

THE STUDY OF SOUND AND VIBRATION ISOLATING MATERIALS APPLICABLE ENVIRONMENTAL PROTECTION

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Abstract

Prevention of composite material, characterized by a high acoustic insulation but satisfying spread of the dynamic interactions in the environment, the sound or vibration in materials requires new solutions task of isolation between the source of noise and vibration and the environment. These new solutions based on the idea of partition (of two or multilayer), the cores of granular materials, characterized by both good characteristics vibroisolation, sound absorption and vibration-damping materials. Using these solutions brings positive results in the reduction of acoustic energy, vibration isolation and acoustic damping material provided that they are the correct selection. The paper presents results of experimental investigations of acoustic insulation properties, parameters, physic - mechanical properties of selected structural elements made of materials belonging to the latest generation of noise and vibration safe guards applicable in the work environment and external environment. The paper presents the methodology and results of new materials used in Cathedrals: Vibroacoustics and Mechanics and Robotics and Mechatronics AGH, which should be standard in the selection of the parameters of vibroacoustic properties of the newly proposed structural engineering. The work was carried out in a research project 4875/B/TO2/2010/38 financed by Ministry of Science and Higher Education and project II.B.12 (2011-2013) "New material solutions in the design of layered Barriers vibroacoustic protection of machinery and equipment", which is one of the objectives of the multiannual program "Improving the safety and working conditions," coordinated by CIOP - PIB in Warsaw.

Keywords: *materials, acoustic insulation, vibroisolation*

1. Introduction

Preventing the process of the proliferation of dynamic influences for the environment, the sound emission or material pulses requires applying material new solutions multi layered, being characterized by a great acoustic but simultaneously fulfilling insularity tasks vibroisolation between the source of the noise emission and pulses and surroundings. In these new solutions based on the idea of layered compartments (of plate arrangements arising from combining layers sound-insulation, sound absorbent and vibroisolation), layers were used elastomer in the form of plates of solid, porous rubber and in the form of pellets. Layered compartments with cores from surfaces elastomer are characterized with both good properties vibroisolation as well as sound-

insulation. However, barriers with cores elastomer in the form of pellets are demonstrating the increased insularity due to their good properties of the sound absorption and containing material pulses. Using these solutions is causing positive effects in limiting the sound energy, vibroisolation of pulses and muffling material sounds under the condition of their correct selection. At the work, findings of experimental parameters were presented physics - of mechanical and acoustic chosen structural members made with applying materials elastomer of securities enabling designing a new generation vibroacoustics, being applicable in the workplace and in the external environment. At the work, a methodology of the research on new materials applied in the Department of Mechanics and Vibroacoustics and Robotics and Mechatronics AGH, which according to authors' they should constitute was, described standard at the selection of the property of parameters vibroacoustics in newly designed engineering structures. Limiting influences vibroacoustics to the environment consists mainly in applying elastic elements applied between energy sources vibroacoustics and with surroundings. Using these centres usually causes positive effects in suppressing both the isolation of pulses and the reduction in the noise emission and the flow of material sounds under the condition of their correct selection. With reference to the above in order to have a possibility of the correct selection of parameters vibro and sound-insulation of materials, authors conducted examining the degree of the usefulness of materials marked out vibroisolation and sound-insulation, different as for composition, of structure (one and multi layered) and of applying on samples prepared according to binding standards. First a research on the ownership of parameters was conducted physic and mechanical (static, dynamic) and then of studying acoustic properties, mainly examining consuming and the acoustic insularity, materials marked out and layered compartments being able to be applicable to real engineering structures.

