CHARACTERIZATION OF A TRANSITIONAL HYPERSONIC BOUNDARY LAYER IN WIND TUNNEL AND IN-FLIGHT CONDITIONS

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The effect of roughness on hypersonic boundary layer transition has been studied for three primary purposes: to trip a laminar boundary layer to turbulence, to determine whether naturally occurring roughness is expected to cause early transition, and to determine the largest allowable roughness that will not affect the location of transition. Roughness is often divided into two classes: *isolated* roughness in which each protuberance can be considered separately, and *distributed* roughness similar to sandpaper, in which the roughness elements are many and are not considered separately. This study is focused on isolated roughness induce transition and enter in the frame of the European EXPERT project.

The EXPERT (European eXPErimental Re-entry Testbed) in-flight research program aims to improve understanding of critical aerothermodynamic phenomena and includes wind tunnel, flights and CFD simulations. This program is setup to enhance the aerothermodynamic tools for design and consists by recording many in-flight parameters on the KHEOPS re-entry vehicle shown on Figure 1. VKI is involved in the development of two of the 14 experiments on board: The Instrumented Junction Experiment and the Isolated Roughness Induced Transition Experiment. This last payload, together with the development of a Boundary Layer Rake for flight experiments constitutes the core of this thesis.

The goal of the Isolated Roughness Induced Transition Experiment is to provide reliable in-flight hypersonic transition data for the study of laminar-turbulent transition physics and the validation of transition criteria. The development of this payload includes extensive wind tunnel testing for the choice of roughness shape and dimensions and the determination of the most reliable transition criterion. The flow topology and the physics of transition is also studied trough fundamental flat plate testing in VKI H3 (an example of such and Infra-red test is shown at Figure 2). This part of the study is focused on the understanding of the transition process, of the effect of roughness shape and aims to improve the transition criteria by including parameters that describe better the physics of the flow.

The development of the flight payload also includes the definition of the in-flight instrumentation able to detect transition. The Boundary Layer Rake payload and a set of 20 thermocouples constitute this instrumentation. The thermocouples are used to detect the characteristic thermal footprint of the turbulent wake on the surface (wake shape and heat flux level) while the boundary layer rake has been designed for characterizing the boundary layer growing on the vehicle for both laminar and turbulent boundary layer cases. Only the total pressure profile and the static pressure within the boundary layer are measured with the rake and some other flow parameters are extrapolated under some assumption for reconstructing the boundary layer profile. Both with and without Pitot probes rake configurations have been investigated and this study have shown that a rake without probes offer the best characteristics in term of precision, weight and impact on the vehicle (a shock-boundary layer interaction taking place upstream to the rake is shown at Figure 3).

Finally, the payloads have to be qualified for flight trough thermal, mechanical and vibration tests. The rake payload being removed from the flight for resources reasons, only the transition payload and it instrumentation are being qualified. Test articles have been built and are under testing phase.

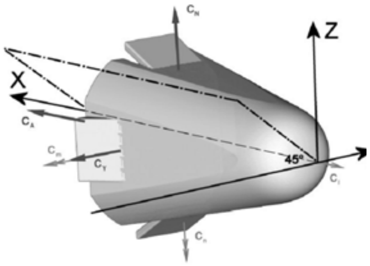

Figure 1: EXPERT Vehicle

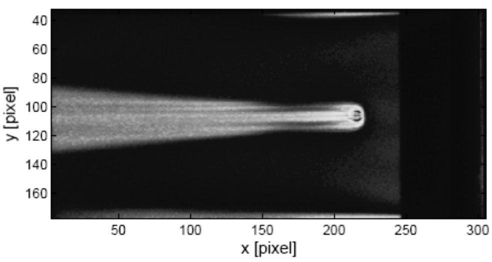

Figure 2: Infra-red measurement of transition on flat plate

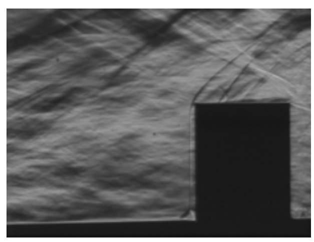

Figure 3: Shock-boundary layer interaction in front of rake