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Vibrational Characteristics of Kenaf & Coir /Epoxy Hybrid Composite

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ABSTRACT: This work presents a combined experimental and numerical study of free vibration of kenaf & coir /Epoxy composite plates. Experimental setup and procedure of the modal testing method is described. Fabrication procedure of the plate is described. Geometrical properties are determined. Elastic parameters of the plate are determined experimentally by tensile testing of specimens. A computer program based on FEM has been developed to perform all necessary computations. The program results compared with other existing literature. The natural frequencies of Ratio(25-75), Ratio(30-70), ratio(35-65) kenaf & coir /Epoxy cantilevered composite plates has been determined experimentally and compared with the present program. The natural frequency and mode shape of the plate has been determined using ANSYS package. The present experimental value and program result compared with ANSYS package. The effects of varying the parameters upon the free vibration frequencies are discussed for taken ratio cantilevered and all edge clamped kenaf & coir /epoxy composite plates by using the program.

KEYWORDS: Tensile test, FEM Analysis, Natural frequency, Mode shapes.

1. INTRODUCTION

Composite material is a material composed of two or more distinct phases (matrix phase and reinforcing phase) and having bulk properties significantly different from those of any of the constituents. Many of common materials (metals, alloys, doped ceramics and polymers mixed with additives) also have a small amount of dispersed phases in their structures, however they are not considered as composite materials since their properties are similar to those of their base constituents (physical property of steel are similar to those of pure iron). Favorable properties of composite materials are high stiffness and high strength, low density, high temperature stability, high electrical and thermal conductivity, adjustable coefficient of thermal expansion, corrosion resistance, improved wear resistance etc.

Due to the requirement of high performance material in aerospace and marine structures, the prospect of future research of composite material, such as FRP (Fiber Reinforced Plastic) is very bright. Analysis of natural frequency and properties of composite plate has started from 40 years ago.

Narita and Leissa (1991) presented an analytical approach and accurate numerical results for the free vibration of cantilevered, symmetrically laminated rectangular plates. The natural frequencies are calculated for a wide range of parameters: e.g., composite material constants, fiber angles and stacking sequences.

Qatu and Leissa (1991) analyzed free vibrations of thin cantilevered laminated plates and shallow shells by Ritz method. Convergence studies are made for spherical circular cylindrical, hyperbolic, paraboloidal shallow shells and for plates. Results are compared with experimental value and FEM. The effect of various parameters (material number of layers, fiber orientation, curvature) upon the frequencies is studied.

Liu and Huang (1994) studied to solve free vibration problems for thick cantilever laminated plates with or without a step-change of thickness in the chord-wise direction by combination of three dimensional FEA and transfer matrix method. Both symmetric and non symmetric, isotropic and laminated plates are considered. For laminated plates, natural frequency with different fiber orientations is studied.

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Free vibration analysis of symmetrically laminated, rectangular plates with clamped boundary conditions is studied using the hierarchical finite element method by Han and Petyt (1995). The frequencies produced using the hierarchical finite element method closely with results in the published literature using a Rayleigh-Ritz type of analysis.

Linear vibration analysis of laminated rectangular plates has been reported by Han and Petyt (1996), who describe the free and forced vibration analysis of symmetrically laminated rectangular plates with clamped boundary condition using hierarchical finite element techniques.

The natural frequencies and corresponding vibration modes of a cantilever sandwich beam with a soft polymer foam core are predicted using the higher-order theory for sandwich panels (HSAPT), a two-dimensional finite element analysis, and classical sandwich theory by Sokolinsky, Bremen, Lavoie and Nutt (2004).

From the above literature review, we understood that the Plenty of work has been done on a number of natural fibers combining with polymer matrices, resulting in improvement in mechanical properties of the composites compared with the matrix material. The major disadvantage of natural fiber reinforced composites is their property to absorb moisture. Accordingly number of researches has been done to understand and improve this quality of natural fiber reinforced composites. Various studies have been done to understand the vibrational characteristics of different fibers reinforced composites. However kenaf & coir reinforced composite vibrational characteristics studies have not been done so far.

II. EXPERIMENTAL PROGRAMME

2.1 FABRICATION METHOD

To meet the wide range of needs this may be required in fabricating composites, the industry has evolved over a dozen separate manufacturing processes as well as a number of hybrid processes. Hand lay-up and spray-up are two basic molding processes. The hand lay-up process is the oldest, simplest, and most labour intense fabrication method. The process is most common in FRP marine construction. In hand lay-up method liquid resin is placed along with reinforcement (woven glass fiber) against finished surface of an open mould. Chemical reactions in the resin harden the material to a strong, light weight product. The resin serves as the matrix for the reinforcing glass fibers, much as concrete acts as the matrix for steel reinforcing rods. The percentage of fiber and matrix was 50:50 in weight.

