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HIGH-ORDER DIRECT NUMERICAL SIMULATION OF FINITE SPAN WINGS

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ABSTRACT

A wide range of modern aerodynamics applications, such as unmanned aerial vehicles (UAV) and electric vertical takeoff and landing (eVTOL) aircraft, require accurate aerodynamic predictions in transitional Reynolds number regimes. However, current industry-standard computational fluid dynamics (CFD) methodologies, specifically the Reynolds-averaged Navier Stokes (RANS) approach, fail to yield accurate results in this flow regime. To address this limitation, we are proposing the use of direct numerical simulation (DNS) in lieu of RANS for these applications. These DNS simulations will serve as a foundation for validating future studies on transitional Reynolds number regimes in the vicinity of Re = 10,000. In this presentation, we will showcase a series of high-order DNS simulations using the flux reconstruction method to analyze transitional and turbulent flow over finite-span NACA 0018 wings. The study examines angles of attack from 0° to 20° and span-to-chord ratios ranging from 1 to 4, simulated over 100 non dimensional time units. A structured mesh was generated with appropriate Y^+ values to ensure the resolution of all turbulent structures down to the Kolmogorov scale. The mesh extends 10 chord lengths in all directions from the airfoil's side view and 2 chord lengths from the wing tips, enabling accurate capture of wingtip vortices and downstream turbulent structures. Particular focus will be placed on analyzing turbulent transitions, resulting in turbulent flow structures, first and second-order turbulent statistics, aerodynamic forces, and surface flow characteristics. Several key physical phenomena in this flow regime will be examined in contrast to conventional aerodynamic configurations, including the generation of negative lift at low angles of attack, a non-linear lift coefficient behavior, and the delayed onset of stall with increasing span-to-chord ratios.