International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-6, August, 2019

Influence of Stacking Sequences on Tensile Behaviour of Areca-Kenaf Hybrid Epoxy Composite

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Abstract: Sustainability of the natural fibers and its composite had created the curiosity among researchers around the globe. Owing to their improved mechanical and thermal properties, natural fiber based materials are replacing the synthetic fibers in most of the automobile, packing industries, sports equipment and semi-structural applications. In this research, the tensile properties of hybrid composite made up of Kenaf and areca fibers in six different stacking sequences with constant 10 weight percentage of wood dust as filler material is studied. Unsaturated polyester resin is used as the matrix. The specimens are prepared by using hand lay-up technique. The prepared specimens are tested for tensile properties as per ASTM Standard and compared with stacking sequence one (S1).The test results revealed that stacking sequence six (S6) of the specimen which has Kenaf fiber as top and bottom layers has about 155% increase in tensile strength.

Keywords: About four key words or phrases in alphabetical order, separated by commas.

I. INTRODUCTION

In recent decades, the awareness towards sustainable product design made the composite industries to replace the synthetic fiber with natural fiber based material for automotive structural and semi-structural applications [1] Natural fibers are of low cost, have good mechanical properties and require less power for production[2].Among the available natural fibers Kenaf is one of the important plant that is cultivated around the world next to cotton. Kenaf fiber has comparatively good mechanical properties than glass fiber due to their low density[3].Few car parts like bumper beams, dashboards are replaced with Kenaf fiber[4]. It is used along with synthetic polymers in wall-boards, ceilings, furniture and interior lining, in automobiles[5].Similarly, areca fiber which is light weight, eco-friendly in nature also has good thermal and acoustic properties. Areca fibers originated in the Malaya peninsula, East India. It belong to the palmecea family and species of Areca Catechu Linnaeus. Composites made up of areca is used in packing materials, sports equipment, marine structures, low cost construction, etc.,[6]. Nano particles are used in polymer composite as potential filler materials that improves the physical and mechanical properties[7].Hybridization is the process of utilizing the combination of natural fibre along with natural filler material in the matrix to enhance mechanical properties and to reduce the water absorption capacity[8–10]. The mechanical properties of the composite filled with organic fillers are influenced by the parameters such as size of the filler, volume fraction, type of filler (chemical composition and shape) and distribution of the filler material [11].Several works have been carried out with natural filler materials in order to increase the mechanical properties of the composite.[12] Dhawan et.al. State that polyester-based composites with natural fillers provide improved results. This research article tries to explore the effect of stacking sequence on the tensile properties of treated areca and Kenaf fiber with constant weight percentage of saw dust as a filler materials. This composite has a potential applications in automotive, aerospace and construction industries. In this study, hybrid composite with six different stacking sequences of treated areca and Kenaf fiber with 10 wt.% saw dust as filler material is fabricated using unsaturated polyester resin by hand lay-up technique. The failure of the composite, interfacial bonding between the filler material, fibers and the matrix is studied by Scanning Electron Microscope (SEM).

Revised Manuscript Received on October 30, 2019.
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II. MATERIALS AND METHODS

A. Materials

The Kenaf and Areca fibers in mat format, Unsaturated Polyester resin along with Methyl Ethyl Ketone Peroxide (MEKP) catalyst and Cobalt accelerator are purchased from M/s. Go Green Products, Chennai, India. The Kenaf and Areca fibers in mat format are shown in figure 1.Saw dust is collected from local sawmill with a maximum particle size of 500 µm. The physical and mechanical properties of the Kenaf and Areca fibers are presented in the Table 1.

Retrieval Number F9035088619/2019©BEIESP
DOI: 10.35940/ijeat.F9035.088619
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Table 1. Physical and Mechanical Properties of Kenaf and Areca Fibers [6]

Properties	Kenaf Fiber	Areca Fiber
Diameter (μm)	1.4-11	396-476
Density (g/cm^3)	-	0.7-0.8
Length(mm)	12-36	10-60
Tensile strength (Mpa)	930	147-322
E-modulus (GPa)	53	1.124-3.155
Elongation at failure (%)	1.6	10.23-13.15
Cellulose (wt. %)	72	57.35-58.21
Hemicellulose (wt. %)	20.3	13-15.42
Lignin (wt. %)	9	23.17-24.16
Moisture absorption (%)	-	7.32

