IConAMMA_2018

REDUCTION OF NOISE IN THE VEHICLE CABIN BY USING NATURAL FIBRES WITH POLYURETHANE AND COMPARISON WITH OTHER ACOUSTIC MATERIALS

Raja Vankayala ¹, Dr R. Saravanan ², C. Lakshmikanthan ³

¹, ², ³ Department of Mechanical Engineering, Amrita School of Engineering, Coimbatore.

Amrita Vishwa Vidhyapeetham, India

rajavankayala1@gmail.com, saravanachandran@gmail.com, c.lakshmi3676@gmail.com

Corresponding author: R. Saravanan
Co-author: C. Lakshmikanthan

Abstract— As natural fibres are noise-absorbing materials, biodegradable and renewable by using natural fibres such as betel nut, sugarcane fibres are combing with polyurethane for the automobile application to reduce cabinet noise of the vehicle, which currently contains traditional materials such as foams, glass, metals and plastics that are difficult to recycle. Four samples of natural fibres were prepared with different quantities of betel nut & sugarcane ratios of 35:35, 50:20, 55:15, 60:10. Polyurethane is common with 30% of all samples. The sound absorption coefficient (SAC) in the material was tested by using impedance tube and compared with other acoustic material like nitrile rubber, nonwoven polyester fabric and glass wool. It was observed that betel nut & sugarcane showing better SAC than other acoustic materials mainly at lower and higher frequency 60% betel, 10% sugarcane & 30% polyurethane showing better sound absorption level.

Keywords-- Biodegradable, vehicle interior, natural fibres, impedance tube, sound absorption coefficient, acoustic materials.

1. INTRODUCTION

Nowadays a superior consideration has been given to the environment and public health which encouraged the research to develop new methods to make use of eco-friendly materials. Usage of biodegradable and recyclable products in all manufacturing sectors doesn’t contribute to global warming. Usage of Natural fibres in industries application is also called it green materials [1].

Vehicle cabinet noise is one of the key problems in automobile industries. Structure-borne and airborne noise are the two different noises contributed to the vehicle cabinet noise. They investing a lot of money to study acoustic behaviour in the vehicle to reduce cabinet noise. Currently, the cabinet noise in the vehicle was controlled by expensive materials like glass fibres, foams, plastics, metals etc..., which are not eco-friendly and it is difficult to recycle or reuse [2]. So, manufacturing companies are approaching to utilize a supreme quantity of eco-friendly materials in manufacturing products to decrease pollutants in the earth, and these eco-friendly materials can simple recycle compared to other metals and plastics.
Why natural fibres as an acoustic material? Natural fibres have very good acoustic properties, renewable, biodegradable, mechanical and thermal properties. Due to low density & cellular structure, natural fibres possess very good acoustic properties. Natural fibres have low weight, good fatigue strength, good stiffness, corrosion resistance and good strength. These resources are less expensive and available easily. America and Europe were already started using supreme quantity of Natural waste to usable way. By using natural fibres in industrial products two problems can be resolved one is controlling the vehicle cabin noise and another one is to the reduction of pollution as natural waste usually burned [1].

Different natural fibres were used as an acoustic material in automobile industries, fibres extracted from kenaf, sisal, hemp, flax, pineapple, coconut coir, banana, sugarcane and betel nutshell these are the main natural fibres which are good sound absorbers.

Why betel nut and sugarcane fibres? These fibres are very thin and fine particles it can absorb more sound and it is a low-density fibre and by its wide particle size distribution. Betel nut fibres have very good thermal conductivity value of 0.034 w/mK which help to resist heat entering from engine to vehicle cabinet. Fibres of betel nut can withstand all kind of weather for an extensively for a longer period, these fibres have good acoustic properties, good strength and air permeability. Sugarcane consisted of very tiny and soft fibres which can act as good acoustic materials. Natural fibres also reduce vibrations in the vehicle which is the main source for generating noise inside the vehicle. As sugarcane waste and betel nut cannot be used as a cattle food it was burning simply by using these wastes as an acoustic material it will be a benefit for manufacturing industries and farmers, industries can utilize the large accessibility of natural products [3-5]. These materials are fully recycled materials and biodegradable materials can be regarded as an alternative to artificial materials, as they contribute to lower waste production and reduced use of raw (virgin) materials [14]. Polyurethane foams are mostly used in all manufacturing industries for their better acoustic properties, good electrical and thermal properties even at lower and higher frequencies. In this literature, survey polyurethane is used as a layer in between sugarcane and betel nut fibres. The main influence factors of SAC material are material density, material porosity and material thickness all these factors play a major role during sound absorption of materials [15]. Acoustic materials selection for any automotive vehicles were based on different properties like SAC, noise reduction coefficient and thermal conductivity based on these properties and testing results acoustic materials were selected for any automobile vehicles [16].

