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Simulations of Separated Flows at Reynolds Numbers Typical of Turbine Blades and Unmanned Aero Vehicles

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Abstract: Flows over airfoils and turbomachinery blades, for unmanned and micro-aerial vehicles (UAV), wind turbines, and propellers consist of a laminar boundary layer near the leading edge that is often followed by a laminar separation bubble and a transition to turbulence further downstream. The unsteady effects of flow separation greatly influence blade/wing lift and drag and thus performance of UAV's, and efficiency and robustness of turbomachinery components. Paradoxically, despite Reynolds numbers for such devices being low to moderate (10^4 - 10^6), numerical predictions for such flows can be more difficult than for high Reynolds numbers flows typical of civilian aeroplanes at cruising velocity (10^7 - 10^8). Reynolds Averaged Navier Stokes (RANS) turbulence models are inadequate for such flows because they often fail to predict the onset and the extent of separated flow regions. Direct numerical simulation (DNS) is the most reliable but also the most computationally expensive alternative, not practical in industrial applications. This leaves Large Eddy Simulation (LES) as a primary candidate for a fast and accurate prediction tool for such flows. This talk assesses the capability of LES to significantly reduce the resolution requirements for such flows and still to provide results of DNS quality. Two different flows are considered and their physics discussed. A flow over a flat plate with suitable velocity boundary conditions away from the plate to produce a separation bubble and a flow over a NACA-0012 airfoil. By employing several different numerical codes we conclude that accurate LES are possible but that the numerical dissipation plays a significant role in such simulations. Consequently, quantifying the numerical dissipation and its interplay with explicit SGS models is necessary for reliable LES of such flows.

Biography: Since 1997 Full Professor in the Department of Aerospace and Mechanical Engineering, the Viterbi School of Engineering at the University of Southern California in Los Angeles. Author or co-author of over 200 scientific contributions, including 60 refereed journal papers, with focus on turbulence theory, modeling, and simulation, with h-index of 26 on Google Scholar. Professional background includes a number of visiting positions (Université Libre in Brussels; Technical University in Dresden; ETH in Zürich; Tokyo Technical University; German Aerospace Establishment in Göttingen) as well as postdoctoral positions at Princeton University and MIT. Major honors: Associate Fellow of the American Institute of Aeronautics and Astronautics (2011), Fellow of the American Physical Society (2008), Ouverture Internationale Award (2006), Invitation Research Fellowship of Japan Society for the Promotion of Science (2000), Alexander von Humboldt Research Award (1992) and Fellowship (1980), and Northrop Research Faculty Award (1991). Professional service includes guiding 15 Ph.D. Theses, with 12 completed and 3 in progress, being a guest editor of the Annual Reviews of Fluid Mechanics, vol. 45, serving as an Associate Editor of the Journal of Turbulence, chairing the organizing committee for the 63th Annual Meeting of the American Physical Society, Division of Fluid Dynamics (2010), and serving as an Associate Chair of the AME department between 2005 and 2008.

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