Synthesis and analysis of acou-physical properties of banana biocomposite

S P Mishra¹, Bhanupriya¹ and G Nath¹*
Department of Physics, Veer Surendra Sai University of Technology, Sambalpur 768018, Odisha, India
E-mail: saktimishra27@gmail.com

Abstract. The sound absorbing materials have been developed using various natural fibres which are renewable, biodegradable, recyclable and economic in nature. After the cultivation of banana fruit as its stem which is fibrous in nature has no use, it may use in various scientific applications as like as the preparation of sound absorbing materials. The suitable and proper mixture of the epoxy resin with the banana fibre gives rise to formation of the biocomposite material which is mechanically firm and tough. The EDS and SEM analysis of the sample gives an idea about the formation of closed chain in between banana fibre and epoxy in the molecular level and porous quality. The thermal conductivity gradually decreases with the increase of particle concentration and the electrical conductivity increases in the order of 10⁻⁵ which demonstrates the insulating behaviour of the prepared sample. At the higher frequencies there is a reduction of dielectric constant due to the interfacial and orientation polarisation. The intensity of sound decreases in presence of the material and the absorption coefficient rise with increase of frequency. Thus the banana fibre biocomposite material can be used as a sound absorber which behaves as thermally and electrically insulator.

Keywords: Banana fibre, SEM, Sound absorption coefficient, Thermal conductivity, Electrical conductivity, Dielectric Constant

1. Introduction

It is imperative to produce cost-effective and environmental-friendly materials that can reduce noise pollution as noise is one of the major pollution in the world. The increased population and their demand of different assets and the growth of different industries have introduced the noise pollution as a serious problem like other pollution in the world. Now, it is the major challenge how the noise problem can be solved in such a way that we can use the different waste material that deposited in tones on the surface of earth without dependence of electronic instruments and software’s in this technological era. One of the major waste materials in the world includes the agricultural waste, which are produced in billion tones in every year. Instatics [1] it is found that annually, Asia alone generates 4.4 billion tones of solid agricultural wastes.

The synthetic fibres are good sound absorbers but these are the cause of various pollutions and health hazards. The environmental friendly natural fibres which can be made from various agricultural wastage like paddy, wheat, straw, husk, waste vegetables, food products, banana steam, jute fibre, groundnut shell, wooden mill waste, coconut husk, cotton stalk etc having more potential in the substitution of synthetic fibres for the manufacturing of acoustic absorption materials. Again these are easily available and biodegradable. The use of agricultural waste materials has not received till the adequate attention though there are many works has been found in literature relating to the use of agricultural waste. Banana is a bast fibre like material which is complex in nature. These are lignocellulosic natural fibre that consists of cellulose (70%), hemicelluloses (06%), lignin (05%), pectin (03%), ash (1%), extractives (3%), residual gum and moisture regain. It has strong mechanical strength, cost effective, having natural cellular porous like structure which can absorb sound effectively the presence of high amount of cellulose. The presence of lignin with hemicellulose, causes role of natural decay resistance of the material. Though it is a bast fibre, for the structural and non structural industrial application the mechanical properties of banana fibre composite are superior to the conventional materials. Again the impact strength and flexural properties of the fibre are more
advanced than hybrid composites. Cellulose which is abundantly present in pseudo banana stem offers to develop light weight structural biocomposite as it is low density, biodegradable, recyclable and economic. The presence of metal ions percentage in banana is Al$^{3+}$ 0.14, Ca$^{2+}$ 0.72, Mg$^{2+}$ 1.77, Na$^+$ 0.28, and Si$^{4+}$ 1.4 [2- 9]. In this paper the experimental data shows the physical and sound absorbing properties of banana stem fibre. The experimental results shows that the banana stem fibre is not only behave as a good thermal and electrical insulator but also behave as a sound absorber.

