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# Numerical Investigation of Flow Dynamics Over a Multi-Element Airfoil in Ground Proximity

Bharathwaj Dharani*, Catherine Mavriplis
Department of Mechanical Engineering, University of Ottawa, Ontario, Canada.
*bdhar053@uottawa.ca

ABSTRACT

Low Reynolds number ($O(10^4)$) flows play a crucial role in aviation, particularly for unmanned aerial vehicles (UAVs), micro air vehicles (MAVs), and low-altitude flights, where aerodynamic efficiency and stability are critical. When operating near the ground, these flows become more complex due to changes in pressure distribution and wake interactions. Understanding these effects on multi-element airfoils is essential for optimizing performance during takeoff, landing, and low-altitude flight. In this study, we employ Direct Numerical Simulation (DNS) with a high-order spectral element method code, Nek5000, to analyze the flow dynamics around a 30P30N multi-element airfoil near the ground, at a low Reynolds number of $1.27 \times 10^4$ and an angle of attack (AoA) of 4°. We compare our results to the previous work of Vadsola (2020), which studied the same airfoil under free-stream conditions, to assess how ground proximity modifies the flow characteristics. Our 2D simulation at one chord length above the ground reveals that the shear layer separates near the leading edge of the main element, forming a wave-like roll-up before periodically reattaching after mid-span. As the reattached flow moves further downstream toward the flap, we observe a periodic slot jet flow between the trailing edge of the main element and the flap. The separation bubble in the slat cove region is significantly smaller in ground proximity than in the free-stream case from earlier work, indicating that ground effect modifies the slat wake evolution, potentially altering transition mechanisms and downstream flow structures. We will also explore how ground effect influences the transition to turbulence as the airfoil moves closer to the ground, while examining its behavior at higher Reynolds numbers. Aerodynamic performance metrics, including lift, drag, and pressure coefficients, will be analyzed for a comprehensive understanding of the airfoil's aerodynamic behavior.