MODELING OF HEAT TRANSFER ATTENUATION BY ABLATIVE GASES DURING THE STARDUST RE-ENTRY

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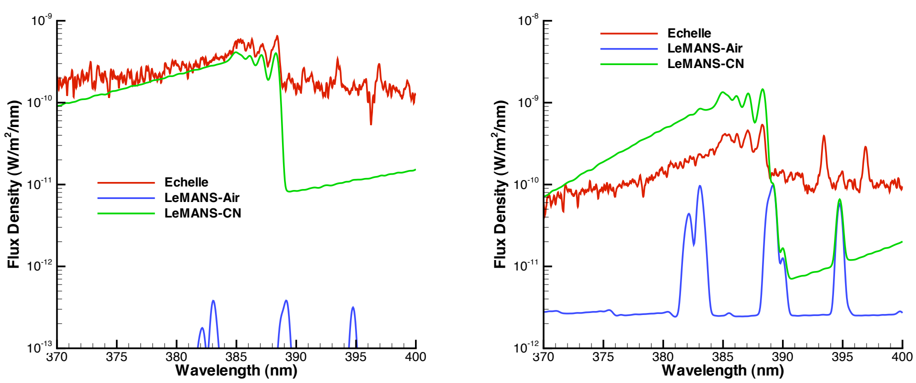
The great majority of modern space vehicles designed for planetary exploration use ablative materials to protect the payload against the high heating environment experienced during re-entry. In order to properly model and predict the aerothermal environment of the vehicle, it is imperative to account for the gases produced by ablation processes. In the case of charring ablators, where an inner resin is pyrolyzed at a relatively low temperature, the composition of the gas expelled into the boundary layer is complex and may lead to thermal chemical reactions that cannot be captured with simple flow chemistry models. In order to obtain better predictions, an appropriate gas flow chemistry model needs to be included in the CFD calculations. The effects of allowing such gaseous species to form in the flow field have notable repercussions on the amount of heat fluxes to the surfaces.

The present study examine the effects of blowing of pyrolysis gas in the outer flow field. Using six points on the Stardust entry trajectory at the beginning of the continuum regime, from 81 km to 69 km, the various components of the heat flux are compared to air-only solutions. Although an additional component of the heat flux is introduced by mass diffusion, this additional term is mainly balanced by the fact that the translational- rotational component of the heat flux, the main contributor, is greatly reduced. Although a displacement of the shock is observed, it is believed that the most prominent effects are caused by a modification of the chemical composition of the boundary layer, which reduces the gas phase thermal conductivity.

In order to validate the models, a flow field solution is used to perform analysis of the CN radiative spectral emission using NEQAIR. The result are compared to the experimental data obtained by the Echelle instrument at the 81 km and 71 km trajectory points. The computed results, shown on Fig. 1, are very close to the observed values, which provides increased confidence in the carbon-phenolic-in-air chemistry model, and the overall approach.



(a) 81 km: 34s into re-entry

(b) 71 km: 44s into re-entry

Figure 1: Spectral emission for the Startdust re-entry vehicle at 81 km and 71 km