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MATERIALS AND STRUCTURES SYMPOSIUM (C2)
Advanced Materials and Structures for High Temperature Applications (4)

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MULTI-DIMENSIONAL ABLATION AND THERMAL RESPONSE PROGRAM FOR RE-ENTRY ANALYSIS

Abstract

In Space missions, the atmospheric (re-)entry phase presents a critical challenge for spacecraft designers due to the extreme external temperatures that it must endure. Thermal protection systems (TPS) are required to prevent any damage to the re-entering spacecraft or its internal components and passengers. TPS are generally divided into two major categories: reusable and non-reusable. Ablative materials are part of the latter group; they are highly common and reliable. These materials perform their task through the pyrolysis phenomenon: an endothermic process that consumes external thermal energy to complete a change of state in the material itself, leading to material degradation.

This process is complex and not trivial to simulate nevertheless a considerable number of ablative material behaviour prediction tools exist and are widely applied in space research and industry. One of the most accurate ways to perform thermal protection analyses is to consider both the internal and external thermal energy balances and examine how the two interact with each other. The external analysis is generally performed by a CFD solver which can produce highly precise results however it can be computationally demanding.

This paper presents the combination of two low fidelity codes: one for material behaviour prediction and one for external heat flux estimation. The latter is a reduced order aero-thermodynamic code developed at Strathclyde University.[1]

The internal solver is a unidimensional code, based on the explicit finite difference method, which has the capability of evaluating; the internal temperature gradients, the pyrolysis phenomenon progression, the change of state and density in the material and the production of pyrolysis gases. If the material B tables are available, the code can also calculate the charred material mass flux and the material recession rate. The pyrolysis phenomenon is analysed as a multicomponent process in which every component of the material has different degradation characteristics and rates. The three-dimensional spacecraft erosion is evaluated running the one-dimensional ablative code for every geometry vertex. This method produces an estimation of the 3D problem solution while avoiding the complexity of a multidimensional thermo-ablative solver.

References

[1] Wuilbercq R., *Multi-Disciplinary Modelling of Future Space-Access Vehicles* (Doctoral dissertation) 2015.