Another acoustic material has been tested in impedance tube apparatus to compare SAC of the acoustic material with natural fibre material and materials like nitrile rubber, nonwoven polyester fabric and glass wool. SAC of betel nut, sugarcane fibres samples showing better value than these acoustic materials and almost equal to glass wool at lower and higher frequencies, but glass wool is hazardous to human health it cannot be used in automobile industries and also it was expelled in some European countries and cost of these acoustic materials was high compared to natural fibres.

2. METHODOLOGY

2.1 Preparation of betel nut fibres: During fibre preparation, raw betel nut fruits were kept in dark room at room temperature for one week. After that betel nut remained soaked in water for 7 days. By using hand stripping method soaked betel nut portion was separated manually. After separating from nut portion these fibres were dried in an industrial furnace at 70°C for 1 day.

2.2 Detergent wash treatment: After dried in industrial furnace these fibres were soaked in 10% detergent for 1-2h. This treatment will improve the fibre surface characteristics by removing both artificial, natural impurities and oily particles from the betel nut portion. Detergent washed fibres were again washed with distilled water for 5-6 times.
2.3 Alkali treatment: Detergent washed fibres remained soaked in 10%-20% NaOH solution for 2 days. This treatment will make fabric fibre bundles into smaller fibres and also removes inorganic impurities. These betel nut fibres were again washed with distilled water and dried in an industrial furnace at 80°C for 1 day.

![Figure 1. Raw betel nut fruit](image1)

![Figure 2. Hand stripped betel nut](image2)

![Figure 3. Alkali-treated betel nut](image3)
2.4 Preparation of sugarcane fibres: There are two main stages in the preparation of sugarcane fibres: pre-treatment stage and fabrication stage. In the pre-treatment stage, raw sugarcane fibres were dried in sun for 7 days later sugarcane fibres were cut into small fibres 1 to 4mm length, then small cut sugarcane fibres were heated in an industrial furnace at 80°C for 10min due to this water contained in the sugarcane will be evaporated. In fabrication stage, sugarcane fibres were mixed with binder composition here in this experiment polyurethane is used as a binder.

Prepare two moulds and two dies for making sample testing pieces. In this experiment, four different samples were prepared with different compositions of betel nut, sugarcane fabric and polyurethane. Sample pieces were prepared by using a hydraulic press with the pressure of 50kPa over the natural fibres and polyurethane.

Four different compositions of betel nut, sugarcane and polyurethane were prepared.

1) 35% betel nut fibres, 35% sugarcane fibres and 30% polyurethane.
2) 50% betel nut fibres, 20% sugarcane fibres and 30% polyurethane.
3) 55% betel nut fibres, 15% sugarcane fibres and 30% polyurethane.
4) 60% betel nut fibres, 10% sugarcane fibres and 30% polyurethane.

Along with the above four compositions, sample pieces of nitrile rubber, nonwoven polyester fabric and glass wool were prepared to test in impedance tube apparatus to check which composition and material type have better SAC. In betel nut, sugarcane fabric samples, polyurethane sheet was kept in between betel nut and sugarcane fibres. After applying 50kPa pressure, fibres were packed so closely so that very less air gap in between the layers which help to allows very less sound to pass through the materials.

Sample workpieces of Nitrile rubber, nonwoven polyester fabric and polyurethane foam were cut into required shape according to testing apparatus specifications.
Figure 5. Betel nut, sugarcane fibre & polyurethane sample

Figure 6. Nitrile rubber sample

Figure 7. Non-woven polyester fabric sample

Sample material for testing SAC
3. EXPERIMENTAL SETUP

Impedance tube apparatus was used for measuring SAC we used Bruel & Kjar UA-1630, Denmark & 2716-C model and test was conducted under ASTM C384 - 04(2016) this is the standard test method for measuring the sound absorption of acoustic materials by impedance tube apparatus. This test method covers the use of an impedance tube, alternatively called a standing wave apparatus, for the measurement of impedance ratios and the normal incidence sound absorption coefficients of acoustical materials. The frequency range of this apparatus is 50Hz to 6400Hz. The experiment was conducted at 20°C. To demonstrate the measurement of SAC and sound transmission loss in the material while the sound is passed at one end. This apparatus contains three microphones which were connected to a digital signal analyzer via signal conditioners and data acquisition system. Loudspeaker connected at one end and plunger is acting at another end. Sample workpiece will be placed near plunger side and some air gap should be maintained between plunger and workpiece. Frequency analyzer was connected to system from apparatus. Two different diameters of materials will be kept while measuring SAC for this model 100mm and 30mm diameter samples were prepared to measure SAC. One is for measuring higher frequency and other is for lower frequencies. The frequency range of this apparatus is 50Hz to 6400Hz. From one side sound will be generated and on other side plunger is placed in that three microphones will give results for sound absorption other microphone is for the amount of sound reflection from that material. The date will be collected in the system connected to the apparatus and SAC values will be given through data acquisition system.

