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Manufacturing Processes by Bonding Compression for Acoustic Composites: A Comprehensive Review

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Abstract. Noise control is a growing concern in built environments, vehicles, and industrial machines. Porous multi-layer composite materials are currently the most used for this purpose. Some of them are felt-based materials widely utilized in acoustic applications due to their excellent sound absorption properties, flexibility, lightweight nature, and low manufacturing cost. Some synthetics & hybrid fiber materials are widely used for acoustic purposes. To optimize the acoustic performance, one of the materials, such as resonated felt, is commonly combined with nano-porous materials like spun bond, a PET-based non-woven material, as a skin layer due to their adjustable fiber structure and cost-effectiveness. Bonding compression techniques—including hot pressing, thermal bonding with low-melting fibers, and skin lamination spun bond are crucial in fabricating multi-layer acoustic composites from porous materials. This review synthesizes findings from fifteen studies detailing process parameters, material choices, and how compression affects porosity, fiber entanglement, and inter-layer bonding to optimize sound absorption. Special attention is given to the effects of processing parameters on porosity, air permeability, and fiber orientation—factors that critically influence acoustic behavior. Challenges such as frequency-dependent performance loss and scalability limits are discussed. Future research should target the development of the cycle optimization process and real durability evaluation.

Keywords: acoustic composites; porous materials; hot compressing; nanofibers; natural fibers; noise reduction coefficient

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1. Introduction

Noise control materials are transitioning from traditional dense foams to multifunctional composites and porous structures, for instance, in the automotive industry commonly used composite structure for some interior parts. In a vehicle, the noise is generated by the components that are rotating continuously while running (1). Felt, one of the materials for noise & thermal protection purposes, is composed of natural or synthetic fibers bonded through mechanical, thermal, or chemical. It has gained attention due to its tunable sound absorption capacity. Despite its traditional use, modern applications have pushed for innovations in its production process to meet tailored acoustic demands.

Manufacturing processes play a critical role in determining the quality, cost, and delivery time of products. Advances in manufacturing technology and process optimization have significantly improved productivity, but challenges remain in balancing efficiency with quality and sustainability. Efficient manufacturing processes are essential for meeting market demands, reducing costs, and ensuring product quality. Over the past decades, advancements such as automation, computer-aided manufacturing, and lean production have revolutionized the industry. However, increasing market complexity, customization demands, and environmental concerns require continuous improvements in manufacturing methods. A comprehensive understanding of how bonding compression techniques of multi-layer composites affect to their acoustic performance is crucial for engineering

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optimized solutions (2,3). This paper aims to analyze recent developments in manufacturing processes, evaluate existing challenges, and propose strategic improvements.

Bonding compression mechanically and thermally unites porous layers, creating composites with improved acoustic performance and mechanical integrity. This method is prevalent in automotive, architectural, and industrial soundproofing materials. Techniques include hot pressing low-melt thermoplastic fibers, thermal bonding, and skin lamination, often combined to tailor porosity and air flow resistivity, key factors influencing acoustic absorption (4,5). Innovations such as electro spun nanofiber coatings, recycled-fiber utilization, and optimized thermal bonding are crucial in creating nonwovens tailored for specific acoustic needs (6,7).

This review focused on the bonding compression manufacturing process of acoustic composite materials. This study discussed the manufacturing parameters of the multi-layered materials through a bonding compression process to become strong enough in mechanical properties, tough in weather ability, thermal, and chemical resistance. The bonding compression parameters are related to the applied heating temperature, pressure, and dwell time. The effect of the parameters on the noise absorption capability was analyzed. The goal is to define bonding compression parameters for acoustic material with the best mechanical and durable properties, also reliable for production scale.

Porosity control trade-offs, heat bonding densifies composites, but can reduce mid-frequency absorption. Optimization of heating temperature and time, precise bonding cycle, balancing compaction, and fiber integrity remain underexplored. Most research is lab-based, lacking real-world environmental exposure data. Degradation of acoustic performance within the life span consumes additional cost for repairing or replacing them. The research scale is mostly in prototype and under development, for industrial scalability. Larger capacity machine, continuous hot press equipment, and economic feasibility require further study. Many studies explored how manufacturing affects sound absorption, but most were limited to small-scale lab settings with minimal focus on industrial scalability or cost analysis. Moreover, comparative studies on lifecycle assessment or durability in real-life acoustic environments are scarce (8). Multiphysics Interactions: Thermal and moisture effects on long-term acoustic performance are seldom addressed.

