University Turbine Systems Research Fellowship

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Summary

- MATLAB Script
- Part-Span Shroud Cascade
  - ICEM Meshing
  - Pressure Ratio Sweep
- Phase I Rig
  - Tip Clearance
  - Reynolds Number

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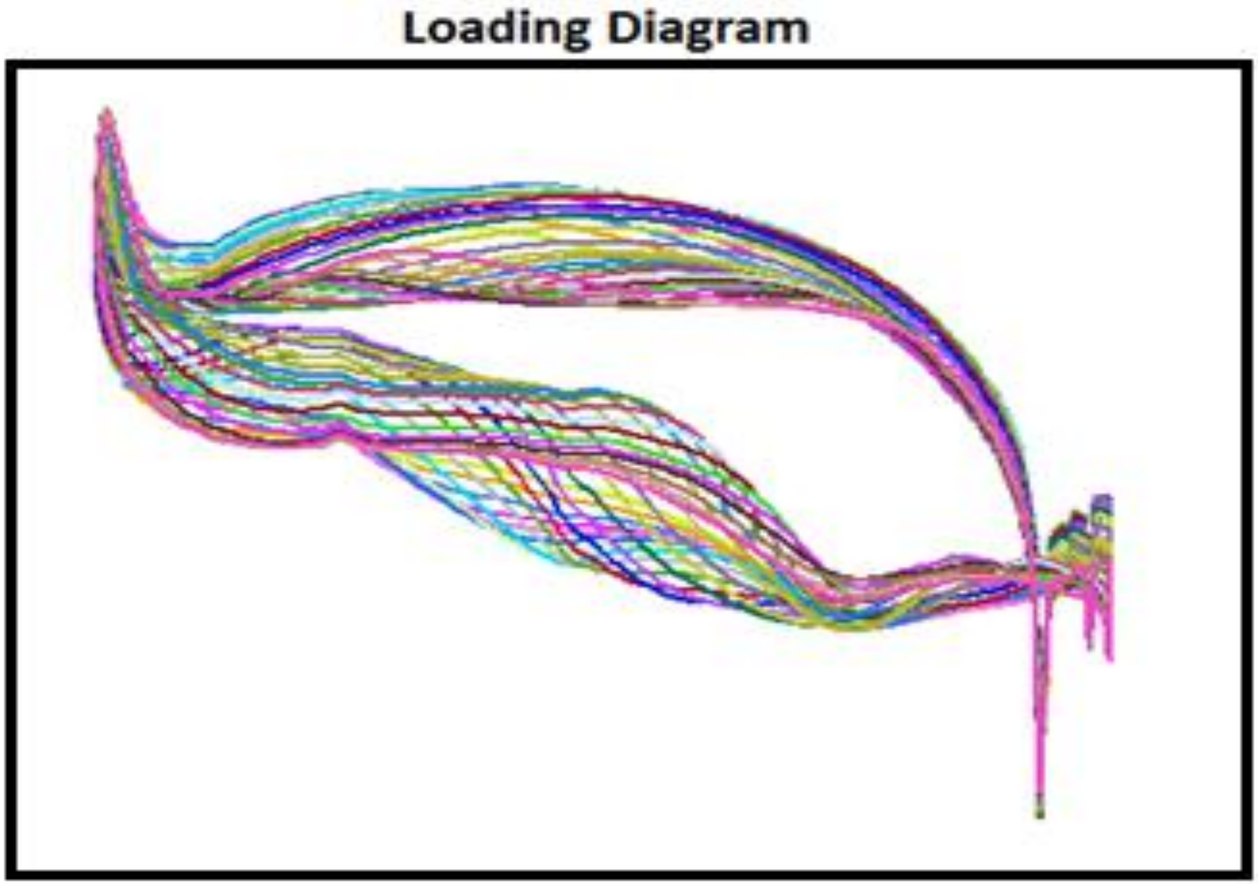
MATLAB Script to Plot Transient Loading

