Investigation on Mechanical Properties of Graphene Reinforced Jute Fibre Reinforced Polymer Composites

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Abstract. In this study, the impact of adding Graphene Nano Platelets on the mechanical properties of Jute Fiber reinforced Polymer (JFRP) composites has been investigated. JFRP composite specimens were fabricated with varying number of layers (3 Layers, 4 Layers, and 5 Layers) and different orientations (30 degree, 45 degree, 60 degree) reinforced with 2% weight graphene nano platelet. Ultrasonicator is used for dispersion of graphene nano platelets into the epoxy matrix. Mechanical Tests namely Tensile test, flexural test and impact test is carried out to study the behavior of JFRP with different layers and orientations. The results proved that the use of 2%weight of Graphene Nano platelets led an enhancement in fatigue strength and impact strength. Also it is found that 3 layered with 30 degree orientation composite specimens had better mechanical properties compared to 4 layered and 5 layered composite specimens.

Keywords : JFRP, Graphene, Layer, Orientation, Mechanical Properties

1.Introduction

Jute Fiber is a natural fiber known for its versatility and also a 100% bio-degradable. Jute fibers are environmental friendly and recyclable one. Jute also known as golden and vegetable fiber that is easily available at affordable cost. Due to it, researchers are interested in replacing conventional fibers with jute natural fibers. The properties of jute fibers that attract the industrialists are as follows. 1. Good insulating properties, 2. Low thermal conductivity, 3. Moisture regains.
These fibers are used in manufacturing mail bags, camp beds, Tarpaulin, motor linings, wrappings. A technique of dispersing graphene in the matrix improves thermal and mechanical properties. The major drawback of jute fibers is its brittleness. To enhance the property of ductility, graphene nano platelets are dispersed in the matrix. The natural jute and graphene matrix polymer composites can be used in industries due to
its light weight, superior mechanical property and stability of thermal property. Graphene is found to improve the machinability of jute fiber epoxy composite and

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also reduces delamination of composites.Graphene nano platelets are scattered by nano level technique for uniform dispersion in jute fibers and its exceptional properties enhance the electrical properties of composites.

The testing is done by increasing the thickness in varying number of layers and by varying orientations.

The mechanical testing is carried by varying weight percentages of multi walled carbon nano tubes and declared that bidirectional woven glass fiber composite showed better mechanical results. Moreover when MWCNTs are dispersed more than 4% weight, agglomeration in composites occurred and hence the properties deteriorates. The properties of glass fiber reinforced with graphene are also studied. GFRP is investigated by varying graphene weight percentage and results proved that composites exhibit better mechanical properties when nano fillers are added at a smaller proportion. The investigations are carried out by utilizing glass fibers for reinforcement and concluded that the JFRP exhibits better properties but the strength of the bundle is decreased.

The objective of this study is to increase the ductility of the jute fiber by reinforcing graphene nano platelets with epoxy and to test the bundle strength by varying the orientations of the jute fibers reinforced with graphene.

2. Experimental Methods

2.1. Materials Used

Graphene Nano platelets with thickness of 0.7 – 7 nm with flake size of 6μm is used for reinforcement. An epoxy resin with low viscosity of density 1.2 g/cm^3 is mixed with curing agent i.e., hardener HY951.Jute fibers woven in a bidirectional manner with density 1.3 g/cm^3 and with young's modulus 26.5 GPa is chosen.

2.2. Fabrication Of Jfrp

Epoxy resin LY5561 with low yield is ultrasonicated with hardener HY951 in the ratio of 10:1. Ultrasonicator is used for stirring and 2% weight graphene is added to the matrix. The ultrasonicator is stirred for 2 hours for better dispersion of graphene in the matrix. Then it is allowed to cool for 40 minutes at room temperature. A rectangular mould is prepared for fabricating jute fibers to test the mechanical properties as per ASTM standards. A layer of epoxy resin matrix is poured into the mould and then jute fibers with different orientations and layers are fabricated. 9 distinct specimens are fabricated incorporating with different layers (3 layers, 4 layers and 5 layers) and orientations (30^0, 45^0 and 60^0).

