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THERMO-STRUCTURAL DESIGN OF ULTRA HIGH TEMPERATURE CERAMIC (UHTC) WINGLETS OF A RE-ENTRY SPACE VEHICLE

Abstract

The purpose of this paper is to present a general overview of a re-entry space vehicle study and a synthesis of the methodologies developed as well as the main results obtained. The final objective is to give a contribution to implement and evaluate the thermo-structural performance of a pair of Ultra High Temperature Ceramic (UHTC) winglets developed by CIRA. Therefore, the test-case consists of two winglets made of fibber reinforced massive UHTC coupled with a metallic interface. A plasma sprayed UHTC coating has also been applied on refractory metal. The winglets are mounted on a carrier vehicle which will fly at Mach numbers approximately equal to 8 over the altitude range 27-32 Km. A massive numerical study has been performed. In order to assess the capability of finite element models to predict the winglet thermo-structural behavior, several models have been developed. Finally, a solid finite element model is necessary. Solid meshes are first developed in order to identify the highly accurate numerical solution and to study the influence of mesh refinement. The performed convergence analysis shows the "just necessary model" is a solid FEM model whose mean element size is 1.0 mm. A thermal as well as a structural analysis have been performed. The main thermal results show that the launch phase is not critical while the re-entry is more demanding. Indeed, the UHTC tip get close to 1600C in a short time and the aluminum is heated up to 362C at the end of the flight. The heating on the aluminum surface of the vehicle is mostly caused by conduction from the winglet to the vehicle, and not by the wake of the winglet. The hot spot downstream the winglet is always cooler than the area just beneath the winglet. These temperatures can be sustained by the material without any relevant degradation. The combination of thermal and mechanical load have also been analyzed. Heat fluxes applied are time- changing depending by the wall temperature. Numerical predictions show how the structure is not affected by the inducted stress. The two winglets as well as the whole vehicle are actually being manufactured and the numerical prediction will be shortly validated by several experimental tests in CIRA's GHIBLI and SCIROCCO plasma wind tunnels facilities.