Three-Dimensional Structures in Cylinder Wakes

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Abstract

The wake of a circular cylinder represents a classic case of transition from laminar to turbulent flow. The stability, and subsequent shedding frequency, of the cylinder wake of a is dependent on the Reynolds number. At a Reynolds number of approximately 40, the steady symmetrical wake behind the cylinder develops an absolute instability that leads to the periodic asymmetrical vortex shedding observed first by Strouhal (1878). At somewhat higher Reynolds number, in the range $10^3 - 10^5$, the Strouhal number is fairly insensitive to the Reynolds number (Roshko 1954)

In the intermediate Reynolds number range, between 180 and 260, the wake undergoes another transition. This was observed by (Roshko 1954) in the form of irregularities in the wake velocity fluctuations. Recent experiments undertaken by (Williamson 1988) have demonstrated that this range represents the transition to three-dimensionality involving two modes of formation of streamwise vorticity in the near wake. The two modes are dominant over different Reynolds number range.

In the present paper, the wake of a circular cylinder is predicted using a high-order spectral element method. The two modes of three-dimensional instability, designated A and B, both found previously experimentally but not both computationally, have been captured. Mode A appears first at a Reynolds number of approximately 200. As the Reynolds number is increased from 230 to 260, energy shifts gradually to Mode B, which has a spanwise wavelength approximately one third that of Mode A. The appearance of each of the two modes results in a discontinuity of the Strouhal number versus Reynolds number curve, consistent with experimental observations.

As a possible new route to turbulence in the wake of a circular cylinder, it has been suggested that period doubling may play a role (Kaiktsis *et al.* 1991, Tomboulides and Karniadakis 1992). In this study, we show that modal interaction can occur that strongly modifies the appearance of doubling doubling, suggesting that other mechanisms may be important in the transition to turbulence.