Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 97 (2014) 573 – 581

Procedia Engineering

www.elsevier.com/locate/procedia

12th GLOBAL CONGRESS ON MANUFACTURING AND MANAGEMENT, GCMM 2014

Sound and Vibration Damping Properties of Flax Fiber Reinforced Composites

S.Prabhakaran[a]*, V. Krishnaraj[b], M. Senthil kumar[c], R. Zitoune[d]

[a]*Assistant Professor, Department of Robotics & Automation Engineering, PSG College of Technology, Coimbatore-641004, India*
[b,c]*Associate Professor, Department of Production Engineering, PSG College of Technology, Coimbatore-641004, India*
[d]*Associate Professor, Institut Clément Ader, Université de Toulouse, F-31077 Toulouse, France.*

Abstract

In recent days, automobile and construction industries are focus on the light weight, environmental friendly materials with good mechanical properties. Glass fiber reinforced composites have excellent specific properties and are widely used because of reduced mass. However the manufacturing of glass fibers and end of life disposal are the major problem to the environment. To overcome these problems, natural fibers are used to manufacture composites. Flax is the one of the naturally available fiber having good mechanical properties than other natural fibers. It needs to be pointed out that most of research effort about the flax fiber reinforced composites focuses on the manufacturing techniques and primary mechanical properties and not on the secondary properties like sound absorption and vibration damping. In this paper, sound absorption and vibration damping properties of flax fiber reinforced composites were characterized and compared with the glass fiber reinforced composites. It was experimentally observed that the sound absorption coefficient of flax fiber reinforced composites has 21.42% & 25% higher than that of glass fiber reinforced composites at higher frequency level (2000 Hz) and lower frequency level (100 Hz). From the vibration study it was observed that the flax fiber reinforced composites have 51.03% higher vibration damping than the glass fiber reinforced composites. The specific flexural strength and specific flexural modulus for flax fiber reinforced composites also good. These results suggest that the flax fiber reinforced composites could be a viable candidate for applications which need good sound and vibration properties.

Keywords: flax, sound absorption, vibration damping

* Corresponding author. Tel.: +91-994-257-2848
E-mail address: kpsprabhakaran@gmail.com

doi:10.1016/j.proeng.2014.12.285

1. Introduction

Traditional fiber reinforced composite materials consist of either glass or carbon fibers, coupled with a resin. These materials are strong, stiff and light-weight, often providing superior mechanical performance at a reduced weight compared to their metallic counterparts. Utilizing these materials provides an even greater improvement in mechanical performance and is preferred in many applications with weight constraints. Unfortunately, the light-weight and stiff properties of traditional materials (glass, carbon, kevlar) as structures make them efficient noise radiators compared to metallic structures [1]. Noise refers to the irregular and chaotic sound which disturbs people's work and impairs people's health. In recent years, with rapid development of modern industry and transportation, noise pollution has become increasingly prominent, and has become a major cause of environmental pollution and personal unhealthiness. There are two main methods to control the noise pollution. One is the control of the noise sources, that is, to make the big vocal sound inaudible through a small device or equipment; the other one is to use a variety of noise reduction materials with special structures, in terms of transmission route. In the last few years, acoustics and materials science experts have introduced new noise reduction materials and there are more and more applications of fibers in the control of noise pollution. Noise reduction materials are divided into two broad categories. One is the sound-absorbing material and the other is acoustic material. Many of the fiber reinforced composites are used as sound-absorbing material and only a small number of them are also used as acoustic materials [2].

Many engineering structures made from composites, including military equipment, automobiles, aircrafts, boat hulls, wind turbine blades and spacecraft's, often suffer from the menace of vibrations during their normal operations. Micro-cracks present in these structures propagate rapidly due to fatigue caused by vibrations, resulting in premature failure [3]. Sound absorbing properties and vibration damping properties are often secondary design criteria in composite structures, whereas mechanical performance and weight are primary concerns. Thus rather than sacrificing mechanical performance, common state-of-art methods involve the addition of sound absorbing and vibration damping material, which is expensive, labor-intensive, and adds more weights to the structure; this often raises the issue of structural integrity. Over the last couple of decades there is an increasing demand for materials that are more environmental friendly [4]. There have been many studies performed on natural material based which take advantage of both natural materials as well as superior mechanical performance over metallic structures and also it has good sound absorbing and vibration damping properties. These natural materials could essentially be grown for the purpose of manufacturing composites, in turn providing such benefits as being both biodegradable and recyclable. Moreover, replacing synthetic materials with natural materials results in a reduction carbon emissions, since oil and other carbon products are needed for the fabrication of synthetic structures [5-7].

