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STUDY OF MECHANICAL PROPERTIES OF COCONUT-SPATHE FIBERS AND KENAF BAST FIBER REINFORCED EPOXY POLYMER MATRIX COMPOSITES

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ABSTRACT

The interest in natural fiber reinforced polymer materials has multiple drivers such as, growing concern for the environment, possible cost competitiveness, and concerns around the sustainability of materials production. Natural fibers show significant potential as environmentally friendly alternatives to reinforcements such as glass fibers. Many natural fibers have been identified which have some appropriate mechanical properties for structural purposes, being of low density, and high specific strength and stiffness. Kenaf and Coconut-spathe fibers are examples of such fibers. Epoxy polymer matrix is much suitable for reinforcement of fibers due to good adhesiveness and mechanical properties. This paper mainly focuses such of mechanical properties like tensile, flexural, impact strengths of these fibers reinforced in epoxy under various proportions. The fabrication method was by "hand layup process" and the fibers were alkali treated; chopped and reinforced thoroughly in definite weight proportions. The weight proportion of the polymer matrix is maintained whereas the proportions of the fibers are altered and analyzed.

Keywords: *Epoxy, Kenaf, Coconut Spathe, Alkali Treatment and Flexural and Impact Strength.*

1. Introduction

Natural fiber reinforced composites have gained a better attention in recent days due to the exclusive properties of natural fibers like low specific weight, high specific strength, high stiffness and biodegradability[1]. The biodegradability is an important advantage of natural fibers when compared to glass fiber. Reinforcement of natural fiber in polymer matrix improves the eco-friendly nature of the composite material and the volume of non-biodegradable material gets reduced. This is one of the main reasons for which natural fibers are preferred when compared with glass fibers.

The mechanical properties of any composite material greatly depend on the adhesiveness between the matrix and the reinforcements. The fibers contain cellulose, hemicellulose, lignin and pectin molecules which possess many hydroxyl groups and are slightly hydrophilic in nature. The polymers like epoxy on the other hand are hydrophobic. This leads to weakness in interface adhesion between the fibers and the matrix material and therefore affects the overall property of the composite material. To enhance the interfacial bonding and to improve the adhesiveness between the reinforcements and matrix material we focus on surface treatment of the natural fibers chemically [2]. This treatment results in the roughening of the fiber surface removing certain amount of lignin, wax and oils that are present in the fiber surface.

The most economical and easiest method of fabrication of these composite materials to study their mechanical properties is "the hand layup process". The composite materials are made into thin sheets as per the ASTM standards for checking their tensile, flexural and impact strengths. The fibers were chopped and thoroughly dispersed in the matrix in random orientation. The matrix weight percentage was maintained throughout in all the specimens and the weight proportions of both kenaf and coconut fibers were changed from 0-10%. [3].

2. Material and Experimentation

2.1 Materials

The kenaf fibers were extracted from Hibiscus cannabinus plant. The fibers were taken from the bast of the plant. The bast fiber is known to have much excellent properties when compared with the fibers in other parts of the plant [4]. The kenaf fibers are long fibers with very small diameter and have a very good interfacial binding nature with polymers. The coconut

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fibers also exhibit many interesting properties like the presence of a waxy layer that contributed to the bonding of fibers with the matrix material. The waxy layer contained fatty aliphatic compounds which acted as adhesion promoters. Both the fibers were surface treated, chopped and then dispersed thoroughly in the matrix material. [5]

The matrix material used is LY556 liquid epoxy resin mixed with HY951 which acts as hardener or curing agent. Epoxy is a polymer matrix which is well known for its adhesive nature with many other materials and its phenomenal strength under different loading conditions. Moreover, epoxy is also known for its temperature resistant property when compared with other polymer materials.

2.2 Alkali treatment of fibers

The raw kenaf and coconut spathe fibers as shown in figure 1&2 respectively are alkali treated to increase the roughness of the fiber surface and hence enhance the adhesive bonding of the fibers with the polymer matrix. The process is called “Mercerization”. In this process, the fibers are immersed in 5% NaOH solution for a period of 4 hours[6][7]. This removes the hydroxyl groups present in the fiber surface and hence increase the roughness of the surface thereby improving adhesiveness with the polymer.

$$\text{Fiber-OH} + \text{NaOH} \longrightarrow \text{Fiber-ONa} + H_2O$$

The above reaction takes place during mercerization and as shown in the equation, a disruption of hydrogen bonding takes place which leads to the roughness of the fiber surface[8]. The alkali treatment removes a certain amount of lignin, pectin and waxy oils that are present in the outer surface of the natural fiber.

