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Linear stability of disks falling or rising freely in a viscous fluid

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The problem of the instability of a solid body moving in a viscous fluid has been extensively studied in the case where the body is fixed and its wake undergoes instabilities when some control parameter is increased (*e.g.* [1,2] for two-dimensional configurations and [3,4] for three-dimensional bodies). On the other hand, the deeply different and frequent case of a body freely falling or rising under buoyancy in a fluid otherwise at rest has received much less attention. Yet, results from experiments[5,6] and direct numerical simulations[7,8] have evidenced a large variety of motion styles ranging from steady oblique to chaotic, though zig-zag and tumbling.

To gain more insight into the nature of the instability that drives the departure from a straight vertical path, we recently carried out a linear study of the coupled fluid-body problem in two dimensions[9]. Here we extend this work to axisymmetric bodies. The linear stability analysis is performed for a disk of finite thickness with an aspect ratio (defined as the ratio of the diameter over thickness) $\chi = 3$ and another disk with $\chi = 10$. We select these two values because past studies[10] led us to consider the corresponding two bodies as prototypes of general thick and thin bodies.

This talk mainly focuses on the parametric modal stability analysis of the coupled fluid-disk problem. We present neutral stability curves in the phase space $(\rho_b/\rho_f, Re)$ and $(\rho_b/\rho_f, St)$, where ρ_b/ρ_f is the body-to-fluid density ratio, St the non-dimensional frequency of the unstable mode and Re the Reynolds number based on the disk diameter and the relative velocity between the fluid and body. These curves reveal how rich the dynamics of the problem are, including features such as destabilization-restabilization regions and abrupt jumps of the marginal frequency. The types and thresholds of the linear instability show close agreement with existing DNS and experimental results, as well as with theoretical predictions from asymptotic theories[11,12]. Finally, we consider the structure of the global modes. This allows us to extract information such as the origin of the instability (i.e. we disentangle “body-related modes” from “fluid-related modes”) and the characteristic footprints of both low-frequency and high-frequency modes.

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