High-fidelity simulations of turbulent boundary layers on flat and curved surfaces

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ABSTRACT

In this presentation, a few recent results obtained in our group related to the simulation of turbulent boundary layer on flat and curved surfaces are presented. In all cases, we focus on wall-resolved simulations, using either sufficiently high resolution adequate for direct numerical simulation (DNS), or a subgrid-scale (SGS) model for LES. Special focus is on an adequate characterisation of the pressure gradient, be it favourable, adverse or zero.

With more (parallel) computer power and adapted high-fidelity simulation codes, it has become possible to simulate flows of practical interest, in particular also related to aeronautics. Whereas 10 years ago we focused on flat-plate boundary layer flows with the (at the time) high Reynolds number of $Re_\theta = 8000$ [1], modern computers made it possible to consider also the important effects of pressure gradient [2], and overall geometry of the immersed body [3]; in our case a NACA4412 wing profile. We start with presenting the approach and selected results of the flat plates, and then move on to simulations of wing profiles at $Re_c = 1{,}000{,}000$ [4].

Several aspects will be discussed, including the requirements on the numerics, some challenges in the postprocessing such as the determination of a proper local length scale [5] (*i.e.* the boundary-layer thickness δ), and some unexpected physical effects as local backflow (flow with reversed direction) in the immediate vicinity of the wall [6], and some pertinent aspects of pressure-gradient boundary layers. Finally, we will also present some initial results of friction flow control on the wing using straight-forward wall blowing and suction, in an effort to extend previous studies in channels to assess the influence on both lift and drag [7]. In the course of a coordinated effort with experiment at KTH we also present a new criterion to determine whether a boundary layer is “well-behaved”, *i.e.* whether it is independent of inflow and (numerical or experimental) artefacts [8].

Finally, we would also like to highlight the outcomes of the recent FET H2020 project ExaFLOW [9] which focused on identifying bottlenecks and solution approaches for pushing selected high-resolution codes to the exascale. In particular, adaptive mesh refinement for the spectral element method (SEM) will be briefly outlined, and the potential benefits on the example of the aforementioned wing simulations are discussed.

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