2. Research of the property physics and mechanical rubber samples

Many materials exist rubbers with elastomers and plastics of which endurance properties are meeting the conditions established in the course of the project and construction of the mechanical structure. This statement is very material, but insufficient to selecting and applying the element rubber and elastomer in cells vibroisolations [6, 7]. Apart from the sufficient endurance element, vibroisolation must meet a lot of other requirements of plastics general and concerning additional requirements applied as elements vibroisolation. Properties are ones of them physics - mechanical of elements rubbers with elastomers. As part of examinations for every tested sample, the following examinations were performed:

- of the measurement of the Shore hardness,
- of appointing the density,
- of appointing the static and dynamic Young's modulus,
- of setting the coefficient of the static and dynamic stiffness,
- of setting the rate of suppressing.

Examining of the modulus of elasticity of oblong E, the stiffness and measures of suppressing samples elastomers in the Laboratory Endurances of Materials were carried out in having Cracow of authorizing the Office of Technical Inspection and National Institute of Standards and Technology the USA in the endurance of construction materials and the implemented quality system of the laboratory for research. The machine is holding the current and still updated legalization certificate. Samples were cut out of delivered blends, with the water-powered laser ensuring the repetitiveness of dimensions, and C subjected to preliminary examinations in room temperature 20°. Preliminary examinations included:

- geometrical measurements of samples,
- examining the ρ density rubber with elastomer,
- measurements of the Shore hardness elastomer they made using the machine of endurance static-dynamic Instron 1273 with the plumbing drive and the electronic guidance, 1 Machine enables the figure performances both of exam.

Fundamental of examination of the samples, execute in quasi conditions of static burdens at the $\pm$ travel of a piston of 50 mm and the maximum force of 100 kN, as well as fast-changeable dynamic burdens about frequencies up to 100 Hz.



Fig. 1. Endurance machine static-dynamic of type Instron 1273

Examination of the samples of elastomeric elements was made in hugging, in cycles with the burden and with lightening, applying the following parameters of the attempt:

- measuring range of the ergometer ($F_{\max}=10.0$ kN),
- speed of deforming samples:
 - quasi statics: 0.1 mm/sec,
 - dynamic: 1.0 mm/sec.

In the course of attempts they were making the registration of the course of the stabilized terminus of the hysteresis of the mechanical work, which they appointed in way in accordance with norms of the value of the E module from the fragment of the terminus of the hysteresis corresponding to the load from pressing samples with power as well as the attenuation of rubbers from both fragments of the loop: of burdening and lightening. Obtained findings of mechanical properties of rubber elements can constitute the base for design and production engineering of elements vibro and sound insulating. Cross sections of tested samples were described on the Fig. 2 and their vital statistics in the Tab. 1. They were carrying out research in direction normal.

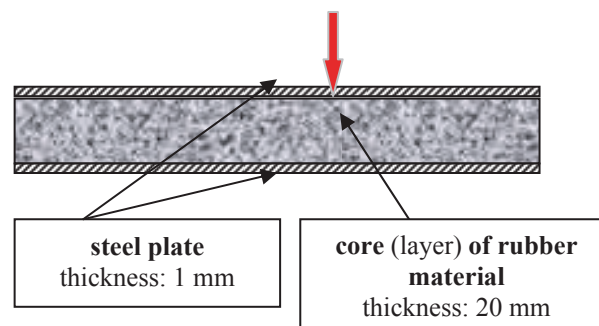


Fig. 2. Cross sections of samples

Next, a seeming density, for which values were described in the Tab. 2 was appointed.

An appointment was a next stage behind the help of hardness tester of the type Short Hardnest H12720 of the dynamic hardness according to the Shore's scale in the scope 0-140 0 in directions to the purpose of fading of the mistake this measurement was normal made repeatedly for every of samples. Averaged results from 9 measurements for individual samples were presented in the Tab. 3.