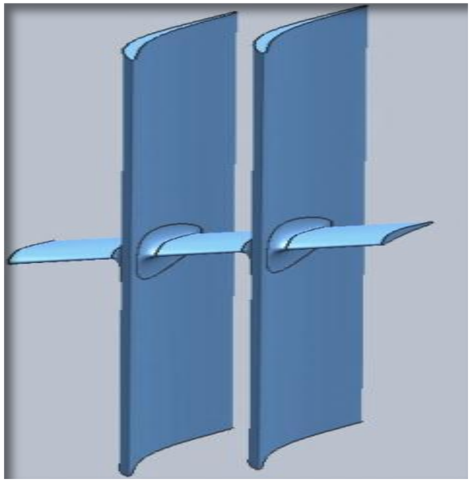
- A MATLAB script was developed to plot transient loadings at different spans
- Data files from CFD at each time step were read in for one specific span
- Code needs to be generalized and more user friendly

MATLAB Script Output

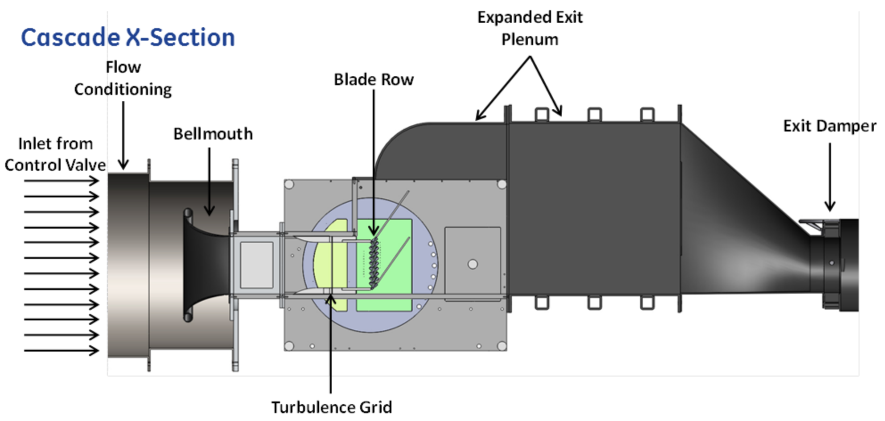


Part-Span Shroud (PSS) Cascade

- PSS used in steam turbine last stage buckets
- ICEM meshing techniques of 2D cross-section
- Contour plots of PSS and no PSS



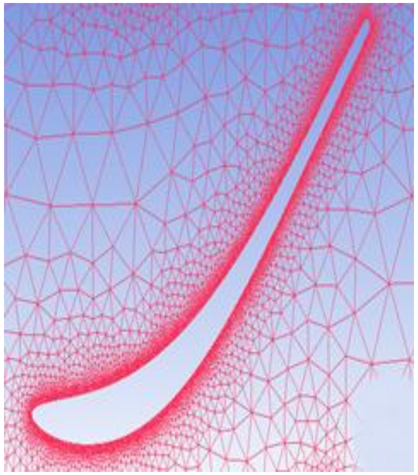
PSS connecting two buckets



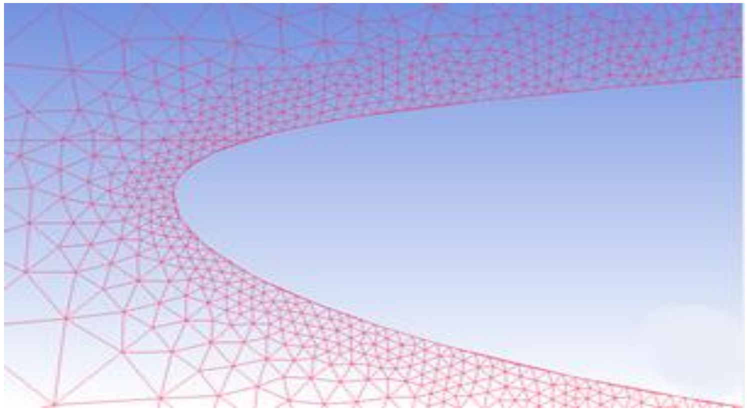
Test Rig Set-Up

ICEM Meshing Techniques

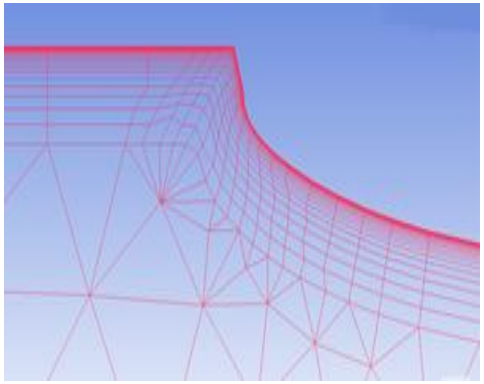
- Meshed a 2-D cross-section of the whole PSS rig
- 2-D tet mesh (unstructured grid) needs finer resolution around airfoil to accurately reflect the curved geometry
- Prism mesh (structured grid) should be along surfaces to capture boundary layer
- High mesh resolution around airfoil made it difficult to add prism mesh



