Alireza Shahrabi Farahani

Project Portfolio

A selection of key projects from my professional career.

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Contents

Portfolio Highlights

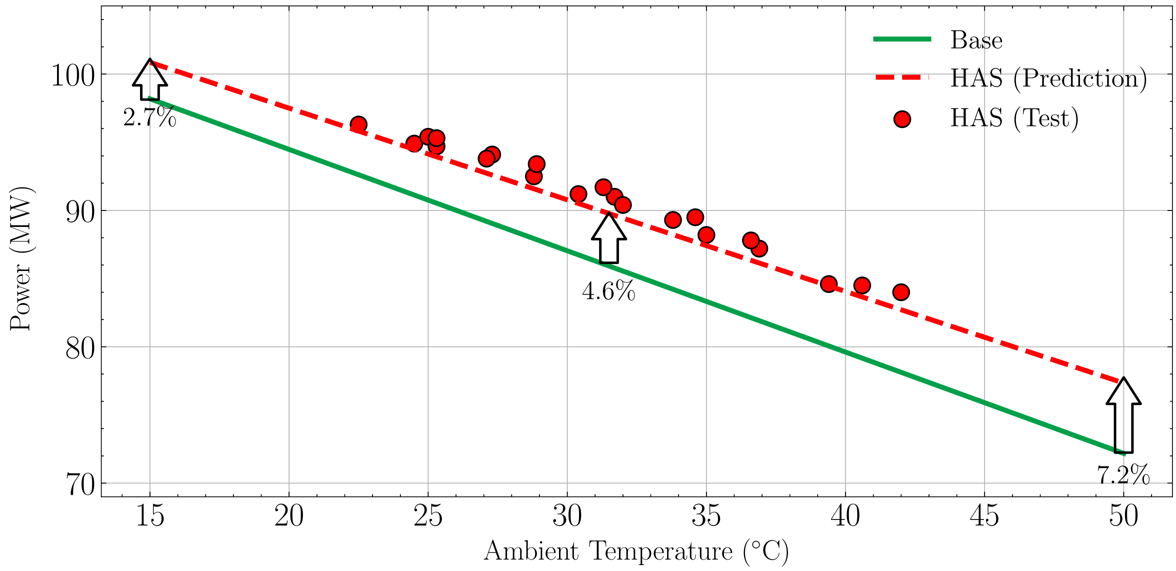


Figure 1: Achieved a **7-8% increase in gas turbine power output** in hot ambient conditions through the HAS retrofit program, validated by real-world field data.