Tab. 1. Sample for thicknesses 21, 5 - 25.5 mm

			
S ₀ - cross sectional area [m2] sample of the vibroisolations elements, temperature -10°C , + 20°C			
9.9*10 ⁻³		10.011*10 ⁻³	
L ₀ – height of the sample [m]			
0.0215		0.0255	
m – mass of the sample [kg]			
0.253		0.267	
V ₀ – volume of the sample [m ³]			
2.13*10 ⁻⁴	2.297*10 ⁻⁴	4.135*10 ⁻⁴	3.479*10 ⁻⁴

Tab. 2. Seeming density of the examined element

Seeming ρ density [kg/m ³] of samples from rubber elements, temperature -10°C, +20°C
1161-1166

Tab. 3. Hardness of the sample in the Shore scale

Shore hardness [Sh]. Scale 0 – 140° (dynamic)	
	
59.00	57.06

Appointing the static and dynamic Young's modulus was a consecutive research stage. These examinations were being conducted on the endurance machine of the type INSTRON 1273. In the first phase, a static research on the Young's E_{stat} modulus was conducted. he was appointed in the static attempt as the secant of the terminus of the hysteresis of the burden - of lightening at the following conditions:

- measuring range of the ergometer 5.0 – 10.0 kN,
- preliminary diffraction $\Delta l = 0.002$ m, $\varepsilon = 10\%$
- enlarging the scale of extending for the area, $\alpha - 50$,
- speed of the static deformation for the sample, $v = 0.1$ mm/s.

E_{stat} findings are presented in the Tab. 4.

Tab. 4. Young's modulus in the function of the temperature

Young's modulus E _{stat} [MPa] temperature +20°C	
	
8.8	5.49
Young's modulus E _{stat} [MPa] temperature -10°C	
	
14.35	8.78

Next dynamic tests of the Young's modulus E_{dyn} module were conducted. He was appointed at identical establishments like in the static attempt as the secant of the terminus of the hysteresis of the burden - of lightening the deformation at one changed condition i.e. the speed:

- speed of the dynamic deformation for the sample, $v = 1.0$ mm/s, $v = 3.3$ mm/s.

Findings were compared in the Tab. 5.

Tab. 5. Dynamic Young's modulus

Young's modulus E_{dyn} [MPa] temperature +20°C	
	
9.75 $v = 1 \text{ mm/s}$	6.66 $v = 1 \text{ mm/s}$
11.10 $v = 3.3 \text{ mm/s}$	7.26 $v = 3.3 \text{ mm/s}$
Young's modulus E_{dyn} [MPa] temperature -10°C	
	
18.00 $v = 1 \text{ mm/s}$	10.10 $v = 1 \text{ mm/s}$
19.50 $v = 3.3 \text{ mm/s}$	11.00 $v = 3.3 \text{ mm/s}$

Next a substitute rate of the springiness was set, based on appointed Young's modules. Results of calculations of the substitute rate of the stiffness were compared in the Tab. 6 for static modules and the Tab. 7 for dynamic modules.

Tab. 6. Substitute static rate of the stiffness

Static stiffness k_z [kN/m] temperature +20°C	
	
3931.91	2452.97
Static stiffness k_z [kN/m] temperature -10°C	
	
6411.58	3922.90

Tab.7. Substitute dynamic rate of the stiffness

Dynamic stiffness [kN/m] temperature +20°C	
	
4356.3 $v = 1 \text{ mm/s}$	2975.68 $v = 1 \text{ mm/s}$
4959.48 $v = 3.3 \text{ mm/s}$	3243.76 $v = 3.3 \text{ mm/s}$
Dynamic stiffness [kN/m] temperature -10°C	
	
8042.4 $v = 1 \text{ mm/s}$	4512.68 $v = 1 \text{ mm/s}$
8712.60 $v = 3.3 \text{ mm/s}$	4914.80 $v = 3.3 \text{ mm/s}$

Since a dissipation factor is the most obvious measure of suppressing for given material. It is quotient of the energy dispersed during one period of pulses F_{petl} to the maximum potential energy in this period:

$$\psi = \frac{F_{petl}}{F} \quad (1)$$

The relation between power and the transfer is building the terminus of the hysteresis in case of established periodic pulses. Field is presenting the dispersed energy F_{petl} . Field under the curve determining the reversible process of pulses of the arrangement (without dispersing the energy) F . Pol is describing the maximum potential energy of the arrangement the ones with the graphics tablet a XXL Pentagram was being outlined and they were writing vector files of graphs into AutoCAD but next with the support function were appointed surface areas of the terminus of the hysteresis. Results of calculations of the dissipation factor of the energy were presented in the Tab. 8.