The goal of this study is to explore the sound absorbing and damping properties of composites composed with natural materials and compare them over commonly used traditional composites, such as glass reinforced composites. By utilizing such materials in the fabrication of structures, significant reductions in emissions could be achieved, along with the ability to have materials which are renewable, recyclable and biodegradable. Natural material based composites with improved acoustic performance and damping properties will be an environmental friendly solution to the structure-noise radiation challenge. Among the natural fibers flax has good mechanical properties and it is nearly equal to E-glass fiber [5]. In this present study three different types of composite materials (glass, flax, combination of glass and flax) are fabricated using Vacuum Assisted Resin Transfer Molding (VARTM) and sound, and vibration test has been carried out in order to investigate the sound absorption and vibration damping properties.

2. Experimentation

2.1. Materials for fabrication of composite laminates

The utilization of lightweight and low cost, natural fibers offers the potential to replace a large segment of the glass and other synthetic fibers in numerous automotive and construction applications [4]. Natural fibers such as kenaf, hemp, flax, jute, and sisal are providing reinforcement due to reductions in weight and cost, less CO_2 consumption for manufacturing, recyclability, and the added benefit that these fiber sources are "green" or ecofriendly. Among the all-natural fibers flax has good mechanical properties. Properties of the flax are nearly equal to the E-glass fiber. In this study utilizes flax as a natural reinforcement for manufacturing composite laminates and E-glass as synthetic reinforcement and E-glass and flax as hybrid reinforcement for manufacturing composite laminates for comparison purpose.

Flax was purchased from Lineo, Belgium as a woven rovings (FlaxPly BL 300 GSM) and E-glass was purchased from CovaiSeenu& Company Pvt. Ltd., India as woven rovings (E-glass Ply BL 300 GSM). Epoxy was used as matrix for manufacturing composite laminates for both Flax, and E-glass fibers. Epoxy (Araldite LY 556) was purchased from CovaiSeenu& Company Pvt. Ltd., India.

Table 1. Properties of fiber materials utilized

Material	Density (g/cm^3)	Tensile strength (MPa)	Young’s modulus (GPa)	Specific modulus (GPa)	Layer thickness (mm)
Flax fiber	1.54	800-1500	50-70	26-46	0.87
E-glass fiber	2.55	2400	76	29	0.47

2.2. Fabrication of composite laminates

The composite laminates have been manufactured by Vacuum Assisted Resin Transfer Moulding (VARTM). The mold surface used for the fabrication of the composite laminates was cleaned using acetone (cleaning agent). A coating of wax is applied on the mold surface for easy removal of composite laminates. The fiber materials (woven roving) were cut to the required shape and size and it is placed on the mold surface. No. of layers of reinforcementwere used based on thickness required. Table 1 shows the details of the fiber materials used for fabrication. The Peel ply is placed over the fibers and a distribution medium is laid on the top of the peel ply. The entire layup was then bagged and placed under vacuum. The resin used in this fabrication process was Araldite LY 556 is mixed with hardener (1:10 ratio) and that is impregnated throughout the reinforcement under the vacuum. After about 12 h, the bag was removed, and the laminate was left exposed to the atmosphere to finish venting the styrene gas produced from the curing resin. The laminates are then cut to the required shape and dimensions.

