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Experimental investigation for the dynamic characteristics of short natural fiber reinforced composite materials

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The study of mechanical and dynamic characteristics of composite materials is important. Vibration is one of the major problems faced because of the uncertainty and the disturbances due to its surroundings. For composite being used in the structures like aircraft, automobiles, railway coaches and buildings it should have sound mechanical and dynamic characteristics. Many researchers have been interested in the natural fiber based composite materials for solving problems such as environmental sustainability while also having good mechanical properties. In this paper, our objective is to explore the use of the short fiber and studied the dynamic and mechanical characteristics of banana-epoxy; kenaf-epoxy and hemp-epoxy natural fiber reinforced composite materials. The use of short fibers in the composites makes it easy to process and thus reduces the production cost when compared to composites which are made from long fiber mat. All composites which are fabricated have shown enhancement in the mechanical strength when the fiber loading in the composite is increased. It is concluded that the composite samples prepared from kenaf, banana and hemp shows better damping characteristics when compares to the neat epoxy material. It is also found that the hemp fiber based composite has shown the highest tensile strength and kenaf fiber based composite has shown the highest damping properties.

Keywords: Short natural fibers, Damping, Tensile strength, Fabrication, Modal analysis

1 Introduction

The conventional composite materials use synthetic fibers such as glass, carbon etc. as reinforcement. Increase in demand of more sustainable products and environmental consciousness has led to less use of these conventional composite materials and increased use of natural fiber based composites. The composite materials based on natural fibers case less pollution, are biodegradable in nature and have very less health hazards as compared to the composites based on synthetic fibers[1,2]. These renewable materials have great potential in replacing the traditional composite materials. Better understanding of the static and dynamic properties of the composite materials is required to use them in structural components. In many industrial applications, specially, for automotive industry, the important factors are the sound absorption, dynamic and damping properties.

The composite materials exhibit much better energy dissipation performance as compared to the traditional materials. This property of composite materials makes them a better alternative to improve the vibration damping performance. Natural fiber reinforced composite materials possess good mechanical properties, are light in weight, exhibit good sustainability and are environment friendly[3,4]. Natural fibers exhibit good potential and have number of benefits including low density, low cost and good sustainability[5]. Natural fiber reinforced composite materials show better acoustic performance and vibration damping properties as compared with the composites based on synthetic fibers[6,7]. Natural fiber based composite materials such as Flax fiber/polypropylene composite material has been used extensively in automotive industry[8]. The significance of natural fiber based composite are becoming more important due to their numerous benefit. Short and randomly oriented fiber based composite found use in many applications due to their easy fabrication. The composite which are fabricated with short fiber possess good mechanical properties such as stiffness, tensile stress and durability[9].

The natural fiber composite has shown great potential to fabricate the composite as they are environmentally sustainability and also have good mechanical properties[10–13]. The use of the natural fiber

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in the in the composite has some disadvantage such as water absorption which can change mechanical properties of the composite and can also cause swelling in the composite[14–16]. Other main problem is the improper adhesion and wetting that exist between the natural fiber and polymer matrix. This is due to the hydrophilic nature of the natural fiber and hydrophobic nature of the polymer, this issue can be mitigated to some extent by the pretreatment of the fiber. The use of natural fiber has continued to grow in recent years especially in the automotive sector. Natural fibers are made up of filament which consists of hemi-cellulose and lignin[17]. Lignin is deposited in the network of the hemi-cellulose. Substances such as pectin and waxes are also present in the fiber. These substances and other characteristics of the fiber such as diameter of the fiber depend on the factors such as fiber harvesting process, climate condition during the growth of the fiber and other growth factors.

Meon *et al.*[18] have investigated the properties of short kenaf fibers treated with sodium Hydroxide. The kenaf fiber treated with 3%, 6% and 9% of sodium hydroxide (NaOH) for a day. The fibers were soaked with 3%, 6% and 9% of sodium hydroxide for 24 hours at elevated temperature. The short fibers which are treated with sodium hydroxide are then used to make composites. The matrix used is Polyethylene (PE) and Polypropylene (PP) with coupling agents. The fiber reinforced composite was prepared in hot press machine. After the preparation of the composite, the Universal Tester Machine (UTM) was used to test the tensile strength of the composite. The tensile result shows that all treated fiber gives better result than untreated fiber. Short fiber reinforcing Polyethylene (PE) which was treated with 6% of sodium hydroxide shows the best results. The author concluded that alkali treatment of the fiber yield better results than untreated fiber and fiber soaked in 6% NaOH solution gives optimum results. Wambua *et al*.[19] have investigated the mechanical properties of composites reinforced of with natural fiber such as hemp and kenaf with polypropylene. The prepared composite shows the tensile strength of all the composite increases with the increase of percentage of fiber in the composite. Hemp and kenaf fibers show the maximum tensile strength. The author also concluded that the mechanical properties of the natural fiber reinforced composite are comparable to that of the composite which are prepared synthetic fibers.

