NUMERICAL SIMULATION OF SUB- AND SUPERSONIC FLOWS IN INDUCTIVELY COUPLED PLASMA TUNNELS

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This report details three improvements made to the von Karman Institute's Inductively-Coupled Plasma numerical simulation, a magneto-hydrodynamics and Navier-Stokes solver with a finite volume discretization on a multi-block structured mesh. (1) Two preconditioned compressible-flow numerical flux schemes were debugged and validated, expanding the domain of applicability of the simulation, previously limited to low speeds, to include the compressible flow regime; (2) a time-dependent implicit scheme was implemented, substantially improving the robustness of the code; and (3) a new scalable dissipation term was added to the numerical flux schemes, reducing the computation time required for many cases, especially those for which poor initial guesses are available.

The full range of new and old capabilities was tested in a simulation of the Minitorch high enthalpy facility, outfitted with a supersonic converging-diverging nozzle. The entire geometry of the facility was simulated, including the torch, the nozzle, the testing-chamber, and the exit pipe. The simulation converged to the topologically correct solution, producing the expected pattern of expansion waves and shocks that was observed in the original experiments. A detailed comparison was not, however, possible, both because there is insufficient quantitative experimental data available and because the exact power delivered to the plasma in the experiments is not presently known.

Three main tasks are apparent as future work. (1) The model used in the simulation should be expanded to include thermo-chemical non-equilibrium, (2) the supersonic plasma jet should be studied parametrically, and (3) efforts should be made to perform measurements with which the numerical results can be validated.

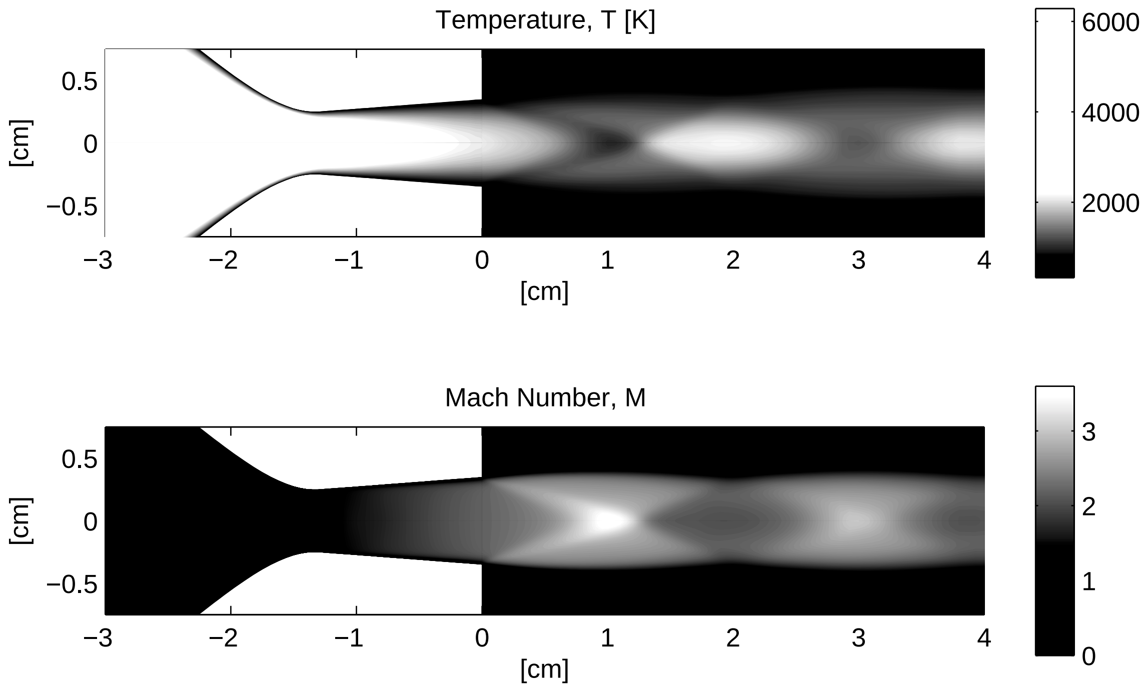

Figure 1: Temperature and Mach number contours in a supersonic plasma jet