28-oji Lietuvos jaunųjų mokslininkų konferencijos „Mokslas – Lietuvos ateitis" teminė konferencija
Proceedings of the 28th Conference for Junior Researchers "Science – Future of Lithuania"

DARNI APLINKA / SUSTAINABLE ENVIRONMENT

2025 m. balandžio 24 d., Vilnius, Lietuva
24 April 2025, Vilnius, Lithuania

ISSN 2029-7157 / eISSN 2029-7149
eISBN 978-609-476-390-8
https://doi.org/10.3846/da.2025.009

Aplinkos apsaugos inžinerija / Environmental Protection Engineering *https://vilniustech.lt/346238*

ACOUSTIC PERFORMANCE ANALYSIS OF PERFORATED METAMATERIALS: COMPARATIVE STUDY OF BIO-COMPOSITES AND SYNTHETIC CONDUCTIVE MATERIALS

Muhammad Usman SIKANDAR[1], Olga KHRYSTOSLAVENKO[2*], Darius EIDUKYNAS[3], Tomas JANUŠEVIČIUS[4]

[1,3]Faculty of Mechanical Engineering and Design, Institute of Mechatronics, Kaunas University of Technology, Kaunas, Lithuania
[2,4]Department of Environmental Protection and Water Engineering, Vilnius Gediminas Technical University, Vilnius, Lithuania

**E-mail: olga.khrystoslavenko@vilniustech.lt*

Received 24 February 2025; accepted 13 March 2025

Abstract. Perforated metamaterials are developed for innovative sound control within this research. This study investigates the effects of varying infill patterns (50 % and 100 %) of perforation on conductive TPU (Thermoplastic Polyurethane) and PLA (Polylactic Acid) circular samples (30 mm diameter, with 3 mm wall thickness), which were produced via FDM (Fused Deposition Modelling) 3D printing and tested using an impedance tube setup. The acoustic performance of 3D-printed perforated metamaterials made from bio-composite materials (ProtoPasta Conductive PLA) and synthetic conductive materials (Nylforce and Ninjatek) is explored, emphasising the potential for reducing the environmental impact through the use of bio-composites. Acoustic testing covered a frequency range of 160 Hz to 5 kHz, with adjustable back cavity depths of 8.5 mm, 23.5 mm, and 43.5 mm to assess a wide range of frequency absorption capabilities. The results indicate that thicker samples (50 mm) with 100 % infill show superior absorption, particularly at mid-to-high frequencies (2000–5000 Hz), while lower infill densities reduce absorption efficiency. Statistical analysis confirmed that conductive TPU showed slightly higher mean absorption than conductive PLA, particularly in denser configurations, but the difference was not statistically significant ($p > 0.05$). Additionally, back cavity depth significantly influenced performance, with deeper cavities enhancing low-frequency absorption. Perforation density and infill geometry played a crucial role in absorption tuning. The comparative analysis underscores the feasibility of sustainable, multifunctional noise control solutions. The findings suggest that perforated metamaterials can be optimised for broad-spectrum and low-frequency noise mitigation, making them suitable for electromagnetic shielding applications.

Keywords: bio-composite materials, frequency, impedance tube, perforated metamaterials, sound absorption coefficient, synthetic materials.

1. Introduction

Due to environmental pollution and CO_2 emissions, it is important to reduce the negative impact of non-biodegradable materials and promote sustainable alternatives, such as PLA-based foams, which offer comparable mechanical properties to traditional materials such as polystyrene foam, polyurethane foam, fiberglass, mineral wool, and PVC, while effective in soundproofing and insulation, contributes to environmental pollution due to their non-biodegradability and harmful production processes while significantly increasing overall environmental impact (Rotini et al., 2024).

Karamanlioglu et al. (2017) demonstrate that PLA offers sustainability benefits through its renewable feedstock and reduced environmental impact compared to conventional plastics; however, its end-of-life treatment requires optimised recycling and composting infrastructure.

