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PREPARATION OF HYBRID LAMINATES OF JUTE & FIBERGLASS AND COMPARISON OF MECHANICAL CHARACTERIZATION WITH FEA

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ABSTRACT

In recent days, the use of Natural Fiber Reinforced Plastic Composites (NFRPC) has been drastically increased as they are eco-friendly, economical, and used for different applications.

This article describes the preparation of jute and fiber glass hybrid composite and fiber analysis of mechanical characterization with the help of finite element analysis. The software being used is ABAQUS. It is an explicit nonlinear finite element software.

The preparation involves jute and fiber glass fabrication with four layers stack, by changing the number and position.

Results are recorded and evaluated for mechanical properties like tensile strength, flexural strength, impact testing with finite element analysis.

Keywords: Composite, Jute, Fiber glass, epoxy, Mechanical properties, FEA, ABAQUS.

1) Introduction

As we know, in the present trend the conventional materials are getting replaced with many new materials among them composites play an important role.

A composite is fabricated by combining two or more different materials. Composite has different unique properties which are not obtained in a single constituent material.

REINFORCEMENT+MATRIX COOMPONENT = COMPOSITE

Composites have the following properties.

- Light weight
- Better strength and stiffness
- Flexibility in design and processing
- Economical

- Excellent functional characteristics
- Corrosion Resistance
- Good electrical insulator

Application of composite materials include aerospace, transportation, automobile and construction industries.

Composites have been in use since ancient times where bricks are made out of chopped straw and mud.

1.1 Classification of Composites

Based on Matrix constituent

a) Metal Matrix Composites
b) Ceramic Matrix Composites
c) Polymer Matrix Composite
d) Carbon Matrix Composites

Based on Reinforcement

a) Fiber reinforcement Composites
b) Laminar Composites
c) Particulate Composites

2) Methodology

2.1 Materials Selection

2.1.1 Jute fiber

Jute is processed from stem and outer bark of jute plant. Through retting process, jute fiber is processed by dipping in water flow.

Fig 2.1 Jute fiber

2.1.2 Glass fiber

Glass fiber is reinforced plastic made from glass containing silica or silicate. This is available in the form of sheets or fabrics (strand mat). Due to its low cost and low brittleness and high stiffness, its applications includes Aircrafts, shipping, automobile, storage tanks, swimming pools, bath tubs etc.

Fig 2.2 Glass fiber

2.1.3 Epoxy Resin

Resin is a material used for fabrication of composites. The resin has following properties.

a) Better adhesiveness
b) Toughness
c) Better curing
d) Processing flexibility
e) Less shrinkage

"Araldite LY556" is used in this experiment.

2.1.4 Hardener:

It's a curing agent which gets mixed with epoxy resin. "HY951 is used in this experiment.

2.2 Manufacturing of Composite Material

Manufacturing process involves following steps.

2.2.1 Mould Preparation

With the combination of plywood sheet and bending sticks, a wooden mould is prepared of size ‘240 x 200 x 4 mm. Mould release agent is applied to the mould for easy removal of laminates.

Fig 2.3 Wooden mould

2.2.1 Reinforcement preparation

The jute and fiber glass is sheared as same as mould size (240 x 200 x 4 mm)

2.2.2 Matrix and Hardener blending

Epoxy resin and hardener is mixed for 10 to 15 minutes with weight ratio of 10:1.

2.2.3 Laminate preparation

Blended matrix will be applied layer by layer for four stacking sequences i.e., (JJJJ, JGGJ, GJJG & GGGG) with 6 samples each for necessary experiments.

Laminate stacking sequence

Symbol	Stacking sequence	Wt.% of Fibers		Total Fiber		Thickness (mm)
		Jute	Glass	Weight fraction (%)	Volume fraction (%)	
S1	JJJJ	100	00	60.69	54.40	5.0
S2	JGGJ	50	50	62.73	49.78	4.5
S3	GJJG	50	50	63.79	50.91	4.4
S4	GGGG	50	50	57.96	44.80	5.0
J-Jute ply, G-Glass ply.						

2.2.4 Curing of composite

After pouring is completed, the mould shall be closed and pressure will be applied from top for proper bonding of composite, will be cured for 72 hours at room temperature. Care should be taken to evade any air bubbles while pouring of matrix material.

Once the laminate is cured, its dismantled from the mould and cut to required size after trimming/finishing operation for testing purpose.

Fig 2.4 Finished composite

2.3 Testing of finished composite

2.3.1 Tensile Testing

This test is carried out on ‘Universal Testing Machine’ with dog - bone specimen as per “ASTMD 3039 – 76”, with 10 m/min cross head speed. All the samples are tested and average is value is considered for analysis.

