Transition dans les couches limites supersoniques: simulations numériques directes et contrôle par stries

Doctorant·e

CELEP MUHITTIN

Direction de thèse

HADJADJ ABDELLAH (Directeur·trice de thèse)
SAFDARI SHADLOO HUGO (Co-directeur·trice de thèse)

Date de la soutenance

01/07/2024 à 14:00

Lieu de la soutenance

Salle de conférence du CORIA, Avenue de l'Université, 76801 Saint-Étienne-du-Rouvray

Rapporteurs de la thèse

CHAZOT OLIVIER PROFESSEUR Institut von Karman de dynamique des fluides
LEHNASCH GUILLAUME MAITRE DE CONFERENCES DES UNIVERSITES HDR École Nationale Supérieure de Mécanique et d¿Aérotechnique

Membres du jurys

CHAZOT OLIVIER, PROFESSEUR, Institut von Karman de dynamique des fluides
HADJADJ ABDELLAH, PROFESSEUR DES UNIVERSITÉS, INSA de Rouen Normandie
LEHNASCH GUILLAUME, MAITRE DE CONFERENCES DES UNIVERSITES HDR, École Nationale Supérieure de Mécanique et d¿Aérotechnique
SAFDARI SHADLOO HUGO, MAITRE DE CONFERENCES DES UNIVERSITES HDR, INSA de Rouen Normandie
SAYADI TARANEH, CHARGE DE RECHERCHE, Institut Jean Le Rond d'Alembert
VERVISCH LUC, PROFESSEUR DES UNIVERSITÉS, INSA de Rouen Normandie

Abstract

In high-speed flows, elevated viscous drag and thermal loads are inherent outcomes over aerodynamic bodies. These effects escalate substantially during the transition phase when the boundary layer becomes turbulent. To mitigate potential mechanical damage and fatigue-related failures, thermal protection systems are integrated into vehicles, adding complexity to the technical and economic aspects of design. The solution lies in gaining a comprehensive understanding of transition mechanisms and developing control systems to prolong laminar boundary layer along the vehicle’s surface. Numerous active and passive control techniques can be employed for transition control, with the streak employment method emerging as a particularly promising approach. This method involves generating narrowly spaced streaks in the spanwise direction, creating alternating high and low-speed regions in the flow field. Although the method has only recently been tested in supersonic flows, demonstrating its effectiveness in delaying transition, its suitability needs to be assessed further. In this research work, direct numerical simulations are performed in supersonic and near-hypersonic regimes. Streaks are introduced through a blowing/suction strip placed at the wall prior to that of the perturbation which is used to trigger transition in a “controlled” fashion, forced by a single frequency and wavenumber disturbance. The investigation at Mach 2.0 confirms that streaks with five times the fundamental wavenumber are most beneficial for transition control. Additionally, cooling enhances the method’s effectiveness, while heating severely deteriorates the capability of control streaks. The isothermal wall condition does not alter the comparable stabilizing impact of the mean flow deformation (MFD) and the 3-D part of the control at Mach 2.0. However, at Mach 4.5, both the type of instability and the characteristics of the streaks change significantly. The stabilizing impact of the MFD becomes nearly absent, and the 3-D part of the control predominates, with the characteristics of the streaks no longer considered independent of their initial disturbance amplitude.