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On the Interaction of Composite Plate Having a Vibration-Absorbing Covering with Incident Acoustic Wave

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Abstract—We formulate the coupled problem of planar acoustic wave propagation through the composite plate which contains in its second layer a damping material possessing large logarithmic decrement. Aero-hydrodynamical interaction between plate and external acoustic environment is defined by three-dimensional wave equations, whilst mechanical behavior of double-layered plate is examined with a model based on classical Kirchhoff–Love's hypothesis. Exact analytical solutions were given for plates with simply supported edges. Based on given solutions we find parameters for second layer which lead to substantially damping of plate vibrations in the case of acoustic loading at resonant modes.

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The traditional construction materials (such as metals and their alloys, modern composite materials) possessing large elastic and strength parameters values, as a rule also have relatively small values of damping properties. Thus, in order to augment damping parameters of the thin-walled constructions based on these materials, their elements are often produced in the form of multilayered structures alternating between the thickness of the rigid layers with nonrigid ones with high damping properties [1]. Almost all the reference literature and that of similar type devoted to the multilayered constructions tell us that these materials possess good sound insulation and sound-absorbing properties. In practice till recently these properties were studied clearly only by purely experimental methods and their theoretical considerations were based only on the simplified statements of respective problems. Often these theoretical statements even have false interpretation of the mechanism to reduce noise inside the vehicle and aircraft by special thin rubber-functional layer sticking to structures (in particular for the case of the civil planes floor), by naming them sound-absorbing layers.

Further we prove that the pasted layers due to their high damping properties allow us to significantly reduce the peak values of deformations and displacements for the structure elements under vibration loading modes. Thus we obtain a subdued sound pressure in the cabin. Moreover, application of such coverings with high damping properties leads to dramatic reduction of cyclic stresses in the design forming elements and, consequently, to dramatic increase in the designs durability.

Consider a plate consisting of two thin layers of thicknesses t_1 and t_2 and made of orthotropic materials. We study it in the cartesian orthogonal coordinate system Ox_1x_2z, whose coordinate plane $z = 0$ coincides with the median plane σ of the first layer and the axes x_1 and x_2 coincide with the layers materials orthotropy axes.

Let u_1, u_2, and w be a plane σ points shifts in the directions of the axes x_1, x_2, and z through which we express arbitrary point displacement and movement components according to the Kirchhoff–Love model for the mean plate bend by the following relations

$$U_i = u_i - zw_{,i}, \quad \varepsilon_{ij} = \varepsilon_{ij}^0 - zw_{,ij}, \quad -t_1/2 \le z \le t_1/2 + t_2, \qquad 2\varepsilon_{ij}^0 = u_{i,j} + u_{j,i} + w_{,i}w_{,j}, \tag{1}$$

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