Experimental Validation of Optimized Designs for Cooling in Gas Turbine Blades

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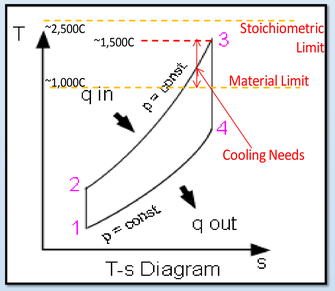
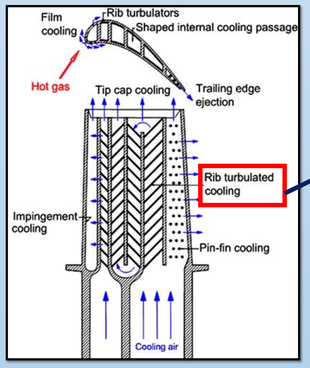
Introduction

- **Turbine inlet temperatures** are typically on the order of **1500-1700°C.**
- **56°C increase** in inlet temperature→ 13% increase in power output or 4% in simple cycle efficiency.



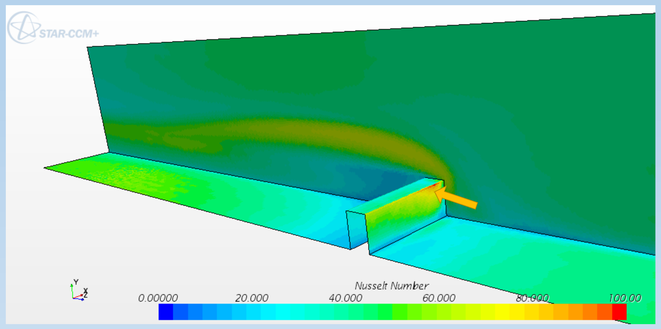
- Material Advancements → 4°C/year
- Cooling Technology Advancements → 11°C/year
- Revolutionary cooling techniques: jet impingement, pin fins, and **rib turbulators.**

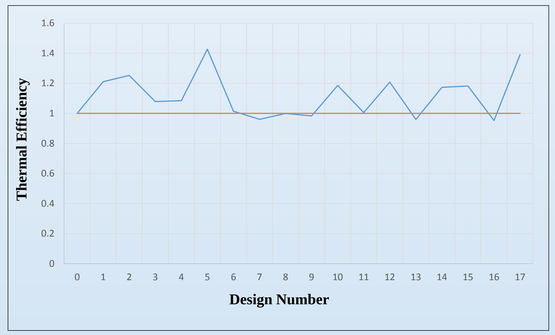


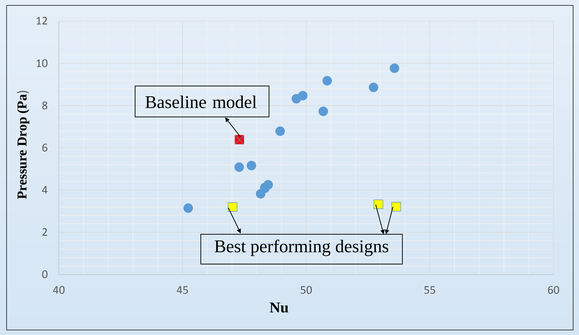
Area of focus

Optimization

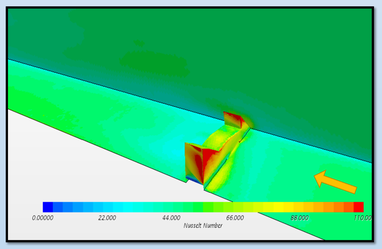
- Baseline model: Rectangular single rib.
- Optimate+ was used to optimize the baseline model.

