BRIEF OVERVIEW OF CMCs ENGINE COMPONENTS EXPERIENCES COUPLED WITH REPRESENTATIVE SUB-ELEMENT TESTS

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From a general point of view, Ceramic Matrix Composites [CMCs], through a clever combination of a wide range of fibers and matrices, are designed to tailor thermomechanical responds at high temperature, in a field where the usual metallic materials have reached their limit, or to bring a mass saving due to their low density, with respect to end-use applications [1]. Ceramics fibers and ceramics matrices are inherently resistant to high temperatures, but they are characterized by a brittle behavior as monolithic ceramics. At the opposite, CMCs end up in damage-tolerant material, when the fiber-matrix bonding is properly optimized, usually achieved by a thin layer of an interfacial material referred to as the interphase. Another way to reach a non-brittle behavior, and particularly developed for oxide composites, is to combine the fiber with a weak matrix, obtained by a tailored nano-porosity.

CMCs were initially developed for aerospace applications, successively for the solid rocket nozzle of military missile and civil launchers, for upper stage liquid rocket engine, atmospheric re-entry bodies, and other high temperatures components of missiles. For these domains, generally characterized by very high functioning temperatures but a very short time of use, Cf/Cm CMCs (carbon fiber/carbon matrix) were developed in the 1970s, and are still used today for these applications, including, in some cases an Oxidation Protection System [OPS]. Later on, C/C technology was very successfully transitioned to aircraft brake application, leading to significant mass-production ramp-up.

Due to their great interest as thermostructural materials, considerable investment has been done, in the two last decade, to introduce CMCs technologies in aero-gas-turbines structural components, where maximum temperatures are relatively moderate compared to rocket propulsion, but where the functioning time in service is very long (life time duration between 1000 to 100.000 hours), in a particularly oxidizing environment. To address the field of aeronautical applications, the approach consisted in successively replacing the carbon fibers then the carbon matrix, which are highly sensitive to oxidation, by carbide and/or oxide fibers and carbide and/or oxide matrices. Today, state-of-the-art, for all actors, which are involved in the ceramization of aero-engines, is to develop and industrialise Cf/SiCm CMCs, SiCf/SiCm CMCs and Oxf/Oxm CMCs.

CMC design allowable are dependent on the type of fiber and matrix. Nevertheless, the choice of CMCs manufacturing processes combined to the design of components, including local singularities, is also a main driver of CMC performance. Considering the multiphasic heterogeneous aspect of CMCs, a building block approach is necessary to optimize both easily industrialized parts and design meeting functional requirements. This requires a fine tuned language and engineering tools between mechanics, design and CMC architecture, to end up, after an iterative path, in CMC parts that meet the best compromise between performance, cost and industrialization. Moreover, if it is relatively easy to determine the basic characteristics at a lab scale, complex technological tests often has to be developed, at the early stage of the design justification and to go toward engine tests, taking into account the most representative thermomechanical loads and environments, as possible.

The aim of this paper is to illustrate these different aspects of the CMC technologies, through different examples of Safran experiences, including different types of CMCs associated to different type of component. A focus will be done on specific tests methodologies development, for a better understanding of damage mechanism and some engine CMCs components tests will be presented.

[1] - Bouillon, E. (2021),” Ceramic Matrix Composite behavior enhancement for Gas Turbines Hot Sections”, Conference of NATO Science & Technology Organization, AVT-356 Research Symposium on Physics of Failure for Military Platform Critical Subsystems, November 15 – 19, 2021.