Nonlinear Dynamics of Slender Cylinders Supported at Both Ends and Subjected to Axial Flow

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Abstract

In this paper the weakly nonlinear equations of motion, correct to third-order magnitude, are derived for a slender cylinder subjected to axial flow, in the case where both its extremities are supported. The cylinder is considered to be extensible and two coupled nonlinear equations describe its motions, involving both longitudinal and transversal displacements. The inviscid component of the fluid force is modeled by an extension of Lighthill's slender-body work, and viscous, hydrostatic, gravity and pressure-loss forces are added in a similar manner as recently done for cantilevered inextensible cylinders by Lopes et al (2002); however, both the derivation and the final equations have many different and distinctive features. The equations are discretized via the Galerkin's method and solved by Houbolt's finite difference method.

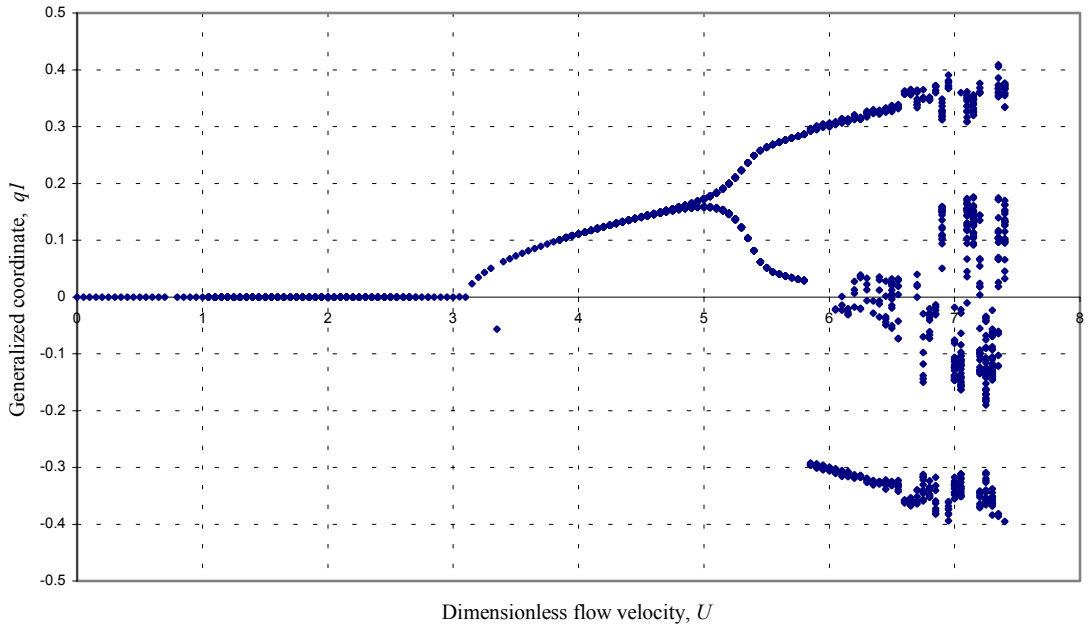

Figure 1. Typical bifurcation diagram for simply supported cylinder showing the first generalized coordinate, q_1, as a function of dimensionless flow velocity, U

Bifurcation diagrams with flow velocity as the independent variable, supported by phase-plane plots, show that the system loses stability via a supercritical pitchfork bifurcation leading to divergence. At higher flow velocities, a secondary Hopf bifurcation leads to flutter, although in some cases an oscillatory large-amplitude limit cycle is found with no clear origination. In some cases, at higher flow velocities, the limit cycle flutter evolves into chaotic oscillation. The predicted dynamics broadly agree with observed behavior in experiments.

Selected References

Lighthill, M. J. 1960 Note on the swimming of slender fish. *Journal of Fluid Mechanics* **9**, 305-317

Lopes, J. L., Païdoussis, M. P. & Semler, C. 2002 Linear and nonlinear dynamics of cantilevered cylinders in axial flow. Part 2: the equation of motion. *Journal of Fluids and Structures* **16**, 715-737

Païdoussis, M. P. 1973 Dynamics of cylindrical structures subjected to axial flow. *Journal of Sound and Vibration* **29**, 365-385

Païdoussis, M. P. 1998 *Fluid-Structure Interaction: Slender Structures and Axial Flow*, *Vol. 1*. London: Academic Press

Païdoussis, M. P. 2003 *Fluid-Structure Interaction: Slender Structures and Axial Flow, Vol. 2*. London: Academic Press