AEROFAST: THERMAL/ABLATION ANALYSIS OF THE FRONT HEAT SHIELD FOR A MARTIAN AEROCAPTURE MISSION

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Abstract

An Aerocapture vehicle travelling from Earth to Mars, approaches that planet on an hyperbolic interplanetary trajectory. Upon arrival, the vehicle will perform a single atmospheric pass to significantly reduce its speed, and enters into an orbit around the planet. This maneuver uses aerodynamic drag instead of propulsion for orbit insertion, and potentially leads to large mass (fuel) savings as well as reduced flight times (higher arrival speed). However, Aerocapture results in significant aerodynamic heating, necessitating a Thermal Protection System (TPS), as well as the use of a guidance system to assure that the spacecraft leaves the planetary atmosphere on the correct trajectory.

In the frame of the seventh European Community Framework Program (FP7), the AEROFAST (AEROcapture for Future space tranSporTation) research and development project aims at preparing a demonstration of a Martian Aerocapture mission and increasing the Technology Readiness Level (TRL). The aim of this paper is to present the preliminary thermo-mechanical analysis and design of the front-shield of the space probe. Despite the fact that several probe aerodynamic shapes and concepts are still being evaluated, this paper focuses only on the analysis of a 3.6 m diameter heat-shield, of an Apollo like shape with a low density phenolic impregnated cork as TPS. The 3D heat load history (convective and radiative), over the front-shield, is based on the maximum energy trajectory associated to a constant bank angle of 180° in a CO_2 Martian atmosphere.

In the first part of this paper we present the validation of the 3D ablation and charring material model in the finite elements program SAMCEF. This is done by comparing the results of the 3D and 2D axisymmetric studies, performed on the leeward and the windward side of the probe. The numerical model consists of three sets of equations, namely the transient heat balance equation, the steady state mass balance equation and the charring equations. For the charring of the material we use a multi-species Arrhenius model with the species densities as degrees of freedom. The ablation is modelled by a surface imposed and temperature dependent ablation speed, followed by an in volume mesh deformation.

In the second part, a preliminary design (allowable thickness versus curvilinear abscissa) of the TPS obtained for the cork based P45 material. The shape and mass evolution, during the Aerocapture phase, provides input for the mass budget and for the guidance and control analysis. In the future, complementary analyses will be performed including a model of an advanced cork based material (currently purchased in the frame of the AEROFAST project), as well as a full 3D thermal and thermo-mechanical analyses of the AEROFAST spacecraft heat shield, during the Aerocapture and post-Aerocapture phase.

REFERENCES

[1] H. Requiston, F. Bonnefond, Ph. Augros, J.-M. Bouilly, S. Reynaud and U. Westerholt. AEROFAST : AEROcapture for future spAce tranSporTation. In *1st EU-ESA International Conference on Human Space Exploration*, number IAC-09-A3.I.3, 2009.

[2] E. Smith, CA Sacramento, B. Laub, R. Beck, and E. Fretter. Thermal/Ablation model of low density Cork Phenolic for the Titan IV stage I engine Thermal Protection System. In *AIAA 27th Thermophysics Conference*, number 92-2905. AIAA, 1992.