3. Mechanical Testing

3.1. Tensile Test

ASTM D638 standard is adopted for tensile test. Universal Testing machine (UTM) is used for carrying out the test. Three identical composite specimens were tested and the average results of it are obtained. Fracture toughness is termed as the ability of the

material to absorb energy i.e., deform plastically before fracture. Fracture toughness can be calculated by

Fracture Toughness $= \dfrac{\sigma^2 \Pi a}{E}$, Where σ is the Stress in (N/mm^2), a is the Crack Length in mm and E, the Young's Modulus

Figure 1. Tensile Test Specimen

3.2. Flexural Test

A Universal Testing Machine Adopting ASTM D790 Standard is used for flexural tests. The stiffness of the material is assessed by this test. Specimens with dimensions 127 mm x 13mm x 3.2 mm is used for this test. Flexural Strength was calculated using the equation,

$$\text{Flexural Strength} = \frac{3PL}{2bt^2}$$

Where P is the break load or force in N, L is the support span in mm,b is the specimen width in mm and t is the specimen thickness in mm.
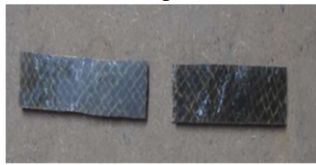

Figure 2. Flexural Test Specimen

3.3. IMPACT TEST

The impact strength of a material was determined by Izod Test. The impact of graphene reinforcement in JFRP is found. Specimens with standards following ASTM D256 are used by fabricating it with dimensions 70 mm × 15 mm × 3 mm.
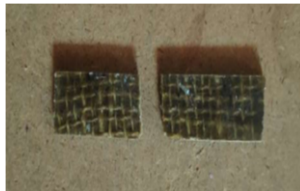

Figure 3. Impact Test Specimen

4. Results and Discussions

4.1. Tensile Test Reports

The results of 9 identical jute fiber composite specimens carried out in UTM are listed below in the table. In order to increase the bundle strength, orientations are varied in the manner of 30^0, 45^0 and 60^0. The observations proved that fracture toughness decreased on varying fiber orientation beyond 30^0. Reinforcement effect is not good in 45^0 and 60^0 orientation. Fracture toughness decreases on increasing layer thickness and by varying fiber orientation. Results showed that 3 layers with 30^0 orientation exhibited better tensile strength. The table and graph lists various tensile properties with respect to layers and orientations.
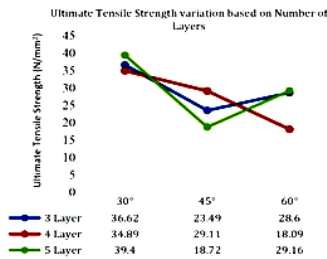

Figure 4. Tensile Fracture Strength based on Number of Layers

4.2. Flexural Test Reports

The results of flexural test for 9 different specimens are listed below in the table. The flexural strength of the JFRP is calculated by using the standard formulation. Observation and results were obtained for Jute fiber with fiber orientations 300, 450 and 600 and number of layers in JFRP (3 Layers, four Layers and 5 Layers). Results proved that 3 layered 30^0 orientation JFRP exhibited better flexural strength compared to other JFRP specimens.

Table 1. Flexural Properties of JFRP

Sl. No	Composition	Ultimate Break load (KN)	Displacement Fmax (mm)	Ultimate Stress (KN/mm^2)	Flexural Strength (N/mm^2)
1.	3 LAYERS 30º	0.185	2.400	0.003	36.2
2.	3 LAYERS 45º	0.220	2.000	0.002	28.43
3.	3 LAYERS 60º	0.185	2.900	0.002	33.1

4.	4 LAYERS 30º	0.235	2.300	0.003	38.7
5.	4 LAYERS 45º	0.200	2.600	0.002	34
6.	4 LAYERS 60º	0.270	1.600	0.003	30
7.	5 LAYERS 30º	0.265	2.300	0.003	31.7
8.	5 LAYERS 45º	0.145	1.700	0.002	20.3
9.	5 LAYERS 60º	0.175	2.100	0.002	29.5

Flexural Strength variation based on Number of Layers

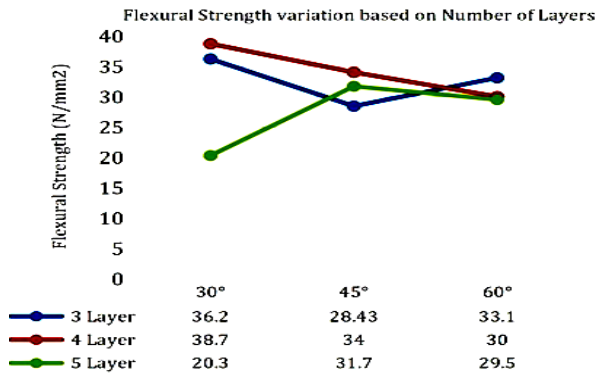|	30°	45°	60°
3 Layer	36.2	28.43	33.1
4 Layer	38.7	34	30
5 Layer	20.3	31.7	29.5

Figure 5. Flexural Strength based on Number of Layers

4.3 Impact Test Reports

The impact strength of the jute fiber specimens decrease with orientations beyond 30^0 and also the same can be seen for layers beyond 3 layers in JFRP.