B. Surface modification of the reinforcement

Alkaline treatment of the kenaf and areca fibers are done with 10 wt. % of NaOH. The fibers were soaked for 30 hours at room temperature in the alkaline solution. Then the treated fiber is washed in running water and then it is neutralized with a 2% acetic acid solution. Finally the treated fiber is dried at room temperature for 48 hours. (Padmaraj et al. 2018)

C. Stacking Sequences

Stacking sequences of the fibers plays an important role in determining the properties of the laminate. In this experimental work six different stacking sequences of Kenaf and areca fibers are chosen. Each stacking sequences has five layers of fibers. The fiber content of around 30 wt. % is being maintained. The stacking sequences, wt. % of fibers and matrix of the composite laminate are shown in the table 2.

Table 2. Stacking sequences, wt. % of fibers and matrix of the composite laminate

S.No	Sample Code	Stacking Sequence	Weight of Fibers (gm.)	Wt.% of Fibers	Wt.% of matrix
1	S1	AKKKA	128	27	73
2	S2	AAKAA	146	30	70
3	S3	KKAKK	119	26	74
4	S4	KAKAK	128	27	73
5	S5	AKAKA	137	29	71
6	S6	KAAAK	137	29	71

III. Fabrication of Hybrid Composites

Figure 1. Shows the fabrication of the hybrid composite which is done using hand lay-up method. The moisture content of the wood dust is removed by drying them in hot oven of 80˚C for 24hours.In this process, the

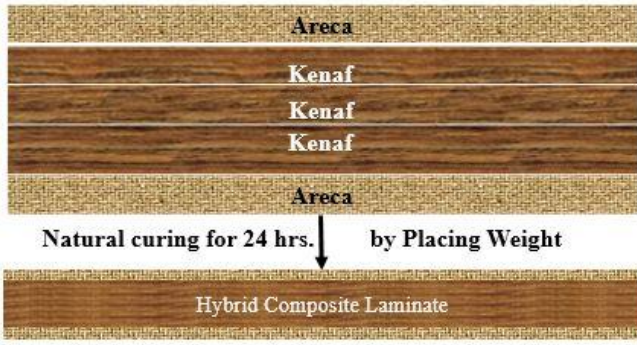

Fig.1 Fabrication of the hybrid composite

Kenaf and areca fibers in mat format are cut into 300 mm x 300 mm, then resin along with 10% of saw dust, 2% of catalyst and 2% of accelerator are mixed uniformly with a stirrer. Stacking sequence one (S1) is selected. It has five layers of fibers. The top and bottom layer of areca fiber and intermediate layers of Kenaf fibers. A mould of suitable size 300 mm x 300 mm x 5 mm is made up of wood plate and releasing agent (shoe wax) is applied to the mold surface. Resin mixture is applied to the mold surface and first layer of areca fiber is placed on the mould. A roller is used to roll on the fiber surface to remove the air gaps. It also to ensure the uniform distribution of the resin over the fibers. Again the resin is applied to the areca fiber and second layer of Kenaf fiber is placed on them. The resin is applied on them, then the same process is being repeated for all five layers and the fabrication of the composite material is completed. The fabricated composite material is allowed to dry in the room temperature for 24 hours by placing a weight on the laminates.

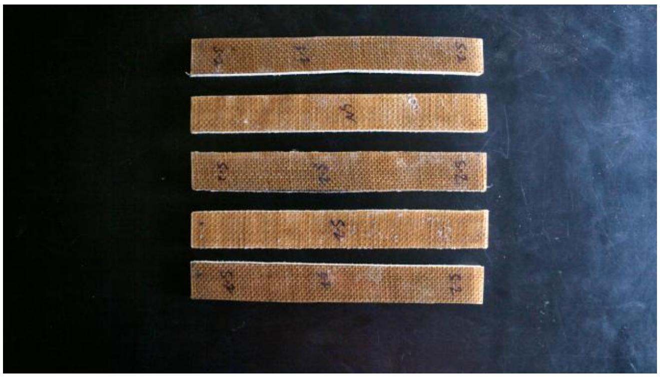

Fig.2 Tensile specimen of the hybrid composite

After curing process the laminates are cut into required dimension and tests are carried out as per ASTM standards. Figure 2 shows the cut specimen of tensile test.

IV. Characterization of the Composite

The objective of the characterization is to determine the tensile properties of the laminate with different stacking sequences with constant wt. % of filler material. The mechanical testing were carried out in Delta metallurgical & analytical laboratory, Chennai.

