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ACOUSTICS ABSORBANTS MADE WITH VIBRATING PERFORATED PLANES

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Abstract: *This work aims to establish the relationships, what determines a specific acoustic impedance structure, consisting of three elements (resonators, membrane perforated planes and an air cavity located behind them), usefull outside environment. Such analysis is carried out starting from the quantization elements encountered in the literature, micro perforated panels, as well as the functionality of a vibrating membrane.*

Key words: *acoustics absorbants coefficients, vibrating plates*

1. INTRODUCTION

This work aims to establish the relationships, what determines a specific acoustic impedance structure, consisting of three elements (resonators, membrane perforated planes and an air cavity located behind them), usefull outside environment. Such analysis is carried out starting from the quantization elements encountered in the literature, micro perforated panels, as well as the functionality of a vibrating membrane.

2. BACKGROUND THEORY

Starting from the relationship given by [MAA 87] and [ALL 93], the acoustic impedance of a perforated panel can be treated as a cylindrical tube, its dimensions have the small values compared with the wavelength of sound interacting with these structures.

So, taking account of surface perforations reported to the Panel surface, acoustic impedance specifies (Z_{sp}) of perforations on the panel is:

$$Z_{sp} = \frac{j\omega\rho_0 h}{rp}\left[1 - \frac{2}{cp\sqrt{-j}}\frac{J_1(cp\sqrt{-j})}{J_0(cp\sqrt{-j})}\right]^{-1} \quad (1)$$

Where: h- perforated panel thickness; j = $\sqrt{-1}$; J_0, J_1 – Bessel function of order 0 and 1; ρ_0- air density; cp – penetration constant determined from the relationship (2); rp – ratio of perforation (perforation/panel surface)

$$cp = r\sqrt{\frac{\rho_0\omega}{\mu}} \quad (2)$$

Notations are: r – the radius of the cylinder; μ - the viscosity of the air.

In view of the dynamic behavior what interacts with of these air vents, it is necessary to add some additional valid acoustic mass on both sides of the panel (Z_{smp}) and a coefficient of acoustic resistance R_S [RAN-00]. RS- „Ingard and Labate define an additional factor for the resistive part of the tube" [ING 50], [ROS -].

$$Z_{smp} = j\omega\rho_0\left(\frac{8r}{3\pi} + \frac{8r}{3\pi}\right) \approx j1{,}7\omega\rho_0 r \quad (3)$$

$$R_S = \frac{1}{2}\left(\sqrt{2\omega\rho_0\mu}\right) \quad (4)$$

Taking into account that the hole panels used in this analysis, has the diameter significantly greater than those of micro-perforated panels, it is necessary to take into account the energy disipates into the propagation located in the vicinity of the hole. Be taken into account and acoustic impedance radiated (Zr) of a cylindrical tube on which termination is an infinite flange [BER-96] .

$$Z_r = \frac{\rho_0 c_0}{\pi a^2}[R_r(2kr) + jX_r(2kr)] \quad (5)$$

$R_r(2kr)$ – is the radiant resistance, and $X_r(2kr)$ – is the radiant reactance, calculated with:

$$R_r(2kr) = 1 - \frac{2 \cdot J_1(2 \cdot k \cdot r)}{2 \cdot k \cdot r} \quad (6)$$

$$X_r(2kr) = \frac{2 \cdot H_1(2 \cdot k \cdot r)}{2 \cdot k \cdot r} \approx \frac{8r}{3\pi} \quad (7)$$

They are: J_1 – Bessel function of order 1; H_1 – Struve function of order 1; k – wavenumber.

The impedance of the air cavity (Zc), located behind the perforated panel, it shall be determined with the resulting relationship depending on the distance between the perforated Panel and a rigid surface [KUT-07].

$$Z_c = -j \cdot \rho_0 \cdot c_0 \cdot \cot(k \cdot L) \quad (8)$$

c_0 – is the speed of sound in air, L - the length of cavity.

Define acoustic impedance of the vibrant panel, starts from the relationship, indicating the force of a mechanical system composed of oscillating mass, damper and spring [FAH-05a], [KIN-00], [HAR-02].

$$M_m \frac{d^2x}{dt^2} + R_m \frac{dx}{dt} + K_m x = F = Spe^{i\omega t} \quad (9)$$

Where: Mm – mechanical mass, R_m – mechanical strength, Km – mechanical elasticity, S – surface, p – presure, t – time, x – displacement, F – force.

