



Investigation of the Dependence of Sound Wave Absorption Coefficient on Frequency

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Abstract: The paper offers a new methodology for investigation of sound waves absorption by various materials. Similarly there has been established the dependence of absorption coefficient on frequency. Experimental results have been analyzed and the resonance peaks of absorption determined.

Keywords: sound waves, absorption coefficient, frequency, signal generator, spectrum analyzer.

I. Introduction

Sound absorption materials and structures are the basic means for regulation of acoustic medium. Part of the energy of a falling sound wave is absorbed by their surface as the remainder part is reflected. Absorption coefficient depends on a number of factors, the most important being the sound wave frequency [1]–[3]. This necessitates to carry out experimental investigation for each particular material which aims at identifying their spectrum absorption capacity.

II. Presentation

The focus of this work is the investigation of the dependence of absorption factor on the sound wave frequency which is applied in sound insulations of buildings, concert and theatre halls, convention centers, offices and work premises.

Bouguer's law is used to determine sound wave absorption

$$J = J_0 e^{-\alpha x}, \quad (1)$$

where J_0 is the wave intensity on the surface of the absorbing material, J - is the wave intensity at a depth x inside the material; α - is the absorption coefficient.

For experimental measurements the value of sound level L is used. Further the connections [4], [5]

$$L_0 = 10 \lg \left(\frac{J_0}{J'} \right) \quad (2)$$

$$L = 10 \lg \left(\frac{J}{J'} \right), \quad (3)$$

are used where J' is the audibility threshold; L_0 and L are the sound level at the surface and at depth x .

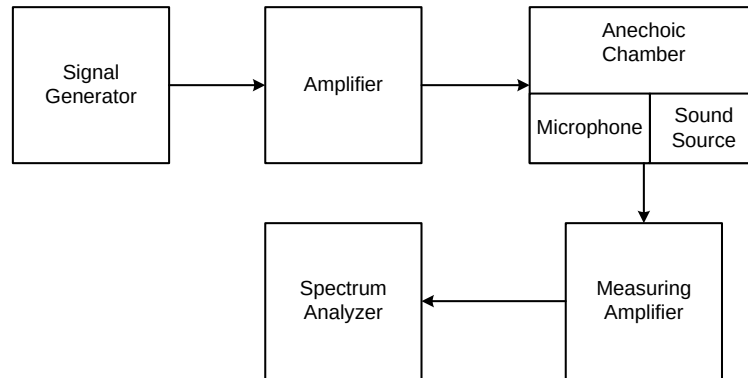
According to (1), (2) and (3) absorption coefficient is expressed by

$$\alpha = \frac{L_0 - L}{10x} \ln 10 \quad (4)$$

III. Experimental set up

In a anechoic chamber there have been installed a sound source, microphone and the investigated sound absorbing material (Fig. 1). The amplitude and frequency of the generated sound signal is assigned by means of a function generator. The sound wave is emitted from electro-dynamic loudspeaker (the sound source) which afterwards is transformed into electric signal through capacitor microphone. To determine sound level in Db there has to be used spectrum analyser.

Figure 1 Block schematic of the experimental set up.



IV. Research tasks:

1. Investigate the dependence of absorption factor on sound wave frequency

Absorption coefficient dependence on the sound wave frequency for Styrofoam, fibrous laminate and geotextile is investigated and it is found that frequency is changed within the interval $f \in [0,1; 15,0]$ kHz by a step of:

- 0,1 kHz within the interval $f \in [0,1; 1,0]$ kHz;
- 0,2 kHz within the interval $f \in [1,0; 3,0]$ kHz;
- 0,5 kHz within the interval $f \in [3,0; 10,0]$ kHz;
- 1,0 kHz within the interval $f \in [10,0; 15,0]$ kHz.

