keeping the GFRP layers at the end possess very good mechanical strength [8]. AC Albuquerque et al [9] worked on the mechanical properties of uniaxially oriented jute roving reinforced polymer composites. It was found that the tensile and flexural strength, modulus and impact strength of longitudinal composites increased with the fibre content.

De Rosa et al. [10] concluded that using the basalt fiber at the top and bottom of the glass laminate improves the post-flexural strength of the hybrid composite. However, it finds difficult to arrive at the conclusion from one hybrid to the other, as there is no theoretical framework available to assess the various material parameters.

The flexure strength of the glass fibre reinforced polymer composite can be enhanced by incorporating it with E Glass epoxy laminates and making it hybrid polymer composite [11]. Very less research have been conducted in the field of kevlar and natural fibre reinforced composite materials [12]. The purpose of present study is to evaluate the utilization of kevlar to the jute epoxy composites and the effect of kevlar to the jute content on the flexural behavior of the composites will be investigated by means of morphological study.

II. EXPERIMENTAL

A. Materials

In present investigation, the jute and kevlar fibres are used for fabricating the composite specimen with epoxy as the matrix. The jute is obtained from Jute cottage, Indiranagara, Bengaluru. Kevlar is obtained from Hindoostan composites, Mumbai. Epoxy resin i.e. Diglycidyl ether of bisphenol is obtained from local source and the type used is Araldite LY556.

B. Natural fibre

In the last two decades, there has been increase in the use of natural fibres in terms of fibre extraction from sisal, jute, coir, hemp etc. for making new environmental friendly composites which is termed as green composites. Recent studies in natural fibre composites offer remarkable improvement in materials with enhanced support for global existence. These natural fibre possess high strength, thermal stability when they are recyclable, but the problems of using pure biodegradable polymers are their low strength and glass transition temperature [13]. The table shows the physical properties of jute fibres.

TABLE 1
PROPERTIES OF EPOXY

Description	Properties
Specific gravity	1.2
Tensile strength	35-130 Mpa
Poisson's ratio	0.37
Compressive strength	100-200 Mpa
Elongation	1-8.5%
Co-efficient of Thermal Expansion	$45\text{-}70*10^{-6}/^{0}C$
Water absorption	0.1-0.4%

C. Jute fibre

Jute usually takes three months, to grow to certain height of 12-15ft, during season. Then cut, bundled and kept immersed in water for "RETTING PROCESS", where the inner and outer stem, gets separated out and the outer plant will move apart, to form a fibre. Then the plant gets separated to remove the dust from the plant. The fibre is taken to jute mills after drying for getting converted to jute yarn and hessian. From the jute various lifestyle products are being produced and it is diversified into various forms, due to R&D support and also from government organizations [13].

D. Kevlar fibre

Kevlar fibre reinforced composite materials are increasingly popular over the years. Its application is considerably vast due to its superior mechanical properties like lighter weight, unique flexibility, corrosion resistant etc. compared to metallic materials. Kevlar fibre possess unique properties. In order to increase the stiffness, it can be viewed as nylon with extra benzene rings in the polymer chain. It is mainly popular for its applications in industrial and advanced technologies like ballistic armour, helicopter blades, pneumatic devices, sporting goods etc. Compared to other synthetic fibres, it possess significantly lesser fibre elongation and higher tensile strength and modulus [14].

TABLE 2
PROPERTIES OF KEVLAR FIBRE

Description	Properties
Density	1.45 g/cm^3
Filament diameter	12nm
Tensile strength	3176 MPa
Tensile modulus	135 GPa
Elongation	2.8 %
Tenacity	20-26 N
Sizing	Epoxy compatible

***E. Preparation of composite specimen*:**
In fabrication of composite, the bi-directional fibre fabric of kevlar and jute fibre are used into the epoxy resin LY556 by adding the hardener HY 951into it. In this method, before laying up, the mould was prepared with a release agent to avoid the adhering of the part to the mould. Reinforcing fibres was cut and laid in the mould as per the dimension. The required amount of resin is added to the fibres. A roller and brusher was used to impregnate the fibres with the resin.