Fine mesh around airfoil



Close-up of high mesh resolution around leading edge



Prism mesh on boundary surface

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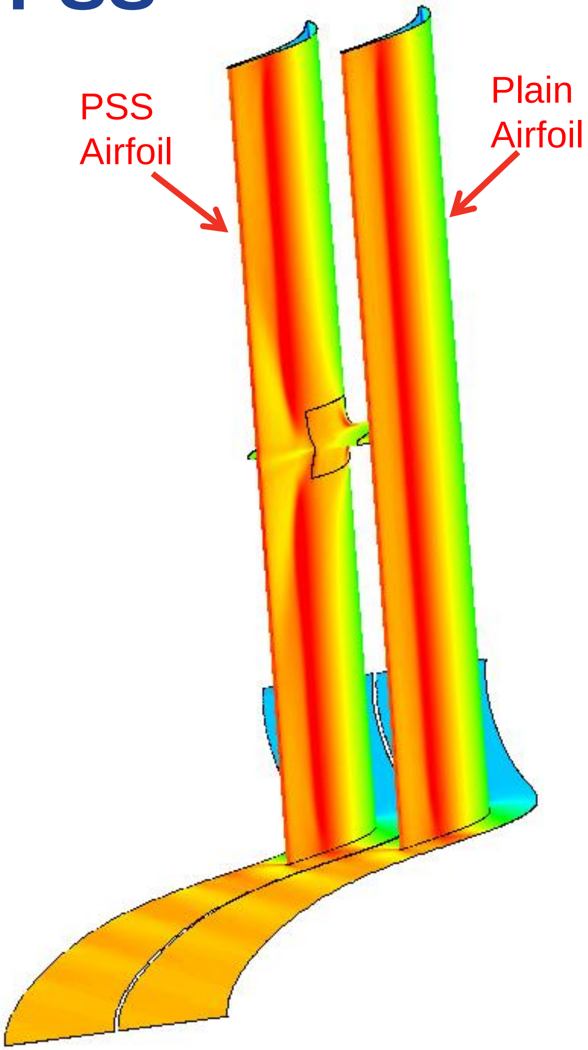
