

Acoustic Performance of Upcycled Materials: Plastics & Cigarette Buds in Laminate Composites

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DOI: <https://doi.org/10.30880/rpmme.2024.05.01.015>

Article Info

Received: 02 February 2024

Accepted: 06 July 2024

Available online: 15 September 2024

Keywords

PET powder, cigarette bud, laminate composite, numerical simulation model, sound absorption coefficient

Abstract

This study investigates the capacity of repurposed materials, such as PET powder derived from plastic bottles and cigarette butts, for the purpose of sound absorption. The objective of the research is to create numerical simulation models that can accurately forecast the sound absorption characteristics of laminate composites. It also seeks to investigate the relationship between material qualities and the arrangement of the laminate, and to provide dependable techniques for predicting the sound absorption coefficient. The research seeks to harness the capabilities of these materials for novel noise mitigation methods, thereby enhancing environmental health and acoustic well-being.

1. Introduction

Noise pollution, a harmful environmental and health issue, is causing a surge in demand for environmentally friendly sound-absorbing materials[1][2]. Noise pollution, defined by the World Health Organization as noise above 65 decibels, can harm wildlife, the environment, and human health, leading to heart problems, high blood pressure, stress, tinnitus, hearing loss, and irregular sleep patterns. It is common in manufacturing facilities, lawn maintenance, and train and airplane traffic[3]. Scientists are exploring composite materials made from upcycled materials, such as high-performance wood-polymer composites, for applications like construction, furniture, and transportation. This approach reduces landfill burden, offers alternative materials, and promotes sustainable development[4]. The study investigates the utilization of recycled materials for sound absorption purposes, particularly composite materials derived from recycled plastic and cigarette butts, which have not been extensively assessed for their sound-absorbing properties[5].

This study investigates the acoustic performance of laminate composites made from recycled PET powder and cigarette buds. This investigation aims to develop numerical models to simulate sound absorption behavior of laminate composites made from recycled plastics and cigarette buds, investigate material properties, and laminate configuration, and predict sound absorption coefficient. The study will examine compositions of 100% PET, 50% PET/50% cigarette buds, 75% PET/25% cigarette buds, 25% PET/75% cigarette buds. The total thickness of the laminate will be 30mm, with diameters of 29mm and 100mm. The findings can be used to optimize these materials for specific noise control applications, promoting an environmentally friendly and efficient noise pollution control system. This project aims to revolutionize noise reduction by using sustainable, cost-effective solutions from waste materials. It investigates components influencing sound absorption and improves noise control effectiveness in various situations. The research aims to advance the field of acoustic materials by providing insights into the behavior of freshly upcycled materials. It aims to address current noise control difficulties and set the groundwork for future breakthroughs in the field. The project aims to close the gap between sustainability and acoustics, promoting a peaceful and harmonious coexistence with the environment.

2. Methods

This chapter examines the numerical analysis of sound absorption qualities in laminate composites made from upcycled materials, specifically plastics and cigarette butts. The study uses COMSOL Multiphysics and finite element methods to examine the interaction between these composites and sound waves at various frequencies. The analysis mimics the response of upcycled materials to different acoustic stimuli, determining their sound absorption coefficient, a crucial measure for evaluating their suitability in noise reduction applications.

The knowledge obtained from this numerical investigation sets the stage for improving and advancing these eco-friendly composites to achieve exceptional soundproofing capacities. Five unique arrangements were selected to examine their sound reactions, with a constant thickness of 30mm for the overall laminate. Finite element analysis (FEA) was used to develop geometric models of cylinders with diameters of 29mm and 100mm, and simulation data was collected and analyzed to reveal the sound absorption coefficient of each laminate design.

COMSOL is a very adaptable and potent instrument for engineers and scientists in diverse fields of study. The software's capacity to address intricate Multiphysics problems, intuitive interface, and wide-ranging applicability render it a significant resource for study, development, and design across numerous domains.

