Aerospace Europe Conference 2023
Joint 10th EUCASS – 9th CEAS Conference

Analysis of an arc heated air plasma generator for material screening applications

Mathilde RIDARD [1], Bruno VAN-OOTEGEM [2], Grégory PINAUD [2], Kevin HARAS [1]*

** Corresponding author*
[1] ArianeGroup, rue de Touban, Les Cinq Chemins, 33185 Le Haillan, France, mathilde.ridard@ariane.group
[2] ArianeGroup, rue du Général Niox, 33165 Saint-Médard-en-Jalles, France

Abstract

ArianeGroup is constantly developing new composite materials, particularly Ceramic Matrix Composites (CMC), Ultra-High Temperature Ceramic Composites (UHTCC) and Polymer Matrix Composites (PMC), used in rocket nozzle and reentry vehicles heatshield. For these applications, ablation properties and thermal protection are critical.
In these developments, material screening ground facilities are needed in order to identify the best materials and processes to reach those two main objectives.
The behavior of a composite material in a rocket nozzle or atmospheric reentry environment can be evaluated with regard to its resistance to mechanical erosion or chemical erosion.
Regarding the oxidation of carbon based materials, two main competing mechanisms are at stake: chemical reactivity of carbon with gaseous oxidizing species, and transport efficiency of gaseous species within the flow field, resulting in a competing reaction-diffusion system at the surface of carbon material in an oxidizing environment.
ThermoGravimetric Analysis (TGA) devices, or tubular reactors for instance, provide some information about the oxidation behavior of materials regarding kinetic models.
However, only realistic oxidizing flow fields would be representative of the complex ablation phenomena occurring in a rocket nozzle environment.
The most representative of all are real scale or reduced scale static fire tests, producing combustion gases chemical compounds. However, those testing methods remain too complex and too expensive for material screening applications.
Plasma and oxy-acetylenic torches are able to produce high temperature oxidizing flows at much lower costs; plasma torches reaching higher temperatures, even though none of both is producing the same chemical species as rocket propellants.

With this objective, regarding experimental aspects of this approach, ArianeGroup is operating an arc heated air plasma generator to test thermostructural and phenolic materials in rocket nozzle and / or atmospheric re-entry environments. This torch is able to produce an oxidizing flow with temperatures of at least 4000°C, heat fluxes of about 6 or 7 MW/m^2 and shear values of about 500 Pa. By its design, the reliability and reproducibility of the torch have been sought to be compatible with the material screening needs.
The surface temperature of the material samples exceeds 2000°C with the plasma torch alone (a laser heating process could have been used as well in addition to the torch, to heat up the surface with constant oxidizing flow, in particular for studies of the reaction-diffusion competition).
In the framework of the presented campaign, the oxidizing and heating flow generated by the torch has been found sufficient and representative enough of the targeted oxidizing regime at the surface of the sample.
Spectroradiometer, pyrometer and thermocouples devices are measuring the evolution of surface and material temperature during the test, and initial and final surface geometry are scanned to evaluate the post-test recession field for each sample.
Morphological analysis may also be performed to analyze the oxidized fibers and matrix facies.

Comparisons will therefore be made between different types of composite materials that are being developed at ArianeGroup, in order to meet the objective set at the start of this campaign.