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EXPERIMENTAL MEASUREMENTS OF THE ACOUSTIC PROPERTIES OF RECYCLED BULK MATERIALS FOR SOUND INSULATION USE IN PRACTICE

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Abstract: This contribution deals with the possibilities of using selected recycled bulk materials for soundproofing applications. Nowadays, materials based on recycled rubber granules as well as recycled textile materials have a wide application in practice. These materials take up a large volume at the landfill and thus fill them up unnecessarily, therefore it is necessary to recycle the mentioned materials again to a high extent and thereby reduce the burden on the environment. One of the options is the production of compact boards from recycled materials, but it is demanding from the financial and time point of view. The production is laborious with a high proportion of human activity and the production requires the use of binders on a synthetic basis, which can have a negative effect on the environment, and the price of these binders is also high, therefore, for the reasons mentioned, it is advisable to look for the application of these recycled materials in bulk form. In the introductory part of this presented article, the acoustic properties of materials and methods of measuring the acoustic properties of materials are analyzed. The analysis and the potential for the creation of recycled bulk materials are also carried out. The article also presents the results of experimental measurements of the acoustic properties of selected rubber and textile materials. In the final part of the article, the obtained results are evaluated and the possibility of applying recycled bulk materials is assessed.
Keywords: test cartridge, measurement of samples, recycled rubber granules, recycled textile materials

1. INTRODUCTION

Nowadays, the acoustic properties of materials play an increasing role in designing and addressing passive unwanted noise control in several sectors such as construction and automotive [1]. Knowing these properties before using specific materials directly in practice is extremely important. Today, there are various methods and options for studying these properties. One of these methods is impedance tube measurements [2]. For smaller samples, it is advisable to use measurement in an impedance tube, resulting in an acoustic absorption factor only for perpendicular impact [13]. A sufficiently large sample of material is required for measurement in the reverberation chamber, but the advantage is the acoustic absorption factor for the omnidirectional impact of acoustic waves [3].

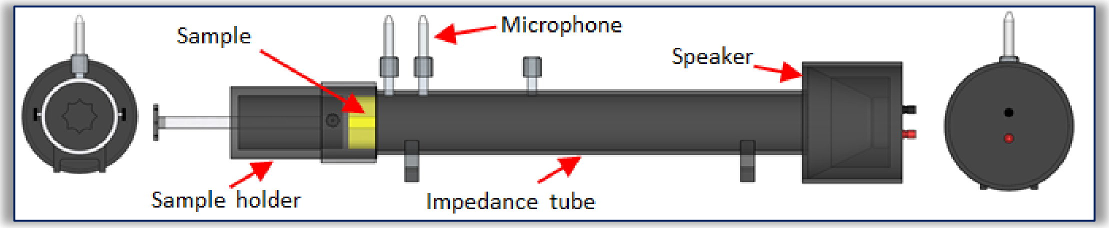

Figure 1. Impedance tube in section [6]

An impedance tube, also called a "Kundt tube" or "interferometer", is a device that is used to determine the sound absorption factor of a material [12], a reflection factor, a surface impedance or the admittance of a material [4]. It is a closed tube with rigid smooth walls, which has a speaker located at one end (Figure 1) and at the other end there is a sample (Figure 1) of the material under examination. Measurements shall be made on pre–prepared samples which are placed in the piston tube [5].

In the case of a horizontal tube, the probe tube must be supported approximately in the center to prevent it from sagging and generating higher wave frequencies [7]. In the case of a rectangular tube, these microphones must be placed exactly in the lower corner of the tube (the most ideal location is in the corners of the tube), since the slightest resonances occur. It is also very important to avoid mechanical contact between the tube and the microphone [9].

Measuring microphones may be located on the side of the device or on top of it. If there are multiple microphones on the device, they must be of the same type. Microphones must be well fixed and insulated on the device [11].

This method can only be used for the perpendicular impact of acoustic energy, therefore it is mainly used in the development of acoustic materials or for comparison of different materials in terms of their sound absorption [12]. The following Figure 2 shows a real view of the impedance tube.

