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Study of Natural Composites with Flax Fiber Through Finite Element Analysis

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A B S T R A C T

Bio composites, also known as natural fiber composites, are gaining popularity in polymeric materials as natural fibres are increasingly utilized for reinforcement. This trend is driven by the enhancements in product properties that the fibres can impart. The composites are fabricated through the hand layup process, with a 2% NaOH fiber treatment employed to enhance the interfacial bonds between the fiber and matrix, thereby improving mechanical properties. Composites consisting of 5% flax fiber by volume and epoxy resin are prepared, with varying fiber lengths of 6mm, 10mm, and 15mm, and an epoxy resin to hardener ratio of 10:01. Manufacturing involved the preparation of three plates with dimensions 300 mm x 300 mm x 3mm. These specimens underwent testing following ASTM standards for ultimate tensile strength. The results revealed that the tensile strength of epoxy resin/flax fiber composites reached its maximum at a 10mm fiber length, measuring 17.14 N/mm2. Experimental results from tensile testing were validated using numerical methods in Finite Element Analysis (FEA) software. Remarkably, the results obtained through experimentation and FEA were closely aligned. This suggests the potential for replacing conventional materials in industrial applications with these composite materials.

Keywords: Flax, NaOH, Tensile, FEA, ASTM, Hand layup

1. Introduction

Natural fibres be obtained from natural resources and are accessible in ample amount but they cannot be used in natural form. It usually requires some easy processing and this processing costs less compared to synthetic fibres [1-4]. Based on certain physical properties, availability and impact on environment some of the advantages of Natural Fibres are Low specific weight, which results in a higher specific strength and stiffness than glass [5-7]. Also, they are eco-friendly, biodegradable, available in large amounts, renewable, cheap. They have low density as compared to synthetic fibres such as glass, aramid, carbon and steel fibres [8-10]. It is a renewable resource, the production requires little energy, CO_2 is used while oxygen is given back to the environment. It also possesses good thermal insulating and acoustic properties [11-14]. In spite of such advantages, they cannot be used directly as natural fibres possess some disadvantages as lower strength properties, particularly its impact strength, variable quality, depending on unpredictable influences such as weather, moisture absorption, which causes swelling of the fibres [15-19]. Various physical and chemical treatments on fibre can be performed to improve its durability considerably [20].

Natural fibres have highly reactive hydroxyl groups (OH) groups, causing them to be prone to moisture and directly impair the properties of composites, especially dimensional stability [21-24]. The solution to this problem, chemical or physical modifications [25-26]. Presently natural fiber reinforced polymer composites market share is limited due to inadequate mechanical properties. So, finding the techniques to enhance mechanical properties of composites has become an essential research area [27-30]. The interfacial bonding between polymer matrices and natural fibres has become a major research topic to fabricate high performance natural fiber composites [31-34].

2. Material - Flax Fiber Based Natural Composite

The mould for manufacturing of plates have been prepared with dimensions of 300 x 300 x 3 mm. Manufacturing – hand layup technique, it is the oldest open moulding method for making composite products [33-36]. In this method successive layers of resin and reinforcements are manually applied to build laminated fiber reinforced composite. Finished moulding need to be trimmed to size outside edges with power saw. It requires no technical skill and no machinery [37-38]. It is a low volume, labour intensive method suited especially for large components, such as boat hulls. It is not economical for high production. A male and female half of the Mold is commonly used in the hand lay-up process. A typical structure of hand lay-up product being made is shown in Figure1 and material used to manufacture laminate is shown in figure 2.

Fig. 1 - Hand layup process for Product making [7]

Fig. 2 - Fiber for Laminate Making

Fig. 3 - Manufactured Laminate

Although glass and other synthetic fiber-reinforced plastics possess high specific strength, their fields of application are very limited because of their inherent higher cost of production. With consideration of this an investigation has been carried out to make use of flax; a natural fiber abundantly available in India. The manufactured laminate is show in figure 3.

3. Methodology and Application in Industry

The alkaline treatment using 2 % Sodium hydroxide (NaOH) are used to carry out fiber surface treatment. For mechanical property testing the composite test specimen were cut according to ASTM standards. Tensile test specimen with ASTM D638 is shown in Figure 4.

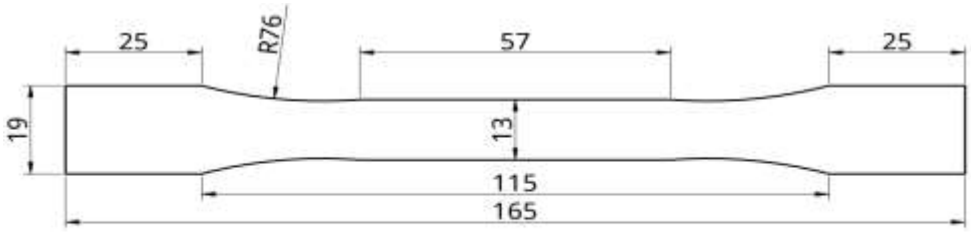

Fig. 4 - Tensile test specimen: ASTM D638 (dimensions in mm)

Static analysis is employed to examine displacements, stresses, strains, and various forces in a model or its components, caused by masses that do not introduce significant inertia and damping effects. In this type of analysis, loading and response conditions are assumed, with the masses and structure responses presumed to change slowly with respect to time. The static analysis involves the application of externally applied forces, moments, and pressures as loading types. Steady-state mechanical forces such as gravity and spinning necessitate non-zero displacements. If the strain values obtained from this finite element analysis exceed the allowable limits, it can result in structural failure under the given static conditions. To prevent failure, this analysis becomes crucial. Finite element analysis has been successfully utilized to assess the durability of fiber epoxy composites.

