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Receptivity in transition prediction

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Abstract

The laminar-turbulent transition is a complex phenomenon involved in several multidisciplinary design issues, such as skin friction drag reduction, anti-icing and de-icing system performance prediction and heat transfer rates assessment. An accurate prediction of the boundary layer state is needed in order to control its thickness by active or passive systems.

The state of the boundary layer is of high importance since skin friction drag and heat transfer rates in a turbulent boundary layer can be several times higher than those expected in laminar one. Furthermore, predicting the state of the boundary layer in wind tunnels and ensuring the same state during the real flight, by taking disturbances resulting from the experimental set up into account, leads to the design of transition triggering devices.

Several European projects had the objective to investigate the laminar to turbulent transition and the last one relative to this topic is the RECEPT program (RECEPTivity and amplitude-based transition prediction) from 2011 and now on going. The major objective of this project is the development of the capability to predict the in-flight performance of a future laminar flow aircraft through development of more accurate transition prediction tools.

The main subject of the present research effort relates to the objectives of the RECEPT project through the study of the boundary layer instabilities and their receptivity to disturbances. Indeed, the goals of the present work are:

- to develop a fast tool that can be integrated in an industrial code for transition prediction;
- to introduce corrections for non–parallel flow in order to assess their importance in real wing designs and more general and complex boundary layers.

Fluid dynamic instabilities leading to transition from laminar to turbulent flow in an incompressible boundary layer are considered, paying attention to the receptivity process.

The problem of boundary-layer receptivity is solved by introducing the multiple-scale technique applied to the linearized Navier-Stokes equations according to an Orr-Sommerfeld non–homogeneous formulation case. The resulting algorithm is not computationally expensive and can be efficiently included in industrial codes for transition prediction.