V. TENSILE TEST

Tensile strength of the materials is determined by tensile test method where the specimen is subjected to an axial pull along the fiber direction at uniform rate using a Universal Testing Machine (UTM). The specimen is pulled at a constant speed where there is a reduction in the cross sectional area and increase in the specimen length, the specimen is pulled until the failure of the specimen occurs. The corresponding test values like tensile strength are noted down. There are many standards prescribed by ASTM to conduct tensile test on the specimen based on the materials of the specimen. The ASTM standard D638-03 with a specimen size of 165 mm x 19 mm x actual thickness is used in this research work. The schematic representation of tensile standard of the specimen is shown in the figure3.

During this process, the elongation of the gauge section is recorded against the applied force. The cross-head speed was 2 mm/min and the gauge length maintained was 50 mm.

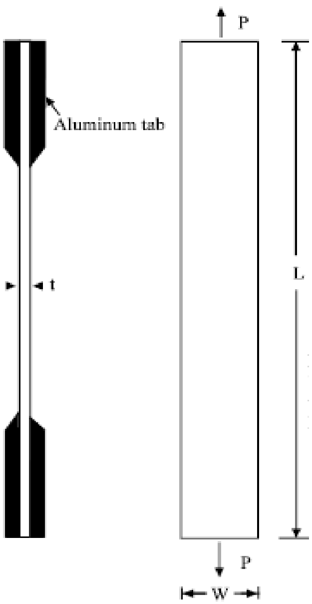

Fig.3 Tensile Test Standard

The Figure 4 shows the tensile testing of the composite specimen universal testing machine. The tensile test was conducted at 28 °C and at a relative humidity of 50 ± 2%.

Fig.4 Tensile Testing of the Specimen

The grippers held the specimen in the longitudinal axis and the load was applied over the specimen. The loads and the corresponding strains were noted. The tensile modulus and elongation at the break of the composites were calculated from the load-displacement curve. Three samples were tested for each composition and the mean value was reported.

VI. RESULT AND DISCUSSION

Tensile strength and tensile modulus of the hybrid composite made up of six different stacking sequences are presented in the figure 5 and 6. The maximum tensile strength and modulus of 55.09 Mpa and 1.32 GPa is observed for the specimen with stacking sequence six (S6) which is fabricated with Kenaf as the top and bottom layers, three layers of areca fibers as intermediate layers. Even though the specimen with alternate layers of areca and Kenaf fibers as in stacking sequence five (S5) has a tensile strength of 36.15 Mpa.

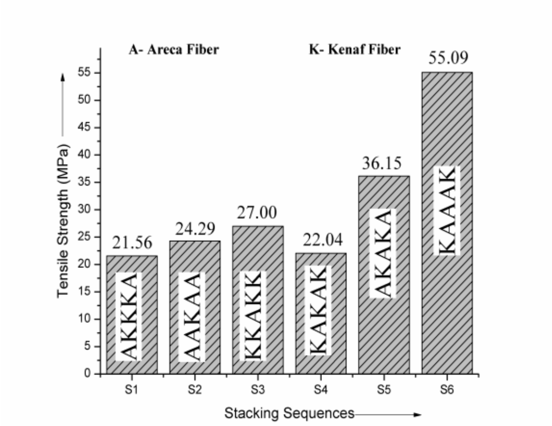

Fig.5 Tensile strength of hybrid composite with different stacking sequences.

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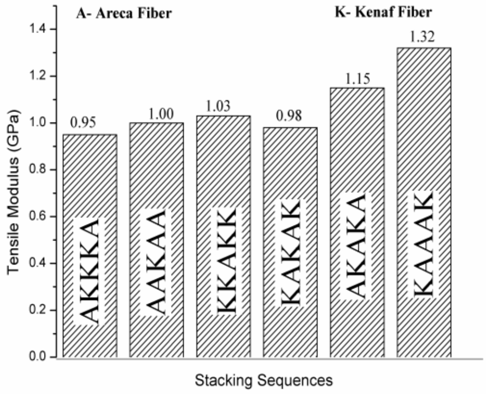

Fig.6 Tensile modulus of hybrid composite with different stacking sequences.

