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Mechanical and microstructure characterization of coconut spathe fibers and kenaf bast fibers reinforced epoxy polymer matrix composites

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Abstract

In this present study, the natural fibers such as kenaf and coconut spathe are reinforced in polymer matrix by hand layup process. Alkali treated coconut spathe and kenaf bast fibers are uniformly dispersed with epoxy resin and cured using tri-ethylene tetra amine (TETA) at 25^0C. The weight proportion of the polymer matrix is maintained constantly 10% whereas the proportions of the fibers are altered within the composites. The mechanical properties like tensile, flexural, impact strengths are analyzed. Fracture analysis of fiber reinforced composites and the effect of alkali treatment on fibers are also observed using scanning electron microscope (SEM).

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Keywords: Polymer composites; Natural fibers; Alkali treatment; Mechanical properties; SEM

1. Introduction

Natural fiber reinforced composites have gained a better attention in recent years due to the exclusive properties of natural fibers like low specific weight, high specific strength, high stiffness and biodegradability and eco-friendly

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nature (Lee et al, 2009) .

The mechanical properties of any composite material greatly depend on the adhesiveness between the matrix and the reinforcements (Aziz and Ansell, 2004). 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 incompatibility between the fibers and the matrix material and therefore affects the mechanical properties of the composite material (Sudsiri et al, 2012). To enhance the interfacial bonding and compatibility between the reinforcements and matrix material, surface treatment of the natural fibers using alkali solution is performed (Yousif and Ming, 2012).

The Kenaf bast and coconut spathe fibers have high potential as a reinforcing fiber in polymer composites. These fibers are abundantly found in south India which is one of the main concerns for selection of these fibers. These fibers have not been really examined as reinforcing materials in polymer composites. Keeping in view the easy availability of these fibers this research work has been initiated on the study of mechanical properties of kenaf and coconut spathe fibers reinforced hybrid epoxy polymer matrix bio composites. Effect of the fiber weight proportions of kenaf and coconut spathe fibers are bonded with a constant weight of epoxy polymer towards mechanical properties and to study the microstructures of the fractured surfaces using scanning electron microscope Further, models with empirical methods are used in determining the various properties of composite materials.

2. Experimental Details

2.1 Material and reagents

The kenaf fibers are extracted from the bast of Hibiscus cannabinus plant. LY556 epoxy resin (Bisphenol A Diglycidyl Ether Polymer) is used as a matrix and the hardener is HY951 (triethylene tetra amine-TETA). The fiber and other materials are purchased from the local source.

2.2 Alkali treatment of fibers

The kenaf and coconut fibers were treated with 5% NaOH solution for 4 hours after which they were dried in sunlight for 48 hours (Luz et al, 2011). The fiber surfaces react with the base that modifies the hydroxyl groups from the aliphatic layers in the periphery of the fiber along the longitudinal axis. The dried alkali treated fibers are used for composites fabrication.

2.3 Composite Fabrication

The composite material is fabricated by “hand layup process”. The chemically treated fibers are chopped into 6 mm length and dispersed evenly as layers in between the polymer matrix using TETA as curing agent at $25^{o}C$ (Davoodi et al, 2010). In the fabricated composite material, polymer matrix occupies 90% of the weight of the composite and the rest is shared by both the fibers in five different proportions.

2.4 Mechanical testing

Composites are analyzed for their tensile strength in a computerized universal testing machines equipped with pneumatic claws. Five specimens of composites with different proportions were tested as per the ASTM D638 standards (Satyanarayana et al, 1982). For flexural strengths, the same universal-testing machine was used, where a load is applied on the specimens by three point flexure testing method. All fabricated are tested as per the ASTM D790 standard (Akil et al, 2011). The impact test specimens were fabricated as per the ASTM D256 and are notched for charpy impact tests (Rassmann et al, 2011). All the tests were conducted with minimum five samples and mean of their values are considered.

