ABOUT THE OWN FREQUENCY OF AN ACOUSTIC MEMBRANE

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ABSTRACT
In this paper it is presented the theoretical and practical aspects regarding own frequency of an acoustic membrane, being considered an oscillator. The membrane mass represents the body mass. The air is considered an arc of the oscillator (elastic component).
From a theoretical point of view, the own frequency does not depend only on the body mass, but, also, on the elastic component mass. The experimental results justify the validity of the theoretical aspects.
Keywords: frequency, oscillator, resonator.

1. INTRODUCTION
This paper shows that the acoustic membrane can be considered an oscillator which functions on resonance. Determining the resonance [2] frequency (own frequency) for this oscillator is done considering that the propagation of sound is followed by an adiabatic process. The experiment emphasizes the fact that the air, under the acoustic membrane, can influence the own frequency through its own mass.

2. THEORETICAL AND PRACTICAL ASPECTS
The acoustic membrane is used in order to attenuate sounds with low frequencies. Those membranes are formed by thin and elastic plates. They can be used and applied at few centimetres away from the wall (fig. 1), which, attached [6] to the supports, [1] contributes to the sound absorption, due to plates flexibility, internal frictions and energy loss in the air interspace.

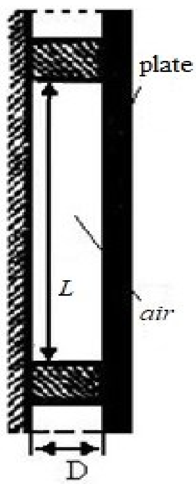

Figure 1 Acoustic membrane, where
L – the cavity length ; D – thickness.

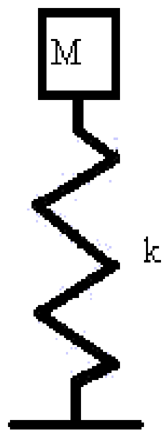

Figure 2. Oscillator, where
M – plate mass; k – air stiffness.

Materials used for [3] membranes can be hard wood [5] fibre board, plastic etc., having resonance characteristics [4] specific oscillating systems. The resonance panel presented in fig.1 is considered to be an oscillator with a single degree of freedom. (fig. 2).
It is considered that the motion takes place around the equilibrium position, due to the force corresponding to air pressure difference from the system cavity, presented in fig 1. The restoring force in equilibrium position can be calculated using the formula:

$$F = dp\pi R^2 = dpS \tag{1}$$

where: dp-pressure variation;
S – surface of the flexible plate.
While in motion, the air [1] from cavity presented in the fig. 1 goes through an adiabatic process, characterised by the equation:

$$pV^{\gamma} = ct \tag{2}$$

where: p-air pressure inside cavity;
V-cavity volume;
γ-adiabatic index.
Applying the logarithm function and subtracting from formula (2) the result will be:

$$\frac{dp}{p_0} + \gamma \frac{dV}{V_0} = 0 \tag{3}$$

where: p_0-atmospheric pressure;
V_0=SD – air volume inside cavity in equilibrium state;
D – air interspace thickness; dV=S ·x-volume variation;
x – displacement from the equilibrium position of the mass M.
The pressure variation can be obtained using equation (3):

$$dp = -\frac{\gamma p_0 dV}{V_0} = -\frac{\gamma p_0 Sx}{SD} = \frac{\gamma p_0 x}{D} \tag{4}$$

If equation (4) is introduced in equation (1), the restoring force, which is an elastic one, can be formulated:

$$F = -\frac{\gamma p_0 Sx}{D} = -kx \tag{5}$$

The equation characteristic oscillating motion system from fig 2 can be calculated, using the following equation:

$$M\frac{d^2x}{dt^2} + kx = 0 \tag{6}$$

The result of the previous equation can be written:

$$x = A\sin\omega t \tag{7}$$

If the given result of equation (7) is replaced in equation (6), the following equation is obtained:

$$M\omega^2 = k = \frac{\gamma p_0 S}{D} \Rightarrow \omega = \sqrt{\frac{k}{M}} = \sqrt{\frac{\gamma p_0 S}{MD}} \Rightarrow$$

$$\Rightarrow f = \frac{\omega}{2\pi} = \frac{1}{2\pi}\sqrt{\gamma \frac{p_0 S}{MD}}, \qquad (8)$$