In this study, the flexural property of jute and kevlar reinforced polymer hybrid composite will be investigated by machining the specimens by means of water jet cutter to the required dimension as per ASTM: D790 standard (sample dimension is 80 × 8 × 3 mm^3). The flexure test for the hybrid composite is obtained using tensometer. The speed of the cross head was 5mm/min. The specimens are loaded step by step until failure under flexural loading along the longitudinal axis. A continuous record of load and deflection is obtained by a digital data acquisition system. The flexural strength and modulus were calculated using the following equations:

$$\text{Flexural strength } \boldsymbol{\sigma}_f = (3PL) / (2bd^2),$$
$$\text{Flexural modulus, } E = L^3m/4bd^3$$

where, P = Load at a given point on the load deflection curve in Newton (Peak load)
L = support span in mm
b =width of the samples in mm
d = thickness of the samples in mm
m= slope of the tangent

TABLE 3
LAMINATE DESIGNATIONS

Laminates	Compositions
L1	J+J+J+J
L2	J+K+J+J+J
L3	J+K+J+K+J+K+J
L4	J+K+K+J+K+J+K+K+J

TESTING AND EVALUATION

The test was conducted on the above four samples as shown in the table 4. The data measured from the mechanical testing device was used to calculate the flexural strength and modulus of the laminates. The table 4 shows the flexural properties that were determined from each laminate.

TABLE 4
FLEXURAL PROPERTIES OF THE LAMINATES

Laminates	Flexural strength (N/mm^2)	Flexural modulus (GPa)
L1	68.17	5670.44
L2	96.29	5989.438
L3	178.44	9352.557
L4	274.212	10484.32

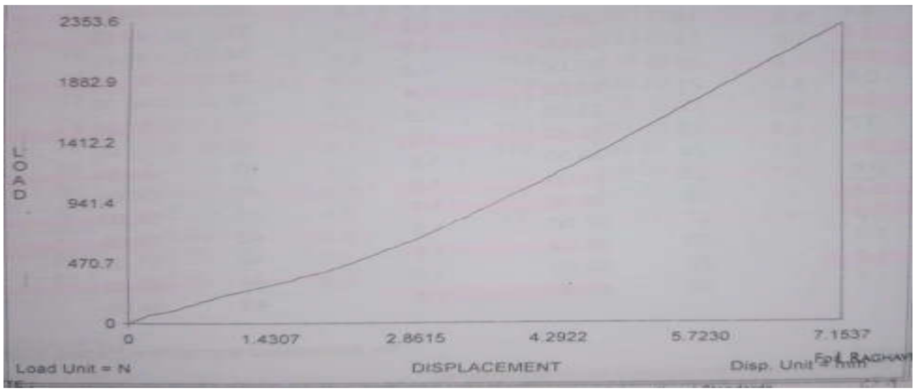

Fig I: Sample graph obtained from tensometer for load vs displacement (Flexural test)