Contact molding in an open mould by hand lay-up was used to combine plies of WR in the prescribed sequence. A flat plywood rigid platform was selected. A plastic sheet was kept on the plywood platform and a thin film of polyvinyl alcohol was applied as a releasing agent by use of spray gun. Laminating starts with the application of a gel coat (epoxy and hardener) deposited on the mould by brush, whose main purpose was to provide a smooth external surface and to protect the fibers from direct exposure to the environment. Ply was cut from roll of woven roving. Layers of reinforcement were placed on the mould at top of the gel coat and gel coat was applied again by brush. Any air which may be entrapped was removed using serrated steel rollers. The plates were left for a minimum of 48 hours before being transported and cut to exact shape for testing. The following constituent materials were used for fabricating the plate:

1. Kenaf/Coir hybrid fiber
2. Epoxy as resin
3. Hardener as diamine (catalyst)
4. Polyvinyl alcohol as a releasing agent



Fig 2.1.1 Compression Moulding Machine



Fig 2.1.2: pattern of kenaf & coir/Epoxy composite specimen

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2.2 DESCRIPTION OF TEST SPECIMEN

In order to respect the assumptions of classical theory of bending of thin plates with small deflections, keep the thickness of plate smaller than 1/5th the largest dimension of the plate. The thickness of test plates was even more reduced up to 1/10th of the largest dimension of the plate, in order to keep resonant frequencies of the test structure as low as possible, thus assuring good vibration measurement. The kenaf & coir/ Epoxy plates were prepared to cast as cantilevered one. Three (25-75 ratio and 30-70 ratio and 35-65 ratio) Plates were properly inserted to the concrete inside the moulds and compacted through the vibrators. After seven days of curing the concrete was used for testing.

Plate no	Total length (cm)	Fiber/Epoxy Ratio (%)	Cantilevered length (cm)	Breadth (cm)	Thickness (cm)
1	20	25-75	15	1.2	0.3
2	20	30-70	15	1.2	0.3
3	20	35-65	15	1.2	0.3

Table 1: Length (a), breadth (b), Thickness (h) of the Kenaf/Coir Plate

2.3 DETERMINATION OF MATERIAL CONSTANTS

The characteristics of kenaf & coir / Epoxy composite plate which can be defined completely by four material constants: E1, E2, G12, and ν_{12} where the suffixes 1 and 2 indicate principal material directions. For material characterization of composites, laminate having given ratio was manufactured to evaluate the material constants. The constants are determined experimentally by performing tests on specimens cut in longitudinal and transverse directions, as described in ASTM standard: D 638-08 and D 3039/D 3039M -2006. A thin flat strip of specimen having a constant rectangular cross section was prepared in all cases. The dimension of the specimen was taken as below:

Sample No.	CS Area(mm ²)	Peak Load(N)	%Elongation	UTS [N/mm ²]
Ratio(25-75)	39.00	740.87	1.220	18.99
Ratio(30-70)	39.00	1510.75	1.633	38.74
Ratio(35-65)	75.00	2215.12	0.667	29.53

Table 2: Tensile Strength Properties

Sample No.	CS Area(mm ²)	Peak Load(N)	Flexural Strength(MPa)	Flexural Modulus (GPa)
Ratio(25-75)	39.00	39.132	31.607	308.106
Ratio(30-70)	39.00	53.121	42.905	2063.422
Ratio(35-65)	39.00	77.509	62.603	744.798

Table 3: Bending Properties

Sample Number	Izod Impact Value for 3 mm Thick Specimen in J
Ratio(25-75)	0.40
Ratio(30-70)	0.30
Ratio(35-65)	0.35

Table 4: Izod Impact Properties

2.4 SETUP AND PROCEDURE

The connections of FFT analyzer, laptop, transducers, modal hammer, and cables to the system were done as per the guidance manual. The lab view software key was inserted to the port of laptop. The plate was excited in a selected point by means of a small impact hammer (Model 2302-5), preferably at the fixed end. The input signals captured by a force transducer, fixed on the hammer. The resulting vibrations of the plate in a select point are measured by an

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accelerometer. The accelerometer (B&K, Type 4507) was mounted on the plate to the free end by means of bees wax. The signal was then subsequently input to the second channel of the analyzer, where its frequency spectrum was also obtained. The response point was kept fixed at a particular point and the location of excitation was varied throughout the plate. Both input and output signals are investigated by means of graph-analyzer and resulting frequency response functions are transmitted to a computer for modal parameter extraction. The output from the analyzer was displayed on the analyzer screen by using pulse software. Various forms of Frequency Response Functions (FRF) are directly measured.



