AEROTHERMAL INVESTIGATION OF TURBINE TIP GAP FLOWS

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The tip leakage flow through the tip gap of a turbine rotor blade is a source of high heat transfer rates. This project is focused on local heat transfer investigations on the flat and squealer blade tip surfaces. The originality of the project comes from the transonic exit Mach numbers. Heat transfer measurements are performed for 16 different cases: different Reynolds number (450,000 and 900,000), exit Mach number (0.9 and 1.1), turbulence intensity (1% and 5%), tip geometries (flat and squealer).

The VKI CT-2 facility is used with a 4-bladed linear cascade. Double layer thin film gauges are instrumented on the blade tip surface as shown in Figure 1. Gauge calibrations are performed. Thermal properties of two layers as well as the first layer thickness are determined by an optimization loop. Flow downstream periodicity is verified and the thermal boundary layer is determined experimentally.

A common question arising in the literature is the validity of the cascade experiments for the tip studies since there is a relative rotation of the shroud with respect to the rotor in the real conditions. This rotation is simulated using CFD and it is found that the tip loading and the surface pressure distribution are similar for non-rotating case, although the magnitudes are altered. Oil dot flow visualizations are enhanced with streamlines computed using CFD, and the flow field is investigated in detail. Streamlines for squealer tip geometry are shown in Figure 2. The static pressure prediction capability of RANS is very well acceptable. It was found that the path lines play an important role in determining the local heat transfer regions besides the flow parameters and the tip geometry.

Heat transfer measurements are performed for flat and squealer tip geometries. Effects of exit Mach number, Reynolds number and turbulence intensity are investigated. Different heat transfer regions are found on the blade tip. Squealer tip geometry exhibited lower maximum heat transfer rates than the flat tip as shown in Figure 3.

One of the main aims of the experimental investigation is to provide reliable data for the CFD calculations. A reliable test case is an outcome of this project. Preliminary CFD computations were performed and compared with the measurements. CFD is capable of determining the heat transfer regions qualitatively, but the predictions do not match quantitatively. A preliminary tip cooling design is suggested for the future film-cooled tip heat transfer studies.

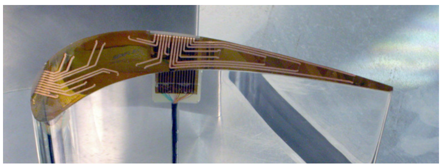

Figure 1. Tip surface instrumentation

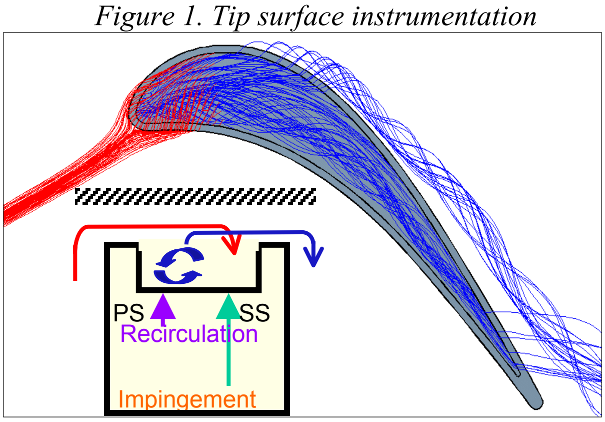

Figure 2. Squealer tip front part streamlines

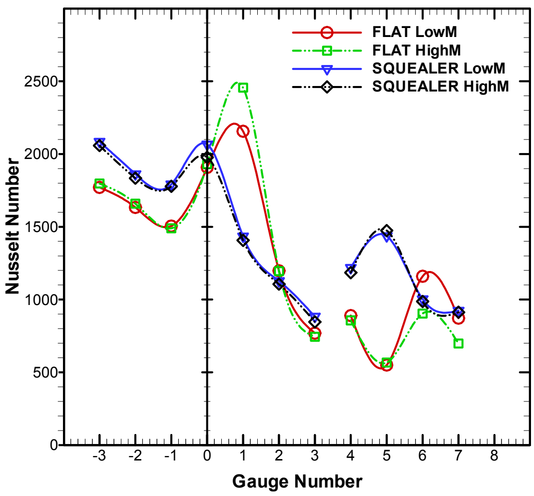

Figure 3. Nusselt number distribution of flat and squealer tip geometries for High Re and Low Tu case