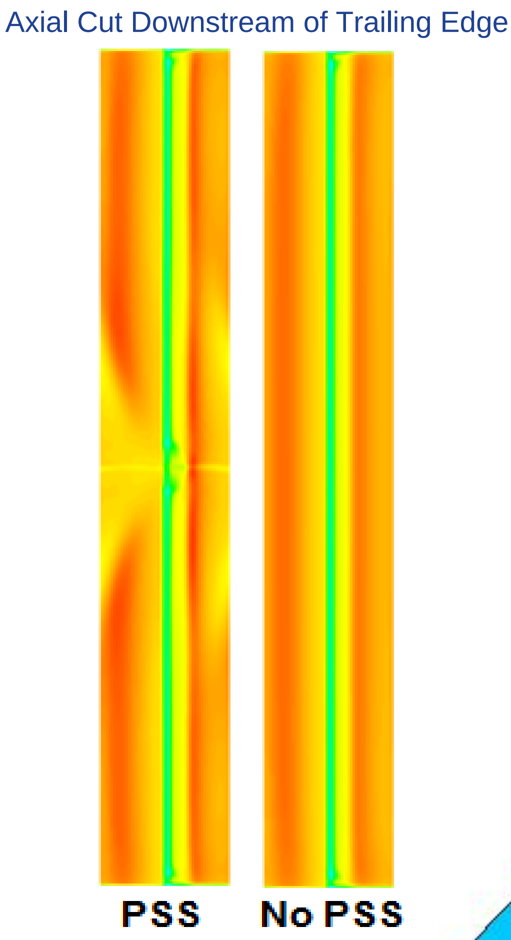
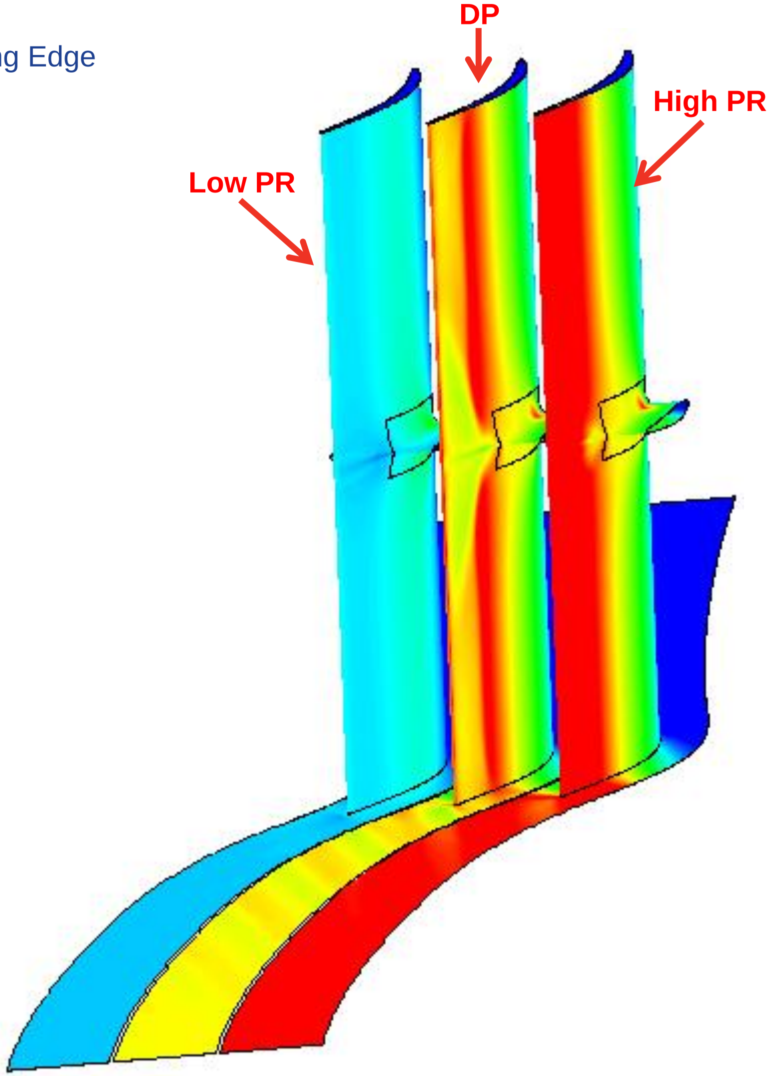
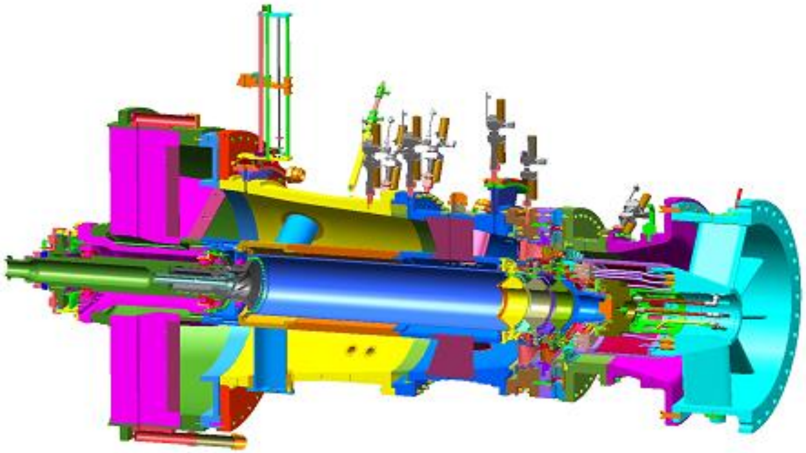
Contour Plots of Mach Number Show Effects of PSS



