Analysing the effect of mechanical properties of various proportions of filler material on jute fibre/epoxy reinforced composites

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Abstract: In the earlier stage of 1500 BC’S composites were invented. The initial stage of composites was created with the help of mixing the mud and straw for construction purpose, in order to build strong and durable component in the view, to ensure the longer life on the products. After some years, the usage of composite materials is become more, depends on different applications such as appliances, construction, electrical distribution, energy and marine usages and so on. Since the past few decades’ natural fibres plays a vital role in structural applications such as ease of fabrication, low cost, high durability, and for low thermal properties. In the present experimental investigation work, jute fiber has been chosen as the reinforcement agent along with the epoxy matrix material. With help of the hand layup technique the composites have been fabricated along with the standard ratio of (3% & 6%) calcium carbonate as the filler material. The fabricated jute fiber reinforced epoxy matrix (standard ratio of calcium carbonate filler) laminate were cut as per the ASTM standards to do the tests like tensile, flexural & impact, in order to completely analyse the physical strengths of the laminate, and the same data’s were compared with filler materials and without filler material. At last the fractured surfaces were thoroughly investigated with help of scanning electron microscope to understand the morphological behaviour of the fabricated composite.

Keywords: Composites, jute fibre, calcium carbonate, Tensile, Flexural, Impact test, Scanning Electron Microscopy.

1. Introduction

The composite is an utmost attracted area of research in automotives for selection because of its superior properties like low density, stiffness, less weight, besides having better mechanical properties. Now-a-days for regular applications the use of composite materials becomes vast [1-2]. In
the manufacturing of highly sophisticated machines and equipment, they have become inevitable. Comparing with conventional materials such as light weight, simple and cheap manufacturing process, and the composite materials proved to have many advantages with their constituent materials. To reduce the cost of the housing needs to the maximum level, the composite boards are used for flush and panel doors. Other product developments such as panel roofing sheets with sisal fibres and glass fibre added to jute fibre produces large increase in mechanical properties of the composites. The aerospace, automotive, marine and energy industries are largely having its applications. Realising the importance, there has been a systematic and continuous search for synthesizing composites without ignoring the mechanical and physical properties with the jute fibres of fibre length 5-6 mm [3-4].

Ashraf et.al stated fabrication and experimental work on jute fibre and hybrid composites, where jute fiber acts as the prime reinforcement agent. In this study, epoxy resin is taken as the matrix material. However, jute fibre biaxial woven mat were prepared by handloom method. In this particular research work, detailed comparisons were made between the jute fibre reinforced epoxy composites and hybrid composites. The results exhibited that hybrid composites shows better mechanical properties than the jute alone reinforcement [5]. Ramesh M et.al investigates Glass/jute/sisal fibre reinforced hybrid polypropylene polymer composites and their fabrication and analysis of mechanical and water absorption properties. The main objective seems to prepare a glass/jute/sisal fibre reinforced polypropylene hybrid composites and analyse the influence of different fibre loadings on its mechanical and water absorption behaviour. With the aid of compression moulding machine, sisal fibre have been fabricated with different fibre proportions. The performances of glass/jute/sisal fibre reinforced polypropylene hybrid composite have a vital positive effect by the fibre loading of different fibres in which almost 40% higher than the value obtained for virgin sample is also shown by the same composition [6]. Ramnath et.al investigates the study of moisture absorption characteristics of jute fibre reinforced waste plastic filled polymer composite. The moisture absorption characteristics of jute fibre reinforced waste plastic filled polymer composites is the study of this work. By varying the amount of reinforcement of fillers, at varying weight ratios, the specimens were produced. Taguchi method was used to establish the process parameters such as weight percentage of plastic particulates, jute reinforcement and type of chemical treatment of jute fibres. The moisture absorption characteristics influencing parameters were optimized. The ratio in which the composite possess maximum water resistance was determined by optimizing the results [7].

