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COMPRESSIBILITY EFFECTS ON THREE-DIMENSIONAL SECONDARY INSTABILITIES IN THE CYLINDER PERIODIC WAKE

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With a growing interest in low Reynolds numbers compressible flows, the aim of this work is to investigate compressibility effects on the wake dynamics of the circular cylinder. In particular, our focus is made on the so called Mode A and Mode B secondary instabilities, which are responsible of the transition from a two-dimensional periodic to a three-dimensional state [1, 2]. Mode A appears at $Re \approx 180 - 190$ and is associated with an elliptic instability of the primary vortex cores with large scale transverse structures at a spanwise wavelength of $\lambda_z \sim 4D$, where D indicates the cylinder diameter. Mode B, which arises at $Re \approx 230 - 260$, is instead associated with a hyperbolic instability developing in the braid region and is related to the formation of finer scale structures of characteristic wavelength $\lambda_z \sim 1D$.
We address the influence of compressibility on these modes. The analysis has been conducted for Reynolds numbers $Re \in [200; 350]$ and Mach numbers up to $M_\infty = 0.5$. The two-dimensional periodic base state is found to exhibit time-averaged properties that substantially vary within the range of Reynolds and Mach numbers considered. Specifically, three different types of time-averaged flow structure are identified when varying both Reynolds and Mach numbers, as shown in Fig. 1 for three representative cases.

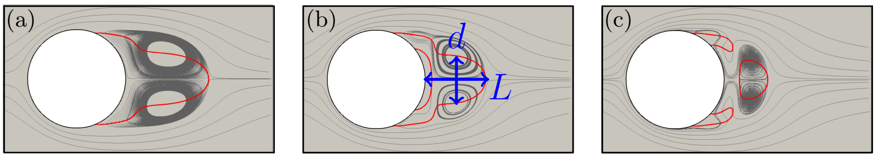

FIGURE 1. *Time-averaged base flow structures: a) Type 1, b) Type 2 and characteristic length scales, c) Type 3. Streamlines are shown in gray color and the time averaged longitudinal velocity isocontour $\bar{u}_x = 0$ is shown in red.*

The two-dimensional periodic flow is used as base state for a global stability analysis performed by means of Floquet theory. The global modal stability solver [3] is based on the Krylov–Schur algorithm with a time-stepping approach. A stabilizing (decreasing Floquet multiplier μ) or a destabilizing (increasing μ) effect of compressibility is observed on Mode A depending on the Reynolds number and the mode wavelength, while Mode B is found to be stabilized by compressibility (see Fig. 2). Interestingly, the

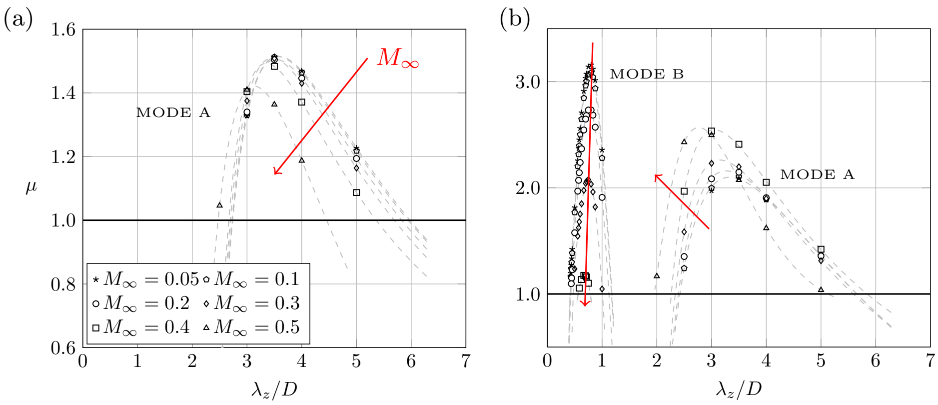

FIGURE 2. *Floquet multiplier μ as a function of the spanwise wavelength λ_z at (a) $Re = 250$ and (b)$Re = 350$ for different Mach numbers. Dashed lines represent the interpolation curves for a given Mach number.*

characteristic length-scales of the time-averaged base flow recirculation region (highlighted in Fig. 1.b) are found to be relevant for the normalisation of the instability wavelengths λ_z. The Mach number increase is also found to promote vorticity anisotropy on Mode A at largest wavelengths, which is not instead observed for Mode B.

References

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