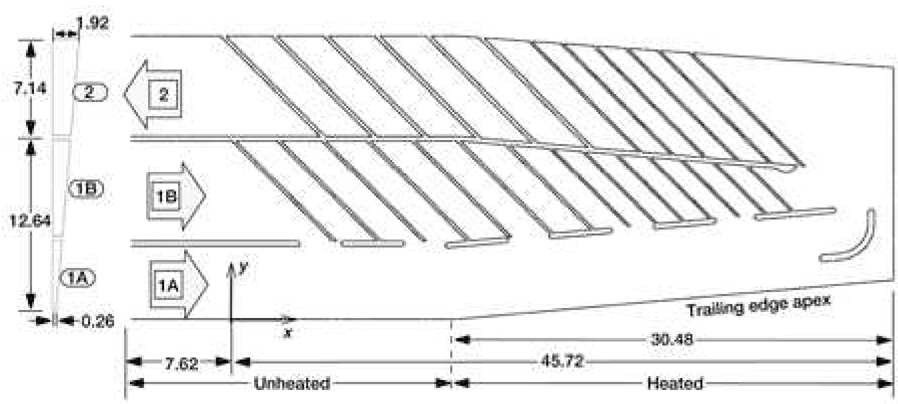
Glenn-HT Code Validated for Complex Turbine Blade Cooling Passage

This work is motivated by the need to accurately predict heat transfer in turbomachinery. For efficient gas turbine operation, flow temperatures in the hot gas path exceed acceptable metal temperatures in many regions of the engine. So that the integrity of the parts can be maintained for an acceptable engine life, the parts must be cooled. Efficient cooling schemes require accurate heat transfer prediction to minimize regions that are overcooled and, even more importantly, to ensure adequate cooling in high-heat-flux regions.

A numerical study validated the predictive capabilities of the Glenn-HT code in complex turbine blade cooling passages. Simulation results were compared with experimental data made available by the General Electric Global Research Center. The geometry consists of a two-pass serpentine passage that tapers toward the trailing edge, as well as from the hub to the tip (see the following sketch). The upflow channel has an average aspect ratio of roughly 14:1, whereas the exit passage aspect ratio is about 5:1. The upflow channel is split in an interrupted way and is smooth on the trailing edge side of the split and turbulated on the other side. A turning vane is placed near the tip of the upflow channel. Reynolds numbers ranging from 31 000 to 61 000, based on inlet conditions, were simulated numerically.



Schematic of geometry showing flat lower surface and inlet cross section. All dimensions are given in centimeters.

Long description of figure 1 Schematic of geometry showing flat lower surface and inlet cross-section (dimensions are in centimeters). The passage is characterized by two inlet sections whose channels are separated by an interrupted rib. After a 180-degree turn, the flow passes through a single return channel. The entire model decreases in height from the hub to the tip and also from the exit channel side to the inlet side. There are turbulators located on the upper and lower surfaces oriented at 45 degrees to the flow direction.

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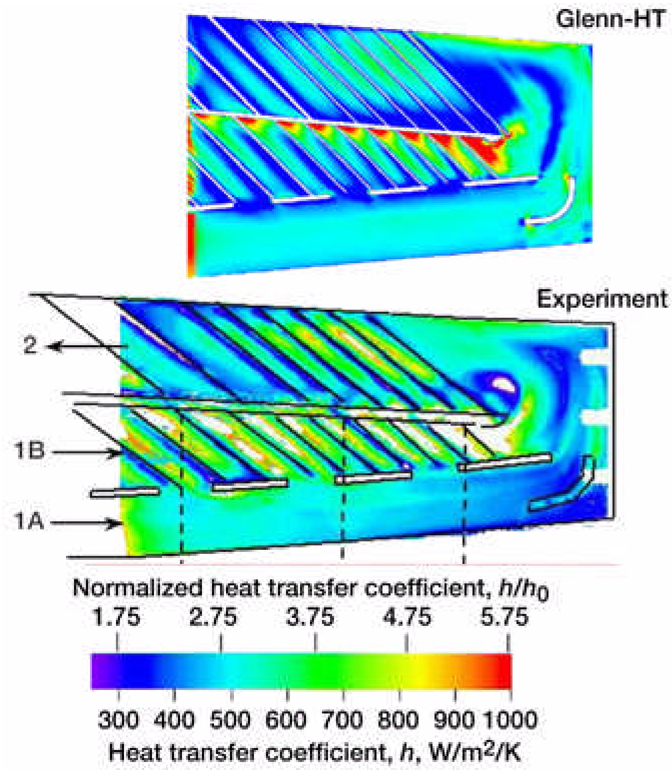
The simulation was performed at the NASA Glenn Research Center using the Glenn-HT code. The Glenn-HT code is a full three-dimensional Navier-Stokes solver using the Wilcox k-ω turbulence model. It has evolved over the years into a highly accurate, robust research tool with over 40 papers published relative to the code and its application. A structured multiblock grid is used with approximately 4.5 million cells. Pressure and heat transfer distributions compare well between the simulation and the experimental data. Although there are some regions with discrepancies, in general the agreement is very good for both pressure and heat transfer.



Heat transfer coefficient on flat lower surface; comparison between the Glenn-HT simulation and the experimental results.

The preceding figure compares the heat transfer predicted by Glenn-HT with the experimental results. Qualitatively, the comparison is very good. High heat transfer is observed between the turbulators, as expected. In addition, the low streak emanating from the tip of the split between passages 1A and 1B is closely matched. Very high values after the final rib in passage 1B, as well as the low region around the tip of the split between passages 1B and 2, are visible in both the experiment and simulation.

Find out more about the research of Glenn’s Turbine Branch
http://www.grc.nasa.gov/WWW/TURBINE/Turbine.htm.

References

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2. Rigby, David L.; and Bunker, Ronald S.: Heat Transfer in a Complex Trailing Edge Passage for a High Pressure Turbine Blade. Part 2: Simulation Results, NASA/CR--2002-211701, 2002.

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