Xu, Feng; Billingham, John; Jensen, Oliver E.
Divergence-driven oscillations in a flexible-channel flow with fixed upstream flux. (English)
Zbl 1287.76253
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Summary: We consider flow in a finite-length channel, one wall of which contains a membrane under longitudinal tension. The upstream flux and downstream pressure are prescribed and an external linear pressure distribution is applied to the membrane such that the system admits uniform Poiseuille flow as a steady solution. The system is described using a one-dimensional model that accounts for viscous and inertial effects. A linear stability analysis reveals that the uniform state is unstable to static (or divergent) and oscillatory instabilities. Asymptotic analysis in the neighbourhood of a Takens-Bogdanov bifurcation point shows how, when the downstream rigid section of the channel is not substantially longer than the membrane, an oscillatory mode arises through an interaction between two static eigenmodes. Perturbations to the uniform state exhibit the dynamics of a weakly dissipative Hamiltonian system for which low-frequency self-excited oscillations are forced by the divergent instability of two nearby steady solutions, before ultimately growing to large amplitudes. Simulations show that the subsequent dynamics can involve slamming motion in which the membrane briefly comes into near-contact with the opposite rigid wall over short length scales.

MSC:

76Z05 Physiological flows
76E99 Hydrodynamic stability
74F10 Fluid-solid interactions (including aero- and hydro-elasticity, porosity, etc.)
92C10 Biomechanics

Keywords:

biological fluid dynamics; flow-structure interaction; instability

Full Text: DOI

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