Fiore *et al.*[20] have compared the mechanical properties of kenaf fiber reinforced epoxy composite. The author has compared the random fiber composite with length of 40 mm with unidirectional fiber composite, study also shows comparison between the treated and untreated fiber. The chemical treatment done on the fiber was sodium hydroxide (NaOH). The time for which the fiber was soaked in 6 % NaOH was varied from 48 hours to 144 hours. The result from scanning electrical microscope (SEM) shows that 144 hours in NaOH result in damaging the fiber which results in lowering the mechanical strength. The author concluded that alkali treatment of the fiber result in increasing the tensile strength of the both unidirectional fiber and randomly oriented fiber. However, the loss factor of the chemically treated fiber is then untreated fiber. Verma *et al.*[21] have investigated and compared the mechanical properties such as tensile strength and flexural strength of the kenaf fiber based HDPE high density polyethylene composite. The fiber is short in length and different weight fraction of fiber is used to prepare the composite. The sodium hydroxide (NaOH) with 5% concentration was used. The weight fraction of the short kenaf fiber was varied for 10 to 30 percentages. The authors concluded that with the increase in the percentage of the fiber the flexural strength of the composite also shows increments. The maximum tensile strength is shown by neat HDPE specimen followed by kenaf reinforced composite with 10% weight fraction. This shows that there is poor adhesion between kenaf fiber and polymer matrix which has negative impact on the load transfer between them. The author also performed (DMA) Dynamic Mechanical Analyzer test on the specimen and concluded that alkali treatment has positive effect on the bond ability and wet-ability between the polymer matrix HDPE and cellulosic reinforcement kenaf.

Kumar *et al.*[22] have investigated the thermal and mechanical properties of the kenaf reinforced Phenolic Resin composite for the brake pads. They concluded that the increase in the reinforcement increases the tensile and the shear strength of the composite, however at 20% weight fraction the composite shows lower tensile and shear strength. Santhosh *et al.*[23] has investigated the impact strength, tensile strength, flexural strength and the impact strength of banana reinforced epoxy composite and banana reinforced with vinyl ester composite. The author has chemically treated the banana fiber for 2 hours with 5% NaOH, sodium hydroxide. After washing them thoroughly the fibers are then dried in oven to remove the moisture. Hand lay-up technique was used to prepare the composite and the weight fraction of the fiber was maintained at 30%. The author has made a comparison between the composite with chemically treated fiber and untreated fiber and concluded that the use of the treated fiber in the composite improves the flexural, tensile and impact strength.

Venkateshwaran *et al.*[24] have studied the effect of the fiber content and the length of the fiber on the composite. The fiber used is banana and the matrix is epoxy. The length of the fiber is varied from 5 mm to 20 mm and the weight fraction of the fiber is varied from 8% to 20%. The composite is prepared by hand layup technique. The prepared composite is then tested for tensile strength, flexural strength, and moisture absorption. The test performed on the composites shows that the increase in the fiber length and fiber content increase the tensile strength however the increase in the fiber weight percentage more than 16 % result in the decrease in the tensile strength, this is due to the poor adhesion between the fiber and the matrix as observed by the SEM image. Pothan *et al.*[25] have investigated the effect of the fiber length and fiber content on the mechanical properties of the banana polyester. The experiment performed by the author clearly shows that the use of increasing quantity of the banana increases the mechanical property of the fiber. They use of silane treatment on the fiber further increase the mechanical properties of the composite such as flexural strength and tensile strength. The author has experimentally determined the critical fiber length of the banana fiber to be 30 mm, beyond which there is not effective transfer of the stress between the matrix and fiber.

Mishra *et al.*[26] have investigated the effect of the effect of maleic anhydride on the banana, hemp and sisal fiber on the composite that has been used to esterify the fibers and later used to fabricate the composite with novolac as matrix. The prepared composite is then tested for hardness, tensile, moisture absorption and hardness. The test was performed with varying the weight percentage of fiber from 40 to 60 percentages for both treated and untreated fiber. The water absorption test shows that there is sharp rise in water absorption in the composite after 50% weight fraction of the fiber for both treated and untreated fiber. All fiber shows there is increase in the young's modulus up to 45% weight fraction of the fiber. After which they shows a decline in their value. The flexural modulus and flexural strength of the composite also increases with the increase in the fiber content up to 50% after which they show a downward trend. However, the tensile test does not show any trend. The author also concluded that malefic anhydride can be used as compatibilizer because treated fiber shows better mechanical properties then untreated fiber in the composite.

Joseph *et al.*[27] have studied banana and glass fiber reinforced phenol formaldehyde composite and compare their properties at different fiber content and length. The author also performed single pullout test and to measure the interfacial shear strength with banana showing better adhesion with phenol formaldehyde than the glass fiber. The increase in the fiber loading also increases the mechanical properties of the composite. The young's modulus and the tensile strength of the composite are increased by 400% and 320% at around 50% fiber weight fraction of banana. However further increase in the fiber content result in the decrease in the mechanical properties, the author attributes it to the fiber entanglement. The optimum length for the banana and glass fiber is 40 and 30 mm respectively. The smaller length fiber result in the deboning from the matrix and result in the failure of the composite. The author has also used Series and Hirsch's model to predict the tensile strength of the composite, with banana fiber based phenol formaldehyde composite showing similar result to the theoretical models, the author conclude that banana fiber has the potential to replace synthetic fiber such as glass fiber in many real world applications.

Benítez *et al.*[28] have investigated the effect of treatment of the fiber on the mechanical and thermal property of the fiber. The fiber with treated with NaOH and malefic anhydride. The author performed thermo-gravimetric analysis and Fourier transform infrared spectroscopy. The author concluded that NaOH treatment of the fiber remove materials such as hemi-cellulose, pectin and lignin, which has profound effect on the fiber. The fiber treated with NaOH shows decrease in the tensile strength, decrease in thermal degradation and increase in elastic modulus. The fiber treated with maleic anhydride shows no significant improvement in the mechanical properties such as tensile strength but shows improvement in reducing thermal degradation at higher temperature. Pothan *et al.*[29] have investigated the effect of acetylation, NaOH and silane treatment on the short banana fiber. The composite was prepared with 30 mm short fiber at 40% fiber content and polyester resin was used as matrix, the fiber was arranged in random orientation. The fabrication was done with compression molding and the composite which have silane and NaOH has displayed highest modulus as compares to other treatment. The composite also displayed lower energy dissipation which is evident from loss modulus curve.

