Evaluation of the Effects of Distributed Roughness. Induced Transition on the EXPERT Vehicle.

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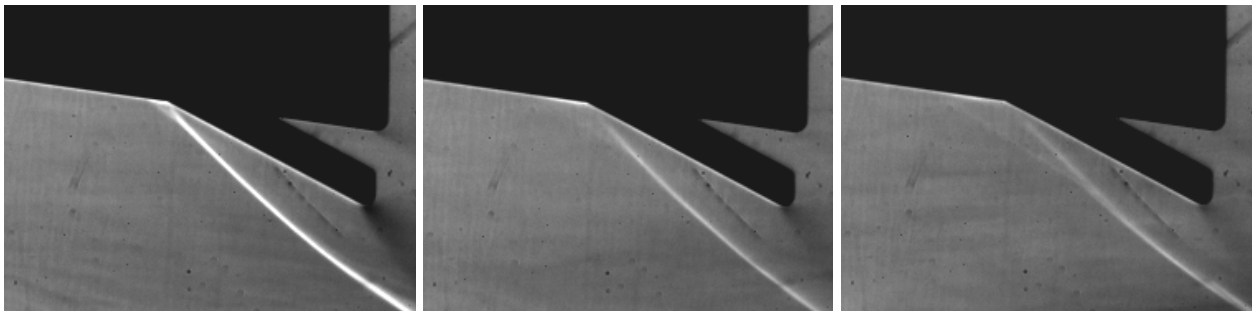
The surface roughness of a vehicle is a key parameter in the design of a flight vehicle as it may induce early boundary layer laminar-to-turbulent transition. This phenomenon is accompanied by higher surface heat transfer and skin friction which can affect the stability of the vehicle and its aerodynamic coefficients.

The present work is part of the EXPERT project lead by ESA aiming to study phenomena occurring during Earth reentry for hypersonic vehicles. Transition from laminar to turbulent flows due to distributed roughness on the non-ablative nose of a blunt vehicle can be a big issue for the thermal protection system. Experiments are carried out with different distributed roughness densities, locations and sizes in the Longshot short duration facility (free-stream Mach number of 14, low enthalpy, Reynolds number between 11.10^6/m and 18.10^6/m) at the VKI. Wall temperature measurements with thermocouples on the scaled EXPERT vehicle allow the determination of heat flux and Stanton number. Comparison between experimental and theoretical Stanton numbers permits the detection of transition.

Pressure measurements support the transition investigation. Following a complementary approach, empirical correlations (Reda and Reshotko) are evaluated from CFD results to determine the distributed roughness critical height leading to transition. Theory predictions and experimental results are compared to determine how correlations are applicable to the EXPERT geometry. An extrapolation to flight conditions is performed on this basis giving the largest allowable height for distributed roughness.



(a) (b) (c)

Schlieren pictures showing the evolution of the recirculation bubble in front of the flap.
Distributed roughness in the range [0.15 - 0.2mm], Reynolds number [13-17.10^6/m].
(a) turbulent flow, (b) transitional flow, and then (c) laminar one.