Influences of Stacking Sequences on the Strength of Treated Kenaf/Carbon Fibers Reinforced Epoxy Hybrid Composites

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INFLUENCES OF STACKING SEQUENCES ON THE STRENGTH OF TREATED KENAF/CARBON FIBERS REINFORCED EPOXY HYBRID COMPOSITES

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ABSTRACT

The hybrid composite materials have assumed a massive importance in aerospace industry, automotive construction and marine sector as a way to enhance the physical and mechanical performance. Glass, Kevlar and light weight carbon fiber are in rise. The goal of this study is an experimental and numerical investigation: natural frequency, mode shape and damping properties of hybrid composite plates consisting of alkaline treatment kenaf mat (300 g/m²) fiber in 5% of NaOH concentration for 48h and unidirectional carbon fibers. Three Hybrid Composites Plates (HC01, HC02 and HC03) of 4 ply had manufactured using hand lay-up process with different fiber orientation ([0/0]s, [0/90]s and [0/45]s), where the carbon fibers had used in the top and bottom. As results, the effects of kenaf orientation have affected considerably on the stiffness and dissipate energy considerably (HCP0 was highly by 16% as compared to HCP90). Besides, the appearance of combined mode shape (flexural and torsional) in the case of [0/45]s plate.

Keywords: Hybrid composite, Hand lay-up, Natural frequency, Mode shape, Damping

INTRODUCTION

The polymeric materials are used in wide variety sectors due to the enhancement in properties, reduction in the manufacturing cost and suitability for several applications. Among different classifications, Polymer composites mainly focus on their use as structural components and the selection and composition of reinforcement play a vital role in determining their characteristics [1,2].

The fiber reinforced polymer composites are developed primarily using synthetic fibers (SFs) such as glass, carbon, Kevlar, Aramid, etc., due to their excellent characteristics. But the growth in environmental consciousness, community interest, the new environmental regulations and unsustainable consumption of man-made materials, led to thinking about the use of bio-friendly materials [3]. Owing that view natural fiber (NF) is considered as an alternative of synthetic fibers in the reinforcement of polymer composites have attracted the attention of many researchers and scientists due to their advantages over conventional glass and carbon fibers and others [4]. Among these natural fibers, flax, hemp, jute, sisal, kenaf, coir, Palm, banana, and many others are very much recognized now. The disadvantage of NF is their low mechanical properties compared to synthetic fibers. This can be overcome with the combination of two or more fibers. Hybridization is one of the effective ways to overcome the drawback of natural fibers [5].

Kenaf fibers are widely used in hybrid composites. Kenaf-glass hybrid composite laminated was developed for passenger car bumper beam, where shows an improvement in tensile properties [6]. A. Supian et al [7] found that incorporation of Kenaf fiber and glass fiber into epoxy resin showed high energy absorber properties compared to the pure glass fiber composite. Azrin Hani et al. [8] have demonstrated that woven kenaf and coir have a high potential to be used as reinforcing materials. N. Sapiai et al [9] investigated the improvements of mechanical properties of kenaf/carbon fiber composite using different stacking sequences; they found 0° unidirectional shows significant tensile properties compared to 90° angle.

The composite structures are subject to different mechanical loads, thermal and/or collision. Affected by earthquake, impact, noise, heating or external vibration, structures with FRP composites can be subjected to large excitation amplitudes in use [10]. In this work, interplay hybrid composites were prepared with carbon fiber and kenaf fiber as reinforcements and epoxy resin as the matrix. The objective of this study was to investigate the effect of different stacking sequences of fabric layers on the tensile properties and vibrational behavior of the hybrid composite, while scanning electron microscopy (SEM) was utilized to check the surfaces of chemical treatment of kenaf fiber.

MATERIALS AND METHODS

The common materials are selected over layup with various stacking sequences. Kenaf is a natural fiber which is collected from go Green Pvt. Limited, Chennai, India, and carbon is synthetic fiber was supplied by Spinteks Tekstil Ins. The epoxy resin employed in the present study is MEDA epoxy and the hardener is HY95. The various properties of the components are given in Table 1.

In order to ensure good adhesion with the epoxy resin (hydrophobic), the kenaf fibers were treated in an alkaline medium (Figure 1). At the beginning, a quantity of sodium hydroxyl NaOH was prepared in a bath of water (5 L) where its concentration was 6%. After 48h of impregnation, the treated fibers were washed with distilled water until the pH became neutral (PH=7). The treated fibers were dried in the oven at a temperature of 50° for 5 hours. A unidirectional arrangement was adopted with an areal density of 600 g/m², where the average fiber length was 250 mm.

a. b. c. d.