![Figure 8. Schematic Sketch of an Impedance Tube Apparatus.](image-url)
4. RESULTS AND DISCUSSION:

Figure 9. Betel nut, sugarcane fabric & polyurethane (frequency vs sound absorption coefficient)

Figure 10. Nitrile rubber, nonwoven fabric & glass wool (frequency vs sound absorption coefficient)
Figure 9 & 10 gives a comparison of SAC of betelnut, sugarcane fabric with nitrile rubber, nonwoven polyester fabric and glass wool. At lower frequencies below 500Hz betelnut, sugarcane fibres showing better SAC than nitrile rubber and nonwoven polyester. From 500Hz to 2000Hz 60% betelnut, 10% sugarcane and 30% polyurethane showing more SAC than nitrile rubber and nonwoven polyester fabric generally in cars while travelling at higher speeds frequency will be at 2000Hz. At higher frequencies from 2000Hz to 3000Hz SAC is better in 50% betelnut, 20% sugarcane and 30% polyurethane combination than nitrile rubber and nonwoven fabric. From 3000Hz to 4000Hz SAC is better at 60% betelnut, 10% sugarcane and 30% polyurethane than other acoustic materials. At higher frequencies more than 4000Hz SAC is good in 60% betelnut, 10% sugarcane and 30% polyurethane combination showing better SAC, generally in heavy vehicles when running at higher speed frequency will be at 2000Hz to 4000Hz. Glasswool is showing better SAC than any other material even at lower and higher frequencies but it was hazardous to human health and recently it was banned in European countries due to long exposure of glass wool to human skin it will affect. Overall 60% betelnut, 10% sugarcane and 30% polyurethane showing better SAC and cost of this natural material are very less and affordable in all type of automobile vehicles due to better sound characteristics at an affordable price.

5. CONCLUSION:

Considering environmental issues and to utilize natural waste as an acoustic material, betel nut and sugarcane fibres as an alternative SAC. Compare to other acoustic materials betel nut, sugarcane fibres and polyurethane showing better acoustic properties. Betel nut fibres are acting as a barrier for both sound, thermal and vibrations can be reduced. The material composition of 60% betelnut, 10% sugarcane fibres & 30% polyurethane showing better sound absorption level for lower and higher frequencies. Compare to nitrile rubber and glass wool cost of natural fibres is cheap and can be used in economy vehicles.

6. ACKNOWLEDGEMENT

The author would like to like to thank C. Lakshmikanthan and Dr R. Saravanan for supporting this research with valid suggestions and arranging required experimental apparatus for completion of the project and also like to thank Prof. Srinivasan Raju for his assistance.

7. REFERENCES:

[1] Chokri Othmani and Mohamed Taktak 2016 Applied Acoustics 109 90–96.
[2] Elammaran Jayamani and Sinin Hamdan 2014 procedia engineering 97 545 – 554.
[3] Azma Putra and Yasseer Abdullh 2013 procedia engineering 53 632 – 638.
[4] J. Chakrabarty and M. Masudul Hassan 2012 J Polym Environ 20 501-506.
[5] G.Thilagavathi and E. Pradeep 2010 Journal of Industrial Textiles, Vol.39.
[6] Satyajeet P Deshpande, Kolano and Saha Engineers 2014 Indianapolis, June 15-18 2014.
[7] S. Pa Murali and Srinivasan Raju Jeyaselvan 2015 International Journal of Applied Engineering Research, vol. 10, pp. 38077-38080.
[8] Chinnasamy Lakshmikanthan and Nikhil Ramesh 2016 International Journal of Vehicle Noise and Vibration (IJVNV), Vol. 12, No. 4.
[9] M. Saimurugan and K.I. Ramachandran 2014 International Journal of Data Analysis Techniques and Strategies Vol. 6, No. 2.
[10] K. Devarajan, R, R., and K, B 2016 International Journal of Acoustics and Vibration, vol. 21, no. 4, pp. 418-428.
[11] Albrecht Nick and Udo Becker 2002, “Improved Acoustic Behaviour of Interior Parts of Renewable Resources in the Automotive Industry” *Journal of Polymers and the Environment, Vol. 10, No. 3.*

[12] Limin Peng and Boqi Song 2014, “Mechanic and Acoustic Properties of the Sound-Absorbing Material Made from Natural Fiber and Polyester”

[13] Jorge P. Arenas and Malcolm J. Crocker “Recent Trends in Porous Sound-Absorbing Materials” *MATERIALS REFERENCE ISSUE.*

[14] F. Asdrubali and S. Schiavoni “A Review of Sustainable Materials for Acoustic Applications” 2012 *BUILDING ACOUSTICS* Volume 19 Number 4 Pages 283–312.

[15] S Amares1 and E Sujatmika, 2017,” Characteristics of Noise Absorption Material” *Journal of Physics: Series 908.*

[16] Hoda S. Seddeq, 2009, “Factors Influencing Acoustic Performance of Sound Absorptive Materials” *Australian Journal of Basic and Applied Sciences 3(4): 4610-4617.*