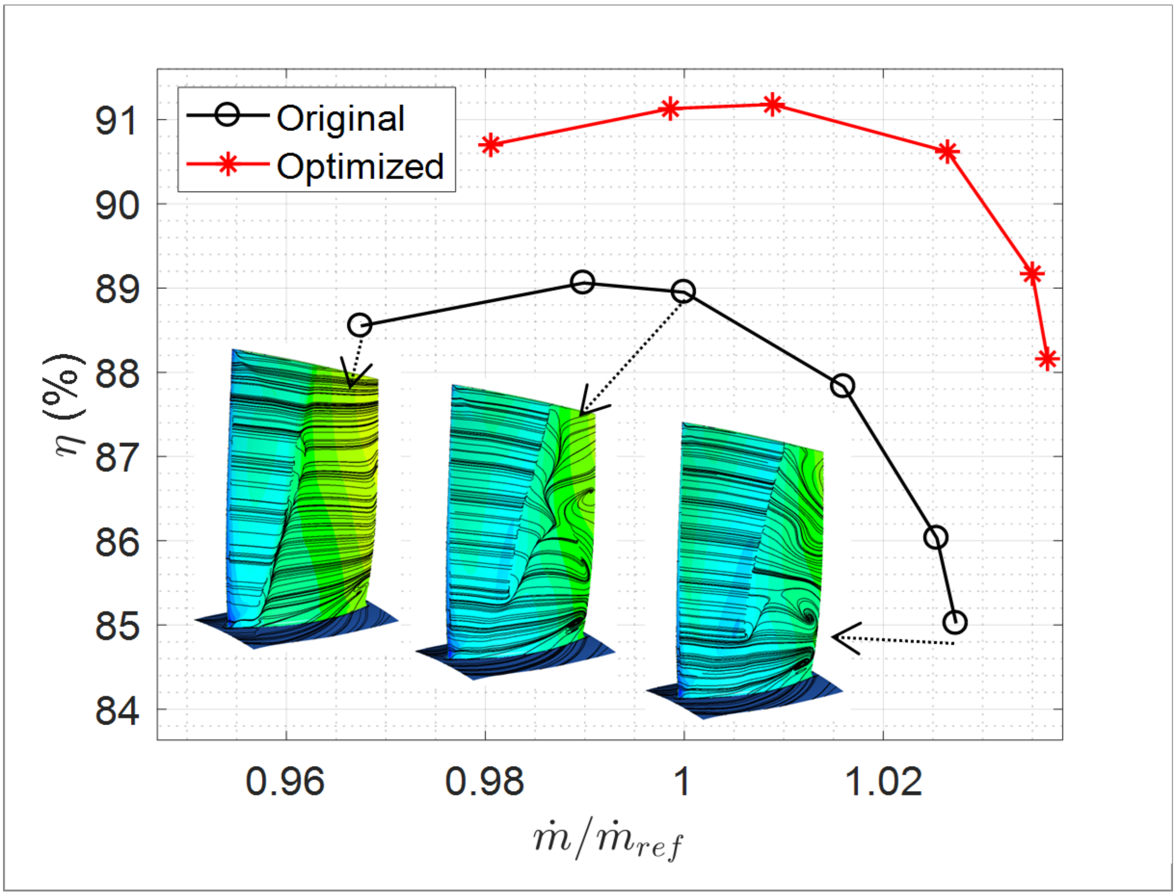


Figure 2: Developed an AI-driven design tool that **reduced airfoil design time by 50%** and delivered a **2% efficiency improvement** in a transonic compressor test case.

SGT-600 Gas Turbine: Foundational Engineering Analysis and Localization Support

My Role R&D / Aerothermal Engineer, Turbotec

Objective To establish a comprehensive engineering understanding of the Siemens SGT-600 gas turbine to support its full localization in Iran (as IGT-25). This involved creating validated analytical models, supporting local manufacturing, investigating field issues, and identifying pathways for future performance upgrades.

Methodology & My Contribution

- **Baseline Performance Mapping (Digital Twin Creation):** My colleagues and I created a detailed "digital twin" of the 10-stage compressor by conducting extensive aerodynamic (CFD) and structural (FEA) analyses. This involved building full 3D models to understand the machine's performance and stress limits under various operating conditions.
- **Structural & Vibrational Characterization**: Performed baseline modal analysis (FEA) and physical modal testing on existing components to establish a validated vibrational signature, which served as a benchmark for all future upgrade work.
- **Manufacturing & Quality Support:** I served as a key engineering authority for production, working closely with the factory to resolve manufacturing challenges. I was responsible for preparing technical dispositions for Non-Conformance Reports (NCRs) and Technical Service Requests (TSRs).
- **First-Article Manufacturing Supervision:** I personally supervised the manufacturing and inspection of the first locally produced components to ensure they met all design specifications and quality standards, a key responsibility across all my upgrade projects I was involved in.
- **Failure Investigation & Root Cause Analysis (RCA):** When failures occurred at various sites, I led the technical investigation. This involved analyzing failed components, reviewing operational data, and using our analytical models to simulate failure scenarios to identify the root cause and propose effective corrective actions.
- **Identification of Upgrade Pathways:** The deep understanding gained from this foundational analysis allowed me to identify specific aerodynamic and structural bottlenecks. This work created the technical business case for the subsequent, highly successful **HAS (Hot Ambient Solution)** and **IGT25+** upgrade programs.

Tools & Technologies Used ANSYS (CFX and Mechanical), Siemens-NX (for CAD modeling), MATLAB, Python

Results & Impact

- Established a validated suite of analytical models for the IGT-25 compressor that became the core asset for all subsequent service and upgrade projects at the company.
- Resolved numerous critical manufacturing and field issues, directly improving fleet reliability and guiding the local production process.
- Provided the foundational analysis that launched the company's successful IGT25+, HAS, and other turbine upgrade programs.

