Effect of stacking sequences on tensile properties of natural fiber hybrid polymer composite

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Abstract: Recent years, researchers have concentrated on eco-friendly materials. In particular natural fiber reinforced composites have an impact on the environment while processing and utilizing such materials. Natural fibers are abundantly available in the world and it is used as reinforcing material into polymers considered replacement of conventional materials in many applications for environmental concern. In this study kenaf and fiber reinforced hybrid composite laminates were fabricated using hand layup technique. with two stacking sequence variant laminate A, laminate B like sandwiched structure. In both the laminates, skin, core and intermediate layers were varied. Tensile properties of these composite laminates were found experimentally using a UTM machine. For analyzing the elastic behaviour of these laminates, finite element analysis was carried out using Ansys workbench. Experimental results were compared with FEA results. There was high correlation between these results. The results justify the hybridization of kenaf and basalt fiber potential. .this hybrid composites are well suited for aerospace structural applications.

Keywords: Hybrid composites; kenaf fiber reinforced polymers; eco-friendly hybrid composites; mechanical properties; basalt -kenaf composites

1. Introduction
Recent years, scope for natural fiber reinforced composites is increasing day by day due to its eco-friendly nature and it can be a good replacement for artificial fiber reinforced polymer composites. These natural fibers have more specific strength than the E glass fibers. This reason makes natural fibers reinforced composites to be affordable and alterations of glass fiber reinforced composites.[1]Most of the natural fibers are moisture absorption characteristics and it is due to its hygroscopic nature. from the outer stem of the plant, natural fibers are extracted and processed further for using it in polymer composites.[2]Even though it has good specific strength, it can be only used in structural applications as it has lower mechanical properties than the artificial fibers. [3]To overcome this issue, artificial fibers are used to hybridize the natural fiber based composites. [4][3][5]Because of the high cellulose content present in kenaf fiber, it can be an eco-friendly material which provides enough mechanical properties [6]. Among other fibers, kenaf is a better fiber for reinforcing into the polymer matrix composites which turns into biodegradable material.[7]Because of its great adhesion with resins, kenaf fiber reinforced composites possess good mechanical characteristics. Accordingly it can be a good alternative to synthetic fiber reinforced composites. [8].Mainly, flexural property of kenaf fiber reinforced polymers is more than the other natural fiber reinforced polymers. This reason makes kenaf fiber reinforced composite can be suitable in flexural loading applications.
Structural design parameters and fiber content chemical treatment improves the characteristics of these hybrid composites [9]. Hybridization of basalt and kenaf fiber reinforced hybrid polymer composites improves the mechanical properties of composites [10].

When moisture content is absorbed in kenaf/glass fiber reinforced hybrid polymer composites, the properties related to mechanical for the hybrid composites are decreased [11]. Hybrid composites made with glass fiber as skin layer provide good mechanical strength [32]. Fiber orientation influences the load transferring capacity of hybrid composites, that results in influence on mechanical behaviour of hybrid composite [12]. One of the main parameters known as Fiber volume fraction influences the mechanical behaviour of hybrid composites [12]. From the literature review, analysing the mechanical behaviour in the hybrid polymer composites are complex. Moreover, in the analysis area, there is still a need for studying in this area of composites due to its insufficiency. Reinforcing kenaf and basalt fiber into the epoxy polymer makes the composites eco-friendly, superior and economical. Based on these advantages, woven kenaf/basalt fiber mat reinforced composites have been fabricated using hand layup technique. The experimental investigation on these hybrid composites has been carried out for tensile properties. Moreover, to analyze the elastic behaviour and to find important mechanical properties of composites, the finite element method is used. The results from the experimental study and finite element analysis have been compared and found that there is high correlation between the values.

2. Material Selection

In this research work, the kenaf/basalt fiber reinforced hybrid polymer matrix composite laminate have been produced by hand layup process. Kenaf fiber and epoxy resin HY951 has been bought from go green products Chennai. Basalt fiber has been supplied by basalt fiber Bangalore. Properties of kenaf and basalt fibers are shown in table 1 and table 2.

### Table 1. Properties of Basalt Fibers

| Mechanical Property       | Value         |
|---------------------------|---------------|
| Density                   | 2.75 g/cm³    |
| Youngs Modulus            | 89 Gpa        |
| Shear Modulus             | 21.7 Gpa      |
| Poisson's ratio           | 0.26          |
| Tensile Strength          | 4840 Mpa      |
| Elongation at break       | 3.15%         |
| Elastic Modulus           | 89 Gpa        |
| Thread count,F/10cm,warp  | 100±5         |
| Thread count,F/10cm,weft  | 95±5          |
| Weight                    | 150±20g/m²    |

### Table 2. Properties of Kenaf Fibers

| Mechanical Property       | Value         |
|---------------------------|---------------|
| Density                   | 1.5-1.6 g/cm² |
| Ultimate Stress           | 350-600 Mpa   |
| Shear Modulus             | 40 Gpa        |
| Strain                    | 2.5-3.5%      |
| Tensile Strength          | 400 Mpa       |
| Elongation at break       | 7.0-8.0%      |
3. Composite Laminate Preparation
Laminates have been fabricated using hand layup technique. Before fabricating the laminate, the mould base and sides are cleaned and coated with teflon for ease the action of removing the laminate after curing. The fiber mats were cut according to the mould size and laid down in the mould. Fiber volume fraction percentage was maintained between 35 to 40%. Mixing ratio 1:10 were maintained in resin hardener mixture for setting of epoxy quickly and poured on the fibers. Rollers were used for resin fiber impregnation and applying resins to the entire fibers. Successive fibers were placed over one another. The process was repeated until the required stacking sequence was obtained. By using this process fiber laminates sequences like K-B-K-B-K and B-K-B-K-B were fabricated at ambient conditions.

