INVESTIGATION OF THE THERMOCHEMISTRY OF ABLATION FOR PLANETARY ENTRY APPLICATIONS

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Since the sixties, the hypersonic flight regime has included a wide range of atmospheric entry and reentry, ground testing and flight of reusable hypersonic vehicles, reentry capsules and scientific probes. To withstand the severe conditions encountered during the entry phase, spacecraft are covered with a thermal protection system (TPS) that has two competing constraints: to provide enough protection of the payload without using all payload capacity for doing this. To fulfill these specifications, one of the most common and successful heat shield materials of the latter part of the 20^{th} century is carbon-phenolic, which has found application on missions to a number of different planets as well as on intercontinental ballistic missile nose cones.

While ablation is an effective means of reducing the heat flux level reaching the vehicle structure, the influence of the ablation products, which can include both gas-phase species and solid particles, on the flow around a planetary entry vehicle is not well understood. Although charring ablators have been extensively used, there is considerable difficulty in modeling the material behavior, owing to the multiplicity of physical phenomena, and their potentially non-linear interaction. The flow and solid domains are solved in, at best, a loosely coupled manner. Simplifying assumptions are often invoked and experimental correlations used, but the underlying “real physics” is still poorly understood.

A major area of uncertainty is the state of the pyrolysis gas leaving the char zone and the effect of this gas on after-body flows and radiant heat flux levels. Consequently, this doctoral study is directed toward evaluating the state of the pyrolysis gas for certain heating conditions relevant to planetary entry applications. It is expected that the results of the present investigation would be used to guide the development of more physically realistic empirical and numerical models of ablative material behavior.

The study is based on spectroscopic measurement techniques and takes place in both Inductively Coupled Plasma (ICP) plasma wind tunnels of the VKI, depending on the required heat flux levels. All of the first demonstration experiments have proven the viability of the design of a sample holder, aimed to provide quasi steady state conditions of ablation, matching surface recession and char-zone propagation speeds. The capability to integrate the ablating material testing and spectral data acquisition was successfully demonstrated on a non-charring material (Fig. 1). The issue of a fiber optic based light collection was also investigated, including stray light reduction. First measurements based on emission spectroscopy provide qualitative information to identify key reactions and species that could then be further probed using laser spectroscopy techniques.

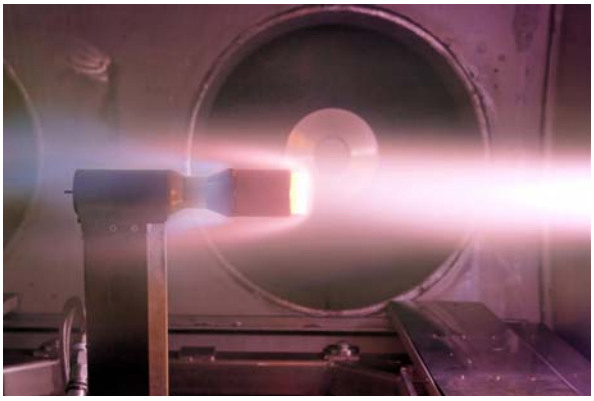

Figure 1: Ablation of graphite in air plasma

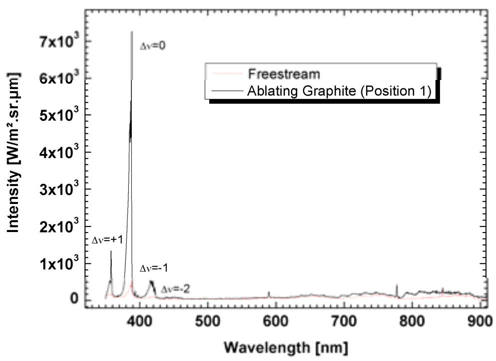

Figure 2: Emission survey of graphite ablation