Free Vibration Behaviour of Alkali Treated Long Kenaf Fibre Reinforced Epoxy Composites

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***Abstract*—Two or more chemically different constituents combined macroscopically to yield a useful material are called composites. There are several naturally occurring composites such as Wood where cellulose fibers are bounded by lignin matrix, also bone and granite are typical examples of naturally occurring composites. Some of the manmade composites are concrete, plywood, glass, Kevlar etc. During recent times, due to increasing interest and research focus in eco-friendly materials, studies on natural plant fibers like Kenaf, Jute, Hemp, Coir are typically used in composites as reinforcing materials. These natural fibers are not only strong and light weight but also relatively cheap and biodegradable. Nowadays manufacturing sectors are in constant research of such materials having low density, low cost, corrosion resistance, good impact toughness as well as chemical resistance. The natural fibers have all these required properties and hence they serve as better replacement for the present materials in various fields including automotive industries. These natural fibers can be very advantageous composites when proper resin has been selected with it.**

Keywords—Long Kenaf fiber, Epoxy resin

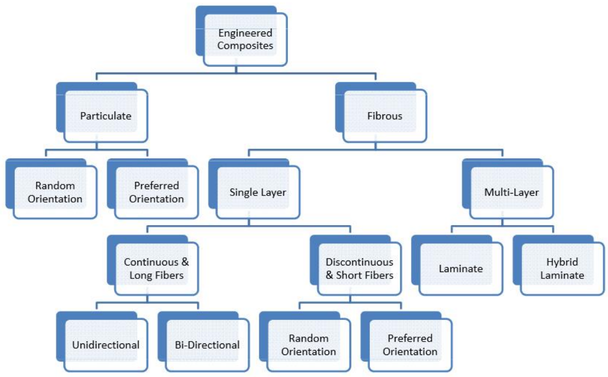
I. INTRODUCTION

The major automakers are increasingly turning to composites to help them meet performance and weight requirements, thus improving fuel efficiency. Cost is a major driver for commercial transportation, and composites offer lower weight and lower maintenance costs. typical materials are fiberglass/ polyurethane made by liquid or compression molding and fiberglass/ polyester made by compression molding. recreational vehicles have long used glass fibers, mostly for their durability and weight savings over metal. the product form is typically fiberglass sheet molding compound made by compression molding. For high-performance Formula 1 racing cars, where cost is not an impediment, most of the chassis, including the monologue, suspension, wings, and engine cover, is made from carbon fiber composites. The commercial applications of composites offer larger business opportunities. Hence introduction of these new polymer resin matrix materials and high performance reinforcement fibers of glass, carbon etc. and the penetration of these advanced materials has witnessed a steady expansion in uses and volume has resulted in reduction of cost. These Fiber Reinforced Polymers has huge applications such as in window panels, doors of automobiles, fuel cylinders, windmill blades, beams of bridges, drive shafts.

1.1 Definition Of Composites

A Composite material can be defined as a combination of two or more materials that results in better properties than those of the individual components used alone. In contrast to metallic alloys, each material retains its separate chemical, physical, and mechanical properties. the two constituents are a reinforcement and a matrix. the main advantages of composite materials are their high strength and stiffness, combined with low density, when compared with bulk materials, allowing for a weight reduction in the finished part**.**

1.2 Classification of Composites



1.2.1 Basic Types of Composites

Based on Matrix

1. Metal Matrix Composites (MMC)
2. Ceramic Matrix Composites (CMC)
3. Polymer Matrix Composites (PMC)

Based on Reinforcement

1. Fiber reinforced polymer (FRP)
2. Particle reinforced polymer (PRP)

1.2.2 FIBRE REINFORCED POLYMER

These fiber reinforced polymers (FRPs, here after referred to as conventional composites) are gaining popularity as primary and secondary structural materials in aerospace, marine, automobile, civil construction applications, sports industry, defense, renewable energy sectors, textile industries and other

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areas because of their inherent mechanical properties, such as low density, high strength-to-weight ratio, high stiffness-to weight ratio, excellent durability, dimensional stability, non-corrosive nature, good thermal and electrical insulation properties and ease of fabrication. In addition, anisotropic nature of composites made them easy to adopt its properties depending upon design requirements. Furthermore, many FRPs possess better internal damping which leads to high impact energy absorption within the material and results in reduced transmission of noise and vibration to neighboring structures. These are some of the main reasons for the popularity and success of conventional composites in structural and non-structural applications.