2.3.2 Flexural Testing

UTM 201 machine is used for flexural testing as per “ASTMD 2344 – 84”, with test specimen of 150 mm length and 20 mm width, under 3-point loading system with span to thickness ratio of 16:1.

2.3.3 Impact Testing

This test is conducted to analyze the impact strength of composite as per “ASTMD – 256 M”. The charpy test specimen is prepared with 63.5 mm length, 12.7 thickness and 10 mm width. A notch is cut with an including angle of 45 degrees to obtain crack/fracture on “Plastic Impact Testing Machine”. Impact strength is calculated from the principle of energy absorbed by the laminate.

3) Finite Element Analysis.

Finite element method is used to predict how the product behaves/withstands at different stresses, vibrations, heat, fluid flow and impact strength. This method uses mathematical models consists of separate elements connected at nodes. Displacements at each node is calculated and relevant forces are applied to arrive the analysis results.

Current experiment is carried out with “ABAQUS” a simulation software to analyze the stress and displacement behavior under impact loading conditions with a projectile.

Various steps of FEA are as follows.

3.1 Elements selection and formulation

In Abaqus, there are various elements are available for different geographic analysis. An element is characterized by certain characteristics such as, family, number of nodes, degrees of freedom, formulation and integration.

In the present work, shell elements of triangular and quadrilateral linear interpolation are considered. Large – strain shell elements are widely used for different applications. The naming convention in Abaqus shell description is “S4R”, where ‘S’ stands for shell, 4 nodes, ‘R’ stands for reduced integration.

Formulation involves rules pertaining to fiber cracking, matrix cracking and compressive failure.

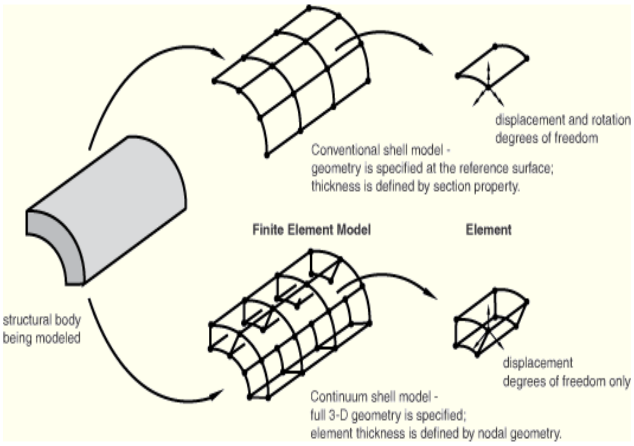


Fig 3.1 Structure of shell elements

3.2 Modeling

A solid square laminate cross-section of 200mmx200mm and 4mm thickness plate is modeled with thickness of 0.2mm of each laminates for the impact simulation. The laminates are arranged in three different orientations. The model of composite plate is shown on below

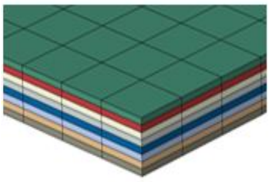


Fig 4.3 composite plate with all layers

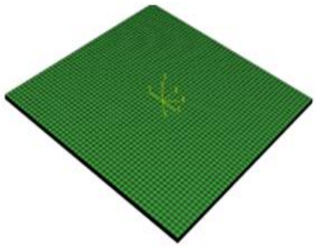


Fig 4.2 Composite plate with required dimensions

For this simulation the projectile sphere of 5 mm diameter is created for making impact on to composite plate and placed at a negligible distance from the composite plate.

3.3 Meshing of models

This step involves the change of mesh structure from finer to coarser in Abaqus/CAE. The element size 4 and element type C3D8R (An 8-node linear brick, reduced integration) is assigned for composite plate. The element size 0.5 and element type C3D4 (A 4-node linear tetrahedron) is assigned for projectile.

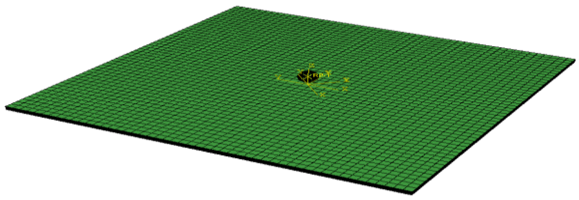


Fig 3.2 Meshed models of plate and projectile

3.4 Boundary and loading conditions

The composite plate is fully constrained on the composite edge faces and the boundary condition are applied as shown in figure.

