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AERO-THERMO-DYNAMIC CHARACTERIZATION OF LARGE-SCALE NEAR-ZERO ABLATION THERMAL PROTECTION SYSTEMS IN ULTRA-HIGH-TEMPERATURE CERAMIC MATRIX COMPOSITES

Abstract

The harsh environment of atmospheric re-entry, characterized by extremely high specific total enthalpies and Mach numbers, ultra-high temperatures and chemically aggressive non-equilibrium flows, makes the design of thermal protection systems (TPS) a crucial step for future space missions. The advancement of hypersonic flight technology sets increasingly demanding requirements for high-performance TPS materials.

Among the most promising candidates for the application are the Ultra-High-Temperature Ceramics (UHTC), namely transition metals carbides and diborides, which display considerably high melting temperatures, high hardness and good conductivity. Oxidation resistance at high temperatures is typically improved by addition of SiC as a secondary phase, which fosters the formation of a glassy oxide protective scale, hampering further oxygen penetration. However, conventional UHTCs lack of damage tolerance and thermal shock resistance, needing therefore the introduction of reinforcing fibers to enhance the mechanical properties, creating the so-called Ultra-High-Temperature Ceramic Matrix Composites (UHTCMC).

In this framework, the Horizon 2020 European C^3HARME research project, involving several universities, research centers and industries all over Europe, is focused on a new class of carbon fiber-reinforced UHTCMCs for near zero-ablation thermal protection systems. The characterization activities of the materials in relevant environment have been designed according to an incremental approach, progressively increasing the Technology Readiness Level of the test prototypes. After a small-scale screening campaign carried out in the supersonic plasma wind tunnel of the University of Naples "Federico II", further experimental activities are ongoing on large-scale prototypes at DLR in Cologne. Materials with different

matrix compositions and fiber architectures have been exposed to the high-enthalpy supersonic flow produced in the arc-jet wind tunnel L3K, in stagnation-point configuration, in different test conditions, in order to reproduce the typical heat fluxes (around 2 MW/m^2) and stagnation pressure (around 70 kPa) of a reference re-entry mission, in presence of a high amount of dissociated oxygen. Re-usability tests were also performed, exposing the same samples to multiple heating cycles. Two-color and spectral pyrometers were used to monitor the time history of the samples surface temperature, while near- and far-infrared thermo-cameras allowed capturing the temperature distribution over the exposed surface. Ablation resistance of the materials was characterized by mass and thickness measurements before and after test. The test campaign is going to be concluded with the characterization of UHTCMC tiles mounted on a complete TPS assembly, in order to achieve a final TRL of 5.