Sound pollution, especially low-frequency noise, is a significant issue in urban, transportation, and industrial areas, causing health problems like hearing loss and cardiovascular diseases (Alves et al., 2020; Jacyna et al., 2017; Wang & Frishman, 2025). Traditional sound control methods, such as dense metals and concrete, are effective but heavy, unsustainable, and unsuitable for low-frequency noise (Wahid et al., 2024). This has led to a rise in sustainable, efficient solutions for noise control (Dušek et al., 2024; Monkova et al., 2022). Sound absorption, particularly low-frequency sounds, is crucial for addressing noise in transportation and industrial settings (Wahid et al., 2024). Perforated metamaterials, with their unique microstructures, offer improved sound absorption, especially at low frequencies (Ma et al., 2021; Wahid et al., 2024). Del Rey et al. (2015) showed that perforated barriers with 4 mm and 6 mm holes achieved a high absorption coefficient (0.9 at 900 Hz). Lightweight lattice structures, like gyroid or honeycomb patterns, improve fuel efficiency in aerospace by replacing dense materials while maintaining strength (Kim et al., 2021; Li et al., 2024; Xu et al., 2024). These structures can be adapted to specific frequencies with advanced additive manufacturing, supporting sustainable projects in both industries.

Research has shown that 3D-printed perforated metamaterials can efficiently control sound absorption and performance (Mudhar et al., 2022). Studies focus on the importance of material composition, perforation density, and structural panel design in optimising acoustic properties. Materials like PLA and bio-composites offer sustainable options without compromising performance (Al Unaizan, 2023; Monkova et al., 2022). However, the full impact of material types, infill density, and back cavity depths on acoustic properties remains underexplored (Al Unaizan, 2023; Monkova et al., 2022).

Metamaterials, with engineered microstructures and unique properties, have shown significant potential in the automotive and aerospace industries. In aerospace, they are utilised in structural components such as wing panels and fuselages, enhancing performance and fuel efficiency (Mohankumar et al., 2024; Saravana Jothi & Hunt, 2022; Sato et al., 2025). These materials combine acoustic and mechanical properties to control low-frequency sound and vibrations, using membrane and silicone rubber compounds to create low-frequency bandgaps. This makes them ideal for mitigating noise below 500 Hz and reducing vibrations in vehicle interiors and aircraft structures (Chen et al., 2021; Chen, 2015).

Synthetic conductive materials, such as metal 3D printed MPP systems (e.g., steel), have been explored for acoustic performance in civil indoor environments. PLA, derived from renewable resources like corn starch or sugarcane, is a biodegradable alternative to traditional plastics, offering an eco-friendlier option compared to petroleum-based plastics (Rotini, 2024). PLA foams have similar mechanical properties to polystyrene foams, but with a reduced environmental impact, although their ecological footprint depends on factors such as raw material sourcing and agricultural practices. Corn-based PLA, while popular for its biodegradability, has varying environmental impacts based on these factors (Rotini et al., 2024). PLA has a shorter lifespan (5–10 years) than synthetic plastics, which can persist for decades to centuries (Gonzalez-Lopez et al., 2019; Vinod et al., 2020).

PLA's biodegradability and natural sound absorption properties make it suitable for acoustic applications, especially in reducing low-frequency noise (Tian & Zhang, 2020). Conductive PLA composites, reinforced with carbon-based fillers such as graphene and CNTs, enhance electrical conductivity, EMI shielding, and acoustic performance. PLA/CNT composites improve EMI shielding and thermal conductivity (Liu et al., 2024), while PLA/rGO composites increase conductivity and mechanical properties for sound-dampening (Gomez et al., 2020).

This research aims to evaluate the acoustic efficiency and sound absorption coefficient of 3D-printed conductive PLA bio-composites reinforced with carbon-based fillers and compare them with synthetic TPU composites, to optimise acoustic applications while balancing sustainability and material efficiency.

