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THE ANALYSIS OF CHOOSEN ACOUSTIC DESCRIPTORS OF SANDWICH ABSORBERS ON THE ALUMINUM FOAM BASE

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Abstract: In spite of existing European and national legislative aimed at noise abatement, public interest and concern about noise are high. The EU Directive 70/157/EEC for setting and controlling environmental noise is aimed at the creating less noisy and more pleasant environment for European residents within „ Sustainable Development in Europe." The authors are presenting a methodology for measuring of selected acoustic descriptors, sound absorption coefficient and sound transmission loss) for acoustic materials, which are currently in process of development. Authors present the results of their scientific - research works, joined with the research of acoustic properties of new material - aluminum foam. The emphasis is layed on the research of sandwich construction, created on the base of aluminum foam material. The aluminum foam becomes known as new suitable acoustic material used for many areas of industrial practice. In the contribution is presented the methodology of acoustic descriptors measuring of new developed acoustic materials. The methodology was verified on the aluminum foam material, which application possibilities are the subjects of the intensive research of research teams in the world.
Key words: aluminum foam, sound absorption coefficient, sound transmission loss, environmental noise.

1. INTRODUCTION

Noise reduction in the life or working environment is important for increasing the quality of the environment. Design of the noise reduction measures consists with different phases. One of the important phases is selection of suitable materials that are able applied for specific condition. Determination of acoustic properties of materials is necessary step before the application of these materials. [7] In spite of existing European and national legislation, aimed at noise abatement, public interest and concern about noise are high. Directive of EU 70/157/EEC for setting and controlling environmental noise is aimed at creating less noisy and more pleasant environment for European residents within "Sustainable Development in Europe". [14]

Harmful effects of environmental noise are various and they can be produced in various ways. They can be categorized into three main categories: effects influencing health, impacts on quality of life and financial implications on affected persons.

Noise protection measures for reducing the effect of noise caused by transportation (road, railway and air transport) can be passive and active. Active measures try to prevent the origination of noise, while passive measures are adopted only then, when noise arises. Passive noise protection measures can be divided into two groups, namely: measures preventing acoustic noise propagation (noise barriers and/or walls, noise protection embankments and the like). [7] [4]

2. IMPEDANCE TUBE

Impedance tube is tool used for measurement and determination of acoustic properties of the materials. The two-microphone method is shown schematically in Figure 2 below. A sample of the material to be tested is placed in a sample holder and mounted to one end of a straight tube. A rigid plunger with an adjustable depth is placed behind the sample to provide a reflecting surface. A sound source, typically a high-output acoustic driver, is connected at the opposite end of the tube. A pair of microphones is mounted flush with the inner wall of the tube near the sample end of the tube. A multi-channel spectrum analyzer is used to obtain the transfer function (frequency response function) between the microphones. In this measurement, the microphone closer to the source is the reference channel. From the transfer function H_{12}, the pressure reflection coefficient R of the material is determined from the following equation [1], [8]:

$$R = \frac{H_{12} - e^{-jks}}{e^{jks} - H_{12}} \cdot e^{j2k(L+s)} \quad (1)$$

where *L* is the distance from the sample face to the first microphone and *s* is the distance between the microphones, *k* = 2•*f*/*c*, *f* is the frequency, and *c* is the speed of sound. From the reflection coefficient, the absorption coefficient *a* and normalized impedance $Z/\rho_0 c$ of the sample may be determined from the following equations [1], [8]:

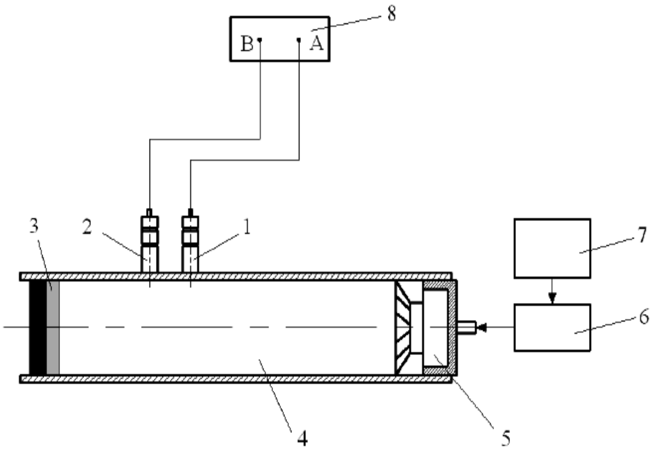
$$\alpha = 1 - |R|^2 \quad (2)$$

$$Z/\rho_0 c = \frac{1+R}{1-R} \quad (3)$$

Figure 2. The impedance tube [5]

The microphones must be mounted flush with the inside wall of the tube and isolated from the tube (to minimize sensitivity to vibration).

The sound source should provide sound energy over a frequency and intensity range sufficient for testing. It is important for the sound source to have a high-power rating (e.g., 50 to 100 watts) so that high intensity sound may be generated inside the tube for certain types of testing. For example, the absorption of many materials is dependent on the intensity of sound. It is therefore helpful to test such materials at several levels above and below field conditions. [14]



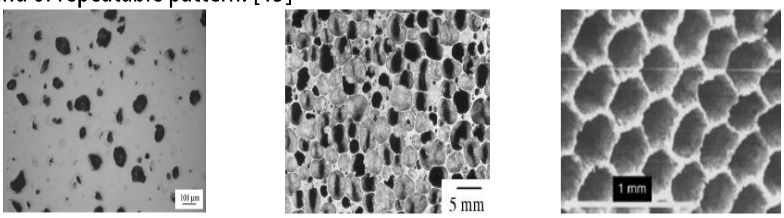
1- microphone A, 2 - microphone B, 3 - test sample, 4 - impedance tube, 5 - sound of source, 6 - amplifier, 7 - signal generator, 8 - system

Figure 1. Displaying of the test equipment [16]

3. ALUMINUM FOAM AS ACOUSTIC MATERIAL

A period of 21th century is connected with the development of new materials or by creating of new structures of materials. There are existing three types of various structures, which are used for the materials as plastics, ceramics and metals.

It is essential to differentiate cellular material from "porous metal", which can be defined as the amount of closed spherical pores, which do not create any kind of repeatable pattern. [15]



a) b) c)

Figure 3. Comparison of cellular substances from different materials [6]

a) porous metal, b) stochastics celular materiál – foam aluminum, c) regular celular materiál – aluminum honeycomb

These cellular materials can be made from different polymers, glass, or metal. The metallic foams belong to the cellular material, where the foam structure forms by a nucleation (vaccination) and by a growth of gas pores in the liquid metal for the foam formation. In the Figure 3 are shown individual non-uniform distributed pores. The walls of the pores contain imperfections due to the expansion of the foam and refrigeration.

The powder metallurgy is the backbone of production of aluminum foam by Alulight method. For thus obtained aluminum foam is preferably a continuous aluminum surface layer and the porous internal structure. [6]

The production was patented early in 1963 for this method, but it was not used very much, especially because from it was not produced any parts. The scientists were lacking more knowledge concerning of the construction principles that are essential and necessary for the application of aluminum foam. Just some time ago, it was developed technological procedures, which in addition to reducing production costs, allow the production of very light structural parts reinforced with steel or ceramic braces, and so begins those reinforced aluminum foam finds application also in the design practice. The products of these procedures have been developed by the Institute of materials and machine mechanics SAV in Bratislava. The main company was Austrian Alulight International Company of Ranshofenu. [12]

The production process begins by mixing of aluminum powder with a foaming agent (TiH_2, ZrH_2). The second step is the cold isostatic pressing and subsequent hot extrusion, but when it is in the solid state. The result is a semi-finished product in the form of rods and different profiles.