2. Material and Method
The banana stem was collected from a well matured banana tree after the cultivation of the fruit. After cutting the tree the stem was extracted and sliced longitudinally. These sliced parts being hammered regularly inorder to expose its thread like fibre structure and then allowed to dry in sunlight for 5-8 days. The dried banana fibre covered with plastic bags and kept in cool and dry place. The small pieces of the fibre was chemically treated with 5wt% of NaOH for one hour and also washed with distilled water. Inorder to remove the moisture content these are dried in oven at 60°C for 2 hours. After removing the small pieces of dried banana fibre from the oven are now grinded through the grinder and by the help of test sieve method the banana stem fibre dust was separated in to particle size of about 150μm and stored in the air tight lid container [10, 11]. A circular, brass mould was prepared having diameter 3.15cm, thickness 0.844cm and volume 26.29 cm$^3$. It was mounted on the wooden slab. To make a gapless contact between the mould and the wooden slab, a rubber pad and a silicone sheet was used. The mould was further tightened using screws. The walls of the mould are further greased with silicone gel to facilitate easy recovery of the prepared sample after being dry. The silicone sheet used was also greased with silicone gel so as to prevent sticking of the wet sample. The experiential procedure for the preparation of the composite involves mixing of the fibre, epoxy resin and hardener manually. The glass beaker and stirrer used for mixing are cleaned using acetone. Initially, epoxy resin and hardener are mixed in a ratio of 10:1 by weight. The epoxy resin and hardener are mixed well by stirring them together for at least 5 minutes. While quick mixing, white air bubbles appear, care should be taken to avoid formation of air bubbles. After mixing them well, the fibre is added. At this moment, the fibre has to be mixed well and quickly as the hardener tends to harden the mixture. Proper stirring is required for uniform mixing of the reinforcing material and the polymer matrix. After stirring it well for at least 10 minutes, the mixture is poured into the greased mould. A greased, silicone sheet is used to cover the upper surface of the sample to prevent contact with the weight. The sample has to be pressed and left to dry for 12-15 hours. For pressing the sample 5-10kg weight can be used. On pressing, the extra epoxy resin squeezes out. On drying, the finished sample was obtained. The method of preparation of sample is represented in Figure 1.

![Figure 1. Sample preparation](image-url)
3. SEM Analysis of the Fibre composite

The surface morphology of banana fibre biocomposite was determined by the help of HITACHI SU 3500 Scanning Electron Microscope. Figure 2 describes about the scanning electron micrographs. The image indicates that the particles are multifaceted type with presence of inter particle void spaces. The surface analysis of the sample indicates the porous nature of the sample about 200 µm [12, 13].

![Figure 2. SEM (a) Surface morphology (b) Image at 200µm](image)

4. Experimental arrangement

4.1 Sound absorption measurement

The experimental arrangement for the measurement of sound absorption coefficient was made as shown in Figure 3. The sample is placed at one end of the cylindrical tube and the microphone at the other end. The microphone is connected to the monitor. The output of the microphone is displayed on the screen using the software ‘EXTECH’. The instrument measures the sound pressure level in decibels. First the reading was taken in absence of the material and then with the presence of the material.

![Figure 3. Arrangement for sound absorption](image)  ![Figure 4. Lee’s apparatus set up](image)
4.2 Measurement of Thermal conductivity and Electrical Conductivity

The thermal conductivity of the sample was measured by using Lee’s apparatus as shown in Figure 4. For the measurement of electrical conductivity of the sample the instruments were arranged as shown in the Figure 5. The sample was placed in between two copper plates in which one of the copper plated was fixed and the other is fixed in such a way that the sample can be easily place and remove. The adjustable terminal of the plate is directly connected with the negative terminal 12V battery and thus the fixed foundation plate was cathode. A digital multimeter was connected with the other end of the battery. By short-circuiting the circuit the fixed resistance was calculated. Then the sample was placed in between the fixed and adjustable foundation and sufficiently tightened by using the bolts.

4.3 Dielectric measurement

For the measurement of dielectric properties of the composite material, HP Impedance Analyzer E4980A was used. The capacity of LCR meter is about 2MHz. The banana fibre composites were analysed by using two contacting metal electrode method in the frequency range 1 kHz - 1MHz with ASTM D150-11 standard.

5. Result and Discussions

Sound intensity decreases in presence of the material because of the porous nature of the sample which was observed in the SEM analysis. Due to the presence of pores air is allowed to flow in to the cellular structure for the sound energy is converted in to the thermal energy and also as the air is pumped in and out of the porous structure there is a loss of viscosity in air.
The randomly orientation of the polymer chain of the epoxy molecule with the molecules of the banana fibre results in to the sound absorption as the phase change takes between the randomly oriented fibre pieces and the air. The absorption coefficient also depends on the particle size, fibre diameter, thickness and density of the sample. With increase of frequency of sound energy the absorption of sound energy goes on increasing. The optimum value is 0.658 and 0.647 for the frequencies of 500 Hz and 1000 Hz respectively. It gives a good absorption coefficient for the higher frequencies. For the lower frequencies (less than 200 Hz) the coefficient are lower [14].

