Overview of Roughness and Blowing Effects in Flows Over Ablating Surfaces

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The scope of this session includes ablation effects on surface roughness and surface roughness effects on ablation. Ablation involves blowing, and so we address blowing including combined roughness and blowing effects. The two distinct types of ablating material surface roughness are defined with examples: 1) roughness related to the material inhomogeneity, and 2) roughness induced by turbulent flow that appears to be unrelated to material inhomogeneties.

Existing approaches for modeling ablative material surface roughness and blowing effects are overviewed. These range from empirical “augmentation factor” correlations to high-fidelity simulations of flow-surface interactions using modern CFD techniques. For models requiring input of roughness morphology information (e.g., effective sand grain roughness height), potential experimental and analytical sources of this information, and associated challenges, will be discussed. With regard to all modeling approaches for predicting ablative material surface roughness and its effects, experimental strategies for generating data needed for model development and validation will be emphasized.

Open questions for development of physics based roughness models	Target experimental objectives
• What kind of surface roughness (i.e., roughness height and character) develops on ablating materials, and how does this depend on material and environment parameters? • What determines when flow-induced ablation patterns (e.g., striations, crosshatching, scallops) do and do not develop? • Can the effects of flow-induced ablation patterns on heat and mass transfer rates be accounted for using models developed from artificial (e.g., machined) roughness data? • How do roughness and blowing effects on heat and mass transfer combine? Can we model these effects independently? Must experiments simultaneously simulate roughness and blowing? • How does surface roughness affect laminar flow heat and mass transfer (i.e., other than the effect on boundary layer transition), and how should this effect be modeled? • For blunt bodies over which the flow is assumed to be turbulent, how should we interpret and model surface roughness effects on stagnation point heat and mass transfer? • What is the most appropriate way to account for surface roughness and blowing effects in the CFD and material ablation analysis tools used for heatshield design?	• Cleverly designed experiments that address the "open questions" are needed • Example experimental approaches and challenges: 1. Rough-wall heat transfer models tested in hypersonic wind or shock tunnel – Facilities with adequate turbulent flow Re, M, size, etc.? – Relating machined model roughness to ablating material roughness? – Rough wall heat transfer instrumentation difficulty? – Fabrication of instrumented models with roughness & blowing? 2. Ablation materials of interest tested in hyperthermal facility – Candidate facilities: arc heaters, ballistics ranges, rockets, other? – Ability to provide appropriate turbulent flow ablation environment and test duration (particularly for blunt bodies)? – How to isolate surface roughness effects from other heat transfer and ablation uncertainties? – How to characterize surface morphology; in situ, post-test? 3. Low-temperature ablator models tested in hypersonic wind tunnel – Facilities with adequate Re, M, size, run time, etc.? – Can LTAs simulate ablative TPS roughness? – Can surface roughness and blowing effects be accurately inferred from ablation data?