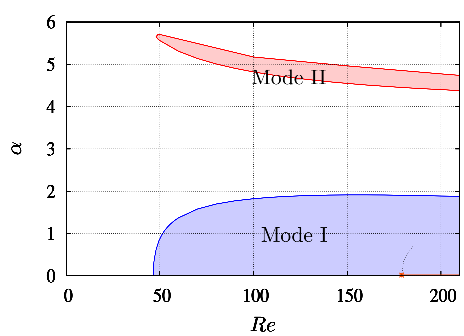
Three-dimensional stability of the flow past a rotating cylinder

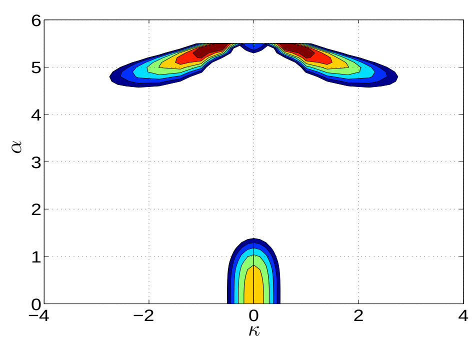
Jan Oscar Pralits*and Flavio Giannetti†

A two-dimensional stability analysis for the flow past an infinitely long rotating circular cylinder was performed among others by[1],[2] and[3]. It was found that besides the classic vortex street (mode I), a second shedding mode (mode II), characterized by a much lower frequency, exists at higher rotation rates. As an example taken from[1], fig (a) shows the two-dimensional neutral stability curve for both mode I and II as function of Reynolds number Re and rotation rate α.

In this presentation we will complete the stability analysis by assessing the effects of three-dimensional perturbations on the two-dimensional base-flow. Previous investigations by[4] indicates that the cylinder rotation has a stabilizing effect on three-dimensional perturbations acting on shedding mode I. However, by increasing the rotation speed, the stagnation point of the base flow moves away from the surface of the cylinder and a region with closed streamline arises. Within it, large pressure differences may induce three-dimensional centrifugal instabilities as suggested by a few numerical simulations performed by[2]. In this work we will present a systematic investigation of the three-dimensional stability properties of the flow past a rotating cylinder. The region of the $\alpha - Re$ plane in which three-dimensional instabilities exist will be discussed. As an example fig (b) shows the growth rate of the unstable modes found for $Re = 60$ as a function of the spanwise wavenumber κ and the rotation rate α: darker colors imply a stronger instability while white corresponds to stability. The characteristics of these three-dimensional modes will be discussed and their nature analyzed by performing a structural sensitivity analysis as first introduced in[5].



(a) Neutral curve for 2D perturbations showing the regions of instability for mode I and II



(b) Growth rate, $\omega_r \geq 0$, for 3d perturbations at Re=60 as function of spanwise wavenumber κ and rotation rate α

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*DICAT, Universit'a degli studi di Genova, Via Montallegro, 1 - 16145 Genova, Italy
†DIIN, Universit'a degli studi di Salerno, via Ponte Don Melillo 1, 84084 Fisciano (SA), Italy

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