3. Results and discussions

3.1 Surface and morphology of fibers

The untreated and treated fiber surfaces of both kenaf bast and coconut spathe are examined. The untreated fibers were found with some waxy layers along with some impurities on the surface of the fibers. The fibers treated with 5% NaOH were found to be having improved surface morphology. The SEM images are shown in Figures 1&2 for kenaf and coconut respectively

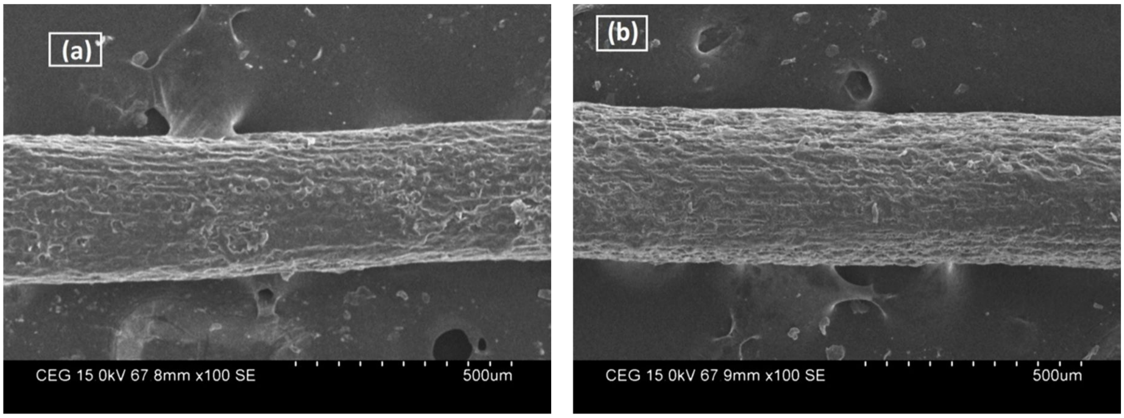

Figure 1 Microstructure of kenaf fiber (a) Untreated (b) Treated

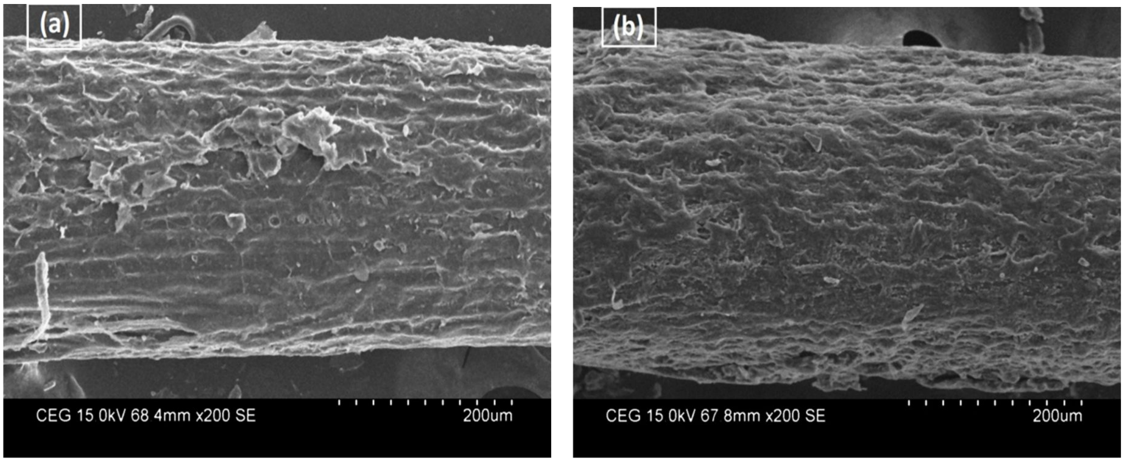

Figure 2 Microstructure of coconut fiber (a) Untreated (b) Treated

3.2 Tensile strength

Figure 3 shows the variation of ultimate tensile strength for the various composites. The ultimate tensile strength of the composites with 7.5% Kenaf /2.5% Coconut reinforced composites exhibits high value than other composites due to twisting and bundling of kenaf and coconut spathe fibers together which leads to increased load carrying capacity of the fibers. The poor entanglement between the kenaf and coconut fibers was also noticed in 1:1 ratio hybrid composite. The SEM images of 7.5% kenaf and 2.5% coconut are shown in Figure 4(a) and 5% kenaf and 5% coconut fiber are shown in Figure 4(b). The images show the bundling and entanglement of fibers in the