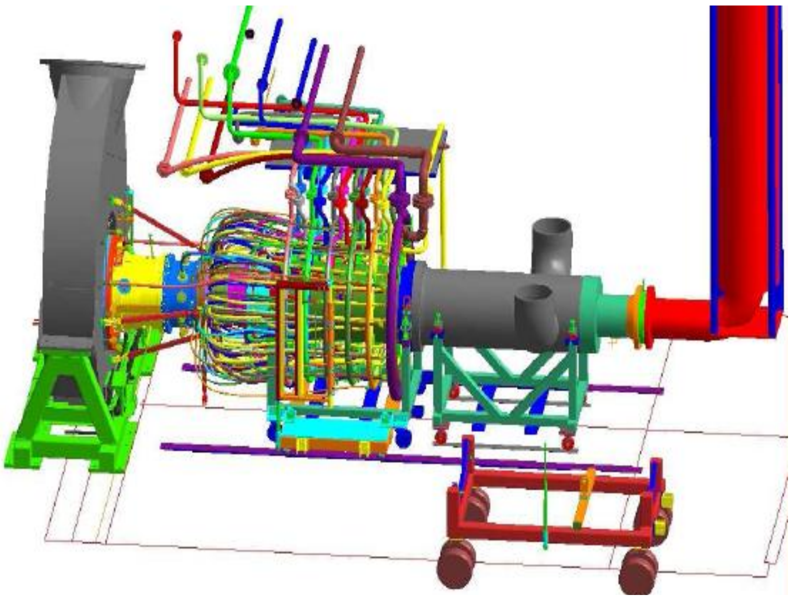




NGGT Phase I Rig



- Phase I Rig is $1/5^{th}$ scaled model of the 7FB engine
- Rig is used to study turbine only
- Cooling circuits simulate secondary flow



- Rig data is used to validate CFD
- Tip Clearance and Reynolds number sensitivity studies show variations between data and CFD

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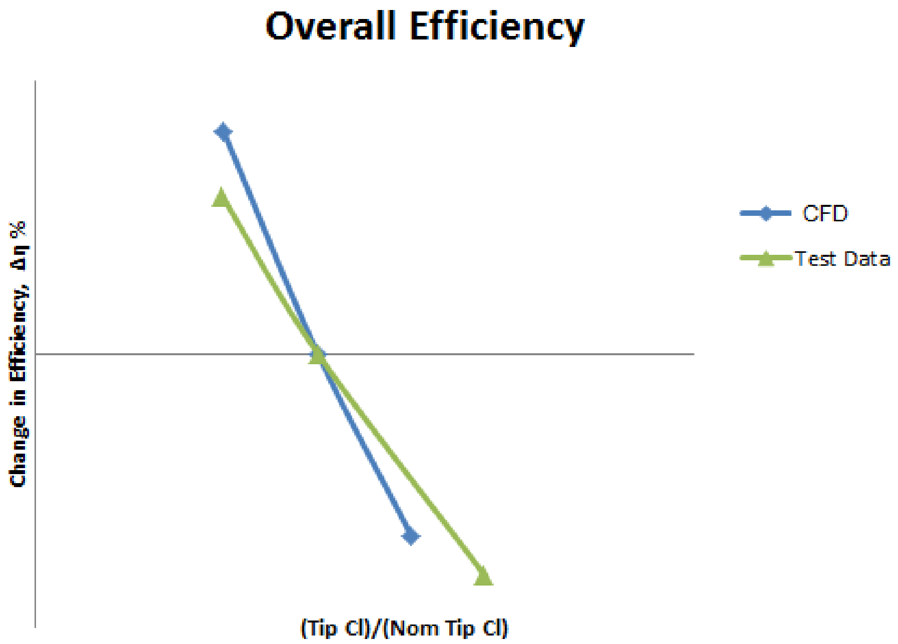
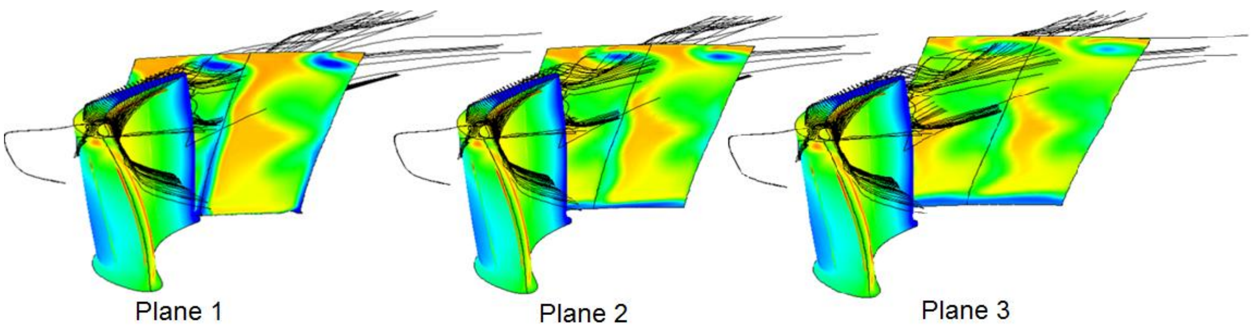
Tip Clearance Sensitivity Study

