The Review of Contemporary Scientific and Academic Studies
An International Multidisciplinary Online Journal
www.thercsas.com

ISSN: 2583-1380 Vol. 4 | Issue No. 2 | February 2024 Impact Factor: 4.736 (SJIF)

Investigation of the Influence of Layer Orientation on the Free Vibration Characteristics of Sandwich Composite Materials Utilizing Fabric Waste for Car Hood Application

1. Melese Shiferaw (mshiferaw07@gmail.com), Corresponding Author; & **2. Assefa Asmare,**
Faculty of Mechanical and Industrial Engineering, Bahir Dar Institute of Technology, Bahir Dar University, Ethiopia
3. Asmamaw Tegegne, Federal Technical and Vocational Education and Training Institute, Addis Ababa, Ethiopia

Crossref/DOI: https://doi.org/10.55454/rcsas.4.02.2024.006

Abstract: *This study examines the impact of layer orientation on the free vibration properties of sandwich composite materials composed of fabric waste, specifically for potential application in car hood manufacturing. The investigation aims to understand how varying the orientation of layers within the composite structure influences its vibration behavior. The research employs experimental analysis to assess the vibrational characteristics of sandwich composites under different layer orientations, providing insights crucial for optimizing material design and performance in automotive applications. The experimental results of the free vibration test, the CGGC orientation showed sound absorption and good toughness properties. In contrast, the GGGG combination exhibited minimal or low sound absorption capabilities. The combinations of GCGC, CCCC, and GCCG had almost identical sound absorption properties. Superior sound absorption is essential for automotive applications.*

Keywords: Composite Materials, Fabric Waste, Free Vibration, Waste Recycling

Article History: **Received: 14 Feb- 2024;** **Accepted: 20 Feb- 2024;** **Published/Available Online: 28 Feb- 2024;**

1. Introduction

Composite materials offer numerous benefits to researchers, including environmental friendliness, enhanced mechanical properties, and the ability to develop new materials. They have been instrumental in various industries such as automotive, furniture, aerospace and marine. Fabricating composite materials necessitates a unique blend of properties not achievable with individual materials. Fiber-reinforced polymers represent a novel composite material class, combining fibers and polymers. These materials are both efficient and cost-effective, making them suitable for a wide range of engineering applications[1]–[3]. There is increasing interest in developing natural fiber composites as an alternative to synthetic ones. The use of hybrid natural fibers for reinforcement in composite structures has gained attention due to their advantages of low cost, environmental friendliness, and favorable biocompatibility compared to synthetic fiber composites[2], [4], [5]. In numerous applications, it's essential to ascertain the viscoelastic properties of reinforced composites before they enter into service. These properties can be assessed through both destructive and non-destructive testing methods[6], [7]. Every motion dissipates disturbance in one form or another. Damping is associated with energy dissipation; that is, damping is the resistance exerted by a body to the motion of a vibrating system. This resistance can be applied through a liquid or solid, internally or externally. As a result of this resistance, vibrations diminish over several cycles of motion[8]–[10]. Composite sandwich materials are widely utilized as structural and non-structural components in shipping and construction applications. These materials offer high performance in bearing flexural loads, enhanced bending stiffness, excellent thermal insulation, effective acoustic absorption, superior vibration damping, and lightweight properties. They find applications as door panels, bonnets, and boot lids in automobiles, as well as ground panels, roof panels, pedestrian bridge decks, and cladding partitions in buildings. Typically, they are fabricated from thin skins with high stiffness and strength, bonded to a thick lightweight core[11], [12]. Polymer composite materials are widely used for manufacturing lightweight and high-strength materials across various engineering applications. Despite the preference for the strength-to-weight ratio in polymer composites, fatigue loads can lead to crack formation at the edges, potentially resulting in damage or failure of components[13]–[15]. The primary construction materials consist of phenolic resin reimpregnated woven fiberglass layers (known as prepreg) for face sheets and honeycomb systems made of aramid paper (commonly referred to as Nomex, a trademark of DuPont) as the middle layer. Potting compound, monolithic systems made from cotton material and phenolic resin, as well as metal inserts between the middle and face sheets, are often used to locally enhance stiffness and compressive strength. These materials present major challenges to automation due to limited variety caused by cumbersome certification processes, as well as the complex behavior of available materials including rigidity, anisotropy, and hydrophilicity, complicating handling[16]–[18].