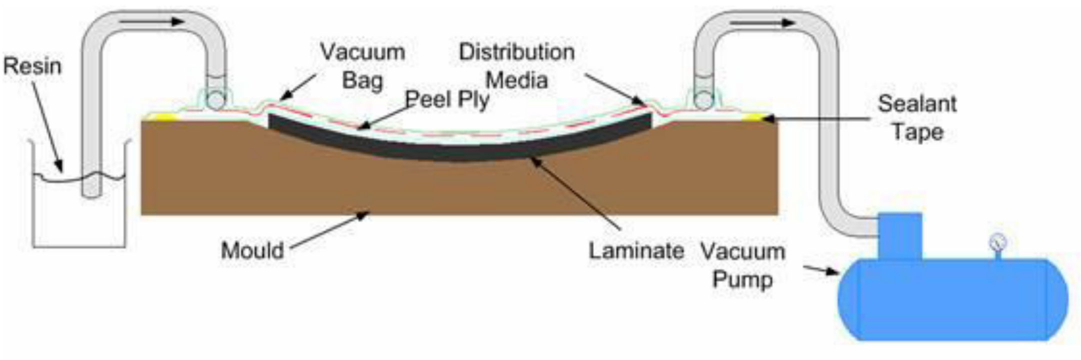

Fig. 1. Vacuum assisted resin transfer moulding

2.3. Sound absorption coefficient measurement

The sound absorption coefficient can be measured with the help of an impedance tube tester as per the ASTM standard E 1050. The impedance tube testing method is implemented by the generation of plane wave in a tube by a sound source and then the sound pressures are measured in a microphone position in close proximity of the sample [8-9].Fig. 2.shows the schematic diagram of impedance tube tester.

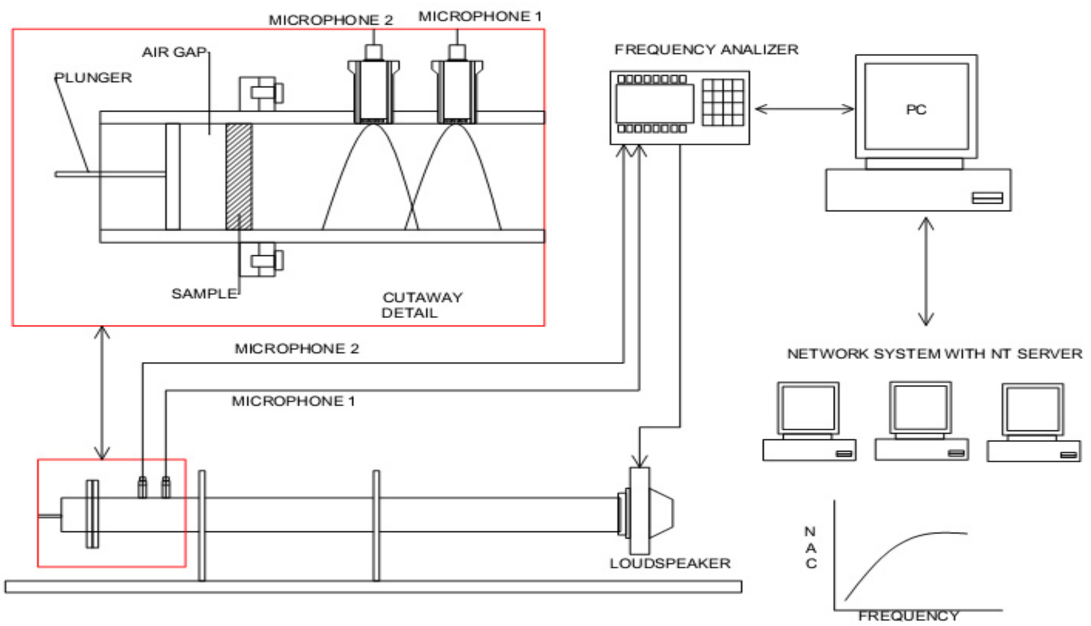

Fig. 2. Impedance tube tester

Table 2. Dimensions of sound test specimens

Specimen name	No. of layers of reinforcement	Thickness (mm)	Diameter (mm)	Weight (grams)
Flax/Epoxy (FE)	3	3	100	25
Glass/Epoxy (GE)	6	3	100	38
Glass/Flax/Epoxy (GFE)	Glass:2; Flax:2	3	100	29