1.3 NATURAL FIBER REINFORCED COMPOSITE

The interest in natural fiber-reinforced polymer composite materials is rapidly growing both in terms of their industrial applications and fundamental research. They are renewable, cheap, completely or partially recyclable, and biodegradable. Plants such as flax, cotton, hemp, jute, sisal, Kenaf, pineapple, ramie, bamboo, banana, etc., as well as wood, used from time immemorial as a source of lignocelluloses fibers are more and more often applied as the reinforcement of composites. Their availability, renewability, low density, and price as well as satisfactory mechanical properties make them an attractive ecological alternative to glass, carbon and man-made fibers used for the manufacturing of composites. The natural fiber containing composites are more environmentally friendly and are used in transportation (automobiles, railway coaches, aerospace), military applications, building and construction industries (ceiling, paneling, partition boards), packaging, consumer products etc.

1.3.1 KENAF FIBER

Kenaf or its scientific name Hibiscus Cannabin's L is a warm season annual fiber crop closely related to cotton and jute. Historically, Kenaf has been used as a cordage crop to produce twine, rope and sackcloth. Nowadays, there are various new applications for Kenaf including paper products, building materials, absorbents and animal feeds. In Malaysia, realizing the diverse possibilities of commercially exploitable derived products from Kenaf, the National Kenaf Research and Development Program has been formed in an effort to develop Kenaf as a possible new industrial crop for Malaysia. The government has allocated RM12 million for research and further development of the Kenaf-based industry under the 9th Malaysia Plan (2006–2010) in recognition of Kenaf as a commercially viable crop. Kenaf has a single, straight and branchless stalk. Kenaf stalk is made up of an inner woody core and an outer fibrous bark surrounding the core. The fiber derived from the outer fibrous bark is also known as bast fiber. Kenaf bast fiber has superior flexural strength combined with its excellent tensile strength that makes it the material of choice for a wide range of extruded, molded and non-woven products. Kenaf fiber could be utilized as reinforcement material for polymeric composites as an alternative to glass fiber.

Fig. 1. Kenaf plant and combed fiber.

II. EXPERIMENTAL DETAILS

2.1 MATERIALS

The fiber used in this case is long kenaf fiber sizes ranging from 350µm to 500µm and the epoxy used in this study is LY-556 along with 10% of hardener.

2.2 ALKALI TREATMENT

Kenaf fibers were soaked for 24 hours with 4% NaOH solutions. The fibers were further washed with distilled water thoroughly, rinsed, and left to dry in an open atmosphere at room temperature and then under sunlight.

2.3 COMPOSITE PREPARATION

Kenaf fiber-epoxy composites were fabricated in the form of plate using a stainless steel mould measuring 210×90×4 mm. Each layer of fabric was pre-impregnated with matrix Material and these layers were placed one over the other in the mold with care to maintain practically achieved tolerance on fiber alignment. Hand lay-up technique is used to prepare specimen as shown in Figure. 2. The working surface was cleaned with thinner to remove dirt and a thin coat of wax is applied on the surface to get smooth finish. Then a thin coat of general purpose wax is applied for easy removal of mold. Kenaf fibers are cut to the required dimensions for test specimen pre-impregnated with matrix material and placed one over the other in the mold, simultaneously applying resin on the layers. Casting was cured under light pressure for 24 hours before removal of mold. All test specimens were molded and prepared according to ASTM-D standard to avoid edge and cutting effect, thereby minimizing stress concentration effect.

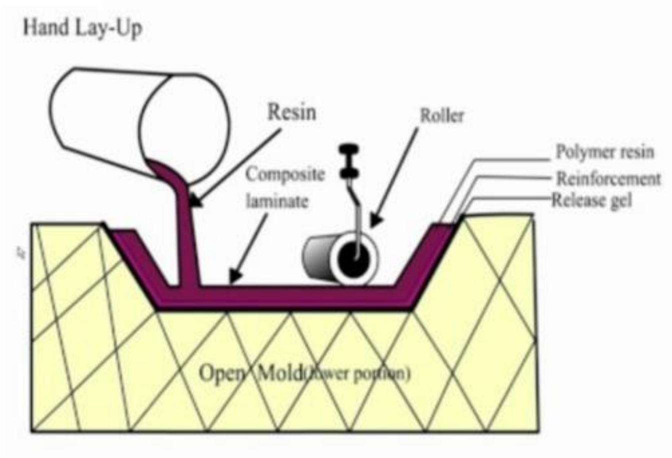

Fig. 2. Hand Lay Up Process

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Fig. 3. Layers of Fiber.