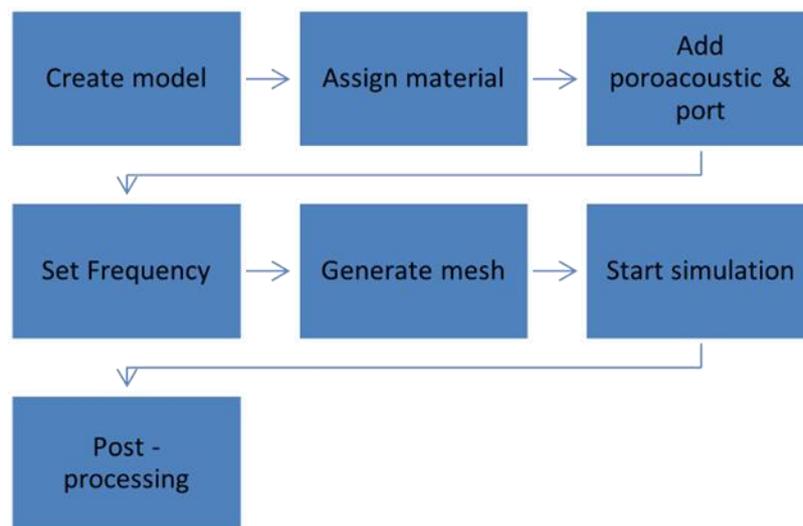


Fig. 1 COMSOL Flowchart

The acoustic simulation procedure commences with the creation of a virtual model using COMSOL. The dimensions of this model include a cylinder with a specific height of 200mm and a radius of 14.5mm. The prototype employed a cylindrical structure of 200mm in height and 14.5mm in radius to examine the material's response to high-frequency sound waves, spanning from 1600Hz to 5000Hz. Another model employed a bigger cylindrical structure with a radius of 50mm to investigate the phenomenon of sound absorption at lower frequencies, specifically within the range of 0-1600Hz. Subsequently, a partition is placed, thereby splitting the cylinder into two sections, with a 30mm gap at one end. To simulate the sound absorption qualities of the material being evaluated, a tiny component within the cylinder is given "poroacoustics" properties. The component is allocated specific parameters, referred to as JCA parameters, to precisely represent its material behaviour.

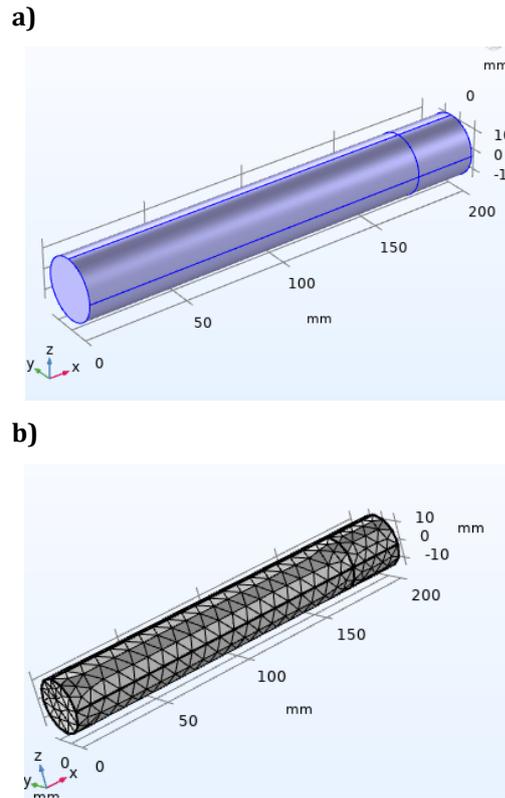


Fig. 2 a) Model Drawing b) Mesh

The COMSOL acoustic simulation procedure involves model generation, parameter specification, simulation implementation, and result examination. The reflection coefficient (R) and sound absorption coefficient (Alpha) are computed to determine the proportion of reflected and incident sound power. A graph is created to illustrate changes in sound absorption properties within a specific frequency range. Understanding each phase helps in examining and forecasting sound absorption properties for noise reduction and acoustic control.

3. Material

The study uses a proacoustics model to simulate the interaction between sound waves and PET powder and cigarette buds laminate, using JCA characteristics to characterize sound absorption. Air is assigned throughout the larger compartment, capturing its unique acoustic properties.

Table 1 JCA parameters for Cigarette Buds and PET powder

Materials	Airflow Resistivity (Ns/m ⁴)	Porosity	Tortuosity	Viscous Characteristics Length (m)	Thermal Characteristics Length (m)
Cigarette Bud	7808	0.974	1.042	0.000081	0.000175
PET powder	1663	0.75	1.01	0.000191	0.000287

4. Results

The sound absorption coefficient (α) is a fundamental measure used to assess a material's capacity to absorb sound waves. The scale spans from 0 to 1, denoting the efficacy of sound wave absorption. A higher value of α suggests superior noise reduction, whereas a lower value of α indicates less efficient absorption at various frequencies.

