RANS modeling and applications

Reynolds-Averaged Navier-Stokes (RANS) techniques are the method of choice for flow predictions in industry in spite of well-known limitations of conventional turbulence closures. Traditionally, RANS efforts during the summer program have focused on the introduction or the evaluation of novel modeling approaches to tackle such limitations. This year, the project led by Stavros Kassinos represents one of such attempts. On the other hand, the other two efforts included in this group explore critical aspects of the application of RANS techniques. Francesco Capizzano's research work aimed at establishing the accuracy in predicting flows with control devices, whereas, Stephane Moreau's group compared RANS techniques to other approaches to compute noise sources in the flow around an airfoil.

Kassinos *et al.* explore the limitations of linear eddy viscosity models in predicting flows in rotating devices. The approach they followed is based on the use of structure-based modeling to construct an algebraic representation of the Reynolds-stress such that the turbulence anisotropy and its response to frame rotation is represented. In this approach the eddy viscosity model is *only* used to build a representative turbulence time scale. The results are extremely encouraging and indicate that over a range of Reynolds and Rossby numbers this approach correctly predicts the effect of rotation on the mean flow and the corresponding turbulent stresses.

Capizzano investigates the predictive capabilities of various RANS closures in computing boundary layer flows with active flow-separation control devices. In particular, the interest is mainly aimed at the simulation of flows with synthetic jets (oscillatory blowing/suction devices). In addition, preliminary work on the development of a lumped model to capture the unsteadiness introduced by synthetic jets was carried out. In this approach the steady-state flow equations are considered and *suitable* body-forces (corresponding to the injection of momentum related to the action of the oscillating jet) are introduced. Initial results are promising.

Moreau *et al.* report on a comparison between various numerical approaches to compute the flow around an airfoil. The main interest is in predicting the pressure fluctuations at the airfoil trailing edge as it has direct implications on the self-generated noise. Conventional RANS techniques, detached eddy simulations and the Lattice Boltzmann method are compared to experimental data. In addition, two Large Eddy Simulations (using a body-fitted mesh and a Cartesian-grid immersed boundary approach) are performed and compared to the other predictions. The results in terms on mean flow characteristics, average wall pressure and velocity profiles in the wake, do not show substantial differences. On the other hand, the analysis of pressure fluctuations spectrum clearly reveals the inadequacy of all but LES techniques to predict the experimental data especially in the high frequency range.

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