- Tip clearance was varied around a design point to study effects on performance
- Rig test data was compared with results from CFD
- Squealer tip geometry was compared to flat tip geometry and rig data

Performance Effects

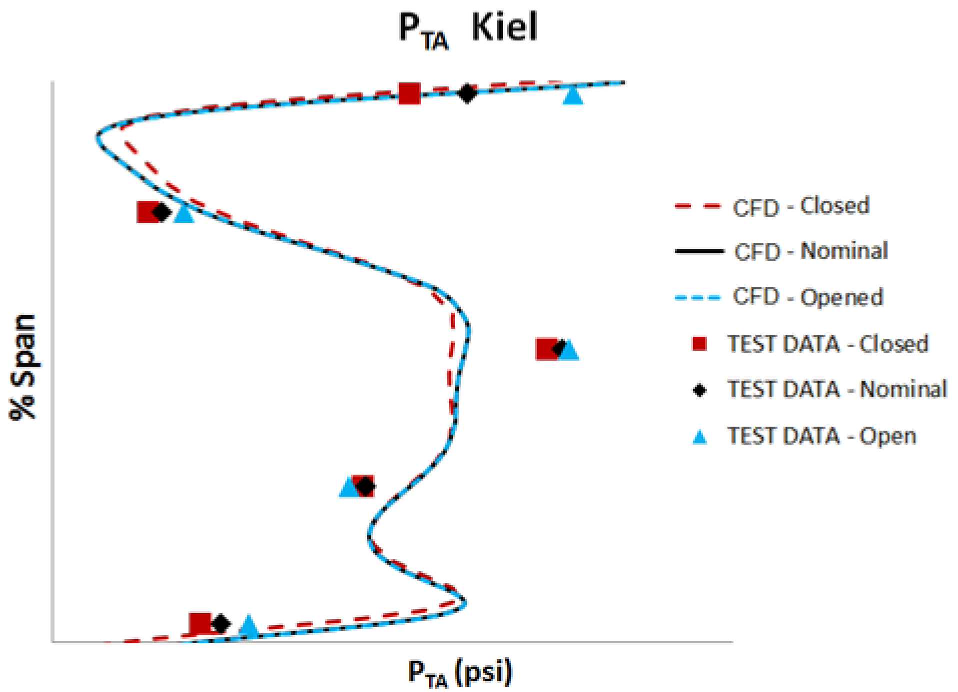


- Performance decreases as tip clearance increases
- CFD is more pessimistic than rig test data
- Streamline contour plots show low pressure vortex from leakage flow
- Vortex eventual mixes out downstream but still contributes to loss



Rig Data vs CFD

- A traverse probe measures total pressure and temperature continuously along the radial direction
- Kiel heads measure the total pressure and temperature at discrete points on the leading edge of an airfoil.
    - Data matches CFD fairly well at kiel head locations