Idicula *et al.*[30] have investigated polyester reinforced with sisal and banana fiber with dynamic mechanical analyzer. The characterization of the hybrid composite with different volume fraction of the fiber is fabricated with 30 mm length. The composite is prepared with hand lay-up method. The author concluded that the increase in the volume fraction result in increase in the tensile strength and flexural strength also shows similar result. The tensile and flexural strength have maximum values at 40% of volume fraction. Kumar *et al.*[31] have carried out microbial growth test on the composite prepared with natural fiber and soy protein based bio composite. The test carried out clearly shows that the composite has good resistance against fungal growth. The composite prepared shows that the fiber loading and plasticizer have very profound effect on the mechanical strength. However, these components cannot be used for structural application.

Udaya Kiran *et al.*[32] have investigated the properties of the hemp; banana and sisal fiber reinforced polyester resin. Different fiber length and the weight fraction were used. In the entire specimen used for testing the composite which are prepared with 30 mm length gives the maximum strength. The author also concluded that with increase in the fiber loading the tensile strength also increases. Saini *et al.*[33] have performed modal analysis of different natural fibers reinforced epoxy. The modal analysis is done with the help of the ANSYS workbench. Natural frequency, damping ratio for each mode was find out with the software. The damping ratio was found out with the half power bandwidth method. Almost all natural fiber reinforced composite shows better damping capacity then the neat epoxy.

Neves *et al.*[34] have investigated has carried out investigated of the composite of epoxy and the polyester reinforced with hemp fiber. The author fabricates the composite by varying the fiber volume fraction from 10% to 30%. The resin along with fiber is poured into the mound cavity and put under pressure for 24 hours until the composite is cured enough for removal. the author compared the tensile strength of both epoxy and polyester resin composite and concluded that epoxy with 30 % volume fraction give best result in tensile and flexural strength. El-Shekeil *et al.*[35] have carried out experiment to examine the effect of treatment of NaOH on the kenaf based fiber. The author uses short kenaf fiber and treats them with NaOH solution with varying the concentration of the solution. The author concluded that the use of the use of NaOH remove unwanted substances such as hemi-cellulose, lignin, pectin, waxy substances, and natural oils. The application of NaOH also cleans the surface of the fiber, which changes the topology of the fiber's surface. However, the use of higher concentration of the NaOH results in damaging the fiber and thereby reducing the fiber's mechanical strength.

Liu *et al.*[36] have carried out chemical treatment of the hemp fiber and examine the effect of the removal of hemi-cellulose and pectin from the fiber. These substances are removed from the fiber by 10 % NaOH solution, endopoly galacturonase and enzyme treatment. The author concluded that the use of NaOH improves the stiffness in the composite. Pectin which was removed by galacturonase results in less porosity in the composite. Landro *et al.*[37] have investigated the damping characteristics of the hemp and epoxy composite the test were done with ASTM E 756 and shows the damping ratio obtained by the natural fiber composite is much more than that of the glass fiber. The author concluded that these composite can be used for structural application.

Miritoiu *et al.*[38] have examined the biocomposites reinforced with the hemp fiber. The matrix constitutes of 60% dammar resin and 40% epoxy resin. The epoxy used here in for hardening. The prepared composite is then tested for the mechanical strength and damping capacity. The authors concluded although composite made from dammar epoxy based composite has less tensile strength than epoxy based composite, however the damping capacity of the dammar epoxy composite is much better. Sawpan *et al.*[39] have investigated different chemical treatment on the hemp fiber such as NaOH treatment, maleric anhydride and silane. The treatment is then examined for tensile strength and concluded that NaOH treatment slight improvement in the tensile strength. However, they soaked the fiber in NaOH solution for only 30 minutes at 5% NaOH concentration.

Väisänen *et al.*[40]made opposite observations as they have done NaOH treatment for longer period of time. They concluded that the reason for the reduced tensile strength of the fiber is due to the reduced diameter of the fiber. Huda *et al*.[41] have investigated the use of NaOH treatment on the kenaf fiber for reinforcing Polylactic Acid. The authors made comparison between the composite which are treated with NaOH and the composite which have untreated fiber. They concluded that there is increment in the mechanical properties such as tensile strength and flexural strength when treated fiber is used.

2 Materials and Methods

Figure 1 shows the composites of banana / epoxy for different volume fractions. The first batch of the composite was made banana fiber and epoxy resin. The banana fiber loading was increased from 0 to 25% as shown in the Table 1 below. The density of the composites can be calculated easily by knowing the density and weight of the fiber and the resin. The density of banana-epoxy composites can be used to fabricate the composite by multiplying it by the volume needed to be made which gives us the weight of the composite for given volume fraction.

Fig. 2 shows the composites of kenaf / epoxy for different volume fractions. The second batch of the composite was made of kenaf fiber and epoxy resin. The fiber loading was increased from 0 to 25% as shown in the Table 2 below. The density of the can be

Fig. 1 — Composites of banana/epoxy for different volume fractions.

Fig. 2 — Composites of kenaf / epoxy for different volume fractions.