After melting of the semi –product, the hydrogen is loosen and creates pores in the aluminum melt. By cooling of the foam is obtained rigid aluminum foam. [6] [12]

For maximum use of aluminum foam to produce components, the low tensile strength prevents him for utilizing. The micro-cracks and non-uniform surface layer leads to a fracture of components already at very low-stress. To avoid this event, a ceramic or metal grid is used or perforated sheets. This reinforcement is used in the production of aluminum foam by powder metallurgy, where is inserted inside the foamable forms together with semi-product. Such reinforcement ensures the transmission of tensile stress by reinforcement and a porous structure is stressed only by pressure. The Figure 4 shows the reinforced foam aluminum and its bending with and without reinforcement. [13]

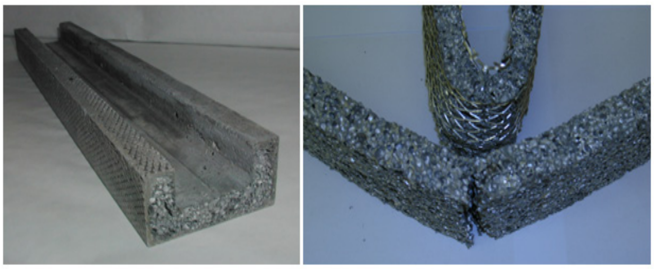
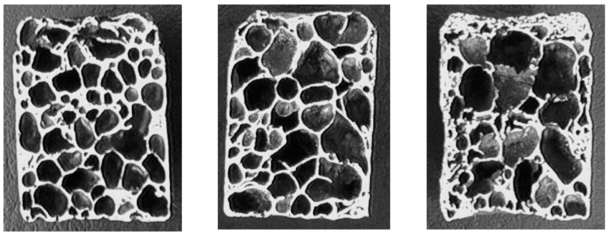


Figure 4. The bending of reinforced and non-reinforced foam aluminum [13]

The partial reinforcement ensures to obtain required mechanical properties of aluminum foam at the minimum weight of part. Therefore, its utilisation in the design is preferred, mainly in automation or traffic technics. Its mechanical properties can also be used in the manufacture of components required to absorb noise and impact energy and vibration damping. This material is also used for the production of heat shields. Except for structural applications it is often used as a decorative material, for example as wallcoverings of airplanes, railways, buses and in the areas where many people meet together (cinemas, theatres, etc). [13]

The foaming temperature is a parameter influencing the pore size and porosity of the component. The Figure 5 shows the effect of temperature on the cell structure, which means that the best porosity is obtained at its optimum temperature. The foamable precursor cannot expand at very low temperatures. However, the result is not good nor on the other hand, because too high temperature will cause foam collapse. [9]

The result of the porous structure is diversity with a stronger and corrugated pore walls. The foaming temperature must be about 10 - 20 °C higher than the melting point of the alloy. Their size is more united, and the pores are uniformly distributed in the foam. [6]

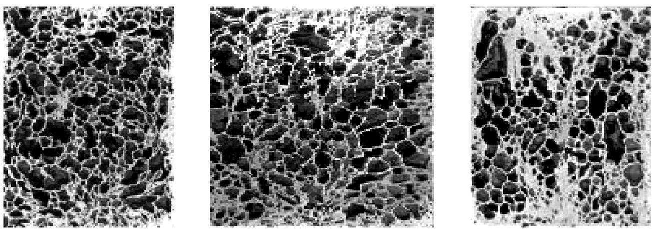


a) b) c)

Figure 5. Influence of temperature on pore structure [9]
a) low temperature – shortage of expanding, b) optimal temperature – the biggest expanding,
c) high temperature – foam collapse

Another of the parameters influencing the pores of the foam is the time. The structure of pores as function of time is shown in the Figure 6. The slower foaming oxidizes the precursor surface, thereby increasing the resistance to expansion of the foam. The resulting porosity is therefore rather low. Long periods foaming occurs in draining (drying), causing thickening of the foam structure. Enough time improves the homogeneity of the pore structure. [11]

