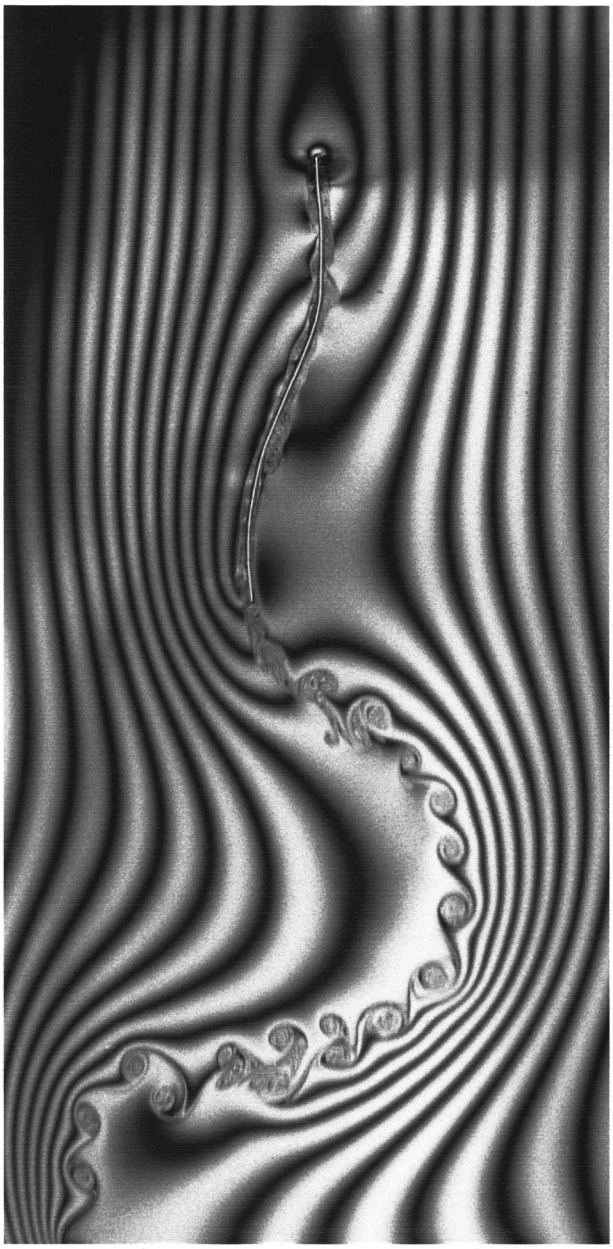

Flexible Threads in a Flowing Soap Film

Submitted by
Jun Zhang, New York University

A flexible silk thread is introduced into a laminar, flowing soap film. Its upstream end is fixed and the rest of the thread is free to interact with the flowing fluid. The typical silk thickness and rigidity are on the order of 0.015 cm and 0.1 erg cm, respectively. The flowing soap film is about 2 μm thick and it runs at a typical speed of 200 cm/s.

Above a critical filament length (or flow speed), while the corresponding Reynolds number is on the order of 10^4, two distinct dynamic states are observed. In one state, the filament is aligned in the flow direction and it remains motionless (left). Trailing off the free end of the filament, the flow pattern is a typical wake after a thin airfoil that is subjected in a laminar flow at zero incidence. This state is stable under small disturbances. If the disturbances are large enough, however, the thread will jump to a dynamically stable flapping state (right). A sinuous wave is formed along its length and it travels downstream. As the length of the filament is increased further, it can only stay in the flapping state. Such bistable behavior indicates a subcritical bifurcation from the linearly stable, motionless state.

Both photographs reveal the flow pattern utilizing the interference pattern produced between the two air–water interfaces of the flat soap film. A 90 W low-pressure sodium lamp is used to render high contrast fringes. 6400 ASA black and white films are exposed at 1/4000 s shutter speed, capturing the motion of the fluid and the filaments.

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