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Smart Sound Absorbing Material for Environmental Noise Reduction

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ABSTRACT

In the current scenario the insidiousness of noise issues regarded as fourth major environmental pollution in the world as per the data published by World Health Organization (WHO, 2011). In advanced countries the peripheral areas of highways, industries, airports and construction sites are well infected by the excessive sound causes significant negative impact on human's health. Thus noise reduction is essential for the present and future generation and significantly increases the importance noise control technology. Due to much unsuitability associated with synthetic sound absorber materials it needs an alternative potential candidate which has improve noise reduction coefficient without producing further pollution in environment. In that context sustainable green acoustic materials like natural fiber composites offer a great opportunity to study the acoustic attenuation technique. Natural fiber composites are carbonaceous, high dielectric value and have good sense of acoustic. The present work encompasses a smart noise absorbing material from luffa cyllindrica which is mostly found in the rural areas of Odisha. The surface modification of the raw luffa fibers are performed with optimized tartaric acid blended alcohol with non destructive ultrasonic technique. Scanning electron microscope image and energy dispersive spectroscopy analysis of the untreated treated and composite fabricated from luffa fibers indicated its potentiality as a sound absorber. The different layers of luffa cyllindrica composite controls the sound propagation in such a way that the noise reduction coefficient enhances to 0.85 making Class-B type sound absorber compared to that of single layered luffa. Further the thermal insulation and mechanical strength of the materials provides the significant support behind the enhancement of sound absorption coefficient of the luffa cyllindrica.

Keywords : Noise reduction coefficient, natural fiber, acoustic material, surface modification, ultrasonic technique

I. INTRODUCTION

It is imperious to fabricate cost effective and eco-friendly materials that can reduce noise pollution as noise is one of the vital problems of the world in these days. The utilization of different kinds of agricultural waste products like biocomposites[1] have properties like acoustic, electrical, thermal, and dielectric which is making them more interesting to be used in industries, new technology applications such as material engineering, economical development of a country, and in different fields where it is needed. The synthetic fibers are good absorbers but production of these fibers contributes to emission of carbon dioxide, methane, and nitrous oxide as a result green house gas releases into atmosphere giving rise to global warming. The lingo cellulosic property of natural fiber composites becomes important due to its non carcinogenic and biodegradable nature. Since luffa sponges are porous material with a high degree of lignifications, they have great potential for applications in composite materials and fabric fibers [2]. In this paper the experimental data shows that the luffa fibre not only shows a good noise absorption quality but also acts as a good thermal and electrical insulator [3].

II. METHODS AND MATERIAL

Materials

Luffa cyllindrica fibers are collected locally which abundendently available. The epoxy LY 556 polymer is used as matrix material for fabrication of reinforced fiber. Hardener HY-951 is used as a curing agent. Tartaric acid with alcohol like methanol, ethanol, butanol and propanol are used for chemical treatment of luffa fibers.

Method

Alcohol treatment of luffa cylindrical fibers

Luffa cyllindrica fibers are collected from a ripe and matured luffa cyllindrica fruit. Collected fibers are now converted to small pieces by cutting it with scissor. Compatible solvent mixtures of tartaric acid blended alcohols have been prepared with the help of ultrasonic interferometer technique. The small pieces of luffa fibers are bleached with the compatible solvent system of tartaric acid blended alcohols to remove the impurities present on the surface of the luffa fiber and converting cellulose/hemicelluloses into activated carbon.

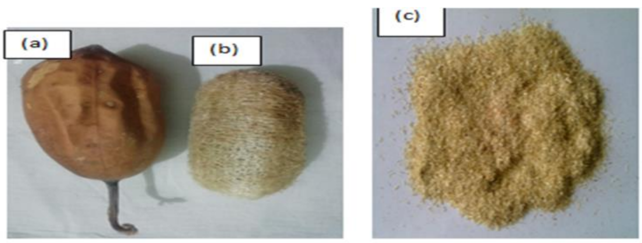

Figure 1 (a) Ripe luffa cyllindrica fruit (b) Luffa cyllindrica fiber (c) pieces of Luffa Cyllindrica fibers