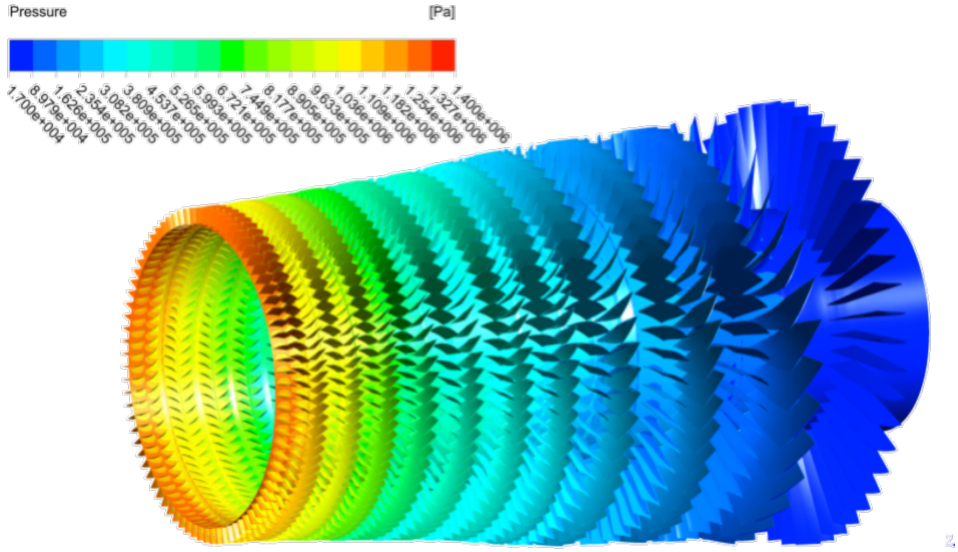


Figure 3: Example of a full 3D CFD pressure analysis performed on a multi-stage axial compressor to establish a baseline performance map.

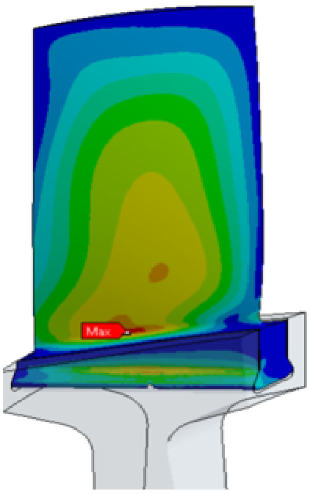


Figure 4: Equivalent (von-Mises) stress analysis of a compressor blade to understand structural limits under full load conditions.

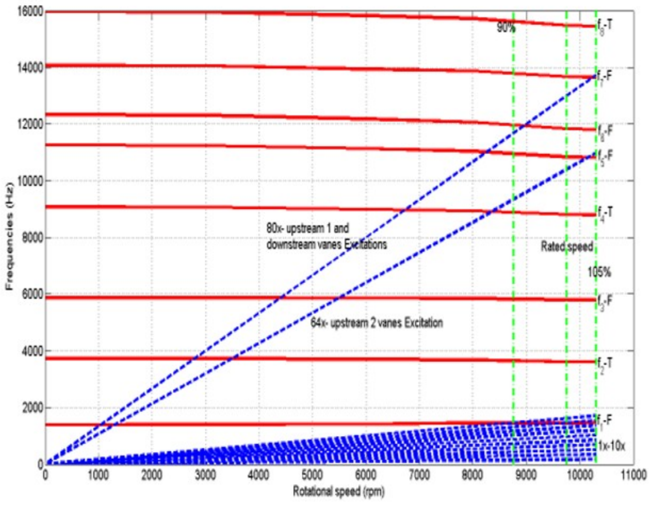


Figure 5: The Campbell diagram to identify potential resonance conditions in the rotor blade by plotting the system's natural frequencies against its rotational speed.

Hot Ambient Solution (HAS) Upgrade for V94.2 & Frame 9 Gas Turbines

My Role Lead Engineer, Turbotec

Associated Publication:

Shahrabi Farahani, A., Kohandel, H., et al. (2024). Power generation gas turbine performance enhancement in hot ambient temperature conditions through axial compressor design optimization. *Applied Thermal Engineering, 236*, 121733.

