The relevance of secondary instabilities in spots nucleation on a flat plate boundary layer

José M. Faúndez[*], André Cavalieri[†], Ardeshir Hanifi[*] and Dan S. Henningson[*]

In boundary layers forced by free-stream turbulence (FST) the transition route is dominated by the growth and breakdown of streaks, triggering the scattered space-time nucleation of turbulent spots, which subsequently grow and merge downstream creating the fully turbulent boundary layer. Therefore, understanding how and under which conditions these turbulent events can develop is of interest for transition prediction tools and control.

The present investigation deals with the stability analysis of FST-induced streaks on a boundary layer. In particular, the relevance of secondary instabilities in the transition to turbulence process is addressed by relating local stability results with the nucleation of turbulent spots downstream in the boundary layer. The data set for this endeavour corresponds to the DNS of a flat plate, including its leading edge, under different FST conditions.

We pose the temporal stability problem by considering the DNS solution as the flow base state and extracting the velocity field along two-dimensional planes normal to the streamwise direction at a fixed time. Figure 1 illustrates the outcome of this analysis, where two unstable eigenmodes are shown on top of the perturbation streamwise velocity. Similarly to previous findings, our results show that the unstable eigenmodes are localised and centred around specific streaks, even when the whole span was taken into account for the stability calculations and streaks of different scales and amplitudes are present.

The 2D stability calculations give us valuable information regarding the span location and time instant of unstable streaks, where they can be related to the upstream appearance of turbulent spots, highlighting the pertinency of secondary instabilities in the bypass transition process. Moreover, by projecting the eigenfunctions at different streamwise stations and time steps we can correlate the unstable modes and identify single events with their corresponding time and streamwise evolution.

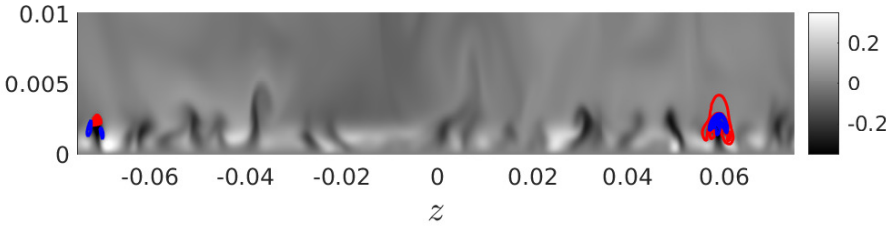

Figure 1: Secondary instabilities in a cross-plane $z - y$ for a specific time instant and streamwise location x. The grey contours show the streamwise velocity perturbation. The two secondary instability modes, at different span locations, are visualized by their positive (red) and negative (blue) streamwise velocity components.

[*]KTH, Linné FLOW Centre, SE-10044 Stockholm, Sweden
[†]ITA, Aerodynamics Department, São José dos Campos, 12228900, Brazil