DESIGN OF THE COOLING SYSTEM FOR A HIGH TEMPERATURE FAST RESPONSE TOTAL PRESSURE PROBE

Marco Pau, Italy
Supervisors: T. Arts & J.-F. Brouckaert

The necessity to have accurate measurements of pressure in high temperature environments, such as the exit of the combustion chamber or first HP stages of a gas turbine, requires the development of cooled probes. The aim of the project was to design an internal cooling system for a high temperature fast response total pressure probe with operating temperature of 1100 °C providing a sensor temperature lower than 60°C.

Starting from an existing internal cooling geometry (Figure 1), a 1-D calculation model was developed in order to evaluate cooling performance maps. Correlations were used to determine heat transfer coefficients and to compute some representative global cooling performance parameters, using water as coolant fluid. Different cooling configurations have been studied, considering water which feeds the probe the probe from the inner cylinder and from the outer annular jacket. Results have been presented in terms of cooling system performances as function of the free stream gas flow temperature for different coolant mass flow rates and for different value of the free stream hot gas flow Mach number.

A numerical assessment using a 3-D Navier-Stokes commercial solver has been carried out. In all the calculations the probe and the internal cooling system have been modeled, imposing the appropriate heat transfer coefficient and hot gas flow temperature as boundary conditions on the probe surface. The full 3-D geometry of the probe were computed, i.e. both and solid parts of the model, solving both momentum and energy equations. For a nominal water flow rate of 0.025 kg/s (~1.5 l/min), temperature levels on the probe tube and the velocity flow field in the internal cooling system have been analyzed for the two above mentioned cooling configurations. The probe bottom was found to be the most critical region to be cooled and the most important heat path from the external hot gas flow to the vulnerable transducer. Different coolant mass flow rates were computed for both cooling scheme configurations. Mass flow rates reduced to 0.0083 kg/s (~0.5 l/min) computed sensible increase of the bottom probe temperature and decrease of the cooling system efficiency. A comparison between the 1-D model and 3-D geometry results was done in terms of global cooling system parameters, showing general agreement.

Finally the cooling system geometry has been modified locally on the probe bottom to improve the cooling efficiency in this region. Different design configurations were computed and the results compared to the original design. A configuration with a 1mm hole diameter connecting the bottom of the inner cylinder and outer external jacket was computed to provide lower temperature on this region than the other designs.

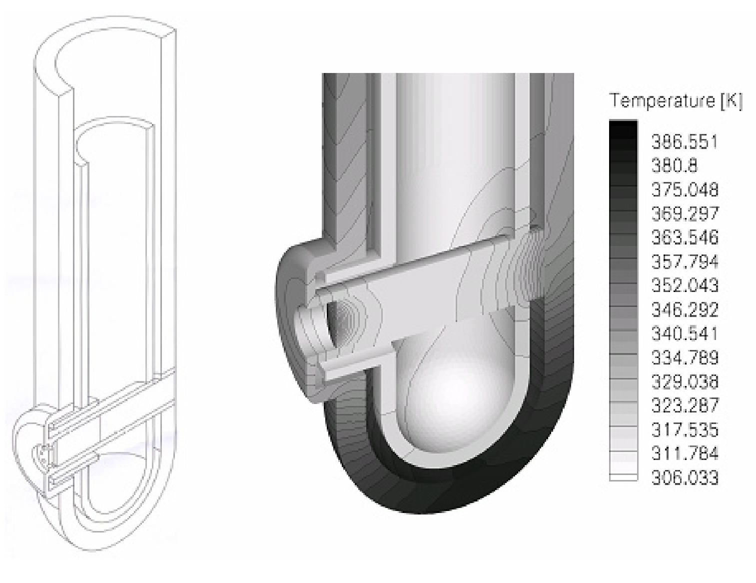

Figure 1: Probe geometry (left side) and temperature contour plot, solid region on the probe bottom (right side)