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RECEPTIVITY AND AMPLITUDE-BASED TRANSITION PREDICTION

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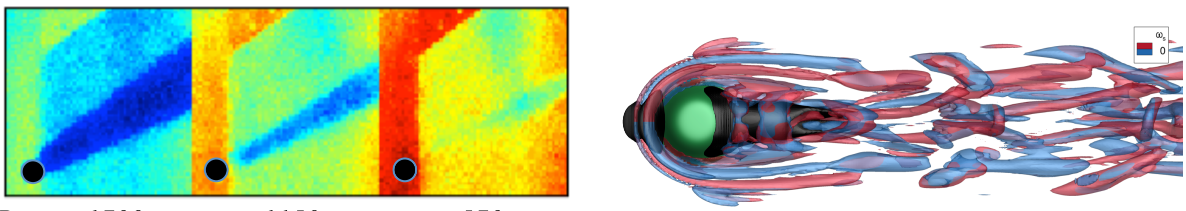
Theoretical and numerical tools are critical to the process of aircraft design. One important area in which they are used is to predict transitions from laminar to turbulent flow, in other words instances where disturbances initiate unstable conditions that lead to turbulence. The classical transition pathway is characterised by an initial receptivity phase during which external perturbations are converted into boundary-layer disturbances. Amplification and breakdown of these disturbances can lead to turbulence.

Most transition prediction methods are amplification-based, ignoring the receptivity phase and the actual amplitudes at which breakdown to turbulence occurs. The EU-funded project 'Receptivity and amplitude-based transition prediction' (RECEPT) is incorporating these components into models to develop more accurate predictions of in-flight performance of aircraft. Given that expensive wind-tunnel tests are an important part of the design phase, addressing discrepancies between wind-tunnel simulations and free-flight conditions makes the former more relevant as well.

Within the RECEPT project, the boundary-layer receptivity has been investigated through a number of experimental and numerical works.



Re_{hh}: 1700 1150 570

Flow behind a medium-size roughness element on a swept wing. Left: IR images. Right: Direct numerical simulations. (Results from RECEPT project.)

The detailed experimental investigations have been performed in MTL wind tunnel at KTH in order to measure the receptivity of three-dimensional boundary layers to surface roughness and free-stream perturbations. Hotwire measurements have provided detailed information about the characteristics of the boundary-layer perturbations. Results of different receptivity models have been compared to results of these and previous measurements. The nonlinear stability tools have been used to incorporate the effects of initial amplitude of perturbations in transition prediction. Further, Effects of small surface roughness elements and free-stream turbulence on generation of cross-flow modes are also investigated through direct numerical simulations.

The critical size of discrete surface roughness elements in cross-flow dominated flows has been studied through wind tunnel experiments and direct numerical simulations including both low- and high-speed flow cases. The obtained data allows to characterise the flow field generated by these surface roughness elements.

Effects of full three-dimensionality of the flow over wings on growth of perturbations have also been addressed through application of tools based on ray-tracing and 3D PSE.

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