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DESIGN AND FABRICATION OF VIBRATION DAMPING PAD USING LUFFA CYLINDRICA FIBER REINFORCED POLYMER COMPOSITE

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Abstract:

The present study deals witha vibration analysis ofLuffa cylindrical fabric reinforced epoxycomposites. The Luffacylindrica composite are prepared by hand lay-up technique using treated Luffa cylindrical as reinforced materials and commercially available epoxy resin as a matrix material. Luffacylindrica fabricreinforced epoxy composite was fabricated by short fibre of 2mm length and compared with the luffa cylindrical mat. In the analysis, a frequency domainmodel is used along with Frequency Response Function (FRF) measurements obtained from the plate. Thesemeasurements are made using a Fast Fourier Technique (FFT) based spectrum analyzer. Damping factor are obtained from the composites.

Index Terms: Polymer Matrix Composite, Epoxy, Damping Factor & Frequency

1. Introduction:

Damping is an important modal parameter for thedesign of structures for which vibration control andcyclic loading are critical. Damping is also a significantfactor for the fatigue life and impact resistanceof structures. All engineering materials dissipate energy under cyclic load. Some of them, such aselastomer, plastic, and rubber, dissipate much moreenergy per cycle than metallic materials. Dampingvaries with different environmental effects, suchas frequency, amplitude of stress, temperature, andstatic preload. Damping is also affected by corrosionfatigue, grain size, porosity, and number of fatiguecycles, especially for metallic materials. There is a functional relationship betweendamping and all the effective factors.

Polymer matrix composites are commonly usedin weight sensitive structures due to their highstiffness-to-weight ratios. They are especially significantin aircraft, aerospace, and military applications.In recent years, the natural fibre reinforced composites have attracted substantial importance as a potentialstructural material. The attractive features of the natural fibres like jute, sisal, coir, banana and luffa have been their low cost, light weight, high specific modulus, renewability and biodegradability.

Even though the basic concepts of compositematerials were known from ancient times, the development of advanced composite materials such as boron epoxy, Kevlar epoxy, glass epoxy, carbon epoxy, etc., suitable for modern engineering applications has received attention only in recent past.Non-conventional fibres such as jute, sisal, coir, banana, palm fibers etc., are extracted fromstem/leaf/fruit of plants. Among all these fibers, luffacylindrica have advantage over others. This fibre possesses shock absorbing property and sound proofing property naturally.

The objective of the present work is to determine the damping factor and mode shapes for aRectangular symmetric plate of Luffa cylindrical fabric reinforced epoxy composite using a Fast Fourier Technique (FFT) based spectrum analyzer.

2. Experimentation:

2.1 Materials:

Figure 1: Luffacylindrica fruit

Luffacyllindica, locally called, as 'Sponge-gourds' is one such natural resource whose potential as fiber reinforcement in polymer composite has not been explored to date. It has a ligneous netting system in which the fibrous cords are disposed in a multidirectional array forming a natural mat. This fibrous vascular system is composed of fibrils glued together with natural resinous materials of plant tissue. The main chemical constituents of luffa are Hemicellulose, cellulose and lignin. Cellulose and hemicellulose are present in the form of hollow cellulose in luffa which contributes to about 82 % of the total chemical constituents present in luffa. Another important chemical constituent present in luffa is lignin. Lignin acts as a binder for the cellulose fibers and also behaves as an energy storage system. The luffa sponge material exhibits remarkable stiffness, strength andenergy absorption capacities that are comparable to those of some commonly used metallic cellular materials in a similar density range. In fact, a comparative study shows that the luffa sponge material outperforms a variety of traditional engineering materials.

Epoxy resins are polymeric or semi-polymeric materials, and as such rarely exist as pure substances, since variable chain length results from the polymerisation reaction used to produce them. High purity grades can be produced for certain applications, e.g. using a distillation purification process. One disadvantage of high purity liquid grades is their tendency to form crystalline solids due to their highly regular structure, which require melting to enable processing.An important characteristic of epoxy resins is the epoxide content. This is commonly expressed as the epoxide number, which is the number of epoxide equivalents in 1 kg of resin (Eq./kg), or as the equivalent weight, which is the weight in grams of resin containing 1 mole equivalent of epoxide (g/mol). In the present work Hardener (araldite) HY 951 is used. This has a viscosity of 10-20 poise at 250C.