Fig2.4.1: Modal Hammer Fig2.4.2:Bruel & Kajer FFT Analyzer Fig2.4.3:Vibration testing of GFRP

However, the present work represents only the natural frequencies and mode shape of plates. The spectrum analyzer provided facilities to record all the data displayed on the screen to a personal computer's hard disk or laptop and the necessary software. Normally in order to determine the natural frequencies of a system, recording the response spectrum for an excitation, where the excitation level is constant over the frequency band under consideration will suffice. However, it was observed, from the auto-spectrum of the excitation force, that it was not possible to maintain such uniform excitation in case of composite plates. So, test should be within linear range. The hammer excitation method is fast and simple method. A sharp impact pulse corresponds to a large frequency domain. Unfortunately, since the energy of the force pulse is limited, the method has poor signal to noise characteristics, but the noise can be minimized by using an adequate weighting function. Nevertheless, the composite plates showed very rapidly to have frequencies above 500Hz, which are difficult to excite with enough energy by means of a hammer.

III. RESULTS AND DISCUSSION

The natural frequency from ANSYS with experiment results is compared. The program value is closely agreed with the ANSYS value. The natural frequency decreases with increase of mode no. Mode shape of the three Kenaf/Coir composite plates is drawn by ANSYS which is shown below.

3.1 MODE SHAPES FOR RATIO (25-75)

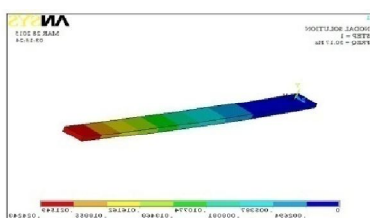


Fig 3.1.1: Mode No 1 (30.17 Hz)

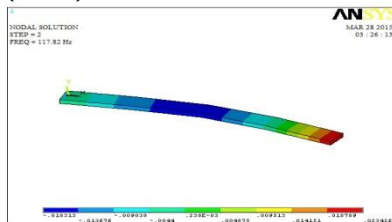


Fig 3.1.2: Mode No 2 (117.82 Hz)

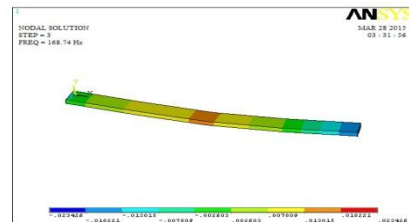


Fig 3.1.3: Mode No 3 (168.74 Hz)

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3.2 MODE SHAPES FOR RATIO (30-70)

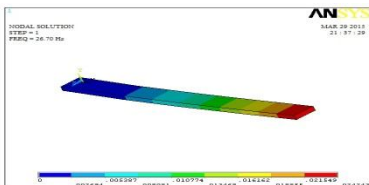


Fig 3.2.1: Mode No 1 (26.70 Hz)

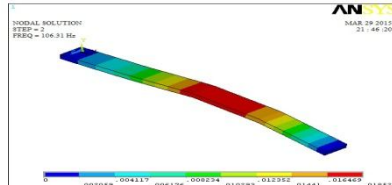


Fig 3.2.2: Mode No 2 (106.31Hz)

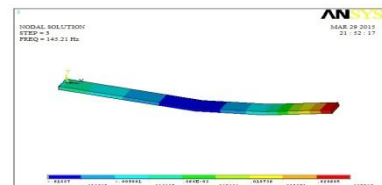


Fig 3.2.3: Mode No 3 (145.21Hz)

3.3 MODE SHAPES FOR RATIO (35-65)

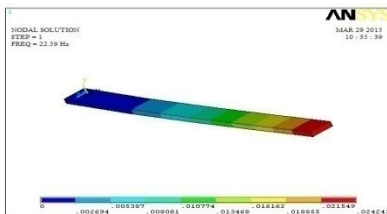


Fig 3.3.1: Mode No 1 (22.59Hz)

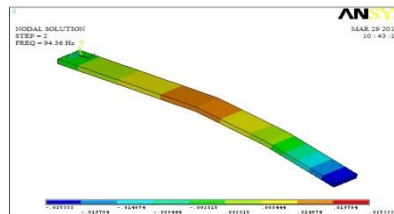


Fig 3.3.2: Mode No 2 (94.36Hz)

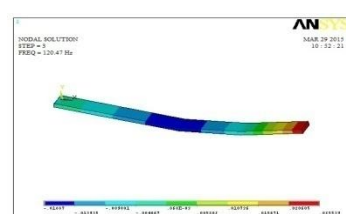


Fig 3.3.3: Mode No 3 (120.47Hz)