The (9) equation has the solution:

$$\frac{dx}{dt} = \frac{SPe^{i\omega t}}{R_m + j\omega M_m + j\omega K_m} = \frac{SPe^{i\omega t}}{Z_m} \quad (10)$$

The mechanical impedance (Z_m) is:

$$Z_m = R_m + j\omega M_m + j\omega K_m \quad (11)$$

Acoustic impedance of a vibrating membranes (Z_{sm}) is:

$$Z_{sm} = \frac{R_m}{S} + \frac{j\omega M_m}{S} + \frac{j\omega K_m}{S} \quad (12)$$

Taking into consideration that wave's front surface of the sample involve both functional structure (perforated Panel and vibrant membrane), it can be considered a parallel connection of them acoustic impedances. Thus, taking account of the relationships (1) to (12) that defines the character of each physical element involved, they could determine the relationship, what defines the impedance of a perforated panel with profile cylinder-shaped perforation, mounted on elastic support. The realtion that gives this fenomenon has the form:

$$Z = \left(\frac{1}{Z_r + \frac{\sqrt{2 \cdot \omega \cdot \rho \cdot \mu}}{2 \cdot rp} + \frac{j \cdot 1{,}7 \cdot \omega \cdot \rho_0 \cdot r}{rp}} + \frac{1}{\frac{R_m}{S} + \frac{j\omega M_m}{S} + \frac{j\omega K_m}{S}} \right)^{-1} + n_p \cdot \rho_0 \cdot c_0 \left(1 - \frac{2 \cdot J_1 \cdot (2 \cdot k \cdot r)}{2 \cdot k \cdot r}\right) - j \cdot \rho_0 \cdot c_0 \cdot \cot(k \cdot L) \quad (13)$$

Determination of the absorption coefficient of this type of sound structure can be achieved, with due regard for the relationship (14), found in the literature [KUT-07].

$$\alpha = 1 - \left| \frac{Z - \rho_0 c_0}{Z + \rho_0 c_0} \right|^2 \quad (14)$$

2. REZULTATE EXPERIMENTALE

We achieved the experimental validation of the relationship (13) through comparisons between the absorption coefficient calculated with measured.

Experimental determination was made by using two samples with thickness of 5 mm, and 10mm respectively. Both samples have a diameter equal to the inside diameter of an impedance tube having 120 mm. They are composed of a perforated plate with 4 perforations of 8mm diameter mounted on elastic support and (Fig. 1) and (Fig. 2).

To highlight the accuracy of theoretical results obtained on the basis of the relationship (13), it has chosen functional testing of this resonator, using several variants of air cavities located behind of the samples. Device for the determination of sound-absorbing coefficient, was carried out on the basis of European standardisation ISO 10534-2. Measurements were made for the absorption coefficients of these structures, staging the samples at the distance of 25, 50, 100 and 150 mm air cavity.

As can be seen in the graphs illustrated figs. 3-10, we used three types of signals (sine, sine with variated amplitude, sine plus white noise) but also an average of these three results experimentally determined.