| LAMINATE(A) | LAMINATE(B) |
|-------------|-------------|
| Kenaf       | Basalt      |
| Basalt      | Kenaf       |
| Kenaf       | Basalt      |
| Basalt      | Kenaf       |
| Kenaf       | Basalt      |

4. Mechanical Characterisation
For designing of composite structure, mechanical properties like strength and stiffness properties can be found using mechanical testing. The tests were carried out according to ASTM standards. Advantages:

4.1. Tensile properties
In this tensile property test, the capability of material response to loading condition and how much load it can withstand under constant rate. This describes the span of survival of material under tensile loads [13]. Moreover, under tensile loading conditions, elongation of material and elastic behaviour of material can be observed. This experiment was conducted according to ASTM D638. The material has been loaded in the UTM. The load is applied and increased with a constant rate until failure occurs on the test specimen. The maximum tensile strength was observed at the failure of samples.

4.2. Flexural properties
Flexural strength of material describes capacity of material withstands the bending load without failure while bending. [14] Three point bending test is preferred by many researchers uniform form cross sectional material s bent to find the flexural strength. According to the ASTM D790 the sample were tested for knowing flexural strength of the laminate.

4.3. FEA Analysis
To analyze the elastic nature of material and elastic to plastic transition behaviour in composites, the FEM analysis was used. Moreover, to validate experimental results, FEA is much needed. ANSYS workbench is the solver which is to analyse the structural, elastic behaviour, dynamic behaviour and for optimization. This solver helps to know the response of structure during loading. The results from the FEA method showed that these composites are brittle in nature and revealed that the composite laminate was deformed linearly in the elastic region. Advantages:

5. RESULT AND DISCUSSION
5.1. Tensile test results
Load versus elongation plot obtained from the UTM after conducting the test for the samples are shown in the figure. The curve shows linear relations between load and elongation till reaching its maximum load that the specimen can withstand. After failure of the sample, the curve was suddenly dropped in displacement. The tensile strength results
of three different stacking sequence hybrid composite specimens were compared in the table. From the table, it is found that Laminate B type hybrid composite has more strength than the other hybrid samples.

**Figure 1.** Stress vs Strain curve for Tensile test of Laminate A

5.1.1. Analysis of tensile property of specimens using FEA
Laminate B has exhibited 54.7 MPa and Laminate B exhibited 49.96 MPa. Under different loading conditions, the simulation of laminate A was obtained. In the center portion of the specimen, the highest tensile stress 83.02 MPa were observed. The simulation plot obtained denotes the composite laminate A is brittle and it is deformed linearly in the elastic region. Simulation pictures for the laminate A under tensile loading condition are presented in the figure 2.

**Figure 2.** Tensile stress analysis for Laminate A

**Figure 3.** Tensile stress analysis for Laminate B
The figure 3 shows the simulation of tensile stress analysis of laminate B. This simulation plot was obtained from different loading conditions. When we observe the simulation plot, the maximum tensile stress 32.3 MPa was obtained at the center region of the laminate. This result in the laminate B also shows the laminate is brittle and deformed linearly in the elastic region. The results revealed that the experimental and FEA results were highly correlated to each other.

The experimental results and predicted results using ANASYS were compared in the table 2

| Tensile test results MPa | Laminate A Composite | Laminate B Composite |
|--------------------------|----------------------|----------------------|
| Experimental results     | 56MPa                | 59.2MPa              |
| Ansys results            | 83.02MPa             | 32.3MPa              |

Laminate B has more tensile value than Laminate A. this is due to basalt fiber is reinforced at the outermost layer and to the core layers in the laminate B moreover basalt fiber has more tensile strength than the kenaf fiber as it was indicated in the table.

5.2. Flexural strength results

Flexural strength value obtained for laminate B is more than the value of laminate B. The reason behind the flexural strength value of laminate B is that basalt fiber placed in the top layer transfers the load because of its high strength value. Moreover the inter lamina bonding is good in the laminate B. Laminate A has skin layer of kenaf fiber and it exhibits load transfer lower than the basalt based skin layer laminates B. FEA results also resembled the results obtained experimentally and showed high correlation between them. The figure 4 and 5 shows the comparison of flexural strength value of laminate A and Laminate B.

![Figure 4. Flexural stress analysis for Laminate A](image-url)
Figure 5. Flexural stress analysis for Laminate B

Table 5. Comparison of Flexural test results

| Flexural Strength in MPa | Laminate A Composite | Laminate B Composite |
|--------------------------|----------------------|----------------------|
| Experimental results     | 76.8MPa              | 128.9MPa             |
| Ansys results            | 107.8MPa             | 160MPa               |

6. Conclusion
In this study, Natural (Kenaf) / (Basalt) fiber reinforced polymeric composites with two different stacking sequences were produced by hand lay-up method. The two different stacking sequences of hybrid composite materials were machined according to ASTM standards of tests and the specimens were tested to obtain tensile strength. The results were obtained both experimentally. The Laminate B hybrid composite gave more tensile strength when compared with Laminate A. The results obtained from ANSYS are nearer to experimental results obtained. From this study the research work results concluded that the tensile property the values of Laminate B obtained experimentally (tensile Strength - 59.2 MPa and flexural strength - 128.9 MPa) is more compared to the Laminate A (tensile Strength - 56 MPa and flexural strength - 76.8 MPa) hybrid composite material. This reveals that basalt fiber in the core and as in the skin layer of laminate produces more strength. Results seem to be that increasing basalt content in the hybrid composite increases tensile properties of hybrid composites. Based on above compared values, Laminate B (stacking sequence of B-K-B-K-B) hybrid composite is more suitable for structural and aerospace application.
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