Dependence of sound insulation of building constructions on the acoustic properties of materials

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Abstract

The article deals with some acoustic properties of materials that have an impact on the sound insulation of building constructions, including sound absorption (abatement). These are namely, the capacity of materials to absorb, i.e. to reduce the sound energy passing through a building construction, the influence of an angle of sound wave incidence onto the partition (construction), etc. Sound pressure on the area of the partition may be uniform, whereas the amplitude of oscillations gets changed throughout the whole area of the partition. The article explores in what cases sound will pass most strongly through the partition of finite dimensions when space-frequency resonance occurs.

Investigation showed that the sound energy absorption depended on deformation losses in that material. Changes in the angle of the sound wave incidence at the same frequencies create the opportunity for manifestation of alternation of maximums and minimums in the motion of plate amplitudes. The property of sound wave incidence, at the sound transmission through the plate of finite dimensions, confirms the rightfulness of the division of the curve of the frequency dependence of sound insulation into three ranges of frequencies with the different intensity of sound transmission.

Keywords: sound insulation, building materials, deformation of materials, inner friction losses, insulation properties, sound permeability.

Introduction

The acoustic properties of materials predetermine the sound penetration through building constructions. At first, we will clarify the properties of the materials that become manifest in the structure of materials with sound passing through constructions from those materials. In our work [1] the properties of building materials, predetermining the sound insulation of building constructions, are indicated. This research covered the density of new building materials and its impact on the degree of sound insulation.

In the present article we shall provide one of the properties that was not mentioned, the characteristic of the incident wave onto the partition and the impact of its parameters on the sound permeability of the partition under study. The distribution of the pressure zones of sound on the surface of the plate under study, which shows the form of its oscillations, is analysed. Here space-frequency resonances are elucidated and the highest amplitude of plate oscillation is identified.

Effect of sound absorption properties on sound insulation increase

With an aim of investigating an effect of sound absorption properties of materials, it is necessary to know the properties of materials to be used for sound insulation improvement on which sound energy absorption depend.

Primarily, it is necessary to make use of the properties of inner friction losses of homogeneous materials. Inner friction losses appear due to deformation of materials.

It is necessary to study whether deformation changes coincide with the changes of tensions.

In the case of harmonic fluctuations, these losses may be expressed through the ostensible parts of elastic constants.

If the material under study is characterized by the complex shearing modulus

$$\overline{G} = G(1 + i\eta_S) = G + iG' \tag{1}$$

and the modulus of elasticity (modulus of compression)

$$\overline{K} = K(1 + i\eta_K) = K + iK', \tag{2}$$

then it is possible to express the rigidity S to plane longitudinal waves, by means of a formula:

$$\rho\bar{c}^2 = \overline{S} = \overline{K} + \frac{4}{3}\overline{G} \tag{3}$$

The rigidity S is related to the sound velocity c of plane longitudinal waves.

We also obtain the complex meaning $\overline{S} = S(1 + i\eta_S)$. The coefficient of losses η_S is the measure of the coefficient of absorption α of longitudinal waves:

$$\alpha\lambda = \pi\eta_S = \frac{\left(K' + \frac{4}{3}G'\right)}{S}, \tag{4}$$

Therefore for obtaining the computed optimum value $\alpha\lambda$ =1,25 at extremely low frequency, it is necessary to select the material with η_S = 0,4.

Sound wave transmission through construction

Let us study the interrelationship of the wave motion of real plates with the wave motion in the environment. For solving the set tasks, the use will be made of the method of the correlation of wave parameters m, m_1, n, n_1 and angles α and α_1, which are interrelated by the following dependences [2]:

$$m_1 = k_0 a/\pi \sin\alpha_1 \sin\Theta_1,$$
$$n_1 = k_0 b/\pi \cos\alpha_1 \sin\Theta_1,$$
$$m = k_u a/\pi \sin\alpha,$$
$$n = k_u b/\pi \cos\alpha,$$

where m_1 and n_1 are the numbers of flexural semi-waves along the sides; a and b are coefficients of wave, propagating with the velocity c_1; k_0, k_n are the wave numbers.

