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NUMERICAL AND EXPERIMENTAL APPROACH FOR THE DESIGN OF CMC AND UHTCMC REUSABLE STRUCTURES: RESULTS OF AM3AC2A PROJECT

Abstract

The development of reusable space vehicles is a fundamental goal for reducing the cost of space access. In the last decades, Ceramic Matrix Composites (CMC) and Ultra High Temperature Ceramic Ceramic Matrix Composites (UTHCMC) emerged as particularly promising candidates for the development of lightweight hot-structures capable of performing structural roles in harsh environments with temperatures in the 1000C2000C and the presence of oxidizing agents. The primary structure of re-entry and hypersonic vehicles, and structural parts of space propulsion systems are among the main application scenarios considered in the studies carried out on such materials. However, a consolidated design approach for the aforementioned structural application has not yet been identified. The experience gained in the aeronautic field for the application of composite materials suggests the adoption of a damage tolerance design philosophy, based on the assessment of the structural capability to withstand the operational loads even in presence of damages difficult to be detected. The project AM3aC2A (Multi-scale Approach for Material Models of CMC and UHTMC in reusable Component for Space) funded by Italian Space Agency was dedicated to developing numerical tools and experimental protocols for damage tolerant CMC and UHTCMC hot-structures. The results of the project that will be presented include a series of material models developed at the meso-scale level, which make possible the prediction of the mechanical properties of structural details with complex geometry and in the presence of manufacturing defects. For UHTCMC, the fundamental role of thermal residual stress originated during manufacturing has been pointed out and modelled. The tolerance to impact damage and the detectability of impact-induced damages was investigated experimentally, proposing a protocol to measure residual bending stiffness. Finally, the

residual strength after exposure to relevant environment in Plasma Wind Tunnel was assessed. These results strongly indicate the possibility of developing damage tolerant CMC and UHTCMC structures and provide the tools for their design at different structural scales.