6th European Conference on Computational Mechanics (ECCM 6)
7th European Conference on Computational Fluid Dynamics (ECFD 7)
11 15 June 2018, Glasgow, UK

THE ROLE OF A LOCALISED THREE-DIMENSIONAL ROUGHNESS ELEMENT ON INSTABILITY WAVES IN A BOUNDARY LAYER

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Key words: *boundary layers, instability*

We are concerned about the role of a smooth localised three-dimensional (3D) roughness on instability of an incompressible boundary layer by linear and nonlinear analysis. Widths of roughness elements are comparable to wavelength of instability waves and depths/heights are less than the 99% local boundary layer thickness. We are interested in the roughness element which gives rise to a local thin separation bubble. Accordingly, two problems are numerically investigated, one of which is complemented by an experimental study. The first concerns the interaction between the local thin separation bubbles and oncoming instability waves, by which spanwise-uniform Tollmien-Schlichting (TS) waves are destabilised and the TS modes' shapes are modified by a gradual switchover into an inviscid inflectional instability mechanism. The second problem concerns the nonlinear effect induced by a localised roughness element by which laminar-turbulent transition is prompted. Direct numerical simulations are employed to address the process of disturbance breakdown to turbulence. The traditional N-factors are used to assess instability of 3D disturbances, which is a general indication of development of strongly nonlinear behaviour, although N-factor, based on linear models, can only be used to provide indications and severity of the destabilisation. As an extension, we finally discuss the likelihood of generating absolute instabilities in the thin separation bubble.

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