Fig. 2, Fig. 3 and Fig. 4 show the graphs of the dependence $\alpha = \alpha(f)$ for the three investigated materials. On the ground of the analysis made there have been drawn the following conclusions:

- Concerning fibrous laminate and geotextile, the absorption coefficient for the entire investigated frequency range changes over the interval $\alpha \in [0,1; 4,1] \text{ cm}^{-1}$. Therefore it is evident that sound wave absorption for these materials is low;
- Within the interval $f \in [0,1; 7,2]$ kHz the Styrofoam absorption factor is comparatively low - $\alpha \leq 4,0 \text{ cm}^{-1}$;
- For Styrofoam there are two marked resonance peaks of absorption:
 - At frequency of $f_1 = 9,0$ kHz absorption coefficient is $\alpha_{\max 1} = 10,8 \text{ cm}^{-1}$;
 - At frequency of $f_2 = 11,9$ kHz absorption coefficient is $\alpha_{\max 2} = 12,1 \text{ cm}^{-1}$;
- Within the interval of $f \in [8,5; 15,0]$ kHz the absorption coefficient for Styrofoam is $\alpha \geq 4,5 \text{ cm}^{-1}$. Therefore for high frequencies a corresponding high absorption of sound waves is observed.

Figure 2 Graphs of experimental dependence of absorption coefficient α on frequency f for fibrous laminate

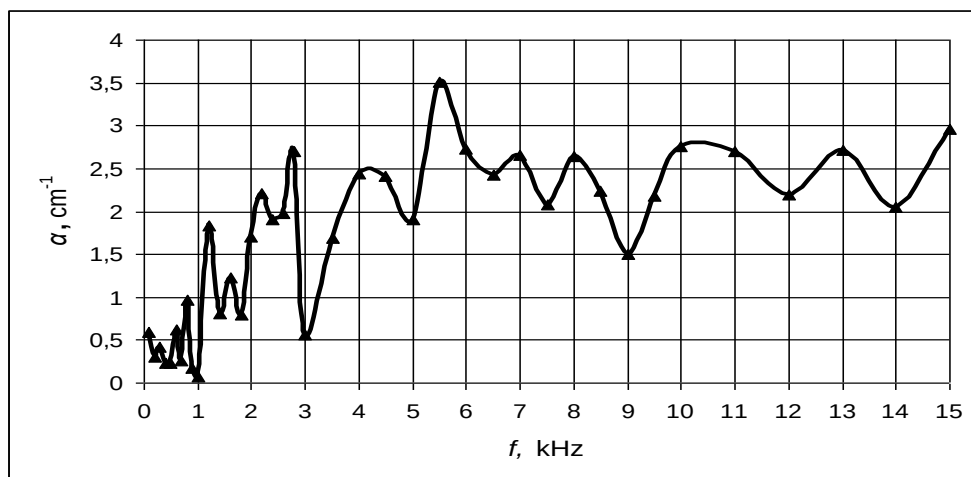


Figure 3 Graphs of experimental dependence of absorption coefficient α on frequency f for geotextile