Fig. 1 Sample number 1 with 5 mm thick

Fig. 2 Sample number 2 with 10 mm thick

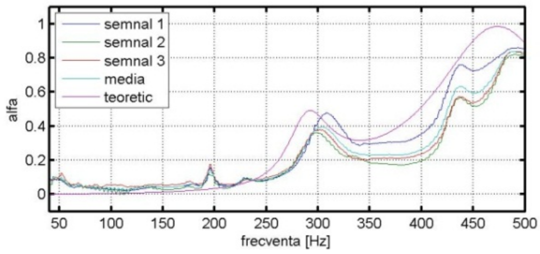

Fig. 3 Sample 1 with 25 mm length air cavity behind its

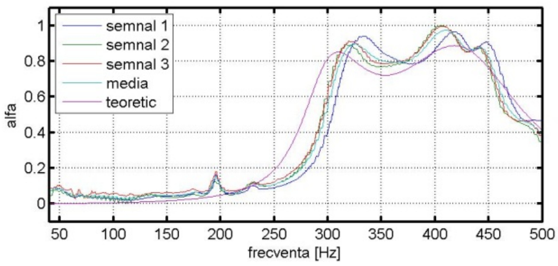

Fig. 4 Sample 2 with 25 mm length air cavity behind its

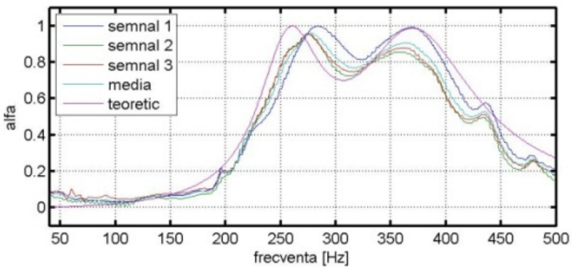

Fig.5 Sample 1 with 50 mm length air cavity behind its

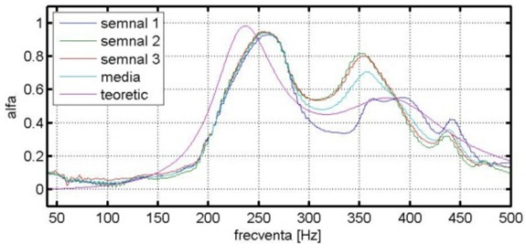

Fig. 6 Sample 2 with 50 mm length air cavity behind its

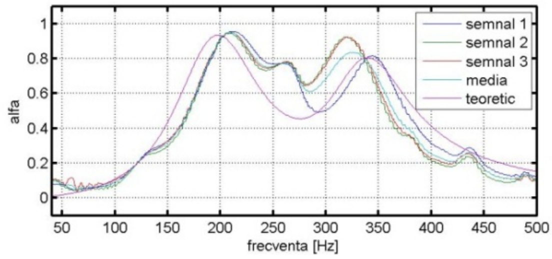

Fig. 7 Sample 1 with 100 mm length air cavity behind its

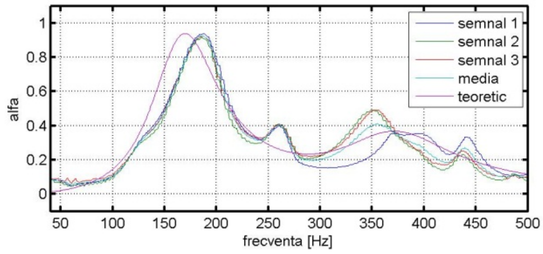

Fig. 8 Sample 2 with 100 mm length air cavity behind its

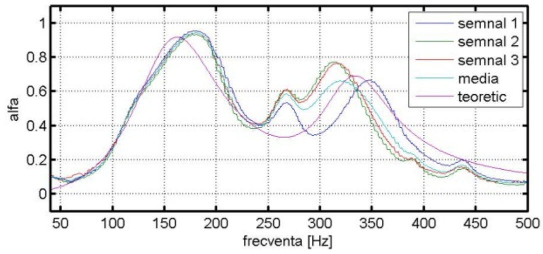

Fig. 9 Sample 1 with 150 mm length air cavity behind its

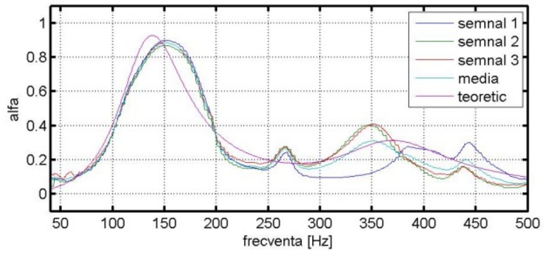

Fig.10 Sample 2 with 150 mm length air cavity behind its

3. CONCLUSIONS

As can be seen in all the graphs illustrated in figs. 3-10, oscillation amplitude theoretical results obtained using relations (13) and (14), faithfully follows the other graphs obtained by experimental measurements. In other words, it can be concluded that the theoretical results offered by relationship (13), applies in reality.

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DETERMINARE A COEFICIENTULUI DE ABSORBȚIE A UNEI PLĂCI VIBRANTE

Rezumat: *Această lucrare îşi propune determinarea unei relații de calcul, ce determină impedanța acustică specifică a unei structurii acustice, compuse din trei elemente (membrană rezonatoare, panou perforat şi o cavitate de aer situată în spatele acestora), pretabilă mediului exterior. Astfel analiză s-a realizat pornind de la elementele de cuantificare întâlnite în literatura de specialitate, a panourilor micro perforate, precum şi funcționalitatea unei membrane vibrante.*

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