CROSSFLOW-DOMINATED LAMINAR-TURBULENT TRANSITION DOWNSTREAM OF AN ISOLATED ROUGHNESS ELEMENT OF SMALL HEIGHT

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The effect of an isolated roughness element on laminar-turbulent transition has been thoroughly investigated in the range of roughness Reynolds numbers Re_k for which the laminar-turbulent transition front advances to the immediate vicinity of the isolated roughness, a behaviour often referred to as direct tripping. Experimental studies for this range have been conducted in both two-dimensional (e.g. [1]) and three-dimensional boundary layers (e.g. [2]). Radeztsky et al. [3] showed that roughness elements with Re_k values orders of magnitude smaller can already have a significant impact on the location of laminar-turbulent transition. In this investigation, the effect of an isolated roughness element with a particularly low roughness Reynolds number of $Re_k = 0.55$ (compared to typical critical values for direct tripping of $Re_k \gg 100$ [3]) is studied experimentally in a three-dimensional boundary layer. Detailed spatially scanned hot-wire anemometry measurements are performed in the SPECTRA-B configuration (shown in Fig. 1a, see [4]). The development of steady and unsteady instabilities is characterized in comparison to a reference case without artificial roughness and a case with spanwise-periodic forcing. In Fig. 1b, isocontours of the nondimensional main velocity component u_s in the coordinate system locally aligned with the boundary-layer edge streamline visualize an overview of the three-dimensional steady boundary-layer flow field. The local boundary-layer edge velocity is denoted by q_e. The red curve follows the flow direction at the wall-normal distance of the inflection point in the crossflow velocity component v_s, starting from the chordwise and spanwise location of the isolated roughness element (represented as a black circle). The artificially excited wave packet can be traced downstream across a large portion of the model chord up to the location of the final turbulent breakdown. The final breakdown is significantly advanced relative to the reference case without roughness. Λ

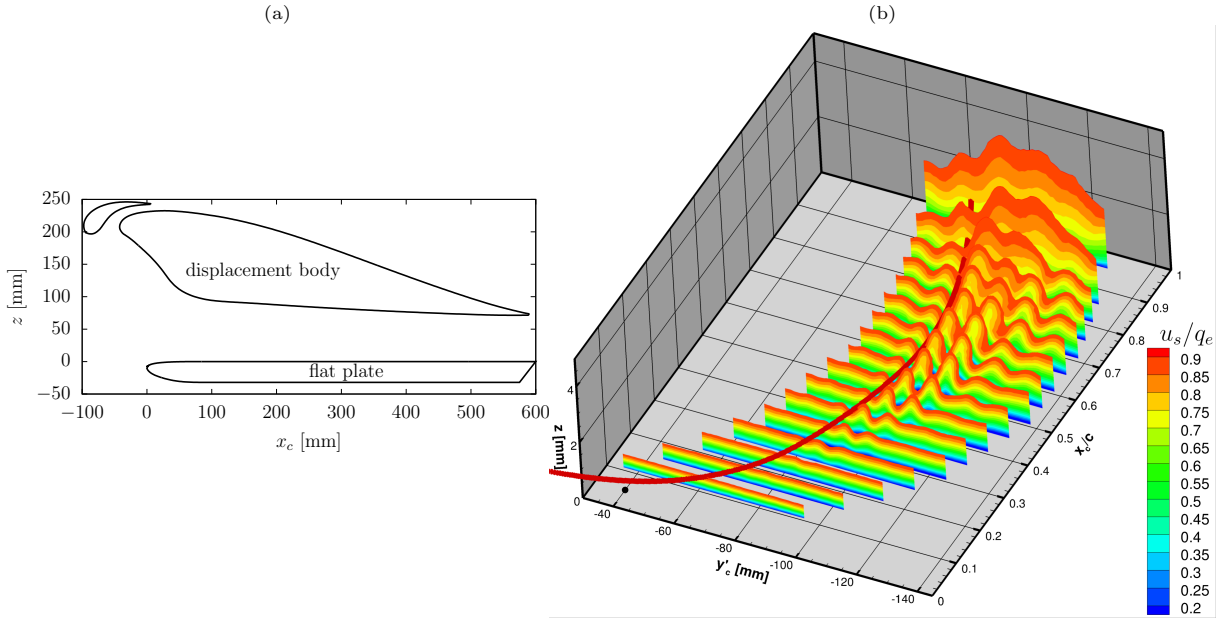

Figure 1: (a) Cross-section of the SPECTRA-B configuration (b) Overview of the steady boundary-layer flow field downstream of the isolated roughness element

References

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