Sound wave, falling onto the plate at a certain angle θ_1, excites the inertial wave in the plate with the same frequency as a free wave that may differ from the inertial one by its form and frequency. The emerging elastic waves as to their type may be flexural and longitudinal. The presence of the edges in the plate (in our case the plate is rectangular) and the incidence of inertial and free waves on them lead to the formation of free flexural waves, propagating from the edges at a certain angle to the sides of the plate.

The most favourable conditions for sound transmission through the plate will be in the case of the best coincidence of the wave parameters of sound and vibration fields.

If the frequency of the incident sound waves at the angle θ_1 is equal to the frequency of normal oscillations of the plate, three cases are possible:

– spatial resonance, where $k_u = k_0$, $\alpha = \alpha_1$, i.e. $m = m_1$, $n = n_1$;

– incomplete spatial resonance, where the amplitude of oscillations is highest in the case of the partial coincidence of the wave parameters $k_{ux} = k'_{0x}$, $k_{uy} \neq k'_{0y}$ or, $k_{ux} \neq k'_{0x}$, $k_{uy} = k'_{0y}$, $\alpha \neq \alpha_1$, i.e. $m = m_1$, $n \neq n_1$ or $m \neq m_1$, $n = n_1$;

– ordinary spatial resonance, characteristic of the highest amplitude of oscillations at the discrepancy of the wave parameters $k_u \neq k'_0$, $\alpha \neq \alpha_1$, i.e. $m \neq m_1$, $n \neq n_1$.

Let the monochromatic plane acoustical wave fall at a certain angle θ_1 on the rectangular plate with sides a and b, which with the help of hinges rests on four sides. We assume the plate as thin, and therefore we take into consideration only its flexural oscillations. We select the rectangular system of coordinates so that its beginning coincides with the lower left top of the plate, and we direct axes x and y along its edges. Let's combine the plane X0Y with the neutral plane of the plate.

In the case of the spatial resonance $k_u = k'_0$, $\alpha = \alpha_1$, the amplitude of displacements of the plate are given by

$$\xi_{mn} = \frac{p_{omn}}{m'\left[\omega_{mn}^2(1 - i\eta) - \omega^2\right]}. \qquad (5)$$

In this expression, the conditions of wave coincidence have been fulfilled in full, and with the condition $\omega = \omega_{mn}$ being followed, the effect of the spatial resonance and the maximum sound transmission is being observed. The condition for the existence of the effect of spatial resonance will be: $k_0 = k_{umn}/\sin\Theta_1$ or $c_{umn} = c_0/\sin\Theta_1$.

In difference from an infinite plate where each frequency is normal, for a finite plate, with sound waves falling at some angle, the spatial resonance and the highest sound transmission are observed only at frequencies of normal oscillations, which are of a discrete character.

At incomplete spatial resonance, where partial coincidence of the wave parameters $k_{ux} = k'_{0x}$, $k_{uy} \neq k'_{0y}$, $\alpha \neq \alpha_1$ takes place,

$$\xi_{m(n)} = \frac{p_{0mn_1}}{m'\left[\omega_{m(n)}^2(1 + i\eta) - \omega^2\right]} \cdot \frac{2c_0\omega\cos\alpha}{b\sin\Theta_1\left(\omega^2\cos^2\alpha - \omega_{m(n)}^2\cos^2\alpha_1\right)}; \qquad (6)$$

and in the case of correlations $k_{ux} \neq k'_{0x}$, $k_{uy} = k'_{0y}$, $\alpha \neq \alpha_1$,

$$\xi_{m(n)} = \frac{p_{0m_1n}}{m'\left[\omega_{m(n)}^2(1 + i\eta) - \omega^2\right]} \cdot \frac{2c_0\omega\sin\alpha}{a\sin\Theta_1\left(\omega^2\sin^2\alpha - \omega_{m(n)}^2\sin^2\alpha_1\right)}. \qquad (7)$$