Tab. 8. Coefficient of dispersing the energy

Coefficient of dispersing the energy ψ temperature +20°C	
	
0.63 $v = 1 \text{ mm/s}$	0.39 $v = 1 \text{ mm/s}$
0.69 $v = 3.3 \text{ mm/s}$	0.42 $v = 3.3 \text{ mm/s}$
Coefficient of dispersing the energy ψ temperature -10°C	
0.49 $v = 1 \text{ mm/s}$	0.39 $v = 1 \text{ mm/s}$
0.47 $v = 3.3 \text{ mm/s}$	0.44 $v = 3.3 \text{ mm/s}$

Appointing the relaxation module was a consecutive research stage. His values they presented in the Tab. 9.

Tab. 9. Coefficient of the relaxation

Coefficient of the relaxation E_r [N/m ²]	
	
$7.56 \cdot 10^6$	$7.41 \cdot 10^7$

3. Methodology of examinations of the research on the ownership of acoustic new materials and layered compartments

In Fig. 3 a methodology of examinations, being aimed at determining the ownership of acoustic new materials and barriers depending on allocating them was described and of the fulfilled function in securities vibroacoustics. During research, works devoted to drawing up new materials and useful barriers in the securities design vibroacoustics, and in examinations on request from the industry, at the Department of Mechanics and Vibroacoustics AGH the following test procedures are also applicable at the preliminary and final evaluation of acoustic parameters:

- in the event of materials absorbing sound and being applicable as sound-absorbent layers and cores sound-absorbent preliminary estimating their properties is moving determining the physical rate of the sound absorption (with method using the rate of waves standing according

to the norm PN-EN ISO 10534-1:2004 - Fig. 4. or with method of the function of the passage from with due respect with the norm PN-EN ISO 105334-2:2003 - Fig. 5), and then selected material or the group of materials it is possible only to have tested for determining the reverberant rate of the sound absorption (according to the norm PN-EN ISO 353:2005 - Fig. 6).

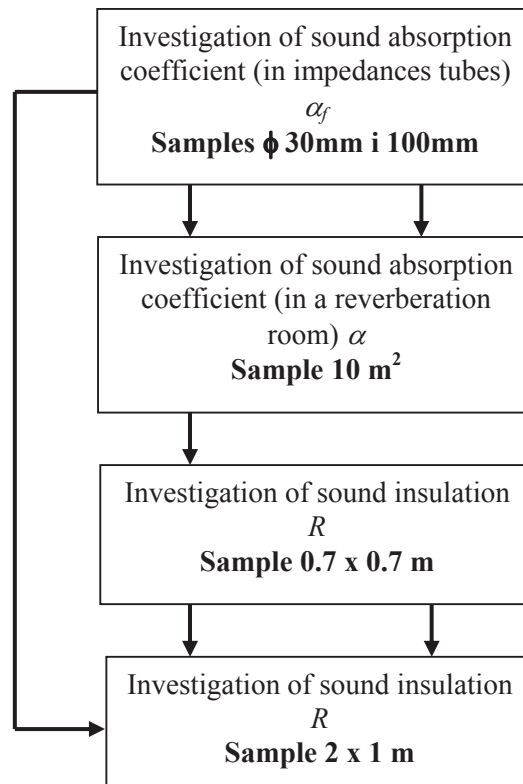


Fig. 3. Methodology of the research on the ownership of acoustic new solutions of materials sound absorbent and sound-insulation of layered compartments

