Overview

Future space exploration missions foresee high-speed entries into planetary atmospheres. The space vehicle is exposed to extreme thermal conditions and requires an appropriate thermal protection system (TPS). A complete set of TPS material properties is not available in open literature. The inter-code comparison exercise proposed by the AF/SNL/NASA Ablation Workshop gives a baseline platform for ablation code calibration, with a complete set of material and gas properties.

Features

- Pyrolysis and charring of a carbon-resin material
- One dimensional, with contracting grid
- Finite-volume space discretization
- Implicit time integration
- Pyrolysis gas chemical non-equilibrium
- Gas/solid thermal non-equilibrium

Hypotheses

- Non-deformable material
- No closed pores
- Sum of resin products density equal to original resin density
- No gas-solid reactions (internal oxidation or carbon deposit)
- Gas diffusion neglected
- Radiative transfer within pores modelled as equivalent conduction

Mathematical model

1. Mass loss and gas formation

\[
\begin{align*}
\frac{d\rho_{\text{res}}}{dt} &= -k_{1}\rho_{\text{res}}^{e} \\
\frac{d\rho_{\text{gas}}}{dt} &= -k_{2}\rho_{\text{gas}} + g_{\text{res}}(1-k_{1}\rho_{\text{res}}^{e}) \\
\frac{d\rho_{\text{char}}}{dt} &= g_{\text{res}}(1-k_{1}\rho_{\text{res}}^{e})
\end{align*}
\]

\[
\dot{\rho}_{\text{gas}} = c_{\text{res}}(1-k_{1}\rho_{\text{res}}^{e})\rho_{\text{res}}
\]

2. Gas products mass conservation

\[
\frac{\partial (\rho_{\text{gas}} V)}{\partial t} + \nabla \cdot (\rho_{\text{gas}} V) = \dot{\rho}_{\text{gas}} + \dot{\rho}_{\text{char}}
\]

3. Momentum conservation

\[
K V p = -\mu_2 V
\]

4. Solid energy conservation

\[
\frac{\partial \rho_{\text{res}} h_{\text{res}}}{\partial t} + \nabla \cdot (\rho_{\text{res}} h_{\text{res}} V) + \gamma(T_p - T_s) = 0
\]

5. Gas energy conservation

\[
\frac{\partial \left(\rho_{\text{gas}} h_{\text{gas}} + \frac{1}{2} \rho_{\text{gas}} V^2\right)}{\partial t} + \nabla \cdot \left(\rho_{\text{gas}} h_{\text{gas}} V + \rho_{\text{gas}} V V\right) - \gamma(T_p - T_s) = 0
\]

TACOT results

A hobby...

Testing of an alumina foam sample in a plasma torch

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