2. Materials and Methods

2.1. Materials

In this proposed work, the material utilized consists of sandwiched layers of garment and cotton fabric waste, bonded together with a polyester matrix. The curing process involves the use of a hardener and fly ash as curing agents.

Figure 1: Gabardine waste and Cotton fabric materials used in the experiments.
a. shows the gabardine waste and b. shows the cotton fabric material.

2.2. Methodology

The experimental methodology involves fabricating sandwich composite specimens using fabric waste as outer layers and suitable core material. Multiple configurations with different layer orientations will be considered to evaluate their impact on the free vibration properties. Vibration testing will be conducted using a modal analysis approach, employing techniques such as frequency response analysis and mode shape identification. The experimental data will be analyzed to determine the influence of layer orientation on natural frequencies, damping ratios, and mode shapes of the sandwich composite structures. The hand layup sample fabrication method was used followed by the following schematic diagram.

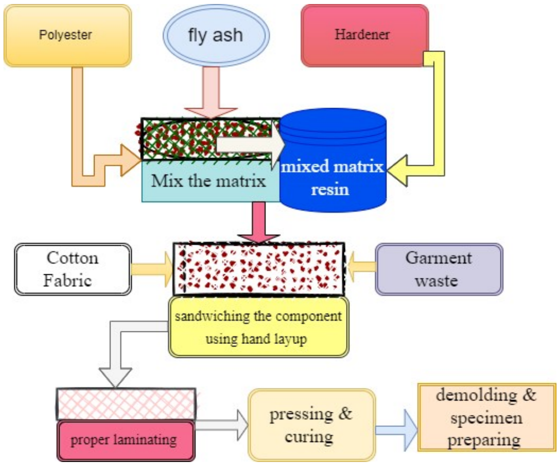


Figure 2: Fabrication process of the sample specimen.

In the automotive industry, the utilization of sustainable materials is gaining significance, with fabric waste emerging as a viable option for composite manufacturing. Sandwich structures, comprising outer layers bonded to core material, offer lightweight and sturdy solutions for car hood production. Understanding the vibration properties of such composite materials is essential for ensuring structural integrity and performance. This study focuses on exploring how altering the orientation of layers within sandwich composites affects their free vibration behavior, contributing to the advancement of sustainable material applications in automotive engineering. The orientation of the layer considered in this finding was the following listed based on the masking and bonding ability of the two constraints of the cotton fabric and garment waste.

✓ C - C - C – C
✓ C - G - C - G
✓ C - G - G - C
✓ G - C - C - G
✓ G – G - G – G
✓ Chopped/ Discontinues

Where
C = grey cotton fabric
G = Gabardine/wool Fabric

Figure 3: Orientation of each constraint.

The experimental sample test was conducted to determine the best combination of reinforcing and matrix materials. In these vibration tests, five combinations of orientation and weight concentration were examined

C - C - C - C (cotton fabric - cotton fabric - cotton fabric - cotton fabric).

C - G - C - G (cotton fabric - gabardine waste - cotton fabric - gabardine waste).

C - G - G - C (cotton fabric - gabardine waste - gabardine waste - cotton fabric).

G - C - C - G (gabardine waste - cotton fabric - cotton fabric - gabardine waste).

G - G - G - G (gabardine waste - gabardine waste - gabardine waste - gabardine waste).

For all six samples fabricated in this research work, a reinforcing-to-matrix (R-M) ratio of 40/60 was used. This combination was employed for both the fabrication and testing of the composite sample specimens, resulting in a better finishing and bonding structure.