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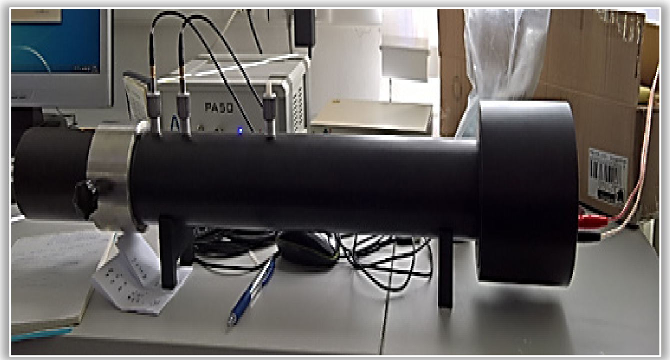

Figure 2. A real view of the Impedance tube [12]

Figure 3. View of the BSWA TECH MPA416 microphone

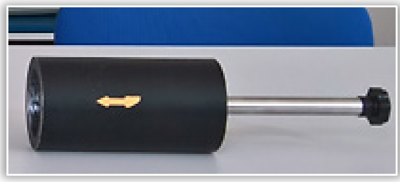

Figure 4. Sample holdr

2. REALIZATION OF EXPERIMENTAL MEASUREMENTS OF ACOUSTIC OWN PRODUCTS OF SELECTED MATERIALS

This chapter focuses on experimental measurements of the acoustic properties of selected materials. An impedance tube was used to measure and evaluate acoustic properties. In the following section, the measurement technique is described in detail, the materials analyzed, and the measurements are taken.

— Measurement technology

N and measurement of the sound absorption factor of selected materials, an impedance tube from BSWA TECH [14] and model SW433 (Figure 2) were used in a dual–microphone configuration also from BSWA TECH MPA416 (Figure 3). The length of the tube was 500 mm, and its inner diameter was 60 mm. A sample holder (Figure 4) with a diameter of 60 mm was also used.

To measure the sound reduction index factor of the examined materials, as in the measurement of the sound absorption factor, an impedance tube model BSWA TECH SW433 in a configuration with four BSWA TECH MPA416 microphones is not connected to the other end of the tube in this case, as in the measurement of sound absorption, but an extension tube is connected (Figure 5). The extension tube has a length of 500 mm and an internal diameter of 60 mm.

Other components of the measurement technology also include: MC3242 4 – channel analyzer (Figure 6) from BSWA TECH [14] for data collection, PA50 measuring power amplifier (Figure 7) from BSWA TECH, computer equipped with VA–Lab4 software (Figure 9) to evaluate information and control the tube, sound level calibrator from Brüel & Kjær 4231 (Figure 8).

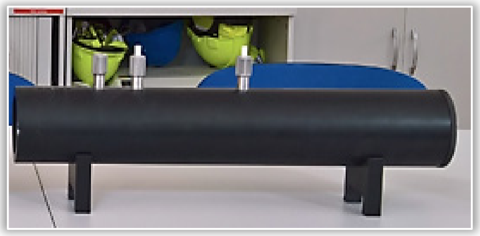

Figure 5. Extension tube

Figure 6. 4 - BSWA TECH MC3242 Channel Analyzer

Figure 7. BSWA TECH PA50 Amplifier

Figure 8. Sound level calibrator Brüel & Kjær 4231

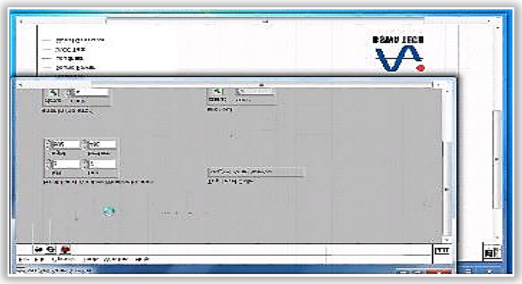

Figure 9. VA–LAB4 software [20]

At the Department of Environmental Engineering, Faculty of Mechanical Engineering, Technical University of Kosice, test cartridges were designed and subsequently manufactured. These cartridges were developed to measure predominantly bulk acoustic materials, especially crushed waste from surviving cars. Among other things, they serve to stuff (compress) the required bulk material such as rubber granules, glass, textile fractions [15, 17], etc., and in this way obtain a compact block for measuring sound and thermal insulation with proven

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properties. Their production made it possible to measure them in the BSWA SW433 impedance tube [14], which is structurally limited to rigid materials. Currently, the test cartridge is protected by a utility model (No. PUV 50024–2022) [19] as well as a patent (No. PP 50020–2022) [18]. The following Figure 10 shows a real view of the test cartridge used.

