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PROC / Process control (including plasma diagnostics, plasma modelling)

Adaptation of SPARK to atmospheric-pressure micro-plasma jets flow conditions

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Abstract content

This work regards the adaptation to the low temperature and low speed flow conditions observed in atmospheric-pressure micro-plasma jets (APMPJs) of the Software Platform for Aerothermodynamics Radiation and Kinetics (SPARK) [1], a CFD code often used for hypersonic re-entry plasmas. Small flows require high fidelity on the calculation of dissipative processes, and low-temperature plasma chemistry requires detailed state-to-state kinetics. SPARK was adapted accordingly, facing other challenges of convergence in low-Mach conditions and the computational cost of state-to-state kinetics. A first adaptation was the inclusion of subsonic boundary conditions. Secondly, the Simple Low-dissipation AUSM solver (SLAU) [2], a low-Mach perfect-gas solver, was implemented. After validation in incompressible flow simulations, SLAU was adapted into a multi-species and multi-temperature flux solver. Inviscid, dissipative, and kinetic calculations were fully coupled with implicit time integration. Convergence was improved by including a time-step preconditioning formulated for flows with a non-equilibrium temperature for the free electrons. A reduced Argon kinetic scheme was included by applying Uniform Grouping to a state-of-the-art scheme, and run times were decreased by adopting 5th order WENO [3] reconstruction and OpenMP parallelization. The effect of the applied field was included by adding an electron energy source term. Due to the existence of streamers in our APMPJs [4], a simplified streamer model was included to improve the fidelity of this term. Benchmark simulations show a stable code, even in relatively sparse meshes, able to compute the problem in reasonable times. First tests with SLAU multispecies and multi-temperature adaptations allow for a good description of inertial effects, attributed to the low numerical dissipation during the calculation of the momentum conservation equation (see Figure 1), and flux solver adaptations prove to accelerate convergence.

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References

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Argon mass fraction in the nozzle flow.