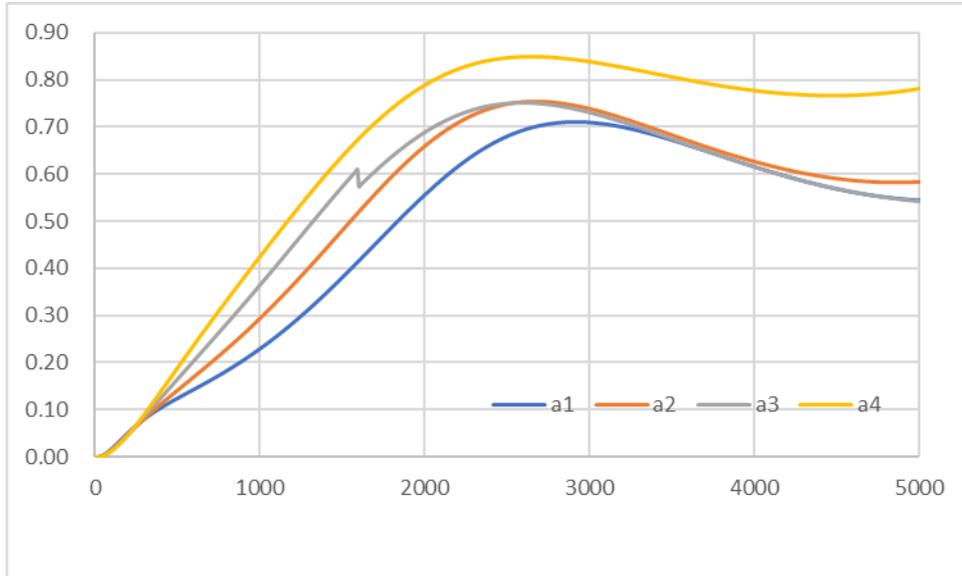


Fig. 3 Sound absorption coefficient of each configuration

The figure 3 displays the sound absorption coefficient of five distinct materials, graphed in relation to frequency. The frequency range spans from 0 to 5000 Hz,

Table 2 Average , mode of sound absorption coefficient at the selected frequency for each configuration

Parameters	a1	a2	a3	a4
Average	0.48	0.53	0.54	0.65
Mode	0.71	0.76	0.75	0.85
Frequency	2840 - 2990	2640 - 2700	2400-2790	2450 - 2860

The study demonstrates that as frequencies increase, all materials exhibit greater sound absorption coefficients, indicating an intensified interaction between sound waves and the internal structures of the materials. The inclusion of cigarette butts in composites also leads to a higher proportion, which suggests their effectiveness. Material a1 exhibits the lowest average and peak absorption values, whereas material a2 improves absorption, a3 consistently demonstrates effectiveness, and material a4 displays exceptional performance.

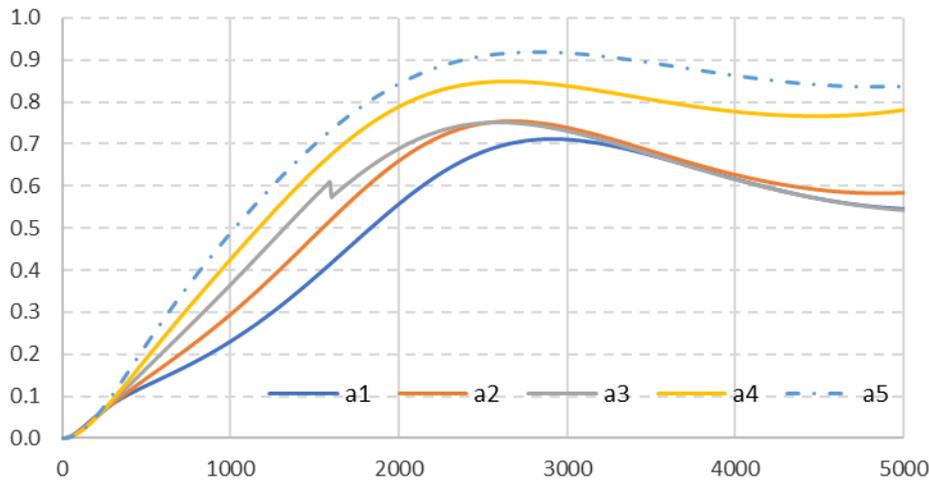


Fig. 4 Sound Absorption Coefficient compared to 100% Cigarette Bud

The graph demonstrates that cigarette butts have a substantial effect on the ability of composite materials to absorb sound. The material labelled as a5, which consists entirely of cigarette butts, exhibits the highest absorption coefficients across all frequencies. With an increase in the concentration of cigarette buds, there is a corresponding increase in the absorption coefficients. Even a minimal quantity of cigarette butts can greatly improve sound absorption, suggesting their potential for use in noise reduction applications. Subsequent investigations should prioritise the examination of the absorption properties of low-frequency noise, as well as the effects of temperature, humidity, and mechanical stress. Additional inquiry is required to guarantee the security and contentment of users.

