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ON EFFECT OF MECHANICAL PROPERTIES OF POROUS MATERIALS ON THE TRANSFER OF ACOUSTIC VIBRATIONS

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ABSTRACT

The effect of open pore materials on transfer of vibrations from the moving mechanism to the solid surface is investigated. The mechanical properties of open pore elastic materials are studied. Then the acoustic measurements of the test assemblies with use of these materials are conducted to investigate the effect of these materials on re-distribution and/or absorption of the vibrations transferred from the source to the solid surface.

Keywords: porous material, acoustics, vibration.

INTRODUCTION

Excited on the surface of a hard body using the initial point sourced force, the vibrations begin distributing in all directions: so called direct (in the direction of applied force) and indirect (in all other directions) vibrations. In the case when the hard body is so-called sandwich-construction consisted of several layers, directly attached to each other the vibrations are transferred through all layers of construction based on some of their mechanical characteristics: layer thickness, absorption coefficient, anisotropy of material etc.

A rectangular plate made as sandwich construction of three layers with various materials used for a middle layer is considered. As the layers are considered being connected without any gaps, the losses of the magnitude of vibration wave, additional refraction in the air and the changes of the angles of field directivity between the layers can be neglected. The energy transfer process through this sandwich construction can be considered as three consecutive stages: generation of the output driving force, mechanical energy transfer from the source through the middle layer to the last layer and radiation of the transferred energy from the last layer in the form of acoustic waves. The top and last layers of the sandwich construction for the research were selected as rigid materials. Rigid materials (the materials which have minor anisotropy for direct and indirect radiation) let through their structure the wide spectrum vibrations without any essential changes. The energy transfer through these layers is expected to be linear and directly depending on the frequency of vibration. The middle layer is selected as a porous material with variable mechanical characteristics. Porous materials can be divided to three main groups: open pore materials (i.e. granulated materials, some foam materials), closed pore materials (most of chemically activated foam materials) and mixed materials (granules of material are made of closed cell foam).

A non-compressed porous material is characterised by the following major parameters: porosity Ω, flow resistivity σ and tortuosity α, which could be averaged across various porous channels. When the rigid layers are divided by the compressible porous layer, especially by open pore material, part of the vibrations going through this layer will be re-distributed or absorbed by this layer. The vibrational wave going through the porous material layer passes the following stages: direct passage of wave from layer to layer, dissipation of the wave and absorption of the wave energy by the porous material, and the dominance of each direction is dependent on the vibrational frequency ω and porous layer's thickness. The vibration transferred in that way into the secondary layer may change the directivity of the vibration and its amplitude.

RESULTS AND CONCLUSIONS

For the experiments, a sandwich construction made of two rigid layers with porous layer between them is considered. The construction is shown in Figure 1. Two different closed-pore silicone gel materials were selected for porous layer.

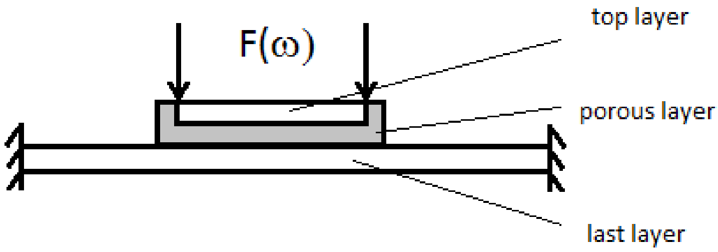

Fig. 1 - Experimental model

It had been demonstrated during the research study that two main characteristics which affect the energy transfer through the sandwich construction are moving mass of the top layer M and compliance of the porous layer C. The compliance C characterises the damping ability of materials in the expression of $tan\,\delta$ (tangent delta or loss factor). The loss factor is a phase angle between the elastic modulus and loss modulus that represents a damping ability of a material.

The output force of the construction can be enhanced by using the material with the large value of compliance of the gel layer and higher mass M_m of the transducer at low frequency range. The relationship between the resonant frequency of the transducer f_0 and the characteristics of the material are shown in Helmholtz Resonance expression:

$$f_0 = 1/(2\pi\sqrt{C} + M_m) .$$

Four samples were manufactured for the series of testing to observe the effect of the change of magnet weight, M_m and compliance C of the gel surround on the increase of the magnitude of the vibrations transferred through the construction. The constructions were simulated by using the COMSOL Multiphysics.

The results suggest that the total output driving force of the sandwich construction can be enhanced by increasing the mass M of the top layer or by choosing the low-hardness elastomer (material with greater C) of the gel middle layer. At the low frequency band where the movement of the magnetic and coil-drive plate assembly is large the effects of these two parameters were significant. This was observed experimentally by COMSOL Multiphysics simulation combined with physical experiments.

As the mass of the top layer is expected to be fixed (and reasonably small) the value of compliance C in gel material is considered as the main mechanism of enhancing the vibration transfer through the construction body.