

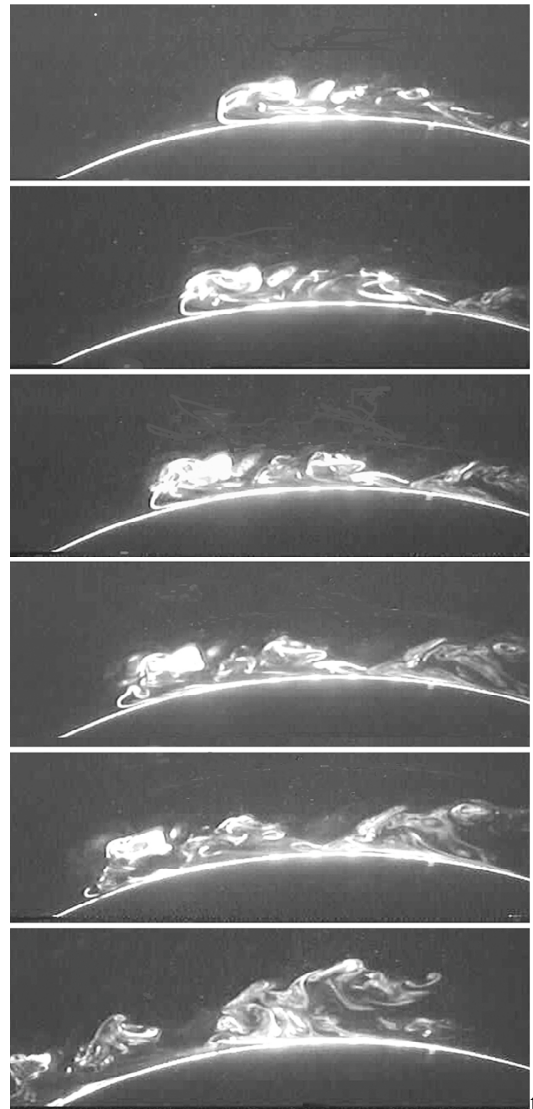
# Hydrodynamic Damping

## Theoretical, Numerical, and Experimental Facts

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The hydrodynamic loading and damping have long been of special interest to offshore engineers. In fact, the forces exerted on bodies subjected to vortex excited oscillations and to the springing and ringing response of compliant systems require a clear understanding of the flow in the range of Keulegan-Carpenter numbers from about  $K = 10^{-3}$  to 10 and frequency parameters  $\beta$  ( $= fD^2/\nu$ ) from about 1 to  $10^8$ . There are, at present no known predictions of the drag and inertia forces exerted on slender structures undergoing excitation, save for those at  $K$  values smaller than about 2 and  $\beta$  values smaller than about 1,000 where the classical solution of Stokes (1851) for *unseparated laminar flow* holds true. Furthermore, the  $(K-\beta)$  plane contains many surprises: *acoustic streaming*, Honji instability, dipole tubes, quasi-coherent structures, transition to turbulence, and multiple separations within the separation 'bubble' as shown in figure. In other words, every possible combination of  $K$  and  $\beta$  is of practical as well as theoretical importance and touches all aspects of time-dependent flows. However, the difficulties encountered in separating very small drag forces from the large inertial forces, the extreme difficulties encountered in physical experiments, numerical simulations (with RANS, LES, and DNS), and a physics-based explanation of the doubling of shear (contrary to theoretical predictions) remain as challenging as ever. These facts provided the impetus for a detailed theoretical, numerical, and experimental investigation of the underlying reasons. The limitations of the analyses of Stokes, Schlichting, Lighthill, Stuart, and others, of unseparated 2-D laminar flow and the results of the most recent studies with separated flow about cylinders are critically examined in the light of the existing data.



Evolution and breakdown of the separation 'bubble' on a cylinder in a sinusoidally oscillating flow.