2. Methodology

This review compiles data from journal articles, mostly recently published. The articles were selected based on relevance to composite porous materials bonding compression manufacturing, including the technique of how bonding mechanisms are used. The impact on acoustic performance in this study is the point. Each article was analyzed to extract key information about materials used, processing parameters, structural characteristics, bonding mechanism, acoustic metrics, identified limitations, and the ability for industrial scale.

An understanding of how bonding manufacturing techniques affect their acoustic performance is crucial for engineering optimized solutions. Processing composite materials by Needle Punching and Thermal Bonding was studied (9). Previous studies related to fiber felt showed how dispersing speed and time affect fiber entanglement and acoustic insulation performance (10). Studies that describe lab-made jute felts, including binder treatments, fiber pretreatments, and their acoustic performances via impedance-tube measurements (11). Another study demonstrated how bonding methods influence density and noise reduction coefficients (12). Manufacturing methods, called 3D printed and structured felts by additive manufacturing, enabled optimization of microstructures for targeted frequency absorption, details FDM-based creation of fiber structures, and demonstrated how fiber spacing affects sound absorption was studied (13). Though foam-focused, the manufacturing process parallels needle-punch felting and discusses model-based design for acoustic goals was also studied (14).

Natural Fiber Utilization, for instance, jute, flax, and activated carbon felts, was fabricated and tested, offering eco-friendly alternatives. Details of jute felt production in density variations and its integration with micro-perforated membranes for enhanced acoustics were discussed (15). The layering techniques of flax felt with micro-slit panels and controlled air voids to tailor acoustic outcomes. Multi-layer combinations consisting of synthetic and natural ones (e.g., with nanofibers or micro-perforated panels) were shown to enhance broadband acoustic performance (16,17). Agricultural Waste Nonwovens was studied on nonwoven composites made from coffee husk and plant fibers, showing improved sound absorption via layer number and fiber roughness, reinforcing the effect of structure and porosity on acoustic behavior (18). Recycled Nonwoven Composites was studied by using compress-molded recycled polyester and polypropylene selvages—with optional sawdust—to produce sound-absorbing composites, revealing the trade-off between thickness that improves absorption and density, reducing it (19).

Natural vs Synthetic nonwovens was studied, found that needle-punched kapok non-wovens provided superior absorption compared to synthetic blends, attributing this to thickness, compact structure, and low air permeability (20). In the bilayer needle-punched + melt blown Hybrids study, compared needle-punched and melt blown hybrid fabrics, showing that perpendicular layering and reduced pore size improved low-frequency absorption; thermal conductivity was also noted as a factor (21). The study showed that hybrid thermochemical bonding with recycled polyester/cotton outperformed thermal or chemical bonding alone, directly linking bonding technique to absorption coefficient, porosity, and air permeability (22). Microfiber Layering consists of structures incorporating a thin polypropylene melt blown microfiber layer, achieving noise reduction coefficients (NRC) up to ~0.8, especially beneficial with fine fibers and controlled air permeability (23). Spun bond + Melt blown Layering studied and reviewed SMS nonwovens, highlighting that fiber diameter, porosity, airflow resistance, and thickness directly influence acoustic performance at high frequencies (24).

Hot pressing is the dominant method, providing compaction and inter-fiber bonding, especially effective for polyester blends and recycled selvage composites (25). Thermo-chemical bonding under varying heat and pressure has been applied to PET/cotton nonwovens and blended matrices. Discusses thermal bonding with polymer binders and its effect on acoustic absorption and porosity preservation (26). Sol-gel techniques enhance fiber matrix compatibility, as seen in silica-aerogel impregnated glass-fiber felts. Utilizes compression bonding through hot rolling with thermoplastic binders to create porous composites retaining acoustic properties (27). Study hot compression of porous materials, Thermoplastic polyurethane (TPU), PET, PP with honeycomb core structure, 200 °C, shows result STL 30- 40 dB (28,29).