- in case of materials typically sound-insulation, preliminary pilot determining being aimed at examinations the acoustic insularity appropriate one should conduct 0.7 x on samples about small dimensions 0.7 m (method developed at the Department [3, 4] - Fig. 7) what much the cost of studies is making smaller as well as making samples is facilitating, and then selected samples of materials or barriers are being had tested to the acoustic insularity on the research position with the measuring hole about dimensions of tested sample 2 x 1 m (in harmony with requirements of norms: PN-EN-ISO 140-1: 1999, PN-EN ISO 140-2:1999, PN-EN 20140-3: 1999 and PN-EN ISO 717-1:1999 - Fig. 7);
- in case of layered compartments with layer (be sound-absorbent layers) examinations include at first examining the physical rate of the sound absorption of materials being included in a compartment (with omitting the research on the reverberant rate of the sound absorption), and then of examining the insularity of the compartment with good acoustics on swatches, and after selecting the most beneficial barriers, final examinations on samples about dimensions 2 x 1 m;
- in case of compartments with new layers sound-insulation and sound-absorbent (of particularly panels of acoustic screens) the evaluation of their acoustic parameters should include the full cycle of examinations: examining the physical absorption factor of sound-absorbent layers, examining the acoustic insularity of particular layers sound-insulation and of the entire barriers on swatches (0.7 x 0.7 m), and after selecting of advantageous solutions of examining the acoustic insularity on samples about dimensions 2 x of 1 m and examining the reverberant absorption factor of the plain consuming barriers. All these examinations are performed on laboratory positions being in a Department of Mechanics and Vibroacoustics AGH.

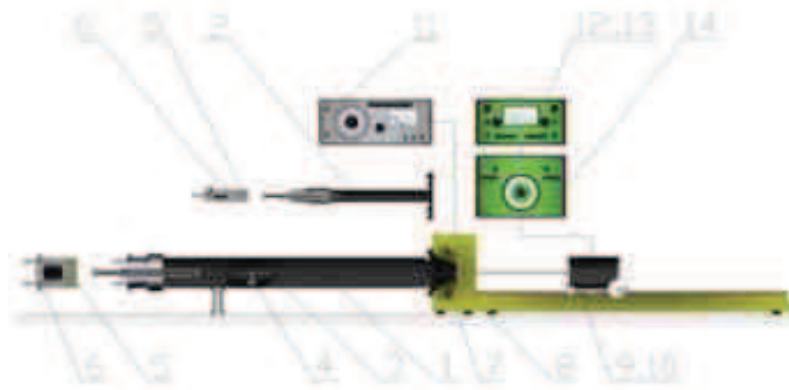


Fig. 4. Outline of the measuring path for setting the physical absorption factor of sound - so-called Kundt's Pipe - with method of standing wave (1 - measuring pipe big, 2 - measuring pipe small, 3 - microphone probe, 4 - cart supporting the probe, 5 - preview of studied material, 6 - sealing disc, 7 - loudspeaker, 8 - casing of the loudspeaker, 9 - measuring microphone, 10 - casing of the microphone - cart, 11 - generator of the ZOPAN power type PO-21, 12 - measuring amplifier, 13 - millivoltmeter, 14 - arrangement of filters octave and of the third)

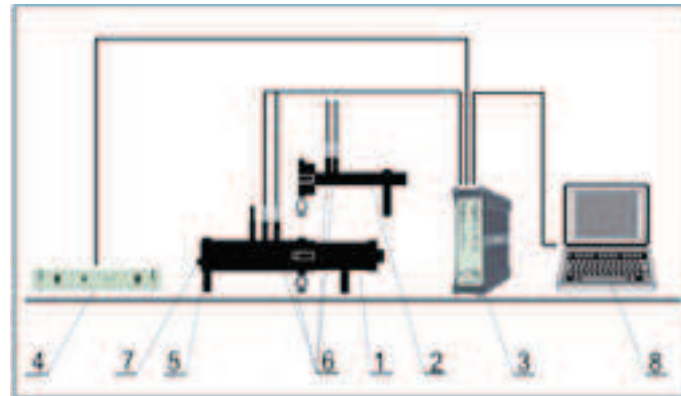


Fig. 5. Outline of the measuring path for setting the physical rate of sound absorption with method of the function of the passage (1-big pipe B&K type 4206, 2 - small B&K pipe type 4206, 3 - measuring cassette (small), 4 - B&K amplifier type 2716 C, 5 - loudspeaker put inside the pipe, 6 - B&K microphones, 7 - manual adjuster of a range of wavelengths measuring, 8 - computer)

