UNIVERSITY OF SOUTHAMPTON

ABSTRACT

FACULTY OF ENGINEERING, SCIENCE & MATHEMATICS

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Doctor of Philosophy

DYNAMICS OF TURBULENT SPOTS IN A COMPRESSIBLE FLOW

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Direct numerical simulations of transitional and fully turbulent spots in an otherwise laminar compressible boundary layer have been performed. A bypass transition scenario using large amplitude localised blowing trips is considered and spot propagation speeds and the lateral spreading rates are calculated to study the effect of Mach number on the spot dynamics. Isolated spots are triggered and tracked at Mach 2, 4 and 6. The Mach number is found to have a strong influence on the growth of the spot, with growth rates reduced by factors of between two and four relative to incompressible flow. The overall spot structure at Mach 2 and 4 is similar to that of incompressible spots, with an arrowhead shaped front overhang, a crescent shaped tail followed by a becalmed region, and an overhang near the lateral wingtips. At Mach 6 by contrast there are additional spanwise structures with similarity to the Mack modes of instability. The interaction of a spot with an oblique shock-induced laminar separation bubble at Mach 2 and 4 has also been studied. The spot/bubble interaction enhances the lateral spreading of the spot and also collapses the bubble by a 'tunnelling' action. To study spot interactions, the lateral and tandem merging of the Mach 2 spot has been simulated. New structures evolved during the lateral merging, while in the inline merging a strong stabilising effect of the calmed region of the downstream spot is observed. The present results are used to derive a qualitative explanation for the lateral spreading mechanism of the spot in various complex flows, based on lateral shear layer characteristics near the spot wingtips.