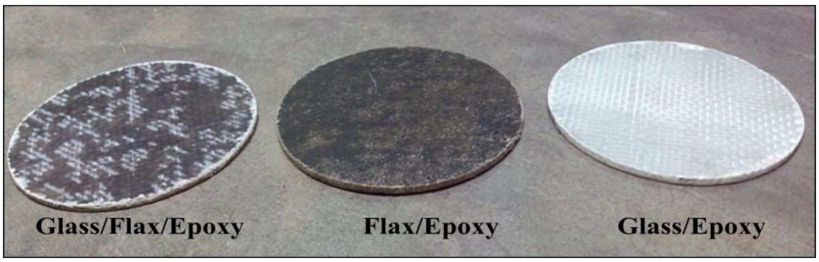

Fig. 3. Sound test specimens

An impedance tube was used with a sound source (loudspeaker) connected to one end, and the test sample shown in fig. 3 was mounted to another end. The dimensions and no. of layers of reinforcements for different specimens are listed in table 2. The loudspeaker generates the broadband random sound waves and the sound waves propagating as plane waves in the tube hit the sample, get partially absorbed, and subsequently reflected. The acoustical properties of the test sample were tested in the frequency range of 100–2000 Hz. This system tests a sound absorptive material, processes the results, and reports the results in a graph of the absorption coefficient in various frequencies. Thus, the absorption coefficient of each sample was obtained.

The ability of the composite material to absorb unwanted noise is based on dissipation of the sound wave energy upon passing through the material and being directed by the fibers, and also on conversion of some of the energy into heat. The amount of original energy less the remaining unabsorbed energy compared to the original energy lead to the measurement referred to as the absorption coefficient (α).

2.4. Vibration damping factor measurement

The damping factor was determined by using the free vibration method as per the ASTM standard E756 [9]. Specimens were cut into the specified dimensions from the laminates. The dimensions and no. of layers of reinforcements for different specimens are listed in table 3. The specimens are placed in the form of a cantilever beam structure by using fixture. Figure 5 shows the different vibration test specimens. An accelerometer sensor supplied by Dytran whose sensitivity of 96.72 mV/g was placed at the tip of specimen at the free end. The output signals are received by means of connecting the accelerometer sensor with a Data Acquisition (DAQ) card 9234 which is connected to the PC and interfaced with Laboratory Virtual Instrumentation Engineering Workshop (LabVIEW) software supplied by National Instruments.

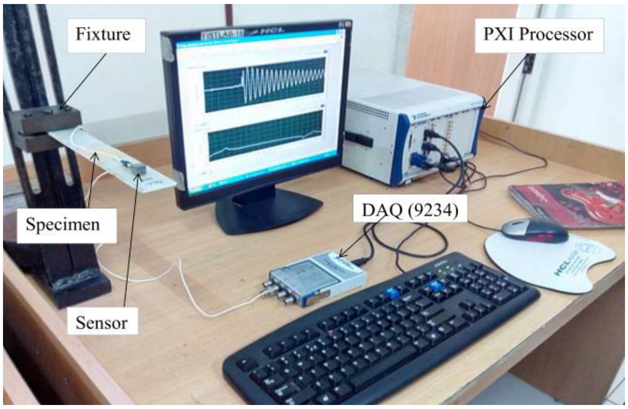

Fig. 4. Free vibration test set up

Table 3. Dimensions of vibration test specimens

Specimen name	No. of layers of reinforcement	Thickness (mm)	Length (mm)	Width (mm)	Weight (grams)
Flax/Epoxy (FE)	3	3	210	35	24
Glass/Epoxy (GE)	6	3	210	35	34
Glass/Flax/Epoxy (GFE)	Glass:2; Flax:2	3	210	35	28

