Modeling and Simulation of Radiative Compressible Flows in Aerodynamic Heating Arc-Jet Facility

Khalil Bensassi[1,2], Alejandro A. Laguna[3], Andrea Lani[3], Nagi N. Mansour[1]

[1] NASA Ames Research Center, Moffett Field, CA 94035, United States

[2] Department of Aerospace Engineering, University of Illinois, Urbana-Champaign, IL 61801, United States

[3] von Karman Institute for Fluid Dynamics, Aeronautics and Aerospace Department,

Waterloosesteenweg 72, 1640, Sint Genesius Rode, Belgium

Corresponding author: khalil.bensassi@nasa.gov

Abstract: Numerical simulations of an arc heated flow inside NASA's 20 [MW] Aerodynamics heating facility (AHF) are performed in order to investigate the three-dimensional swirling flow and the current distribution inside the wind tunnel. The plasma is considered in Local Thermodynamics Equilibrium(LTE) and is composed of Air-Argon gas mixture. The governing equations are the Navier-Stokes equations that include source terms corresponding to Joule heating and radiative cooling. The former is obtained by solving an electric potential equation, while the latter is calculated using an innovative massively parallel ray-tracing algorithm. The fully coupled system is closed by the thermodynamics relations and transport properties which are obtained from Chapman-Enskog method. A novel strategy was developed in order to enable the flow solver and the radiation calculation to be preformed independently and simultaneously using a different number of processors. Drastic reduction in the computational cost was achieved using this strategy. Details on the numerical methods used for space discretization, time integration and ray-tracing algorithm will be presented. The effect of the radiative cooling on the dynamics of the flow will be investigated. The complete set of equations were implemented within the COOLFluiD Framework [1]. Fig. 1 shows the geometry of the Anode and part of the constrictor of the Aerodynamics heating facility (AHF) [2]. Fig. 2 shows the velocity field distribution along (x-y) plane and the streamline in (z-y) plane.

Keywords: Finite Volume method, Unsteady, Arcjet, Pasma flows, LTE, Radiation
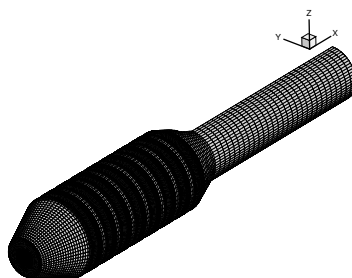

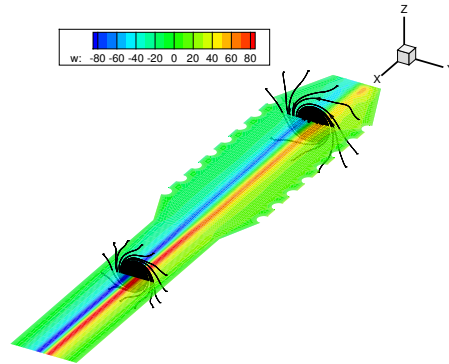Figure 1: Geometry and computational grid

Figure 2: Velocity field distribution in (x-y) plan and streamlines in (y-z) plane

References

[1] Andrea Lani, Nadege Villedie, Khalil Bensassi, Lilla Koloszar, Martin Vymazal, Sarp M. Yalim, and Marco Panesi. *COOLFluiD: an open computational platform for multi-physics simulation and research: http://andrealani.github.io/COOLFluiD/*. American Institute of Aeronautics and Astronautics, 2016/02/03 2013.

[2] Balter-Peterson A., F. Nichols, B. Mifsud, and W. Love. Arc jet testing in nasa ames research center thermophysics facilities. *AIAA-92-5041, American Institute of Aeronautics and Astronautics, Washington, DC, 1992.*