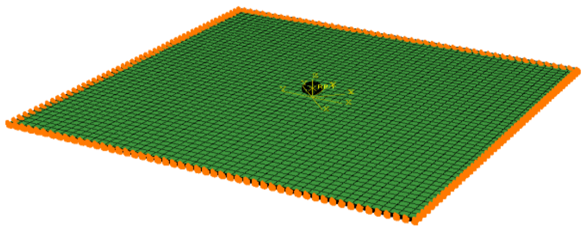


Fig 3.3 Model with boundary conditions

The projectile is given an initial velocity of 100m/s and acceleration of gravity 9.81 m/s^2 is applied by defining array parameters for time and acceleration values in the solution.

4) Results and Discussions

This section presents the results of mechanical characterization of hybrid laminate (Jute & Fiber glass). Analysis is carried out for tensile and flexural strength for different stacking sequences.

These simulations are executed for velocity of impactor with 100m/s a period of 0.3. The simulation values are obtained from Abaqus viewer.

4.1 Mechanical Properties

4.1.1 Tensile Strength and Modulus

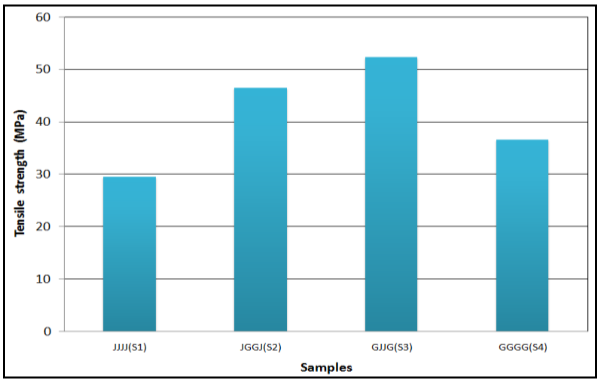
Its noticed that laminate ‘S3’ has highest tensile strength of 52.35 MPa and modulus of 3.236 GPa and ‘S1’ has lowest of 29.52 MPa and 1.746 GPa respectively.

The reason for ‘S3’ higher values could be glass fiber is stronger and stiffer than Jute fiber and position of glass plies at both ends of laminate.

Fig 5.1 Before Tensile Testing

Fig 5.2 After Tensile Testing

Stacking Sequence	Tensile strength (MPa)	Tensile Modulus (GPa)
S1	29.52	1.746
S2	46.49	2.727
S3	52.35	3.236
S4	36.53	2.399



4.1.2 Flexural strength and modulus

As shown in below table, the test results for 'S3' laminate is recorded higher flexural strength and modulas whereas 'S2' showed lower results.

Fig 5.5 Before Flexural Test

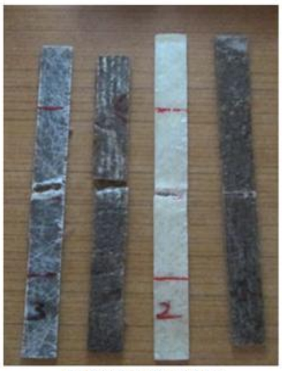
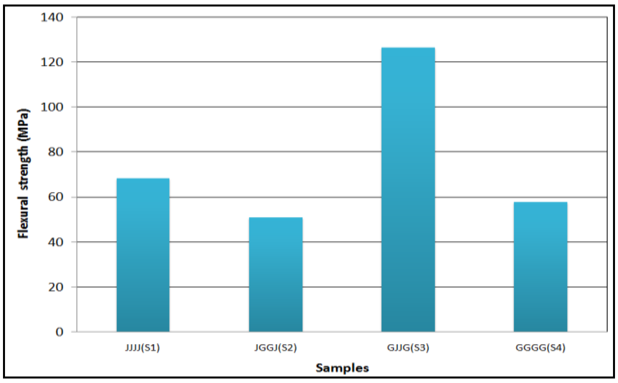


Fig 5.6 After Flexural Test

Stacking Sequence	Flexural strength (MPa)	Flexural Modulus (GPa)
S1	69.2	5.8
S2	50.8	4.8
S3	126.4	9.8
S4	58.7	5.2



4.1.3 Impact Testing

With the help of finite element analysis, laminates with different stacking sequence are applied for velocity of impact 100 m/s for a period of 0.3 sec. The results from Abaqus viewer are shown below.