Objective To increase the power output of existing V94.2 and Frame 9 heavy-duty gas turbines operating in high-temperature environments, where power demand is highest but engine performance typically degrades. The primary goal was to increase the compressor mass flow rate through a minimal-cost "retrofit" design that could be implemented during standard overhauls without affecting plant availability.

Methodology & My Contribution As detailed in my first-author publication, I led a comprehensive design and validation process that followed a multi-stage analytical approach:

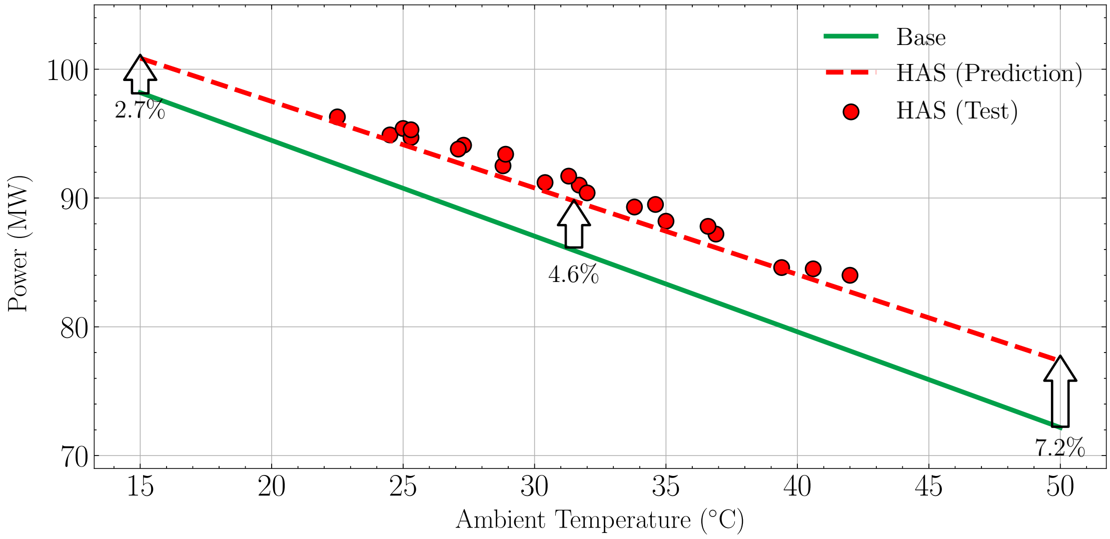
- **Constraint Definition:** I identified critical operating points for the compressors, including high-temperature/IGV-open and low-temperature/IGV-closed scenarios, to ensure stability across the full operational map.
- **1D Mean-Line Analysis & Optimization:** I utilized an in-house optimization tool incorporating a Genetic Algorithm (GA) and an Artificial Neural Network (ANN) to perform a broad search for the optimal stator "re-stagger" angles. The objective was to maximize mass flow while preserving efficiency and stability.
- **Detailed 3D Design:** I implemented the optimized re-staggered vane designs and incorporated advanced 3D features, including **"end-bend" techniques and elliptical leading edges**, to control end-wall flow separation and sustain high efficiency.
- **Structural Analysis & Validation:** I conducted full 3D stress and modal (vibrational) analysis on the new HAS vanes. This included creating **Campbell diagrams** to verify that blade natural frequencies did not interfere with engine excitation frequencies, ensuring structural integrity.
- **First-Article Manufacturing Supervision:** I personally supervised the manufacturing of the first set of redesigned HAS vanes, working with the factory to address production challenges and conducting final inspections to ensure all components met precise design tolerances.

