UTSR Summer Fellowship at GE Energy
Gas Turbine Aero Group

NEXT GENERATION GAS TURBINE
(NGGT) AERO RIG

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INTRODUCTION

- In gas turbines applications, CFD plays greater part in the aerodynamic design of turbomachinery than in any other engineering application
  - Shorter design cycles – performance optimization
  - Reduced cost
- GE Energy designed, constructed, and tested a 3-stage power generation turbine rig to validate and verify CFD design tools and methodologies

Fellowship Description

The project involves performing data reduction, data interpretation, and CFD model analysis of a power generation turbine rig
NGGT TURBINE AERO RIG

- 1:5 scale of the turbine from an actual power generation turbine
- Fully cooled rig with 16 independent secondary flow circuits to distribute cooling flows to airfoils, shrouds, wheelspace, etc
- Equipped with multiple sensors to measure pressure (total and static), temperature (total and static), mass flow, torque, and speed.
- Aero similarity maintained through scaling of airfoil rows, trailing edge thicknesses, throats, surface profiles, etc
**OBJECTIVES**

**DATA** – Using the test data collected from the NGGT turbine rig:

- Refine a Matlab script that can be used to determine mixed-out profiles of pressure, temperature, velocity, and swirl at different locations of the flowpath
- Generate contour plots of pressure, velocity, temperature, and swirl

**CFD** – Using current CFD tools and methodologies:

- Run pre-test CFD analysis for all the operating conditions of the NGGT rig test
- Interpret the results given by the pre-test CFD model at the locations of the sensors used in the test
  - Determine mixed-out profiles of pressure, temperature, velocity, and swirl
  - Generate contour plots of pressure, velocity, temperature, and swirl
- Compare the profiles and contour plots with the data
- Update pre-test CFD model to match data to validate and verify the CFD design tools and methodologies
Test data collected by data acquisition system is calibrated and reduced

• Script requests user input to read test data and perform radial and circumferential averaging, define constant variables, and contour limits.

• Script performs a constant area 2D mixing calculation to determine mixed-out profiles
Matlab Output
- Due to proprietary limitations, output plots are generated for illustrative purposes only
- Mixed-out profiles

- Contour Plots
CFD

- TACOMA: In-house 3D CFD program used to solve structured or unstructured grid non-linear and linear Euler/Navier-Stokes equations for turbomachinery blade rows.
- Capable of evaluating mixed-out profiles and contour plots at any location of the flowpath

CFD Output

- Mixed-out profiles

- Contour Plots
DATA Vs. CFD

• Mixed-out profiles

• Contour Plots
RESULTS

- **Mixed-out profiles**
  - **Pressure profile** – shows a similar relationship between both cases; however, there are some discrepancies at the hub and tip of the airfoil.
  - Differences might be caused by shock losses due to secondary and/or cooling flows, which could be captured differently between the data and the CFD model.
  - **Temperature profile** is significantly different, which suggests that it’s due to source term modeling.
  - Pre-test CFD program needs to be updated with correct flow levels, boundary conditions, source terms, and post-test configurations.

- **Contour Plots**
  - Use different frames of reference. Hence, plots do not portray the same information
  - Similar characteristics

- **Future work** - Redefine source term modeling and boundary conditions in TACOMA to match the secondary and cooling flows. The expectative is to match the CFD to the data and set a CFD model benchmark to be used for future gas turbine designs.
AIRFOIL SURFACE FINISH

- CFD – Capable of modeling surface roughness but set-up to assume smooth airfoils
- SURFIN – Computer-aided tool that estimates surface roughness effects much faster than CFD

Objective: Perform a surface finish analysis of turbine airfoils for the NGGT rig using a computer-aided tool (SURFIN)

SURFIN Program Concept:

- Design tool for estimating the effects of surface finish on airfoil performance
- Calculates surface roughness (RMS) – Causes increase in drag generating efficiency losses
- Determines Hydraulically Smooth point – Max. RMS that causes no losses
**SURFIN Results:**

- Airfoils need to be polished to an RMS equal to the Hydraulically Smooth point.
- If the manufacturing process can’t produce such RMS, then it is necessary to know how much efficiency is lost to adjust the CFD performance estimate.
- For instance, given a measured RMS of $x$, the loss in efficiency corresponds to $y$ points in the bladerow efficiency.
- Typically, a small decrease in the overall turbine efficiency can increase the operating cost of an engine by thousands of dollars per hour.
CONCLUSION

- The developed 1:5 scaled prototype of an actual power generation turbine and its instrumentation demonstrated good response to the testing operating conditions and were able to generate the data necessary to conduct research and validate and verify the advanced 3D CFD design tools and methodologies used to design gas turbines. Refine a Matlab script that can be used to determine a mixed-out profiles of pressure, temperature, velocity, and swirl at different locations of the flowpath.

- The analyzed data and pre-test CFD solution depict discrepancies that can be attributed to the modeling of source terms, boundary conditions, shock losses, leaks, pre-test assumptions, and other phenomena. Hence the need to update the pre-test CFD model to validate it and provide a 3D CFD model benchmark.

- Due to proprietary limitations, not all the work that was performed on the NGGT turbine aero rig or other projects could be discussed.

- The UTSR Fellowship is an excellent program for all students with interest in the gas turbine industry. The experiences learned through the 10-12 week program can only be learned in an industrial work environment such as the one provided by the UTSR Industrial Sponsors.