Table 1 — Composite density at different fiber loadings of banana, and epoxy composite

Sample notation	Percentage of fiber volume (%)	Percentage of fiber weight (%)	Percentage of resin volume (%)	Percentage of resin weight (%)	Composite density (gram/cc)
SAMPLE- 1	0	0	100	100	1.20
SAMPLE- 2	5	5.73	95	94.27	1.21
SAMPLE- 3	15	16.92	85	83.08	1.23
SAMPLE- 4	25	27.78	75	72.22	1.25

Table 2 — Composite density at different fiber loadings of kenaf, and epoxy composite

Sample notation	Percentage of fiber volume (%)	Percentage of fiber weight (%)	Percentage of resin volume (%)	Percentage of resin weight (%)	Composite density (gram/cc)
SAMPLE- 1	0	0	100	100	1.2
SAMPLE- 5	5	6.24	95	93.76	1.22
SAMPLE- 6	15	18.23	85	81.77	1.25
SAMPLE- 7	25	29.63	75	70.37	1.275

calculated by knowing the density and weight of the kenaf fiber and the epoxy resin. The density of kenaf-epoxy composite can be used to fabricate the composite by multiplying it by the volume needed to be made which gives us the weight of the composite for given volume fraction.

The third batch of the composite was made hemp fiber and epoxy resin as shown in Fig. 3. The fiber loading was increased from 0 to 25% as shown in the Table 3. The density of hemp-epoxy composite can be calculated easily by knowing the density and mass of the fiber and the resin. The density of the composite can be to fabricate the composite by multiplying it by the volume needed to be made which gives us the weight of the composite for given volume fraction.

The dried fiber of banana, kenaf and hemp are chopped of approximately size of 0.5-0.7cm. Composites having different fiber content were prepared by varying the volume fraction of fibers from 0.05 to 0.25. Three different fibers namely kenaf, banana and hemp are used as reinforcement. Figure 4 shows the procedure for the preparation of the fiber. The epoxy is prepared by mixing the resin and the hardener in the required ratio and then mix thoroughly for 10 minutes the fabrication was done first by weighing the resin and the fiber accordingly to their volume fraction and then mixed with each other. The mixture of the fiber and the resin is stirred vigorously to ensure that there is fiber left that is not wetted with the resin. The mixture was then put into the mould cavity. The mound is then closed by activating the hydraulic pressure. The hydraulic pressure is then controlled at maintained at 0.1MPa. The pressure is then maintained for 24 hours until the composites are cured.

After the specimens are cured under pressure for one day of curing, the specimen is taken out from the mould cavity with proper care to ensure that the specimen is damaged in any way. After the specimens are removed the mould is cleaned with acetone and other chemical reagent, so that so particle of the previous batch is not present before the next batch is applied. The maximum strength of the epoxy based composite is reached just after one day. Thus the specimen is left for one week in ambient temperature so that the specimen is cured and its maximum strength is achieved.

The specimens are produce as per the ASTM standard 756 E. The modal analysis is done with the help of FFT (Fast Fourier transform) analyzer to find natural frequency, damping and mode shape. The transducer or accelerometer is placed on the composite as shown in the Fig. 5. The composite specimen is fixed at cantilever condition. The hammers used to lightly hit the composite at regular interval marked on the composite prior to its testing. However, the transducer (accelerometer) is not displaced, after the hammer hits all the marked points. The data is processed by the OROS 36 software and the FRF (Frequency Response Function) curve is produced which is used to find the natural frequency and damping.

The density is measured with the help of the buoyancy method or Archimedes principle. The fiber whose density is measured is weighed in the balance and then weighed in liquid. The change in weight is due to the buoyancy. This is then divided by the liquid

Fig. 3 — Composites of hemp / epoxy for different volume fractions.

Table 3 — Composite density at different fiber loadings of hemp and epoxy composite

Sample notation	Percentage of fiber volume (%)	Percentage of fiber weight (%)	Percentage of resin volume (%)	Percentage of resin weight (%)	Composite density (gram/cc)
SAMPLE- 1	0	0	100	100	1.2
SAMPLE- 8	5	5.89	95	94.52	1.21
SAMPLE-9	15	17.33	85	82.67	1.23
SAMPLE- 10	25	28.37	75	71.63	1.26

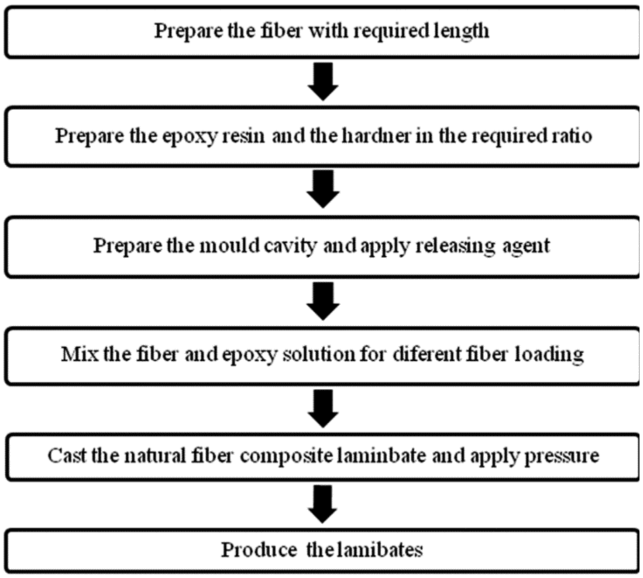

Fig. 4 — Procedure for the preparation of the fibers.