2.2 Fiber extraction

The fruit of the sponge-gourd (L. cylindrica) plant which is of the Cucurbitaceae family is shown in fig 1. The ripe fruit shown in has a thick peel and the sponge gourd, which has a multidirectional array of fibers comprising a natural mat, presents an inner fiber core and an outer mat core. Fiber of luffaacutangala is extracted by means of peeling of the skin by manually. Then the fiber has chopped to 2 mm thickness and for mat the edges are cut to get a rectangle shape of size 140mm*100mm.

(a) **(b)**

Figure 2: Luffacylindrical (a) short fiber, (b) mat structure.

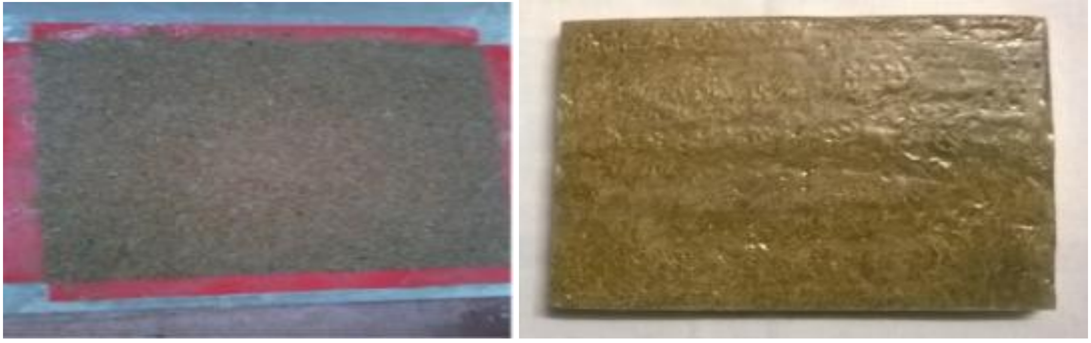
2.3 Chemical Treatment:

Natural fibers have the advantages of low density, low cost, and biodegradability. However, the main disadvantages of natural fibers in composites are the poor compatibility between fiber and matrix and the relative high moisture sorption. Therefore, chemical treatments are considered in modifying the fiber surface properties. Alkaline treatment or mercerization is one of the most used chemical treatments of natural fibers when used to reinforce thermoplastics and thermosets. The important modification done by alkaline treatment is the disruption of hydrogen bonding in the network structure, thereby increasing surface roughness. This treatment removes a certain amount of lignin, wax and oils covering the external surface of the fiber cell wall, depolymerizes cellulose and exposes the short length crystallites. Addition of aqueous sodium hydroxide (NaOH) to natural fiber promotes the ionization of the hydroxyl group to the alkoxide. In alkaline treatment, fibers are immersed in NaOH solution for a given period of time. These researchers observed that alkali led to an increase in amorphous cellulose content at the expense of crystalline cellulose. It is reported that alkaline treatment has two effects on the fiber: (1) it increases surface roughness resulting in better mechanical interlocking; and (2) it increases the amount of cellulose exposed on the fiber surface, thus increasing the number of possible reaction sites. Alkaline treatment also significantly improved the mechanical, impact fatigue and dynamic mechanical behaviors of fiber-reinforced composites.

Chemical treatment of fibres consists of Cleaning the fibre with the help of distilled water and Addition of aqueous sodium hydroxide (10-15 ml) to the fibre and dried with the help of hot air woven and placed it in room temperature.

2.4 Fabrication:

Fabrication is done by means of manual hand layup method is used for preparing composite laminates. At first the fibres are set to dry under direct sunlight for removing moisture present in it. Then, the releasing agent (poly-vinyl alcohol) was properly spread over a flat table for easy removal post processing. The LY556 epoxy resin and HY951 hardener mixture is completely mixed with fibre for an effective binding. Then fibre and resin-hardener mixture is applied on the die. After the releasing agent is set and dry, a roller is used to evenly spread the resin-hardener mixture according to the required dimension.Finally a uniform weight of 25 kg is placed over the laminate undisturbed for 24h, to get the perfect shape and thickness. The thickness of the lamina is limited to 5mm and the size is 300x300mm for short fiber and 140x100mmfor mat structure. After dried, the edges of the specimen are neatly cut by using saw as per the required dimensions.



(a) **(b)**

Figure 3: Fabricated specimen (a) short fiber (b) mat

2.5 Studies on Mechanical Properties:

2.5.1 Tensile Test:

The mechanical properties of plastic as well ascomposite materials, tensile properties are probably themost frequently considered. Tensile strength were carriedout using a Universal testing machine toevaluate the tensile strength of composites as perASTM D-3039.