Figure 10. Selected test cartridge with a length of 55 mm

— Selected materials

For experimental measurements of acoustic properties, 4 materials were selected. The list and characteristics of the individual samples are clearly presented in Table 1 below. On the following Table 2 shows individual tested materials.

Table 1. List of test materials

Sample number	Material	Test cartridge	Material thickness [mm]	Volumetric weight [kg.m^{-3}]
1.	Compact AVE rubber panel	not	40	812
2.	Recycled rubber granules	yes	50	464
3.	Stered Compact Panel	not	50	276
4.	Textile Chopped Material Stered	yes	50	91

Table 2. Test materials

1. Sample – Compact rubber material

2. Sample – Recycled rubber granules – fraction size 2,5 – 4 mm

3. Sample – Compact textile material – Steered

4. Sample – Recycled bulk textile material [17]

— Measurement procedure

During the measurement, the test cartridges were filled with bulk material (recycled rubber granules and textiles), while the material was freely poured into the cartridges without applying additional pressure to the bulk material. When measuring, the following acoustic parameters are evaluated:

- sound absorption coefficient (α) [–],
- sound reduction index (R) [dB].

Sample measurements were carried out at the Department of Environmental Engineering, Faculty of Mechanical Engineering, Technical University of Kosice using a BSWA TECH SW433 impedance tube with BSWA TECH MPA416 capacitor microphones. 4 samples were measured. Measurements of each sample were made repeatedly five times and the results were then averaged. To assess the impact of the test

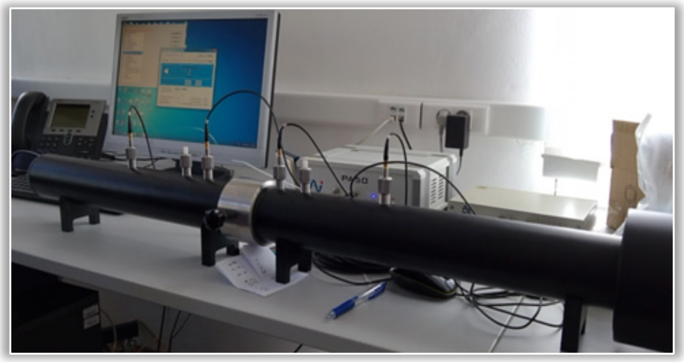

Figure 11. View of the sample measurement on the Impedance tube

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cartridge on the measurement results, measurements of the empty test cartridge were also made. Based on these measurements, it is possible to correct the measurement results of bulk materials placed in the test cartridge. Measurement and evaluation were carried out in the frequency range from 100 to 2500 Hz in accordance with ISO 10534–2. The following Figure 11 shows a view of the sample measurement on the Impedance tube.

— Measurement results

This chapter discusses the results from experimental measurements and the assessment of the possibilities of applying recycled materials in practice. The sub–chapter describes and graphically illustrates comparisons and evaluations of the measured materials. To evaluate the acoustic properties of the samples, the sound absorption coefficient (α) and the sound reduction index (R) were used. The results from individual measurements from VA–Lab4 were then converted to Microsoft Excel, in which the following tables and graphs were created.

3. COMPARISON AND EVALUATION OF MATERIALS BASED ON RECYCLED RUBBER GRANULATES

In general, rubber material is characterized by having good absorption and lower reduction. This is also confirmed by the measurements made. The main objective of the measurements was to compare the properties of bulk rubber recycled materials with the compact rubber panel, which is commonly commercially manufactured. Based on the measurements made, we can conclude that the coefficient of sound absorption (Figure 13) of bulk materials reaches higher values compared to a compact rubber sample. This is mainly due to the fact that in bulk materials, sound absorption occurs not only by the material itself, but also by the contribution of air gaps between individual rubber particles. When measuring the sound reduction index (Figure 12), the best values as expected are achieved by a compact rubber sample. Almost identical values are achieved by loose rubber granules with a fractional size of 2.5 – 4 mm.

