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NUMERICAL REBUILDING OF ATMOSPHERIC ENTRIES WITHIN THE EU PROJECT MEESST

Abstract

Up to this day, atmospheric entry remains a critical phase for human exploration and sample return missions due to the high kinetic energy of the spacecraft. As a result of the hypersonic velocities, a shockwave develops in front of the spacecraft, where kinetic energy is transformed into thermal energy. This leads to the creation of a plasma layer encasing the vehicle. Consequently, a high heat load acts on the spacecraft, particularly in the stagnation region. Additionally, radio blackouts occur.

The objective of this work is to discuss the reconstruction of atmospheric entry test cases using numerical simulations of representative plasma wind tunnel (PWT) experiments at the Institute of Space Systems at the University of Stuttgart (IRS). It is a part of the *EU New Horizon 2020* project *Magnetohydrodynamic Enhanced Entry System for Space Transportation* (MEESST). This project aims to demonstrate the possibility of active magnetic shielding to mitigate the high thermal loads and radio blackouts, which spacecrafts are experiencing during atmospheric entry. It thus offers the possibility of providing a key technological solution for future entry vehicles, which will be able to mitigate the aforementioned problems through the utilization of artificial magnetic fields. This magnetohydrodynamic (MHD) shielding aims on using lightweight high temperature superconducting coils to create a sufficiently strong magnetic field to deflect charged particles of the ionized plasma out of the spacecraft's stagnation zone. Consequently, thermal loads can be decreased, and radio blackouts lessened.

Currently, PWT experiments are conducted at the IRS to replicate these respective entry scenarios using air plasma. In this context, this research focusses on the numerical reconstruction of the experiments to further comprehend the plasma behavior. For this PWT high enthalpy flow simulation, the in-house developed CFD-solver URANUS *(Upwind Relaxation Algorithm for Nonequilibrium Flows of the University of Stuttgart)* is used. A hyperbolic and a highly elliptic entry test case are thus defined, with free stream specific enthalpies of $80\frac{\mathrm{MJ}}{\mathrm{kg}}$ and $60\frac{\mathrm{MJ}}{\mathrm{kg}}$, respectively. The general numerical approach and the simulation process are presented, including the computational domain definition and mesh generation as well as the boundary definitions and inflow conditions. This work establishes the foundation for further technological development, including the simulation of MHD effects in atmospheric entry plasmas, by validating and verifying the simulation results with PWT experiment measurements of these test cases. Therefore, the numerical simulation results without MHD effects are presented and compared to the corresponding experimental measurements.