Fig. 1: Alkali treatment of kenaf fiber process

Table 01: Reinforcement mechanical properties

Components	Kenaf fiber	Carbon fiber
Tensile strength [MPa]	930	3800
Tensile Modulus [MPa]	60	240
Strain [%]	1.4	1.6
Areal density [g/m²]	600	300
Orientation angle	0°	0°

EXPERIMENTATION METHODS

- Scanning electronic microscopy SEM

Meanwhile, SEM was performed to identify and examine impurities on the surface of the kenaf-treated fibers. Magnifications ranging from 1.00 to 10.00 KX are offered. The samples were covered with gold before submitting it to the SEM.

- Tensile test

Tensile samples were prepared according to the ASTM D3039 standard. After cutting, the plates allowed us to have six different stacking sequences [0/0]s, [0/45]s, [0/90]s, [90/0]s, [90/45]s, [90/90]s. Five identical specimens in each sample were subjected to Zwick/Roell device of loading cell 50KN.

- Testing of hybrid composites beams for modal response

Modal characteristics of produced test specimens were determined using an experimental set-up as shown in Figure 4. A general purpose PCB 352C03 ceramic shear ICP ® accelerometer (Brüel & Kjær Sound & Vibration Measurement A/S, Nærum, Denmark) was used for output signal acquisition, a PCB 086C03 general purpose modal impact hammer was used for stimulus force signal, a National Instrument product NI cDAQ-9184 data acquisition device with m+p SO Analyzer software was used in the experiments.

For conducting the vibration test, one end of the specimen is rigidly fixed by work clamping device and the other end was left as free end for offering fixed-free boundary condition. A beam length of 180 mm was set as suspended length for impulse testing. Next, 5 points was marked on the specimens to excite using hammer fig. The responses are recorded in a personal computer (PC).

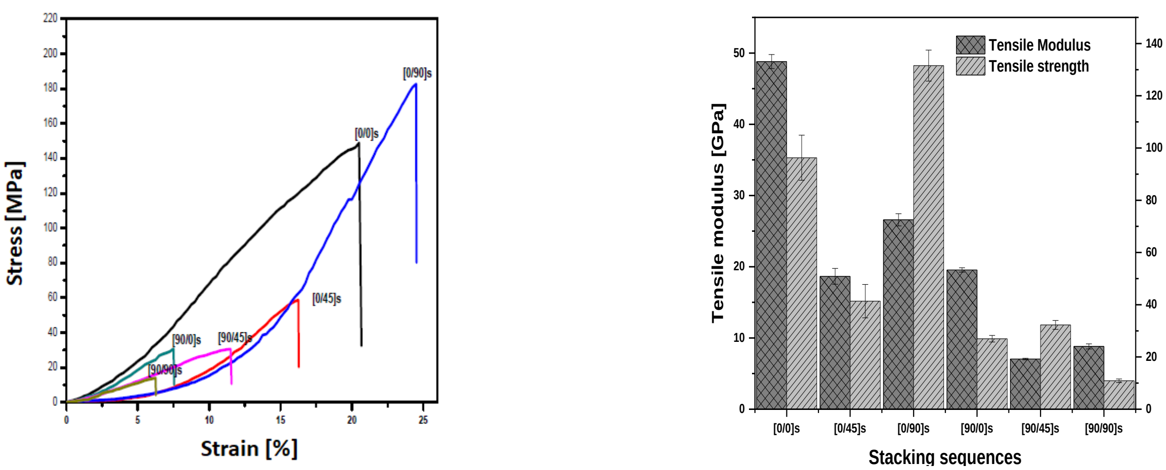
The determination of the effective modulus of various specimens were analyzed for the first resonance frequency level since the design approach prefers the first modal response as one of the major consideration for dynamic performance. The effective modulus (Eeff) of linear viscoelastic composite beam in flexural bending was calculated using the expression stated in ASTM E756 standard.

RESULTS AND DISCUSSION

Untreated kenaf fibers possessed impurities that were removed after immersing in NaOH solution. The treated fibers also appeared clean and rough, and had a clear physical appearance after alkaline treatment. This treatment was necessary to remove hemicelluloses, lignin, and wax from the fibers core.

