Free vibrations of an axially travelling Zener panel subjected to axial flow

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ABSTRACT

We analyze the free vibrations of an axially travelling panel (plate undergoing cylindrical deformation) subjected to axial flow, using the standard viscoelastic solid (SLS, Zener) material model for the panel, and two-dimensional potential flow for the flow component; in the small deformation range and for stability analysis, flow separation is not expected to be a significant factor. The study is motivated by applications in process industry, such as paper making. Especially for lightweight materials, the inertial contribution of the surrounding air is important for correctly predicting vibrations and possibly also the critical velocity [1,2,3].

To treat the coupled fluid–structure interaction problem, a strong coupling approach is used. The analytical solution developed in [4,5] is used to solve the flow subproblem, reducing the fluid–structure interaction problem into one integro-differential equation. The eigenvalue problem corresponding to the free vibrations of the panel is then discretized using Hermite type finite elements and solved numerically. This extends earlier studies using the same flow model, which have concentrated on the axially travelling elastic panel [4,5], and the axially travelling viscoelastic panel of the Kelvin–Voigt type [6,7].

As the main result, the lowest eigenfrequency pairs are obtained as a function of the axial drive velocity of the panel. Also obtained is a prediction for the critical velocity where mechanical instability sets in. The results shed light on the interaction between the SLS model and the analytical flow model. Comparison to existing results allows determining which parts of the qualitative behaviour of this coupled model can be attributed to the solid and which to the fluid components.

The model is computationally lightweight, allowing for nearly real-time solution on a regular desktop or laptop computer. Fast solvers have applications in real-time prediction and control of industrial processes, and in modelling-based indirect measurement tools, toward the development of which the model can be applied.

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