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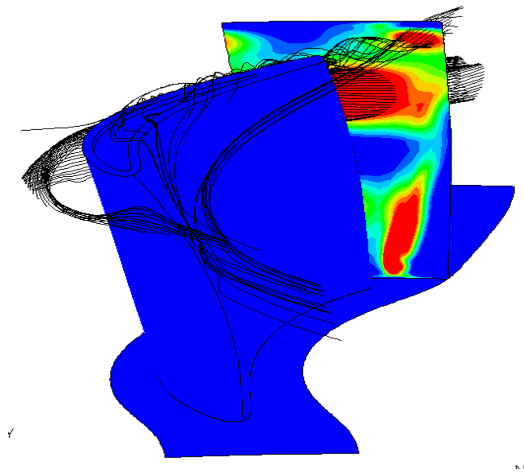
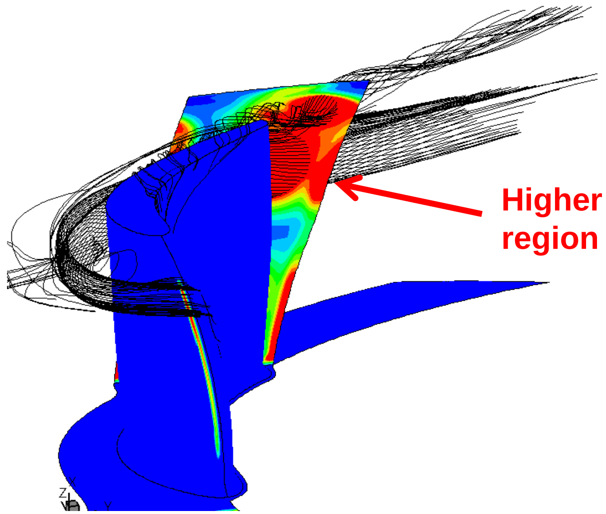
Squealer Tip Geometry

- Flat tip buckets are modeled in CFD for simplicity
- Squealer tip is actual geometry
  - Reduces over tip leakage
- Loss is seen in the streamline plots (below)
  - Flat tip shows a stronger vortex from flow leaking over the tip meaning higher loss

