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Periodic and quasiperiodic vortex shedding in the wake of a spinning sphere

Benoît PIER*

As the Reynolds number (Re) is increased for a non-rotating sphere in uniform flow, two bifurcations are known to lead from a steady axisymmetric state to a periodic vortex shedding régime. The present investigation addresses the influence of sphere rotation (Ω) around an axis aligned with the incident flow[1]. The introduction of a second control parameter leads to richer dynamics while retaining the axisymmetry of the problem. The present flow therefore provides a possible illustration of a recently developed symmetry-breaking theory[2].

Numerical simulations[3] of the complete three-dimensional incompressible Navier–Stokes equations and covering the parameter ranges $100 \leq \mathrm{Re} \leq 400$ and $0 \leq \Omega \leq 2$. are carried out using an immersed-boundary method[4].

By using a linearized version of the governing equations, the linear stability characteristics of the axisymmetric base flow are obtained. It is shown that the fastest growing mode among the two most unstable (or least stable) ones depends on the control parameters and the boundary in parameter space between dominance by the one and by the other is determined.

Using fully nonlinear computations, a variety of flow dynamics is observed and the different régimes are characterized by monitoring the hydrodynamic forces acting on the sphere (drag C_z and lift coefficients C_x, C_y) and analysing the spatiotemporal dynamics of the flow fields.

The different symmetry-breaking mechanisms involved in periodic, quasiperiodic and irregular flow régimes (see the figure) are identified. The competition and interaction between different instability modes is discussed, and the prevailing flow régime is mapped out in the (Re, Ω)-parameter space.

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[1]Kim & Choi, *J. Fluid Mech.* **461**, 365–386 (2002).

[2]Fabre, Auguste & Magnaudet, *Phys. Fluids* **20**, 051702 (2008).

[3]Computing resources from IN2P3 are gratefully acknowledged.

[4]Pier, *J. Fluid Mech.* **603**, 39–61 (2008).

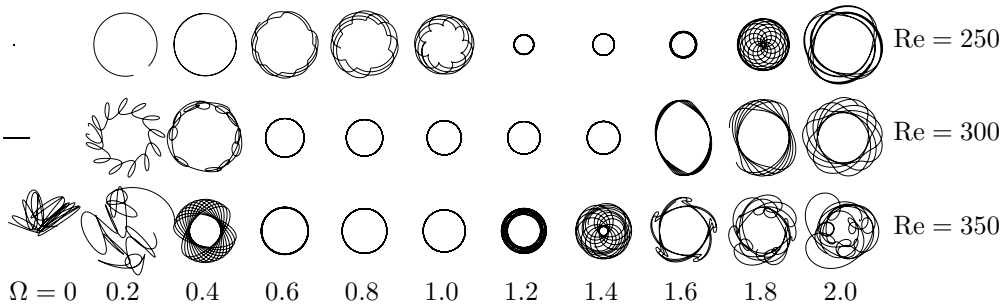

Figure 1: Graphs of the time-varying transverse force in the (C_x, C_y)-plane for $\mathrm{Re} =$ 250, 300, 350 and $\Omega = 0.0, 0.2, 0.4, \ldots, 2.0$.