Tools & Technologies Used

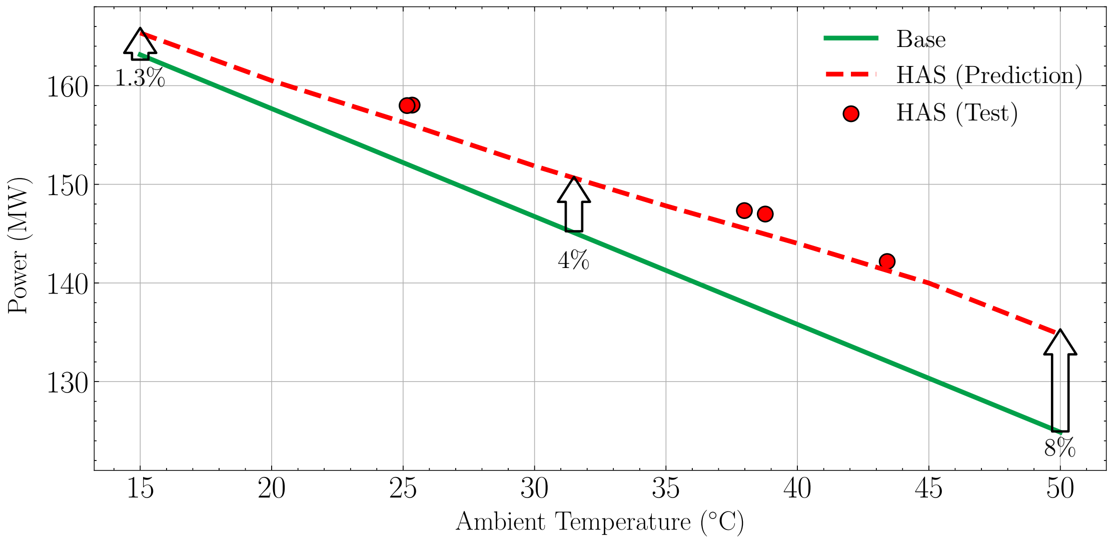
- CFD: ANSYS-CFX, for aerodynamic flowpath optimization.
- FEA: ANSYS Mechanical for blade stress, modal, and Campbell diagram analysis.
- CAD: Siemens NX for 3D geometry and drafting.
- Optimization: Python + AI algorithms for parametric airfoil design
- Preliminary Design : AxStream for conducting 1D Mean-Line Analysis and design.

Results & Impact The HAS upgrade was successfully implemented and validated with field data from the Yazd and Kerman power plants. The project achieved:

- A **9.5% increase in mass flowrate** for the V94.2 turbine at 45°C.
- A **7.0% increase in mass flowrate** for the Frame 9 turbine at 45°C.
- A measured **7.0% to 8.0% increase in gas turbine power output** at hot ambient conditions.



(a) Frame9 Gas Turbine Test Values



(b) V94.2 Gas Turbine Test Values

Figure 6: Comparison of predicted and test values

(a) Manufactured V94.2 HAS stator blades

(b) Manufactured Frame9 HAS stator blades

Figure 7: Manufactured stator blades

Development of an AI-Driven Airfoil Family for Gas Turbine Compressors

My Role Lead Engineer, Turbotec

Associated Publication **Shahrabi Farahani, A.**, Mohammadi, E., & Alizadeh, M. (2023). Utilizing artificial intelligence to develop an advanced compressor airfoil family for industrial, aero-derivative, and heavy-duty gas turbines. *Proc IMechE Part A: J Power and Energy.*

Objective To accelerate the preliminary design phase of new axial compressors by developing a machine learning model capable of generating optimized airfoil profiles based on key performance parameters. The ultimate goal was to create a fast, optimized airfoil generator to replace the time-intensive manual design and optimization process.

Methodology & My Contribution As the first author of the resulting publication, I conceived and executed the entire project workflow:

- **Established an Automated Optimization Package:** I built a system that integrated a parametrized airfoil generator (using Bezier curves), a blade-to-blade flow solver (MISES), and an evolutionary Genetic Algorithm (GA).
- **Created a Comprehensive Design Space:** I analyzed 430 reference airfoils from five different types of industrial, heavy-duty, and aero-derivative gas turbines to define a six-dimensional design space. This space included parameters like Mach number, flow angles, and solidity.
- **Developed a Surrogate Model:** I used an Artificial Neural Network (ANN), trained on a database of airfoil samples, to act as a surrogate model for the computationally expensive flow solver. This dramatically accelerated the optimization process from over a day to approximately ten minutes per airfoil.
- **Validated the AI Model:** The final AI-driven airfoil family was validated by redesigning a complete transonic rotor blade row.A full 3D CFD analysis was then performed to confirm the superior performance of the AI-generated geometry.

