NATURAL AND INDUCED TRANSITION ON A 7DEG HALF-CONE

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Laminar-to-turbulent transition during atmospheric re-entry is a major issue for vehicle design. The process of boundary layer transition is accompanied by an increase in surface heat transfer and skin friction on the vehicle. ESA EXPERT project addresses the testing of critical re-entry technologies, leading in particular, to a more accurate design and effective development of thermal protections and boundary layer transition control systems. In this frame, VKI is contributing to the project with a payload for induced transition studies.
Pressure fluctuations in the boundary layer are among the causes which lead to instabilities and after to a turbulent boundary layer. The knowledge of these unsteady fluctuations could help to identify the mechanisms which take part into the transition process and better predict them. With this target, surface pressure measurements have been performed in the VKI H3 Hypersonic Wind Tunnel on a 7deg half-angle cone with and without an isolated roughness element. The cone, with exchangeable nose, was equipped with a stream-wise array of high frequency pressure transducers (PCB 132A31) and a Plexiglas surface to enhance infrared imagery. Instabilities in the boundary layer are investigated, with respect to the tunnel noise influence and the induced laminar-to-turbulent transition mechanism. Moreover, pressure fluctuations, normalized Stanton number and oil flow visualization were used to interpret the flow field structure behind the roughness element versus the Reynolds number effect, the nose bluntness and the roughness height.
Additional numerical studies and CFD have been performed in support of the eN transition prediction method and the calibration of the ground facility. The results provided on standard ground test models are helping to enhance the understanding of the boundary layer transition characteristics for the forthcoming post-flight analysis on the EXPERT vehicle.
Second mode waves have been measured in the VKI H3 Hypersonic Wind Tunnel. Initial growth of second mode modes has been confirmed on a smooth 7deg sharp half-cone. Frequency of second modes is decreasing with increasing downstream measurement location. Moreover, frequency of second modes are also increasing with the increasing Reynolds number and the thinning of the boundary layer since instabilities frequencies are scaling with the inverse of boundary layer thickness. Second mode breakdown has been observed starting from a Reynolds number of 18E6 1/m on the rear part of the 7deg half-cone. With the increasing Reynolds number, several sensors' locations were affected by breakdown to turbulence validating the upstream movement of the onset of natural transition. The effect of nose bluntness has been also characterized, showing that a strong entropy layer created by the bow shock is able to change the boundary layer characteristics, like Mach number at the edge, stabilizing the boundary layer itself and damping all the instabilities. Comparison between experimental results and linear stability computation are in fairly good agreement, while the N factor for the VKI H3 facility is around 5 and 5.2. An isolated roughness element, ramps shaped, is amplifying and modifying the second mode waves on the cone for relatively low Reynolds numbers. An increase of the latter one enables the bypass transition mechanism induced by the roughness element when the ratio between the roughness height and the boundary layer displacement thickness is around the unity.

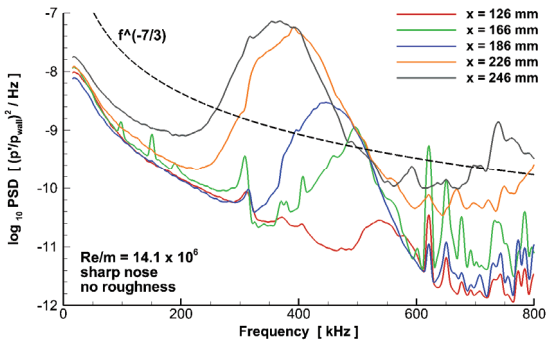

Figure 1: Second mode instabilities on a 7deg sharp half-cone in VKI H3 conditions

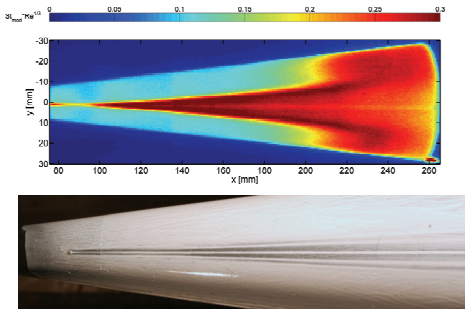

Figure 2: Heat flux measurements and Oil flow visualization of a 7deg half-cone with a 0.3mm ramp roughness element