NUMERICAL SIMULATION OF EQUILIBRIUM AND NON EQUILIBRIUM CO_2 PLASMA FLOWS

Pietro Rini, Italy
Supervisor: G. Degrez

The von Karman Institute has been involved since 1997 in the determination of catalytic properties of Thermal Protection System (TPS) materials. A hybrid methodology, which relies on the combination of experimental measurements and computational calculations, has been employed for this purpose. The principles of this methodology lay on the Local Heat Transfer Simulation (LHTS) concept developed at the Institute for Problems in Mechanics of Moscow (IPM).

The VKI high enthalpy flow solvers are interfaced with libraries to compute the thermodynamic and transport properties and non-equilibrium chemistry. The thermodynamic and transport libraries have been recently updated to incorporate a Carbon Dioxide mixture. This research aims to complete the physico-chemical description of a CO_2 flow and allows for chemical non-equilibrium simulations.

Under the characteristic operating conditions of the ICP facilities, which will be firstly used with a pure CO_2 gas, further simplifications that prove to be useful from a computational point of view can be made. Based on a thermodynamic equilibrium analysis (Fig. 1), two low cost mixtures have been defined, with respectively 5 and 8 species.

The reaction rates required to model the bulk reactions have been selected amongst those proposed in the literature. The interaction between the flow and the surface site has been modeled by using the simple Eley-Rideal and Langmuir-Hinshelwood mechanisms. In a parallel literature survey, at least three main heterogeneous recombination processes have been identified.

A critical output of the LHTS methodology is the heat load on the stagnation point of a flying body, where great gradients in temperature and mass concentrations are present. These features make this point a suitable benchmark for testing thermo-chemical models. The flow field in the vicinity of a TPS material placed in a plasma jet its vicinity has also been analyzed by means of boundary layer calculations.

A result of this analysis consists in the determination of so-called Heat Flux maps (Fig.~2), which show the behaviour of the stagnation point heat flux (q_w) as a function of the wall temperature (T_w), and the recombination probability (γ_w).

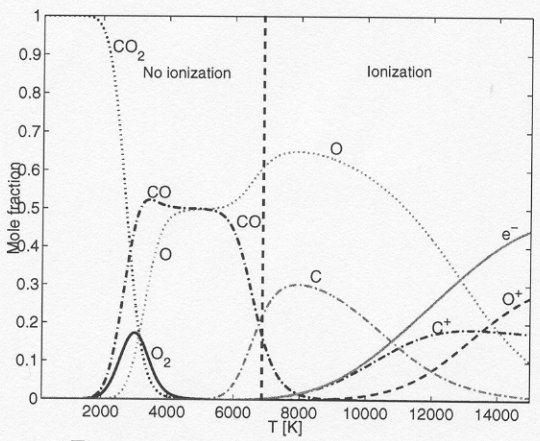

Figure1: Composition of a pure CO_2 mixture at 20000 Pa.

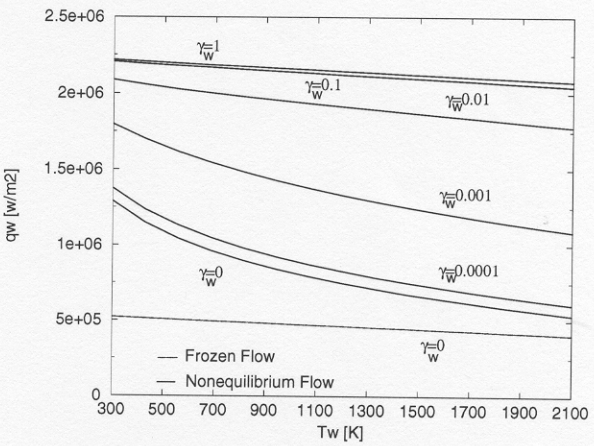

Figure 2 : Stagnation point Heat Flux Map computed with two different models, for various recombination probabilities $[h_e = 39MJ/kg, p = 10132.5Pa]$