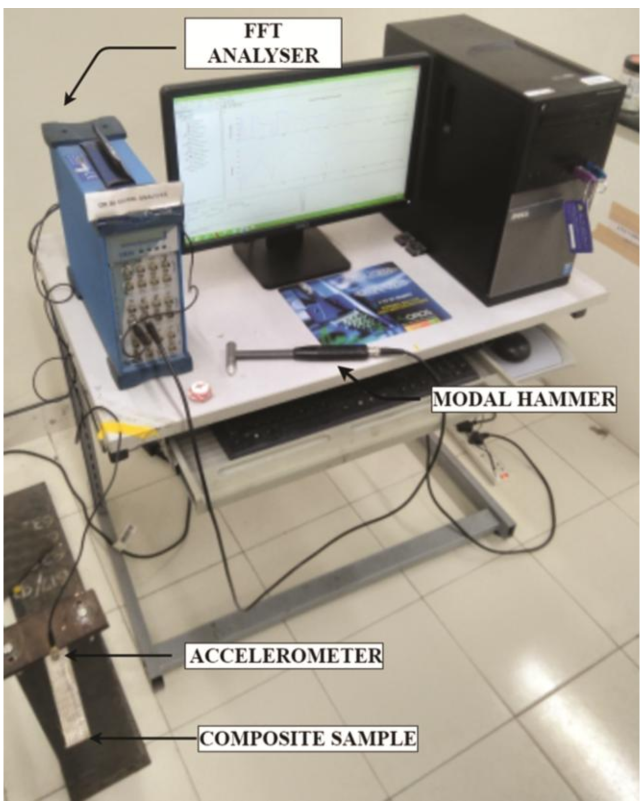

Fig. 5 — Experimental modal analysis (EMA) setup used in present study.

density. The density of the fiber is then calculated by the weight in air and then dived by the volume. The fiber should be thoroughly wet otherwise it will affect the reading taken.

We employ this test to find the ultimate tensile strength of the structure. This test is used to find the tensile strength of the natural fiber based composite. The specimen prepared is according to the ASTM 3039 D standard with dimensions 25×2.5×5mm. The specimen is then fitted with bracket on both end of the specimen and fitted between the cross head of the machine. The specimen is then tested for by pulling on both the end. The maximum load is noted from the graph produced. After the composite break from the tensile load the composite specimen is removing and the next specimen is replaced. In total 10 specimens are tested with different fibers and different fiber loading as shown in Fig. 6.

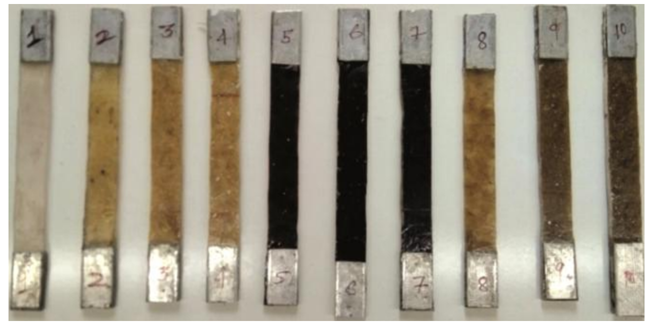

Fig. 6 — Samples used in the tensile testing.

3 Results and Discussion

The experimental result of the tensile strength of all the banana fiber based epoxy composite cured at ambient temperature and under the pressure is shown in the table. Results show the tensile strength of the banana reinforced epoxy composite. The banana fiber treated with 5% NaOH treatment shows viable reinforcement as it increases the tensile strength of the composite. The maximum increase in the tensile strength is 12%. However, the increase in the tensile strength with 5% fiber loading does not show a significant increase in the tensile, but at fiber loading at 15% and 25% the tensile strength increase is 8% and 12% respectively. Table 4 and Fig. 7 show the tensile strength for different volume fraction of the banana fiber.

The experimental result of the tensile strength of all the kenaf fiber based epoxy composite cured at ambient temperature and under the pressure is shown in the Table 5. Results show the tensile strength of the kenaf reinforced epoxy composite. The kenaf fiber treated with 5% NaOH treatment shows viable reinforcement as it increases the tensile strength of the composite. The maximum increase in the tensile strength is 18%. Kenaf being one the strongest fiber has given better strength then banana. Table 5 and Fig. 8 show the tensile strength for different volume

Table 4 — Tensile strength for different volume fractions of the banana fiber reinforced composite material

Sample No.	Materials	Volume Fraction (%)	Ultimate Tensile Stress (MPa)	Percentage Increase (%)
Sample 1	Neat Epoxy	100%	24.19	0%
Sample 2	Banana 5%	5%	25.45	4.5%
Sample 3	Banana 15%	15%	26.01	8%
Sample 4	Banana 25%	25%	27.13	12%

Table 5 — Tensile strength for different volume fraction of the kenaf fiber reinforced composite material

Sample No.	Materials	Volume Fraction (%)	Ultimate Tensile Stress (MPa)	Percentage Increase (%)
Sample 1	Neat Epoxy	100%	24.19	0 %
Sample 5	Kenaf 5%	5 %	26.15	8%
Sample 6	Kenaf 15%	15 %	26.997	12%
Sample7	Kenaf 25%	25 %	28.54	18%

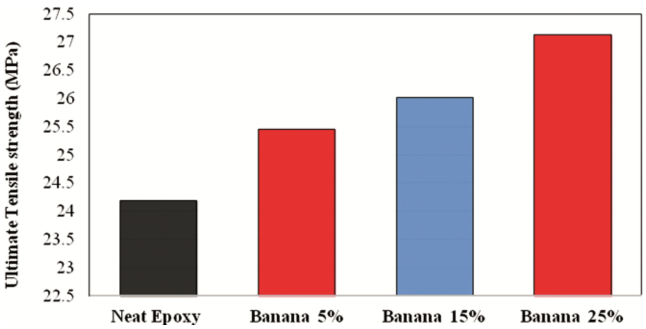

Fig. 7 — Tensile strength for different volume fractions of the banana fiber reinforced composite material.

