HIGH FREQUENCY GAS TEMPERATURE AND SURFACE HEAT FLUX MEASUREMENTS

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The largest benefits achievable during the development of engines with more power, less fuel consumption and also less weight are obtained from a higher turbine entry temperature. It is therefore necessary to improve vanes and blades so that they can withstand these temperatures. Not only a better knowledge of the heat transfer along these vanes and blades is often required for a better thermal stress analysis, but also the flow temperature must be accurately known, because in turbomachines, the mean and the fluctuating components of this quantity are used to determine the efficiency when dealing with complex stator/rotor interactions. For this reason, the present study mainly aims at the development of two particular applications of the thin film sensors used for heat flux measurements: the multi – layered thin film gauge for wall heat transfer and the dual thin film probe for flow temperature.

Till now, single layered thin film gauges, painted on a ceramic substrate, have been used mainly for blade surface heat flux measurements. However, this instrumentation is quite difficult to use in high speed rotating rigs, due to its fragility against centrifugal forces. The solution envisaged in this research consists in the use of a multi – layered arrangement in which the first layer acts as a thermal and electric insulator and the second one is the material from which the blades are usually constructed. The measured value is the surface temperature evolution of the gauge and the corresponding wall heat flux is calculated from the solution of the unsteady conduction equation into the two layers supporting the sensor. Measurements with the two-layered gauges were performed i) in CT-2 on a blade tip and ii) at 50% of a second stator blade of the Brite turbine, (*Fig-1*). In CT-2, 8 combinations of operating conditions were tested (2 Mach numbers, 2 Reynolds, 2 Turbulence Intensities) on 2 blade tip geometries (flat and squealer). In CT-3, both time-averaged and time-resolved (fluctuations due to rotor blade passing events) were processed. The repeatability of the measurements is good. The results are also successfully compared with measurements obtained with the more classical one layer technique based on platinum gauges deposited on a ceramic substrate.

The accurate measurement of the mainstream flow temperature also remains an intense subject of research. This measurement is absolutely needed for an accurate efficiency determination. The proposed approach relies upon the use of a dual thin film probe (D.T.F.P.), allowing the temperature determination via a heat flux measurement. The definite advantage of this probe is that it can easily be operated at much higher frequencies than thermocouples and cold wires even with compensation. In addition, it does not require a complicated calibration procedure. Furthermore, it is very robust, as opposed to thermocouples and cold wires. This new probe offers a number of other advantages such as independence to gas composition, application in unsteady compressible flows at high free stream turbulence intensity. The operational principle of the probe was validated by tests performed behind a cascade in CT-2. Measurements were also performed behind the rotor and the 2nd stator of the Brite turbine. Both time-averaged and time-resolved informations were processed (*Fig-2)*. The significantly faster response time of the dual thin film probe compared to the thermocouple is evident.

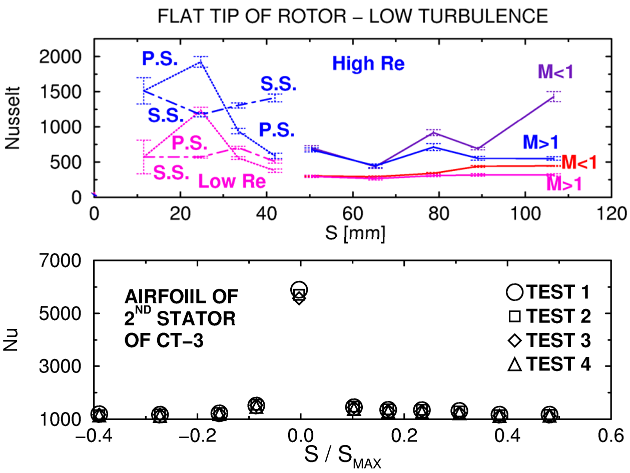

Figure 1: Nusselt distribution on the tip of a rotor blade and around an airfoil on the second stator of CT-3, by using two-layered thin film gauges

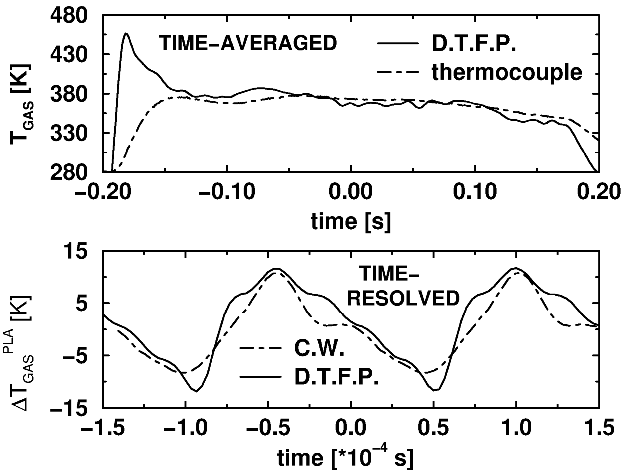

Figure 2: Time-averaged and time-resolved total gas temperature comparisons between the D.T.F.P. and a thermocouple or a cold wire (C.W.) respectively (behind the rotor of CT-3)