In the case of an ordinary space resonance, where $k_u \neq k'_0$, $\alpha \neq \alpha_1$,

$$\xi_{m(n)} = \frac{p_{0m_1n_1}}{m'\left[\omega_{(m)(n)}^2(1 + i\eta) - \omega^2\right]} \cdot \frac{}{ab\sin\Theta_1\left(\omega^2\sin^2\alpha - \omega_{(m)(n)}^2\sin^2\alpha_1\right)} \cdot \frac{16c_0^2\omega\alpha\cos\alpha}{\left(\omega^2\cos^2\alpha - \omega_{(m)(n)}^2\cos^2\alpha_1\right)}. \qquad (8)$$

At deducing frequency-angular characteristics of the displacement of plates, we substitute the indexes m, m_1, n, n_1 by their values. After further averaging the frequency-angular dependences of sound transmission in the frequency integral Δf, we write the square of the amplitude of plate displacements:

- at the frequency of spatial resonance

$$\xi^2 = p^2/\left(32\pi^3 m'^2 f^2 \Delta f\eta\right); \qquad (9)$$

$$\xi^2 = \frac{p^2}{32\pi^3 m'^2 f^3 \Delta f\eta} \cdot \frac{c_0^2\cos^2\alpha}{\pi^2 b^2\sin^2\Theta_1\left(\cos^2\alpha - \cos^2\alpha_1\right)^2 f^2}; \qquad (10)$$

$$\xi^2 = \frac{p^2}{32\pi^3 m'^2 f^3 \Delta f \eta} \cdot \frac{c_0^2 \sin^2\alpha}{\pi^2 a^2 \sin^2\Theta_1 \left(\sin^2\alpha - \sin^2\alpha_1\right)^2 f^2}; \quad (11)$$

- at the frequency of ordinary spatial resonances

$$\xi^2 = \frac{p^2}{32\pi^3 m'^2 f^3 \Delta f \eta} \cdot \frac{\Omega c_0^4 \sin^2\alpha \cos^2\alpha}{\pi^4 a^2 b^2 \sin^4\Theta_1 \left(\sin^2\alpha - \sin^2\alpha_1\right)^2 \left(\cos^2\alpha - \cos^2\alpha_1\right)^2 f^4}. \quad (12)$$

Each of these expressions characterizes the highest response of the plate in conformity with the condition of coordination of wave parameters. In the expression (12) the numerical coefficient $\Omega = 16$ for ordinary resonances in the range of frequencies is higher of spatial resonance and $\Omega = 4$ in the range lower of spatial resonance.

From comparison of correlations (Eq.9 - 12), we see that the response of the plates to the effect of a sound wave, incident at the angle θ_1, is different for each of the conditions of the correlation of wave parameters.

At the specific frequency for each preset angle of sound incidence θ_1, its own only (for thin plates) spatial resonance exists. The value of this frequency practically in many cases with a sufficient degree of precision may be determined according to the frequency of wave coincidence at the oblique incidence of sound on the infinite plate, i.e. according to the Cremer's formula, since the spectrum of normal frequencies of the limited plate at relatively high frequencies is dense enough and correction on the discrete character of its oscillations is insignificant.

Let's trace the character of the frequency dependence of sound transmission, directed at a certain angle θ_1, through the plate of glass with the dimensions a = 1.21 m and b = 1.08 m; thickness h = 0.0052 m; m' = 13 kg/m^2; D/m' = 56.3 m^4/c^2; $\eta = 2\cdot 10^{-3}$.

Applying expressions Eq. 9 - 12, we construct frequency characteristics of the amplitude of displacement of the plate, excited by a noise band Δf, for the angle of incidence $\theta_1 = 75°$.