Tools & Technologies Used Python (Scikit-learn, TensorFlow), MATLAB, SQL Server, MISES, ANSYS-CFX

Results & Impact The AI-driven design tool successfully reduced the compressor airfoil design process time by 50%. A test case redesign using the new airfoil family demonstrated a 2% efficiency improvement over the original design in 3D CFD simulations.

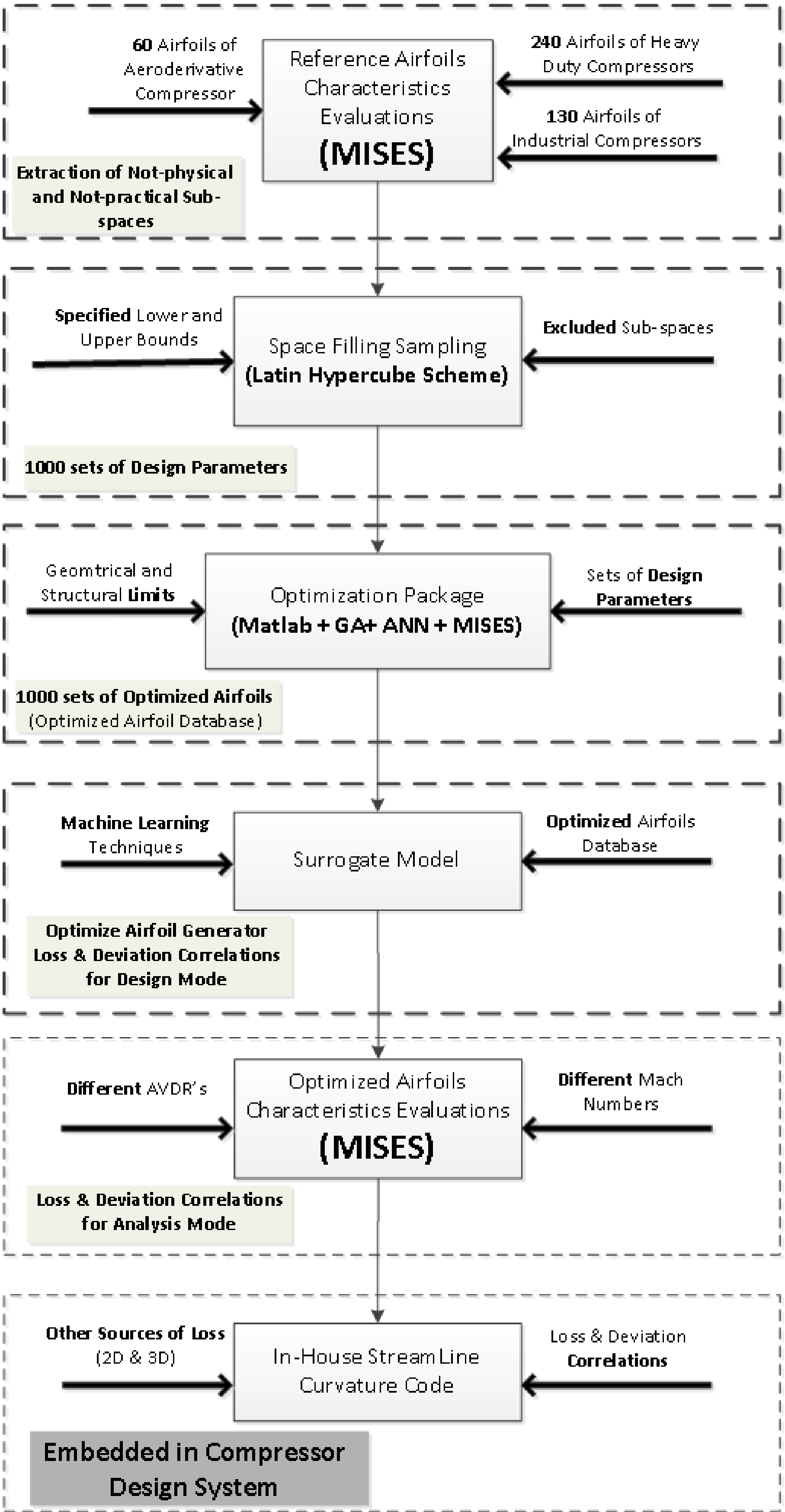


Figure 8: Overall roadmap for the creation of the AI-driven airfoil family, from data extraction to the final embedded design system (Figure from Farahani et al., *J Power and Energy*, 2023)

