The 8th European Congress on Computational Methods in Applied Sciences and Engineering
ECCOMAS Congress 2022
5 – 9 June 2022, Oslo, Norway

CONTROL OF OBLIQUE BREAKDOWN USING STREAK EMPLOYMENT METHOD

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Key Words: Transition Control, Flow Instabilities, Streak Employment, Supersonic Flows.

In the present era of supersonic aviation and environmental concerns, researchers are witnessing an unprecedented and ever-increasing focus to make supersonic transportation feasible. Achieving this goal requires retaining the laminar boundary layer on an aerodynamic body to decrease the skin friction and thermal load on the vehicle. Thus, transition control of supersonic boundary layers necessitates an in-depth understanding of the transition mechanism.

Transition mechanism in supersonic flows, known as oblique breakdown, is governed by a pair of most-amplified waves (fundamental mode) traveling at identical but opposite wave angles with respect to the free-stream [1]. Once emerged, the self-nonlinear interaction of these waves generates a steady vortex mode which carries a spanwise wavenumber, two times the fundamental disturbance. Further downstream, higher harmonic modes are formed as a result of the interaction of the existing disturbances, while extending the energy exchange mechanism to a more complex stage. The oblique breakdown might be controlled by various active or passive control methods, among which streak employment is one of the promising techniques that has proven its capabilities for incompressible flows and now has been extended to supersonic flows. Unfortunately, there is a lack of knowledge regarding the effectiveness and limitations of the method in suppressing the convectively growing boundary layer instabilities despite the recent studies [2, 3]. As the nature of high-speed flows including diverse instability modes complexifies both the experimental and numerical investigations, a simplified flat plate geometry is used in this study to better understand the governing transition mechanism.

Figure 1 compares the Direct Numerical Simulation (DNS) of uncontrolled and controlled cases for their skin-friction coefficient evolutions. The streaks carrying five times the wavenumber of the fundamental disturbance are introduced by a blowing and suction strip that is placed immediately before that of perturbation. It is seen that transition is delayed further downstream in the presence of the control streaks which reduces the growth rate and the maximum amplitude of disturbances at a given streamwise position. Ultimately, the method has also been tested successfully in more complicated transition scenarios [2]. However, an extensive study is required with various wall heating/cooling rates to mimic realistic flight scenarios albeit the utilized geometry. Therefore, the current research is aligned in the direction of elaborating the effects of isothermal boundary conditions on the transition mechanism in the absence/presence of the control streaks at high-speed flow regimes.

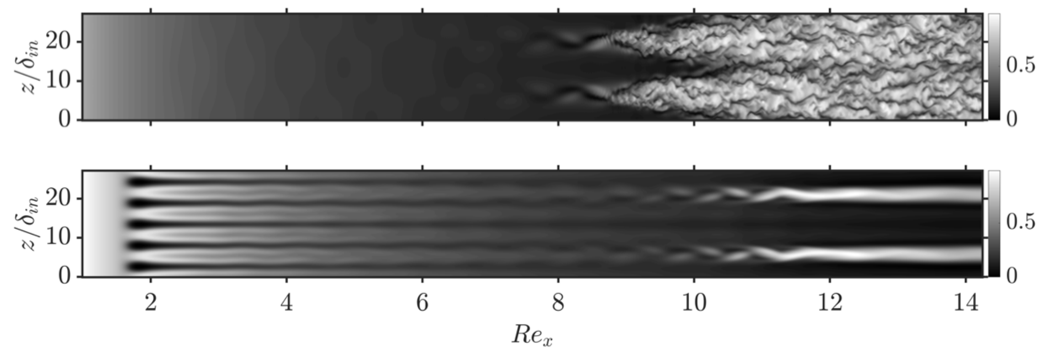

Figure 1. Contours of normalized streamwise velocity u/u_∞ at $y/\delta_{in} = 0.517$ at $X - Z$ plane for uncontrolled (top) and controlled adiabatic flow cases at $M_\infty = 2$ [4]. u_∞, δ_{in} and Re_x are the free-stream velocity, boundary-layer thickness at the inlet and Reynolds number, respectively.

ACKNOWLEDGEMENTS

The authors acknowledge the access to French HPC resources provided by the French regional computing center for Normandy (CRIANN) (grant nos. 1998022 and 2017002). The funding resources are provided by the Region of Normandie.

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