Fabrication of composites

By weight proportion of 10:1 ratio the luffa fiber and epoxy are mixed together and stirrer for 15 minutes to form a uniform matrix. After stirring it well for 15 minutes, the mixture is poured into the mould. A silicon sheet is used to cover the upper and lower surface of the mould. The sample is pressed using ½ kg weight and left to dry for 24 hrs. Composites are fabricated by a general hand lay-up technique. The composites are cast with a single, double, and triple layer of a natural mat Luffa cyllindrica fiber in three different weight proportions. The weight percentage of the fiber is calculated by using the following formula:

$$\text{weight \% of the fiber} = \left(\frac{\text{Weight of fiber}}{\text{Weight of fiber} + \text{Weight of epoxy resin}}\right) \times 100$$

Each ply of the Luffa cyllindrica fiber was of dimensions 140 mm × 100 mm. The cast of each composite was cured under a load of 25 kg for 72 h. Specimens of required dimensions were cut using a diamond cutter for physical characterization and mechanical testing.

Characterization of Sample

The surface morphology of the raw luffa fiber and chemically treated luffa fibre composite has been examined with HITACHI SU 3500 Scanning Electron Microscope. Scanning electron micrographs of luffa fibers and the luffa fiber composites are shown in the Fig.2 (a-e) with EDS. SEM micrographs show porous structure in the luffa fibre and micro voids in the luffa fibre composites and randomly arrangement of carbon and silica particles.

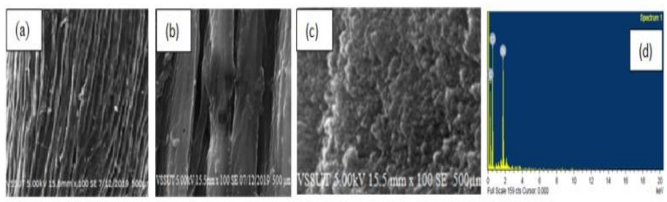

Figure 2 (a) SEM of luffa (untreated) (b) SEM of luffa (treated) (c) SEM of luffa composite (d) EDS of luffa composite

Experimental measurement

A multi-frequency ultrasonic interferometer (2MHz) is used to measure the ultrasonic velocity in the blended solution of tartaric acid and different alcohols within accuracy of ± 0.01 ms^{-1} from which the compressibility has been calculated. Thermal conductivity is measured with the laboratory arrangement Lee's experimental set up.The hardness measurement of the sample has been performed with Vickers's hardness test. The sound absorption coefficient was computed by laboratory designed experimental set up with EXTECH software.