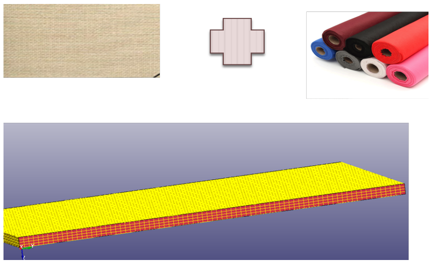


Figure 4: Composite Sample plate Model.

2.3. Experimental Test

Vibration testing simulates the conditions that a product or structure might encounter throughout its lifespan in a test environment. This testing method is utilized to ensure that products are robust and can perform safely during operation or transit, enabling the detection of performance issues and potential failures before they occur. According to the ASTM E756 standard, the sample for vibrational analysis is prepared with dimensions of 250x30x3. In this test, five samples are utilized, and the average natural frequency is calculated. An impact hammer is employed to initiate the initial excitation of the composites to determine their natural frequency. To detect the frequency signal from the impact hammer test, an ACC103 accelerometer is utilized. The natural frequency is calculated using a block diagram and the LabVIEW 2018 program. A DAQ USB NI-6009 data connection is connected to the PC, with the analog signal being converted into a digital signal using the DAQ.

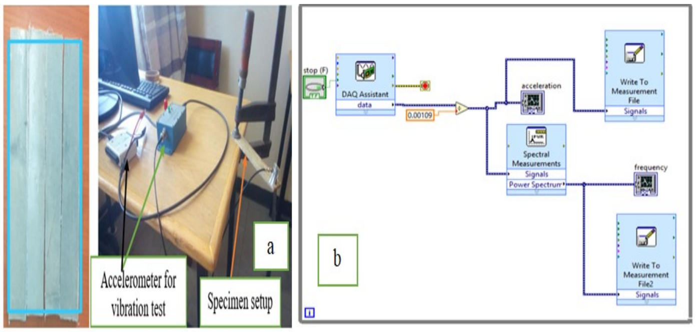


Figure 5: Experimental setup of free vibration test in accelerometer and the LabVIEW Software diagram. a = the experimental setup, and b = the LabVIEW software block diagram used to test free vibration.

3. Results and Discussion

The results of the experimental investigation will be presented and analyzed to assess the effects of layer orientation on the free vibration properties of fabric waste-based sandwich composites. Insights gained from the analysis will help elucidate the relationship between layer orientation and vibrational behavior, guiding the design and optimization of composite materials for car hood applications. Potential implications for enhancing structural performance, reducing vibration-induced noise, and improving energy absorption capabilities will be discussed.

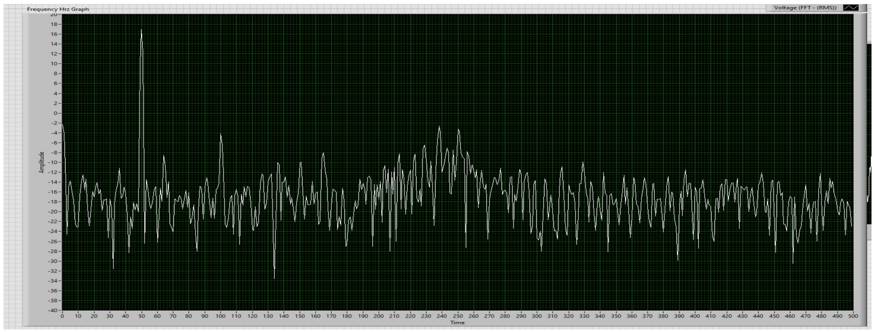
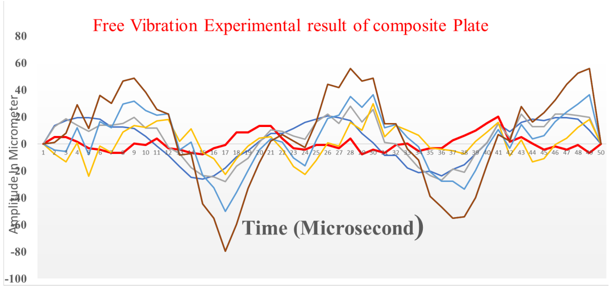


Figure 6: Experimental results of Free Vibration Test from LabView software block diagram.