7.5K/2.5C composition and their absence in 5K/5C composition. Figure 5(a & b) shows the micro structure of both these composition of fibers after loading, which exhibits the breakage of fibers in 7.5K/2.5C and the pull out of fibers from the matrix in 5K/5C.

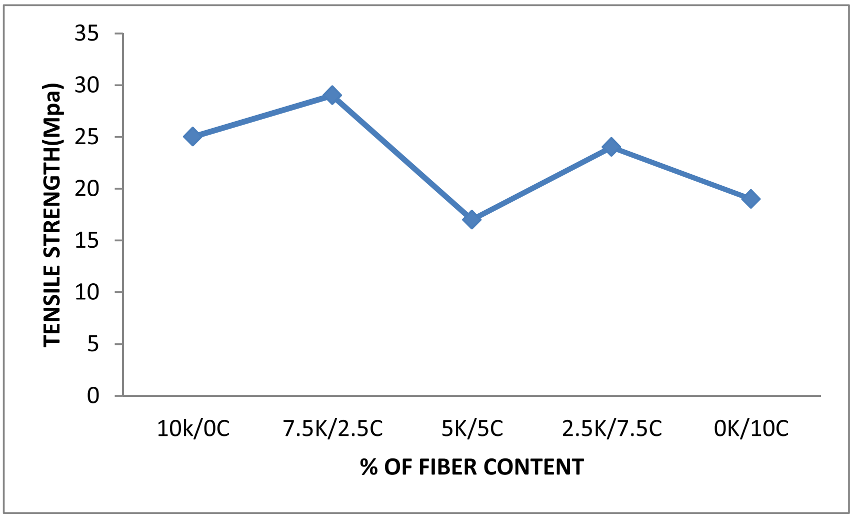

Figure 3 Effect of reinforcement weight fraction in tensile strength

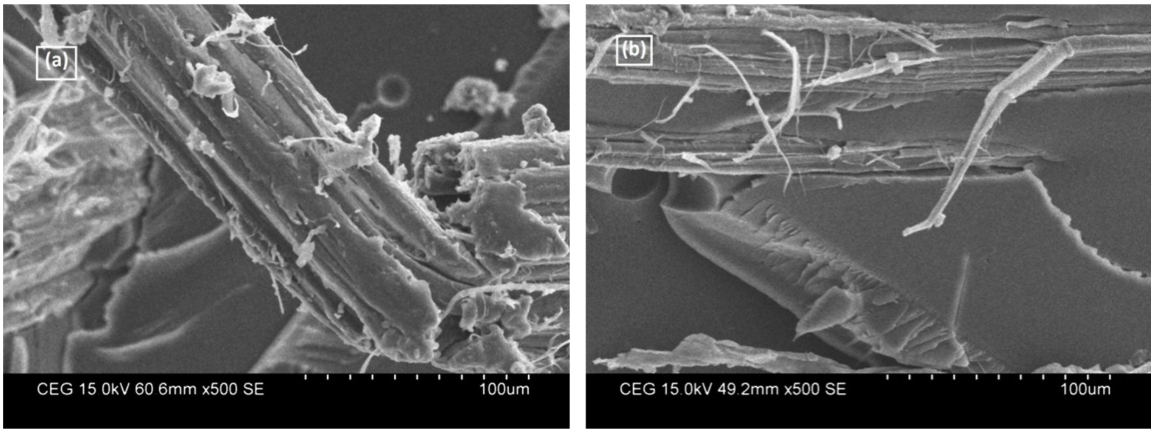

Figure 4 (a) Microstructure of twisted bundle of fibres in 7.5K/2.5C (b) Microstructure of absence of entanglement fibers in 5K/5C

3.3 Flexural Strength

The Figure 6 shows the flexural or bending stress of the all fabricated composites.. The flexural test results are similar to the tensile tests except that fiber bending was observed in both 2.5K/7.5C and 7.5K/2.5C in addition to fiber breakage. The fiber bending could be explained by the fibrillation of fibers due to the removal of waxy layer and impurities on their longitudinal surfaces. The fiber breakage and bending are observed from SEM images as shown in Figure 7.