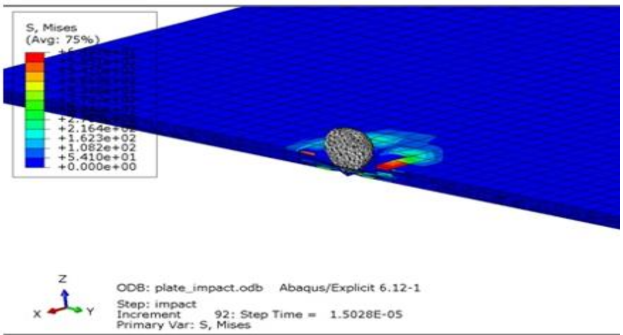
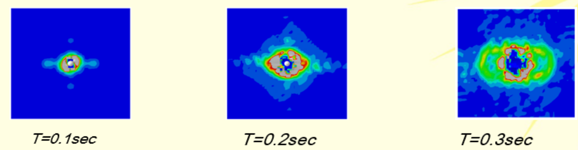


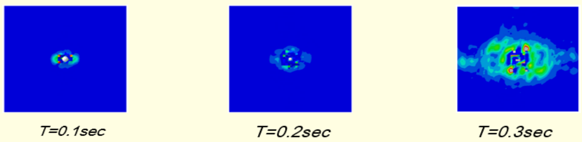
Fig 4.1 Fiber breaking at impact location

S1 (Jute-Jute-Jute-Jute Ply Sequence)

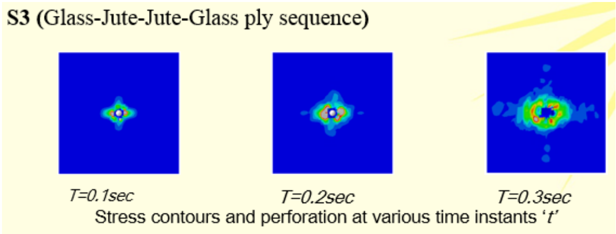


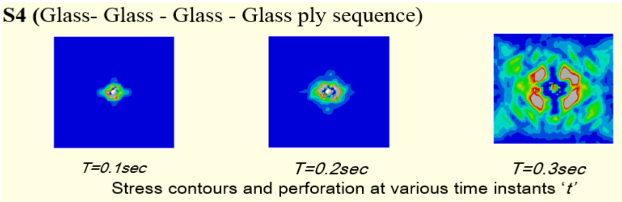
Stress contours and perforation at various time instants '*t*'

S2 *(* Jute-Glass-Glass-Jute ply sequence)



Stress contours and perforation at various time instants '*t*'





The graph of variation of time Vs velocity is shown in below fig from this graph we notice that the GJJG of laminate sequence show the better performance to withstand the impact as it reduces the max velocity of projectile compare to remaining ply laminate sequences.

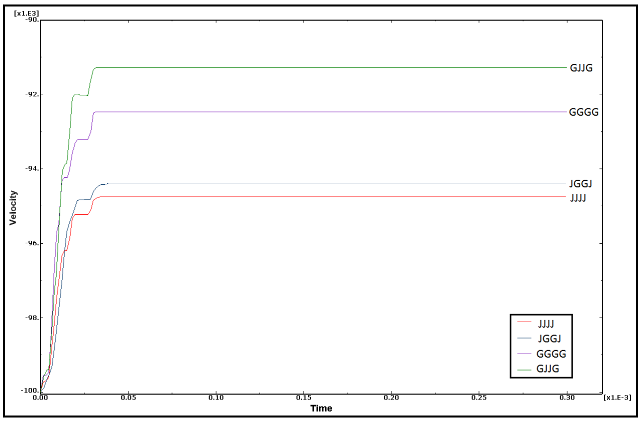


Fig 4.2 Ball velocities during the perforation from 100 m/s ball impact on the plates

5) Conclusions

The following conclusions are arrived through this experimental study of Mechanical characterization & Finite Element Analysis of hybrid laminates.

- Laminates are manufactured in 4 different stacking sequences like JJJJ, JGGJ, GJJG and GGGG. (J stands for Jute & G for glass fiber)
- Mechanical characterization of the developed hybrid composite was performed. The samples were prepared as per the ASTM standards and performed Tensile, Flexural & Impact tests were performed.
- The stacking sequence S3 has recorded highest tensile strength 52.35MPa and highest. tensile modulus 3.236GPa, whereas S1 has lowest values 29.52 MPa and 1.746 GPa respectively.
- It is also noticed that laminate S3 has reported highest values "flexural strength of 126.4MPa and highest flexural modulus of 9.8GPa" and S2 exhibits lowest "flexural strength of 50.8MPa and modulus of 4.8GPa".
- Finally, the stacking sequences were analyzed using the finite element technique and the results were discussed. According to Maximum stress theory and displacement stress distribution the four stacking sequences were analyzed using finite element technique and noticed that the sequence S3(GJJG) shows the optimal results.

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