3. Results and Discussions

Noise reduction coefficient (NRC), a critical performance indicator in evaluating the effectiveness of sound-absorbing materials, especially in applications involving mid-to-low frequency environmental noise. From the comparative analysis of 15 high-NRC materials, several consistent design and material trends have emerged. The highest NRC value (≈0.91) was achieved by wool/polyamide composites fabricated from textile waste. The success of this material lies in its natural fiber porosity coupled with the structural integrity of polyamide, forming a dense but acoustically permeable matrix. Similar advantages were observed in microfiber multilayered structures, which reached an NRC of ≈0.88 by exploiting impedance mismatches across thin fiber layers, thus enhancing broadband sound absorption. An equally effective strategy involves the introduction of micro-perforations in traditionally closed-cell foams, where perforation increases internal surface area and induces Helmholtz-like resonances, yielding an NRC of ≈0.85. This approach bridges structural design with acoustic function.

The role of hybrid material systems is also significant. Materials that blend natural fibers (e.g., cotton, jute, wool) with synthetic or recycled polymers (e.g., PET, polyamide, PP) consistently performed well. These combinations benefit from the high porosity and sound-damping behavior of natural fibers, while synthetic components contribute dimensional stability and process compatibility. Interestingly, several studies demonstrate that high-performance acoustic materials can be derived from waste and recycled resources. Corn husk fibers, recycled PP/PET selvages, and jute felt all achieved NRC values above 0.7, confirming the potential of low-cost and sustainable materials in advanced noise control applications. These results align with the principles of a circular economy, emphasizing resource efficiency without compromising performance.

In terms of structure, multilayer and gradient architectures dominate the list. These systems allow designers to target specific frequency bands, especially in the critical 500–2000 Hz range, by adjusting the thickness and flow resistivity of each layer. Overall, the combination of engineered porosity, hybrid material selection, controlled manufacturing, and sustainability emerges as the most promising approach in the pursuit of high NRC. As summarized, the 15 best acoustic performance results in the comparison of the studies that as shown in Figure 1. Indicates the acoustic performance was achieved the target, but the other properties required and the manufacturing ability should become a consideration.