The tensile Testing and results, FEA modelling and results as shown in figure 5 and figure 6.

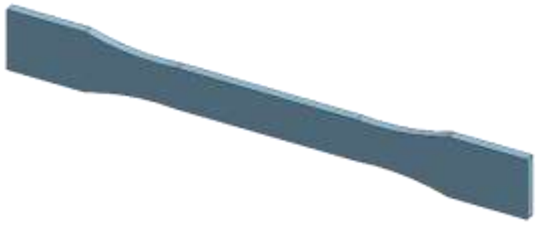

Fig 5 - CAD Model of Tensile test specimen

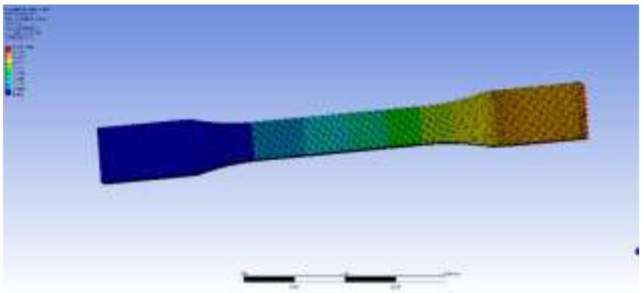

Fig 6 - FEA model of the Laminated model

4. Result Discussion

4.1 Results of Tensile Test

The tensile test was conducted using ASTM standard on UTM. A reading of load acting on specimen with progressive extension of specimen is obtained. Tensile test is conducted up to failure of specimen and various observations are noted in table 1.

Table 1 - Tensile Test Results

Composite Specimen	**Tensile strength (MPa)**	
	Trial 1	**Trial 2**
1	11.24	10.99
2	12.54	11.98
3	13.98	12.64
4	14.99	13.46

Fig 7 - Result comparison of Tensile Test for different sets

Figure 7 shows the comparison for laminates of the test specimen for both trails have a close match.

4.2 Comparison of Experimental & ANSYS results of Tensile Testing

The tensile test was conducted and ANSYS was compared with the same as given in table 2.

Table 2 - Tensile Test Result comparison vs Composite

Composite Specimen	Experimental (MPa)	Results	ANSYS (MPa)	Results
1	11.11		13.19	
2	12.26		16.57	
3	13.31		18.87	
4	14.22		20.45	

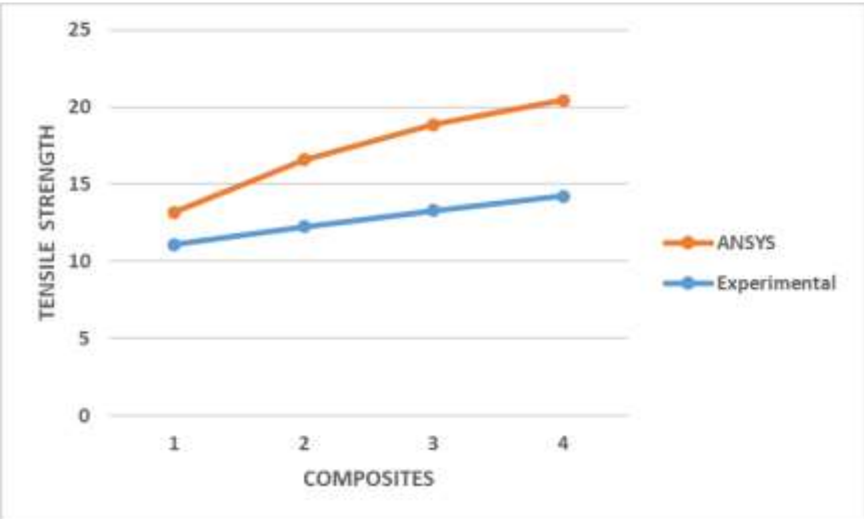

Fig 8 - Comparison of Experimental and ANSYS results

Manufacturing defects account for the observed variation in results. Employing an alternative manufacturing technique has the potential to minimize errors as shown in figure 8.

4.3 Mechanical Properties of Flax Composite Laminates

Table 3 - Mechanical Properties

Composite Specimen		**1**	**2**	**3**	**4**
Tensile Strength (MPa)	Test 1	11.24	12.54	13.98	14.99
	Test 2	10.99	11.98	12.64	13.460

The aforementioned results indicate a gradual increase in the tensile properties of coir composites with the augmentation of fiber lengths as shown in table 3. This increment occurs progressively, without sudden spikes, suggesting the necessity for a more in-depth analysis to comprehend the nuanced effects of these changes.

5. Conclusion

An extensive investigation was undertaken to explore the mechanical properties of Flax/epoxy composites based on varying fiber lengths, preceded by alkali treatment of the flax fiber prior to composite manufacturing. The study yielded the following conclusions:

1. The fabrication of epoxy resin-reinforced composites with alkali-treated fiber was carried out using the hand lay-up method.

2. Tensile testing revealed a gradual increase in the tensile strength of the composites with an elongation of fiber length. The maximum tensile strength was observed in specimens with a 10mm fiber length.

3. Alkali treatment applied to the fiber in the composites demonstrated remarkable enhancement in tensile strength.

4. Finite Element Analysis (FEA) results validated the experimental findings with a variation of ±8%. This variation was attributed to manufacturing defects such as voids or cavities.

The research highlights the efficacy of alkali-treated flax fibers in enhancing the tensile strength of epoxy composites, with experimental and FEA results aligning closely.

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