Venkateshwaran et.al has done investigation on effects of jute fibre content on the mechanical and dynamic mechanical and dynamic properties of the composites in structural applications. The fabrication and tests were conducted on six types of fabricated composites specimen with various constituents such as jute, carbon and their hybrids. With increasing the carbon content relative to the jute fibre content, the increase of fatigue lifetime of hybrid is noted. Jute composites had the highest strain while carbon composites exhibited highest fatigue resistance and semi brittle tends in both mechanical and fatigue performance. From the results arrived, it is concluded that the plain jute fibres could partially replace high- cost synthetic carbon fibres to produce more eco- friendly hybrids to be used in different composites industries [8]. Santulli et.al have done experimental investigation of dry sliding wear behaviour of jute/epoxy and jute/glass/epoxy hybrids using Taguchi approach. Under dry sliding wear condition, the behaviour of jute/epoxy and jute/glass/epoxy were tested by pin- on- disc wear testing machine, the design of experiments was carried out using Taguchi technique, and their corresponding results were analysed. The main parameters used are sliding velocities (1 m/s, 2 m/s and 3 m/s), applied loads (10 N, 20 N and 30 N) and sliding distance (1000 m, 1500 m, 2000 m) to find out the effect of wear performance. For the study of relative significance of individual factors on wear characteristics, the analysis of variance was conducted [9].

In this particular work, the biaxial woven jute fiber has been chosen as the fibrous material, whereas the epoxy resin have been chosen as the matrix material. The standard ratio of calcium carbonate was chosen as the filler material and it was thoroughly mixed with the epoxy material in order to fabricate the three variant of filler (0%, 3% & 6%) laminate, and their corresponding physical strengths like tensile, flexural and impact tests were conducted and their results were compared with each other. As well as, to understand the interfacial strengths of the fiber and matrix material, fractured surfaces were thoroughly analysed with help of the scanning electron microscope.
2. Materials and methods

2.1 Materials

Initially the jute fibres are extracted by retting process. The jute fibres and epoxy resin were purchased from sakthi glass fibres limited saidapet, Chennai. The base material used in this current study is jute fibre which is available in the form of woven mat. The resin and hardener used in this study are epoxy resin, type of ARALDITE LY556 and HY917 hardener. In addition to the above material, filler materials are used for enhancing the mechanical properties, calcium carbonate were used as a filler material to fabricate the laminate [10]. All the materials photographic views are shown in the figure 1.

![Photographic view of materials](image1)

**Figure 1.** Photographic view of (a) Jute fibre woven mat (b) Epoxy resin (c) Hardener (d) Calcium carbonate

2.2 Preparation of Composite laminates

The composite laminates are manufactured by compression moulding machine. Compression moulding process is a technique used to create composite plate. The jute is the base material; it is in the form of jute woven mat. The first stage is of jute fiber composites were fabricated in the size of dimensions 300 X 125 X 3 mm by compression moulding technique. After cutting required dimensions, fibers are placed on the mould. After placing a material on the mould, epoxy resin and hardener are taken in a plastic cup separately. Then 240 grams of epoxy and 24 grams of hardener are mixed in the ratio of 10:1 and some amount of calcium carbonate is added as 0%, 3%, 6% weight ratio, then the resin is uniformly applied throughout the mate. The mould is then kept for 12 hours for curing action.

![Fabrication process](image2)

**Figure 2.** Photographic view fabrication process (a) Epoxy with hardener mixing (b) Calcium carbonate mixing (c) Stirring process (d) Jute mate on the flattened surface (e) Wetting process of mat (f) Placing the specimen on the mould (g) Jute reinforced laminate
Finally curing action is done, sprayed the silicon wax on the mould surface in order to remove a cavity from mould. After completing a single mat and then placing a next mat on the mould. The same procedure is being followed up to five mat in order to get the 3 mm thickness of laminate [11]. The pictorial representation of the fabrication process is shown in the figure 2.

