STABILITY OF COMPLIANT PIPE FLOW WITH AXISYMMETRIC AND NON-AXISYMMETRIC DISTURBANCES

By

MUNENDRA KUMAR

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ple fluid dynamics

CERTIFICATE

This is to certify that the thesis entitled **"Stability of compliant pipe flow with axisymmetric and non-axisymmetric disturbances"** being submitted by **Mr. Munendra Kumar** for the award of the degree of Doctor of Philosophy, to the **Indian Institute of Technology, Delhi** is a record of bonafide work carried out by him under our guidance and supervision. The material embodied in this thesis, unless acknowledged otherwise, has not been submitted in part or in full for any other Diploma or Degree of any University.

(P. K. Sen)
Professor
Department of Applied Mechanics
Indian Institute of Technology, Delhi
New Delhi – 110016, India.

(A. K Raghava)
Associate Professor
Department of Applied Mechanics
Indian Institute of Technology, Delhi
New Delhi – 110016, India.

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M. Kumar.

(Munendra Kumar)

ABSTRACT

The present work discusses the hydrodynamic stability of compliant pipe low, considering a visco-elastic pipe, with an outer rigid shroud, and, with Iagen Poiseuille flow through the pipe. The work includes the normal comliance studies by the Sen and Arora method, physical realisability studies by he equivalent plate-spring model, normal compliance studies for the full viscolastic wall, and combined normal plus tangential compliance studies. Both the xisymmetric and non-axisymmetric disturbances have been considered. The oupled fluid-solid equations have been solved numerically by extensions of the nethods of Sen and Venkateswarlu (1983), Sen, Venkateswarlu and Maji (1985) ind Sen and Arora (1988). Energy methods have also been extensively used.

Fluid flow in a pipe with flexible walls generally occurs in nature, e.g., in biological systems like flow of blood and other fluids in the body. Such a system also occurs in industrial applications for internal flow through hollow fibres, reactors and membranes. It is found that such a system is unstable to both axisymmetric and non-axisymmetric disturbances, although, the rigid pipe problem is stable to all infinitesimal disturbances. For a given azimuthal wavenumber, it is found that there are broadly two unstable mode classes, for both the axisymmetric and non-axisymmetric instabilities. One is a solid based flow induced surface instability, while the other is a fluid based surface instability that asymptotes to the least damped rigid wall mode as the thickness of the visco-elastic wall tends to zero. All modes are stabilized, to different degrees, by the viscoelastic wall viscosity.

The Sen and Arora (1988) method is used for the only-normal compliance problem. Here the normalized disturbance velocity at the wall, $\overline{\phi}_w$, is used as a kinematic wall parameter. Physical realisability of modes can be found out by back calculating the values of the surface wave speed c_0^2 and damping d for an equivalent plate spring model: realisability given by the criterion $c_0^2 > 0$ and $d > 0$. All rigid type (deviant of rigid wall) modes are centerline modes, and are *stable*. Unstable modes are basically either static divergence modes or transitional modes.

In the "force method", we study the neutral stability curves for different values of the Kumaran parameter Γ, and the solid to fluid viscosity ratio μ_r, for axisymmetric and non-axisymmetric disturbances. However, the normal compliance modes are more unstable and are substantially different from the normal plus tangential compliance modes. It is also observed that wall dissipation tends to damp all the modes. Static divergence (SD) modes are also found in the $n = 0, 1$ modes, where n is the azimuthal wavenumber.

From the "energy methods" we obtain the significance of each term in the energy balance. In the rigid wall problem, the production term I_2 and the dissipation term I_3 are *both negative*; thus the rigid wall modes are always stable. Our results based on the energy method provides a much deeper insight into the relevant mechanisms involved. We are able to see for which class of modes I_2 is the dominant production term, and for which class of modes the tractive work term B_4 is the dominant production term. We are also able to see which are the main dissipation terms or redistibution terms for the fluid-side and the solid-side for various classes of modes.

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