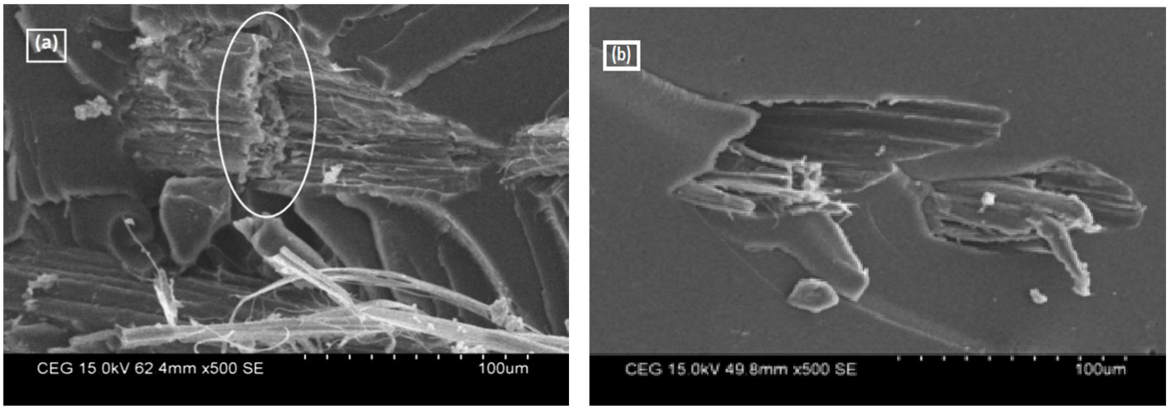

Figure 5 Microstructure of tensile fracture surface (a) 7.5K/2.5C (b) fibre pull out in 5K/5C

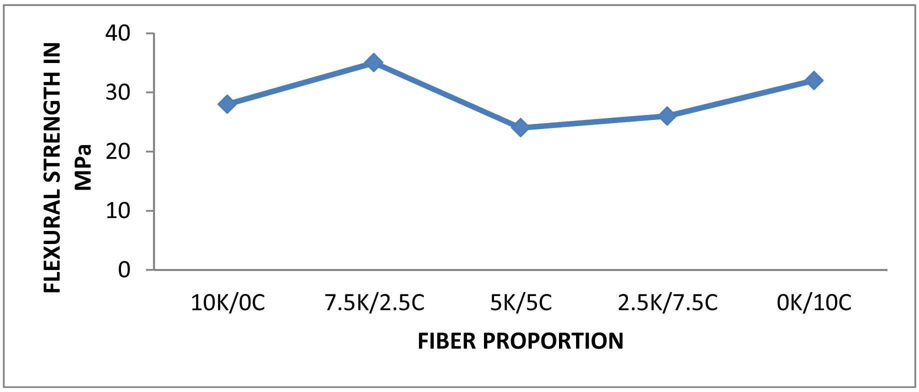

Figure 6 Effect of reinforcement weight fraction in Flexural strength

3.4 Impact strength

The charpy impact test results are graphically represented in Figure 9 that shows the dominance of coconut spathe fibers in the composites increased the charpy impact energy absorption before fracture. Micro-structural analysis predicts the presence of too many voids in 5K/5C when compared to 2.5K/7.5C and 0K/10C. This might have weakened the material causing it to absorb lower energy than the other compositions. The fracture surfaces showing the fiber breakage and void content are depicted in Figure 10. The kenaf fiber dominant composites also absorbed noteworthy amount of impact energy but not as good as coconut spathe dominant composites. The 5K/5C composition exhibited poor flexural strength due to the poor entanglement, which is characterized by the pull out of fibers from the matrix as shown in Figure 8.