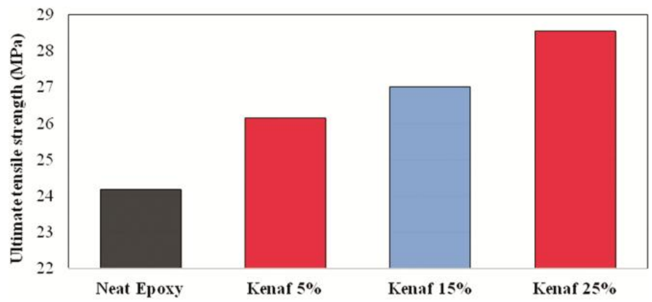

Fig. 8 — Tensile strength for different volume fractions of the kenaf fiber reinforced composite material.

fraction of the kenaf fiber reinforced composite material.

The experimental results of the tensile strength of all the hemp fiber based epoxy composites cured at ambient temperature and under the pressure is shown in the Table 6. Results show the tensile strength of the hemp fiber reinforced epoxy composite. The hemp fiber treated with 5% NaOH treatment shows one of the best reinforcement. The maximum tensile strength is achieved in the hemp /epoxy composite with 41% increase in the composite strength when compared with neat epoxy. Figure 9 shows the load-displacement graph for hemp fiber at different fiber loading. Figure 10 shows the tensile strength for different volume fractions of the kenaf fiber.

All three fibers used have shown viable reinforcement for the composite as all three fiber shows with the increase in the fiber content increase in the tensile strength. The hemp fiber has generally have less tensile strength then the kenaf fiber however hemp fiber composite shows much more tensile strength then the kenaf fiber composite. The reason is the fibrous nature of the kenaf fiber and allows porosity to exhibit in the composite which reduces the contact area between the fiber and the matrix for load transfer. This is due reduced area of contact between the fiber and matrix which reduced the load transfer due to shear stress between them. This results in reducing the composite strength. Figure 11 shows the tensile strength of different fiber based composite at different fiber loading.

The specimens are produced as per the ASTM E756 standard. The experimental modal analysis is done by FFT analyzer (Oros 36) to find the natural frequency, damping and modal of the composite material. Kenaf, hemp and banana fibers are used as cellulose reinforcement. From the graph it is clear that the use of these fibers treated with 5% NaOH resulted in the increase in the damping capacity of the composite when compared to neat epoxy. Table (7–9) shows the damping ratio extracted from the FRF of kenaf, hemp and banana reinforced epoxy composite material and the frequency corresponding to it.

The modal analysis is done by FFT analyzer (Oros 36) to find the natural frequency, damping and modal of the composite material. The banana fiber is used as cellulose reinforcement. From the graph it is clear the use of banana treated with 5% NaOH resulted in the increase in the damping capacity of the composite. The incorporation of the fiber increases the damping of the composite and with increments in

Table 6 — Tensile strength for different volume fractions of the hemp fiber reinforced composite material

Sample No.	Materials	Volume Fraction (%)	Ultimate Tensile Strength (MPa)	Percentage Increase (%)
Sample 1	Neat Epoxy	100%	24.19	0
Sample 8	Hemp 5%	5%	26.78	11%
Sample 9	Hemp 15%	15%	30.1	24%
Sample10	Hemp 25%	25%	34.1	41%

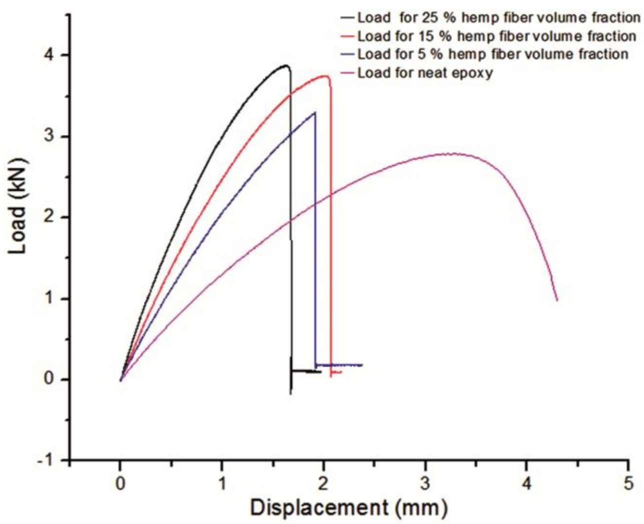

Fig. 9 — Load-Displacement graph for hemp fiber at different fiber volume fractions.

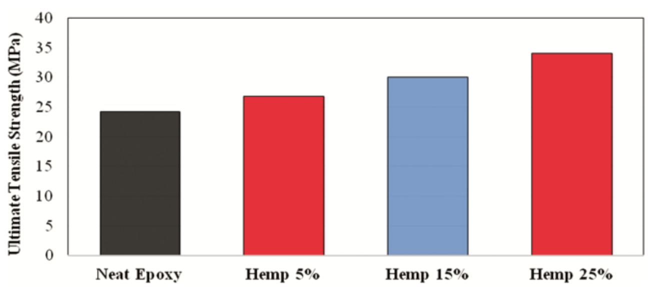

Fig. 10 — Tensile strength for different volume fraction of the hemp fiber reinforced composite material.