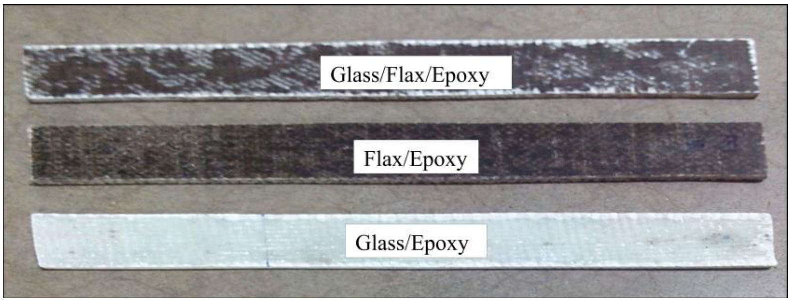

Fig.5. Vibration test specimens

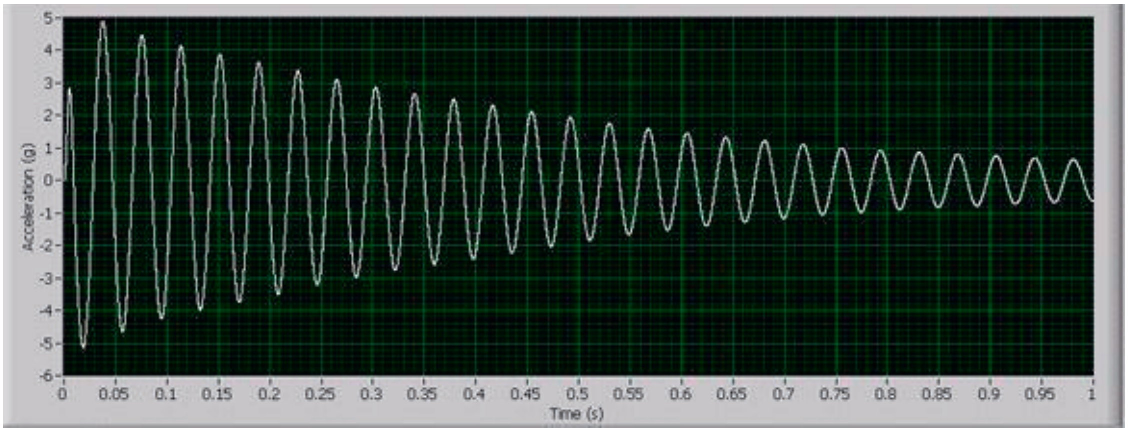

Fig. 6. Free vibration response (acceleration vs. time) of composite laminates

Fig. 6 shows the free vibration response of composite laminates obtained from the LabVIEW software while the specimen was made to oscillate. Numbers of trails were taken to obtain accurate readings for the calculation of damping factor (ζ). The damping factor was calculated by taking the values of the successive peaks from the free vibration response graph (wave form graph) obtained from the LabVIEW software and substituted in the Equation 1 [10-12].

$$ln\frac{x_1}{x_2} = \frac{2\pi\zeta}{\sqrt{1-\zeta^2}} \qquad (1)$$

where, x_1, x_2 - successive peaks from the free vibration response graph.

2.5. Flexural strength measurement:

The flexural test was made as per the ASTM D 790 [13]. It is used to determine the flexural strength and modulus of the composites. Specimens were tested in 3-point bending apparatus with a span to thickness ratio of 8. The dimensions and no. of layers of reinforcements for different specimens are listed in table 4. The specimens were tested using Zwick/roell universal test machine at a cross head speed of 1.2 mm/min. Figure 6 shows the different flexural test specimens. During the test, load vs. extension of the beam was recorded.

Table 4. Dimensions of flexural test specimens

Specimen name	No. of layers of reinforcement	Thickness (mm)	Length (mm)	Width (mm)	Weight (grams)
Flax/Epoxy (FE)	3	3	125	25	9.8
Glass/Epoxy (GE)	6	3	125	25	14.7
Glass/Flax/Epoxy (GFE)	Glass:2; Flax:2	3	125	25	12.2