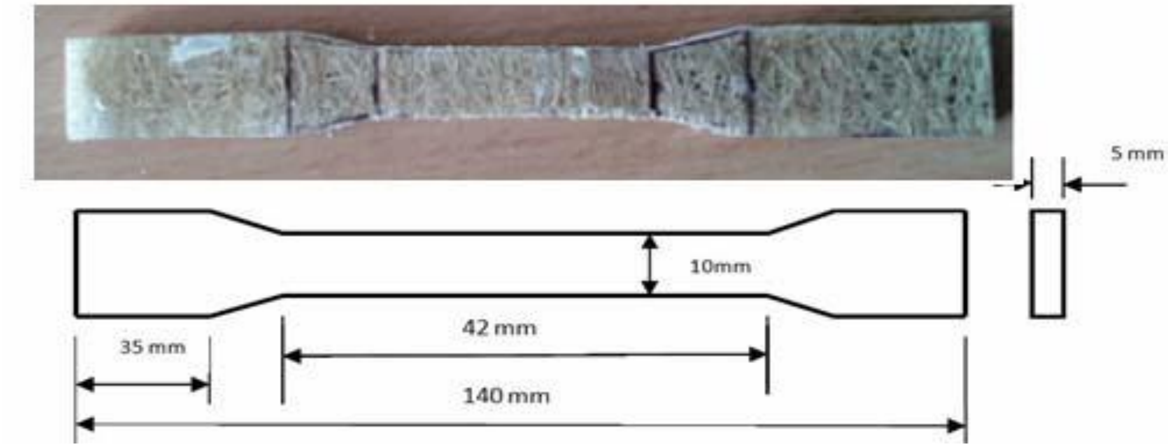


Figure 4: Tensile specimen as per ASTM D638

2.5.2 Flexural Test:

The 3-point flexure test is the most common for polymers. Specimen deflection is usually measured by the crosshead position. In a 3-point test the area of uniform stress is quite small and concentrated under the center loading point. Test results include flexural strength and flexural modulus.

Figure 5: Flexural test specimen as per ASTM D790.

2.5.3 Hardness Test:

Hardness is the resistance of a material to localized deformation. The term can apply to deformation from indentation, scratching, cutting or bending. Rockwell hardness values are expressed as a combination of a hardness number and a scale symbol representing the indenter and the minor and major loads.

2.5.4 Damping Behaviour:

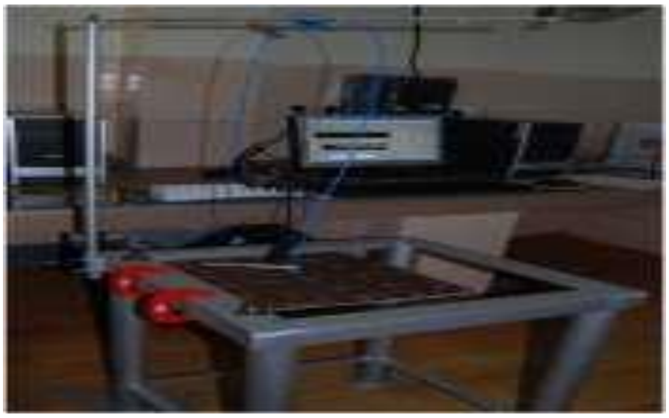


Figure 6: Experimental setup.

A grid of 7x6 (42 points) measurement points are marked over the surface of the composite .The composite is then clamped on test fixture and an impulse technique was used to excite the structure by impact hammer with forcetransducer built in to the tip to register the force input. The excitation signal is fed to the analyzer through amplifier unit.A piezoelectric accelerometer stuck on the desired measuring point of the specimen senses the resulting vibrationresponse. The accelerometer signals were conditioned in the charge amplifier and fed to the analyzer. The analyzer inconjunction with Fast Fourier Transform (FFT) gives mathematical relation between time and FrequencyResponse Spectrum (FRS) and coherence functions are registered in the selected frequency range. At each grid point fivemeasurements were made and their average was obtained. The output data of all 42 measurements was used as an inputdata for LABVIEW- 2009 package to identify response frequencies. From the response frequencies natural frequencies,damping factor and mode shapes were obtained.

3. Results and Discussion:

3.1 Tensile Test:

The tensile specimen was prepared as per ASTM D3039 and the results have been taken for both short fiber and format structure. It has been found the mat structure has higher tensile strength than the short fiber. The tensile strength and tensile modulus of the mat structure is 17.628 Mpa and 76.3 N/mm^2 whereas the short fiber has 13.56 Mpa and 72.29 N/mm^2.