2. Materials and methods

The acoustic properties of 3D-printed conductive PLA and TPU samples with varying infill densities (50 % and 100 %) and thicknesses (15 mm, 30 mm, and 50 mm) were tested using an impedance tube setup. A cup 6.5 mm was used to adjust the air gap for precise control over the total thickness and cavity depth during testing (Figure 1).

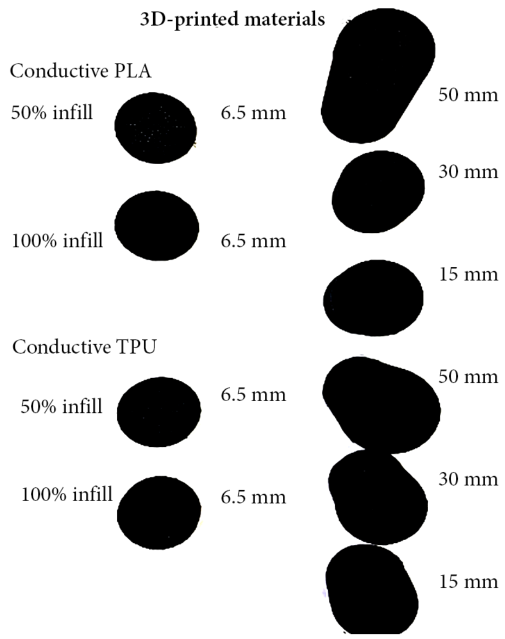

Figure 1. Perforated metamaterial samples

Printed with controlled porosity and material distribution, the samples feature two-part modular components with a perforated front panel (1 mm perforations) and adjustable back cavities. The sound absorption coefficient is highly dependent on perforation diameter and porosity, as these factors influence airflow resistance, resonance behaviour, and energy dissipation mechanisms. In our study, we selected a 1 mm perforation diameter, which was the cleanest achievable using FDM 3D printing on a Prusa MK3 with a 0.4 mm nozzle. Smaller perforations (<1 mm) were unreliable due to extrusion inconsistencies, while larger perforations (>1 mm) reduced viscous and thermal losses, thereby lowering absorption efficiency. The 1 mm perforation provided an optimal balance between structural integrity, printability, and acoustic performance for noise barriers and soundproofing applications. Acoustic testing from 500 Hz to 5 kHz and below 200 Hz will evaluate performance.

3. Experimental setup/methodology

An impedance tube was used to analyse the acoustic properties of 3D printed samples, as shown in Figure 2. The impedance tube was calibrated before measurements to consider the incompatibility of the microphone phases. Ambient temperature, atmospheric pressure, and relative humidity were measured (Figure 2).

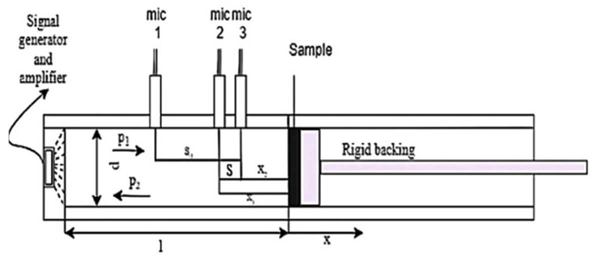

Figure 2. Scheme setup of AED1000 type-3 impedance tube microphone where S – the spacing between measurement microphones 2 and 3, S_0 the distance between microphones 1 and 2 in the figure, which depends on the lower limiting frequency f_l of the tube, l is the length of the impedance tube, x_1 is the distance between the sound source and the first microphone (microphone 1), x2 is the distance between the sound source and the second microphone (microphone 2), p is acoustic pressure measured by the microphones in the impedance tube setup

The configuration setup for the impedance tube is presented in Equations (1)–(4).