Where colors represent: C-G-G-C, G-C-C-G, C-C-C-C
G-C-G-C, G-G-G-G, Chopped

Figure 7: Experimental Graph of Tested Result.

Based on the experimental results of the free vibration tests, it was observed that the CGGC orientation exhibited the highest sound and disturbance absorption properties. Conversely, the GGGG combination of the composite plate demonstrated minimal or low sound absorption capabilities. The three combinations, GCGC, CCCC and GCCG showed nearly identical sound absorption properties. It is important to note that superior sound absorption properties are essential for automotive applications.

4. Conclusion

This study contributes to the understanding of how layer orientation influences the free vibration characteristics of sandwich composite materials utilizing fabric waste for car hood applications. By investigating the vibrational behavior of various layer configurations, valuable insights are gained into optimizing composite designs for enhanced performance and sustainability in automotive engineering. The findings of this research inform future developments in material selection, manufacturing processes, and structural design for lightweight and eco-friendly automotive components. The CGGC orientation demonstrated the highest sound and disturbance absorption capabilities. This means that when subjected to vibrations or sound waves, the material in this orientation effectively dampened or absorbed the energy, reducing the level of sound or disturbance transmitted through it. The GGGG combination exhibited minimal sound absorption properties. It implies that the material configuration in this combination was less effective at absorbing sound or disturbance compared to others. GCGC, CCCC, and GCCG combinations showed similar sound absorption properties. While not explicitly stated, it suggests that the arrangement of materials in these configurations resulted in comparable levels of sound absorption. Effective sound absorption properties are crucial in automotive settings to minimize noise within the vehicle cabin, improve overall comfort, and enhance the driving experience. Therefore, materials with superior sound absorption capabilities, such as those exhibited by the CGGC orientation, are highly desirable for automotive applications.

References

[1] M. N. Islam *et al.*, “Fabrication and Characterization of E-Glass Fiber Reinforced Unsaturated Polyester Resin Based Composite Materials,” *Nano Hybrids Compos.*, vol. 24, no. July 2020, pp. 1–7, 2019, doi: 10.4028/www.scientific.net/nhc.24.1.

[2] R. Gideon and D. Atalie, "Mechanical and Water Absorption Properties of Jute/Palm Leaf Fiber-Reinforced Recycled Polypropylene Hybrid Composites," *Int. J. Polym. Sci.*, vol. 2022, 2022, doi: 10.1155/2022/4408455.

[3] N. M. Nurazzi *et al.*, "A review on natural fiber reinforced polymer composite for bullet proof and ballistic applications," *Polymers (Basel).*, vol. 13, no. 4, pp. 1–42, Feb. 2021, doi: 10.3390/polym13040646.

[4] G. Pramudi, W. W. Raharjo, and D. Ariawan, "Investigation of Flexural strength of Sandwich Panels Recycled Carbon Fibre/Polyester with Cotton Mesh Fabric Reinforcement in Polyurethane Core," *J. Appl. Sci. Eng.*, vol. 25, no. 5, pp. 823–831, 2022, doi: 10.6180/jase.202210_25(5).0013.

[5] S. Mesfin, R. G. Rengiah, M. Shiferaw, and T. Guadie, "Effect of fiber content on tensile and flexural strength of water lily fiber reinforced polyester resin composite," pp. 1–8.

[6] M. M. Jalili, S. Y. Mousavi, and A. S. Pirayeshfar, "Flexural free vibration as a non-destructive test for evaluation of viscoelastic properties of polymeric composites in bending direction," *Iran. Polym. J. (English Ed.*, vol. 23, no. 5, pp. 327–333, 2014, doi: 10.1007/s13726-014-0227-x.