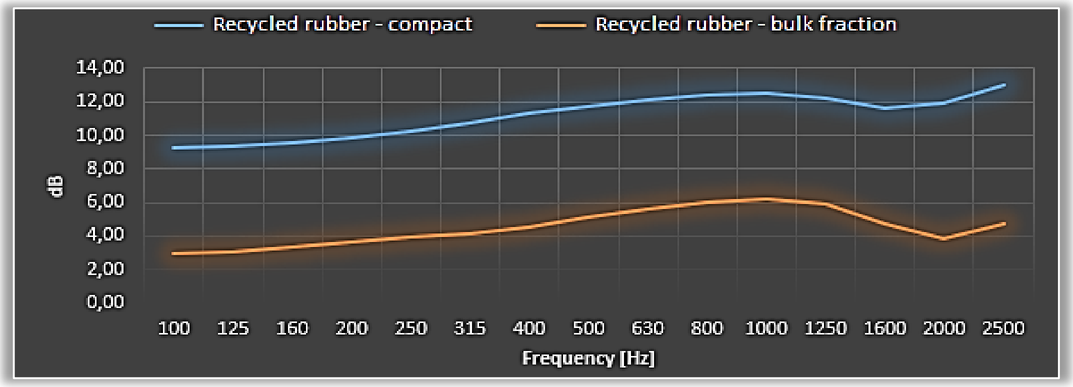

Figure 12. Sound reduction index (R) – Recycled rubber – compact and recycled rubber – bulk fraction

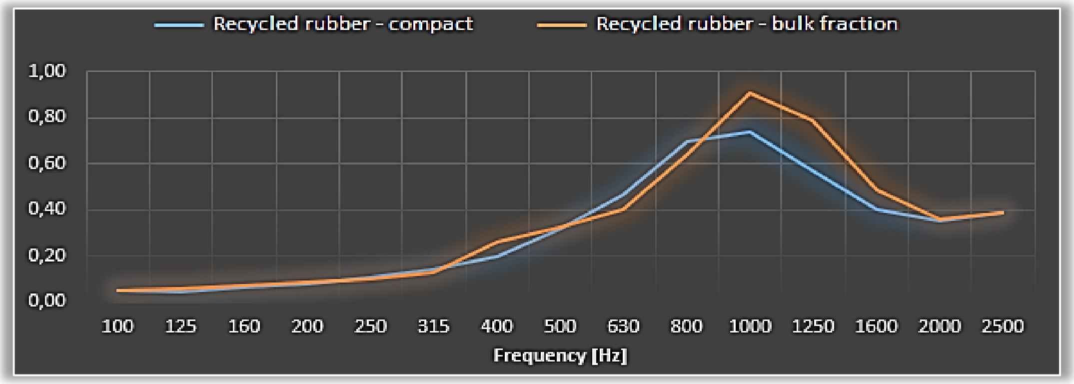

Figure 13. Sound absorption coefficient (α) – Recycled rubber – compact and recycled rubber – bulk fraction

4. COMPARISON AND EVALUATION OF RECYCLED TEXTILE MATERIALS

Based on the measurements of the sound absorption coefficient (Figure 15), we can conclude that the compact textile material achieves better parameters in the frequency bands 100 – 500 Hz and in the frequency band 1600 – 2500 Hz. The loose textile material achieves better absorption parameters in the frequency range of 500 – 1250 Hz.

Based on the results of measuring the sound reduction index (Figure 14), it follows that the compact textile material has better properties in the entire frequency band. This result could be expected, since the volume weight of the compact material is 4 times higher than the volume weight of the loose textile material.

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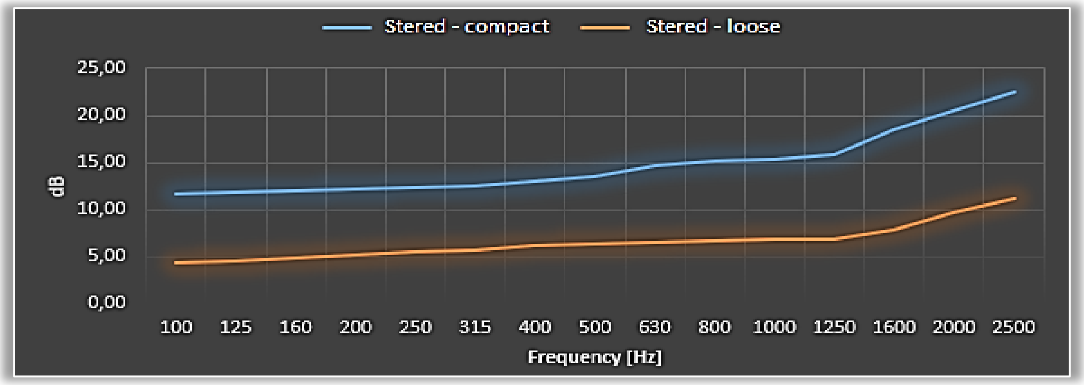

