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LARGE-EDDY SIMULATION OF SHOCK-INDUCED SEPARATION OF A TURBULENT BONDARY LAYER

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ABSTRACT

The low-frequency unsteadiness observed in shock-wave turbulent boundary layer experiments remains only partially understood and there are currently several competing or overlapping explanations of the phenomenon. In this study we have used large eddy simulation (LES) to study the interaction arising when a shock wave impinges on a turbulent boundary layer developing along a flat plate under a Mach 2.3 free stream. The basic configuration matches the experiments carried out at IUSTI for the case with an 8 degree shock generator (for details of the experiment see for example Dupont et al. 2006). Particular care has been devoted in the present LES to developing and optimising inflow conditions that do not contribute any spurious low frequencies. Methods based on either turbulence recycling or synthetic modes of turbulence have therefore been discarded in favour of a digital-filter approach with broadband randomised inflow disturbances. Extensive grid and domain-size dependency studies have been carried out and the mean flow is predicted with good accuracy compared with the experiment and with the first LES of this flow by Garnier et al. (2002). Figure 1 uses a combination of visualisation techniques to show the basic structure of the interaction.

To study the low-frequency in more detail a simulation in a narrow box with an extended run time has been conducted (Touber & Sandham 2008), allowing spectra to be analysed. Figure 2 shows how a broad spectral peak of low-frequency pressure fluctuations under the reflected shock is detected in the simulations, at a Strouhal number (based on bubble length) in close agreement with that seen in the experiments. No spectral peak at this frequency is seen in the upstream boundary layer. Thus it is clear that the low frequency is a natural product of the shock interaction and not an artifact of the upstream forcing in the simulations, or of an external feedback loop in the experiments.

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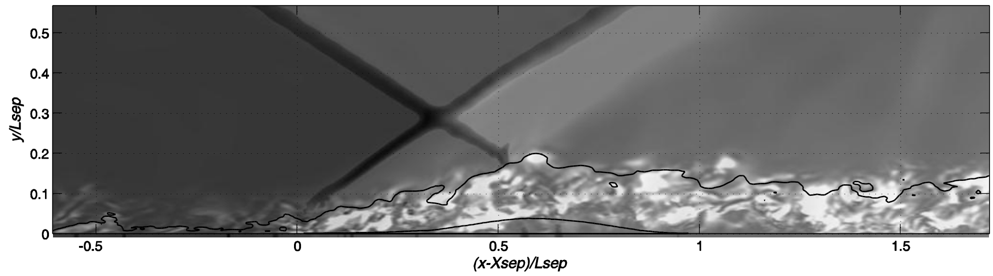

Figure 1 Instantaneous flowfield visualised with contours of pressure and turbulence kinetic energy. The lines show where the velocity is zero and 60% of freestream.

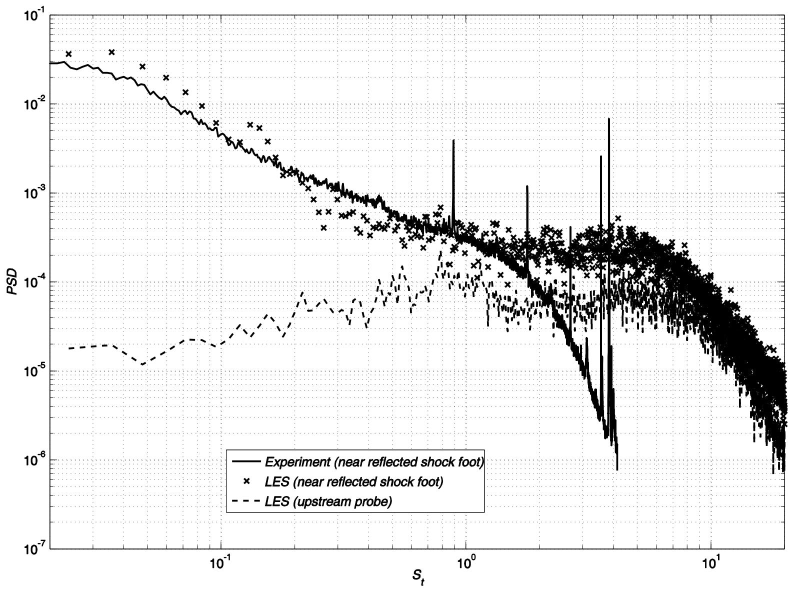

Figure 2 Comparison of the wall pressure spectrum at the shock foot location with experiment and with a location upstream of separation.