Paper ID: 12868
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MATERIALS AND STRUCTURES SYMPOSIUM (C2)
Specialised Technologies, Including Nanotechnology (8)

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INVESTIGATION OF GAS-SURFACE INTERACTION AND MODELLING OF THE REFERENCE CATALYCITY FOR THERMAL PROTECTION MATERIAL TESTING IN PLASMA WIND TUNNELS

Abstract

When it comes to thermal protection system (TPS) design, ground testing is a major tool to perform thermal protection material (TPM) selection and qualification, and to validate the computational fluid dynamics (CFD) tools and methodologies used for flight prediction. Impulse facilities are used for studying aerothermodynamic effects, gas kinetic, and radiation process. Long duration facilities, such as plasma wind tunnels, are used for studying the material response mechanisms, which are characterized by much larger timescales. This approach is valid as long as the two phenomenon are uncoupled. However, the increasing fraction of radiative heat transfer in super-orbital entries poses a challenge from the experimental point of view, as it couples the two problems. The different phenomenon have to be investigated separately, and corrected afterwards through adequate CFD. Therefore, it is of uttermost important to build up reliable and accurate models, as flight duplication is not possible anymore.

One of the main parameters used for the sizing TPS is the catalycity of the TPM, e.g. the ratio between the number of atoms that recombined on the surface and the number of atoms that impacted the surface. Recombination being an exothermic process, high catalycity is undesirable as it increases the heat flux that the thermal protection system has to withstand. Catalycity is experimentally determined in plasma wind tunnels, based on the comparison with a material of known catalycity. That reference is often a copper sample, assumed to be of constant catalycity. However, it was demonstrated in previous studies that that assumption is wrong, resulting in an over-estimation of TPM catalycity and over-sizing of TPS. Space missions with stringent mass budget are therefore penalized with heavy heat shield and the payload mass is reduced. A new model for the reference catalycity is thus necessary, especially for super-orbital entries.

The present paper addresses the question of that reference catalycity: what is exactly its influence on the final mass budget, and how could it be more accurately modelled? Due to the high complexity of the process, a simple but not simplistic engineering approach was preferred based on results obtained in the von Karman Institute's Plasmatron. A new model is proposed, taking into account the specifications of the test set-up. Although focus is set on copper probes in mixtures corresponding to the Earth's atmosphere, indications are given on how to extend the results to a broader range of probe materials and mixture.