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The role of experiments and data reduction techniques in the tuning of different transition models

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The Reynolds averaged Navier Stokes-based CFD solvers require closure strategies for the estimation of the Reynolds stress tensor, providing an eddy viscosity affecting the momentum transfer processes of the mean flow. Different turbulence and transition schemes have been developed in the past, especially for prediction of transitional boundary layer flows, relying on different assumptions and ability to predict transitional and turbulent flows of various applications. However, irrespective of the specific kind of numerical scheme considered, such model strategies necessarily require empiricisms to properly set the key terms appearing in the set of transport equations, definitively adopted to provide an accurate estimation of the eddy viscosity.

In the present work, an experimental data base spanning a large Design of Experiments devoted to tuning of possibly different transition closure schemes will be described in detail. This large database has been acquired in the last years in the Laboratory of Aerodynamics and Turbomachinery of the University of Genova. It includes more than 90 combinations of the most influencing parameters affecting transition, like the flow Reynolds number, the adverse pressure gradient and the free-stream turbulence intensity. Time-Resolved Particle Image Velocimetry (TR-PIV) has been used to characterize the response of the boundary layer transition process to variation of the inflow parameters. Data have successively been further reduced to provide closure elements required by different transition models. The spot production rate source term appearing in the $\gamma - Re_\theta$ model, the energy transfer rate appearing in the Laminar Kinetic Energy (LKE) transition model and the apparent viscosities characterizing the Pope's tensorial expansion are a few examples that will be discussed in detail during this presentation. The focus will be also paid to the reduction techniques and machine learning algorithms used to identify parsimonious models able to maximize their generalizability. Additional examples involving schemes for parallelized codes will be also discussed.