

PROCEEDINGS

Non-Uniform Eigenvalue Perturbation Method for Detached Eddy Simulation Uncertainty Quantification in Transonic Compressor Flows

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ABSTRACT

Reynolds-Averaged Navier–Stokes (RANS) models remain widely used in turbomachinery design and analysis, yet their predictive accuracy is constrained by structural uncertainties inherent in the eddy-viscosity assumption. This limitation becomes particularly pronounced under off-design operating conditions, where large-scale flow separation and unsteady vortex structures dominate. In such scenarios, even RANS-based uncertainty quantification (UQ) methods cannot fully capture the discrepancies in predicted pressure ratio and efficiency [1]. Detached Eddy Simulation (DES), which combines RANS in attached boundary layers with Large-Eddy Simulation (LES) in separated regions, offers improved capability in resolving massive separation flows. To enhance the credibility of DES predictions, this study develops a non-uniform eigenvalue perturbation method designed for DES to quantify structural uncertainties arising from turbulence modeling. By perturbing the eigenvalues of the Reynolds stress tensor in a physically realizable manner, the proposed framework extends uncertainty quantification to the DES formulation, accounting for modeling uncertainties in both RANS and LES-dominated regions. The method is applied to transonic compressor flows under near-stall conditions. The generated confidence intervals effectively bound the discrepancies between numerical predictions and experimental data, demonstrating that the proposed DES-based non-uniform eigenvalue perturbation method provides a robust framework for quantifying structural uncertainties in complex compressor flows where RANS-UQ approaches fail.

KEYWORDS

Detached eddy simulation; uncertainty quantification; compressor; turbine

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References

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