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NUMERICAL REBUILDING OF PLASMA WIND TUNNEL EXPERIMENTS FOR INVESTIGATION OF MAGNETOHYDRODYNAMIC FLOW INTERACTIONS WITHIN THE EU PROJECT MEESST

Abstract

Atmospheric entry is a critical phase for interplanetary human spaceflight and sample return missions, as spacecraft face extreme conditions with high heat fluxes in the order of several MW/m^2. In addition, the shock generated dissociates and ionizes the surrounding atmospheric gases leading to a plasma which results in a communications blackout. Both aspects jeopardize the safety of the spacecraft's mission. Therefore, advanced thermal protection systems are needed to ensure the success of future planetary missions. Previous theoretical, numerical and experimental studies have shown that the plasma behavior can be manipulated by applying strong electromagnetic fields, changing the boundary layer (distance), the shock structure and its standoff distance, which in turn reduces the heat flux. Magnetic windowing effects have also been observed, which can reduce the communications blackout period.

The Horizon 2020 project MHD Enhanced Entry System for Space Transportation (MEESST) aims to harness magnetohydrodynamic (MHD) effects to create an active magnetic shield using superconductor coils. MEESST conducts experimental campaigns in plasma wind tunnels led by the Von Karman Institute (VKI) and the Institute of Space Systems (IRS). These experiments are conducted alongside numerical

simulations to validate and improve these simulation tools that can predict the complex behavior of plasma as spacecraft enter the atmosphere. This includes accounting for electromagnetic forces, thermochemical non-equilibrium, and corresponding plasma radiation. The improved numerical MHD plasma tools used to calculate the heat fluxes for MEESST are SINA (developed by IRS), COOLFluiD (from VKI/KU Leuven) and HANSA (from the University of Southampton). These tools have been enhanced to accurately reproduce the behavior of a multi-species plasma corresponding to realistic atmospheric entry conditions and to account for strong MHD effects. Results from experimental campaigns will be used to verify the implemented models.

This work focuses on numerical reproduction of the campaign experiments conducted in the plasma wind tunnel PWK1 at IRS and VKI's Plasmatron, which both serve as provider for a verification test case data base in MEESST. The test cases consist of an air plasma flow impinging on a hemispherical probe that is equipped with a system of superconducting coils designed to modify the shape of the plasma that surrounds it. The results of the simulations computed by the different codes will be cross-checked within the consortium and validated against the experimental findings.