Comparative Experimental and FEA Fracture Study of Hybrid Jute-Glass and Ordinary Glass Fibre Composite

Akhil Sugathan[1], Aravind R[2]

[1] PG Scholar, Dept. of mechanical Engineering, Sri Vellappaly Natesan College of Engineering, Pallickal P O, Mavelikara, Kerala, India
[2] Asst. Professor, Department of mechanical Engineering, Sri Vellappaly Natesan College of Engineering, Pallickal P O, Mavelikara, Kerala, India

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Abstract - *Composite is a structural material that consists of two or more combined constituents that are combined at a macroscopic level and not soluble in each other. The aim of the present work was to investigate the hybridization of glass fiber (synthetic) with natural fiber (jute) for the application in the aerospace and naval industry. Here two different composite materials using glass-jute as reinforcement and glass as reinforcement are prepared with epoxy as the matrix material .the Hybrid Composites were prepared by using hand lay-up method, flexure or bending test and mode-1 fracture toughness testing were carried out by cutting the material into ASTM standards in the computerized UTM and the result will be recorded. A reduction scheme based on beam theory and specimen compliance is used in order to overcome the difficulty inherent to crack monitoring during propagation. A cohesive surface model is used for fracture stimulation in ABAQUS. Then comparison of experimental and numerical result is done in the study. After that a comparison was done between jute-glass composite and glass composite. From these studies we can see that the jute-glass composite incorporate with the glass composite results. Besides that jute-glass hybrid composite is economical and environmental friendly.*

***Key Words*: Jute fire, Glass fibre, Hybrid composite, Jute-Glass composite, Mode I fracture.**

1. INTRODUCTION

A composite material can be defined as a structural material which consists of two or more dissimilar materials that are combined at a macroscopic level to ensure a better result than those of the individual components used alone [1]. The composite material comprises of reinforcing phase and matrix phase. The reinforcing phase materials may be in the form of fibres, particles or flakes and they provide strength and stiffness to the composite material. The Matrix phase materials are always continuous and it transfer the stresses from the fibre to fibre and protect them from mechanical and/or environmental damage. Fibres in polymer composites can be either synthetic (man-made) fibres or natural fibres the main advantages of using natural fibre as reinforcement are: environmentally friendly, biodegradable, abundantly available, low energy conception, non- abrasive and cheap. But on the other side it has low moisture resistance and poor fibre-matrix adhesion. A hybrid composite comprising both natural and synthetic fibre will solve these problems by taking the advantages of both natural as well as synthetic fibre.

The comparison between jute and glass fibre is shown in Table -1.

Table -1: Comparison between jute and glass fiber [2]

	Jute fibre	Glass fibre
Density	Low	Twice that of natural fibre
Cost	Low	Low, but higher than natural fibre
Renewability	Yes	No
Recyclability	Yes	No
Energy conception	Low	High
Distribution	Wide	Wide
Abrasion to machines	No	Yes
Health risk	No	Yes
Disposal	Bio degradable	Non biodegradable

1.1 Fracture

The three basic modes of separation of the crack surfaces (modes of fracture) are shown in Fig -2, Fig -3 and Fig- 4.

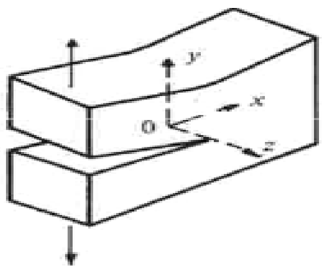

Fig -1: Mode I fracture

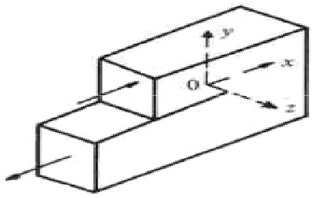

Fig -2: Mode II fracture

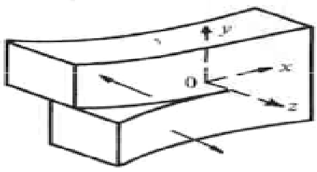

Fig -3: Mode III fracture

In mode I fracture (tensile opening mode) the crack faces separate in a direction normal to the plane of the crack and also the displacements are asymmetric with respect to the x-z and y-z planes. In mode II fracture (in-plane sliding mode) the crack faces are mutually sheared in a direction normal to the crack front. The displacements are symmetric with respect to the x-y plane and anti-symmetric with respect to the x-z plane. In mode III fracture (tearing or anti-plane shear mode) the crack faces are sheared parallel to the crack front. The displacements are asymmetric with respect to the x-y and x-z planes.