Substituting in the dependences (3) and (4) k_u by its value $\frac{\omega}{c_u}$, we get: $\sin^2\alpha = \frac{\pi m^2}{2 f a^2}\sqrt{\frac{D}{m'}}$; $\cos^2\alpha = \frac{\pi n^2}{2 f b^2}\sqrt{\frac{D}{m'}}$, where $D = Eh^3/12\left(1-\nu^2\right)$ is the flexural rigidity of the plate, depending on the module of elasticity (Young) – E, the Poisson's coefficient ν and the plate thickness h.

In the range of frequencies of a lower spatial resonance on the same frequencies, the wave length in air λ_0 is higher than the wave length of a flexural wave in the plate λ_u and accordingly $c_0 > c_u$, $k_0' < k_u$. Here the ordinary and incomplete spatial resonances are possible. The latter are observed in the range of frequencies from the boundary frequency of the incomplete spatial frequency to the boundary frequency of the complete spatial frequency.

In this range for each number m_1 and n_1 in the plate the number m and n equalling them will be found and the angle α corresponding to them. The amplitude of displacements of the points in the plate may be calculated for mean values of the angle α in each estimated band of the frequencies Δf and the angles θ_1. Hence $m^2 = m_{1u\nu}^2 = m_{1u} m_1 \nu$; $n^2 = n_{1u\nu}^2 n_{1u} n_{1\nu}$, where m_{1u}, n_{1u} are the numbers of sound semi-waves in the plane of the plate along the sides a and b, relating to the lower frequency of the interval; m_{1u}, n_{1u} are the numbers relating to the higher frequency of the interval.

Lower of the boundary frequency of the incomplete spatial resonance the movement of the plate is determined by the ordinary spatial resonance.

In the range of frequencies higher of the spatial resonance on the same frequencies, wave length in air becomes less than that of the flexural one λ_u, $c_0 < c_u$, $k_0' > k_u$, therefore, only the ordinary spatial resonances are manifest. On those frequencies for the known numbers m_1 and n_1, the numbers m and n equal to them with the real angle α are not found. Therefore, the amplitude of oscillations of the plate in this range we calculate for our example at preset α (45, 60 and 75°).

Making calculations according to Eq.9 - 12 we assume that plate displacement at the frequency of the spatial resonance is equal to unity, and the angle $\alpha \approx \pi/2$. Fig. 1 presents the envelope curves of sound transmission through the given plate made of glass for the angle of incidence $\theta_1 = 75°$ versus the frequency.

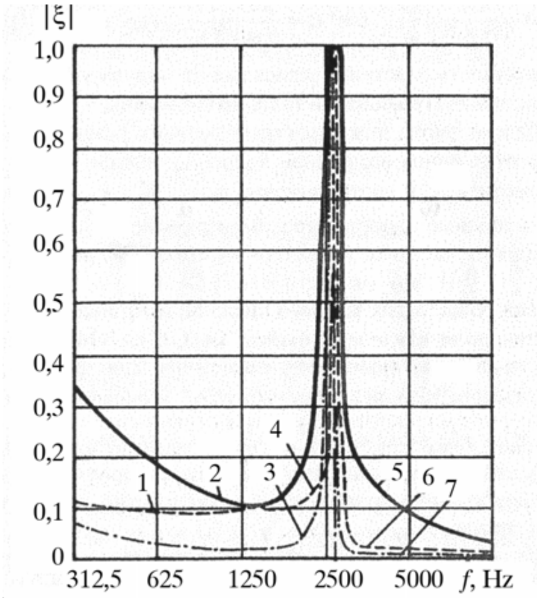

Fig. 1. **Frequency dependence of resonant sound transmission through glass with thickness h = 0.0052 m, with dimensions of 1.21×1.0.8 m**

In the range of frequencies lower of the spatial resonance, the curve 4 is structured according to Eq. 10, and the curve 1 according to Eq. 11. The curve 2 envelopes maximum sound transmission at the incomplete space resonance. The envelope curve 3 reflects the case of ordinary resonances.