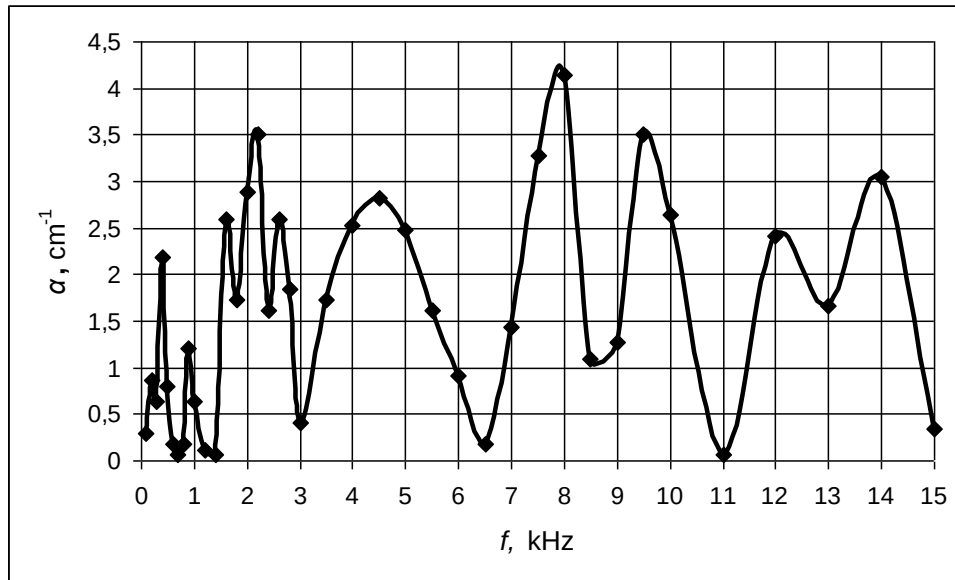
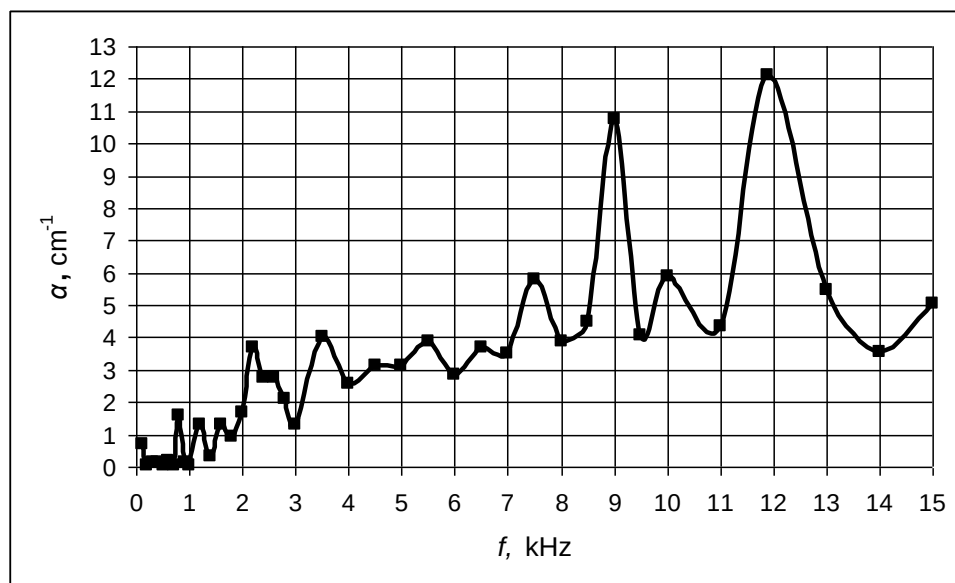


Figure 4 Graphs of experimental dependence of absorption coefficient α on frequency f for styrofoam



2. Identification of absorption coefficient according to Gauss method

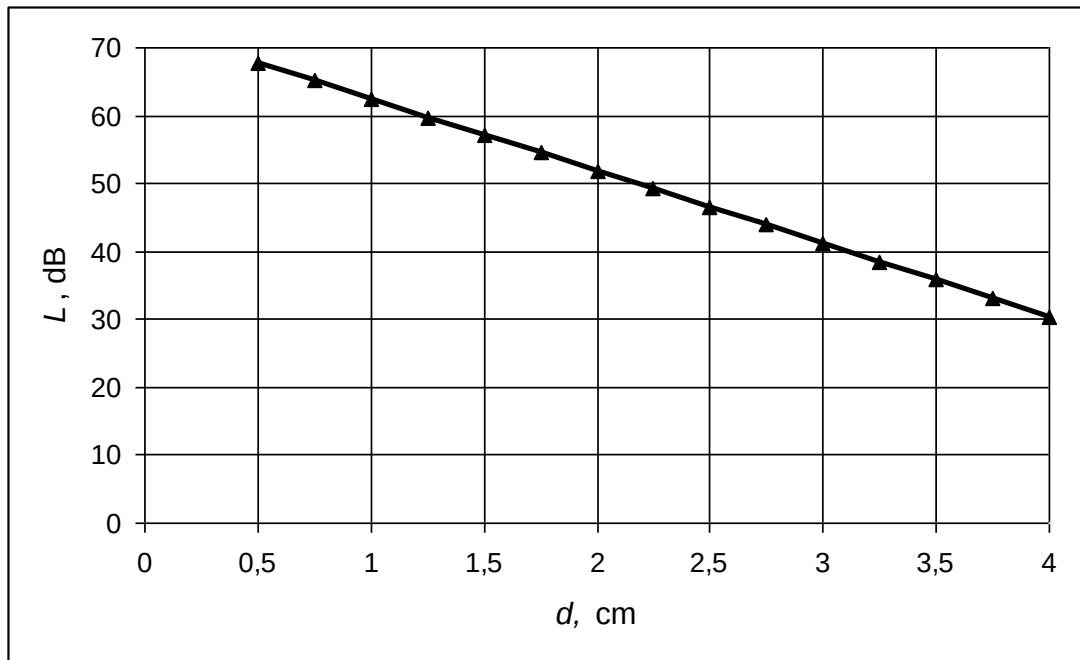
For more precise identification of absorption coefficient for particular frequency it is advisable to use Gauss method [6]. A set of sheets is used of specific thickness made of one of the three investigated materials. It changes within the interval $x \in [0,5; 4,0]$ cm by step of 0,25 cm. In Table 1 and Fig. 5 are given the obtained experimental results for fibrous laminate. The sound wave frequency is $f = 4$ kHz and the sound level at the surface of the absorbing material is $L_0 = 73,1$ dB.

