THESE

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Salle AY.02.63 à l'ONERA Meudon

Unsteadiness in transonic shock-wave/boundary-layer interactions: experimental investigation and global stability analysis

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A transonic interaction between a shock wave and a turbulent boundary layer is experimentally and theoretically investigated. The configuration is a transonic channel flow over a bump, where a shock wave causes the separation of the boundary layer and a recirculating bubble is observed downstream of the shock foot.

First, the mean flow is experimentally investigated by means of PIV, then different techniques allows to identify the main unsteadiness of this shock-wave/boundary-layer interaction. As recognised in similar configurations, the flow presents two distinct characteristic frequencies, whose origins are still unknown.

Numerical simulations are performed solving Reynolds-averaged Navier-Stokes equations. Results are in good agreement with the experimental investigation on the mean flow, but the approach fails to predict the unsteady behaviour of the configuration. The solution of RANS equations is then considered as a base flow, and a global stability analysis is performed. Eigenvalue decomposition of the linearised Navier-Stokes operator indicates that the interaction is stable, and the dynamics cannot be described by unstable global modes.

A linearised approach based on a singular-value decomposition of the global Resolvent is then proposed: the noise-amplifier behaviour of the flow is highlighted by the linearised approach. Medium-frequency perturbations are shown to be the most amplified in the mixing layer, whilst the shock wave behaves as a low-pass filter. Optimal forcing and optimal response are capable to reproduce the mechanisms that are responsible for these two phenomena. A restriction on the location of the forcing can give an insight on the origin on the unsteadiness.

The same approach is then applied to a transonic flow over the OAT15A profile, where the flow can present, for a range of angles of attack, high-amplitude self-sustained shock oscillations. Global stability analysis indicates that the shock buffet onset is linked to a Hopf bifurcation, and the eigenvalue decomposition can describe the phenomenon when an unstable global mode is present. Regardless of the angle of attack, singular-value decomposition of the global Resolvent can describe the convective instabilities responsible of medium-frequency unsteadiness.

Composition du jury

Jean-Christophe Robinet	Professeur, ENSAM Paris	*Rapporteur*
Neil D. Sandham	Professeur, University of Southampton	*Rapporteur*
Jean-Paul Dussauge	Directeur de recherche au CNRS, IUSTI, Marseille	*Directeur de Thèse*
Denis Sipp	Maître de recherche ONERA, Meudon	*Examinateur*
Pierre Dupont	Chargé de Recherche au CNRS, IUSTI, Marseille	*Examinateur*
Uwe Ehrenstein	Professeur, Aix-Marseille université	*Examinateur*
Reynald Bur	Maître de recherche ONERA, Meudon	*Invité*