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Aftwall Inclination in Surface-Embedded Airfoil Cavities: A Review of Aeroacoustic Mechanisms and an Unexplored Design Frontier for Passive Noise Control

[1]Trupti, Trupti; [2*]Khatir, Zinedine

[1]School of Mechanical Engineering, University of Leeds, Leeds LS2 9JT, UK. Truptit204@gmail.com . [2]School of Mechanical Engineering, University of Leeds, Leeds LS2 9JT, UK. Z.Khatir@leeds.ac.uk *Trupti Trupti

Airframe trailing-edge noise is a dominant source during aircraft approach, particularly at low Reynolds numbers (Re ~ 10^4–5×10^5) relevant to UAVs and wind turbines, where discrete tonal noise arises from a self-sustaining aeroacoustic feedback loop involving Tollmien–Schlichting instabilities, trailing-edge scattering, and upstream acoustic propagation [1,2]. Surface-embedded cavities (recessed into the airfoil pressure surface) offer a passive, zero-energy means of disrupting this loop, making them a practically attractive noise reduction strategy.

Prior numerical and experimental studies [3,4] identify cavity depth and chordwise position as the primary governing parameters: shallow, mid-to-aft chord cavities sustain a single coherent recirculation zone that energises the boundary layer and yield the most favourable noise-to-drag tradeoff, while deeper or leading-edge-proximate cavities amplify tonal noise through multiple stacked recirculation zones. Separately, the standalone open-cavity literature demonstrates that aftwall geometry modification (slanted or chamfered walls) reduces overall sound pressure levels by 5–10+ dB at subsonic conditions by distributing vortex impingement energy [5,6].

Despite this, aftwall inclination has never been explored as a design variable in the surface-embedded airfoil context; no study to date has investigated angled or inclined aftwall geometries, whether at 45° or any other inclination. This review identifies aftwall inclination as a clearly unexplored design variable in this context and develops the physical rationale for a 45° configuration: the inclined surface deflects rather than reflects the arriving vortex, distributing impingement energy, attenuating the peak acoustic pulse, and promoting a stable single-recirculation flow structure, consistent with bio-inspired noise reduction principles [7]. Future work is directed towards scale-resolving CFD across inclination angles (30°–75°), frequency-resolved acoustic characterisation of individual Rossiter mode suppression, and extension to continuously curved aftwall profiles, collectively advancing passive aeroacoustics for UAVs, urban air mobility, and approach noise reduction.

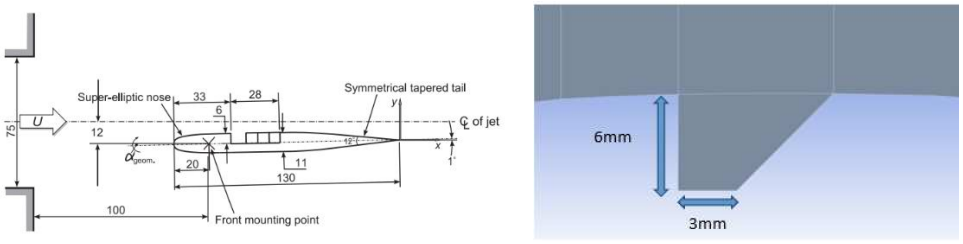


Figure 1. Cross-sectional schematic of the two surface-embedded cavity geometries compared in this review: (left) rectangular cavity with vertical aftwall (90°)(Schumacher et al. [5]), as used in all prior embedded airfoil studies; (right) proposed cavity with 45° inclined aftwall.

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