Transition delay in boundary-layer flows via reactive control

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Reducing the energy consumption required for transportation has been one of the main challenges in the past few decades. In this framework, a particular interest has been given to the delay of the laminar-to-turbulence transition in boundary-layer flows. In a low-turbulence environment, e.g. the cruise condition for an airplane, this transition is dominated by local instabilities of the flow – Tollmien-Schlichting (TS) waves – that exponentially grow, eventually breakdown and lead to turbulence.

Reactive-control techniques are one of the several solutions that have been studied in order to delay the laminar-to-turbulence transition. In this scenario, the aim is to remove the disturbances from the flow by a system of localised sensors and actuators before they may lead to transition. Once sensor and actuators are fixed, the main effort is to compute the transfer function between those objects, i.e. the control law.

Model-based and adaptive control techniques are the two antithetic strategies to approach the control design [1]. The former relies on a model of the flow to guide the actuators' action and it has been shown to be able to effectively delay transition in DNS [2]. However, this technique may lack of robustness when it comes to experimental investigations or, in general, to cases where an accurate model of the flow is available. Adaptive control techniques have been shown to be a possible solution to this problem [3]. In this framework, in fact, the control is not entirely based on a model of the system but also on on-line measurement of the control performance.

After an overview of advantages and limitations of these two control-design approaches via numerical and experimental results, this talk will focus on the real transition delay and drag reduction capabilities of adaptive control techniques. The control performance is investigated for increasing disturbance amplitude, up to the point where transition is incipient in the control region. Parallel to this, the net-energy-saving is evaluated via ideal as well as real actuator models.

References

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