Stability and bifurcation analysis of the flow around a pair of side-by-side circular cylinders at low Reynolds numbers.

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ABSTRACT

The incompressible flow past a pair of circular cylinders in side-by-side configuration has been found to develop different wake patterns and bifurcation scenarios depending on the Reynolds number, Re, and on the gap width between the cylinder surfaces, g/D, where D denotes the cylinder diameter. Exploiting two-dimensional direct numerical simulations (DNS), up to six different patterns in the parameter range $40 \leq Re \leq 160$ and $g/D \leq 5$ have been identified, [2]. In addition to in-phase and antiphase synchronized vortex shedding, asymmetric flow states appear that are characterized by either steady or unsteady (*flip-flopping*) asymmetric deflection of the gap flow. Such flow behaviors have been described experimentally by flow visualizations in the work of Williamson, [1].

Until now the global stability analysis has been restricted to the symmetric baseflow only, [3]. Starting from these results, the present work investigates global modes of both the symmetric and the asymmetric baseflow in the parameter range $Re \leq 100$ and $0.2 \leq g/D \leq 2.0$. The Navier-Stokes equations are discretized by means of second order finite differences on Cartesian staggered grids and an immersed boundary tecnique has been used to enforce boundary conditions on the body surfaces. Newton iterations are performed to obtain steady state solutions while ARPACK and LOCA open source libraries have been employed to extract eigenmodes and to track bifurcations, respectively. Both direct and adjoint modes have been computed, allowing a description of the inherent *structural sensitivity* of flow instabilities, as done in the work by Giannetti and Luchini, [4]. Most of the asymmetric baseflow modes show oscillations localized in the far wake region, but for the single vortex shedding mode and the asymmetric in-phase synchronized mode. The analysis is supplemented by several DNS runs, sampling different regions of the parameter space, which illustrate the different flow regimes.

The region of linear stability for the steady asymmetric flow has been delimited in the $(Re, g/D)$ plane. This region is bounded by different neutral stability curves related to different system bifurcations which are expected to play a crucial role to understand highly non-linear asymmetric regimes, such as flip-flopping, and their configuration in the phase space.

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