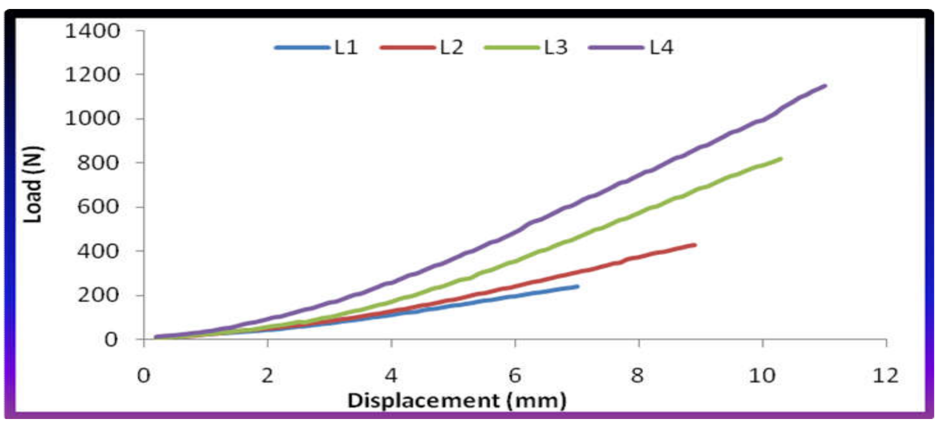

Fig II: Load vs Displacement

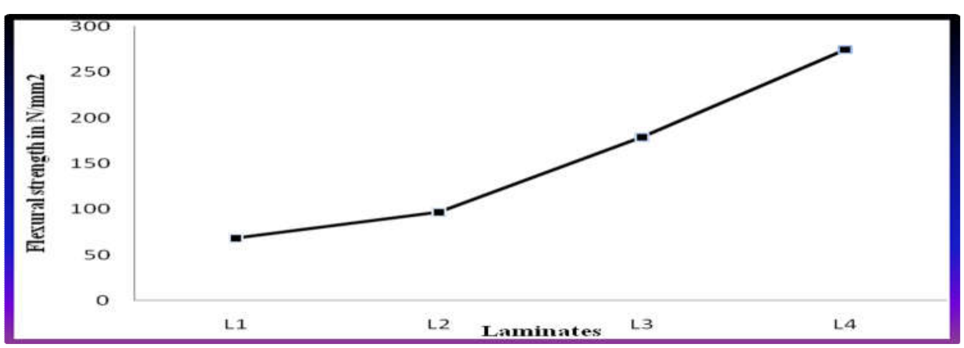

Fig III: Flexural strength vs laminates

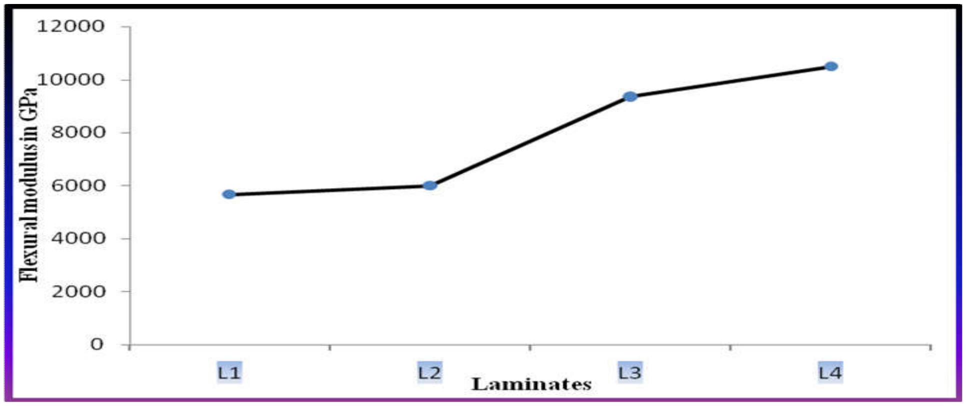

Fig IV: Flexural modulus vs laminates

III. SCANNING ELECTRON MICROSCOPY (SEM) ANALYSIS

The surface morphology of the composite material used for the investigation is studied through Scanning electron microscopy. The cross sectional view of the flexural specimen consisting of jute, kevlar epoxy composite before and after failure is presented in fig 5a and 5b. Scanning electron microscopy (SEM) images are taken to observe the interfacial properties, internal cracks and internal structure of the fractured surfaces of the specimen. Initially the specimens are coated with conducting material before observing the surfaces in SEM. It is clearly evident that the laminated composite exhibited smooth fracture surface where resin separates from the failure surface that shows the weak bonding between jute, kevlar fibre and epoxy matrix. The issue can increase the toughness and strength of fibre reinforced resin. However the brittle nature of the resin can reduce the mobility and increase the modulus and strength.

