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WATER-COOLED ADJUSTABLE MATERIAL PROBE DESIGN FOR THE EVALUATION OF TRANSIENT HEAT FLUXES OF HIGH TEMPERATURE MATERIALS

Abstract

Atmospheric re-entry provides one of the harshest environment a spacecraft can face, where the high kinetic energy is mainly dissipated through heating of the surrounding atmosphere. This translates into high thermal loads transferred to the vehicle and demands for effective Thermal Protection System (TPS) designs. In case of LEO entries, the complexity of the heating problem lays behind the interdependence between gas-surface interactions' mechanisms, such as catalysis, oxidation and emissivity change.

Within the framework of the investigation of candidate materials for re-usable TPS applications, a test campaign has been conducted at Plasma Wind Tunnel 3 (PWK3) of the Institute of Space Systems (IRS) of the University of Stuttgart. Several Sintered Silicon Carbide (SSiC) samples have been characterised and the effect of catalysis-oxidation coupling has been observed. Post-test data analysis allowed assessing the sensitivity of oxidation processes on the determination of heat fluxes. The sensitivity analysis revealed that even small uncertainties on temperature measurements due to spectral emissivity changes at the front surface might trigger significant deviations in the derivation of transient heat fluxes from measured temperatures.

Therefore, a new material probe design has been proposed and manufactured at the IRS, aiming to directly evaluate transient heat fluxes and be a valuable tool in the framework of material characterisation for re-usable TPS. The newly-designed material probe is based on a calorimetric working principle and allows deriving heat fluxes by measuring the temperature change induced into the cooling fluid. A dedicated water-cooled circuit has been designed and particular care has been taken into selecting appropriate geometries and materials for each component. The probe consists of a main brass cylinder where dedicated channels distribute and collect the water used to cool down the material sample. The heat from the sample's back surface is transferred via conduction to a tungsten-lanthanum (W-La) heat sink and consequently to the water-cooled cylinder via radiation and conduction through a W-La ring. The use of W-La ensures excellent thermal conductivity and high operational temperatures, together with a low coefficient of thermal expansion, paramount in case of contact between sliding components. The ring is remotely adjusted with a step motor and allows for controlling of heat losses induced from the heat sink to the water-cooled circuit. Moreover, this feature allows for tuning of sample's front surface temperature for more than 200 K without changing stagnation conditions, triggering important applications into the investigation of materials' catalytic properties.