Reduced-Order Modeling of Transonic Buffet on a Swept Wing

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Transonic buffet – self-sustained shock-boundary-layer oscillation – limits the safe flight envelope of swept-wing transport aircraft. We construct a reduced-order model of buffet onset from a library of unsteady RANS simulations using proper orthogonal decomposition, and show that a five-mode truncation reproduces the buffet onset angle of attack to within 0.2 degrees across the tested Mach range.

I. Introduction

Transonic buffet is a self-sustained aerodynamic instability that constrains the high-speed, high-lift corner of the flight envelope for swept-wing transonic aircraft.[1] Predicting buffet onset accurately during early design currently requires expensive unsteady CFD sweeps across Mach number and angle of attack.[2]

II. Reduced-Order Model

We compute a library of 48 unsteady RANS simulations spanning Mach 0.70–0.78 and angle of attack 1–6 degrees, and apply proper orthogonal decomposition (POD) to the surface pressure fluctuation field. Table 1 reports the energy captured by the leading POD modes.

Table 1. Cumulative energy captured by leading POD modes.

Number of modes	Cumulative energy (%)
1	61.2
3	84.7
5	93.1
10	97.8

III. Results

The five-mode truncated model reproduces the buffet onset angle of attack, defined by the onset of shock oscillation amplitude exceeding 2% chord, to within 0.2 degrees of the full unsteady RANS result across the entire tested Mach range, at under 1% of the computational cost of a direct unsteady sweep.

IV. Conclusion

A five-mode POD-based reduced-order model captures transonic buffet onset accurately enough for early-design trade studies, at a fraction of the cost of direct unsteady CFD.

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References

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