Fig. 4. Final Composite Specimen.

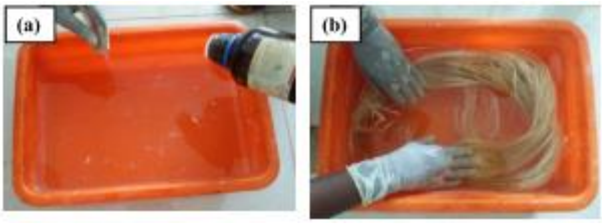

Fig. 5. Alkaline treatment of fibers.

2.4 DIFFERENT COMPOSITION OF SPECIMENS

SPECIMEN	MATRIX (%)	FIBRE (%)
A	70	30
B	60	40
C	50	50

Table. 1. Specimen composition by percentage weight.

2.5 TEST METHODS

2.5.1 MODAL ANALYSIS

Modal analysis is a technique used to study the dynamic characteristics of a mechanical structure. Moreover, this technique can describe a structure in terms of its natural characteristics which are the natural frequency, damping and mode shapes. There are two well-known methods for performing modal analysis, namely impact test and vibration shaker. From a theoretical standpoint, the measured Frequency Response Functions (FRF) may be obtained with both, but there are usually differences due to practical aspects related to data collection. In this study, modal analysis is performed with the help of an impact hammer test (PIEZOELECTRIC TYPE). The photograph of the experimental setup and the line diagram are shown in Figures 6. It is comprised impact hammer with a sharp hardened tip (Kistler model 9722A500), and accelerometer attached to the end of the rectangular composite laminate with wax. This system is used for obtaining higher frequencies and the hitting with the impulse hammer occurs at 42 equally spaced nodes of the laminate. The displacement signal from the accelerometer is recorded in a PC using data acquisition system (DAS), (DEWE43) and ICP conditioner (MSIBRACC). Two separate adaptors are used for capturing the output signal, one forth accelerometer signal and the other for the hammer response after impact with the laminate.

2.5.2 DAMPING FACTOR

Damping is vital to the study of the dynamic characteristics of fiber reinforced composites. Damping mechanisms in natural fiber composites differ entirely from those in conventional material sand energy dissipation depends upon factors like viscoelastic nature of matrix and/or fiber, interphase, damage and other characteristics. In particular, damping of materials with natural fiber is difficult to study, due to their chemical constituents. Nevertheless, it shows good damping characteristics due to their inherent porous nature. The half-power band width method is employed to find the damping coefficient values of kenaf fiber reinforced composites through FRF curves obtained from the FFT analyzer.

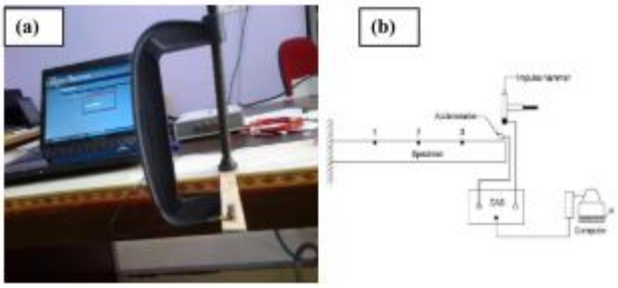

Fig. 6. (a) Experimental setup of Modal analysis, (b) Line diagram.

III. CALCULATIONS

- DIMENSIONS OF MOULD: - L=180mm, B=90mm, H=4mm
- VOULUME OF MOULD= L×B×H= 64800mm³
- Density of kenaf fiber= 1.13 gm/cm³
- Density of epoxy resin= 1.17 gm/cm³

For specimen A,

Calculations for 70% epoxy resin and 30% kenaf fiber.

- Density of composite (ρ_c)

  $(1/\rho_c) = (W_f / \rho_f) + (W_m / \rho_m)$

  $= (0.3 / 0.00113) + (0.7 / 0.00117)$

  $\rho_c = 1.1617\times10^{-3}$ gm/mm³

- Weight of the composite

  $W_c = \rho_c \times V_c$

  $= 1.1617\times10^{-3} \times 64800$

  $W_c = 75.54$gm

- Volume of fiber and matrix.

