Fluid-Elastic Instabilities of Clamped-Clamped Cylinders in Turbulent Axial Flow

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ABSTRACT

Fluid-elastic instabilities arise due to the coupling of structural motion and fluid flow. In the specific case of a clamped-clamped cylinder in axial flow, it will buckle at a sufficiently high flow velocity and start to flutter at even higher flow velocities. This dynamic behavior is of importance to nuclear reactor core design, undersea pipe lines and devices for energy harvesting.

In this paper, the fluid forces and the dynamics of a flexible clamped-clamped cylinder in turbulent axial flow are computed numerically. The dynamics are computed by means of the methodology developed earlier [1]. In contrast to present analytical approaches, this numerical model does not require to tune parameters for each specific case or to obtain coefficients from experiments. The results are compared with the dynamics measured in experiments available in literature [2]. The specific case studied here consists of a silicone cylinder mounted in axial water flow.

Computationally it was found that the cylinder's natural frequency decreases with increasing flow velocity, until it loses stability by buckling. The threshold for buckling is in quantitative agreement with experimental results and weakly-nonlinear theory [3]. Above this threshold, the amplitude of buckling increases with increasing flow speed. Eventually, a fluttering motion is predicted, in agreement with experimental results. It is also shown that even a small misalignment (1°-2°) between the flow and the structure can have a significant impact on the dynamical behavior.

To provide insight in the results of these fluid-structure interaction simulations, forces are computed on rigid inclined and curved cylinders, showing the existence of two different flow regimes. Each regime gave rise to a different lift force behavior. This in turn affects the damping of the coupled system. Furthermore it is shown that the inlet turbulence state has a non-negligible effect on these forces and thus on the dynamics of the cylinder.

REFERENCES

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