DEVELOPMENT OF A LOCAL THERMODYNAMIC EQUILIBRIUM MODEL OF INDUCTIVELY COUPLED PLASMAS

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The VKI plasmatron facility has been operational since 1997. In this plasmatron wind tunnel, a plasma is generated by means of electro-magnetic induction. It is used for testing thermal protection materials (TPMs) that constitute thermal shield protecting spacecrafts during atmospheric reentry.

The objective of this project was to complete the implementation of a Local Thermodynamic Equilibrium (LTE) numerical model of Inductively Coupled Plasmas (ICPs) developed by a former DC student (Radek Honzátko). The implementation is a module of a framework for simulation of multi-physical problems COOLFluiD. This objective oriented C++ framework developed at VKI is easily extensible and can be used for simulations on unstructured grids using different numerical methods.

The model of LTE of ICPs consists of the system of the Navier-Stokes equations and the Induction equation. The implementation without influence of the plasma part of the electric field was corrected and tested. To this end an extensive debugging of the C++ code was performed and numerous corrections were incorporated. Subsequently it was necessary to finalize the electromagnetic field implementation by adding the plasma-induced electric field intensity and to create routines for computation of the components of Lorentz forces constituting source terms in the momentum equations.

Finally the verification of the model at this stage was done against the legacy code ICP Fortran. Results achieved by both codes are in good agreement as can be seen for air 11 species $\left(O_2, N_2, O, N, NO, NO^+, O^+, N^+, O_2^+, N_2^+, e^-\right)$ on the figures 1 and 2 showing comparison of temperature profiles along radial and axial direction in the middle of the plasmatron torch. The temperature field of air11 in the plasmatron torch is presented on the figure 3.

As a next step one can consider the addition of swirl velocity into the LTE model for ICPs that is used in plasmatron to stabilize the flow of the plasma.

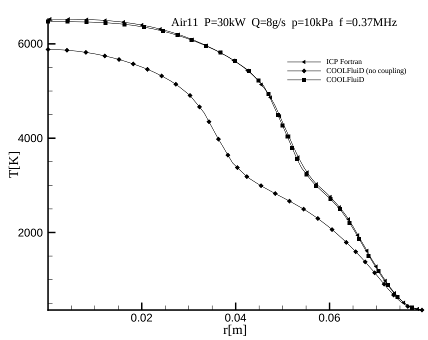

Figure 1: Temperature profiles comparison in the radial direction at the position z = 0.25m

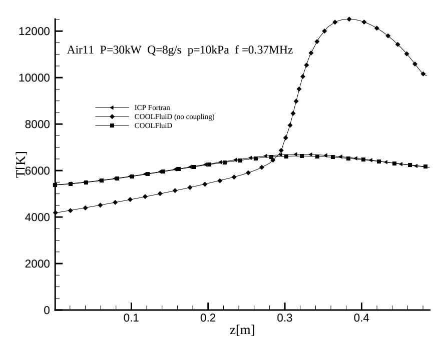

Figure 2: Temperature profiles comparison in the axial direction at the position r = 0.0m

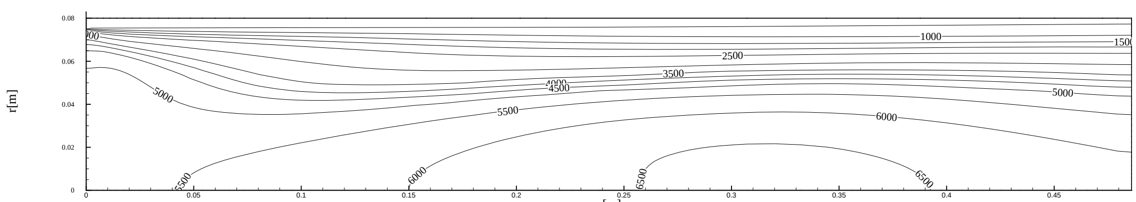

Figure 3: Temperature isolines of air11, P = 30kW, Q = 8gs^{-1}, p = 10kHz, f = 0.37Hz