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A Study of TPS Defects using a One-Domain Porous Media Model

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Abstract

To better understand the multi-physics processes occurring during atmospheric reentry and enable the design of the next generation of thermal protection systems (TPS), NASA has developed the porous material response solver (PATO). Of the many coupled processes occurring during reentry, understanding the mechanical wear of TPS has become a recent priority due to the defects observed on the surface of the Orion spacecraft from the Artemis I mission; The buildup of thermal energy inside low permeability regions of the ablative TPS material AVCOAT lead to cracking and ultimately cavity formation. Recent work on PATO has included the development of a Unified solver, where both the material response and flow are modeled in a single domain using field variables to capture the solid and fluid regions. In addition, a gas phase chemistry solver has been implemented utilizing Mutation++, which is a thermochemistry library capable of providing thermodynamic properties such as enthalpy, transport models for viscosity and diffusion, kinetic parameters such as the forward and backward rates, and analytical Jacobians of the total production rates. In this work we demonstrate the Unified solver's capabilities and study the gas phase behavior in response to defects in charred TPS. It is observed that the pressure build-up inside of the material is greatly affected by the permeability distribution, and that there is a decrease of the heating rate inside the cavity due to pyrolysis gas blowing.