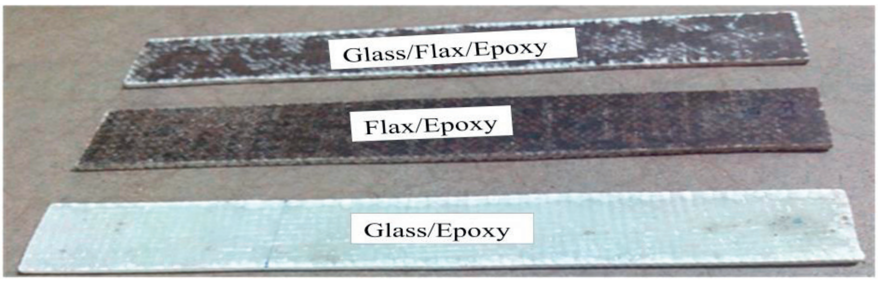

Fig. 7. Flexural test specimens

3. Results and Discussions

3.1. Analysis of sound absorption coefficient measurement

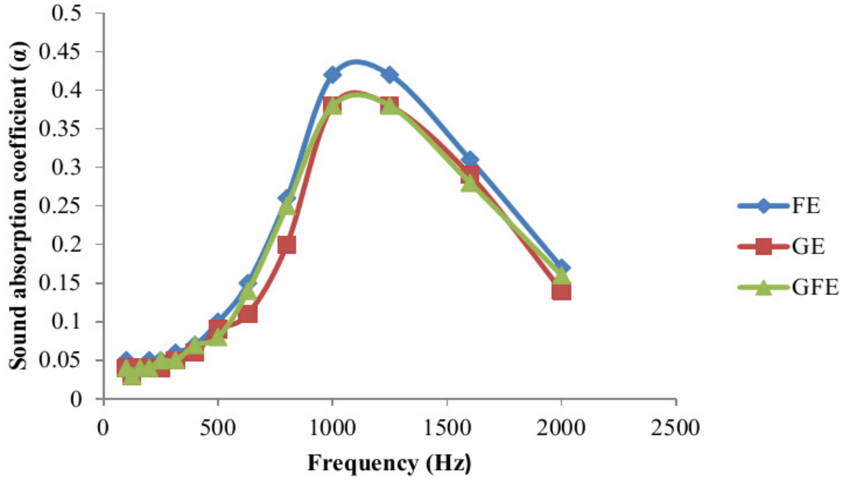

Fig.8. Sound absorption coefficient vs. frequency for FE, GE, and GFE specimens

From fig. 8, it is evident that, the sound absorption coefficient of FE is greater than that of GE and GFE in all frequency levels. The maximum sound absorption is observed at 1000 Hz for all the reinforcements. The sound absorption of FE has 21.42% and GFE has 14.28% higher than that of GE at higher frequency of 2000 Hz. At lower frequency level (100 Hz), the FE has 25% of higher in sound absorption over GE. The GFE has a similar sound absorption over GE. Out of the three developed fiber reinforced composites, FE with higher sound absorption coefficient can be suitably used in the applications were sound absorption is considered as important design criteria.

3.2. Analysis of vibration damping factor measurement

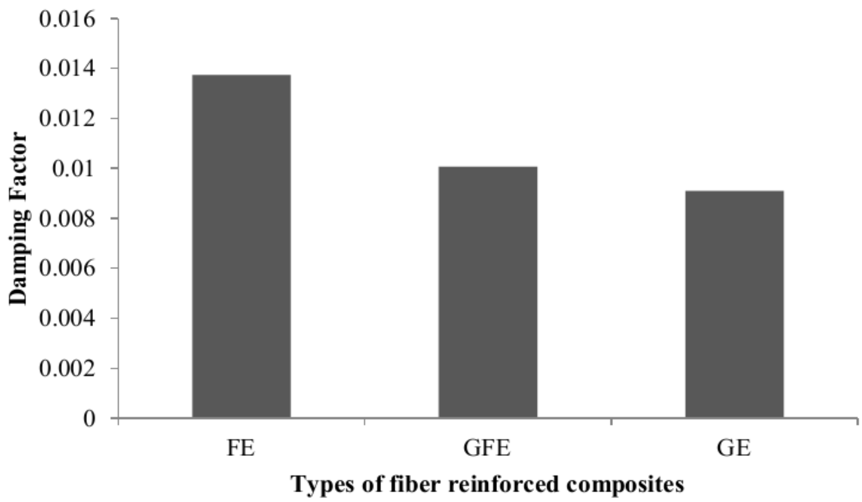

Fig.9. Damping factor for FE, GE, and GFE specimens

From fig. 9, it is inferred that when compared to the GE, the FE have 51.03% higher and the GFE have 10.73% higher in vibration damping, which means that the utilisation of natural fiber reinforced composites have better results in vibration damping properties.