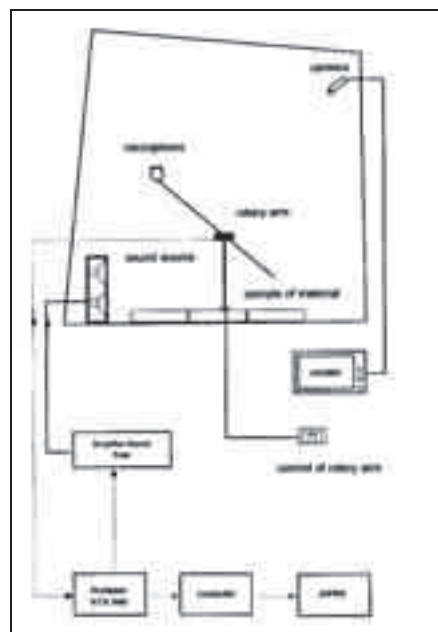


Fig. 6. Outline of the measuring path for setting the reverberant rate of sound absorption



Fig. 7. Outline of the measuring path for measurements of the acoustic insularity appropriate of barriers applied in securities vibroacoustics

4. Investigation of the property of thin layered compartments with good acoustics

New solutions of thin-layered compartments applied in securities vibroacoustics have machines and devices special application in integrated sound-absorbent-insulating casings [4]. Partition wall (barrier) should be characteristic of an integrated casing oneself with two basic parameters: acoustic ensuring the very good insularity acoustic, comparable with the insularity of walls of classical casings and technical limiting the thickness for her to the essential minimum (10-30 mm) in order not to cause increasing dimensions of the fitted machine or organising. Below model, findings of the property of dihedral compartments with good acoustics were presented with applied cores - with rubber layers about the different structure. In Fig. 2, a schematic diameter of the dihedral compartment was described, however in Tab. 3 description of applied cores of rubber materials. In the design and the assortment of compartments sound-insulations, sound absorbent insulating and of sound-absorbent materials acting in them, for many years rubber layers being applicable in the form of solid and porous rubber is taking into account. Rubber pellets received on the road of the recycling have good properties of the sound absorption and can successfully be applied as sound-absorbent cores in dihedral compartments [2, 3]. In Fig. 10 and 11 results of consuming and the insularity for materials for example chosen about the structure described in Tab. 10 were presented.

Tab. 10. Variants of the filling of the layered compartment (dihedral)

Description of rubber layers (of cores) applied in the dihedral compartment	
Core I	Plate of porous rubber for densities of 800 kg/m ³ . Material composition: blend of rubber with ethylene and propylene
Core II	Plate of solid rubber (solid) for densities of 1290 kg/m ³ . Material composition: blend of rubber ethylene-propylene
Core III	Rubber pellets obtained from the recycling. Seeming density: 510 kg/m ³ , fraction of the grain: 4x4 mm to 8x8 mm, shape of the grain: irregular petals, of type "coarse-grained"
Core IV	Pellets rubbers with texture obtained from the recycling. Seeming density: 340 kg/m ³ , fraction of the grain: 2x2 mm to 3x3 mm, polluted with quiffs of cotton fibre, of type "fine-grained".