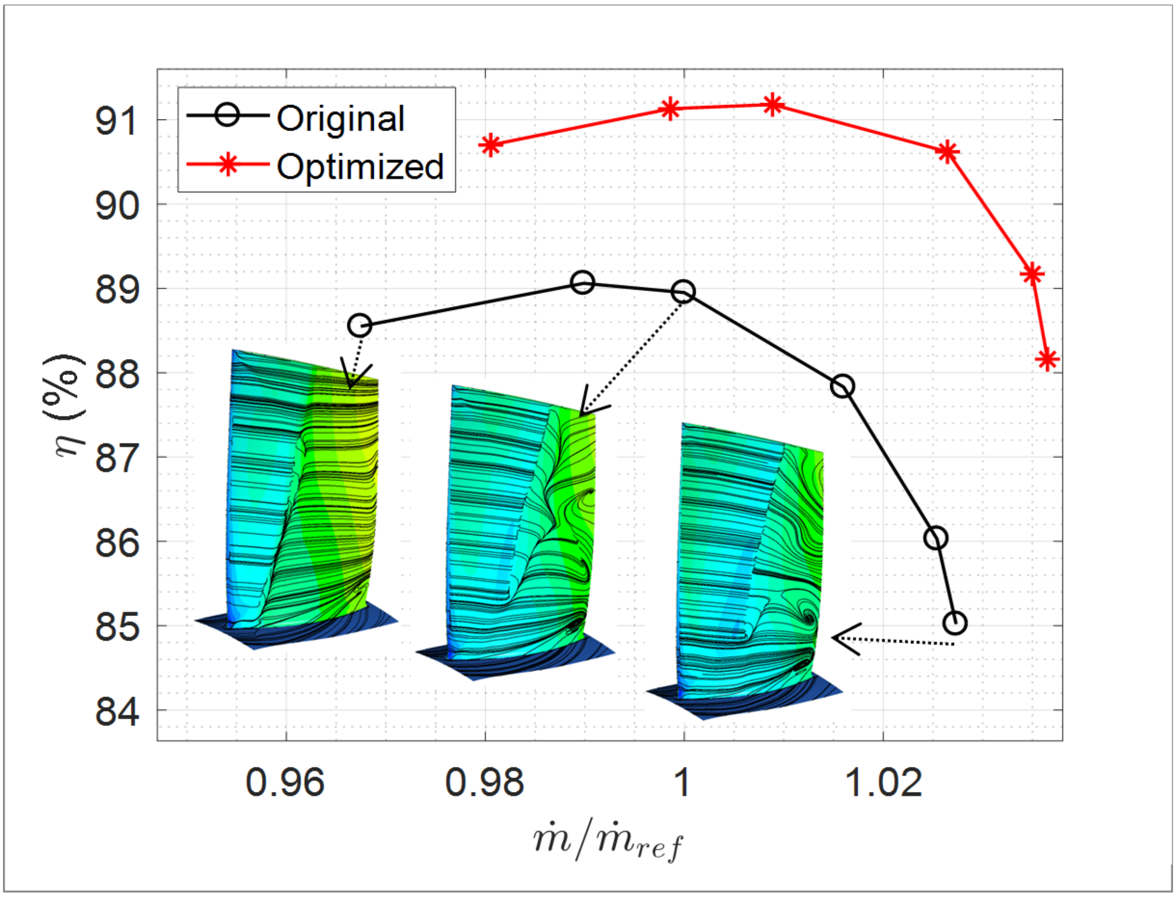


Figure 9: Compressor map for the redesigned transonic rotor, showing a ~2% efficiency improvement for the optimized blade row vs. the original design (Farahani et al., *J Power and Energy*, 2023).