It is known that the gas inside the cavity [1] suffers an adiabatic process. The ratio $\sqrt{\frac{\gamma p_0}{\rho_0}}$ represents the speed of sound, v. Taking into account formula (8), own frequency can be written as:

$$f = \frac{\omega}{2\pi} = \frac{v}{2\pi}\sqrt{\frac{\rho_0}{mD}}, \qquad (9)$$

where: v-speed of sound in air;
ρ_0-air density;
$m = \frac{M}{S}$ -surface unit mass of plate (fig 1).
Equations (8) and (9) were calculated considering the plate without stiffness
In case of an acoustic membrane from fig. 1, with the following dimensions $S=1,5\ m^2$, $M = 1,5\ kg$, $D = 10^{-1}\ m$, $\rho_{air} = 1,4 kg$, $v = 340\ m/s$, the own frequency determined with the equation (9) has the value $f = 185\ Hz$

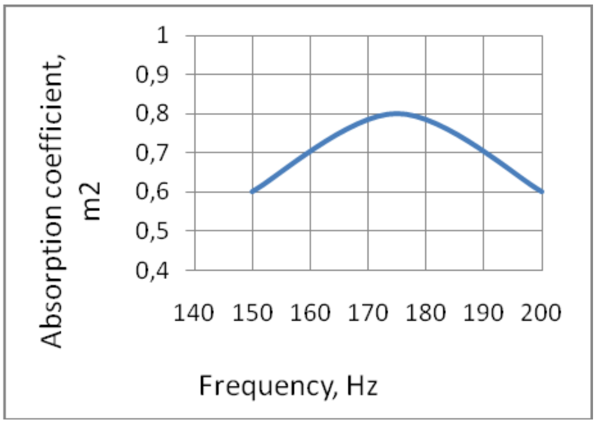

Figure 3. Graph of the absorption coefficient variation function of frequency

Tab. 1. Values of the absorption coefficient corresponding to the frequency

Nr. Crt	α [m²]	f [Hz]
1	0,6	150
2	0,8	175
3	0,6	200

After conducting the experiments, the values of absorption acoustic coefficient corresponding to the frequency are prezented in tab. 1. Using the results, the graph of the absorption coefficient variation function of frequency was produced and presented in fig. 3
It can be seen that the maximum value of the absorption coefficient corresponds to the frequency $f = 175\ Hz$.
In order to obtain a theoretical [1], [2] value closer to the experimental one , the following equation must be used:

$$f=\frac{1}{2\pi}\sqrt{\frac{k}{M+\frac{m_{air}}{3}}}=\frac{1}{2\pi}\sqrt{\frac{\gamma p_0 S}{(M+\frac{m_{air}}{3})D}}\Rightarrow$$

$$\Rightarrow f=\frac{v}{2\pi}\sqrt{\frac{\rho_0 S}{(M+\frac{m_{air}}{3})D}} \tag{10}$$

where $m_{air}=S.D.\rho_{air}\cong 0{,}21kg$

Introducing the value of the air mass in equation, the value of the own frequency will be obtained, $f=178Hz$. Comparing the values of the own frequency using equations (9) si (10) with the value of the own frequency from the experimental result, it can be seen that the result from equation (10) is closer to the later one.

3. CONCLUSIONS

In case of acoustics absorbers assimilated as oscillators, it can be seen that the own frequency depends, also, on the component of the elastic mass. In case of acoustic membrane, due to the air mass value (elastic component) being much lower than actual membrane mass, the frequency band, when absorption coefficient has relatively great values, is large. In case of Helmholtz resonator, due to the air mass from the neck of the resonator is much lower than the air mass from the resonator cavity, the frequency band, when absorption coefficient has relatively great values, is thin.

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