Linear and nonlinear stability analysis of the flow past two side-by-side circular cylinders.

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ABSTRACT

Flows past two or more cylinders in various arrangements have received considerable attention in the past, [1]. These flows are indeed prototypical of wakes interference phenomena that can be found in many engineering applications such as heat exchangers, bridge pilings and off-shore platforms, among the others. An example is represented by the flow past two identical circular cylinders in side-by-side arrangement which has been extensively investigated both in experiments and numerical simulations, [2].

Despite the simple geometry, the two cylinder wakes can experience complex interactions yielding several different flow patterns that significantly depend on the Reynolds number, Re, and even more on the nondimensional gap spacing between the two cylinder surfaces, $g = g^*/D^*$ (where D^* is the cylinder diameter). Exploiting two-dimensional direct numerical simulations (DNS), up to six different patterns in the parameter ranges of $40 \leq Re \leq 160$ and $g \leq 5$ have been identified, [3]. In addition to *in-phase* and *anti-phase* syncronization of vortex shedding past the two cylinders, mainly occurring for $g > 1$, asymmetric flow states develop in an intermediate range of gap sizes, showing either steady or unsteady (*flip-flopping*) deflection of the gap flow. Similar behaviors have been described experimentally by flow visualizations in the work of Williamson, [4].

The talk addresses the onset of these various flow instabilities within the parameter ranges $Re \leq 100$ and $0.1 \leq g \leq 3.0$ based on numerical investigations of the incompressible two-dimensional flow past the two cylinders. Three main topic will be presented. First, the linear global stability of the symmetric base flow is revisited and new results from the structural sensitivity of the unstable global modes are presented by describing their inherent wavemaker regions of self-excitation, [5]. Second, nonlinear dynamics and mode selection in the neighbourhood of a co-dimension two bifurcation point are investigated by means of a *centre-manifold* reduction of the Navier-Stokes equations. For such a purpose an original numerical approach suitable for large scale dynamical systems is introduced. Finally, a novel interpretation of the flip-flopping instability is proposed based on the two-dimensional Floquet analysis of the in-phase periodic vortex shedding flow.

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