The figure 2 (a, b) presents the evolution of the stress/strain of the typical curves. The specimens tested in this work have different stacking sequences: [0/0]s, [0/45]s, [0/90]s, [90/0]s, [90/45]s, [90/90]s, where the tensile surface was 40 mm2. All the curves present a similar behavior (fragile) with different performances. Due to the effect of density and morphology of kenaf fibers (porous), an important variation was noted on the properties of each group. In contrast, the stacking sequences leads to a significant variety on the stiffness and the resistance of the samples.

The figure 2 (b), shows us that the stress reaches higher values when the orientation of carbon fibers is 0° (parallel to the loading). Plus, the orientation of the kenaf fiber layers was less influence on the strength. This result is attributed to the high mechanical strength of carbon fiber compared to kenaf fiber. On the other hand, we observe that the orientation effect of the kenaf layers was considerable, where the hybrid [90/45]s has a high stress (37.07 MPa) compared to [90/0]s and [90/90]s (21% and 66%, respectively). From these, it is found that the strength was affected by the kenaf fiber when the orientation of carbon perpendicular to the loading.



a. b.

Fig. 2 : a, Typical stress/strain curves of the 6 stacking sequences, b, variation of tensile properties respect to the stacking sequence

The figure 3 Show the natural frequency and damping factor associated with the first three lowest frequency obtained by placing accelerometer at different periodic known location. Table 2 indicates modal frequency level for various kinds of test samples considered. The modal shape observed was related to transverse bending. The increase in natural frequency is found to depend upon the stiffness of the composite.

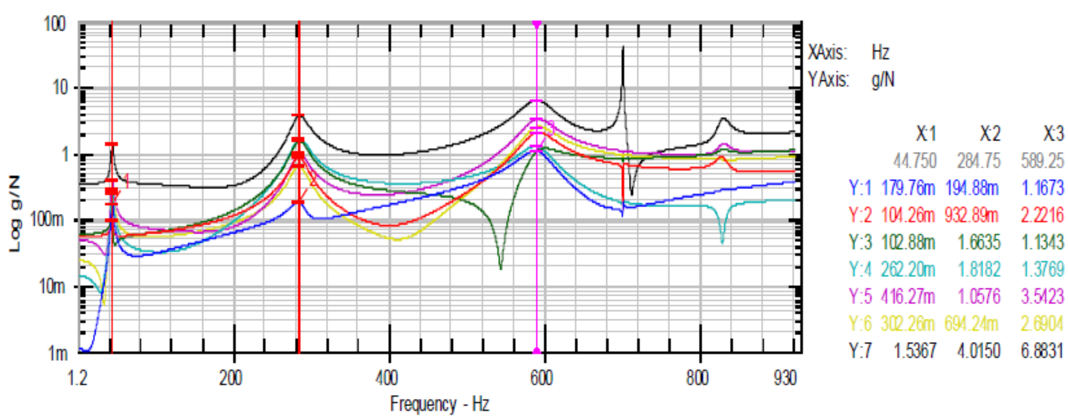


Fig. 3: typical plots of log vibration analysis versus frequency of composite stacking beam [90/45]s.

Table 2 : Natural frequencies and damping coefficients of hybrid composite fabricated

	[0.0]	[0.45]	[0.90]	[90.0]	[90.45]	[90.90]
f_1	145.68	107.23	76.3	42.66	44.74	41.84
f_2	560.55	512.91	486	243.84	284.84	240.33
f_3	1265.66	1114.33	1114.33	553.82	590	525.18
ξ 1	1.01	1.56	2.79	2.46	3.16	10.56
ξ 2	2.55	2.1	2.84	3.49	3.53	4.18
ξ 3	1.75	1.18	1.53	2.19	3.46	0.31

CONCLUSIONS

Based on the above experiments, the following conclusions were made:

- Alkali treatment led to clean and rough fiber surface by removing the impurities and wax.
- Experimental investigations shows a good mechanical performance of the hybrid composite fabricated compared to those in literature.
- The vibration tests were carried out on specimens with stacking [0/0]s [0/45]s [0/90]s [90/0]s [90/45]s [90/90]s led us to find that the orientation of the fibers plays an essential role on the change in frequency and damping factor. Further, the important damping factor was due to the presence of viscoelastic material (kenaf fiber)
- This material has remarkable mechanical and viscoelastic properties which allow us the possibility of exploiting it in various fields such as: the marine and automotive fields.

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