FURTHER NUMERICAL INVESTIGATION OF THE NEQ EFFECTS IN A PLASMA FLOW: TWO TEMPERATURE MULTI-SPECIES PLASMA FLOW 1D SIMULATION

Youri Elkouch, Belgium
Supervisors: D.G. Fletcher, P. Rini, D. Vanden Abeele

During atmospheric reentry, spacecrafts are submitted to very high temperatures, and the vehicle thermal shield must be designed to withstand this severe heat load. Therefore, thermal protection materials that constitute this shield must be tested beforehand on ground facilities like Inductively Coupled Plasma torches. The nonequilibrium effects occurring in such plasma flows are of great importance in these applications, but their physical understanding and numerical implementation are still far from being complete. My Diploma Course project deals about numerical simulations of plasma flows along the radial direction of an Inductively Coupled Plasma torch, under non-equilibrium conditions.

The first objective of the project is the implementation of a two temperature multi-species model applied to several mixtures like argon, nitrogen and air. The model is designed to compute the radial profiles of chemical composition, temperatures and electric field intensity. As a first step, Local Thermodynamic Equilibrium simulations were already done in 2003-2004. They were performed using an implemented finite element non-linear ODE system solver and the physico-chemical Mutation library. Upgrade to thermal and chemical non-equilibrium conditions was performed for this year's project using a two temperature assumption and finite reaction rates in the species mass conservation equations. For this purpose, another chemical-kinetic library (Pegase) was linked to the solver and used to obtain the needed thermodynamic, transport and chemical properties of the mixture. Results are still missing because of a bug in the code that has finally been isolated and must be corrected.

The other objective of this project is to lay the basis of a state-to-state approach applied to this first model in the case of a diatomic nitrogen mixture. This leads to the implementation of a state-to-state library (so-called 'collisional-radiative', model for which the concepts are explained in the report) capable to compute the energy level populations of the nitrogen mixture species. This library can be gradually developed by including more and more elementary processes arising between these energy levels. Achieving this goal requires accurate knowledge of the corresponding rate coefficients.

A Matlab code has been built to compute these rates once the corresponding cross-section expression is known and the needed spectroscopic data are gathered. The computation of a vibrationally-specific coefficient rate for the ionization of N_2 illustrates the working of this program. Some results concerning the first vibronic transitions are shown below.