[7] Melese Shiferaw, Dr Asmamaw Tegegne, and Dr. Assefa Asmare, "Roles of Composite Materials for the Application of Lightweight Automotive Body Parts and their Environmental Effect : Review," *Int. J. Sci. Res. Sci. Technol.*, pp. 36–46, 2023, doi: 10.32628/ijsrst52310293.

[8] I. M. Navaneeth, S. Poojary, A. Chandrashekar, A. Razak, N. Hasan, and A. I. Almohana, "Damped Free Vibration Analysis of Woven Glass Fiber-Reinforced Epoxy Composite Laminates," *Adv. Mater. Sci. Eng.*, vol. 2022, 2022, doi: 10.1155/2022/6980996.

[9] A. Tegegne and M. Shiferaw, "Experimental of Flexural and Hardness Property of Palm-Sisal Reinforced Epoxy Resin Hybrid Composite Materials," vol. VII, no. I, pp. 143–153, 2020.

[10] M. N. M. Merzuki, Q. Ma, M. R. M. Rejab, M. S. M. Sani, and B. Zhang, "Experimental and numerical investigation of fibre-metal-laminates (FMLs) under free vibration analysis," *Mater. Today Proc.*, vol. 48, no. xxxx, pp. 854–860, 2021, doi: 10.1016/j.matpr.2021.02.409.

[11] S. Prabhakaran, V. Krishnaraj, K. Shankar, M. Senthilkumar, and R. Zitoune, "Experimental investigation on impact, sound, and vibration response of natural-based composite sandwich made of flax and agglomerated cork," *J. Compos. Mater.*, vol. 54, no. 5, pp. 669–680, 2020, doi: 10.1177/0021998319871354.

[12] W. Mesele, "A Comparative Study on Mechanical Property and Free Vibration Analysis of Natural Fiber Reinforced Epoxy Composites," *Dsp. Inst. Dsp. Repos. http//dspace.org*, no. Thesis, 2021.

[13] E. Gowtham, V. Velmurugan, V. Paramasivam, and S. Thanikaikarasan, "Experimental investigation of vibration characteristics of polymer composites subjected to edge crack," *Mater. Today Proc.*, vol. 21, no. xxxx, pp. 694–700, 2020, doi: 10.1016/j.matpr.2019.06.741.

[14] V. Santhanam, R. Dhanaraj, M. Chandrasekaran, N. Venkateshwaran, and S. Baskar, "Experimental investigation on the mechanical properties of woven hybrid fiber reinforced epoxy composite," *Mater. Today Proc.*, vol. 37, no. Part 2, pp. 1850–1853, 2020, doi: 10.1016/j.matpr.2020.07.444.

[15] M. D. Stanescu, "State of the art of post-consumer textile waste upcycling to reach the zero waste milestone," *Environ. Sci. Pollut. Res.*, vol. 28, no. 12, pp. 14253–14270, 2021, doi: 10.1007/s11356-021-12416-9.

[16] K. S. Kumar, I. Siva, N. Rajini, P. Jeyaraj, and J. W. Jappes, "Tensile, impact, and vibration properties of coconut sheath/sisal hybrid composites: Effect of stacking sequence," *J. Reinf. Plast. Compos.*, vol. 33, no. 19, pp. 1802–1812, 2014, doi: 10.1177/0731684414546782.

[17] H. Eschen, M. Harnisch, and T. Schüppstuhl, "Flexible and automated production of sandwich panels for aircraft interior," *Procedia Manuf.*, vol. 18, pp. 35–42, 2018, doi: 10.1016/j.promfg.2018.11.005.

[18] M. Shiferaw, "Utilization of textile fabric waste as reinforcement for composite materials in car body applications : A review," vol. 5, no. 1, pp. 279–290, 2023, doi: 10.25082/MER.2023.01.004.