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Low-order Modelling of Quasi-periodic Turbulent Wakes

Abstract: Low-order representations of quasi-periodic turbulent wake flows are discussed as a tool for investigating large-scale vortex dynamics and energy exchange based on experimental data. Considered are moderate Reynolds number wakes of finite-aspect-ratio cantilevered bluff bodies protruding nominally then boundary layers. These flows are generally turbulent and characterised by quasi-periodic vortex shedding. Due to the influence of the free-end and obstacle-wall junction conditions, these vortical structures are highly distorted giving rise to highly three-dimensional flow fields with significant cycle-to-cycle variations poorly captured using traditional phase-averaging techniques. A surface-pressure based remote-sensing estimation methodology, based on proper orthogonal decomposition (POD), is described for the construction of global representations of the coherent flow field. Particular attention is brought to improving estimation accuracy using a suitable orthonormal subspace. Using the five most energetic constructed global POD modes, the wake structure and dynamics are considered for a square-section cantilevered cylinder and for a square-based pyramid. The influence of the on-coming boundary layer and free-end conditions on the wake structure is discussed. A dynamically consistent reduced order model is presented. It is shown that the wake dynamics are consistent with mean-field theory and that the cycle-to-cycle variations arise from energy transfer between a slow-drift global instability and the first harmonic modes. The initiation of the energy cascade through transfer to the second harmonic mode is also evidenced.

About the speaker: Prof. Robert Martinuzzi, P. Eng., is a Pratt & Whitney Canada Research Fellow and Professor of Fluid Mechanics in the Dept. of Mechanical and Manufacturing Engineering; Schulich School of Engineering, University of Calgary (Calgary, Alberta, Canada). His fundamental area of research is physics of turbulent, separated flows. The research strategy includes development of reduced or low-order models for inter-scale energy transfer dynamics. He is an expert in non-intrusive experimental techniques, especially in optical velocimetry (PIV, LDV). His work focuses on transport phenomena in bluff-body wakes, turbulent wakes, remote-sensing and fluid-structure interactions. His applied research focuses on unsteady load predictions on structures, aerodynamics in high-speed aviation compressors and power turbines, scouring and erosion in river systems, prediction of MIC in pipelines and bioremediation of drilling fluids, design of entrainment nozzles for Ground Source Heat Pumps.