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EXPERIMENTAL INVESTIGATION OF ARC JET HYPERSONIC PLASMA FLOWS THROUGH OPTICAL EMISSION TECHNIQUES

Abstract

The experimental characterization of the hypersonic plasma jet produced by the SCIROCCO arc jet facility was carried out by combining high resolution optical emission spectroscopy (OES) and high speed camera (HSC) imaging. The gas mixture was air and the plasma was investigated at free-stream condition and at a single operating condition: arc current of 4000 A and air mass flow rate of 1.3 kg/s. High resolution optical emission spectroscopy was performed 44 cm away from the exit section of the nozzle (about 0.4 nozzle diameters). The attention was focused on the NO-γ and NO-δ 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 645 K (with a measurement error of 20 K), while the vibrational temperature resulted 1100 K (with a measurement error of 15 K), indicating a significant departure from the local thermodynamic equilibrium (LTE) condition. However, Boltzmann distribution seems to be a reliable assumption for both rotational and vibrational levels population. A short term repeatability analysis was also performed. Using a time interval of 5 minutes between the measures, both rotational and vibrational temperatures resulted in agreement within error bands. Temporal and spatial uniformity was, instead, investigated using HSC imaging. The plasma jet radiation was recorded at 1 kHz. Time and spectral domain elaboration procedures were performed on the recorded frames to investigate the unsteady features of the jet. In particular, power spectral density distributions showed how dynamics is essentially concentrated in the shear layer of the jet, while mean radiation radial profiles showed that the plasma jet can be considered as a homogeneous and uniform column. This last hypothesis brings to a significant link between the two optical emission techniques: the thermodynamic state of the plasma jet can be investigated using line-of-sight emitted spectra, avoiding de-convolution techniques (like Abel inversion) on spatial resolved spectra. The homogeneity, uniformity and repeatability of its plasma jet make SCIROCCO an attracting ground facility for reliable tests on spacecraft protections.