An LES investigation of the 2D Tollmien-Schlichting wave instability in channel flow.

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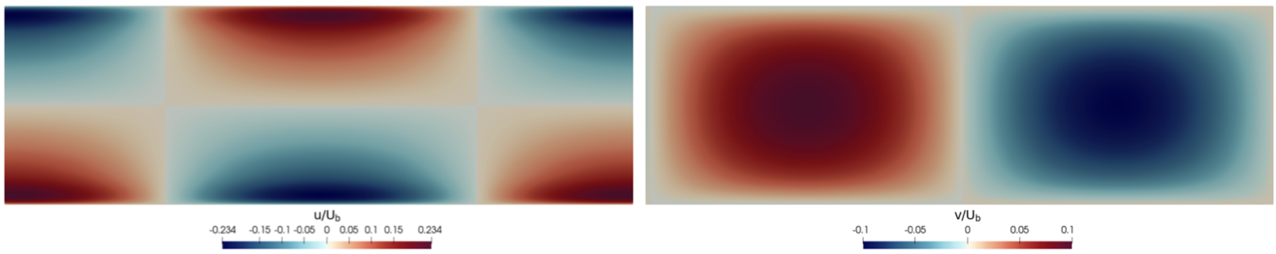
Abstract

Classical linear hydrodynamic stability analysis predicts the existence of an unstable 2D 'Tollmien-Schlichting' (T-S) wave, which may be excited in parallel boundary layer flows by mechanisms of receptivity. Of particular interest is the evolution of these disturbances beginning with the linear growth phase governed by the Orr-Sommerfeld equation, subsequent non-linearity with the development of 3D flow structures and the breakdown to turbulent flow. Understanding the mechanisms by which these unstable waves derive energy from the mean flow has significance with regard to the aim of maintaining laminar boundary layer flow and reducing the drag generated by aerodynamic surfaces. In this paper we solve the Orr-Sommerfeld eigenvalue problem numerically via a spectral method in MATLAB, approximating the solution via a truncated series of Lagrange polynomials. The streamfunction of the single unstable mode was found from the spectral solution from which the streamwise and wall-normal components of the perturbation's velocity were derived.



(a) Streamwise velocity component

(b) Wall-normal velocity component

Figure 1: Velocity components of the 2D wave perturbation

The growth behaviour of the instability was investigated through LES (Large-Eddy Simulation) solution of the Navier-Stokes equations by superimposing the small amplitude disturbance onto developed Poiseuille channel flow between two parallel plates on a mesh with periodic boundary conditions. The growth of the instability was monitored via vortex identification methods and it was shown that a large period of 2D linear growth takes place before three dimensionality develops which is in keeping with the small linear growth rates predicted from spectral solution of the Orr-Sommerfeld equation. Our aim in the paper will be to compare the solution predicted by Orr Sommerfeld to the LES calculation to see range of applicability of the OS equation.

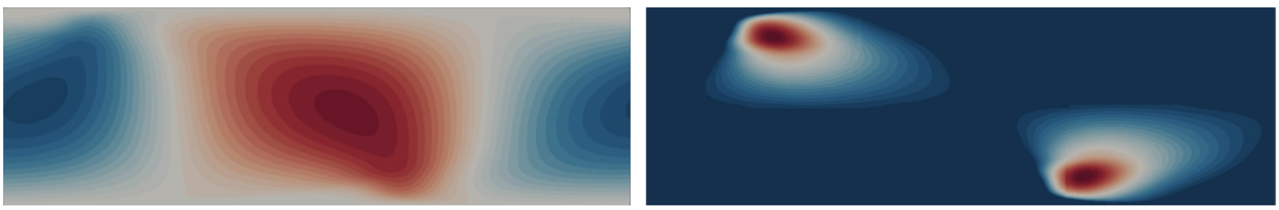


Figure 2: Developing wall normal velocity component (above) and Q-criterion (below), monitoring growth of the instability