In this study the jute- glass hybrid composite is fabricated and then evaluated its effectiveness by studying the mechanical behavior and mode I fracture characteristics.

1.2 literature Review

Dalbehera and Acharya (2014) did a study by stacking natural fibre and synthetic fibre in a suitable matrix medium to enhance the properties of a hybrid composite. Here jute (natural), glass fibre (synthetic) and epoxy resins are taken for hybridization and found that the tensile strength, flexural strength and inter-laminar shear strength etc enhanced to a great extent. The results indicated that the properties of jute E-glass epoxy and its composites considerably improved by incorporating glass fibre as extreme glass piles ie, the untreated woven jute fibres are placed at the centre of the composite (GJJG).

Sanjay *et.al* (2014) successfully fabricated jute-glass fibre reinforced polyester composites by work hand lay-up process and then specimens are prepared and tested as per ASTM standards. The composites are prepared using jute-glass fibers of 50/50, 40/60 and 30/70. After testing they revealed that the tensile and impact strength of 50% jute-50% glass found to be better than others and 40% jute and 60% glass gives better flexural strength than others.

Suresh *et.al* (2015) carried out the dynamic analysis of an automobile car frontal component like bumper beam by using jute-epoxy-glass hybrid composite by finite element approach; this work evaluates the safety of occupant and the mechanical behavior of the composite as bumper beam. From the analysis they found that the resulting bumper beam reduces the weight from 6.6 kgs of steel to 2.9 kgs of jute glass epoxy composite. The weight reduction leads to fuel efficiency of the car and a cost saving of upto 70%.

A review on mechanical properties of hybrid composite was done by Madhusudhan and Keerthi (2016) and they concluded that hybrid composite of jute /glass fibre have better properties compared to that of individual fibre composite, the hybridization of natural fibre with glass fibre decreases the water absorption and increases the mechanical properties of the composites and finally epoxy resins are preferred first among the polyester resin and vinyl ester resin.

Velu and Srinivasan (2013) investigated the tensile, bending and impact test on jute-glass-epoxy composite specimen, with two layer of jute and two layer of woven glass fibre (as reinforcement) in epoxy matrix. The Jute glass epoxy hybrid composite is successfully developed and found that the tensile, bending and impact strength of composite Increases with increase in fibre weight fraction in the composite compared to pure resin.

Wambua *et.al* (2003) investigated the mechanical properties of natural fibres such as sisal, hemp, coir, kenaf and jute reinforced polypropylene composite. They found that the tensile strength and modulus of the composite increases with increasing fibre volume fraction.

2. METHODOLOGY

Composites are made up of individual materials referred to as constituent materials. There are two main categories of constituent materials: matrix and reinforcement. In the present study, composite are manufactured using glass fibre (bidirectional, woven material) and epoxy resin. The method employed for manufacturing is general hand lay-up procedure.

2.1 Hand Layup process

Resin is mixed with hardner with appropriate ratio. After preparing the mixture, it is applied to the platform. Fibre glass mat is laid over the mixture. Then more resin is added on the mats using a roller or brush. Air entrapped between the resin and the fibre mats are removed by repeated rolling. Additional resin is applied to the layers of mats and the process continued until the required thickness of the specimen is obtained. Rollers are applied after each layers to remove the trapped air between resin and glass fibres. Though it is advantageous to use vacuum bagging to get better specimens, in the present study, only hand rolling is done to remove air.

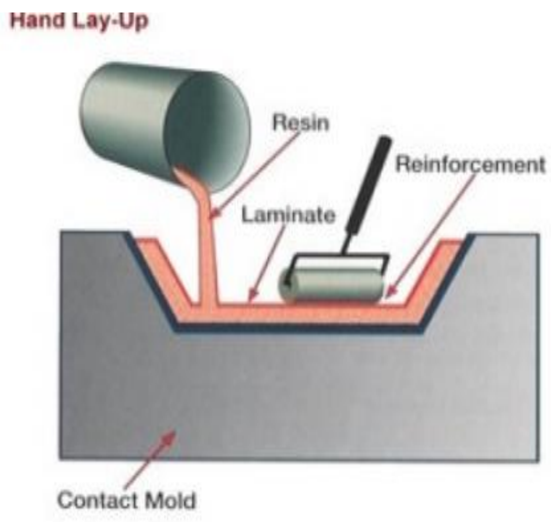

Fig -4: Hand Lay Up Process

2.2 Experimental Analysis

Tensile test

The tensile test is conducted on the prepared tensile test specimen in order to determine the elastic properties of that specimen. Test is conducted on KALPAK (100 kN capacity) UTM using 25 mm extensometer.

