DS Journal of Modeling and Simulation
Volume 3 Issue 3, 16-19, Jul - Sep 2025
ISSN: 2584-1564 / https://doi.org/10.59232/MS-V3I3P102

Original Article

On Model of Oscillations of a Multilayer Structures

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Received: 18 July 2025; Revised: 20 August 2025; Accepted: 05 September 2025; Published: 16 September 2025

Abstract - An approach for increasing sound insulation using a multilayer building construction. As an example of such analysis, we consider sound processing of multilayer enclosing and load-bearing constructions to increase sound insulation. It has also been introduced to analyze the above processes.s

Keywords - Sound-insulation of building constructions, Analytical approach for prognosis.

1. Introduction

At present, noise is a serious problem, especially in large cities. Noise from city highways is one of the main sources of negative impact. The second most intense source is noise inside the building (including from technological equipment). Increasing noise impacts both outside and inside the house force us to pay more attention to noise protection [1-8]. It is necessary to improve the sound insulation of newly erected buildings in every possible way. At present, a significant number of city residents live in houses where the level of sound insulation is not high enough. The problem of sound insulation of the premises must be solved comprehensively.

Installing additional soundproofing cladding only on the outer wall of an apartment facing a busy avenue will not solve the problem [9-13]. It is advisable to completely soundproof the premises. In addition, it is necessary to remember that there are two types of noise - airborne and impact. For effective soundproofing from different types of noise, it is necessary to use different design solutions. This paper considers it a load-bearing building construction with sound-insulating enclosing. A model has also been presented to analyze the sound-insulating properties of the building.

This effect will be analyzed using an example of transverse oscillations in a multilayer construction under the influence of a plane wave of sound perpendicular to the interface between the considered layers of the above plate construction. The qualitative structure of the considered construction is presented in Figure 1. An analytical approach has also been presented to analyze the considered processes. The approach makes it possible to take into account the spatial and temporal variations of the parameters of the considered process. The considered approach to increase the sound-insulating properties of buildings and the approach for analysis of the considered model for such wide possibilities were not found in the literature.

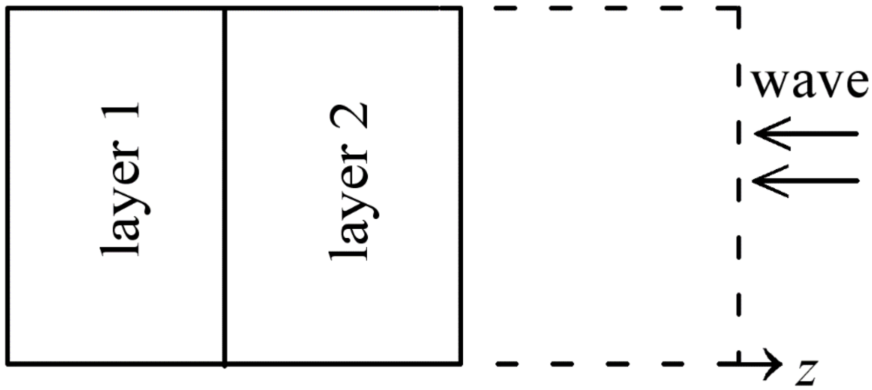

Fig. 1 Structure of the considered construction

2. Method of Solution

Oscillations in the considered multilayer construction have been determined by solving the equation that describes the spreading of waves

$$\frac{\partial^2 u}{\partial t^2} = F + \frac{E(z)}{\rho(z)[1-\sigma(z)]}\frac{\partial^2 u}{\partial x^2} + \frac{E(z)}{\rho(z)[1-\sigma(z)]}\frac{\partial^2 u}{\partial y^2} + \frac{\partial}{\partial z}\left[\frac{E(z)}{\rho(z)[1-\sigma(z)]}\frac{\partial u}{\partial z}\right] \tag{1}$$

Here E (z) is the elasticity modulus; ρ (z) is the materials density of the considered multilayer structure; σ (z) is the ratio of Poisson, function u (x,y,z,t) describes the points displacement of the considered structure during oscillations; function F (x,y,z,t) describes the external processing (knock, wave of sound, .); parameters x, y and z describe spatial coordinates; parameters L_x, L_y and L_z describe spatial dimensions of the considered structure in directions x, y and z, respectively; parameter t describes current time. It has been considered the case when the edges of the considered structure are fixed rigidly. In this case, the conditions for the function u (x,y,z,t) are

$$\left.\frac{\partial u}{\partial x}\right|_{x=0} = 0,\ \left.\frac{\partial u}{\partial x}\right|_{x=L_x} = 0,\ \left.\frac{\partial u}{\partial y}\right|_{y=0} = 0,\ \left.\frac{\partial u}{\partial y}\right|_{x=L_y} = 0,\ u\ (t=0) = 0 \tag{2}$$

Next, Equation (1) was solved by using the method of averaging of functional corrections. It has been considered an approximation of the second order. Usually, the approximation is enough to make qualitative analysis and to obtain some quantitative results.

