TOTAL TEMPERATURE PROBES FOR TURBINE EFFICIENCY MEASUREMENTS IN TRANSONIC ROTATING RIGS

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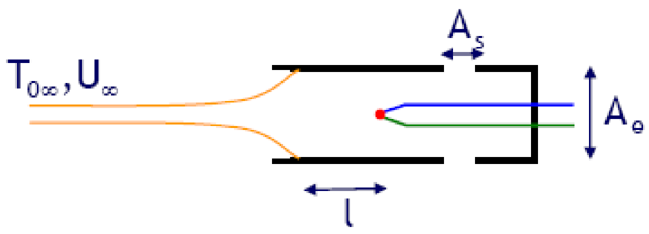
ABSTRACT

Modern Low Pressure Turbines (LPT) shown very high efficiencies, therefore future improvements are expected to be low enough to produce a small exit temperature variation. That trend requires a continuous precision increase of the total gas temperature measurement system if a good global descriptor of the turbine efficiency is sought.

Traditionally gas turbine temperatures have been measured using thermocouples. However, several total temperature probes are available nowadays like dual hot wire aspirating probe, cold wire thermo resistor or the dual thin film total probe. Due to the high reliability, robustness, low cost and simplicity the thermocouples are the most used device to measure total temperature.

In this paper, a detailed experimental study of total temperature probe composed by a Kiel Head instrumented with thermocouples is presented, throwing some light onto the physics of the probe. This study yields the systematic error of the total temperature probe measurements and its relationship with probe geometry and fluid characteristics. In order to quantify the different heat fluxes an analytical model has been developed to simulate the temperature behavior of the total temperature probe.



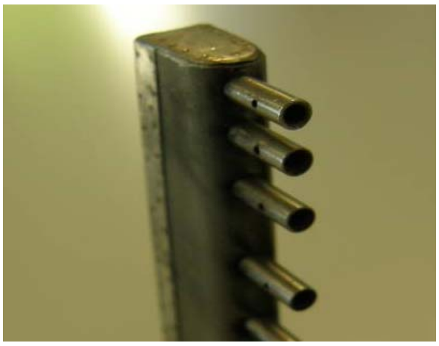


Fig. 1: Tested Kiel Head.

Several Kiel Head geometries have been tested for different Mach numbers and flow yaw angles, yielding the temperature error for each condition. The next figure compares the measured total temperature error and the calculated one for Kiel head geometry. The analytical results correlates pretty well with the experimental values and the analysis of the different heat fluxes gives an insight of the total temperature error sources.

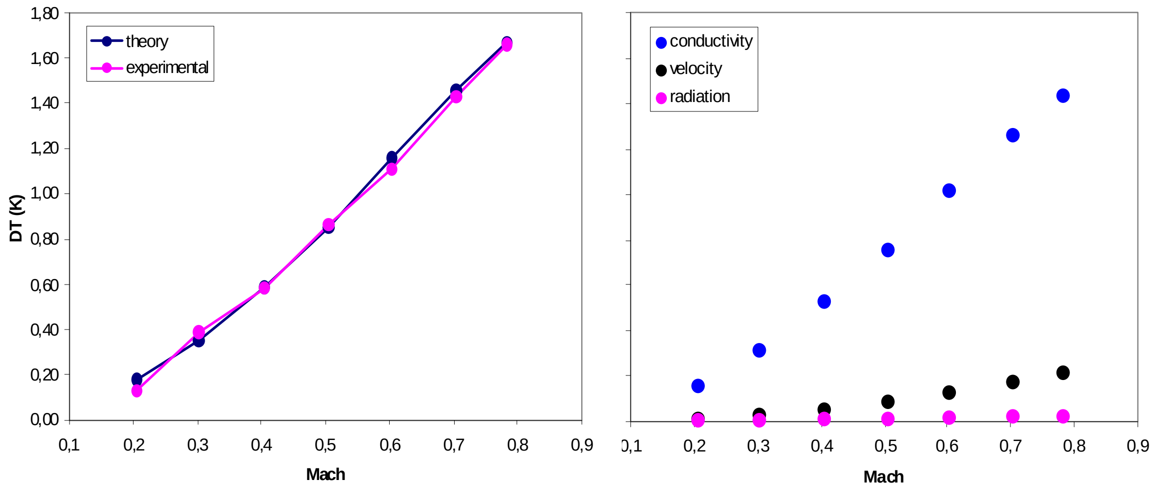


Fig. 2: Mach number influence.

The incidence flow angle has a relatively big influence on the probe total temperature error. This variation is a conduction error consequence. The probe base temperature controls the conduction error, and figure 5 shows how this temperature changes in function of the yaw angle.

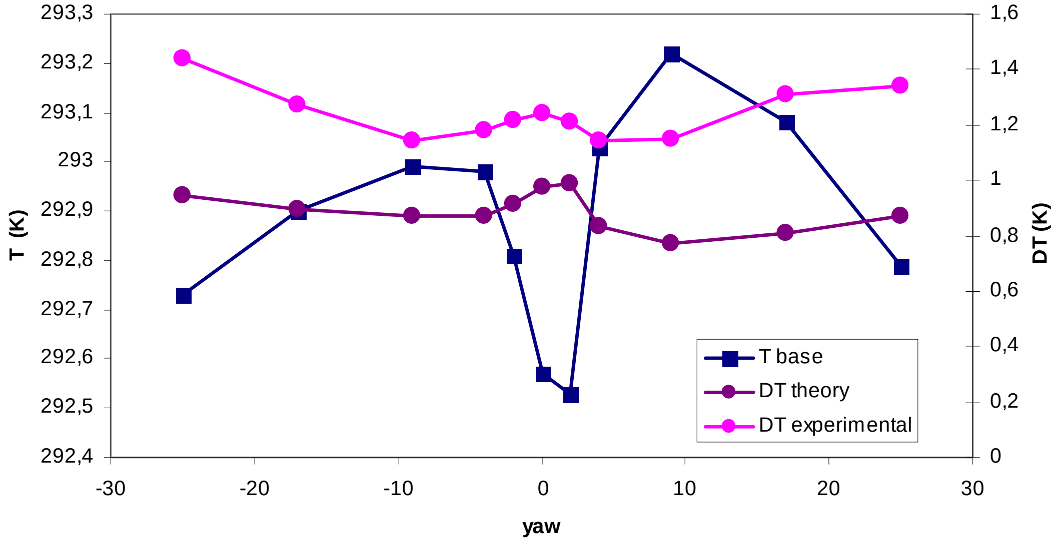


Fig. 3: Yaw angle influence.

From angle 0º (probe orientated to the flow) to ± 10º the base temperature goes up and gets closer to the total temperature because the heat transfer is more efficient for perpendicular cylinders ($Nu=0.44Re^{0.5}$) than parallel cylinders ($Nu=0.085Re^{0.674}$). Then the conduction heat flux is reduced and the total temperature error goes down. For angles higher than ± 10 º two different effects take place. For these angles the probe gets out of the potential core, so the base temperature goes down as figure 3 shows. Additionally, for high yaw angles the Kiel is unable to straighten the flow, so a big flow separation area appears that causes a lower measured temperature by the thermocouple. Results show the total temperature error is 0.1K for a yaw angle range of ± 10º.