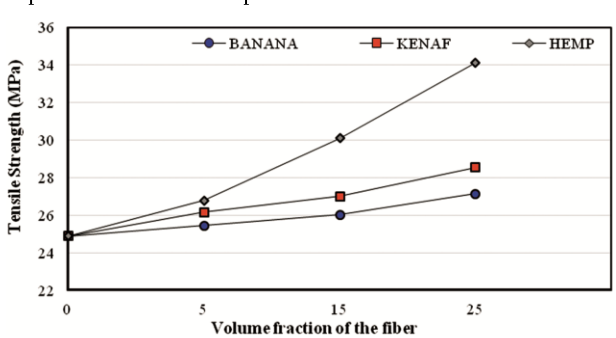

Fig. 11 — Tensile strength of the composites at different fiber loading.

the banana fiber content the damping increases. Table 7 and Fig. 12 show the damping ratio against different mode and their frequency for Banana/Epoxy composite for different fiber loading.

The modal analysis is done by FFT analyzer (Oros 36) to find the natural frequency, damping and modal of the composite material. The kenaf fiber is used as cellulose reinforcement. From the graph it is clear the use of kenaf treated with 5% NaOH resulted in the increase in the damping capacity of the composite. The incorporation of the fiber increases the damping of the composite and with increments in the kenaf fiber content the damping increases. Table 8 and Fig. 13 show the damping ratio against different mode and their frequency for kenaf/Epoxy composite for different fiber loadings.

The modal analysis is done by FFT analyzer (Oros 36) to find the natural frequency, damping and modal of the composite material. The hemp fiber is used as cellulose reinforcement. From the graph it is clear the use of hemp treated with 5% NaOH resulted in the increase in the damping capacity of the composite. The incorporation of the fiber increases the damping of the composite. Table 9 and Fig. 14 show the damping ratio against different mode and their frequency for Hemp/Epoxy composite for different fiber loadings.

The measure of density is vital for fabrication of the as it is one of the constituent property and is used to find out the reinforcement volume in the composite. The density of the three fiber banana, kenaf and hemp are calculated before and after the chemical treatment. The chemical reagent NaOH is dissolved in the water at 5% concentration and the dry fiber are soaked in it. After the treatment the fiber are washed and the dried and their weight is then calculated again with the help of the density apparatus. Table 10 shows the reduction in the fiber weight in grams.

From the Table 11 shown below, it is clear that the use of NaOH treatment will increase the density of the fiber as it removes wax, dirt and clean the surface of the fiber. The surface of the fiber is now clean which leads to better adhesion between the fiber and the matrix. The use of the alkali treatment reduces the diameter of the fiber which can be concluded from of loss of weight. Fig. 15 shows the density of the treated and untreated fibers of different natural fibers.

Table 7 — Damping ratio against different modes and their frequency for Banana/Epoxy composite for different fiber loadings

Material	Banana /Epoxy Composite						Neat Epoxy	
	Fiber volume fraction							
	5%		15%		25%			
Mode	Frequency	Damping	Frequency	Damping	Frequency	Damping	Frequency	Damping
1	17.5	1.328	18.772	1.478	20.2503	2.38	12.423	1.342
2	115.95	2.874	118.523	4.1024	133.66	3.57	100.412	2.11
3	311.304	1.256	316.224	1.39	344.57	2.66	268.82	2.239

Table 8 — Damping ratio against different modes and their frequency for Kenaf/epoxy composite for different fiber loadings

Material	Kenaf/Epoxy Composite						Neat Epoxy	
	Fiber volume fraction							
	5%		15%		25%			
Mode	Frequency	Damping	Frequency	Damping	Frequency	Damping	Frequency	Damping
1	15.21	2.21	18.704	2.38	22.573	2.569	12.423	1.342
2	109.23	2..23	116.256	2.978	143.453	3.667	100.412	2.11
3	311.304	1.256	331.624	3.196	344.57	4.1966	268.82	2.239

Table 9 — Damping ratio against different modes and their frequency for Hemp/Epoxy composite for different fiber loadings

Material	Hemp/Epoxy Composite						Neat Epoxy	
	Fiber volume fraction							
	5%		15%		25%			
Mode	Frequency	Damping	Frequency	Damping	Frequency	Damping	Frequency	Damping
1	17.821	1.428	19.6704	1.628	23.25	1.03	12.423	1.342
2	110.998	2.3	123.523	2.573	153.66	2.621	100.412	2.11
3	311.304	1.256	333.903	1.5933	369.423	1.22	268.82	2.239

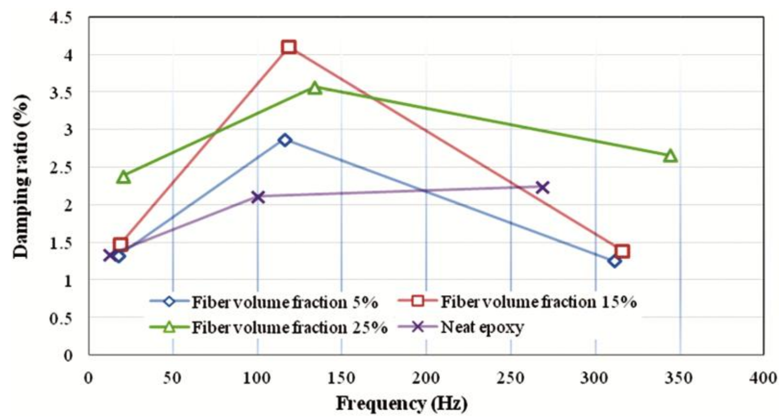

Fig.12 — Damping ratio v/s frequency for banana/ epoxy composites for different fiber loadings.

