Towards Improved Prediction of Compressor Flow by Uncertainty Quantification of Spalart-Allmaras Turbulence Model

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Motivation

Reynolds-Averaged Navier-Stokes (RANS) simulation with the Spalart-Allmaras (SA) turbulence model is a conventional approach to analyze compressor stall. However, it falls short of predicting the compressor stall boundary especially at off-design speeds. This research explores the uncertainty and the sensitivity of SA model coefficients on predicting compressor flow features. It aims to guide future modifications of the SA model for improved compressor stall prediction.

Methodology

Compressor flows are simplified by backstep and bump flows.

The in-house solver AU3D is then verified in both backstep and bump flows against NASA’s simulation and experiment results.

496 sets of SA coefficients are generated within physical bounds by Latin hypercube sampling, then simulated by AU3D.

An artificial neural network is built and trained on the database, serving as a surrogate model of the AU3D solver.

Reynolds Stress. SA models fail to reproduce the Reynolds stress in separated region. Coefficients $\sigma$, $\kappa$, $c_{\mu_1}$, $c_{\mu_2}$, and $c_{\lambda}$ are important to Reynolds stress prediction.

Results

**Shock.** SA models predict a delayed shock front with a smaller pressure. Coefficients $\sigma$, $\kappa$, $c_{\mu_1}$, $c_{\mu_2}$, and $c_{\lambda}$ are found important to shock prediction.

**Separation.** SA models predict a smaller size of separation. Coefficients $\sigma$, $\kappa$, $c_{\mu_1}$, $c_{\mu_2}$, and $c_{\lambda}$ are found important to separation prediction.

Conclusion

- The SA model fails to reproduce shock, separation and Reynolds stress, thus inducing uncertainties on compressor stall prediction.
- $\sigma$, $\kappa$, $c_{\mu_1}$, and $c_{\mu_2}$ are most influential on compressor flow features. Physics-informed modifications on these terms are recommended in future research.

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