Figure 14. Sound reduction index (R) – Stered – compact and stered – loose

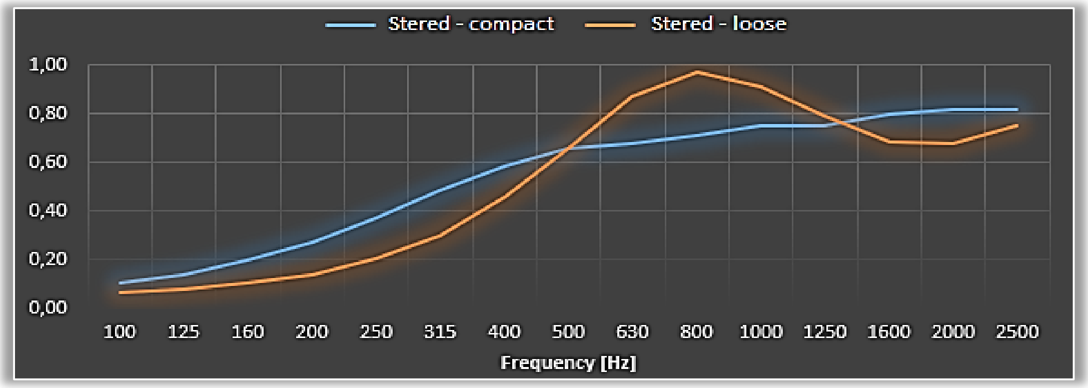

Figure 15. Sound absorption coefficient (α) – Stered – compact and stered – loose

5. CONCLUSIONS

Currently, materials based on recycled rubber granules as well as recycled textile materials have a wide application in practice. These materials in landfills occupy a large volume and thus fill them unnecessarily, so it is necessary to recycle the mentioned materials to a high degree and thus reduce the burden on the environment. Making compact boards from recycled materials is challenging in terms of both financial and time. Production is laborious with a high proportion of human activity, and production requires the use of synthetic–based binders, which can have a negative impact on the environment, and the price of these binders is also high. For these reasons, it is a good idea to look for the application of these recycled materials in bulk form. Based on the measurements made and comparisons of the acoustic properties of rubber materials with compact ones, we can conclude that the acoustic properties of free–flowing materials are comparable to compact materials. The sound reduction index of loose–flowing materials reaches lower values than compact materials, which is mainly due to the difference in volumetric weights. The absorption coefficient of bulk materials reaches comparable values with compact materials, even in some frequency bands they achieve better values. In conclusion, the use of recycled bulk materials has its justification and can be used in various areas for acoustic purposes.

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References

[1] ADAMS, T.: Sound Materials: A Compendium of Sound Absorbing Materials for Architecture and Design. Publisher: Frame Publishers, 2017, 288 p.
[2] ALLARD, J. – ATALLA, N.: Propagation of Sound in Porous Media: Modelling Sound Absorbing Materials. 1st Edition. Publisher: Wiley, 2009, 376 p.
[3] BADIDA, M. – BADIDOVÁ, A. – DZURO, T. – SOBOTOVÁ, L.: Acoustic properties of sandwich absorbers made on the basis of components from vehicles after their lifetime. Available on the Internet: http://annals.fih.upt.ro/pdf–full/2021/ANNALS–2021–1–12.pdf... – 2021. In: Annals of Faculty Engineering Hunedoara – International Journal of Engineering. Roč. 19, č. 1 (2021), s. 101–109
[4] BADIDA, M. – PIŇOSOVÁ, M. – MORAVEC, M. – DZURO, T. – KRÁLIKOVÁ, R. – SOBOTOVÁ, L.: Use of Secondary Raw Materials from Old Vehicles in the Production of Acoustic and Thermal Insulators – 2021. In: Analysis of the state, forecasts and new technologies of waste recovery in the automotive industry. – Lüdenscheid (Nemecko): RAM–Verlag s. 111–136 [print]
[5] BADIDA, M. – SOBOTOVÁ, L. – DZURO, T. – MORAVEC, M. – PIŇOSOVÁ, M. – KRÁLIKOVÁ, R.: Development of materials and products with sound and thermal insulating and other properties on the basis of waste from the automotive. 2022. In: Smart technologies for waste processing from the automotive industry. – Lüdenscheid (Nemecko): RAM–Verlag s. 105–146