At the lower concentration of the particle the thermal conductivity increases because of the low loss of kinetic energy as shown in Figure 8. With the increase of the particle concentration due to the heavy air dragging force between the vibrations of air particles at 0.08g/cm$^3$ and increasing further due to increasing of the smoothness of the sample, for which as compared to the low density thermal energy increases slightly because of the ion exchange characterisation of epoxy polymer chain and banana fibres. The electrical conductivity increases with the increase of particle concentration as shown in Figure 9. This increase trend is of the order of 10$^{-5}$, for which the biocomposite material can be behave as an electrically insulator.
The hydrophilicity of the NaOH treated banana steam fibre reduced due to destroy of hydrogen bonding. For which the tendency of moisture absorption reduces as the random interaction between the cellulosic hydroxyl –OH groups and water molecules decreased. In higher frequencies due to more molecular vibration of the composite material reduces its ability of complete dipole orientation. For which the dielectric constant gradually reduces from lower to higher frequencies as shown in Figure 10.

6. Conclusion

In this paper the method of preparation of sound absorbing material using banana fibre was developed which is environmental friendly, biodegradable and economic. The results demonstrate that, the banana fibre biocomposite material behaves as thermally and electrically insulator. As the dielectric properties decreases with the increase of frequencies then it can be used as a better dielectric material. The decrease in sound intensity by using banana fibre material and increase in absorption coefficient with increase in frequency explains that it can be used as a good sound absorbing material for the reduction of indoor sound pollution. Thus banana fibre biocomposite can be a better preference than all other natural fibre for the preparation of sound absorbing and dielectric materials. The future scope for the research is to completely characterisation of the banana stem for the preparation of natural fibre reinforced biocomposite and facilitates proper application in automotive, marine and construction industries.

7. Acknowledgement

The authors are very much thank full to Defence Research and Development Organization (DRDO) for financial support under the project ERIP/ER/1203150/M/01/1559 and Vice-Chancellor of VSSUT for all kind of Laboratory support.

8. References

[1] Yoshizawa S, Tanaka M, Shekhar AV Global trends in waste generation. In: Gaballah I, Mishar B, Solozabal R, Tanaka M, editors. Recycling, waste treatment and clean technology. Spain: TMS Minerals, Metals and Materials Publishers; 2004. p. 1541–52 (II).
[2] Bledzki AN, Monzon MD, Angulo I, Ortega Z, Hernandez PM, Marrero MD 2013 Treatment of banana fiber for use in the reinforcement of polymeric matrices *Measurement* 46 1065-73
[3] Mukhopadhyay S, Fangueiro R, Arpac Y, Şentürk U 2008 *Journal of Engineered Fibers and Fabrics* 3 39-45
[4] Chandramohan D, Marimuthu K 2011 *IJRRAS* 8 (2) 194-206
[5] Mamta H, Fouladi M H, Al-Atabi M, Namazivayam S N 2016 *Journal of Engineering* link: http://dx.doi.org/10.1155/2016/5836107
[6] Vijaya Ramnath B, Junaid Kokan S, Niranjana Raja R, Sathyarayanan R, Elenchezian C, Rajesh S 2013 *Adv Mater Res* 683 21-24.
[7] Maries I, Abderrahim B, Umadevi L, Laurent I, Yves C, Sabu T 2006 *Compos Sci Technol* 66 2719-25.
[8] ALRahman L A, Raja R I, Rahman R A 2013 *American Journal of Applied Sciences* 10 (10) 1307-1314
[9] Peng L, Song B, Wang J, Wang D 2015 *Advances in Materials Science and Engineering* link: http://dx.doi.org/10.1155/2015/274913
[10] Riduan M A, Harith Z Y H *Jurnal Intelek* 6(1)
[11] Nath G, Mishra S P 2016 *IOP Conf. Series: Materials Science and Engineering* 012101 doi:10.1088/1757-899X/149/1/012101
[12] Bhatnagar R, Gupta G, Yadav S 2015 *International Journal of Scientific and Engineering Research* 6(5) 2229-5518
[13] Pothan L A, Oommen Z, Thomasc S 2003 *Composites Science and Technology* 63 283–293
[14] Mohanty A R, Fatima S 2011 *Applied Acoustic* doi: 10.1016/j.apacoust.2010.10.005 link: https://www.researchgate.net/publication/251448249