Fig -5: Prepared specimen for tensile test

In plane shear test

In plane shear test is conducted to determine the shear modulus of the hybrid specimen.

Flexural test

Flexural test of jute/glass epoxy fibre is conducted on UTM as per the standard ASTM D 7264M-15. Size of the specimen used is 75x25x30mm and an effective span of 60mm.

Fracture test

Mode-I fracture toughness testing is carried using DCB specimens on Universal Testing Machine (UTM) under displacement control mode with a travel rate of 1 mm/min.

Fig -6: Specimen for mode I fracture toughness test

2.3 Finite Element Fracture Analysis

Numerical fracture simulation is done in the finite element code ABAQUS. Two-dimensional finite element analyses (2D-FEAs) were conducted, using cohesive surface method. The numerical analysis include part modelling of DCB with interface cohesive surface, applying cohesive surface interaction and boundary condition, element selection and meshing, solution procedure and post processing.

3. RESULTS AND DISCUSSION

3.1 Experimental Fracture Analysis of Jute- Glass Composite

From the experiment the displacement is measured at the loading point and the crack propagation is analyzed. Five specimens are tested and the mean load displacement curve from the experimental analysis is shown in the Fig- 7. The peak load obtained is 27 N and corresponding displacement is 11.33 mm, the mode1 fracture energy, G_{1c} = 0.04N/mm.

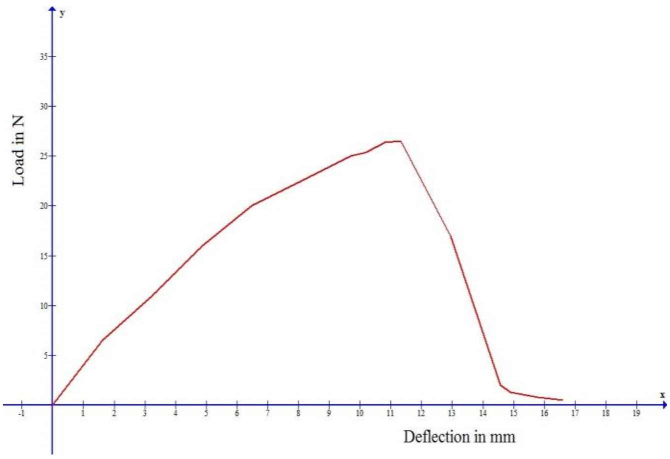

Fig -7: The P-δ curve of glass jute hybrid composite

3.2 FEA Result of Jute- Glass Composite from Cohesive Surface Method in ABAQUS

The vertical reaction at a point 'P' has been plotted against the vertical displacement 'u' of the same point after the analysis. The variation of the load with displacement of the point for the ordinary DCB specimen is shown in the Fig -8.

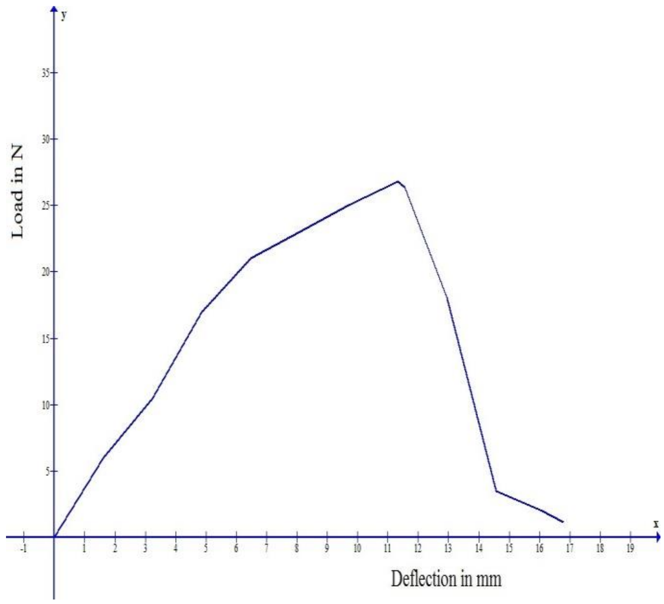

Fig- 8: The p-δ curve of glass jute hybrid composite by using ABAQUS

From Fig- 7 and Fig- 8 we can see that the variation in load deflection curve is negligible.

