TUNABLE DIODE LASER ABSORPTION SPECTROSCOPY CHARACTERIZATION OF IMPULSE HYPERVELOCITY CO_2 FLOWS

Jason Meyers, United States of America
Supervisor: D.G. Fletcher
Promoter: G. Degrez (Université Libre de Bruxelles, Belgium)

Tunable diode laser absorption spectroscopy using an external cavity diode laser operating in the infra-red has been developed to monitor CO_2 in the freestream of the Longshot hypervelocity facility at the Von Karman Institute for Fluid Dynamics. The Longshot facility offers a unique European facility for ground testing and numerical validation applications, however, some of the traditional data rebuilding aspects for CO_2 are in question. A non-intrusive absorption sensor could significantly aid in improving the knowledge of freestream static values thereby improving the models used in data rebuilding and numerical simulation. The design of such a sensor also expands the spectroscopic capabilities of the Von Karman Institute.

The absorption sensor is designed around the single P12 (00001)→(30013) rovibrational transition near 1.6μm (6218.09cm^{-1} specifically) which yields relatively weak direct absorption levels at about 3.5% per meter for typical Longshot freestream conditions. However, when handled carefully, adequate signal-to-noise can be acquired to exploit significant flow information. By being able to operate in this range, total sensor cost can be easily an a factor of two or more cheaper than sensors designed for the deeper infrared. All sensor elements were mounted to a compact portable optics bench utilizing single-mode optical fibers to allow for quick installation at different facilities by eliminating tedious optical realigning. Scans at 600Hz were performed over 20ms of the 40ms test time to extract core static temperature, pressure and velocity. These results are compared with the current state of the Longshot data rebuild method.

The non-uniform flow properties of the shear layer and test cabin rested gas accumulation were of an initial concern. The temperature and density gradients along with significant radial velocity components could result in DLAS temperature, pressure and velocity that are significantly different than that of the target freestream inviscid core values (Figure 1). Fortunately, with the proper selection of the P12 rotational number, this effect could be more or less ignored as the higher temperature and lower density gas of this region is relatively transparent. Ultimately, acquired temperature and density were moderately accurate when compared to Longshot rebuilt results owing primarily to the baseline extraction which poses issues for such low absorption signals. However, the extracted velocity data are quite accurate. This is a definite plus for the sensor as the freestream enthalpy of cold hypersonic facilities is dictated primarily by the kinetic energy contribution. Being able to compare velocity gives insight to the level of vibration non-equilibrium in the flow. The velocity, and thus enthalpy (Figure 2), of the DLAS and the Longshot rebuild are quite close. This adds more weight to the argument that vibrational excitation is very low (if present at all) in the free stream and that the van de der Waals equation of state usage and constant specific heat assumption might be an adequate model for the data rebuild after all.

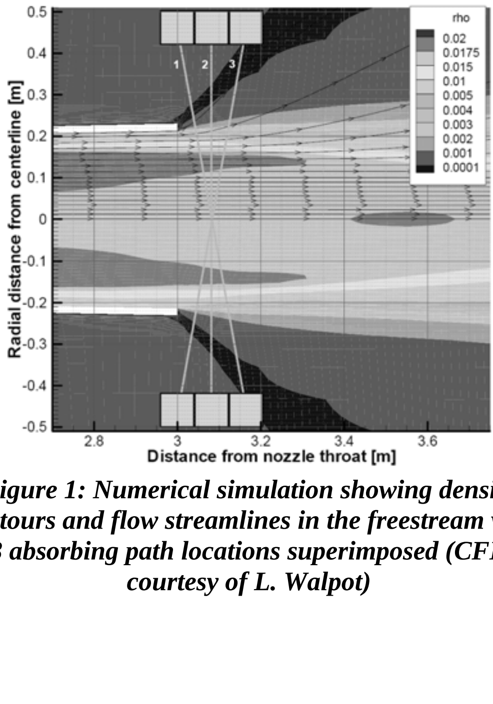

Figure 1: Numerical simulation showing density contours and flow streamlines in the freestream with 3 absorbing path locations superimposed (CFD courtesy of L. Walpot)

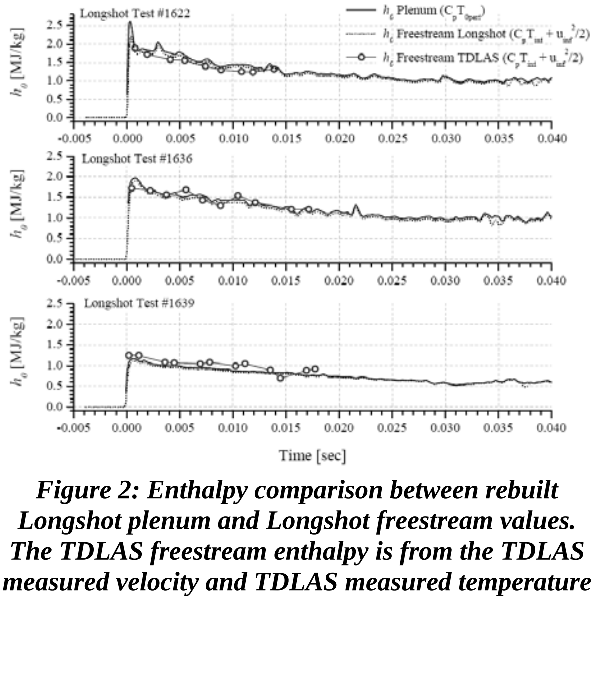

Figure 2: Enthalpy comparison between rebuilt Longshot plenum and Longshot freestream values. The TDLAS freestream enthalpy is from the TDLAS measured velocity and TDLAS measured temperature