After 4 hours, the fibers are removed from the alkali solution and then dried for two days in sunlight to make sure that the fibers are completely dry and free from moisture.

Fig. 1 Raw Kenaf Fiber

Fig. 2 Raw Coconut Fiber

Fig. 3 Chopped Kenaf Fiber

Fig. 4 Chopped Coconut Fiber

2.3 Fabrication of natural reinforced composites

The liquid epoxy resin, LY556 can be solidified by mixing 100 parts of it with 10 parts of the hardener material, HY951. The setting time usually ranges from 30-45 minutes. The reaction that takes place during setting of the epoxy resin is exothermic and heat is evolved during the reaction. Provisions must be made to dissipate the evolved heat from the material so that there are no defects created due to the heat that is evolved. Otherwise, the heat thus produced may result in formation of pores in the material and making the material unfit for its application.

The chemically treated fibers are chopped into small pieces as shown above in figure 3&4 (kenaf and coconut respectively) of less than a centimeter long and are dispersed layer by layer in the epoxy matrix which is slowly solidifying. Both the coconut and kenaf fibers need to be mixed up and dispersed thoroughly in definite weight proportions for which the weight of each fiber to be dispersed, weight of the polymer matrix and the weight of the final material must be known. In our experimentation we are focusing on materials that have 90% weight of polymer matrix and 10% weight of fibers. The 90% weight of the matrix remains unchanged throughout the experiment and the 10% weight of the fibers are shared by the coconut and kenaf fibers in various proportions.

We are interested in finding the fiber proportion that gives better results for tensile, flexural and impact tests that are being conducted as per the ASTM standards. The fabrication of the test specimens for analyzing the above mentioned properties will be carried out by "the hand layup process". The specimens are fabricated as mentioned in Table 1.and machined for the dimensions that are specified in the ASTM standards. The testing standards that are used are ASTM D638 for tensile, ASTM D790 for flexural and ASTM D256 for impact tests.

Table 1: List of Fabricated Composite with Different Fiber Proportions

Sample	Description of Fiber Content
10 K/ 0 C	10% wt Kenaf
7.5 K/ 2.5 C	7.5%wt Kenaf & 2.5% wt Coconut
5 K/5 C	5% wt Kenaf & 5% wt Coconut
2.5 K/ 7.5 C	2.5% wt Kenaf & 7.5% wt Coconut
0 K/ 10 C	10% wt Coconut

The fabricated NFRCs are cut to the dimensions that are specified in the ASTM standards that are mentioned above and then are subjected to the corresponding tests. The NFRCs after fabrication and cutting to the required dimensions for impact, flexural and tensile tests are shown in figure 5, 6 and 7 respectively.

Fig. 5 Impact Test Specimens

Fig. 6 Flexural Test Specimens

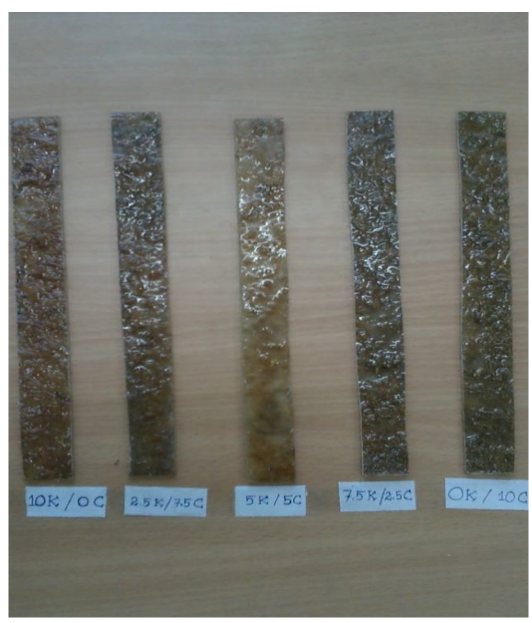

Figure 7. Tensile Test Specimens

3. Results & Discussions

3.1 Effect of fiber content on tensile strength

A tensile test, also known as tension test, is probably the most fundamental type of mechanical test performed on material. Tensile tests are simple, relatively inexpensive, and fully standardized. By pulling on something, you will very quickly determine how the material will react to forces being applied in tension. [9] The tensile strength of the composites was measured with a computerized universal testing machine in accordance with the ASTM D638 procedure.