3.4 EXPERIMENTAL MODE SHAPES FOR RATIO (25-75)

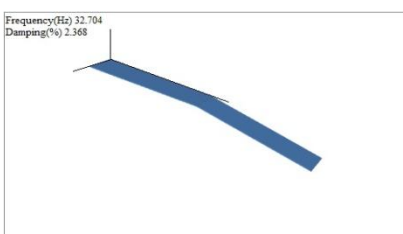


Fig 3.4.1 Mode View 1

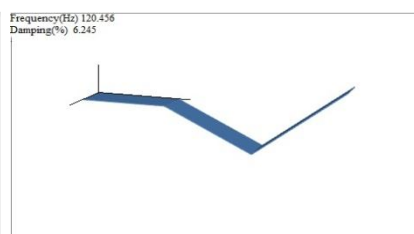


Fig 3.4.2 Mode View 2



Fig 3.4.3 Mode View 3

3.5 EXPERIMENTAL MODE SHAPES FOR RATIO (30-70)

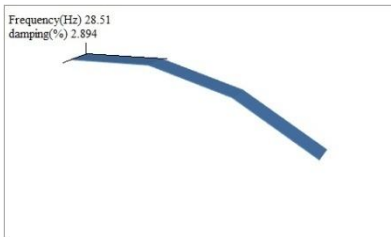


Fig 3.5.1 Mode View 1

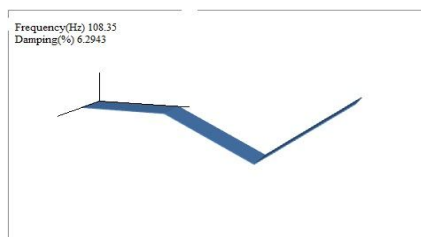


Fig 3.5.2 Mode View 2

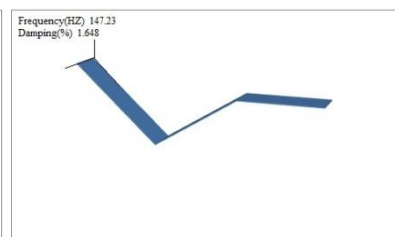


Fig 3.5.3 Mode View 3

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3.6 EXPERIMENTAL MODE SHAPES FOR RATIO (35-65)

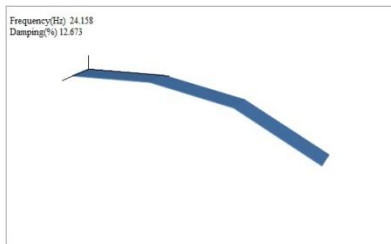


Fig 3.6.1 Mode View 1

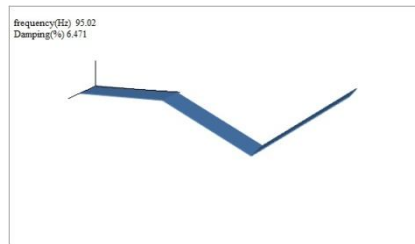


Fig 3.6.2 Mode View 2

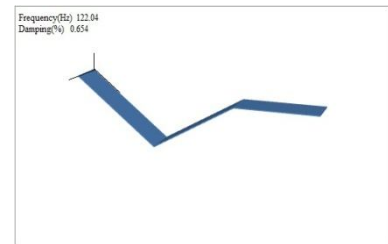


Fig 3.6.3 Mode View 3

PlateNo	Fiber/Resin ratio (%)	ModeNo	Experimental Natural frequency (Hz)	ANSYS Natural frequency (Hz)
1	25-75	1	32.704	30.17
		2	120.456	117.82
		3	172.549	168.72
2	30-70	1	28.51	26.70
		2	108.35	106.31
		3	147.23	145.21
3	35-65	1	24.158	22.59
		2	95.02	94.36
		3	122.04	12.47

Table No 5: Comparison of Experiment Result With ANSYS

Natural frequencies of kenaf & coir / epoxy cantilevered composite plates were measured by modal hammer testing method. Natural frequencies of (25-75) ratio, (30-70) ratio and (35-65) ratio kenaf & coir / epoxy cantilevered composite plates were found out experimentally. FEM has used to measure the frequencies of the plates. The experimental and ansys values were compared. From experimental result, natural frequency and mode shapes are measured.

VI. CONCLUSION

The natural frequencies of three varieties of cantilever laminated plates have been reported. The program result shows in general a good agreement with the existing literature. The experimental frequency data is in fair agreement with the program computation. The Percentage of error between experimental value and ANSYS package is within 15%. The difference is probably due to uncertainty in elastic properties and other described reasons. From different boundary condition (cantilever and all edge fixed), it is found that the natural frequency of all edge fixed plate is very higher than cantilever plate. Program results show clearly that changes in elastic properties yield to different dynamic behavior of the plates. Natural frequency decreases with the increasing of a/b ratio, b/h ratio, and density value. Whereas, it increases with the increase of shear modulus, and elastic modulus. It increases slightly with Poisson's ratio variation; but it is comparatively insensitive. Natural frequency decreases as the ply orientation increases up to 300 and again increases up to 300. The lowest value is at 100 ply orientation.

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