  $V_f = 0.3\times64800 = 19440$ gm/mm³

  $V_m = 0.7\times64800 = 45360$ gm/mm³

- Weight of fiber and matrix.

  $W_f = 1.13\times10^{-3}\times19440 = 21.967$gm

  $W_m = 1.17\times10^{-3}\times45360 = 53.071$gm

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Therefore, for 30:70 specimen (A) weight of the composite is 75.54gm and weight of fiber and matrix are 21.967gm and 53.071gm respectively. Similarly, calculations are made for all the three different composition and specimens are prepared.

IV. MODAL ANALYSIS RESULTS AND DISCUSSION

The first three modes of fundamental natural frequencies of long kenaf fiber reinforced composite structures are studied. The first three modes of deformation pattern that exist in the structure are named bending (Mode 1), twisting (Mode 2) and second bending (Mode 3), and are also known as the mode shapes of the structure.

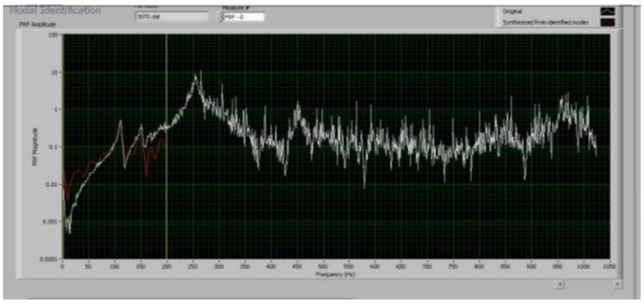

Fig. 7. FRF graph for specimen A

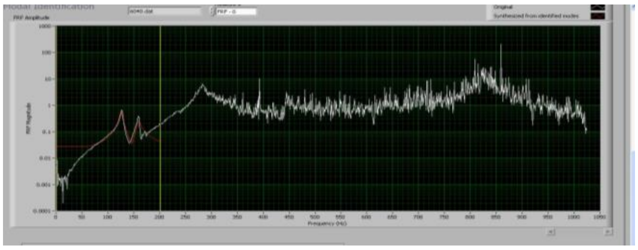

Fig. 8. FRF graph for specimen B.

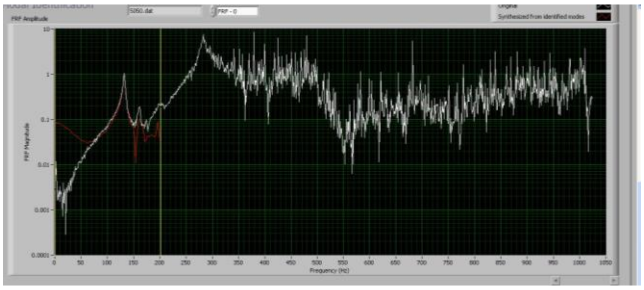

Fig. 9. FRF graph for specimen C.

SPECIMEN	FREQUENCY (Hz)			DAMPING RATIO		
	MODE 1	MODE 2	MODE 3	MODE 1	MODE 2	MODE 3
A	111	142	150	0.0179	0.0346	0.0783
B	126	158	179	0.0158	0.0250	0.0458
C	152	163	173	0.0343	0.0405	0.0251

TABLE 2. Comparison of natural frequency and damping ratio of three different specimens.

4.1 CONCLUSION

The following points can be drawn as conclusions from the experimental study of free vibration behavior of alkali treated long kenaf fiber reinforced epoxy composites.

1. The composite specimens prepared are subjected to free vibrational test and the results were analyzed and compared.
2. This investigation revealed that different composition of fiber influences the enhanced properties of composites.
3. It can be observed that the damping ratio of the kenaf fiber ranges around 0.02 to 0.04 and is 50% higher than that of the glass composites and hence these fibers are having a better vibration damping properties.
4. By using natural fiber based composite materials, it is possible to create a composite laminate with superior vibration damping performance without sacrifices in stiffness-to-weight ratios.
5. It can also be observed that with increase in the fiber percentage by weight, the natural frequency and the damping factor also increases, resulting in a better vibrational damping.
6. These composites can find a suitable application in automotive body parts such as panels and frames as well as in transportation and housing goods.

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