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

[6] BADIDA, M. – SOBOTOVÁ, L. – KRÁLIKOVÁ, R. – DZURO, T. – MORAVEC, M. – PIŇOSOVÁ, M.: Vývoj technológií a techník na zhodnocovanie odpadov do zvukovo a tepelnoizolačných produktov – 2021. In: Progresívne technológie zhodnocovania odpadov v automobilovom priemysle. – Bratislava (Slovensko): Spektrum STU s. 144–182 [print]
[7] BARTKO, L. – BADIDA, M. – KONKOLY, J.: Vytvorenie metodiky merania vybraných akustických deskriptorov meraných pomocou impedančnej trubice – 2015. In: Ukraine – EU. Modern Technology, Business and Law. – Chernihiv: Chernihiv National University of Technology, 2015 P. 10–12.
[8] BARTKO, L. – KONKOLY, T. – BADIDA, M.: Research of acoustic descriptors of sandwich absorbers – 2015. In: Global management and economics. No. 1 (2015), p. 18–28
[9] BEGHI, G. M.: Modeling and Measurement Methods for Acoustic Waves and for Acoustic Microdevices. Publisher: Intechopen, 2013, 616 p.,
[10] BRUNEAU, M. – POTEL, C.: Materials and Acoustics Handbook. Publisher: WILEY, August 2009, 960 p.
[11] GRIGORIEV, D. A. – Ivanov, A. V. – Molokovsky, I. S.: Microwave Electronics. 1st ed., Publisher: Springer, 2018, 945 p.
[12] GUMANOVÁ, V. – SOBOTOVÁ, L. – DZURO, T. – BADIDA, M. – MORAVEC, M.: Experimental survey of the sound absorption performance of natural fibres in comparison with conventional insulating materials. In: Sustainability. – Bazilej (Švajčiarsko): Multidisciplinary Digital Publishing Institute Roč. 14, č. 7 (2022), s. [1–16] [online]
[13] GUMANOVÁ, V. – SOBOTOVÁ, L. – DŽUŇOVÁ, L. – YEHOROVA, A.: Sound absorption properties of natural fibers as sustainable acoustic solution – 2021. In: Novus Scientia 2021: zborník príspevkov z 18. Medzinárodnej vedeckej konferencie doktorandov strojníckych fakúlt technických univerzít a vysokých škôl. – Košice (Slovensko): Technická univerzita v Košiciach s. 86–92 [online]
[14] Impedance tubes from the company – BSWA–TECH. (online)
[15] KRISHNARAJ, G. – GOKARNESHAN, N.: Recycling of Textile Waste. Publisher: Eliva Press, 2021, 243 p.
[16] MORAVEC, M. – DZURO, T. – BADIDA, M. – SOBOTOVÁ, L. – BADIDOVÁ, A.: Potential of using components from old cars for production of thermal and sound isolation materials – 2020. In: Scientific Letters of Academic Society of Michal Baludansky. – Košice (Slovensko): Akademická spoločnosť Michala Baluďanského Roč. 8, č. 5 (2020), s. 30–32 [print].
[17] NOVÁKOVÁ, A. – BADIDA, M.: Analysis of sound absorption of recycled textiles from end–of life vehicles. – 2022. In: Novus Scientia 2022. – Košice (Slovensko): Technická univerzita v Košiciach s. 10–13 [online]
[18] Patent: Číslo prihlášky: 50020–2022: Kazeta na rozšírenie možností merania sypkých materiálov v impedančnej trubici a spôsob jej použitia. (online)
[19] Úžitkový vzor: Číslo prihlášky: 50024–2022. Kazeta na rozšírenie možností merania sypkých materiálov v impedančnej trubici a spôsob jej použitia. (online)
[20] VA–LAB4 software. (online)


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