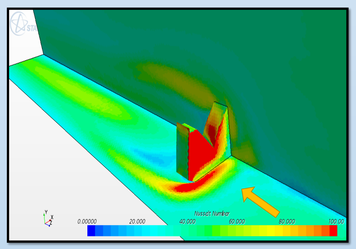


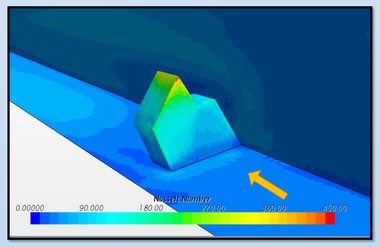




- A total of **17 optimized models** were obtained. Thermal efficiency, Nusselt number, and pressure drop for each optimized model was compared to that of the baseline model
- **3 best performing designs**: High thermal efficiency, high Nusselt number, and low pressure drop





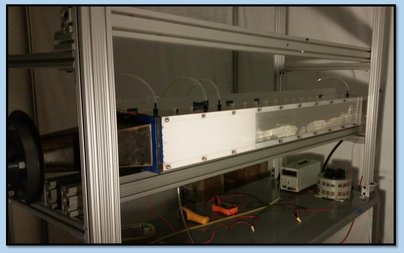


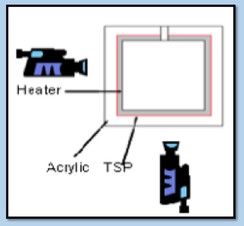
Experimental Set-Up

- The 3 best designs were 3D printed due to required precision and low tolerances.

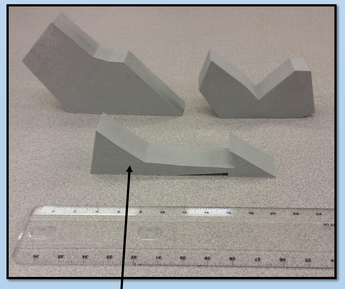
Wind Tunnel Set-up:

- To validate the computational analysis, a wind tunnel was built to meet the needs of the experiment.
- The test section has dimensions of 0.12 x 0.2 m. It had to be modified to allow heating capabilities to test the thermal efficiency.





- Cameras are used to measure the temperature across the channel by impregnating the wall of the tunnel with Temperature Sensitive Paint (TSP). Heat was applied by using strips of Inconel attached to the wall, and a current was passed through the metal to achieve temperatures ranging from 90°C to 100°C.
- Thermal imaging of the tunnel was captured using special cameras to compare results from the computational analysis.

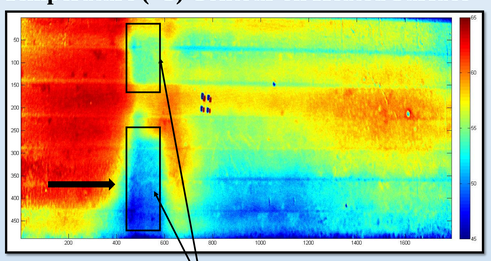


Optimized model currently tested in the wind tunnel

Results

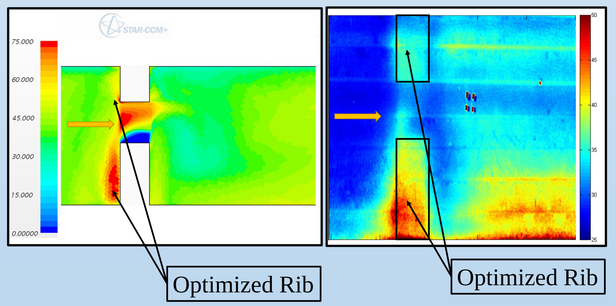
- Velocity at inlet = 7.27 m/s.
- Reynolds number (Re) = 72954.29
- Pressure drop = 9.95 Pa

Temperature (°C) Contour on Heated Surface



Optimized Rib

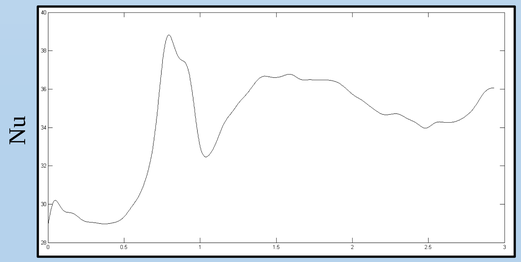
Nusselt Number Contour on Heated Surface



Optimized Rib

Optimized Rib

Spanwise Average Nusselt number



Conclusion

Experimental and Computational Comparison

- Further testing needs to be performed to validate computational results

Optimized Design Characteristics

- Side pockets
- Non-continuous rib

These characteristics help the flow to circulate, thus enhancing heat transfer.