5. Conclusion

The study effectively accomplished its goals by offering a thorough comprehension of the sound absorption characteristics of laminate composites that include recycled plastics and cigarette butts. The study utilised sophisticated computational models to replicate sound absorption, facilitating precise forecasts without the need for substantial physical experimentation. Based on the data, materials containing cigarette buds (a2 to a5) exhibited a significantly higher sound absorption coefficient compared to pure PET (a1). The material consisting solely of cigarette butts (a5) displayed an average coefficient of 0.71, surpassing that of pure PET which had a coefficient of 0.48.

The investigations revealed a distinct correlation between the characteristics of materials and their acoustic performance, specifically highlighting the porous and fibrous composition of cigarette butts as a significant factor in improving sound absorption. The arrangement of laminates, consisting of varied proportions of PET and cigarette butts, had a significant impact by allowing precise adjustment of sound absorption at different frequencies.

The material made only of cigarette butts (a5) was shown to be the most effective sound absorber, with an average coefficient of 0.71, compared to the coefficient of 0.48 observed for pure PET (a1). The sound absorption of all materials demonstrated a clear dependence on frequency, as higher frequencies resulted in more absorption. This can be explained by the interaction between sound wavelengths and the interior structures of the materials.

In addition, the study combined simulations with experimental results, developing a dependable approach for forecasting the sound absorption coefficient of these composites. The technique, which has been confirmed by the gathered data, offers a potent tool for accurate acoustic design and focused applications, in line with specific requirements for noise reduction.

Furthermore, the research highlighted the study's capacity to contribute to the creation of sound absorption materials that are both sustainable and exceptionally efficient. The acquired insights, bolstered by quantitative data, offer a potential framework for the utilisation of recycled cigarette butts. This can contribute to the creation of quieter settings, the mitigation of noise pollution, and the enhancement of the value of waste materials. In summary, the study presents a comprehensive strategy that integrates numerical simulations, material insights, and predictive capabilities to promote creative and environmentally friendly sound absorption systems.

Acknowledgement

Authors expresses gratitude to the Faculty of Mechanical and Manufacturing Engineering at Universiti Tun Hussien Onn Malaysia for their support.

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Appendix A: Acoustic Pressure

Table 3 Acoustic Pressure Level for each configuration with 100mm diameter

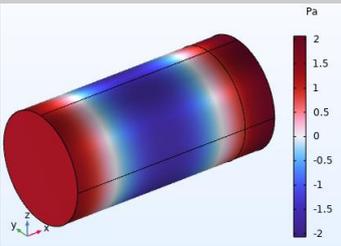
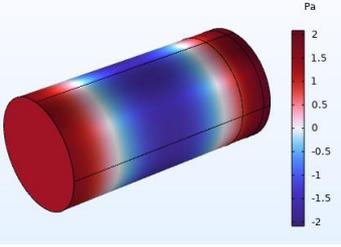
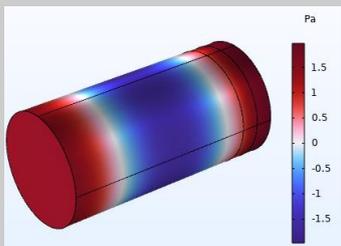
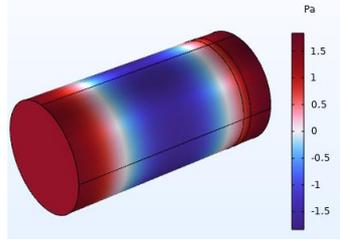
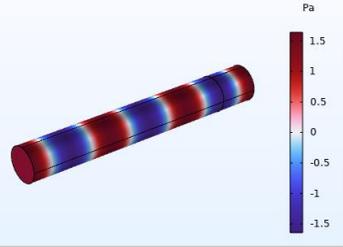
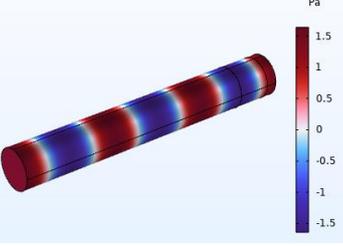
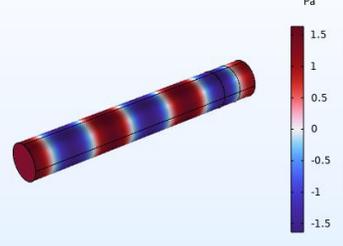
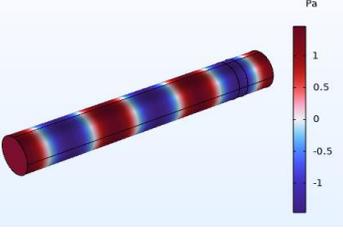
Configuration	Pressure Level
100% PET	
75% PET 25% C.B	
50% PET 50% C.B	
25% PET 75% C.B	