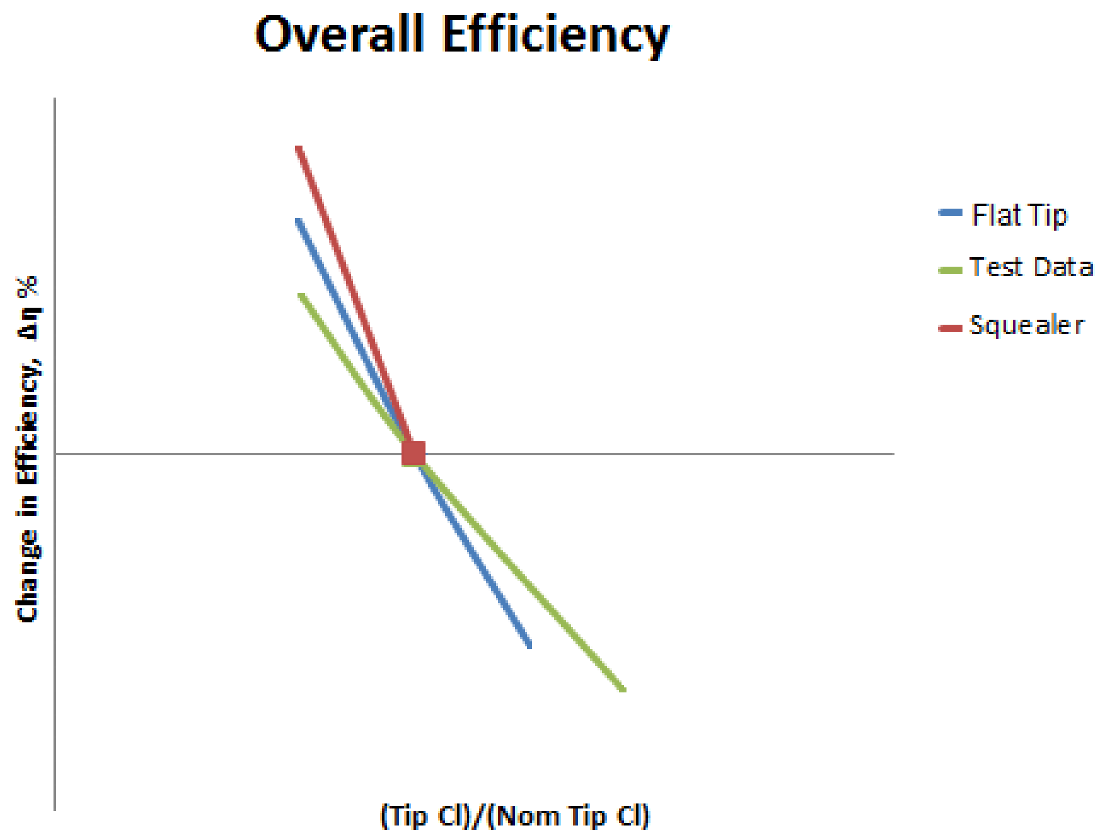


Squealer Tip



Flat Tip

Performance Effects

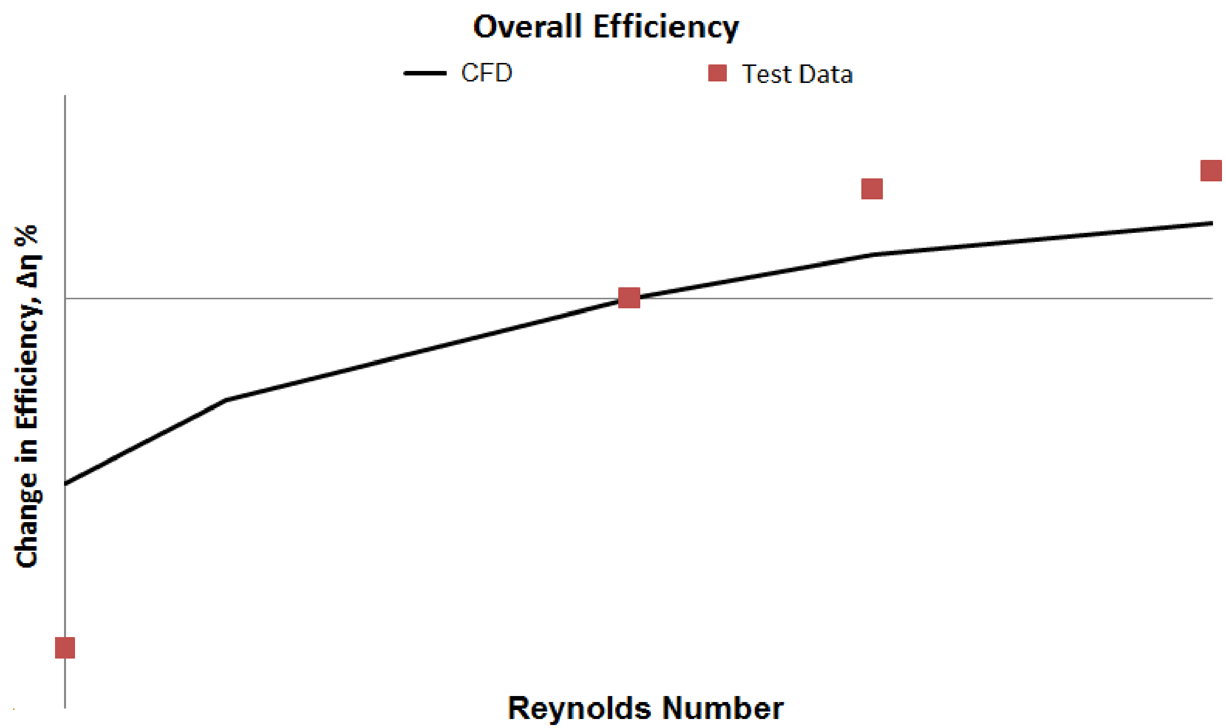


- Squealer tip case has a steeper slope meaning a more drastic effect on performance when varying tip clearance.
- Problem could be grid related. One grid might be higher res than the other.
  - Next step: Run same type of grid for both flat tip and squealer tip

Reynolds Sensitivity Study

- Scaled source terms and kept same pressure ratio
- Ran each case with a fully turbulent model
- Checked to make sure loading diagrams were the same for each change in Reynolds number
- Plotted a performance curve with test data and CFD

Performance



- Efficiency increases as Reynolds number increase
- Test data matches CFD fairly well near the design point, but drops off at low Reynolds number
- Next step: Run transition model at rig and engine Reynolds numbers

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Conclusions

- MATLAB script will be used to plot transient loading diagrams
- Part-Span Shroud Cascade
  - ICEM meshing techniques used to create an unstructured grid of a 2D cross-section
  - Pressure ratio sweep shows how Mach number changes around a part-span shroud
- Phase I Rig
  - Tip clearance study conveys that a larger tip gap will increase over tip leakage and decrease efficiency
  - Reynolds sensitivity shows an increase of performance at higher Reynolds numbers

Acknowledgements

Special thanks to:

- UTSR Program for allowing me to work in the gas turbine field
- Gunnar Siden, Sylvain Pierre, Neil Ristau and the Turbine Aero team at GE for their mentorship
- US Department of Energy for investing in the UTSR fellowship program

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