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▶ To cite this version:

Benoît Pier. Local and global instabilities in the wake of a sphere. Euromech Fluid Mechanics Conference 6, Jun 2008, Stockholm, Sweden. hal-00632344

HAL Id: hal-00632344

https://hal.science/hal-00632344

Submitted on 14 Oct 2011

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Local and global instabilities in the wake of a sphere

Benoît PIER*

The wake of a sphere is known to display the following behaviour at moderate Reynolds numbers: the steady axisymmetric wake is stable for Re < Re₁ \simeq 210; a steady planar-symmetric flow is observed for Re₁ < Re < Re₂ \simeq 270; at Re₂ a periodic régime takes over with a vortex shedding Strouhal frequency of St \simeq 0.14 near onset.

The present investigation revisits this flow and compares the global behaviour, reproduced by direct numerical simulations, to the local stability characteristics, computed for the basic flow under a quasi-parallel flow assumption. It is shown that the time-periodic régime may be interpreted as a nonlinear global mode and its naturally selected frequency derived from local stability considerations.

For a given Reynolds number, the local linear stability characteristics are determined using the corresponding basic wake flow, defined as the time-independent solution of the Navier–Stokes equations. The axisymmetric and non-axisymmetric base flows are obtained by direct numerical simulation or, when they are gobally unstable, by a Newton–Raphson iterative scheme.

After computation of these time-independent basic flow fields, the local linear dispersion relation is derived from two-dimensional eigenproblems based on the velocity fields prevailing at each streamwise station z. The essential feature of the frequency selection mechanism is the complex local absolute frequency $\omega_0(z)$ shown in Figure 1 for Re = 300. According to the theory of "elephant global modes" , a self-sustained nonlinear oscillating structure is triggered by a front at the transition station z^{ca} from convective ($\omega_{0,i} < 0$) to absolute ($\omega_{0,i} > 0$) local instability. This front acts as a wave-maker and imposes its frequency on the entire system. The front frequency equals the (real) local absolute frequency $\omega_0^{ca} = \omega_0(z^{ca})$ prevailing at its location. At Re = 300, this frequency selection criterion yields a prediction of $St = \omega_0^{ca}/2\pi \simeq 0.17$, in reasonable agreement with the observed St = 0.14. Bearing in mind that the present flow is rather far from parallel, one may consider that this establishes the validity of the proposed underlying frequency selection mechanism.

¹Pier et al. *Physica D*, **148**, 49 (2001).

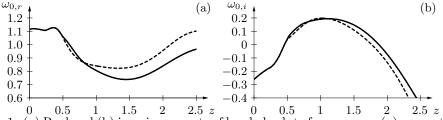


Figure 1: (a) Real and (b) imaginary parts of local absolute frequency $\omega_0(z)$ computed for the two most unstable modes of the non-axisymmetric basic wake flow at Re = 300 for a sphere of radius 0.5 with center at z = 0.

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