## EFFICIENCY OF A HP TURBINE TESTED IN A COMPRESSION TUBE FACILITY

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Highly loaded single stage gas turbines are being developed to minimize the turbine size and weight. Such highly loaded turbines often result in transonic flows, which imply a reduction in the efficiency due to the shock losses. The efficiency of a turbine is defined as the ratio between the real work extracted by the turbine rotor from the fluid and the maximum available enthalpy for a given pressure ratio. The relationship between turbine performance and design parameters is not yet fully comprehended due to the complexity of the flow field and unsteady flow field interactions. Hence, experimental and numerical studies remain necessary to understand the flow behavior at different conditions to advance the state of the art of the prediction tools.

The purpose of the current research is to develop a methodology to determine the efficiency with an accuracy better than 1 % in a cooled and uncooled high pressure (HP) turbine tested in a short duration facility with a running time of about 0.4s. Such low level of uncertainty requires the accurate evaluation of a large number of quantities simultaneously, namely the mass flow of the mainstream, the coolant, and leakage flows properties, the inlet total pressure and total temperature, the stage exit total pressure, the shaft power, the mechanical losses and the heat transfer.

The experimental work is carried out in a compression tube facility that allows testing the turbine at the temperature ratios, *Re* and Mach numbers encountered in real engines. The stage mass flow is controlled by a variable sonic throat located downstream of the stage exit. Due to the absence of any brake, the turbine power is converted into rotor acceleration. The accurate measurement of this acceleration as well as those of the inertia and the rotational speed provides the shaft power. The inertia of the whole rotating assembly was accurately determined by accelerating and decelerating the shaft with a known energy. The mass-flow is derived from the measured turbine inlet total pressure and the vane sonic throat. The efficiency of a HP turbine tested in a compression tube facility in turbine sonic throat was evaluated based on a zero-dimensional model of the turbine.

The efficiencies of two transonic turbines are measured at design and off-design conditions. The turbine design efficiency is obtained as 91.8 %. The repeatability of the measurements for 95% confidence level varies between 0.3 % and 1.1 % of the efficiency depending on the test case. The theoretical uncertainty level of 1.2 % is mainly affected by the uncertainty of exit total pressure measurements. Additionally, the effect of vane trailing edge shock formations and their interactions with the rotor blade are analyzed based on the experimental data, the numerical tools and the loss correlations. The changes of blade and vane performances are measured at mid-span for three different pressure ratios which influence the vane and rotor shock mechanisms. Moreover, the unsteady forces on the rotor blades and the rotor disk were calculated by integration of the unsteady static pressure field on the rotor surface.

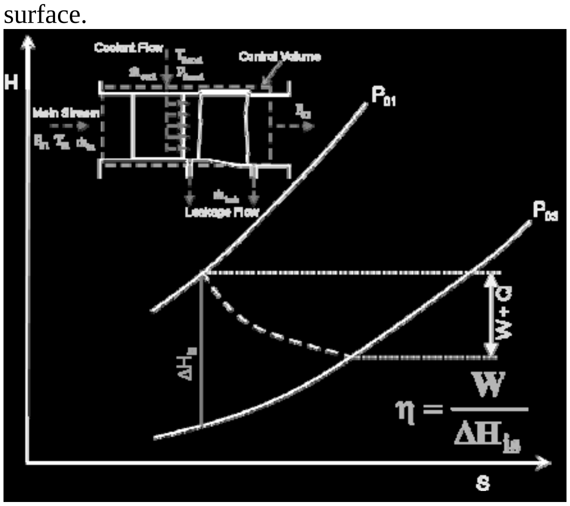


***Figure 1: Enthalpy-entropy diagram of a gas expansion in a turbine; Definition of the control volume and the flow quantities that influence the turbine efficiency; simple efficiency definition***