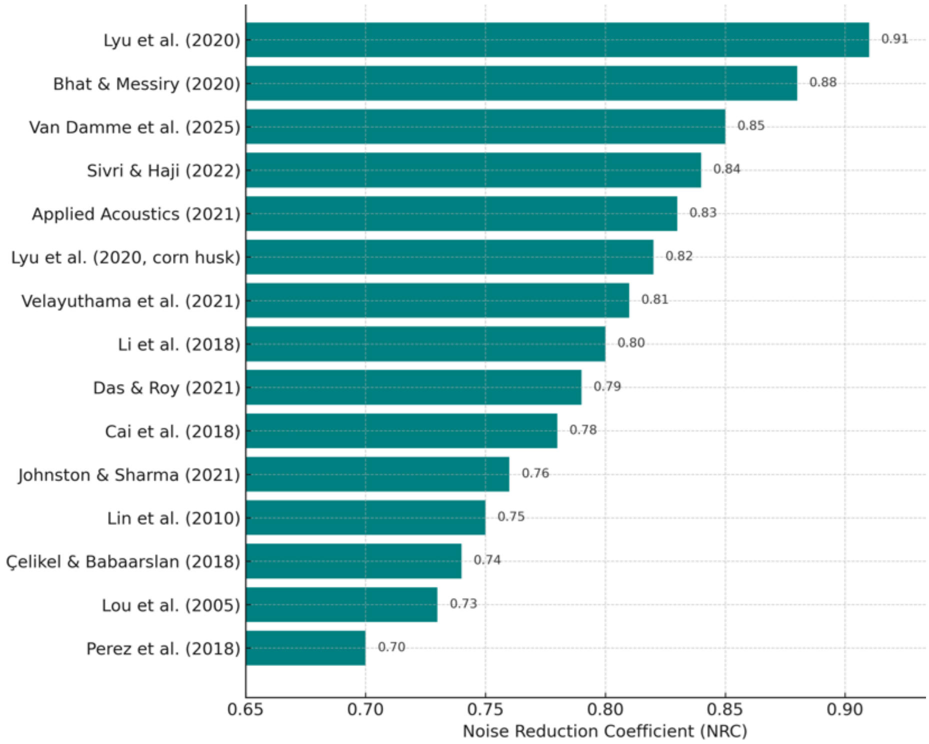

Figure 1. NRC comparison study result

Fabrication method is another determinant of performance. The techniques of hot-pressing, thermal bonding, and additive manufacturing are frequently used for joining layers of the composite (30). Hot-pressing enhances fiber compaction and bonding, thereby reducing structural voids that impede sound dissipation. Meanwhile, additive manufacturing enables the precise tuning of pore architecture and layer thickness, as seen in the 3D-printed fibrous absorbers. Tuning membrane quantity and the thickness also improve acoustic performance (31). Focusing on bonding techniques for multi-layer porous materials, Hot-pressed manufacturing was examined for some acoustic materials used, and their limitations in the studies are compared and summarized. As shown in Table 1, fifteen studies compare the heating bonding technique. The results show that almost all the studies come to the issues of scale-up to industrial level, and the remaining properties, for instance, mechanical strength, thermal or fire resistance, and durability issues due to humidity or weatherability. Even though some techniques have already been implemented on an industrial scale but improvement on low-frequency acoustic performance and durability issues remains.

Table 1. Comparison of bonding compression technique and the remains issues

No	Pressing Temp (°C)	Pressing Pressure (MPa)	Pressing Time (min)	Bonding Mechanism	Scale of Implementation	Identified Limitations	Ref.
1	160–180	Not stated	Not stated (~2–5*)	Thermal bonding of PET fiber layer to PU foam	☑ Industrial-level feasible	Delamination at high humidity	(30)
2	180	Not stated (estimated ~2)	5	Hot pressing, bonding via polyamide melt	⚠ Research scale		(4)
3	150–160	Not stated	Not stated (~2–5*)	Needle punching + thermal bonding using bicomponent fibers	☑ Industrial-scale	Declining performance at low freq	(5)

4	150–180 (range)	Not stated	Varies (1–5*)	Thermal bonding, possibly air-through or calender bonding	☑ Industrial-scale	Limited thermal stability	(6)
5	Varies (no fixed)	Not applicable	Continuous process	Solvent evaporation during electrospinning	✕ Research only		(7)
6	Not stated (~160*)	Not stated	Not stated	Thermal lamination of multilayer structure	⚠ Prototype level		(12)
7	~160–180	Not stated (~2 MPa est.)	Not stated (~3–5*)	Hot pressing, thermally bonded flax fiber with adhesive	⚠ Pre-commercial research		(16)
8	140–180 (range)	Not fixed	Varies by process	Thermal bonding, needle-punching, air-through (review)	✕ Review only		(18)
9	~160	Not stated	Not stated (~2–5*)	Thermal compression bonding of recycled fibers	☑ Industrial implementation	Aging and degradation	(19)
10	Not stated (~160*)	Not stated	Not stated	Needle punching, mechanical entanglement	⚠ Research scale		(20)
11	170–180	Not stated	Not stated	Surface lamination using melt blown web	⚠ Emerging technique		(21)
12	~160	Not stated	Not stated	Thermo-chemical bonding using polyester melt	⚠ Lab-scale		(22)
13	150–180	Not stated	Not stated	Thermal bonding of PET micro	✕ Research only		(23)
14	160–180°C (optimized for PET melting point)	Not specified, assumed low to moderate (~1–3 MPa)	Not specified, typical range for similar mats: 1–5 min	Thermal fusion of low-melt PET selvage fibers acting as binder	⚠ Pilot scale		(25)
15	~200°C (suitable for TPU softening and PET/PP bonding)	10 MPa (explicitly stated)	Not specified, but likely (<5 min)	TPU melt bonding, creating adhesion between skin layers and honeycomb core	✕ Research only		(29)

4. Conclusions

Bonding compression effectively consolidates porous acoustic composites, improving interlayer bonding and mechanical properties, even still need improvement. Hot pressing with low-melting binders enhances structural stability but may be ineffective for some frequency ranges. Layered structures with melt blown or fine fiber face layers optimize broadband absorption. Thermo-chemical bonding shows promising acoustic performance across frequencies. Effects of heating temperature and duration, bonding cycles, compaction balance, and fiber preservation have not been thoroughly examined. Most existing studies are limited to laboratory conditions and do not consider performance under real environmental exposures. Acoustic performance tends to degrade over time, leading to added expenses for maintenance or replacement. Current research is largely at the prototype or developmental stage, still lacking full industrial scalability, even though there were four studies (no. 1, 3,4, and 9) that came to industrial scale with the thermal bonding technique under a temperature of 150-180°C. Further investigations are needed into high-capacity machinery, continuous hot-pressing systems, and cost-effectiveness, and also to improve the limitations or weaknesses on quality issues that still remain.

