Characterising Noise Sources of Two-Element 30P30N Airfoil via Large Eddy Simulation

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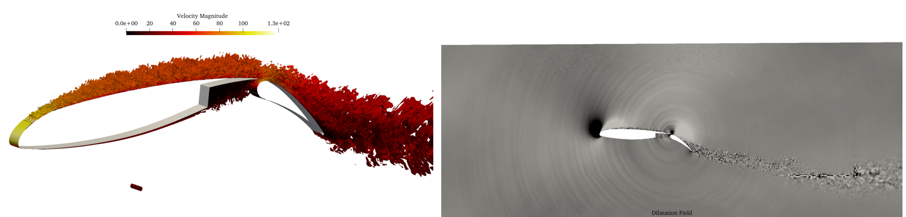
Previous studies have shown that, aside from leading-edge aerodynamic effects, the flap cove, main-element wake, and flap region of the three- and two-element 30P30N configurations exhibit negligible differences over a range of angles of attack. Similar recirculation behavior and turbulent kinetic energy levels in the flap cove indicate comparable mean loading in the flap region. Consistently, wall-pressure spectra at the flap cove and flap leading edge show nearly identical broadband levels and spectral shapes for both configurations. In contrast, the mid-frequency narrowband peaks disappear when the slat is removed, leading to corresponding changes in the shape and slope of the far-field spectrum. The persistence of similar broadband levels suggests that flap broadband noise is governed by a mechanism distinct from slat-induced tonal feedback. Motivated by these findings, the present study focuses on the two-element McDonnell-Douglas 30P30N high-lift configuration to isolate and characterize the intrinsic mechanisms of flap noise generation.

The airfoil is investigated at an angle of attack of 3°. The free-stream velocity is $U_\infty = 50\,\mathrm{m/s}$, resulting in a chord-based Reynolds number of $Re_c = U_\infty c/\nu = 1.29 \times 10^6$ and a free-stream Mach number of $M_\infty = 0.14$. The simulation procedure consists of three phases. First, an unsteady Reynolds-averaged Navier–Stokes (uRANS) simulation is performed on a coarse mesh and advanced for 10 convective times to initialize the flow field and allow the initial transition to develop. Next, the solution is interpolated onto a finer mesh, where a low-order wall-resolved large-eddy simulation (WR-LES) is conducted for an additional 10 convective times to capture the unsteady flow structures. Finally, the simulation is continued using a high-order WR-LES for a further 10 convective times to obtain the final flow field for analysis.

The simulation campaign is still ongoing. To date, the flow has been advanced for 10 convective times using uRANS, followed by 5 convective times of low-order WR-LES, for a total of 15 convective times. Q-criterion contours colored by velocity magnitude, shown in Figure 1a, reveal separation near the leading edge of the main element. In addition, the dilatation field shown in Figure 1b suggests that flap noise is the dominant acoustic source, although a weaker contribution associated with the laminar separation bubble near the leading edge of the main element is also observed.



(a) Q-criterion coloured by velocity magnitude.

(b) Dilatation field.

Figure 1: The flow field after 15 convective times.

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