Proceedings of the 1st international Symposium on AI and Fluid Mechanics
Abstract No S14 A9

Data-Driven Multi-Fidelity Framework for Real-Time Optimization of LPT Blades

[1]Matteo Giovannini*; [1]Mattia Silei; [1]Juri Bellucci; [2]Ennio Spano; [2]Bertini Francesco

[1]*Morfo Design, Firenze, Italy*

[2]*Avio Aero, Torino, Italy*

Abstract

The increasing complexity of modern low-pressure turbine (LPT) design for aeroengines necessitates the development of innovative methodologies to enhance aerodynamic performance while reducing time to design. This study introduces a novel, real-time design framework that integrates multi-fidelity computational CFD simulations with machine learning (ML) techniques to optimize LPT blade geometries. At the core of the proposed approach is the derivation of near-optimal 3D blade configurations informed by AI-optimized 2D profiles.

The framework leverages surrogate models constructed using artificial neural networks (ANNs) and Gaussian processes, trained on extensive numerical datasets comprising tens of thousands of URANS and LES calculations, exploiting the computational resources of modern HPC infrastructures. These surrogate models provide accurate predictions of aerodynamic performance metrics, including blade loading and 2D flow field maps. Advanced optimization techniques, such as particle swarm optimization, are employed to explore the design space efficiently and identify optimal solutions.

This work emphasizes the surrogate modeling components, particularly the integration of multi-fidelity predictions. Traditional approaches rely on low-fidelity tools during the preliminary design phases, while high-fidelity analyses, due to their computational cost, are typically confined to validation and final verification stages, thereby limiting their influence on early design decisions. The developed framework overcomes these limitations by enabling the incorporation of high-fidelity performance predictions at the preliminary design stage, directly influencing key design choices. This integration accelerates the design cycle while improving decision-making accuracy.

The findings suggest a transformative potential for data-driven tools in enhancing the impact of high-fidelity CFD on LPT aerodynamic design, paving the way for next-generation aeroengine advancements.

Keywords:

Multi-fidelity, LPT design, ANN, Gaussian processes