From the data inferred in the table below, it can be concluded that 3 layer with 30° orientation exhibits improved impact strength and the impact strength diminish for 45° & 60° orientations. The impact strength diminish with increase in ply amid the same orientations,.

Table 2. Impact Properties of JFRP

Sample I.D	Values in Joules
3 layer 30°	8.0
3 layer 45°	6.2

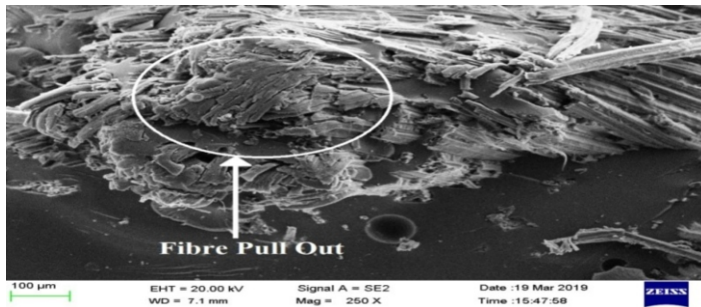| 3 layer 60°	5.4
4 layer 30°	4.8
4 layer 45°	4.0
4 layer 60°	3.2
5 layer 30°	3.9
5 layer 45°	3.1
5 layer 60°	2.1

Figure 6. Fibre pull out in JUTE FIBER Reinforced Polymer with 60^{0} orientation

The morphological features are studied by SEM images. The fiber pull out can be seen in the image. When interfacial adhesion is not good, fiber pull out occurs. When the orientation is beyond 30^{0} delamination occurs and normally fiber gets pulled out from the matrix.

Fig.7shows the river lines when the load is applied and initiates crack propagation and lead to delamination. Fig8 shows that the graphene filler is not uniformly dispersed throughout the fiber. This leads to Agglomeration of Nano filler graphene ensuing in meager mechanical properties. The load carrying capability of the composite decreases due to agglomeration.
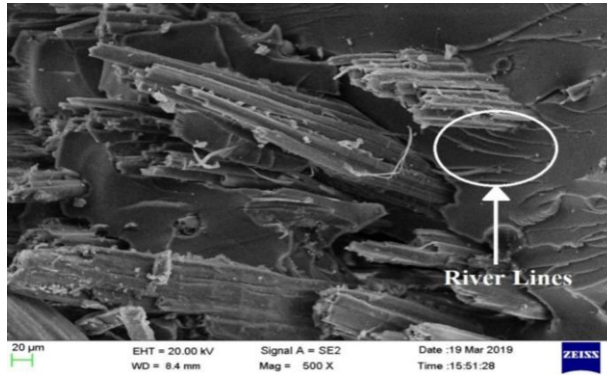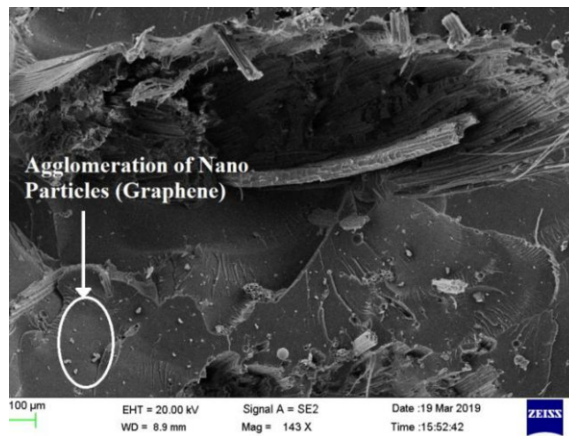
Figure 7. River Lines in JFRP

Figure 8. Agglomeration in JFRP

5. Conclusion

In general, Jute Fiber Reinforced Polymers are chosen due to its low weight which is alike in strength to other fibers. The Jute fiber reinforced polymer composites are incorporated with graphene with various Jute fiber orientations to further increase the bundle strength of JFRP. The Jute fiber specimens are fabricated and tested to acquire the mechanical properties.From the study 3 layer 30° orientations jute fiber reinforced polymer with graphene weight of 2% gave a prominent stress-strain value and is suggested to get hold of superior strength, while specimens with 45° and 60° orientation resulted with lesser values of fracture toughness and flexural strength due to fiber pull out and agglomeration.

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