The Nonlinear Dynamics of Unsteady Separation

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Flow separation refers to the phenomenon in which fluid particles are suddenly ejected from the proximity of a solid boundary. The phenomenon is of great practical importance, primarily because it is the limiting factor in the performance of air-space and marine vehicles. The zero-skin-friction principle has become the most broadly used indicator of separation, even though numerical work in the 1970's showed that the principle fails for unsteady flows. In the absence of a theoretically-sound and practical separation criterion the experimental detection and control of unsteady separation has remained ambiguous.

The reason for the failure of the zero-skin-friction principle in unsteady flows is quite straightforward. Provided a flow field is sufficiently unsteady (i.e. that instantaneous streamlines change on a timescale much shorter than the time for particles to move significantly away from the boundary) the streamline pattern at a given instant in time does not determine the transport of material away from a rigid boundary; rather one must consider the integrated effect of unsteady streamlines over time. To deal with unsteadiness Haller [1] has developed a kinematic approach to unsteady separation, deriving analytic criteria for the location of wall-based unstable manifolds that govern the unsteady separation process. These wall-based unstable manifolds are the eruptive material spires reported in both low and high Reynolds number separation. The criteria are valid for any mass-conserving fluid flow and require knowledge of the time history of measurable quantities along a boundary, such as shear-stress and pressure

The goal of this study is to investigate this new approach to unsteady separation in a physical setting. For practical reasons we choose a low Reynolds number flow, for which the time and length scales of unsteady separation are readily amenable to both experimental investigation and simulation. The flow we investigate is the so-called rotor-oscillator flow - a two-dimensional flow generated by a rotating cylinder adjacent to a rigid boundary. To the best of our knowledge, this arrangement is the simplest geometry in which one can establish and influence a low Reynolds number separating flow. Here we present the latest results from these experiments.

References

[1] G. Haller, "Exact theory of unsteady separation for two-dimensional flows," *J. Fluid Mech.* **512**, 257-311, 2004.

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