Abstract Submitted
for the DFD09 Meeting of
The American Physical Society

A Tightly Coupled Solver for Hypersonic Ablation Problems

NATHAN MULLENIX, ALEX POVITSKY, University of Akron Dept. of Mechanical Engineering — Ablation is a process of rapid material removal from a solid surface by chemical reactions, sublimation and other erosive processes, absorbing large quantities of heat, and is one of the techniques used for thermal protection on hypersonic vehicles. It consists of several coupled sub-processes including gas dynamics, heat transfer, and ablative mechanisms at the surface. The past state of the art models include only a subset of these and generally ignore transient phenomena involving shape changes (i.e. formation of cavities). The current study presents the development of a solution methodology for the ablation problem in which the model for each sub-process are linked at the point of their development, the solution of each is tightly coupled to the solution of the others, and shape changes effects are intrinsically included. Starting from first principles, the Reynolds Transport Theorem is used to derive a set of governing equations that takes into account the movement of the ablating surface and the resulting mass transfer. Existing explicit-in-time finite-volume numerical methods are modified for this set, and a reactive-Riemann solver is derived for ablative fluxes. Methods for avoiding numerical artifacts such as plumes of ablated material are described. Results are provided for graphite ablation in hypersonic flow, and are compared to relevant experiments, and their sensitivity to particular parameters will also be presented.

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Date submitted: 11 Aug 2009 Electronic form version 1.4