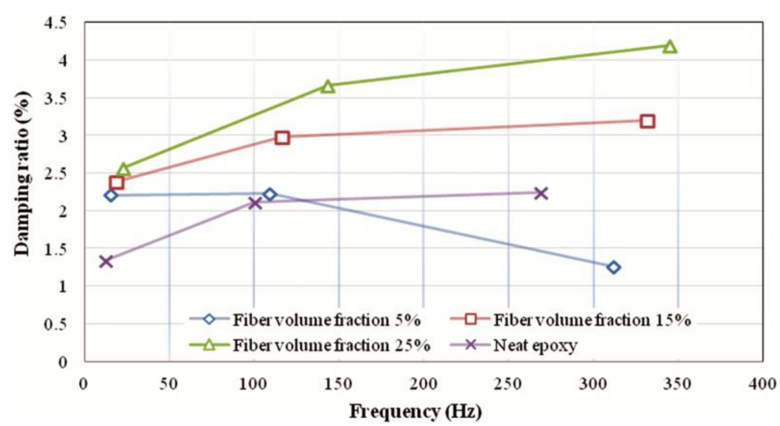

Fig. 13 — Damping ratio against their frequency for Kenaf / Epoxy composite for different fiber loadings.

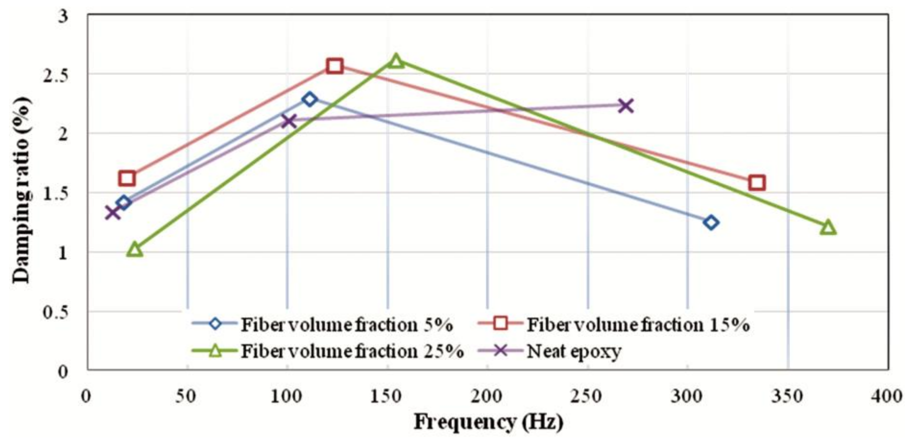

Fig. 14 — Damping ratio against their frequency for Hemp/Epoxy composite for different fiber loadings.

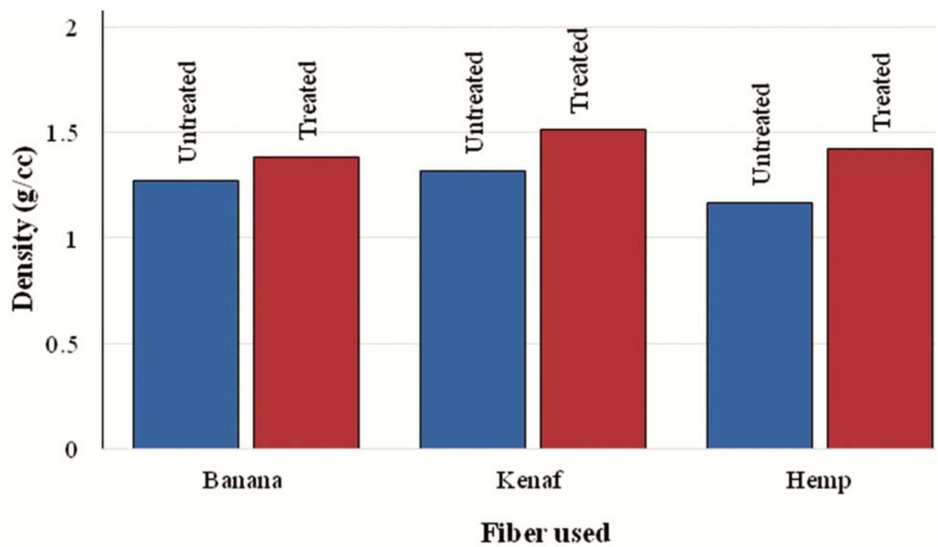

Fig. 15 — Density of the treated and untreated fibers of different natural fibers.

Table 10 — Weight of the fiber before and after the alkali treatment

Fiber	Weight before chemical treatment(in grams)	Weight after chemical treatment (in grams)
Banana	4.05	3.69
Kenaf	6.05	5.6
Hemp	6.35	4.9

Table 11 — Change in density before and after alkali treatment

Fiber	Density of the fiber before treatment (g/cc)	Density of the fiber after treatment (g/cc)
Banana	1.27076	1.38473
Kenaf	1.31969	1.51612
Hemp	1.16992	1.42574

4 Conclusion

Synthetic fibrous materials are being replaced by natural fibers for vibration damping. For example in automotive industry, composites based on natural fibers are being used extensively. The chemical treatment is very helpful in cleaning the fiber, improving the adhesion between fiber and matrix, reducing the fiber diameter and thereby enhancing the quality of natural fiber. All three natural fibers have shown that they are viable reinforcement for the composite. The use of short fibers in the composites makes them easier to process and fabricate the composite which directly reduce the cost of composite material. All composites have shown that they have better damping characteristic then the neat epoxy. Controlling the porosity of the composite during the manufacturing may result in increase in its vibration damping. The vibration damping of the composites may also be increased by the use of more fibrous fibers such as cotton material. This however, may result in decrease in the mechanical strength of composite. This issue may be mitigated by using the hybrid composite of two natural fibers with different bends.

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