Non equilibrium spectroscopic diagnostics of supersonic air plasma jet

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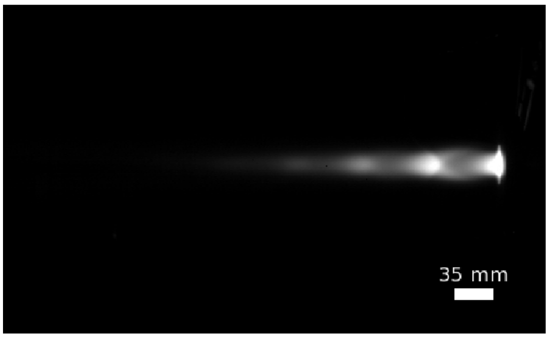
Supersonic air plasma jet produced in the Plasmatron facility at the von Karman Institute is investigated. An extensive analysis is performed for various operating conditions. Plasma flow regimes corresponding to underexpanded and highly underexpanded situations are investigated by means of Optical Emission Spectroscopy (OES) technique. Using various diagnostics, the deviation from Boltzmann equilibrium is presented. Electronic and vibrational excited states distributions are spatially measured in compression and expansion zones. Additionally, electron density is derived from Stark broadening of H_β hydrogen lines.

During hypersonic atmospheric re-entry, the radiative heating experienced by a vehicle is a major issue for accurate prediction of the thermal heat flux. Computational tools development requires experimental data to assess the reliability of their models. In particular, non equilibrium kinetic models need to be assessed in order to replicate the radiative contribution of the excited gas in the shock layer where collisional and radiative processes lead to thermodynamic non equilibrium situations.

In this framework, a sonic throat has been installed onto the Plasmatron facility to obtain a strong ex-



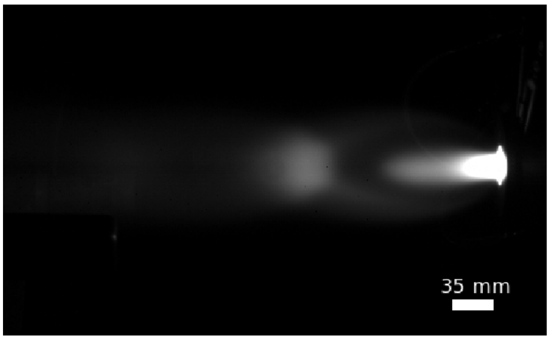
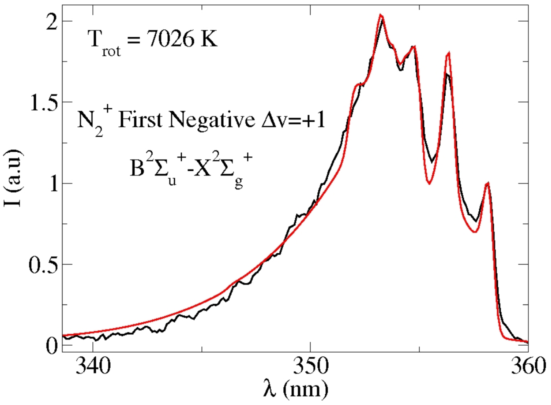


Fig. 1: Underexpanded (left) and highly underexpanded (right) supersonic air plasma jets.

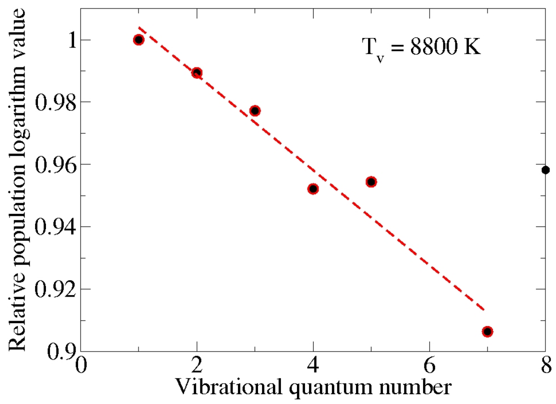
pansion (figure 1) leading to Saha-Boltzmann equilibrium deviation.

Non intrusive methods based on Optical Emission Spectroscopy (OES) are used to spatially resolved the excited levels densities of the emitting species and the electron density. Although OES studies are largely employed to study supersonic plasma jets, the characterization have to be carried using cautious assumptions [1]. In this contribution, proper diagnostics based on atomic and molecular spectra have been developed to characterize the non equilibrium situation.

Atomic lines allow a straight determination of the excitation temperature through the electronic excited population measured distribution. In the expansion region, measured density indicates that deviation from Boltzmann equilibrium occurs. Electronic number density is determined through the fitting of calculated hydrogen Stark broadened lines onto experimental data in order assess the ionization degree of the plasma. Up to date databases are used to generate hydrogen spectral lineshape on the basis of various assumptions. Plasma characterization using molecular spectra is made on the basis of common fitting approaches consisting in the minimization of the Root Mean Square Error between experimental spectrum and spectrum calculated under various equilibrium assumptions. Additionally to the thermal situation, an other assumption is considered and consists in calculating spectra at rotational equilibrium



(a) Best fit obtained in the first expansion zone at 25 mm from the throat (r = 17 mm).



(b) Vibrational population distribution.

Fig. 2: Spectroscopic diagnostic based on the molecular contribution of N_2^+ First Negative system Δv=+1 using rotational equilibrium and vibrational nonequilibrium assumption.

and with no assumption on the vibrational distribution. It allows to get the details of the energy distribution among the quantum states within the vibrational mode as presented in figure 2. No severe deviation from vibrational equilibrium was noticed.

References

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