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Transient microscale compressible flow in a viscoelastic tube[1]

VISHAL ANAND, IVAN CHRISTOV, School of Mechanical Engineering, Purdue University, West Lafayette, Indiana 47907, USA — We analyze transient compressible flow at low Reynolds number conveyed in a compliant, linearly viscoelastic tube. A linear equation of state accounts for the compressibility of the fluid, whilst the slenderness of the tube allows the use of the lubrication approximation. The structural mechanics is governed by Donnell shell theory, augmented with Kelvin–Voigt viscoelasticity. The hydrodynamic pressure couples the fluid mechanics of the flow with the structural mechanics of the tube. Within this theoretical framework, we study the start-up flow created by an oscillatory inlet pressure imposed on an initially static fluid and structure. We show that the frequency response of the deformed viscoelastic tube is akin to that of a band-pass filter; the deformation reaches a peak value at the resonant frequency determined by a balance of inertia and viscoelastic damping. We demonstrate that the interplay of compressibility and compliance leads to acoustic streaming: the hydrodynamic pressure and velocity fields have nonzero means when averaged over a period of the inlet pressure's oscillations. A frequency-dependent flow rate enhancement is induced by streaming, exhibiting a low-pass response.

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