Similarly, the specimen with stacking sequences three (S3) is made up of top two and bottom two layers with Kenaf fibers has the tensile strength and modulus of 27 Mpa and 1.03 GPa. The specimen with stacking sequence two (S2), four (S4) and (S1) has the tensile strength of 24.29 Mpa, 22.04 Mpa and 21.56 Mpa and modulus of 1 GPa, 0.98 GPa and 0.95 GPa respectively. Stress Vs strain graph for the hybrid composite laminate is shown in the figure 7.Tensile strength and tensile modulus of the hybrid composite conclude that there is a good bonding between the areca and areca fibers followed by the Kenaf and areca fibers which enhances the tensile strength of the composite. There is poor bonding between the Kenaf and Kenaf fiber due to void formation, improper distribution of matrix on the Kenaf fiber surface resulting in poor wettability. Similar case was reported by [13] were the effect of stacking sequence on the Kenaf and banana fiber was studied .Highest modulus, tensile strength and flexural strength was obtained in the composite having outer layer of Kenaf and core of banana fibers.

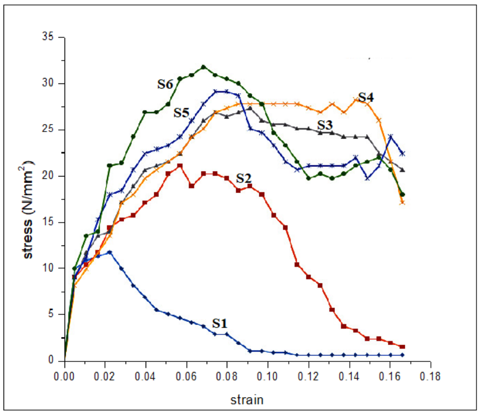

Fig.7 Stress Vs Strain Graph

VII. MORPHOLOGICAL ANALYSIS

The morphological analysis of the tested specimens are carried out by using scanning electron microscope (SEM).The SEM image of the tensile fractured specimens in figure 8 shows that there is a good bonding strength between the Kenaf and matrix materials.

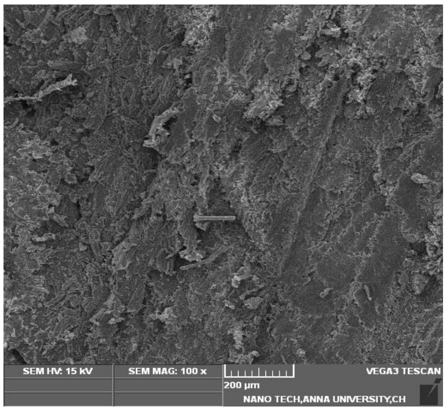

Fig.8 SEM image of Tensile Fractured Specimen

There is uniform dispersion of wood dust particle in the resin, this also increases the adhesion between the Kenaf and matrix material rather than areca fibers. The adhesion gradually decreases as the load increases and finally the composite fail as a single unit due to fiber pull out which leads to fiber breakage. There is less void present. In case of specimen with Kenaf and Kenaf fibers. The failure of the Kenaf and Kenaf based specimen is due to improper distribution of resin over the surface. There is poor wettability between the surfaces.

VII. CONCLUSION

In this work the tensile properties of hybrid composite made up of Kenaf and areca fibers in six different stacking sequences with constant 10 weight percentage of wood dust as filler material is evaluated and arrived at the following conclusions.

1. Among the six stacking sequences, the Specimen (S6) made up of Kenaf fiber as the top and bottom layers absorbs more tensile strength of 55 Mpa followed by the specimen (S5) made with areca fiber as the top layer which absorbs 36.15 Mpa. The least tensile strength is observed in the specimen (S1) which has areca fibers as top and bottom layers. Thus Kenaf fibers as top and bottom layers absorb more tensile strength when compared with top and bottom layers of areca fibers.
2. There is a good adhesion between Kenaf and matrix. The filler material wood dust particle uniformly dispersed in the unsaturated polyester resin.
3. The specimen (S2) made with top two and bottom two layers of areca fibers cannot absorb more tensile strength equivalent to a specimen (S6) which is made up of top and bottom layers with Kenaf fibers.

ACKNOWLEDGMENT

The authors would like to thank the Hon'ble Chairman, Vel Tech University, Chennai, India for providing the research facilities and support to publish the research paper. The authors are also thankful to Dr. R. Velu, Dr. P. Lakshmanan and Dr. P. Anand for their valuable guidance to carry out the research work.

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