$$H_{12} = \frac{P2(f)}{P1(f)},\ H_{23} = \frac{P3(f)}{P2(f)}, \quad (1)$$

where H_{12} and H_{23} are the acoustic transfer functions between the two microphone locations 1 and 2. Here, $P_1(f)$, $P_2(f)$, and $P_3(f)$ denote the pressure measurements at microphones 1, 2, and 3, respectively, at a given frequency f. For the frequency range 160–1000 Hz, the incident and reflected wave transfer functions are given by:

$$H_{I\ (160\text{-}1000\ Hz)} = \frac{P_{2I}}{P_{1I}} = e^{-jk_0(x_{12}+x_{23})}; \quad (2)$$

$$H_{R\ (160\text{-}1000\ Hz)} = \frac{P_{2R}}{P_{1R}} = e^{-jk_0(x_{12}+x_{23})}. \quad (3)$$

For the 1000–5000 Hz range, the transfer functions become:

$$H_{I\ (1000\text{-}5000\ Hz)} = \frac{P_{3I}}{P_{2I}} = e^{-jk_0(x_{23})}; \quad (4)$$

$$H_{R\ (1000\text{-}5000\ Hz)} = \frac{P_{3R}}{P_{2R}} = e^{-jk_0(x_{23})}. \quad (5)$$

The reflection coefficient R is calculated as follows:

$$R = \frac{H_I - H_{I(1000-5000\ Hz)}}{H_{R(1000-5000 Hz)} - H_{12}} = e^{2jk_0(x_1+x_{23}+x_{3S})}; \quad (6)$$

$$R = \frac{H_I - H_{I(160-1000\ Hz)}}{H_{R(160-1000 Hz)} - H_{12}} = e^{2jk_0(x_1+x_{23}+x_{3S})}, \quad (7)$$

where k_0 is the wave number $k_0 = \frac{2\pi f}{c}$, where c is the speed of sound, j is the imaginary number in the complex number, x_{12} – distance between microphone 1 and 2, mm, x_{23} – distance between microphone 2 and 3, mm and x_{3S} is distance between microphone 3 and the sample holder, mm. The reflection coefficient R is derived from the difference between the incident and reflected wave transfer functions. The sound absorption coefficient was calculated as follows:

$$\alpha = 1 - |R|^2. \quad (8)$$

4. Results and discussion

The analysis of the acoustic absorption performance of conductive TPU and conductive PLA samples across different thicknesses and infill densities reveals significant trends in sound attenuation. The samples function like a simple perforated panel, combining Helmholtz resonance, viscous losses, and material-dependent damping. The differences between PLA and TPU arise due to material viscoelasticity – PLA is rigid and relies more on resonance, while TPU is flexible, increasing energy dissipation. This leads to higher absorption peaks in TPU, especially at mid-to-high frequencies. The significant variation in peak values is due to material properties, microstructural porosity, and back cavity effects, with

TPU showing superior broadband absorption. Thicker samples (50 mm) consistently perform better in sound absorption across all frequencies compared to thinner samples (15 mm, 30 mm). Thinner samples show poor absorption at low frequencies (<1000 Hz), while thicker samples perform better due to increased material volume. At mid-to-high frequencies (2000–5000 Hz), both 30 mm and 50 mm samples reach peak absorption, showing effective resonance.

Infill density plays a crucial role in absorption performance, with 100 % infill samples generally achieving higher absorption than 50 % infill. Specifically, conductive TPU with 100 % infill reaches a peak absorption coefficient above 0.8 between 2000–4000 Hz, while 50 % infill TPU stays below 0.6. Similarly, conductive PLA samples with denser infill configurations show better acoustic attenuation but with lower peak absorption values than TPU. Lower infill percentages reduce the material's ability to dissipate sound energy, decreasing absorption efficiency.

While conductive TPU outperforms PLA at mid-to-high frequencies (2000–5000 Hz), conductive PLA offers more balanced absorption across a wider frequency range, making it more suitable for broadband acoustic applications. At low frequencies (<1600 Hz), conductive PLA slightly outperforms TPU, but TPU shows sharper absorption peaks in specific frequency bands.