In the range of frequencies higher than the spatial resonance, the envelope curves are represented by lines 5, 6 and 7, structured according to Eq. 12 for the angles α, equalling correspondingly 75, 60 and 45°. For $\alpha = 75°$, the values of displacement are highest, since that angle is closer of all to the angle of incident sound waves $\alpha_1 = \pi/2$.

From the curves in Fig. 2 it is seen that in the range of frequencies lower than the spatial resonance (range II), the decisive contribution into sound transmission belongs to the incomplete sound resonance (Fig. 2.).

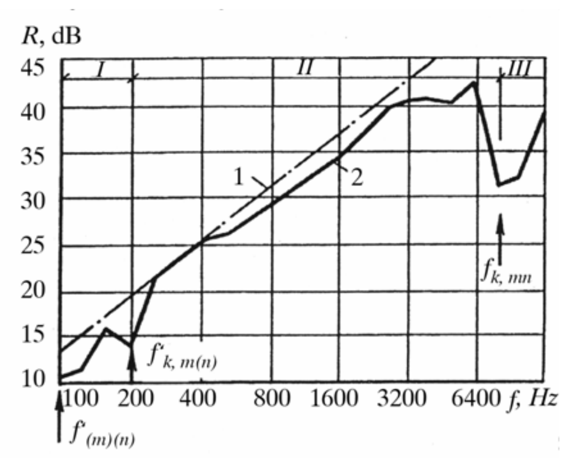

Fig. 2. **Frequency sound insulation characteristic of a duralumin plate with thickness *h* – 0.003, with dimensions of 1.21×1.0.8 m: 1 – the law of mass for the angle $\theta_1 = 45°$; 2 – experiment**

Lower of the boundary frequency of incomplete spatial resonances, where only conditions $k_u \neq k'_0$, $\alpha \neq \alpha_1$, $m \neq m_1$, $n \neq n_1$ are fulfilled, the contribution to sound transmission by determination belongs to ordinary spatial resonances (range I). In the range higher of spatial resonance (range III) the main contribution into sound transmission is also made by ordinary resonances.

The approximated values of the lowest or boundary frequencies (at low frequencies) and incomplete spatial resonances will be:

- boundary frequency of the ordinary space resonance at $m_1 = 1/2$ and $n = 1/2$:

$$f''_{r(m)(n)} = c_0 / \left(4a \sin\alpha_{m_1 n_1} \sin\Theta_{m_1 n_1}\right), \qquad (13)$$

or

$$f''_{r(m)(n)} = c_0 / \left(4b \cos\alpha_{m_1 n_1} \sin\Theta_{m_1 n_1}\right); \qquad (14)$$

- boundary frequency of the incomplete space resonances, at $m_1 = m = 1$,

$$f'rm(n) = c_0 / 2a \sin\alpha_{mn_1} \sin\Theta_{mn}, \qquad (15)$$

or at $n_1 = n = 1$

$$f'_{r(m)n} = \frac{c_0}{2b \cos\alpha_{m_1 n} \sin\Theta_{m_1 n}}. \qquad (16)$$

The lowest value is taken as the estimated value of boundary frequencies that is calculated according to Eq.13 - 16. The exact value of those boundary frequencies is determined with account taken of the correction in the discrete character of natural oscillations of the plate.

As illustration of the values of boundary frequencies, Fig. 2 presents the frequency characteristic of sound insulation of the duralumin plate with the parameters a = 1.21 m, b = 1.08 m, h = 0.003 m; m' = 7,93 kg/m^2, D/m' = 22.8 m^4/c^2; $\theta_1 = 45°$, $\alpha = \pi/2$, obtained experimentally. The values of boundary frequencies here are constituted of $f''_k = 100$ Hz, $f'_k \approx 201°$ Hz and $f_k = 7880$ Hz, whereas the measured (experimental) are equal, accordingly, to 100, 200 and 8000 Hz.

