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Author: Ms. Jasmine Giacomelli
Institute of Space Systems, University of Stuttgart, Germany, giacomellij@irs.uni-stuttgart.de

Prof.Dr. Georg Herdrich
Institute of Space Systems, Germany, herdrich@irs.uni-stuttgart.de
Mr. Johannes Oswald
Institute of Space Systems, University of Stuttgart, Germany, oswaldj@irs.uni-stuttgart.de
Mr. Adam S. Pagan
Institute of Space Systems, University of Stuttgart, Germany, pagan@irs.uni-stuttgart.de
Mr. Alexander Behnke
University of Stuttgart, Germany, behnke@irs.uni-stuttgart.de
Mr. Truell Hyde
Baylor University, United States, Truell_Hyde@baylor.edu
Prof. Rene Laufer
Luleå University of Technology, Sweden, rene.laufer@ltu.se

EXPERIMENTAL AND NUMERICAL STUDIES OF MHD EFFECTS ON PLASMA FLOWS FOR RE-ENTRY APPLICATIONS

Abstract

Atmospheric entry into a target planet is a critical phase for space missions, because spacecraft have to face harsh conditions involving thermal loads in the order of MW/m^2. During the entry, the atmospheric gas can be dissociated and (partly) ionized thus creating a boundary layer. This sheath subjects the spacecraft to high heat fluxes and leads to communication blackout. Since both aspects can compromise the safety of the vehicle, a design which employ advanced protection systems is necessary to ensure the success of future planetary missions. As proven in previous studies, charged particles in a plasma flow can be manipulated by applying an adequately high electromagnetic field, which modifies the shock structure and distance, mitigates the heat flux and creates a magnetic windowing that can reduce the communication blackout period.

The MHD Enhanced Entry System for Space Transportation (MEESST) Horizon 2020 project will exploit magnetohydrodynamic (MHD) effects and develop a demonstrator implementing active magnetic shielding by means of a superconductive coil system. MEESST includes experimental campaigns in the plasma wind tunnels of the Von Karman Institute (VKI) and the Institute of Space System (IRS), and numerical simulations relying upon improved models. Enhanced MHD simulation tools will allow to predict the plasma physics during the atmospheric entry, which involves electromagnetic phenomena, thermochemical non-equilibrium and radiation. This work presents the enhancement and verification of the pre-existing MHD-tools for heat flux plasma modelling: SAMSA (by IRS), COOLFluiD (by VKI/KU Leuven), OP^2A (by the University of Southampton). As a starting point, current numerical modelling capabilities will be assessed and displayed synoptically. The needed extensions of these tools will include the ability to reproduce the behavior of air plasma flows, resembling the realistic atmospheric conditions of spacecraft Earth/Mars entry.

This work focuses on the numerical rebuilding of previous experiments carried out at the plasma wind tunnel PWK1 at IRS which simultaneously serve as a verification test case in MEESST. The test case

involves an argon plasma flow impacting a spherical probe which is equipped with a variable ring magnet system, and has already been successfully computed with SAMSA. The results of the simulations will be cross-checked within the consortium and validated with the experimental results. The successful rebuilding of this test case with argon will allow for verifying the enhanced numerical tools and will provide a first milestone towards validating the target experimental data involving polyatomic air plasma flows with simulations within the consortium.