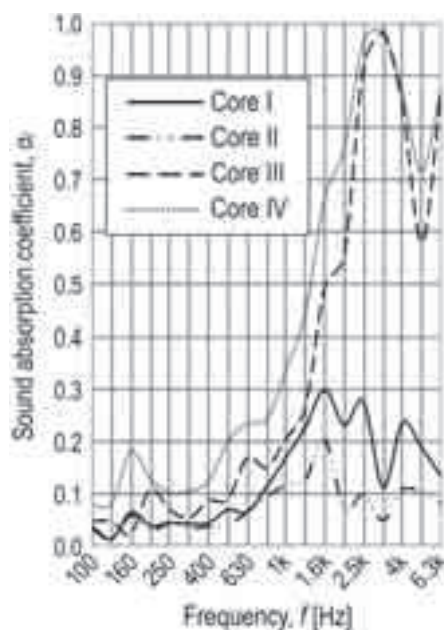


Fig. 10. Sound absorption coefficient

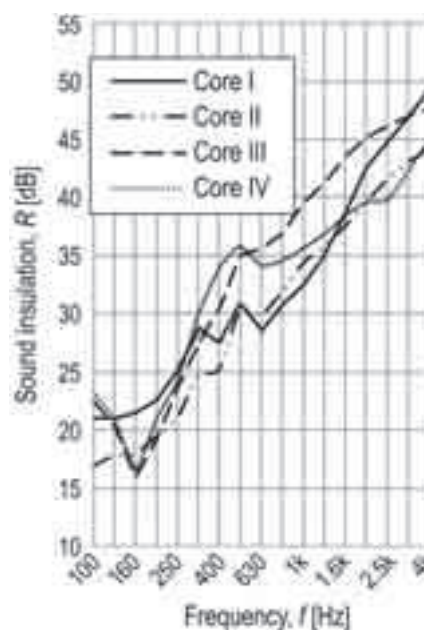


Fig. 11. Sound insulation coefficient

5. Evaluation of the usefulness of studied materials vibro- and soundisolation as securities vibroacoustics of engineering structures and machines and devices

Based on conducted examinations, both properties vibroisolations well as properties acoustic one should state, that new materials coming into existence as a result of recovering certain of elements in the process of the recycling, are characterized by very good properties immediately visions vibroisolations and properties sound isolations. On account of the limited quantity of sides, presented findings will be detailed in the course of the conference.

References

- [1] Kaczmarek, A., Engel, Z., Sikora, J., *Dobór warstwowych zabezpieczeń przeciwhałasowych - wytyczne dla projektantów*, Bezpieczeństwo Pracy, Nauka i Praktyka Nr 6 (6/2005), Miesięcznik Centralnego Instytutu Ochrony Pracy - PIB, str. 10-13, Warszawa 2005.
- [2] Sikora, J., Turkiewicz, J., *Sound absorption coefficients of granular materials*, Mechanics and Control, AGH University of Science and Technology, Faculty of Mechanical Engineering and Robotics, Commission on Applied Mechanics of Polish Academy of Science, Vol. 29, No. 3, pp. 149-157, Cracow 2010.
- [3] Sikora, J., *Stanowisko do badań właściwości dźwiękoizolacyjnych przegród o małych wymiarach*, Wyd. Politechniki Krakowskiej, Czasopismo Techniczne Mechanika, Z. 5-M/2011, Z. 15 (108), str. 65-77, 2011.
- [4] Sikora, J., *Warstwy gumowe w rozwiązaniach zabezpieczeń wibroakustycznych*, Wydawnictwa AGH, Kraków 2011.
- [5] Sikora, J., Turkiewicz, J., *Właściwości dźwiękochłonne i zastosowanie granulatów gumowych*, Izolacje: Budownictwo, Przemysł, Ekologia, Nr 1, str. 54-58, 2012.
- [6] Targosz, J., *Układy wibroizolacji w transporcie szynowym i samochodowym*, Rozprawy i Monografie, AGH, Wydawnictwa Naukowo-Dydaktyczne, str.1-237, Kraków 2007.
- [7] Targosz, J., *Analiza i Badania właściwości fizykomechanicznych ustrojów elastomerowych, minimalizujących dynamiczne oddziaływania podtorza kolejowego na otoczenie*, TTS Nr 5-6, str. 87-91, 2008.