From the given example it is seen that at the directed incidence of sound the scheme of division of the curve of frequency characteristic of sound insulation into three ranges, with the different degree of sound transmission, is well confirmed by experimental data and the obtained values of boundary frequencies agree with the said data.

At the estimation of the character of the directed sound transmission, of interest is that part of the process where sound waves of one frequency fall onto the plate at all possible angles from 0 to $\pi/2$.

On the example of the same plate made of glass, we calculate the relative displacements of the plates using Eq.9 - 12. Hence, we assume that the fixed frequency is the frequency of the spatial resonance $f_{mn} = 5000$ Hz for the angle of incidence of sound $\theta_{1mn} = 45°$.

Fig. 3 represents the envelope curves of maximums of sound transmission in dependence on the angle of incidence. The curves 1 and 4 are calculated according to Eq. 10 and 11 at the change of angle θ_1 from 0 to 45°.

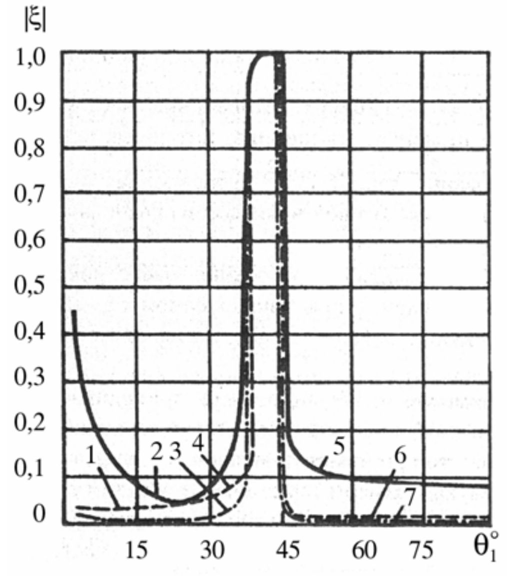

Fig. 3. **Angular dependence of resonant sound transmission through glass with thickness *h* – 0.00052 m, with dimensions of 1.21×1.0.8 m**

The curve 2 envelopes maximums of relative displacements at the incomplete space resonance. The envelope curve 3 belongs to the cases of ordinary resonances. In the range of angles of sound incidence from 45 to 90°, the envelope curves 5, 6 and 7 are calculated at α equal to 75°, 60° and 45°, wherefrom it is seen that degree of intensity of sound transmission depends on the correlation of the angles α and α_1, and the closer the angle α to the angle of incident sound α_1, the higher the amplitude of plate displacement.

Construction of the frequency characteristic of sound insulation

At the directed incidence of sound waves onto the rectangular thin plate with the sides *a* and *b*, for each angle of incidence of sound its own frequency of spatial resonance exists, where sound transmission is at maximum. In the ranges of frequencies higher and lower of that frequency, response of the plate is different and depends on the conditions of interaction of the acoustic field of disturbance and the field of flexural oscillations of the plate.

Investigation of the conditions for the interaction of the fields in the cases of ordinary, incomplete and complete space resonances enables one to trace the mechanism of sound transmission, i.e. to identify the contribution of those resonances in each calculated range of frequencies into sound transmission through the plate along its amplitudes of displacements.

Quantitative correlations of the amplitude of oscillations and the oscillating speed of the plate [2, 4] give the opportunity to express the acoustic power that is radiated by the plate when it gets excited by a plane sound wave falling at the angle θ_1. Hence, knowing the incident and through transmitted in the resonant regime acoustic powers, we obtain the expression of sound insulation in the form of

$$R = 10\lg \Lambda \frac{m'^2 f \Delta f \eta}{\bar{s}} \cos\theta_1, \qquad (17)$$

where Λ is the numerical coefficient, which covers the permanent integrations and depends on the width of the frequency interval and the calculated area of research (Table 1); $\bar{s}_1$ is the averaged characteristic of acoustic 76 radiation, the values of which in each of the calculated ranges are found according to Table 1.

