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Local time-dependent ("dimple") forcing of laminar channel flow[1]

HENRIK KOBERG, BEVERLEY J. MCKEON, JONATHAN F. MORRISON, SPENCER J. SHERWIN, Dept. of Aeronautics, Imperial College, London — Laminar channel flow over smooth time-dependent depressions of sinusoidal and Gaussian shapes is investigated by means of direct numerical simulation using the spectral/hp element solver Nektar. In previous simulations the dimple was approximated by a linearized boundary condition which does not permit separation and so is only valid for very shallow depressions ($\epsilon/D = 5 \times 10^{-6}, Re_D \approx 100$ and Strouhal numbers (based on dimple diameter), $St = 0.1 - 1.0$). These results showed that the dimples generate 'lobes' of contra-rotating streamwise vorticity, with the vorticity roughly in antiphase with the dimple acceleration. For St of order one, the magnitude of the vorticity is at least two orders of magnitude larger than that for the static case in which vorticity generation proceeds by the action of pressure gradients alone. In the present work, a fully non-linear solution is obtained by use of a time- dependent, curvilinear transformation of the channel with time- dependent wall perturbations, permitting a Fourier representation in the spanwise direction. A detailed analysis of the results is presented for both sinusoidal and Gaussian dimple shapes for a range of St and Re_D: these include the effects of local, time-dependent separations.

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