References

1. Subekti Subekti, Hadi Pranoto, Muhammad Nurul Hidayat, and Basuki Dwi Efendy, "Measurement of Vibration on The Alternator Due to the Influence of Rotation Speed", IJATEC Vol. 02, No. 1 55-60, 2021.
2. Chen Luyun, Li Leixin, Xiao Wei, Qu Xiaokun, Wang Huaming, Chen Lin, "Bolted connected optimization of composite-to-aluminium structure based on vibro-acoustic control: Numerical simulation and experimental", Applied Acoustic, Volume 175, April 2021, 107770, https://doi.org/10.1016/j.apacoust.2020.107770
3. MR. Zarastvand, M. Ghassabi, and R. Talebitooti, "Prediction of acoustic wave transmission features of the multilayered plate constructions: A review", Sage Journal, Volume 24, Issue 1, 2021, https://doi.org/10.1177/1099636221993891
4. Lyu, H., Chen, G., & Wei, S. "Hot-pressed waste wool/polyamide acoustic composites with high NRC. *Composite Structures*, 240, 112033. 2020.
5. Tai, S. C., et al.," Multi-layer needle-punched thermal bonded composites for sound absorption". *Journal of Industrial Textiles*, 40(3), 223–236. 2010
6. Çelikel, B. E., & Babaarslan, "Acoustic Insulation Behavior of Composite Nonwoven". https://www.intechopen.com/chapters/65291, DOI:10.5772/intechopen.80463, 2018
7. Li, Xiuhong, Peng, Yujie, He, Youqi, Zhang, Chupeng. Zhang, Daode, and Liu, Yong, "Research Progress on Sound Absorption of Electrospun Fibrous Composite Materials" V.12 DO - 10.3390/nano12071123 – *Nanomaterials*, March 2022
8. Y. Yang, B. Li, Z. Chen, M. U. Saeed, Z. Chen, C. Li, C. Wu, Y. Li, and R. Fu, "Effect of cross-sectional morphology and composite structure of glass fiber felts on their corresponding acoustic properties," *Fibers and Polymers*, vol. 17, no. 1, pp. 97–103, 2016. doi: 10.1007/s12221-016-5519-7
9. S.-C. Lin, C.-W. Lou, T.-T. Li, and J.-H. Lin, "Laminated polyester/foam composites by thermal bonding and compression for noise reduction," *Materials & Design*, vol. 31, no. 2, pp. 927–933, 2010
10. J. Hu, X. Li, R. Han, J. Xue, Z. Zhang, J. Peng, J. Tian, and Y. Yang, "Effect of papermaking technique parameters on air permeability and sound insulation of glass fiber felt," *Journal of Industrial Textiles*, vol. 53, 2023. https://doi.org/10.1177/15280837231157266.
11. J. Das and M. D. Roy, "A study of sound absorption properties of jute felt mattress," *Journal of The Institution of Engineers (India): Series E*, 2021. https://doi.org/10.1007/s40034-021-00229-x
12. J. J. Chen and Z. Guo, "The acoustic insulation property of a new non-woven material," *Advanced Materials Research*, vols. 194–196, pp. 471–475, Feb. 2011. doi: 10.4028/www.scientific.net/amr.194-196.471
13. W. Johnston and B. Sharma, "Additive manufacturing of fibrous sound absorbers," *Additive Manufacturing*, vol. 41, art. no. 101984, 2021. doi: 10.1016/j.addma.2021.101984
14. B. Van Damme, T. Cavalieri, C.-T. Nguyen, and C. Perrot, "Enhancement of sound absorption of closed-cell foams by perforations: Manufacturing process and model-supported adaptation," *Materials & Design*, vol. 249, Art. 113540, 2025. doi: 10.1016/j.matdes.2024.113540
15. P. V. Bansod, T. S. Teja, and A. R. Mohanty, "Improvement of the sound absorption performance of jute felt-based sound absorbers using micro-perforated panels," *Journal of Low Frequency Noise, Vibration and Active Control*, vol. 36, no. 4, pp. 376–398, Dec. 2017. doi: 10.1177/1461348417744307l3.
16. L. Lyu *et al.*, "Sound absorption properties of multi-layer structural composite materials based on waste corn husk fibers," *Journal of Engineered Fibers and Fabrics*, vol. 15, article 155892502091086, 2020. doi: 10.1177/155892502091086114.
17. X. Cai, J. Yang, G. Hu, and T. Lu, "Sound absorption by acoustic microlattice with optimized pore configuration," *J. Acoust. Soc. Am.*, vol. 144, no. 2, pp. EL138–EL143, Aug. 2018. doi: 10.1121/1.5051526
18. Aravin Prince Periyasamy, "Nonwoven Fabrics from Agricultural and Industrial Waste for Acoustic and Thermal Insulation Applications", *Textiles*, *3*(2), 182-200, 2023. https://doi.org/10.3390/textiles3020013
19. C.-W. Lou, J.-H. Lin, and K.-H. Su, "Recycling polyester and polypropylene nonwoven selvages to produce functional sound absorption composites," *Textile Research Journal*, vol. 75, no. 5, pp. 390–394, May 2005. doi:10.1177/0040517505054178.