The best-performing configurations are conductive PLA 50 mm 100 % for low frequencies and conductive TPU 50mm 100 % for mid-to-high frequencies. These findings suggest that material choice should depend on the target frequency range and required sound-dampening properties. Additionally, the dual-functionality of samples is based on the intrinsic conductivity of Proto-Pasta Conductive PLA (~15 Ω·cm resistivity) and NinjaTek Conductive TPU (~10 Ω·cm resistivity), both containing carbon-based fillers known for EMI shielding. While this study focused on acoustic absorption, prior research shows carbon-filled polymers achieve 10–40 dB EMI shielding, depending on thickness and filler distribution (Thomassin et al., 2013).

A statistical comparison between conductive TPU and conductive PLA was conducted to evaluate the significance of absorption performance differences across various sample configurations (Figures 3 and 4).

Figures 3 and 4 show that TPU (30 mm, 100 % infill) had a mean absorption coefficient of 0.398 (SD = 0.285), while PLA (30 mm, 100 % infill) had 0.294 (SD = 0.168). However, the t-test (p = 0.314) showed no significant difference at the 95 % confidence level. For 15 mm 50 % infill, TPU had 0.236 (SD = 0.189) and PLA had 0.348 (SD = 0.252), with a t-statistic of 1.173 and a p-value of 0.256, indicating no significant difference. For 50 mm 50 % infill, TPU had 0.354 (SD = 0.136) and PLA had 0.381 (SD = 0.172), with a t-statistic of −0.418 and a p-value of 0.680, reinforcing that the differences are not statistically significant.

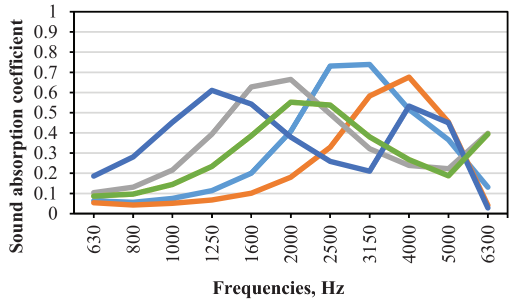

Figure 3. Conductive PLA sound absorption coefficient

Despite TPU's higher variability, both materials have comparable practical application effectiveness. TPU's higher mean absorption in denser configurations suggests better performance in high-frequency applications.

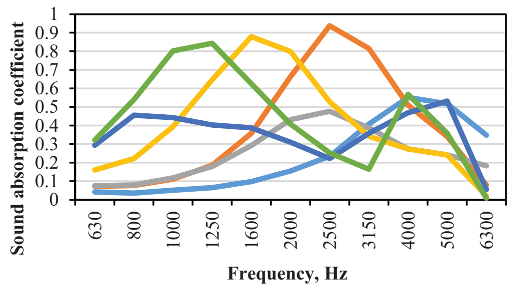

Figure 4. Conductive TPU sound absorption coefficient

A comparison of 50 % and 100 % infill densities in TPU reveals that 100 % infill shows 44.1 % greater absorption (mean = 0.387) than 50 % infill (mean = 0.268), but the difference is not statistically significant (p = 0.086). While 100 % infill TPU absorbs more sound, particularly at mid-to-high frequencies (1000–5000 Hz), this comes with higher material usage. The 50 % infill offers a balance between material efficiency and acoustic performance, making it a practical choice in applications where cost and sustainability are concerns.

For PLA, 50 % infill provides better absorption (mean = 0.338) compared to 100% infill (mean = 0.254), a 25 % improvement, though the difference is not statistically significant (p = 0.175). The superior performance of 50 % infill in PLA is due to its increased porosity, allowing for greater sound dissipation through viscoelastic damping. In contrast, the denser 100 % infill structure reflects more sound, reducing absorption efficiency. These findings suggest that 50 % infill is the more sustainable and cost-effective choice, particularly for PLA-based acoustic metamaterials.

