TURBULENCE DYNAMICS TRANSITION OF FLOW PAST A CIRCULAR CYLINDER AND THE PREDICTION OF VORTEX-INDUCED FORCES

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We investigate the transition of three-dimensional (3D) to two-dimensional (2D) turbulence of incompressible viscous flow past a circular cylinder as the span is constricted. The inclusion of a bluff body provides novel information with respect to previous work on free turbulent flow [1, 2, 3]. The coexistance of both turbulence dynamics can be found at the mid wake region for highly anisotropic geometries as shown in figure 1 (left). Both 3D and 2D turbulence (-5/3 decay rate and -3 decay rate respectively) are captured on the inertial subrange for the $L_z = 0.5$ case, where L_z is the cylinder span relative to its diameter. Small-scale 3D structures detach from the wall even on very constricted domains. These structures are rapidly two-dimensionalised by the large-scale rotation of the Kármán vortices when the span is 50% of the diameter or less. The large-scale rotation as a mechanism of two-dimensionalisation is in agreement with other studies such as [3, 4].

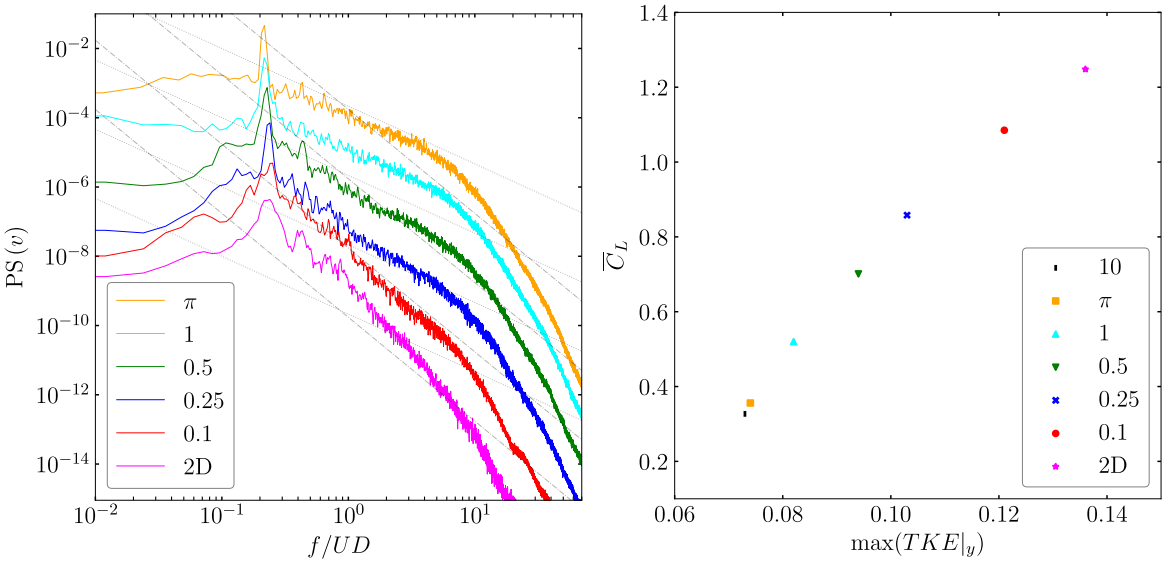

Figure 1. Left: Vertical velocity component temporal power spectra (PS) at $(x, y) = (4, 0.8)$ in the wake. Each PS line corresponds to a different span and the lines are shifted a factor of 10 for clarity (the vertical axis ticks correspond to the $L_z = \pi$ case). The dash-dotted line corresponds to a -3 slope and the dotted line corresponds to a -5/3 slope. Right: Effect of the span constriction on the vertically averaged (noted as $|_y$) TKE and $\overline{C}_L$. The latter is calculated as $\overline{C}_L = |2F_y/(\rho U^2 D L_z)|_{\text{rms}}$, where F_y is the vertical lift force and ρ is the constant fluid density.

On the other hand, the constriction of the span induces larger forces on the cylinder as displayed in figure 1 (right). There is a quasi-linear relation between the r.m.s value of the lift coefficient $\overline{C}_L$ and the turbulence kinetic energy (TKE). Higher values are found on both parameters as the span is reduced because of the emerging energised 2D vortical structures. Evidencing the strong relation of the forces induced to the cylinder and the turbulence statistics, a regression model is included to provide an a priori analysis given a sufficiently large data set.

References

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