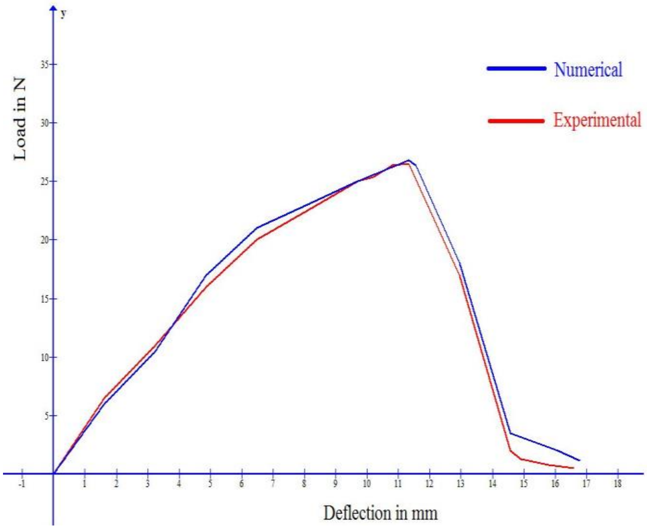

Fig-9: Comparison of numerical and experimental results

3.3 Experimental Fracture Analysis of Glass Composite

From the experimental analysis, the displacement is measured at the loading point and the crack propagation is analyzed. Five specimens are tested and the mean load displacement curve from the experimental analysis is shown in the Fig-10. The peak load obtained is 32 N and corresponding displacement is 13.42 mm, the mode1 fracture energy, G_{1c} = 0.05 N/mm.

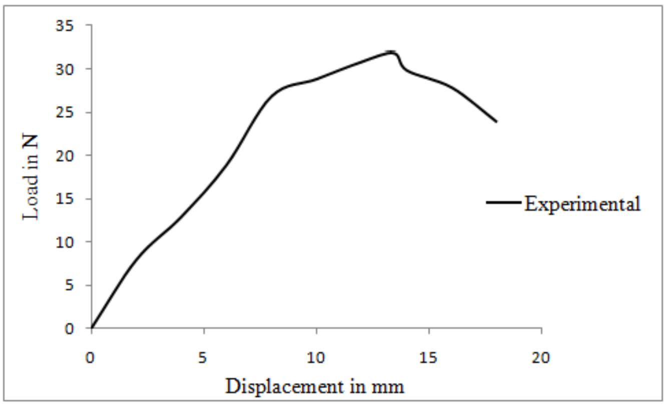

Fig-10: The P-δ curve of glass composite

3.4 FEA Results of Glass Composite from Cohesive Surface Method in ABAQUS

The vertical reaction at a point 'P' has been plotted against the vertical displacement 'u' of the same point after the analysis. The variation of the load with displacement of the point for the ordinary DCB specimen is shown in the Fig-11.

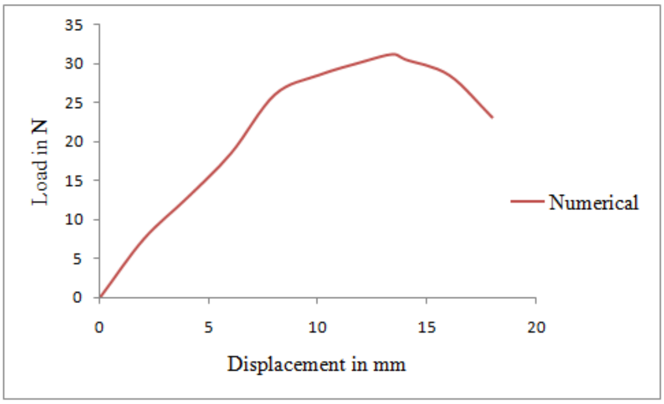

Fig-11: The p-δ curve of composite by using ABAQUS

3.5 Comparison between Jute-Glass Composite and Glass Composite

The results from mode I fracture analysis indicate that the energy release rate for both jute-glass and glass composites are almost same. In cost and ecological point of view we can say that jute-glass composite is effective than glass fibre composite.

4. CONCLUSIONS

The fracture study of jute glass hybrid composite is done experimentally and numerically. Then the results were compared to the glass composite. The following conclusions are drawn from the present study.

1. The jute-glass hybrid composite is prepared using hand lay-up method.
2. The mode I fracture toughness of jute glass hybrid composite can be easily calculated experimentally without monitoring crack growth during propagation.
3. The two dimensional cohesive surface method in ABAQUS is used for fracture mechanics study of jute glass hybrid composite is well matches with the experimental results.
4. Comparison done with glass fibre composites shows that the results closely matches each other.
5. The mode 1 energy release rate obtained for jute-glass composite is 0.04 N/mm where as the mode 1 Energy release rate for glass fibre is 0.05 N/mm.

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