The different behaviours of conductive PLA and TPU are due to their material properties. Being rigid and brittle, PLA reflects sound more, while TPU's flexibility allows for better energy dissipation. TPU benefits from 100% infill for better absorption, but with higher variability. Conversely, PLA performs better with 50 % infill due to increased porosity and energy dissipation, showing the need for infill optimisation based on material properties.

5. Conclusion

In conclusion, this study demonstrates the dual functionality of conductive TPU and conductive PLA composites for acoustic absorption and electromagnetic interference (EMI) shielding. The results reveal that thicker samples (50 mm) show significantly better sound absorption, particularly at mid-to-high frequencies, with conductive TPU achieving peak absorption in the 2000–5000 Hz range, while conductive PLA offers a more balanced absorption response across the entire frequency spectrum. Higher infill densities (100 %) significantly increase sound absorption, with samples showing an improvement in the sound absorption coefficient, especially at higher densities.

Conductive TPU and PLA, with their respective characteristics, are suitable for a wide range of applications in industries such as robotics, aerospace, automotive, and innovative infrastructure, where both noise reduction and EMI shielding are crucial.

References

Al Unaizan, M. (2023). *The effect of infill parameters on the sound absorption characteristics of 3D printed structures* (Master's thesis, King Fahd University of Petroleum and Minerals). KFUPM ePrints. https://eprints.kfupm.edu.sa/id/eprint/142388/

Alves, J. A., Paiva, F. N., Silva, L. T., & Remoaldo, P. (2020). Low-frequency noise and its main effects on human health: A Review of the literature between 2016 and 2019. *Applied Sciences,* 10(15), 5205. https://doi.org/10.3390/app10155205

Chen, C., Guo, Z., Liu, S., Feng, H., & Qiao, C. (2021). Hybrid acousto-elastic metamaterials for simultaneous control of low-frequency sound and vibration. *Journal of Applied Physics*, *129*(5). https://doi.org/10.1063/5.0028332

Chen, Y., Li, Y., Xu, D., & Zhai, W. (2015). Fabrication of stretchable, flexible conductive thermoplastic polyurethane/graphene composites via foaming. *RSC Advances*, *5*(100), 82034–82041. https://doi.org/10.1039/C5RA12515D

Del Rey, R., Bertó, L., Alba, J., & Arenas, J. P. (2015). Acoustic characterization of recycled textile materials used as core elements in noise barriers. *Noise Control Engineering Journal*, *63*(5), 439–447. https://doi.org/10.3397/1/376339

Dušek, K., Koc, D., Veselý, P., Froš, D., & Géczy, A. (2024). Biodegradable Substrates for Rigid and Flexible Circuit Boards: A Review. *Advanced Sustainable Systems, 9*(1), 2400518. https://doi.org/10.1002/adsu.202400518

Gharde, S., Goud, R., Nimje, S., & Kandasubramanian, B. (2019). Aggrandized flexural properties of assorted natural biological materials. In M. Jawaid, M. Thariq, & N. Saba (Eds.), *Biodegradable composites: Materials, manufacturing, and engineering* (pp. 157–192). De Gruyter. https://doi.org/10.1515/9783110603699-006

Gomez, J., Villaro, E., Perez, J., & Haidar, B. A. (2020). Preparation of electrically conductive PLA/rGO nanocomposite filaments. *Graphene Technology*, *5*(3–4), 41–48. https://doi.org/10.1007/s41127-020-00031-3

Jacyna, M., Wasiak, M., Lewczuk, K., & Karoń, G. (2017). Noise and environmental pollution from transport: Decisive problems in developing ecologically efficient transport systems. *Journal of Vibroengineering*, *19*(7), 5639–5655. https://doi.org/10.21595/jve.2017.19371

Karamanlioglu, M., Preziosi, R., & Robson, G. (2017). Abiotic and biotic environmental degradation of the bioplastic polymer poly(lactic acid): A review. *Polymer Degradation and Stability, 137*, 122-130. https://doi.org/10.1016/j.polymdegradstab.2017.01.009

