IMPLEMENTATION OF A FINITE-VOLUME INDUCTIVELY COUPLED PLASMA MODEL INTO THE OBJECT-ORIENTED SOLVER COOLFLUID

Radek Honzátko, Czech Republic
Supervisors: H. Deconinck, D. Vanden Abeele, A. Lani, M. Panesi, T. Quintino

When a shuttle or capsule enters a planetary atmosphere from space, it faces very high temperatures. To prevent damage to the spacecraft, it needs to be protected by a heat shield. Samples of new thermal protection materials may be tested in high-temperature wind tunnels in which they are subjected to a hot jet of inductively heated thermal plasma.

During the past decade a Fortran code for numerical modelling of such plasma flows has been developed at the von Karman Institute (VKI). However, it is very complicated to make grids, run the code and perform further extensions.

The aim of this project was to implement a similar solver for numerical simulations of inductively coupled plasmas (ICPs) into the VKIs object-oriented CFD solver COOLFluiD. The solver should be more user-friendly, more robust and faster than the existing code. The possibility of using unstructured hybrid meshes generated in an easy-to-use interface mesh generation software is a logical time-saving strategy. It allows to simulate plasma flows in complex geometries, such as encountered in industrial situations. Therefore, a convertor of the widely used Gambit neutral file format to the native format of COOLFluiD was implemented.

Since high pressure ICPs are characterized by low Mach numbers, a strictly incompressible and bw Mach number flow solver was developed for this project, and was validated against several benchmark solutions.

Furthermore, the effect of an electromagnetic (EM) field generated by coils surrounding a plasma torch had to be incorporated. The implemented EM field was successfully compared to the results computed by the older Fortran code.

There were also some limitations considered with respect to the Fortran code in this project. First, a simplified EM field approximation was used. Second, the work dealt with flows under the assumption of local thermodynamic equilibrium with a fixed elemental composition.

Numerical results of ICP flows under operational conditions of a plasmatron used at VKI were compared to the solutions computed by the previous code. Both a qualitative and quantitative comparison was made. The induction equation, coupling EM field generated by the inductor with plasma-induced one, was still missing. Nevertheless, for argon plasmas at low powers, reasonable agreement was already found. The efficiency of COOLFluiD in terms of computation times and memory usage also compared well with the older Fortran prototype code.

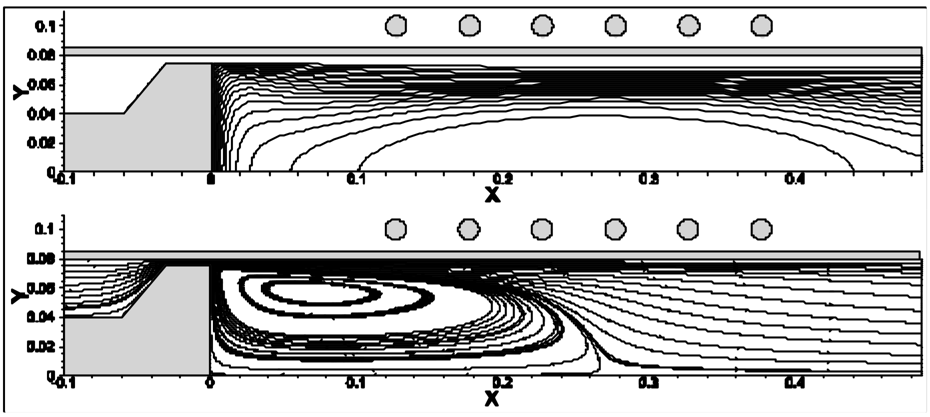

Figure 1: Temperature isolines (upper) and streamlines (lower) of argon plasma in a plasmatron torch