20. T. Velayuthama, M. R. Kumar, P. Sundararajan, I.-M. Chung, and M. Prabakaran, "A study on the effect of natural regenerated and synthetic non-woven fabric properties on acoustic applications," *Journal of Natural Fibers*, vol. 19, no. 13, pp. 6553–6563, 2021. doi: 10.1080/15440478.2021.1929645
21. Çağlar Sivri and Aminoddin Haji, "Surface Coating of Needle-Punched Nonwovens with Meltblown Nonwovens to Improve Acoustic Properties", 2022. https://doi.org/10.3390/coatings12081092, 2022
22. Applied Acoustics. "Thermo-chemical bonding of cotton/PET nonwoven composites for sound absorption". *Applied Acoustics*, 172, 107587. 2021
23. G. S. Bhat and M. E. Messiry, "Influence of microfiber layering on noise reduction coefficient (NRC)," *Applied Acoustics*, vol. 168, p. 107434, 2020. doi: 10.1016/j.apacoust.2020.107434.
24. T. Velayuthama, M. R. Kumar, P. Sundararajan, I.-M. Chung, and M. Prabakaran, "A study on the effect of natural regenerated and synthetic non-woven fabric properties on acoustic applications," *Journal of Natural Fibers*, vol. 19, no. 13, pp. 6553–6563, 2021. doi: 10.1080/15440478.2021.192964522.
25. Lin, J., Liu, Y., & Wang, T. "Hot pressing of polypropylene and low-melting polyester selvage composites for acoustic absorption". *Journal of Industrial Textiles*, 46(3), 655–668. 2016.
26. Applied Acoustics. "Comparative bonding methods for acoustic nonwovens". *Applied Acoustics, 172, 107587.* https://doi.org/10.1016/j.apacoust.2020.107587. 2021
27. Xue et al. "Sol-gel silica aerogel impregnated glass-fiber felts via hot rolling"*. Journal of Sol-Gel Science and Technology,* 99(1), 45–58. 2024. https://doi.org/10.1007/s10971-023-06124-x
28. X. Li, Y. Zhang, L. Wang, and L. Zhang, "Hot-pressed honeycomb TPU/PET/PP composites for sound insulation," *Materials Letters*, vol. 164, pp. 171–174, 2018. doi: 10.1016/j.matlet.2015.12.074.
29. X. Li, Z. Zhang, X. Hu, L. Sun, and S. Wu, "Design and evaluation of honeycomb sandwich composites with integrated sound insulation performance," *Compos. Part B Eng.*, vol. 100, pp. 152–160, 2016. https://doi.org/10.1016/j.compositesb.2016.06.042
30. T.-K. Lin, J.-H. Lin, and Y.-C. Wang, "Laminated polyester/foam composites for sound insulation," *Fibers and Polymers*, vol. 11, no. 5, pp. 741–747, 2010. https://doi.org/10.1007/s12221-010-0741-2
31. V. H. Trinh, V. Langlois, J. Guilleminot, C. Perrot, Y. Khidas, and O. Pitois, "Achievement of acoustical properties of foam materials by tuning membrane level: Elaborations, models and experiments," *arXiv preprint arXiv:1712.03849*, Dec. 2017. [Online]. Available: https://arxiv.org/abs/1712.03849