CHEMICAL ASPECTS OF HYPERSONIC STAGNATION POINT HEAT TRANSFER

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As entering a planet atmosphere, a hypersonic vehicle experiences a severe heat flux, so that its nose must be properly shielded with Thermal Protection System. One important component of this heat transfer results from recombination reaction in the boundary layer, representing the diffusive heat flux also called “chemical heat flux”.

A better knowledge of the homogenous (gas phase) and heterogenous (catalytic) reactions is expected to save a significant payload on re-entry probes. For such studies, the Institute for Problems in Mechanics of Moscow and the Von Karman Institute developed and implemented the Local Heat Transfer Simulation in order to reproduce part of the real flight condition of hypersonic vehicles.

In this framework, the project is devised to explore the chemical state of the gas phase in the reacting boundary layer and its consequences on the heat transfer to the wall and on catalycity determination.

At first, a methodology for the scaling of the chemistry kinetics is developed. It allows the computation of the Damkohler number for the main recombination reactions that occur in the boundary layer. For a typical plasmatron regime, and according to chemical model used, Nitrogen recombination reaction is found to happen very fast, close to an equilibrium sate. On the contrary, Oxygen recombination is found to be inside the non-equilibrium area, close to frozen flow.

Two new heat flux probes for the plasmatron wind tunnel are designed. They are meant to control the chemical state of the boundary layer by imposing a different velocity gradient to the boundary layer. It is then possible to bring the boundary closer to an equilibrium state or a frozen state. A small diameter probe impose a velocity gradient that is about 175% of the standard one, and a big diameter geometry impose a velocity gradient that is about 38% of the standard one.

Finally, an experimental characterization of these new probes is realized inside the plasmatron. Through heat flux measurements and pitot pressure measurements under various facility settings and with different catalycity surface, one indeed sees that the kinetics of the flow and of the chemistry is modified. The result are quantitatively analysed through analytical correlations.

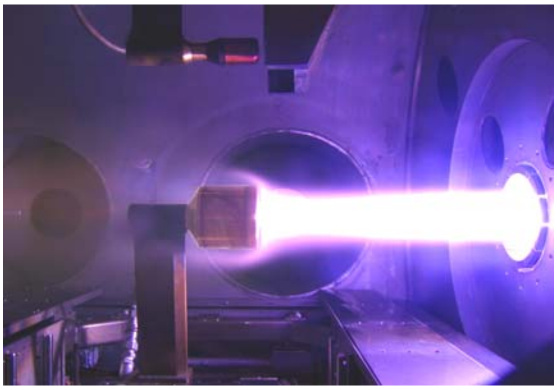

Figure 1: Test of the big diameter heat flux probe inside the plasmatron

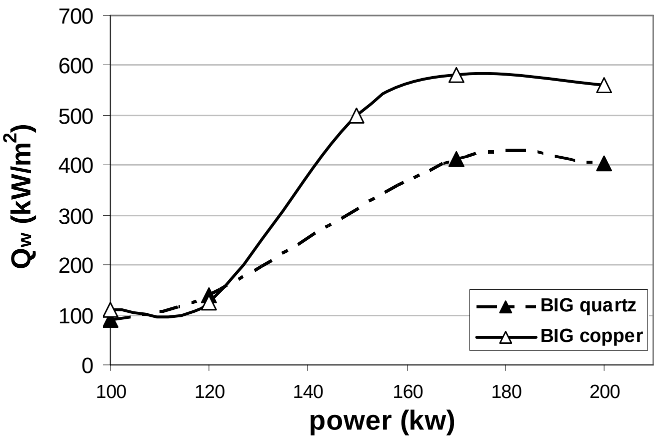

Figure 2: Heat transfer measured by the big diameter heat flux probe with either a copper surface (highly catalytic) or a quartz surface (non catalytic)