FILM COOLING AND HUB DISK LEAKAGE FLOW EXPERIMENTS IN A FULLY ROTATING TRANSONIC TURBINE STAGE

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Continuous increases in the specific work and cycle efficiency of gas turbine engines are achieved through higher turbine inlet temperatures. Preserving an adequate life at these high temperatures requires efficient cooling methods. In high pressure turbine stages cold flow is ejected from the cavity that exists between the stator rim and the rotor disk, in order to avoid hot gas injection into the wheel-space cavity. The cold cavity flow is mostly entrained into the rotor hub vortex, leaving the platform directly exposed to the hot gas. Therefore some portions of the rotor platform remain unprotected, resulting in high thermal and mechanical stress buildup at the hub platform. Active platform cooling on those regions and on the fillet trailing edge is required.

The aim of this thesis is to study the hub disk leakage and rotor platform cooling aero thermal impact on a transonic turbine stage under engine representative condition. Experiments have been carried out at the VKI compression tube facility CT3, at M_{2is}=1.1, Re 10^6, reproducing the temperature ratios of engine conditions. A complex secondary air system has been designed in order to feed the cooled turbine (Figure 1). The hub disk leakage and platform cooling blowing ratios have been varied independently in order to assess their impact individually. The stator has been instrumented at rim and hub allowing the aero-thermal characterization of the purge flow. The rotor blade has been heavily instrumented at the platform, 7% and 15% of the blade height with fast response pressure sensors and double-layer thin film gauges.

The stator-rotor interaction is particularly affected by the stator rim cavity flow both in terms of heat transfer and pressure fluctuations. The flow exchange between the rotor disk cavity and the main stream passage is found to be imposed by the vane shock patterns. Such results should help us to redesign the stator rim geometry to minimize the amount of wheel-space coolant ejected. The effect of the platform cooling is restricted to the platform with negligible effects on the blade suction side. The platform cooling results in a clear attenuation of pressure pulsations at some specific locations.

A three dimensional steady CFD analysis was performed modeling the purge flow cavity existing downstream of the stator blade row. Several calculations were considered, evaluating the effect of purge flow ejected or ingested into the wheel space cavity as well as different pressure ratios. Static pressure measurements at the hub and tip 4%Cax downstream of the stator, as well as relative total pressure measured at 15%, 50%, 85% of the rotor blade span, are compared with the computational results, showing general agreement. The interaction between the vane shock structures and the purge flow has been studied and quantitatively characterized as function of the purge rate ejected. An ejection of purge flow as 1.5% of the core flow leads to an increase of the hub static pressure downstream of the vane of approximately 7%. This effect contributes to move the vane trailing edge shock upstream, decreasing the trailing edge loss in transonic turbine blades. The experimental and CFD results show an increase in the turbine performance compared to the no rim seal case (Figure 2). The presented results should help designers improve the protection of the rotor platform while minimizing the amount of coolant used.

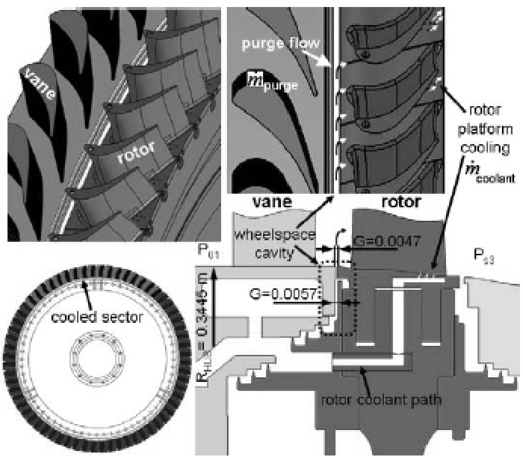

Figure 1: Turbine stage and rotor platform coolant path

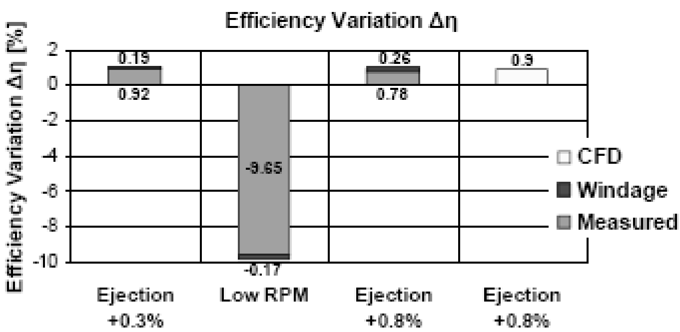

Figure 2: Measured turbine efficiency path