The practical method for constructing the frequency characteristic of sound insulation of the barrier at the directed incidence of sound onto a rectangular thin plate is based on the use of the dependence given by Eq.17.

It is seen from Eq.17 that at the directed sound incidence, the quantitative and qualitative measure for sound insulation of real one-layered thin plates is as follows: the weight of the barrier, the frequency of the incident sound, the plate dimensions, its flexural rigidity, the loss factor and the angle of incidence of sound waves onto the plate.

Calculations are carried out on the geometric mean frequencies of the three-octave bands for three frequency ranges:

– at the frequency of the spatial resonance:

$$f_{\Gamma\theta} \approx 18843{,}31(\sin^2\theta_1\sqrt{D/m})^{-1}; \qquad (18)$$

– at frequencies higher of the spatial resonance $f > f_{\Gamma\theta}$;

– at frequencies lower of the spatial resonance to the boundary frequency of incomplete space resonances:

$$f'_{\Gamma\theta} = 172(a\sin\theta_1)^{-1}. \qquad (19)$$

The procedure for construction of the calculated dependence of sound insulation is as follows:

– we define the boundary frequencies $f_{\Gamma\theta}$ and $f'_{\Gamma\theta}$ according to Eq.18 and 19 for the preset angle θ_1;

– we find the value of sound insulation at the frequency of spatial resonance according to Eq.17 and Table 1;

– in dependence on the angle θ_1 according to Eq.20 we find the averaged characteristics of sound radiation in the range of frequencies higher of the spatial resonance;

– we define sound insulation in that range of frequencies according to Eq.17;

– from Eq.21 (see Table 1) on each geometric mean frequency we find the averaged characteristics of sound radiation for the range of frequencies lower of the spatial resonance;

– we define sound insulation in this range of frequencies from Eq.17;

Table 1. **Values of sound insulation characteristics**

<table>
<tr><td rowspan="2">Calculated range of frequencies</td><td rowspan="2">Numerical coefficient Λ</td><td colspan="5">Averaged characteristic of sound insulation, s at Θ_1 degree</td></tr>
<tr><td>15</td><td>30</td><td>45</td><td>60</td><td>75</td></tr>
<tr><td>Range of space resonances (SR) $f_{r\Theta}$</td><td>$2{,}92\cdot10^{-4}$</td><td>0,52</td><td>0,58</td><td>0,71</td><td>1</td><td>1,93</td></tr>
<tr><td rowspan="2">Range higher of space resonance (SR) $f > f_{r\Theta}$</td><td rowspan="2">$2{,}92\cdot10^{-4}$</td><td colspan="5">$\bar{s}_1 = \Delta' \frac{f_{r\Theta}}{abf^3}$, (20)</td></tr>
<tr><td>$\Delta' = 1{,}16\cdot10^7$</td><td>$\Delta' = 3{,}12\cdot10^6$</td><td>$\Delta' = 1{,}56\cdot10^6$</td><td>$\Delta' = 1{,}04\cdot10^6$</td><td>$\Delta' = 8{,}36\cdot10^5$</td></tr>
<tr><td>Range lower of space resonance (SR) $f_{r\Theta'} \le f < f_{r\Theta}$</td><td>$1{,}17\cdot10^{-3}$</td><td colspan="5">$\bar{s}_1 = \frac{0{,}524 f_{r\Theta} f'_{r\Theta}}{\left(f - f_{r,\Theta}\right)}$ (21)</td></tr>
</table>

– we construct the frequency characteristic of sound insulation of the given barrier.