Kim, M.-K., Kim, S., Yun, J.-W., Gyun, J.-H., Kwak, M.-J., Ahn, Y.-L., Park, C.-W., Kim, Y.-C., & Suhr, J. (2021). Design and Manufacturing of Mechanical Metamaterials: A Review. *Composites Research, 34*(4), 199-211. https://doi.org/10.7234/composres.2021.34.4.199

Li, X., Chua, J. W., Yu, X., Li, Z., Zhao, M., Wang, Z., & Zhai, W. (2024). 3D-Printed Lattice Structures for Sound Absorption: Current Progress, Mechanisms and Models, Structural-Property Relationships, and Future Outlook. *Advanced Science, 11*(4). https://doi.org/10.1002/advs.202305232

Li, X., Wang, G., Yang, C., Zhao, J., & Zhang, A. (2021). Mechanical and EMI shielding properties of solid and microcellular TPU/nano graphite composite membranes. *Polymer Testing*, *93*. https://doi.org/10.1016/j.polymertesting.2020.106891

Liu, T., Feng, H., Deng, L., Jin, C., Vahabi, H., Saeb, M. R., & Kuang, T. (2024). Crafting "brick-mud" segregated nanocomposites: a novel approach to superior electromagnetic interference shielding, electrical insulation, and thermal conductivity in biopolymers. *Nanoscale*, *45*. https://doi.org/10.1039/d4nr03175j

Ma, Q., Rejab, M. R. M., Kumar, A. P., Fu, H., Kumar, N. M., & Tang, J. (2021). Effect of infill pattern, density, and material type of 3D printed cubic structure under quasi-static loading. *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science*, *235*(19), 4254–4272. https://doi.org/10.1177/0954406220971667

Mohankumar, A., Packkirisamy, V., & Thirugnanasambandam, A. (2024). Aerospace and automotive marvels applications of friction stir processed hybrid composites. In P. Sagar, Y. Huang, S. Khanna, & M. Kumar (Eds.), *Utilizing Friction Stir Techniques for Composite Hybridization* (pp. 293-315). IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3693-3993-0.ch014

Monkova, K., Vasina, M., Monka, P. P., Vanca, J., & Kozak, D. (2022). Effect of 3D-Printed PLA Structure on Sound Reflection Properties. *Polymers*, *14*(3). https://doi.org/10.3390/polym14030413

Mudhar, R., Mucolli, A., Ford, J., Lira, C., & Yazdani Nezhad, H. (2022). Electrical and Magnetic Properties of 3D Printed Integrated Conductive Biodegradable Polymer Nanocomposites for Sustainable Electronics Development. *Journal of Composites Science*, *6*(11). https://doi.org/10.3390/jcs6110345

Nordin, N. M., Buys, Y. F., Anuar, H., Ani, M. H., & Pang, M. M. (2019). Development of conductive polymer composites from PLA/TPU blends filled with graphene nanoplatelets. *Materials Today: Proceedings, 17,* 500–505. https://doi.org/10.1016/j.matpr.2019.06.328

Ramôa, S. Das, Barra, G. M., Oliveira, R. V., De Oliveira, M. G., Cossa, M., & Soares, B. G. (2013). Electrical, rheological and electromagnetic interference shielding properties of thermoplastic polyurethane/carbon nanotube composites. *Polymer International*, *62*(10), 1477–1484. https://doi.org/10.1002/pi.4446

Rotini, F., Fiorineschi, L., Conti, L., & Rossi, G. (2024). Investigating Polylactic Acid Foam–Plant Fiber Composites for Sound Absorption and Insulation. *Sustainability*, *16*(16). https://doi.org/10.3390/su16166913

Saravana Jothi, N. S., & Hunt, A. (2022). Active mechanical metamaterial with embedded piezoelectric actuation. *APL Materials*, *10*(9). https://doi.org/10.1063/5.0101420

Sato, K., Yonak, S. H., Nomura, T., Matsuzawa, S.-I., & Iizuka, H. (2025). *Metamaterials for Automotive Applications*.