Table 4 Acoustic Pressure for each configuration with 29mm diameter

Configuration	Pressure Level
<p style="text-align: center;">100% PET</p>	
<p style="text-align: center;">75% PET 25% C.B</p>	
<p style="text-align: center;">50% PET 50% C.B</p>	
<p style="text-align: center;">25% PET 75% C.B</p>	

Appendix B: Sound Pressure Level

Table 5 Sound Pressure Level for each configuration with 100mm diameter.

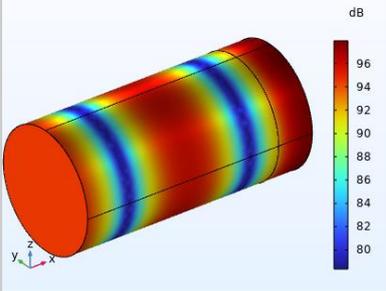
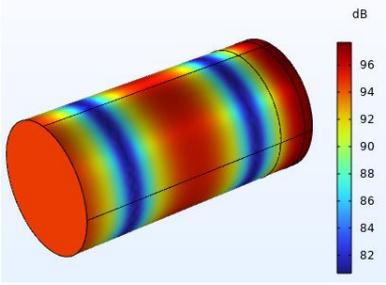
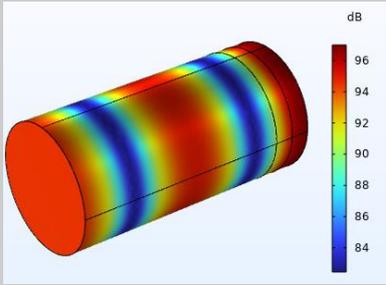
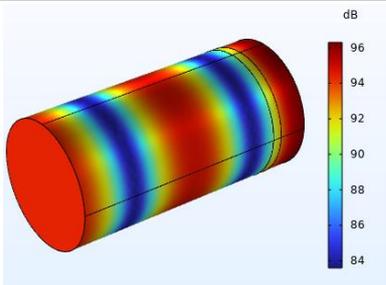
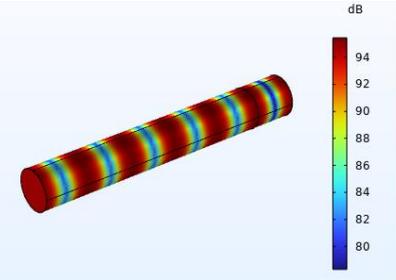
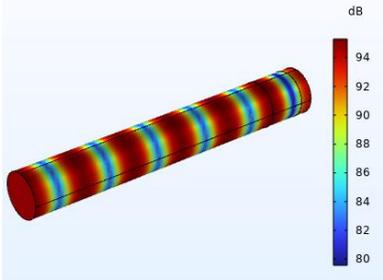
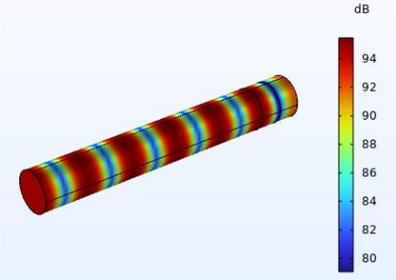
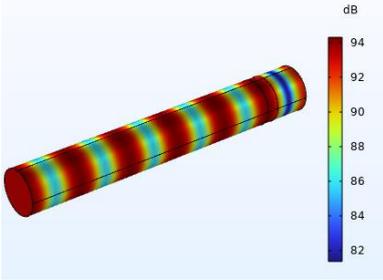
Configuration	Pressure Level
100% PET	
75% PET 25% C.B	
50% PET 50% C.B	
25% PET 75% C.B	

Table 6 Sound Pressure Level for each configuration with 29mm diameter

Configuration	Pressure Level
100% PET	
75% PET 25% C.B	
50% PET 50% C.B	
25% PET 75% C.B	

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