3. Discussion

Now, the distribution of points displacement in space and time of the considered multilayer building construction during their oscillations under the influence of the plane F = A·exp(ω t-$k_z z$). Here, parameter A describes the amplitude of the considered wave; parameter k_z describes the projection of the wave's number on the axis Oz; parameter ω describes the frequency of the wave. Figure 2 presents the distribution in space of the point's displacement of the considered structure on the coordinates x and y at time t. Figure 3 presents the distribution in space and time of the considered displacement on coordinate z and moment of time t.

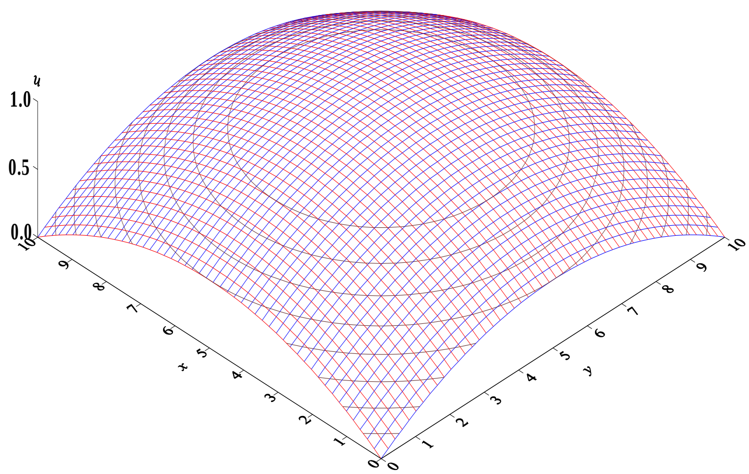

Fig. 2 Distribution in space of the point's displacement of the considered structure on the coordinates x and y at time t

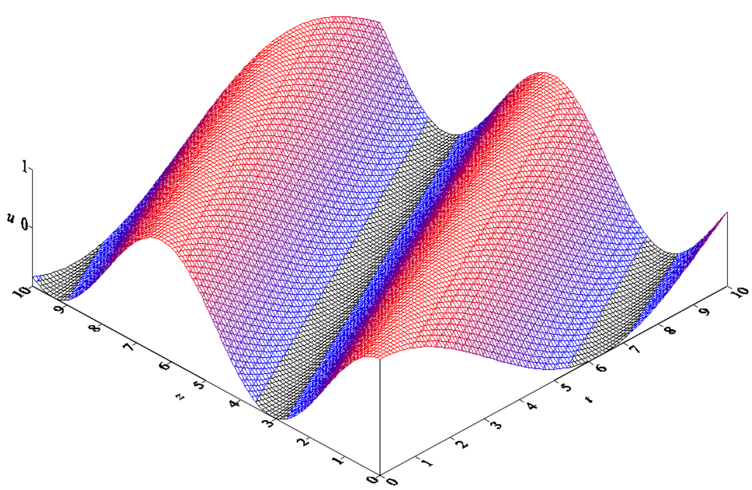

Fig. 3 Distribution in space and time of the considered displacement on coordinate z and moment of time t

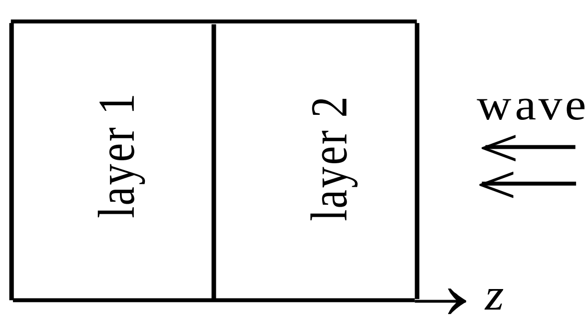

Fig. 4 Optimal multilayer structure for the sound-insulation

Analysis of spatio-temporal distribution of the considered displacement shows, that compromise between increasing of sound-insulation of by multilayer constructions and increasing of their complications are using two layer structures, which are presented on Figure 4. These structures consists of load-bearing layer for reflection of received signal (see layer 1 on Figure 4) and facing layer for absorption of the received signal (see layer 2 on Figure 4).

4. Conclusion

An approach for increasing sound-insulation by using a multilayer building construction. As an example of such analysis, we consider sound processing of multilayer enclosing and load-bearing constructions to increase sound-insulation. An analytical approach has also been introduced to analyze the above processes.

Data Availability

All appropriate data are available.

Authors' Contributions

All results of this paper are the author's.

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