Impact of arc-jet tests at 2200°C and thermal vacuum cycles on microstructure and mechanical behaviour of C_f-ZrB_2 UHTCMCs

Pietro Galizia[1], **Antonio Vinci**[1], **Luca Zoli**[1], **Alessandro Airoldi**[3], **Antonio Maria Caporale**[3], **Stefano Mungiguerra**[2], **Raffaele Savino**[2], **Mario De Stefano Fumo**[4], **Diletta Sciti**[1]

[1]*CNR-ISSMC, National Research Council of Italy - Institute of Science, Technology and Sustainability for Ceramics, Via Granarolo 64, 48018 Faenza, Italy*

[2]*University of Naples "Federico II", Dept. of Industrial Engineering, Naples – 80125 Naples, Italy*

[3]*Politecnico di Milano, Department of Aerospace Science and Technology – Milan, Italy*

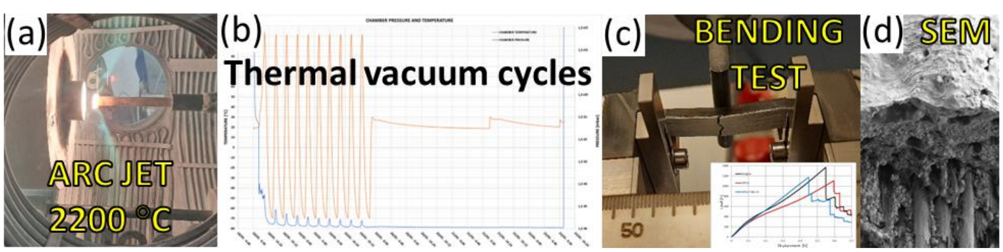
[4]*CIRA, Italian Aeropsace Research Centre -Capua, Italy*

pietro.galizia@issmc.cnr.it

Abstract

Ultra-high ceramic matrix composites (UHTCMC) are emerging as promising candidates to develop reusable launch vehicles (RLVs) because they merge their intrinsic temperature capabilities with the needed structural properties. This new class of CMCs showed unprecedented ablation and oxidation resistance and a combination of fatigue resistance and strength-toughness overturning the idea that CMCs cannot be densified without losing damage tolerance. However, the reusability of these CMCs with inherently high-temperature capabilities and ablation resistance goes through understanding of the effects of residual thermal stresses (RTS) caused by thermal expansion mismatch between fibre and matrix.

In this study, fully dense UHTCMCs, based on ZrB_2 and C_f, with small amounts of SiC, were produced using a slurry impregnation and sintering process to create bars for flexural strength tests. Additionally, sample holders suitable for fitting into an arc jet chamber and holding the bars were fabricated from the same material. Bars of dimensions 60x10x2.5 mm^3 (length x width x thickness) were exposed to a plasma of dissociated air at a temperature of 2200°C for two minutes and/or 10 cycles of thermal vacuum cycles at 10^{-6} mbar and fluctuating between -70 °C and 110 °C. Subsequently, they were weighed and subjected to 3-point bending tests to evaluate the impact of oxidation damage and thermal fatigue on their mechanical behaviour. Unexposed bars were also tested to assess their baseline load-displacement curves. The oxidized layer was analysed using optical microscopy and SEM-EDS. The materials retained more than 80% of the initial strength despite the high temperature reached. Furthermore, prolonged tests lasting up to 4 minutes at 2200°C were conducted on additional samples, demonstrating the material's durability. The reusability of the sample holder for up to four cycles was also confirmed. Finally, the study revealed the efficacy of thermal vacuum cycles in inducing RTS release without compromising mechanical strength.



(a) Picture of a specimen during arc jet test. (b) Profile of temperature (orange curve) and pressure (blu curve) during thermal vacuum cycles. (c) Picture of performed bending test and typical load-displacement curves. (d) SEM of the oxide scale.