Advanced Aerodynamic and Structural Upgrade of the IGT25 Compressor (IGT25+)

My Role Lead Design & Analysis Engineer, Turbotec

Objective To significantly upgrade the performance of the 10-stage IGT25 industrial gas turbine compressor by increasing mass flow rate and isentropic efficiency, while ensuring the structural integrity and vibrational reliability of all new components under operational loads.

Methodology & My Contribution I was deeply involved in the parallel streams of aerodynamic design and structural validation to ensure a holistic and reliable upgrade.

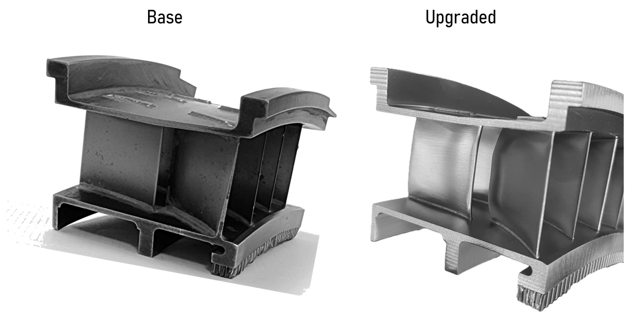
- **Advanced Aerodynamic Design:** I implemented a suite of state-of-the-art 3D aerodynamic techniques to optimize the blade and vane geometries, including **Blade Lean & Sweep**, 3D **Stator Bowing**, **End-Bends**, and a new **Tandem Vane** OGV. The design process was guided by a formal optimization routine to balance performance gains across the compressor's operating range.
- **Rigorous Structural & Vibrational Validation:** I conducted a complete structural verification of the new designs.
  - **Experimental Modal Testing:** I performed physical modal tests on manufactured vanes using impact hammers and accelerometers. This crucial step provided real-world data to validate our material properties and Finite Element models.
  - **Finite Element Model (FEM) Correlation:** I built detailed FE models in ANSYS and correlated the simulation results directly against the experimental test data for various boundary conditions (Free-Free, Clamped-Free, Clamped-Clamped).
  - **Prestressed Modal & Harmonic Analysis:** Using the validated models, I performed prestressed modal analysis to simulate the components under operational loads. This was used to generate **Campbell diagrams** and ensure the redesigned components were free from dangerous resonance.
  - **Iterative Design Feedback:** The analysis identified specific vibrational modes in the initial designs that required modification. This feedback was used to further refine the blade geometries, demonstrating a closed-loop design process.

Tools & Technologies Used ANSYS (CFX and Mechanical), BladeGen, AxCent, MISES, Siemens-NX, Python, MATLAB

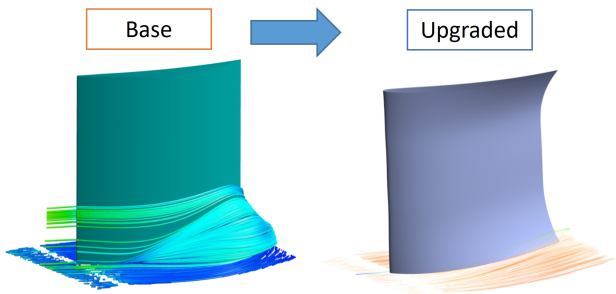
Results & Impact

- The final IGT25+ aerodynamic design achieved a **2.9% increase in mass flow rate** and a **1% increase in the isentropic efficiency** of the critical front stages, contributing to an overall engine power uprate of 5%.
- Successfully validated the structural and vibrational integrity of all redesigned components through a combination of high-fidelity simulation and **direct correlation with experimental test data**, ensuring a safe and reliable upgrade.

Figure 10: Experimental modal test setup for a vane segment used to validate FE models.



(a) Manufactured Base (left) vs. Upgraded (right) stator vanes for the IGT25+ project.



(b) 3D CFD analysis of streamlines on the suction surface. The Upgraded vane shows a significant reduction in endwall secondary flow separation.

Figure 11: Validation of the IGT25+ Stator Vane Redesign: From Hardware to Aerodynamic Performance.