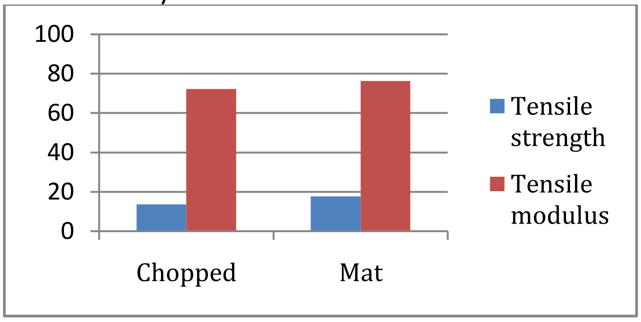


Figure 7: Tensile properties of short fiber and mat structure

3.2 Flexural Test:

The flexural specimen was prepared according to ASTM D790 and the results have been taken for both short fiber and mat structure. In the flexural test the short fiber results higher than the mat structure. The flexural strength and flexural modulus of short fiber is 41.36Mpa and 72.25N/mm^2 whereas for mat structure the flexural strength and flexural modulus is 39.1Mpa and 69.25N/mm^2

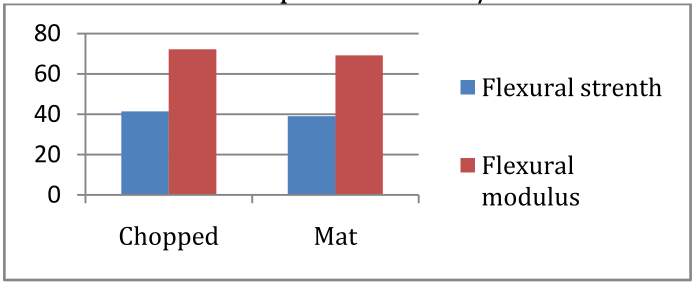


Figure 8: Flexural properties of short fiber and mat structure.

3.3 Hardness Test:

The hardness test was performed using the rockwell hardness machine. The Load applied was 60kgf and the Indenter diameter was 1/16 inch. The hardness value of short fiber was higher than the mat structure. The hardness number of short fiber was 83 RHN and for the short fiber was 50 RHN.

3.4 Damping Factor:

Luffacylindrica fiber reinforced composites were tested for input frequency of 250 Hz to obtain modal properties. The structural testing, analysis and reporting (LAB VIEW-2009) software which uses frequency response function (FRF) method to identify the modal parameters of a structure is used.As explained, in this method, FRF measurements are made with an FFT analyzer and transferred to the lab view systemfor processing and curve fitting. Table 1 and Table 2 shows the modal properties of short fiber composite and hybrid mat structure composite and that areobtained using experimentation.

Table 1: Modal properties of short fiber composite

Mode No.	**Frequency (f) (Hz)**	**Damping Factor (ξ) %**
1	24.09	3.547
2	47.804	3.682
3	129.448	2.166
4	145.595	2.087

Table 2: Modal properties of mat structure composite

Mode No.	**Frequency (f) (Hz)**	**Damping Factor (ξ) %**
1	24.35	3.20
2	45.50	2.09
3	129.07	0.53
4	165.51	1.59

The mode shapes give the information of dynamic behavior of composite under various natural frequencies. Themode-1 is called as fundamental mode in bending, mode-2 is in twisting and the rest of the modes are under combinationof bending and twisting. The average damping factor obtained for fundamental frequency of short fiber composite is 1.15 times greater than the mat composite.

4. Conclusion:

The main emphasis of the present work is on development, testing and characterization of Luffacylindrica fabric reinforced epoxy composites to know their suitability and adaptability for various structural applications.Experimentally determined the natural frequency and mode shapes for short fiber and mat structure composite by using FastFourier Technique (FFT) analyser.

a) The average damping factor obtained for fundamental frequency of short fibercomposite (3.681%) is 1.15 times higher than that of mat structure composite (3.19%). The variation in damping factor may be due to difference in flexural stiffness of short fiber composite and mat composite and changes in the fiberangle yields to different dynamic behavior of the composite.
b) Short fiber reinforced epoxy composites possess good damping factor as compared toconventional composites. Therefore, these composites can be used as vibration absorbing materials in certain applicationssuch as automobile industries, for house construction roofing material and for indoor applications.

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