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INFLUENCE OF CONCENTRATED MASSES ON THE DYNAMIC CHARACTERISTICS OF VISCOELASTIC PLATES

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Abstract. This thesis synthesizes published results on the free and forced vibrations of thin viscoelastic plates carrying concentrated masses. Particular attention is paid to the interaction between discrete inertia, distributed plate stiffness and hereditary material behavior. The analytical framework and previously reported frequency trends are discussed with an emphasis on vibration design.

Keywords: viscoelastic plate; concentrated mass; natural frequency; forced vibration; relaxation kernel; damping

Introduction

Thin plates with locally attached equipment or structural components occur in mechanical engineering and civil infrastructure. Their vibration response is governed not only by distributed inertia and bending stiffness, but also by the mass and attachment characteristics of discrete elements. In viscoelastic materials, time-dependent stress relaxation additionally changes the resonance frequencies and attenuation of motion. Consequently, conventional elastic-plate models may not fully represent the dynamic behavior of these combined systems [1–3].

Mathematical approach

In a linearized bending model, the deflection w(x,y,t) of a plate is governed by the balance between bending resistance, distributed inertia and external forcing. For point-attached masses, their inertia is introduced through generalized Dirac delta functions concentrated at the attachment coordinates. Schematically, the governing relation can be expressed as

$$D(1 - R^*)\nabla^4 w + \frac{\rho h\, \partial^2 w}{\partial t^2} + \Sigma\, m_j\, \delta(x - x_j)\delta(y - y_j)\frac{\partial^2 w(x_j, y_j, t)}{\partial t^2} = p(x,y,t)$$

where R^* denotes the hereditary relaxation operator. This schematic expression is intended to convey the model structure; the precise operator and boundary conditions depend on the adopted constitutive assumptions [1, 2].

The associated spectral problem is generally non-self-adjoint because of energy dissipation. Thus, natural frequencies are complex: their real parts describe the oscillatory component, whereas their imaginary parts characterize attenuation under the selected time-dependence convention. Published analytical treatments use separation of variables and numerical root-finding procedures, including the Gauss and Müller methods [1].

Discussion of published results

The circular-plate study by Safarov and coauthors [1] reports that point attachment of concentrated masses can reduce both real and imaginary parts of natural frequencies by up to 20% in the numerical cases considered. This percentage is a result of those particular modeled configurations and should not be interpreted as a

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universal bound. The same study finds that direct mass attachment does not change the number of natural frequencies in its model, whereas connection through massless elements introduces additional frequencies and decreases the first frequency.

A complementary study of rectangular plates [2] demonstrates how hereditary material properties may be represented by memory functions in forced-vibration calculations. The plate-on-elastic-foundation analysis [3] further indicates that support reaction models influence dynamic stress–strain predictions. Taken together, these studies motivate treating attachment inertia, material relaxation and foundation conditions as distinct but interacting design parameters.

Conclusion

The reviewed analytical and numerical results show that concentrated masses and viscoelastic relaxation must be considered jointly when estimating plate resonance and damping. For practical applications, mass placement, connection stiffness, boundary restraints and relaxation parameters should be specified before a reliable frequency assessment is made. Future studies can extend the established linear framework to multiple attachment layouts and compare predicted complex frequencies with controlled experiments.

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