Reduction of Wing-Wall Junction Noise Using Fillet Geometries

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Past studies in the University of Toronto Hybrid Anechoic Wind Tunnel have revealed that the presence of undesirable wing-wall junction noise can contaminate certain acoustic sources of interest. To improve future experimental measurements, understanding the underlying cause of this source and identifying treatment methods was desirable. This acoustic source was typically understood to be induced by the horseshoe vortex that forms close to the wing-wall junction [1]. This feature is created when the flow along the wall experiences an adverse pressure gradient as it approaches the wing and separates [2]. The presence of the vortex near the wing and wall can introduce pressure fluctuations that may propagate as acoustic waves [3]. To suppress the horseshoe vortex formation, curved leading edge fillets were recommended to reduce the adverse pressure gradient. Past studies have also implemented fillets with a straight swept leading edge [2].

In the experiments performed in this work, a two-dimensional NACA 0012 airfoil model with a chord $c = 0.3$ m and a span $b = 0.83$ m formed the wing-wall junction. Acoustic measurements were performed using a phased microphone array, from which the resulting beamforming maps help identify noise source locations on the airfoil and wing-wall junction. Several junction fillet designs of varying shape and wall boundary layer heights were studied.

Interestingly, curved fillet designs, which would be expected to best reduce the formation of the horseshoe vortex, had negligible impact on the far field acoustic signature, while the straight swept designs showed appreciable improvement. This indicated that the junction noise source was not simply induced by the horseshoe vortex and instead may have been created by turbulence interaction noise at the leading edge of the airfoil, which itself was created by a larger-than-expected boundary layer over the wind tunnel floor. To extend the utility of the fillet designs, tests were also performed at several wing angles of attack (α). As expected, the leading edge fillets that improved performance at $\alpha = 0°$ were not beneficial at non-zero α, as flow separation occurred behind the fillet. An alternative design was introduced, consisting of a contour around the full wing root region. This was the most beneficial treatment method, with demonstrated reductions in junction noise sound pressure level of up to 8 dB.

References

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