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# Transition to Two- and Three-Dimensional Instabilities in Bluff Body Wakes

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## Summary

Flows around bluff bodies lead to the generation of vorticity on their surfaces and, for sufficiently high Reynolds numbers, subsequent separation of the boundary layers to form first steady and then unsteady wakes. These wakes are marked by concentrations of vorticity and are subject to interesting vorticity dynamics and stability transitions. Secondary instabilities in the wakes can occur in a variety of ways. As the Reynolds number of a uniform flow is increased, the wake of the generic two-dimensional bluff body, the circular cylinder, is first steady, then undergoes a regular Hopf bifurcation leading to the familiar Bénard-von Kármán vortex shedding, followed by the successive appearance of mode A and B three-dimensional instabilities (**??**).

In this presentation, the wake of the circular cylinder is first explored. Using the saddle-point criterion and the time-mean wake profiles from experiments and computations, the vortex shedding frequency is predicted and compared with observations. The transition to three-dimensions in the wake is then presented, comparing the predicted modes with those observed. Shear layers are known to be sensitive to external influences, which can provide a by-pass transition to saturated growth, thereby camouflaging the fastest growing linear modes. Here, the spatial amplification rates of the shear layer instabilities are calculated using power-spectral density estimates, allowing the fastest growing modes rather than the largest structures to be determined. This method is found to be robust, producing results closely matching the low scatter results of a previous experiment to determine the fastest growing modes. Together with a reassessment of previous data, a solution to the longstanding problem of the power law for the ratio of the Bloor-Gerrard to Bénard-von Kármán vortex shedding frequencies is offered (**?**).

Finally, results of investigations of the wake transitions for other bluff bodies is presented. The pattern of wake development found for the circular cylinder is not generic to all bluff bodies. In fact, modifying the circular cylinder to different geometries or applying relative motion can lead to change of order of the onset of wake unsteadiness and asymmetry. Furthermore, the order of appearance of the three-dimensional modes can change; indeed, new modes that are not observed in the wake of the circular cylinder are found (**???**).

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