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Frequency Response and Resonance of a Thin Fluid Film Bounded by Elastic Sheets with Application to Mechanical Filters

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Abstract

We study steady-state oscillations of an thin viscous film bounded by two elastic sheets, excited by traveling pressure waves over its upper surface. The fluid within the cell is bounded by two asymmetric elastic sheets which are connected to a rigid surface via distributed springs. The fluid is modeled by the unsteady thin film lubrication approximation and the sheets are modeled by the linearized plate theory. Modal analysis yields the frequency response of the configuration as a function of three parameters: the fluidic Womersley number and the ratio of solid stress to viscous pressure for each of the sheets. These ratios, analogous to the Capillary number, combine the effects of fluid viscosity and the sheets inertia, bending and tension. The resonance frequencies of the configuration include the resonance frequency of the upper sheet, the resonance frequency of both sheets, and a new resonance frequency related to the interaction between the fluidic motion parallel to the elastic solids and the relative elastic displacements. Near the resonance frequency of the upper sheet, the fluid pressure is identical in amplitude and phase to the external excitation. For configurations where both sheets are near resonance, small changes in frequency yield significant modification of the fluidic pressure. The amplitude ratio of the fluidic pressure to the external pressure is presented vs. frequency for several