HYPERSONIC BOUNDARY LAYER STABILITY AND TRANSITION INVESTIGATION ON A FLAT PLATE

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Transition phenomenon has a large influence on the design of thermal protection design for hypersonic vehicles but is still poorly understood.

A way towards its understanding is the study of the amplification of boundary layer perturbations before the flow turns turbulent (i.e. at the onset of transition).

To this aim, measurements are performed on a flat plate at Mach 14 and Re=7 000 000 / m using nitrogen and carbon dioxide in order to capture the so-called second mode of instabilities. Instrumentation includes thermocouples, accelerometers and flush-mounted pressure sensors aiming to probe the boundary layer at very high frequencies.

Post-processing of the non-stationary and unsteady signals with Huang decomposition is successfully applied. Flow fluctuations at about 100 kHz are retrieved and these frequencies are decreasing further downstream when the boundary layer is getting thicker. Nevertheless, similar frequencies are retrieved from the accelerometer indicating vibrations of the flat plate during the boundary layer measurements.

A fluid-structure interaction is thought to occur during the 20 ms blow down of the facility. No amplification of perturbations seems to occur downstream the leading edge. The inclusion of 2D roughness perturbation materialized as a 6mm height backward facing step seems not to change significantly the recorded spectra of pressure fluctuations and the flow remains laminar at a distance of 30 cm downstream the leading edge.

CFD results obtained with CFD++ show a good agreement with experiments regarding to heat fluxes. Extraction of boundary layer profiles will allow determining the stability of the boundary layer with a compressible linear stability tool developed in a parallel research.
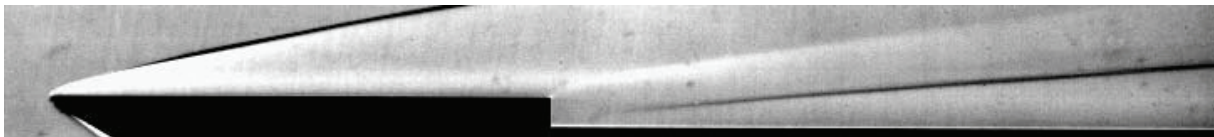

Figure 1: Schlieren view of a flat plate equipped with a 6mm backward facing step
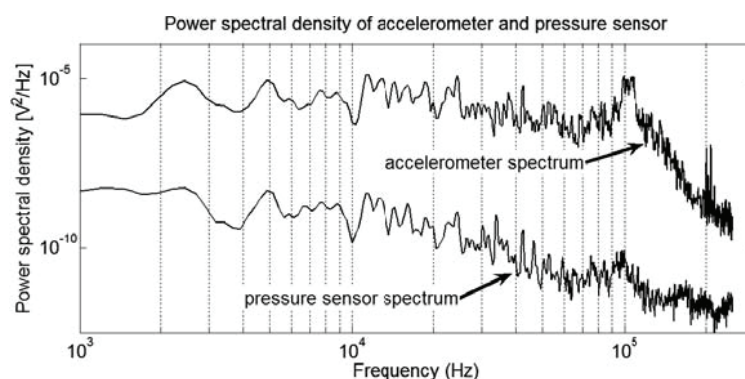

Figure 2: Spectra of accelerometer and pressure fluctuations on a smooth flat plate