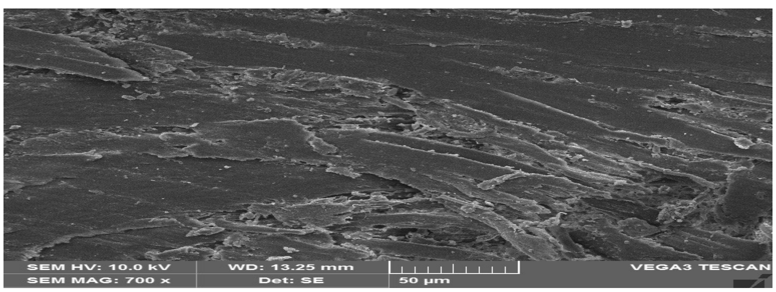

Fig V: (a): SEM image of jute- kevlar composite (c/s view)

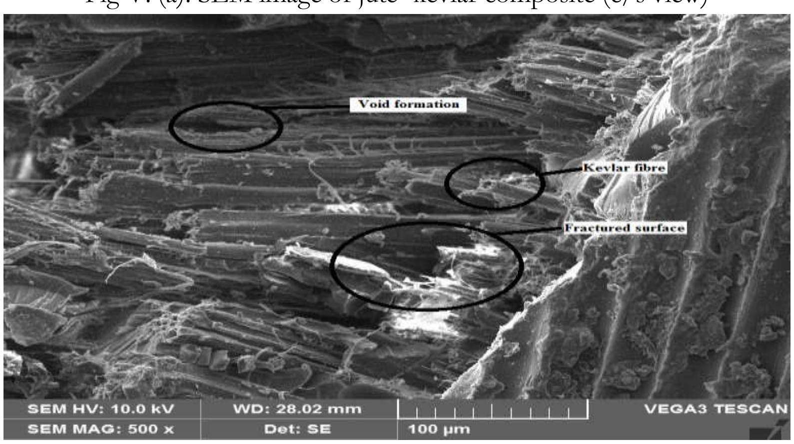

Fig V: (b): SEM image of jute- kevlar composite of L5 laminate

IV. RESULTS AND DISCUSSION

The composite specimens L1, L2, L3, L4 are tested in tensometer and properties obtained are shown in **Table 4**. The sample graph of load vs displacement obtained from tensometer after flexure test is shown the **fig 1**. The load vs displacement graph is shown in **fig 2.** The variation in flexure strength and flexure modulus of composite with increase in fibre content is shown in **fig 3 and fig 4** respectively. It is very much evident that with the increase in kevlar content in the jute epoxy matrix, the load is increasing and as such the elongation gets enhanced which shows the improvement in flexure strength. It is attributed to the fact that there is proper transmission and distribution of the applied stress by the epoxy resin resulting in higher strength. Similar obsevations have been made by Vivek Mishra [15] in case of Bi-Directional jute fibre epoxy composites. It can be seen that in the laminate L1 which consists of pure jute layers shows lower flexure strength as the layers of kevlar is not been placed. The kevlar fibre inclusion enhances the load bearing capacity to the jute epoxy composite and the ability to withstand the bending strength. The Thus from the results, it can be asserted that the laminate L4 is performing well as compared to the other type of fibres used.

V. CONCLUSION

This work proves successful fabrication of the bidirectional jute kevlar reinforced epoxy hybrid composite that is obtained by simple hand layup technique for different proportions. It is proved that when natural fibre (jute) and synthetic fibre (kevlar) are incorporated to the resin, the flexural strength is greatly influenced by the different fibre proportions. The proper transmission and distribution of the applied stress by the epoxy resin results in higher strength of the hybrid composite. The flexural properties of the bidirectional jute kevlar reinforced epoxy hybrid composite increases with increase in the layer of kevlar addition, this is due to the strong bonding of the matrix with the reinforcement and the load carried by them. In this study it is observed that the thickness of the composite enhances the tensile strength due the addition of kevlar which is required for the dynamic loading applications.

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