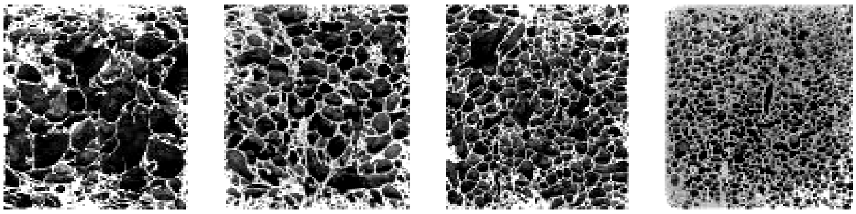
The effect of surroundings and its properties are also important in the process of foaming and porosity. It is also important to the action of external forces / pressure - Figure 7.



420 s 790 s 1120 s

Figure 6. Influence of time on the pore structure [11]

The high pressure prevents the growth of pores, and thus can contribute to a uniform structure of these pores. The lower pressure causes greater pores with strong walls. Too low pressure creates pores with asymmetrical walls. The influence of external pressure is dependent on the type of alloy and the surface tension. [10]



0.05 MPa 0.1 MPa 0.2 MPa 0.3 MPa

Figure 7. The influence of the external pressure on the pores structure [10]

4. EXPERIMENTAL MEASUREMENT ACOUSTIC PROPERTIES OF ALUMINUM FOAM

For measurement was prepared two samples of aluminum foam with diameter 60 mm as shown Figure 8. By the measurement was determined sound absorbtion coefficient and transmission loss. Sound absorption is defined, as the incident sound that strikes a material that is not reflected back. Sound Transmission Loss (STL) represents the amount of sound, in decibels (dB), that is isolated by a material or partition in a particular octave or 1/3 octave frequency band.

Figure 8. Aluminum foam samples

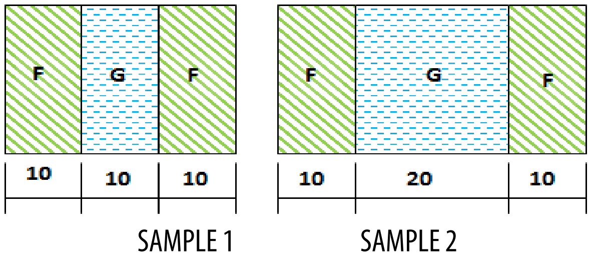


Figure 9. Investigated aluminum foam samples
Legend: F – aluminum foam, G – air gap

Measurement was realized with two samples. Between the two layers of aluminum foam was air gap. First sample with air gap 10 mm and second sample with air gap 20 mm. Thickness of aluminum foam was 10 mm. Samples are shown in Figure 9.
After the preparing samples was realized measurement of acoustic properties – sound absorption and transmission loss from 100 Hz to 2500 Hz.
The Table 1 and the Table 2 showed the average results of measurement of sound absorpion and transmission loss of both samples. Measurement was realized repeatedly 20 times.
Sound absorbtion coefficient for sample with air gap 10 mm reach the best value for frequency 800 Hz and sample with 20 mm air gap for frequency 630 Hz.

Table 1. Sound absorption coefficient of aluminum foam samples

Frequency [Hz]	Sound absorbtion coefficient	
	Sample 1	Sample 2
100	0.12	0.09
125	0.05	0.07
160	0.04	0.07
200	0.06	0.09
250	0.1	0.13
315	0.12	0.21
400	0.2	0.38
500	0.31	0.66
630	0.64	0.99
800	0.99	0.82
1000	0.71	0.51
1250	0.55	0.35
1600	0.47	0.38
2000	0.48	0.38
2500	0.31	0.25

Table 2. Transmission loss of aluminum foam samples

Frequency [Hz]	Sound absorbtion coefficient	
	Sample 1	Sample 2
100	5.81	5.81
125	6.27	6.25
160	6.85	6.78
200	7.49	7.31
250	8.11	7.85
315	8.76	8.41
400	9.42	8.82
500	9.78	8.88
630	10	8.65
800	9.57	8.38
1000	9.68	11.51
1250	12.74	17.94
1600	20.87	25.61
2000	25.09	28.63
2500	32.84	35.92