Thomassin, J.-M., Jérôme, C., Pardoen, T., & Detrembleur, C. (2013). Polymer/carbon-based composites as electromagnetic interference (EMI) shielding materials. *Materials Science and Engineering: R: Reports, 74(7),* 211–232. https://doi.org/10.1016/j.mser.2013.06.001

Wahid, Z., Tahir, M. F. M., Dwisatrya, L. H. H., Khamis, N. K., Ahmad, M. A. F., & Nuawi, M. Z. (2024). 3D Printed Nature Pattern Metastructure for The Sound Absorption Coefficient. *Journal of Physics: Conference Series*, *2721*(1). https://doi.org/10.1088/1742-6596/2721/1/012013

Xu, L., Yang, Z., Zhang, Z., Li, E., Zhou, J., & Li, B. (2024). Lightweight composite meta-lattice structures with inertial amplification design for broadband low-frequency vibration mitigation. *Composites Part B: Engineering*, *292*. https://doi.org/10.1016/j.compositesb.2024.112091

PERFORUOTŲ METAMATERIJŲ AKUSTINĖS SAVYBĖS: BIOKOMPOZITINIŲ IR SINTETINIŲ LAIDŽIŲ MEDŽIAGŲ LYGINAMOJI ANALIZĖ

M. U. SIKANDAR,
O. KHRYSTOSLAVENKO, D. EIDUKYNAS,
T. JANUŠEVIČIUS

Santrauka. Tyrimo metu buvo tirtos perforuotos metamedžiagos, sukurtos inovatyviam garso valdymui. Nagrinėtas skirtingų užpildymo modelių (50% ir 100%) perforacijos poveikis laidžiuose TPU (termoplastinio poliuretano) ir PLA (polipieno rūgšties) mėginiuose (30 mm skersmens, 3 mm sienelės storio), pagamintuose naudojant FDM (*Fused Deposition Modeling*) technologiją ir 3D spausdinimą. Buvo tiriamos 3D spausdintų perforuotų metamedžiagų, pagamintų iš biologinių kompozitų (ProtoPasta Conductive PLA) ir sintetinių laidžių medžiagų (Nylforce ir Ninjatek), akustinės charakteristikos, pabrėžiant galimybę sumažinti aplinkos ir psichologinį poveikį naudojant biologinius kompozitus. Akustiniai bandymai apėmė dažnių diapazoną nuo 160 Hz iki 5 kHz, keičiant užpakalinės ertmės gylį (8,5 mm, 23,5 mm ir 43,5 mm), siekiant įvertinti garso sugerties galimybių spektrą. Rezultatai parodė, kad storesni (50 mm) mėginiai su 100 % užpildu pasižymi geresne sugertimi, ypač vidutiniams ir aukštiems dažniams (2000–5000 Hz). Mažesnis užpildymo tankis sumažino sugerties efektyvumą. Statistinė analizė patvirtino, kad laidus TPU vidutiniškai sugeria šiek tiek geriau nei laidus PLA, ypač tankesnėse konfigūracijose, tačiau skirtumas nebuvo statistiškai reikšmingas ($p > 0,05$). Be to, užpakalinės ertmės gylis reikšmingai paveikė veikimą, o gilesnės ertmės pagerino žemo dažnio sugertį. Perforacijos tankis ir užpildymo geometrija suvaidino lemiamą vaidmenį reguliuojant absorbciją. Lyginamoji analizė pagrindžia tvarių, daugiafunkcių triukšmo kontrolės sprendimų naudą. Tyrimo išvados rodo, kad perforuotos metamedžiagos gali būti optimizuotos tiek plataus dažnių spektro, tiek žemo dažnio triukšmui mažinti, todėl jas galima naudoti elektromagnetiniam ekranavimui.

Reikšminiai žodžiai: biokompozitinės medžiagos, dažnis, impedanso vamzdis, perforuotos metamaterijos, garso sugerties koeficientas, sintetinės medžiagos.