2.3 Mechanical testing of Composites

The prepared jute fiber composites are cut as per ASTM standards. The tensile test (ASTM D3039) specimens were cut as 300 mm x 30 mm x 3 mm, similarly the flexural (ASTM D790) test specimens were cut as 127 mm x 12.7 mm x 3 mm. The impact test (ASTM D256) specimens were cut as 62.5 mm x 12.5 mm x 3 mm. During the initial stage of tensile test, both the ends of the specimens were fixed on the upper and lower jaw of the universal testing machine, then the cross head speed of 2 mm/min was maintained until fracture prevails on the specimen. Similarly, during the flexural test, the mid of the specimen was subjected with the vertical load, till the specimen fractures, as such maintained in the tensile test, in flexural strength analysis as well, the cross head speed of 2 mm/min was maintained. Finally, impact analysis test specimens were placed on the anvil and hanging pendulum was allowed to fall over the work piece. For each test, five trails were carried out and averages were reported [12].

3. Results and discussion

3.1 Mechanical testing.

The mechanical testing of composites was carried out viz tensile, flexural and impact tests. The discussion reveals that different proportions of jute fibre reinforced epoxy with filler and without filler material (i.e) calcium carbonate. The results from the various testing process was clearly discussed. The table 1 exhibits the physical strength of the laminates of variation proportion of calcium carbonate reinforced laminate.

| Specimen            | Peak Load (N) | Average Load (N) | % Elongation | Average Tensile Stress (N/mm²) | Average Flexural Test (N/mm²) | Impact Specimen (J) |
|---------------------|---------------|------------------|--------------|-------------------------------|-------------------------------|---------------------|
| Jute + epoxy        | 4535.312      | 4111 N           | 3.147        | 55.15                         | 72.53                         | 0.52                |
|                     | 4083.491      |                  | 3.127        |                               |                               |                     |
|                     | 3715.027      |                  | 2.753        |                               |                               |                     |
| Jute + epoxy + 3% of CaCO₃ | 4336.687 | 4360 N           | 2.807        | 58.52                         | 105.51                        | 0.72                |
|                     | 4341.357      |                  | 2.747        |                               |                               |                     |
|                     | 4403.307      |                  | 2.667        |                               |                               |                     |
| Jute + epoxy + 6% of CaCO₃ | 4985.668 | 4721 N           | 2.912        | 63.54                         | 97.52                         | 0.91                |
|                     | 4674.465      |                  | 2.667        |                               |                               |                     |
|                     | 4504.362      |                  | 2.667        |                               |                               |                     |

3.2 Tensile & Flexural Test Analysis

During the tensile test analysis, initially the specimen was gripped in the universal testing machine and gradually the pulling load was applied until the specimen fractures, simultaneously their corresponding loads against failure were notified. As such process, followed in the tensile test analysis, in flexural test analysis, transverse load was applied over the specimens and their
corresponding strain rate and load enduring capability were notified [13]. Based on the values arrived in tensile and flexural tests, the bar chart was plotted as mentioned in the figure 3.

![Bar Chart](image)

**Figure 3.** Tensile and Flexural analysis of jute fiber reinforced epoxy matrix composite laminate

While doing the tensile test analysis, the pure jute reinforced epoxy composite laminate had shown the tensile stress value as 55.15 N/mm$^2$, following which, the calcium carbonate incorporated jute fiber reinforced epoxy composite laminate had shown the tensile strength (3% calcium carbonate) value as 58.72 N/mm$^2$, the obtained value was nearly 5.7% higher than the pure jute fiber reinforced epoxy laminate. The incorporation of the calcium carbonate abruptly increases the tensile strength value in considerable way, again it evidences that, the talc powder had completely and evenly distributed in the epoxy compound and gives the load bearing capacity to the laminate. Similarly, the 6% calcium carbonate incorporation showed the tremendous increase in the tensile strength value as 63.54 N/mm$^2$, it was nearly 7.9% which was higher than that of 3% incorporation of the calcium carbonate. From the obtained results, clearly understood that, the calcium carbonate takes the tensile load and gives the lesser strain rate, as well as it transfers the tensile load along the direction of the fiber, thus the way increases the load bearing capacity [14]. The fractured specimens were shown in the figure 4.

