WASTE CORN HUSK FIBERS FOR SOUND ABSORPTION APPLICATIONS

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1 Introduction

This study addresses the pressing concerns of noise pollution, energy consumption, emissions, and global warming within the construction industry [1,2].
Currently, conventional materials, such as minerals and synthetic materials, derived from petroleum resources are used for sound absorption and thermal insulation. However, this prevalent practice raises notable environmental and health concerns [3].
In response to these challenges, there is an exploration of natural fibers, such as corn husks, are explored as sustainable and biodegradable alternatives [4].
This research comprehensively investigates the sound absorption (employing an impedance tube) and thermal insulation (employing a guarded hot plate) properties of corn husk fibers (CHFs). Additionally, it introduces an improved predictive model (Dunn–Davern). By utilizing this abundant agricultural waste, the study contributes to the development of eco-friendly building materials, aligning with the imperative for environmentally conscious construction practices.

2 Method and Materials

Corn husk fibers (CHFs) were cleaned, dried, and cut into uniform lengths before being combined with a Polyvinyl Alcohol (PVA) solution. The mixture was then molded into samples of various thicknesses and densities. Samples with 3 cm and 10 cm diameters were used for acoustic measurements in an impedance tube, while 29 cm diameter samples were employed for measuring effective thermal conductivity (K_{eff}) using the guarded hot plate (GHP) technique. The sample preparation process is in Fig. 1.
Sample thickness (d) was determined following ASTM D1037 guidelines, Bulk density was calculated from the measured mass per unit area and thickness, keeping the density of PVA-added CHF constant at 950 kg/m³.
To assess the sample's solid volume fraction (SVF) and porosity (ε), ρ_{bulk} was divided by ρ_{CHF}. Porosity (ε) was calculated as 1 minus SVF.

Figure 1: Sample preparation of Corn husk fibers (CHFs).

3 Sound absorption measurement

The impedance tube with a diameter of 10cm was employed to evaluate the SAC (a) of the samples based on the transfer function method in accordance with ISO 10534-2 [6]. The experimental setup is illustrated in Fig. 2.

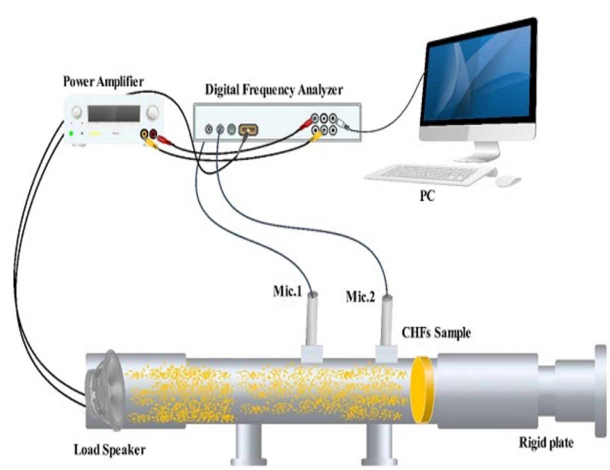

Figure 2: Impedance tube schematic.

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Dunn and Davern (DD) proposed an empirical model to evaluate the frequency-dependent SAC of completely reticulated polyurethane foams [5]. In this model, the propagation of an acoustic wave through a homogeneous and isotropic material is determined by characteristic wave impedance and characteristic propagation constant.

4 Results and Discussion

The Sound Absorption Coefficient (SAC) of the samples increases with rising frequency until it reaches a peak, typically around 1.5-2.5 kHz. Higher bulk density improves SAC at high frequencies. Similarly, increased thickness enhances SAC at low and high frequencies. Experimental data were compared to the Dunn and Davern (DD) empirical model and an optimized DD model using the Nelder-Mead Simplex (DD-NMS) algorithm.

The DD-NMS model not only offers higher accuracy than the DD model but also effectively represents the trends in experimental data and the position of the SAC peak for all samples. Sample thickness was found to have no significant effect on effective thermal conductivity (K_{eff}). Conversely, an increase in density led to a rise in K_{eff}). Prior research indicated that Higher bulk density enhances the SAC because it increases

flow resistivity (σ). This means that sound waves encounter a more complex path, leading to energy dissipation [7]. Also, the lack of influence of thickness on thermal conductivity can be attributed to the inherent nature of this property, which remains constant regardless of material thickness.

This result is similar to that found in many studies about the acoustic characterization of natural and recycled fibers for sound absorption [8,9].

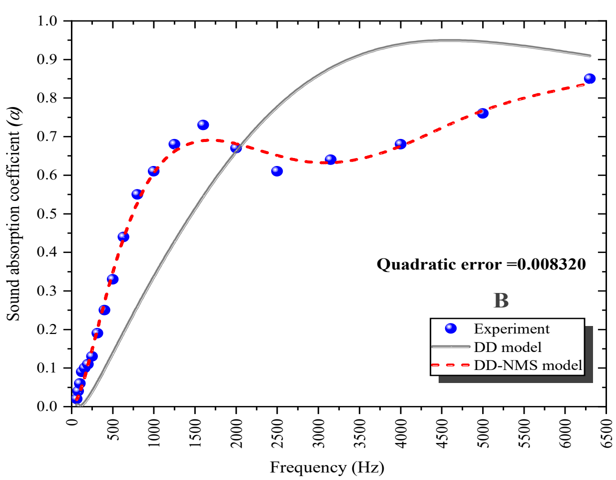

Figure 3: Comparisons of experimental data with the DD and DD-NMS model for the 3cm thick material

5 Conclusions

The results demonstrated strong noise reduction capabilities and excellent sound absorption prediction accuracy using the proposed model. Moreover, CHFs display reliable thermal insulation properties. This resilience positions CHFs as eco-friendly and efficient materials suitable for applications requiring both sound absorption and thermal insulation.

Acknowledgments

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References

[1] Taban, E., et al., Measurement, modeling, and optimization of sound absorption performance of Kenaf fibers for building applications. *Building and Environment*, 180, 107087, 2020.

[2] Taban, E., et al., Use of date palm waste fibers as sound absorption material. *J. Build. Eng.,* 41, 102752, 2021.

[3] Mamtaz, H., et al., Acoustic Absorption of Natural Fiber Composites. *Journal of Engineering,* 5836107, 2016.

[4] Mehrzad, S., et al., Sugarcane bagasse waste fibers as novel thermal insulation and sound-absorbing materials for application in sustainable buildings. *Building and Environment,* 211, 108753, 2022.

[5] Dunn, I.P. and W.A. Davern, Calculation of acoustic impedance of multi-layer absorbers. *Applied Acoustics*, 19(5), 321-334, 1986.

[6] ISO 10534-2 Acoustics — Determination of acoustic properties in impedance tubes. 2023.

[7] Soltani, P. and M. Norouzi, Prediction of the sound absorption behavior of nonwoven fabrics: Computational study and experimental validation. *Journal of Sound and Vibration*, 485, 115, 2020.

[8] Yun, B.Y., et al., Circular reutilization of coffee waste for sound absorbing panels: A perspective on material recycling. *Environmental Research*, 184, 109281, 2020.

[9] U Berardi, G Iannace. Acoustic characterization of natural fibers for sound absorption applications *Building and Environment* 94, 840-852. 2015.