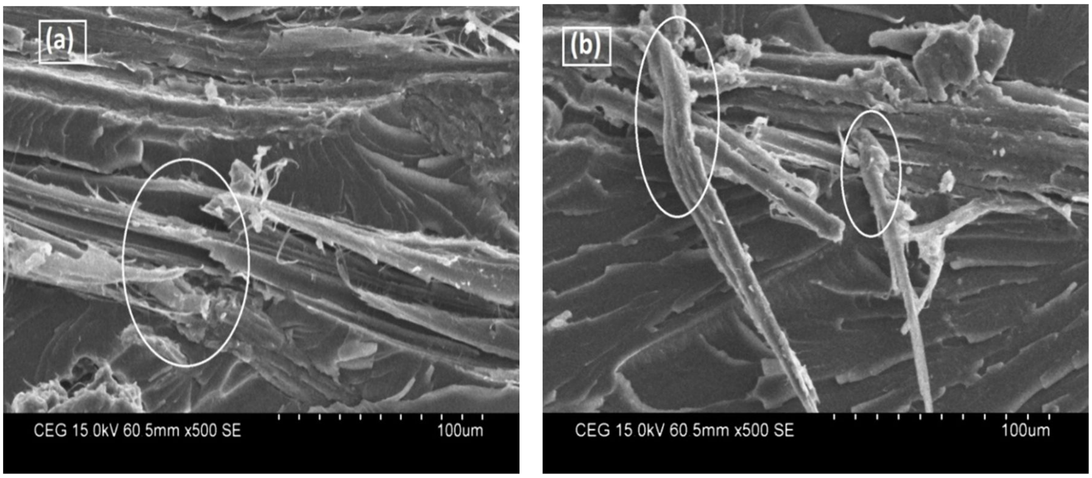

Figure 7 SEM of flexural fracture surface of 7.5K/ 2.5C showing (a) fibre breakage (b) fibre bending

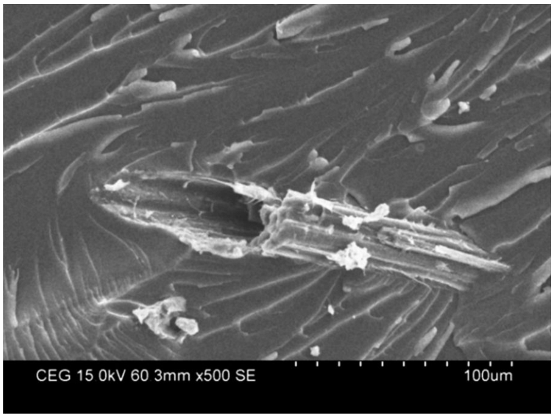

Figure 8 SEM of flexural fracture surface showing 5K/5C showing fibre pullout

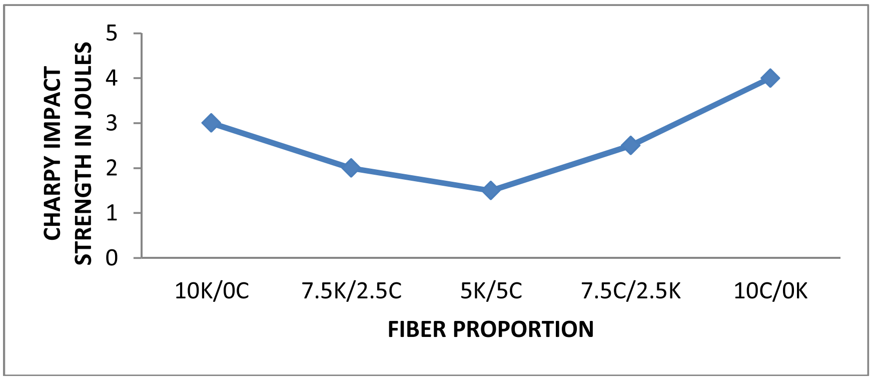

Figure 9 Charpy impact strength in joules as a function of weight fraction of fibres in epoxy matrix