3.3. Analysis of flexural strength measurement

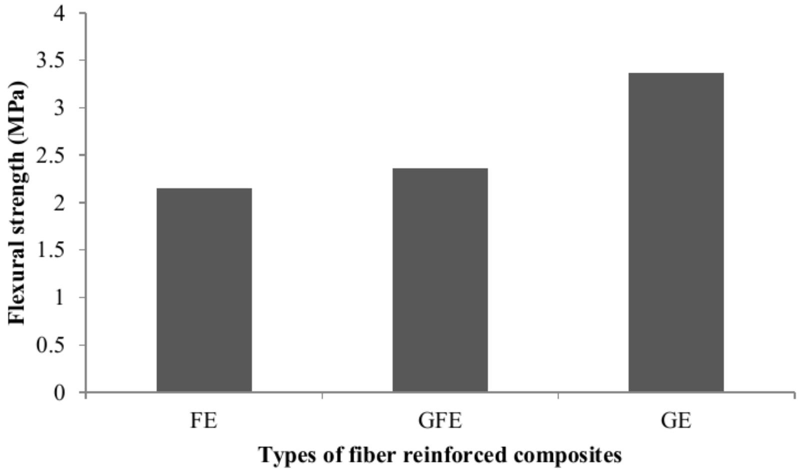

Fig.10.Flexural strength vs. Types of fiber reinforced composites

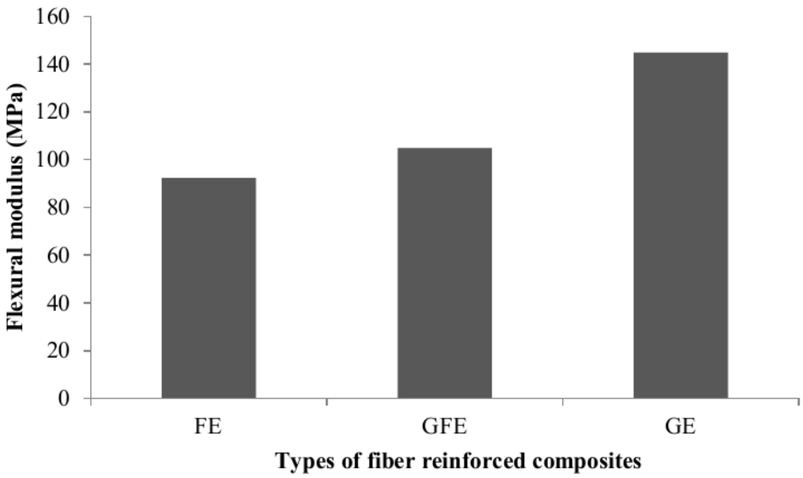

Fig.11. Flexural modulus vs. Types of fiber reinforced composites

From the flexural test, load vs. extension response of the FE, GFE, andGE specimenswere found out. By using the strength and modulus formulas, flexural strength and flexural modulus of FE, GFE, andGE were calculated. Flexural Load-Extension response of FE, Load values increases linearly in the elastic region. Maximum stress occurs at the mid span in three point bending configuration. Above the maximum stress, the composite layers delaminate and failure occurs. The average flexural strength and modulus values of the FE were found to be 2.146 ± .078 MPa and 92.45 ± 12.05 MPa, respectively. Flexural Load-Extension response of the GE, the average flexural strength and modulus values of the composite material were found to be 3.357 ± 2.19 MPa and 144.89 ± 3.43 MPa, respectively. Flexural Load-Extension response of GFE, the average flexural strength and modulus values of the composite material were found to be 2.352 ± 0.47 MPa and 105± 7.93 MPa, respectively.

From the fig. 10 it evident that FE has 36.07% lower in flexural strength compared to the GE and GFE has 29.93% lower in flexural strength compared to the GE. Fig. 11 shows the flexural modulus of FE, GFE, andGE.The loading in the bending test consists of tension, compression and shear forces. All specimens were tested along the fiber direction and they generally experienced brittle failure in the outer ply as delamination on the tensile surface. The delamination starts at the middle of the specimen because of the maximum bending moment, in the middle section of the tensile surface fiber rupture occurred. Delamination was observed on both tensile and compressive surfaces of the specimens. Until the fiber failure, large deflection was achieved.