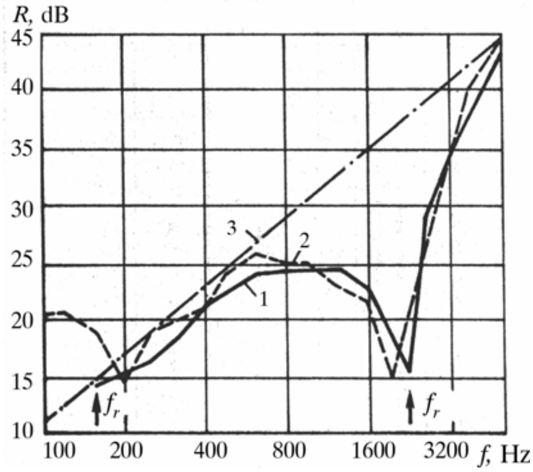

Fig. 4. **Frequency characteristic of insulation of the directed sound with silicate glass: thikness $h = 0.0052$ m, dimensions 1.21×1.08 m, $m' = 13$ kg/m^2, $\eta = 0.2\ 10^{-2}$**

The frequency characteristic 1 in Fig 4 is constructed by using the proposed practical method (see Table 1). The frequency dependence 2 is obtained by experiment in a big acoustic chamber. The line 3 shows for comparison of the "Mass Law". All dependences are constructed for the angle $\theta_1 = 75°$.

Conclusions

1. In estimating the acoustic properties of insulating materials, it is important to determine whether the deformation changes do not coincide with the changes of tensions.

2. In order to determine the optimum values, the changes of deformations and the changes of tensions $\alpha\lambda$ should equal $\alpha\lambda = 1.25$. The material for low frequencies is selected with $\eta\varsigma = 0.4$.

3. Calculations show that change of the angle θ_1 at the same frequency (see Fig. 3) leads (in dependence on the character of interaction of wave parameters and angles of the sound and vibration fields) to the emergence of the alternating maximums and minimums of the amplitudes of plate displacement. The angular characteristic of the directed sound transmission through the plate of finite dimensions confirms the rightfulness of the division of the frequency dependence of sound insulation into three ranges of frequencies with the different intensity of sound transmission.

4. Investigation of the conditions for the interaction of the fields in the cases of ordinary, incomplete and complete spatial resonances enables one to trace the mechanism of sound transmission, i.e. to identify the contribution of those resonances in each calculated range of frequencies into sound transmission through the plate along its amplitudes of displacements.

5. It is seen from Eq.17 that at the directed sound incidence, the quantitative and qualitative measure for sound insulation of real one-layered thin plates is as follows: the weight of the barrier, the frequency of the incident sound, the plate dimensions, its flexural rigidity, the loss factor and the angle of incidence of sound waves onto the plate.

6. The given practical method makes it possible by the method of calculation to construct the frequency characteristics of sound insulation of real thin barriers at the preset angles of sound incidence.

References

1. **Čiučelis A, Gailius A., Gužas D.** Application of vibroacoustic properties of building. Materials. 2nd International Conference Mechatronic Systems and Materials MSM, Cracow, Poland. 31 08 ÷ 3 09 2006. P. 20.
2. **Sedov M. S.** Theory of inertial sound transmission through barrier constructions. Higher Institutions News. Series Construction and Architectures. 1990. No. 2. P. 37–42 (in Russian).
3. **Cremer L.** Theorie der schalidannung dumer wande bei schrigem einfall. Acoustische Zeitschrift. 1942. No. 7. P. 81.
4. **Stauskis V. J.** Sound insulation of the barrier constructions in residential and public buildings and ways for its improvement. Vilnius: LIINTI. 1973. P. 37.

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Statybinių konstrukcijų garso izoliacijos priklausomybė nuo medžiagų akustinių savybių

Reziumė

Tyrinėjamos medžiagų savybės, kurios turi didžiausią įtaką statybinių konstrukcijų garso izoliacijai. Ištirta medžiagos vidaus trinties nuostolių įtaka garso slopinimui, kai garso energija pereina per statybines konstrukcijas. Plačiau tyrinėjama garso, krintančio į pertvaros bangos kritimo kampą, dažnių įtaka. Nustatyta, kada ir kokiems dažniams esant garso izoliacija geriausia ir kada ji yra prasta, t. y. praleidžia tam tikrų dažnių garsą į kitą konstrukcijos sienelės pusę.

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