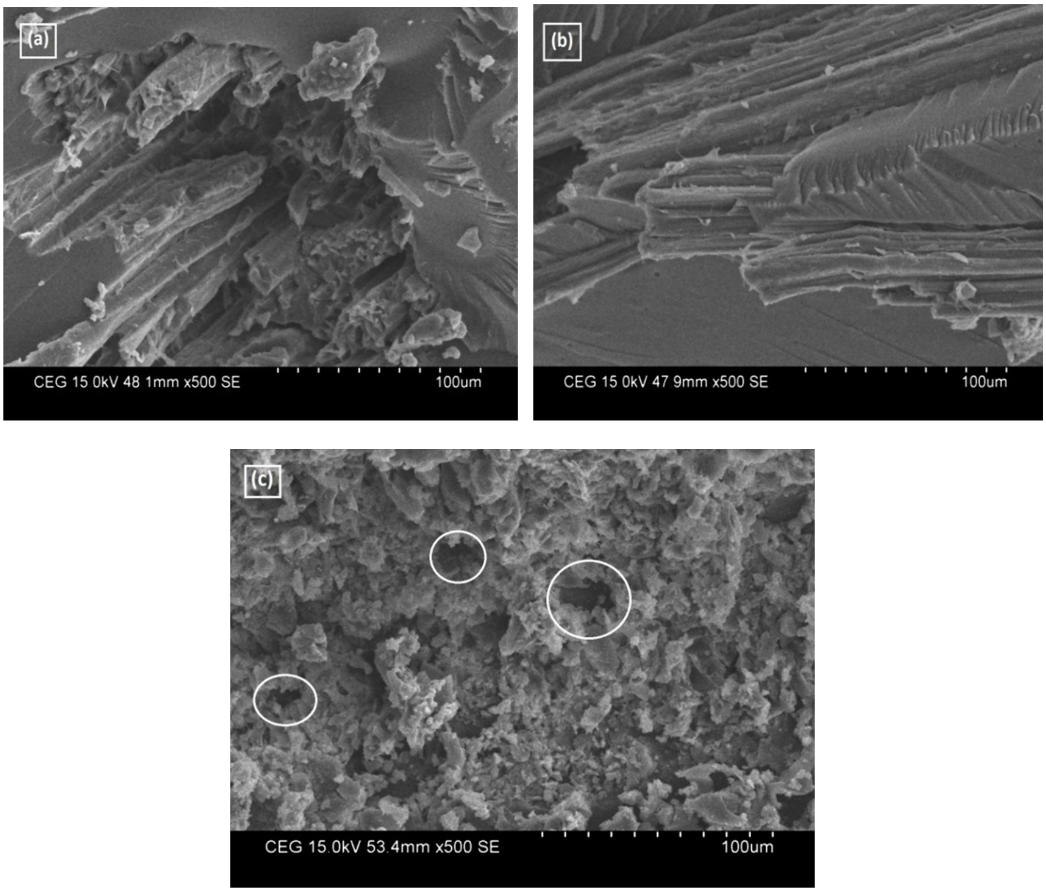

Figure 10 SEM image of impact fracture of surfaces (a) Fibre breakage in 2.5K/7.5C (b) Fibre breakage in 0K/10C (c) voids in 5K/5C

4. Conclusion

The natural fiber reinforced epoxy polymer composites with kenaf bast fibers and coconut spathe fiber reinforcements are successfully fabricated. The fabricated specimens are characterized for the mechanical properties. From the results, it is inferred that the entanglement of fibers produced a synergetic effect up to a certain proportion after which the properties are greatly reduced due to the discontinuity of load transfer between fibers and the matrix. This in turn is due to absence of twisting and bundling of different fibers that are present in equal proportion. The 5K/5C composites on micro structural analysis show the voids in the internal structure. This may be the reason for low absorption of charpy impact energy.

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