![Fractured Samples](image)

**Figure 4.** Fractured samples of jute (Calcium carbonate filled) fiber reinforced epoxy composite

Besides that, to thoroughly investigate inter-laminar shear strength and fracture behaviour of the composite material, morphological analysis was carried out and shown in the figure 5. It was clearly seen that; the jute fiber had come across the pull out fracture when the threshold limit of the composite exceeds the ultimate strength of the laminate. The specimen had come across the matrix fracture following with the matrix fracture [15]. Initially the matrix material fractures itself and loses its interfacial strength between the fiber and matrix and at last pull out fracture was observed on the specimens as shown in the figure 4.
As details arrived from the tensile tests, in flexural strength analysis as well, same trend of increase in the flexural strength was observed, during the 3% addition of calcium carbonate the flexural strength value was 105.51 N/mm², whereas pure neat jute fiber reinforced composite laminate had shown the flexural strength value as 72.53 N/mm². The obtained results evidenced that, the calcium carbonate filler material predominately increases the flexural value as 31.25%, this value was quite high as compared with remaining all set of variables. The increase in the value shows that, the filler materials was completely and thoroughly mixed with the epoxy resins and evenly distributes the load, when the flexural load was applied over the composite material. But in the contrary, the 6% calcium carbonate incorporated jute reinforced composite laminate had shown the flexural strength value as 97.52 N/mm². This value was 8.19% lower than the value of 3% incorporation. This phenomenal effect adversely shows that, the calcium carbonate had not been effectively distributed among the epoxy matrix material, thus the why it could not show the increase in the flexural strength value.

3.3 Impact strength analysis

The impact strength (or) strength withstanding capability of the jute fiber reinforced, with filler and without filler (calcium carbonate) reinforced composite laminate results were shown in the figure 6. During the impact strength analysis, it was found that, the impact strength of the pure and neat jute fiber epoxy compound specimen had shown the impact strength value as 0.52 J, whereas the 3% calcium carbonate incorporated specimen had shown the impact strength value as 0.72 J, almost there was 27.86% increase was noted in the loading of calcium carbonate in the jute fiber reinforced epoxy laminate.
Figure 6. Impact strength analysis of fiber reinforced epoxy matrix composite laminate

The above results evidences that, the calcium carbonate filler materials were evenly distributed in the epoxy compound, thus the way it kept increases the strength in abrupt way. Similarly, the 6% calcium carbonate specimen as well showed the tremendous increase in the impact strength value, it had showed the value of 0.91 J. There was almost 20.86% of impact resistance was seen by incorporating the 6% calcium carbonate in the jute fiber reinforced (with 6% calcium carbonate) epoxy laminate. Also it evidences that, the calcium carbonate was evenly distributes itself in the epoxy compound and increases the strength of the composite in massive way, further to this, there was no agglomeration effect was seen in the laminate. This (agglomeration) effect was clearly seen in the figure 7. In the figure 7, there was only fiber agglomeration was noticed in 3% calcium carbonate filler reinforced epoxy composite, also in the 6% calcium carbonate incorporated laminate cluster effect only seen [16].

Figure 7. Morphological analysis of impact test – fractured specimen

4. Conclusion

From the incorporation of the filler material (calcium carbonate) in the jute fiber reinforced epoxy composite material, as well as doing the physical examination, the following observations were noted.

1. The tensile strength of the jute fiber reinforced epoxy composite was increased up to 7.91%, while gradually increasing the filler material in the epoxy compound. Moreover, there was no agglomeration of calcium carbonate was seen in the morphological analysis of the fractured specimens.

2. Similarly, in the flexural stress analysis, the incorporation of the calcium carbonate adversely increases the strength of the composite up to the level of 31.12% in loading of 3% calcium carbonate. But there was sudden dip in the flexural strength on the 6% calcium carbonate loading in the composite specimen, during morphological analysis of the flexural test as well, have not noticed any agglomeration of the calcium carbonate.
3. Impact strength analysis as well, shows the increase in the strength, while incorporating the calcium carbonate in the laminate.

4. At last, it was clearly observed that, calcium carbonate has had clear distribution in the epoxy compound and increases the strength of the composite in many folds.

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