Scale-Interactions in the Wake of an Actuated Cylinder

A. Zhelebovskiy*, G. Cui*, S. Verma†, B. Cukurel* and I. Jacobi*

Unsteady interactions between coherent structures in the wake of a cylinder were studied by perturbing the near-wall flow via surface actuation. Scale interactions in wall-bounded turbulence have been an important part of turbulence modeling since the early work of Bandyopadhyay and Hussain[1], but most subsequent studies[2] have focused on stationary flows. In this study, we extend the analysis of scale-interactions to the classical non-stationary problem of flow behind a cylinder.

Circumferential, moving-wall actuators were used to modify the wake behind a cylinder, first by a passive control scheme and then by a reinforcement-learning, active-control system in order to reduce the net drag force. Experimental measurements of the cylinder system were carried out in a high speed water tunnel facility. Force measurements on the cylinder were coupled with time-resolved, particle image velocimetry (PIV) of both the actuation region and the wake. The PIV measurements were then used to identify coherent structures associated with the drag modification. Figure 1 illustrates the large-scale coherent structures generated downstream of the unactuated cylinder, highlighting the natural periodicity of vortex shedding.

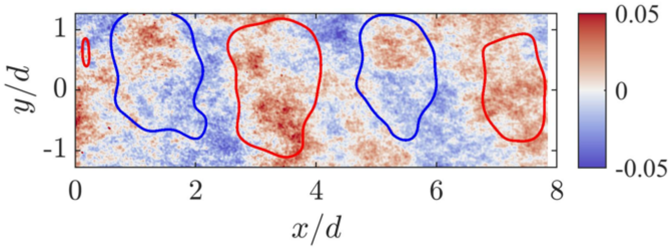

Figure 1: The phase-locked envelope of small-scale streamwise velocity fluctuations in the wake of a cylinder, with the boundaries of the corresponding large-scale vorticity fluctuations superimposed as contour lines.

The spatial and temporal behavior of these coherent structures was studied using correlation analysis, with an emphasis on the unsteady scale-interactions between large- and small-scale motions in the wake. Phase-locked measurements were used to synchronize the actuation inputs, time-resolved forced measurements, and resulting coherent motions, in order to characterize the non-linear dynamics of the system and to identify the most salient coherent motions associated with the drag modification.

*Faculty of Aerospace Engineering, Technion, Haifa, Israel

†Department of Ocean and Mechanical Engineering, Florida Atlantic University, Dania Beach, FL, USA

[1] Bandyopadhyay, P. R. and Hussain, A. K. M. F., *Phys. of Fluids* **27**, 2221-2228 (1984).

[2] Mathis, R. and Hutchins, N. and Marusic, I., *J. Fluid Mech.* **628**, 311–337 (2009).