Influence of bigger air gap is clear for lower frequencies to 630 Hz, sound absorbtion coefficient reach better values for sample with 20 mm air gap. For frequencies over 800 Hz better values of sound absorbtion coefficient was achieved with sample with 10 mm gap.
Result of measurement of sound absorbtion coefficient in frequency range 100 – 2500 Hz shown in the Figure 10.
Measurement of transmission loss of both aluminum foam samples start with value 5,81 dB for 100 Hz frequency.
By increasing the frequency value of transmission loss is also increasing. For frequencies 100 – 800 Hz results for both samples are similar. For frequencies over 1000 Hz better values of transmission loss are achieved with sample with bigger air gap. Result of measurement of transmission loss in frequency range 100 – 2500 Hz shown in the Figure 11.

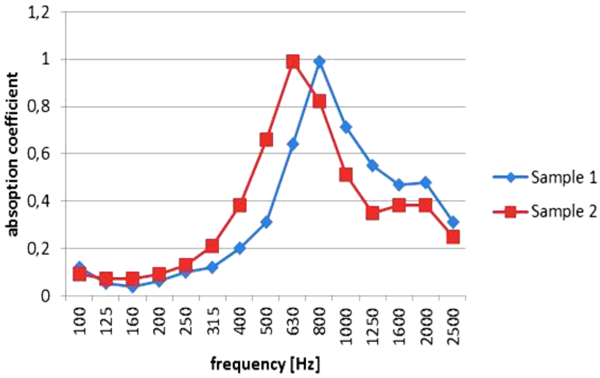


Figure 10. Comparison of sound absorption coefficient of aluminum foam samples

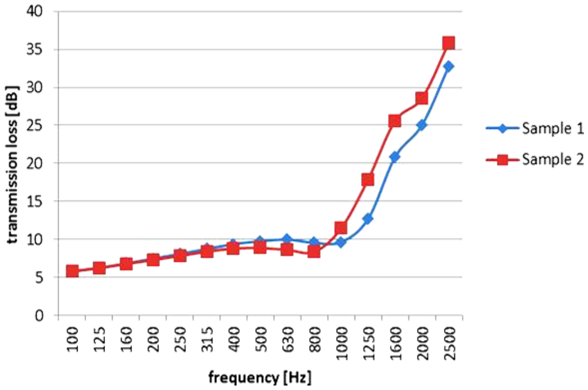


Figure 11. Comparison of transmission loss of aluminum foam samples

5. CONCLUSION

Aluminum foam is a cellular structure consisting of a solid metal, as well as a large volume fraction of gas-filled pores. Aluminum foam is material that is new progressive material with variety of applications. Aluminum foam is applicable mainly in automotive and building industry but also in other fields of industry.

Foam structures are both durable and lightweight, with a large surface area to volume ratio. The unique mechanical properties of aluminum foam include a high strength to weight ratio and a completely isotropic load response. By the comparison of acoustic properties of aluminum foam samples with other comparable materials with same thickness acoustic material is clear that values of sound absorption coefficient for low frequencies to 400 Hz is much lower by the comparison with other materials. In the frequency band 630 – 1250 Hz sound absorbtion coefficient of aluminum foam samples achieves very similar values or better values by the comparison to other acoustic materials. Transmission loss of aluminum foam samples achieves values very similar to values of other acoustic materials. Main advantage of use of aluminum foam is application to environment with difficult conditions (humidity, temperature, solid aerosols and vibrations). Aluminum foam is suitable to this environment and also keeps proper acoustics properties.

Aluminum foam is a new material with variety of application that is suitable for self-supporting lightweight panels for road and building construction, non-flammable construction materials and coatings in hotels, shopping malls and other public areas with heat and sound insulation effect, significantly non harmful to environment.

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