PREDICTION OF NATURAL AND FORCED TRANSITION IN HYPERSONIC FLOWS. APPLICATION TO EUROPEAN SPACE VEHICLES (EXPERT, IXV, ARV)

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Space vehicles are exposed to harsh conditions during their atmospheric reentries. Boundary layer transition from a laminar to a turbulent state increases by a factor two or more the wall heat fluxes, among other effects, and this may lead to a failure of the thermal protecting system and a mission loss. Deeper knowledge of transition phenomena would benefit the future space missions by using better suited designs.

Boundary layer transition can either be a natural phenomenon or being forced by protruding elements on the surface of the vehicles introducing disturbances and by-passing the natural destabilizing process. Linear stability theory can be used to predict the boundary layer stability and the different modes leading to a turbulent boundary layer. These phenomena have already been predicted numerically, observed and partially characterized at low hypersonic Mach numbers. However, at larger hypersonic numbers (Mach 12-15), which correspond to the time of peak heating during reentry trajectories such as the one of the EXPERT vehicle, precise knowledge is still lacking. Transition phenomena at that time of the reentry would be critical for the thermal protecting system and it is thus of primary interest to be able to predict when a hypersonic boundary layer will turn turbulent.

This project takes place in the von Karman Institute for Fluid Dynamics where worldwide unique hypersonic facilities can be used. The Longshot facility (Mach 14) can partially duplicate flow conditions on the reentry trajectory of the EXPERT vehicle and will be used for experimental studies.

As a first step to this doctoral project, a better characterization of the facility is being performed. This calibration first determines the mean flow properties by using different measurement techniques (pitot pressure rake, static pressure probe, mass-flux probe) and assesses different methods for the rebuilding of flow conditions in the free-stream while comparing their uncertainties. Beside, a dynamic calibration is performed describing the free-stream noise levels which are equivalent to turbulence levels at lower speeds and are known to influence the boundary layer transition process. Experiments will then be performed in this calibrated environment over simplified vehicle geometries to characterize boundary layer fluctuations at their surface. The aim is to measure the development of the instabilities prior to transition and their influencing parameters. Results will be compared to numerical predictions of disturbances characteristics.

The final aim of this project is to obtain a better knowledge of the hypersonic facility used and to enhance the knowledge of high speed boundary layer transition by developing new tools for the prediction of hypersonic transition over the different cases studied.

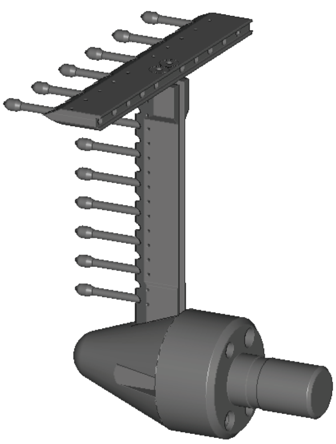

Figure 1 : Hypersonic pressure rake used for nozzle flow characterization

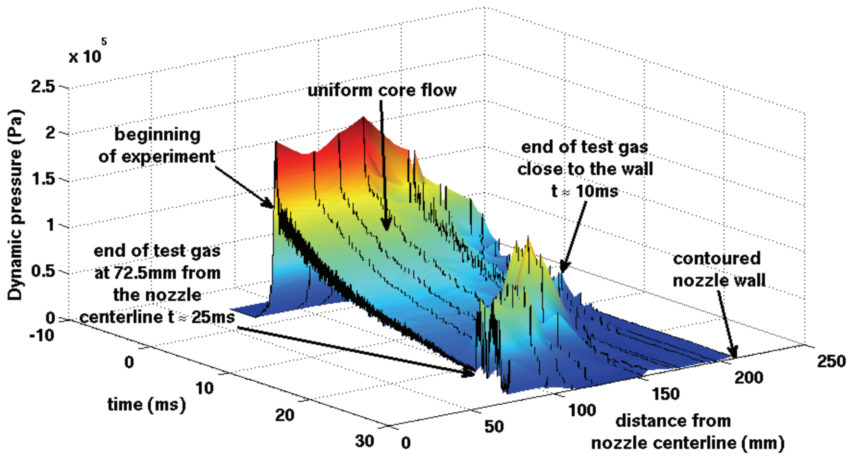

Figure 2 : Dynamic pressure as a function of time recorded across the Longshot Mach 14 contoured nozzle