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ON-GROUND TESTING METHODOLOGIES IMPROVEMENT IN ARC-JET PLASMA FACILITIES USING OPTICAL EMISSION DIAGNOSTICS

Abstract

Future scenarios regarding space station, transportation and planetary exploration will be highly influenced by the development of new materials for Thermal Protection Systems (TPS). On-ground testing plays a central role in TPS characterization and validation, and the world-class arc-jet plasma facility SCIROCCO represents one of the cornerstones for the future of aerospace. The main aim of this work was to apply innovative optical emission diagnostics to improve the SCIROCCO air plasma flow characterization capabilities. The experimental campaign was carried out by combining high resolution optical emission spectroscopy (OES) and high speed photomultiplier tube spectroscopy (PMT). The plasma was investigated both in free-stream and inside the arc heater region for a set of operating conditions ranging from a current I = 2000 A to I = 4700 A. High resolution OES was performed in free-stream for the highest current case using the "AURORA" configuration, which is relevant for interplanetary re-entry heat fluxes reproduction. The attention was focused on the NO delta and NO gamma vibrational bands (in the UV region). The thermodynamic state of the plasma was investigated by fitting theoretical spectra, extracted from the simulation software Specair 2.2, to the calibrated line-of-sight experimental spectrum. The rotational temperature resulted Trot = 321 +/- 20 K, while the vibrational temperature for the NO resulted Tvib = 1125 +/- 10 K, indicating a significant departure from the local thermodynamic equilibrium (LTE) condition. High resolution OES was also applied, for the first time in the SCIROCCO history, in the arc heater region. The attention was focused on the O an N lines emitting in the IR region. An innovative optical-path reversal method based on Specair 2.2 theoretical spectra and ARCFLO simulations allowed to estimate the radial LTE temperature profile and to get a direct measure of the total enthalpy (H0). The resulting centerline plasma temperature ranged from T = 7780 +/- 117 K to T = 8360 +/- 88 K. High speed PMT spectroscopy was applied in the arc heater region to investigate the plasma jet optical emission oscillations induced by the arc root motion and power supply AC/DC conversion ripple. The frequency analysis showed no significant components, indicating that the plasma can be considered stationary. Optical emission diagnostics demonstrated powerful for plasma flows characterization and allowed to measure both plasma temperature and total enthalpy: essential parameters for a correct interpretation of TPS characterization results.