ASPECTS OF SIMULATING SYNTHETIC-JET INJECTION INTO ATTACHED AND SEPARATED BOUNDARY LAYERS

M.A. Leschziner[*], G.M. Fishpool[†], S. Lardeau[††]

[*†††]Imperial College London
Prince Consort Rd.
e-mail: mike.leschziner@imperial.ac.uk

ABSTRACT

A synthetic jet is formed as a consequence of fluid being periodically ejected from and drawn into an orifice connecting two flow domains, one of which is, in practice, a closed cavity. While there is no net mass flux between the two connected domains, the asymmetry in the instantaneous motion across the orifice, associated with separation, results in momentum and vorticity being ejected on either side of the orifice, as is shown in Fig. 1. This configuration is of substantial interest in the context of controlling boundary layers, in particular in relation to their ability to resist separation in adverse pressure gradient.

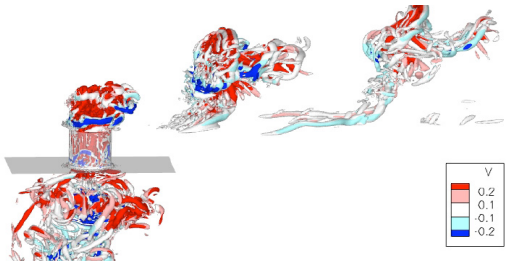

Fig. 1: Turbulent synthetic jet injected into a laminar boundary layer

The simulation of synthetic jets poses a number of challenges not encountered in many other flows. First, the jets – the features of primary interest – are very small in relation to the size of the simulation domain, the length-scale ratio being, typically 0.01 or less. Second, and related, the actuated outer flow is usually a relatively thin and long boundary layer, whether with or without embedded regions of separation. Both features combine to pose major resolution challenges if high-fidelity solutions are to be obtained. Third, the flow is temporally periodic, thus requiring extremely long simulation times to achieve convergence in the mean and phase-averaged statistics. Periodicity, and lack of homogeneity in any one direction, also poses particular problems in respect of dynamic sub-grid-scale modelling. Fourth, the flow to be controlled is typically a long turbulent boundary layer, the evolution of which cannot be simulated from its origin. The structure of this boundary layer is very important to the predicted control effectiveness, and thus, great care is required in its prescription.

Following earlier simulation studies on slot and round synthetic jets (Avdis et al, Flow, Turbulence and Combustion, 83, p. 343, 2009; Wu & Leschziner, Int. J. Heat and Fluid Flow, 30, p. 421, 2009), current efforts by the authors focus on the target configuration shown in Fig. 2, a twin-jet injection into a fully turbulent, separated Boundary layer, for which experimental data are generated through a collaborative effort with S. Zhang at the University of Manchester.

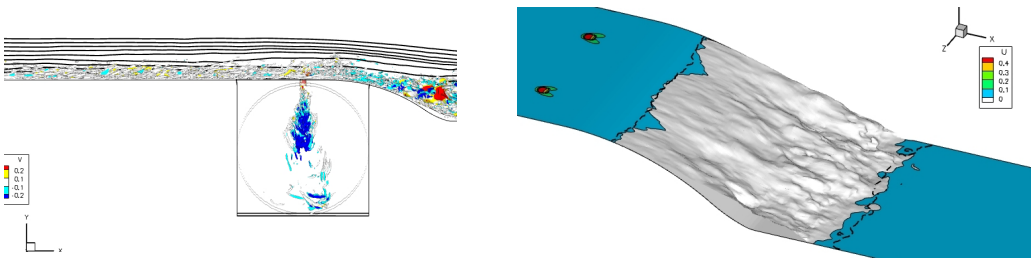

Fig. 2: Simulation of twin-synthetic jet injection into a separated Boundary layer

The paper will review these efforts, focusing on a variety of computational and physical issues, including sensitivity to resolution and the global effects of the jets on attached boundary layers, based on a macro control-volume momentum analysis based on simulation data.