III. RESULTS AND DISCUSSION

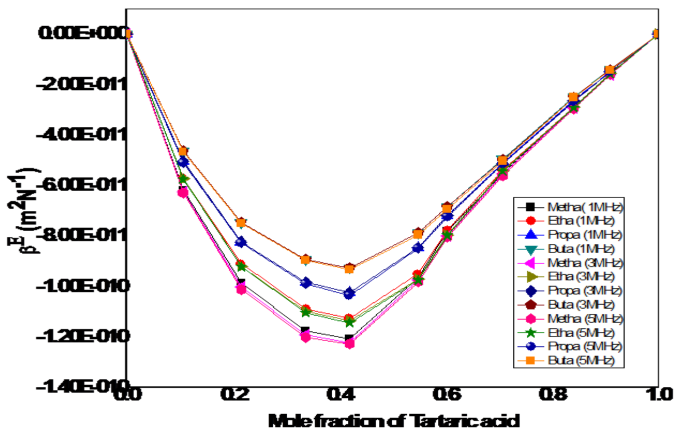

Figure 3: Variation of with tartaric acid Blended alcohols

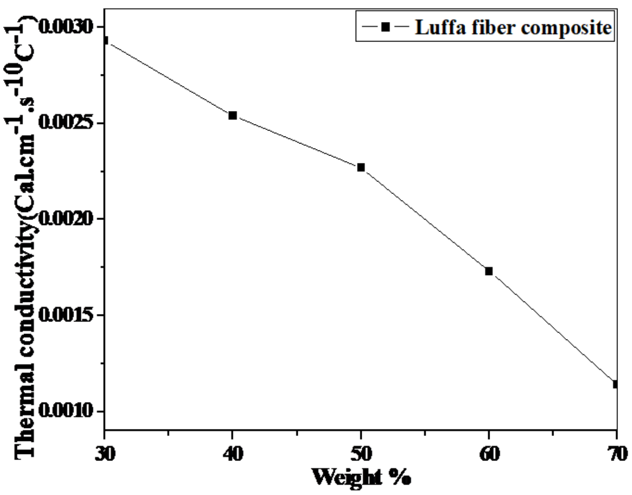

Figure-4 Variation of thermal conductivity with different wt. % of luffa fibre

The optimum blend for ethanol with tartaric acid has been found the suitable modifier for surface modification of the raw luffa fiber. From the variation of excess isentropic compressibility it was observed that both the values are negative over the entire mole fraction range and even with the rising of frequencies. This indicates that sound waves cover long distances due to decrease in intermolecular free length describing the dominant nature of hydrogen bond fiber and optimized blend. As shown in fig.4 thermal conductivity decreases with increase in different weight percentage of alcohol treated luffa fiber composites which indicates the thermal insulator property of luffa fiber composite.

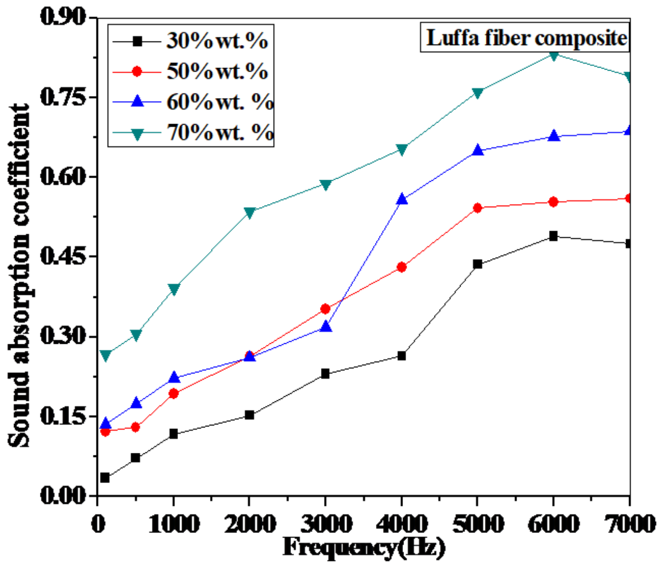

Figure 5: Sound absorption coefficient of luffa composite

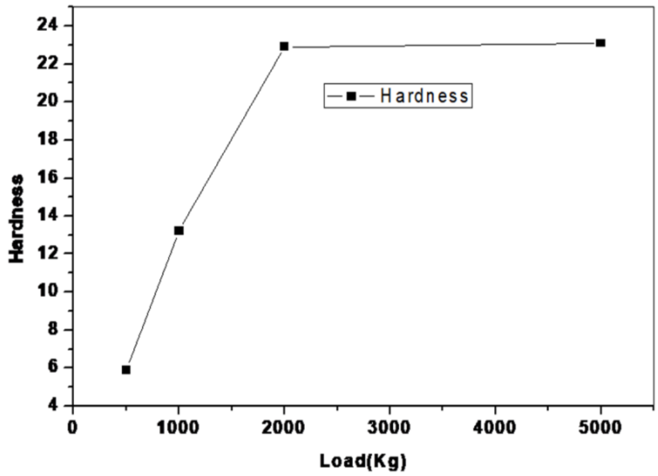

Figure-6 load v/s hardness test

Based on fig.5 it can be observed that the sound absorption of 70 wt% untreated and treated fiber have a higher sound absorption coefficient compared to other fiber contents. Which means higher fiber containt exhibits a high sound absorption coefficient as the frequency is increased. The optimum value enhances to 0.85 making Class-B type sound absorber compared to that of luffa. Fig.6 shows the load v/s hardness graph on 253mm^{2}area of luffa composite. It is observed from the figure that the hardness of the composite increases as the load on the composite increases up to 1800gm. With the further increase of load to 6000gm, the hardness is found to remain constant. So the composite material attains its maximum breaking load at1800gm. This might be due to higher fibrillation caused at this load level, which gives rise to crack initiation.

IV. CONCLUSION

The organized paper describes the uses of bio waste material for potential sound absorber .The method of preparation involves green synthesis without producing the pollution to the environment. The synthesized material can be potentially applied as acoustic material for different purposes where it needs its application. The layered designed acoustic material shows its efficiency as a class-B material as per ASTM standard. Further the acoustic material has good thermal insulating value as well as mechanically strong which supports the material to be act as good acoustic shielding material.

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