Table I

x , cm	0,50	0,75	1,00	1,25	1,50	1,75	2,00	2,25
L , dB	67,8	65,2	62,4	59,7	57,1	54,5	51,8	49,2
α , cm ⁻¹	2,44	2,44	2,46	2,46	2,46	2,45	2,45	2,45

x , cm	2,50	2,75	3,00	3,25	3,50	3,75	4,00
L , dB	46,5	44	41,3	38,4	36	33,2	30,4
α , cm ⁻¹	2,45	2,44	2,44	2,46	2,44	2,46	2,46

Figure 5 Graphs of experimental dependence of the sound level L on depth x for fibrous laminate



Mean value of absorption coefficient is determined by the formula

$$\bar{\alpha} = \frac{1}{n} \sum_{i=1}^n \alpha_i \quad (5)$$

Mean quadratic error for absorption coefficient is expressed by

$$\sigma_{\alpha} = \frac{\sum_{i=1}^n (\Delta \alpha_i)^2}{n(n-1)}, \quad (6)$$

where $\Delta \alpha_i = \alpha_i - \bar{\alpha}$ is absolute error of individual measurement.

Percentage error is

$$\varepsilon_{\alpha} \% = \frac{\sigma_{\alpha}}{\bar{\alpha}} \cdot 100\% \quad (7)$$

The result is presented as

$$\alpha = \bar{\alpha} \pm \sigma_{\alpha} \quad (8)$$

$$\alpha = \bar{\alpha} \pm \varepsilon_{\alpha} \% \quad (9)$$

Drawing upon the experimental results as presented in table 1, we get

$$\alpha = (2,451 \pm 2,28 \cdot 10^{-3}) \text{ cm}^{-1},$$

$$\alpha = 2,451 \text{ cm}^{-1} \pm 0,09\%.$$

V. Conclusion

The developed method contributes to the formation of a research approach to solving practical problems. The resulting relationships and regularities of studied sound absorbing materials are stage by the create a database. It is open and can be supplemented with the results of other such materials, having applications in industry and households.

VI. References

- [1] Smetana Ts., *Izmervane na shum i vibracii*, DI Tehnika, Sofia, 1976.
- [2] Georgiev D., B. Bogdanov, I. Markovska, Y. Hristov and D. Stanev, A Kinetic Study on the Adsorption of Cd(II) and Zn(II) Ions from Aqueous Solutions on Zeolite NaA, *World Academy of Science Engineering and Technology*, Issue 59 November 2012, Venice, Itali, 2650-2653, pISSN 2010- 376X, eISSN 2010-3778.
- [3] Draganov N., K. Kamenov. Four channel Preamplifier for Accelerometric Sensors. *Journal of the Technical University of Gabrovo*, Vol. 43, 2012, pp 71-74

- [4] Jelyazkov I., Trepteniya I valni, univ. izd. Sv. Kliment Ohridski, Sofia, 2000.
- [5] Mihailova V., Osnovi na fizikata, I i II chast, izd. Siela, Sofia, 2011
- [6] Andreev M., V. Lyudskanov, Laboratorna fizika, izd. Nauka i izkustvo, Sofia, 1975