4. Conclusions

By using natural fiber based composite materials, it is possible to create a composite laminates with superior acoustic and vibration damping performance without sacrifices in stiffness-to-weight ratios. The sound absorption coefficient of flax fiber reinforced composites has 21.42% higher than that of glass fiber reinforced composites at higher frequency level (2000 Hz). At lower frequency level (100 Hz), the flax fiber reinforced composites has 25% higher in sound absorption over glass fiber reinforced composites. From the vibration study it is observed that when compared to the glass fiber reinforced composites, the flax fiber reinforced composites have 51.03% higher in vibration damping, which means that the utilization of natural fiber reinforced composites have better results in vibration damping properties. The weight of the flax fiber reinforced composites also 33.33% lesser than that of glass fiber reinforced composites. The specific flexural strength and specific flexural modulus of flax fiber reinforced composites are also at par with that of glass fiber reinforced composites. These results suggest that the flax fiber reinforced composites could be viable candidate for applications which need of good sound and vibration properties.

References

[1] James J. Sargianis, Hyung-Ick Kim, Erik Andres, JonghwanSuhr. Sound and vibration damping characteristics in natural material based sandwich composites. Composite Structures, 2013(96): 538–544.

[2] Dakai Chen, Jing Li, JieRen, Study on sound absorption property of ramie fiber reinforced poly(L-lactic acid) composites: Morphology and properties, Composites: Part A 41 (2010) 1012–1018

[3] ShafiUllah Khan, Chi Yin Li, Naveed A. Siddiqui, Jang-Kyo Kim, Vibration damping characteristics of carbon fiber-reinforced composites containing multi-walled carbon nanotubes, Composites Science and Technology 71 (2011) 1486–1494

[4] GeorgiosKoronis, Arlindo Silva, MihailFontul, Green composites: A review of adequate materials for automotive applications, Composites: Part B, 44 (2013) 120–127

[5] Libo Yan, NawawiChouw , Krishnan Jayaraman, Flax fibre and its composites – A review, Composites: Part B 56 (2014) 296–317.

[6] M.Senthilkumar, Determination of notch sensitivity of Jute/Isophthalic composites–an experimental study, International Journal of Engineering, 3(8),2010,pp.249-352.

[7] K.Sabeelahmed, S.Vijayarangan and M.Senthilkumar, Water absorption behavior and strength degradation studies on isothalic polyester-based Jute-Glass fabric hybrid composites, National Journal of Technology, Vol.2, No.3, 2006, pp. 62-71.

[8] Zhou Hong, Li Bo, Huang Guangsu, He Jia, A novel composite sound absorber with recycled rubber particles, Journal of Sound and Vibration 304 (2007) 400–406.

[9] EulaliaGliścińska, Marina Michalak, IzabellaKrucińska, JanuszKazimierczak, ArkadiuszBloda, DanutaCiechańska, Sound Absorbing Composites from Nonwoven and Cellulose Submicrofibres, J. Chem. Chem. Eng. 7 (2013) 942-948

[10] F. Duc, P.E. Bourban , C.J.G. Plummer, J.-A.E. Månson, Damping of thermoset and thermoplastic flax fibre composites, Composites: Part A 64 (2014) 115–123.

[11] E.C. Botelho, A.N. Campos, E.de Barros, L.C. Pardini, M.C. Rezende, Damping behavior of continuous fiber/metal composite materials by the free vibration method, Composites: Part B 37 (2006) 255–263.

[12] Zheng Wang, Ling Li, Meng Gong, Measurement of dynamic modulus of elasticity and damping ratio of wood based composites using the cantilever beam vibration technique, Construction and Building Materials 28 (2012) 831–834

[13] Murali Mohan Rao K, MohanaRao K, Ratna Prasad AV, Fabrication and testing of natural fibre composites: vakka, sisal, bamboo and banana, Materials and Design 31 (2010) 508–513