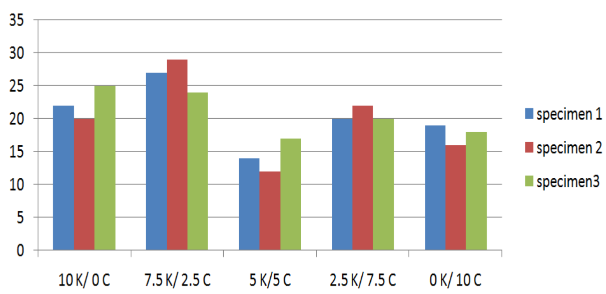

Fig. 8 Tensile Strength (in MPa) as a Function of Weight Fraction of Fibers and Epoxy Matrix

From figure 8, it is clear that the ultimate tensile strength is relatively higher for 7.5K/2.5C that contains predominantly kenaf fibers. The other NFRCs offer a considerably low resistance when compared to 7.5K/2.5C. The 5K/5C NFRC that contains equal proportion of both the fibers is said to exhibit a very poor tensile property when compared with other NFRCs.

3.2 Effect of fiber content on Flexural Strength

A flexure test produces tensile stress in the convex side of the specimen and compression stress in the concave side. This creates an area of shear stress along the midline. To ensure the primary failure comes from tensile or compression stress the shear stress must be minimized [9]. This is done by controlling the span to depth ratio; the length of the outer span divided by the height (depth) of the specimen. For most materials S/d=16 is acceptable. Some materials require S/d=32 to 64 to keep the shear stress low enough. The flexural tests were performed on the same machine, using the 3-point bending method according to ASTM D790.

The Figure 9 holds the flexural or bending stress of the all the 5 NFRCs. The flexural property or the flexural strength of 10K/0C and 0K/10C which are not hybrid are observed to be superior to the other entire three hybrid NFRCs.

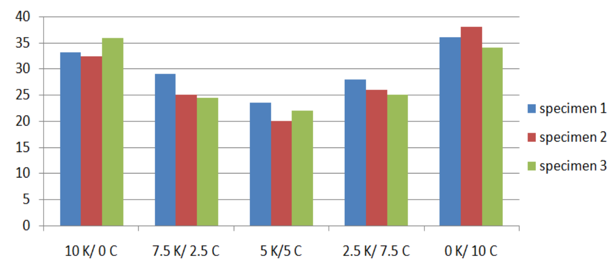

Fig. 9 Flexural Strength (in MPa) as a Function of Weight Fraction of Fibers and Epoxy Matrix

3.3 Effect of fiber content on impact strength

Impact tests are designed to measure the resistance to failure of a material to a suddenly applied force such as collision, falling object or instantaneous blow [10]. The test measures the impact energy, or the energy absorbed prior to fracture. Charpy test is one of the most common methods of measuring impact energy. The impact tests were performed according to ASTM D256. The data obtained at the end of the charpy tests are shown in figure 10.

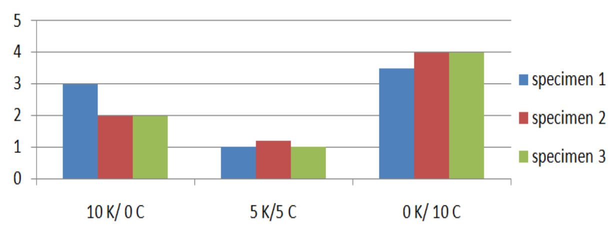

Fig. 10 Impact Strength (in Joules) as a function of Weight Fraction of Fibers and Epoxy Matrix

From this we see that, the coconut reinforcement has a better impact strength when compared with other reinforcements.

4. Conclusion

The NFRCs have been successfully fabricated using the Hand Layup technique and the reinforcement weight fraction has a significant effect on the mechanical properties of the NFRCs. The tensile properties of Kenaf bast fiber/Coconut spathe fiber reinforced epoxy composites are enhanced by the predominance of kenaf fiber content and the value is close to 27Mpa. The flexural properties are inferior when kenaf and coconut fibers are together reinforced and the strength is improved as the hybrid nature is reduced. The maximum value occurred for pure coconut reinforcement and the next greater value was for pure kenaf reinforcement. The impact properties were observed to be slightly higher for pure coconut spathe fiber reinforcement and the other samples showed similar behavior in the charpy tests. It is inferred that the hybrid NFRCs exhibited comparatively inferior flexural and impact strengths but showed good tensile strength with the predominance of kenaf fiber in the fiber weight proportion.

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