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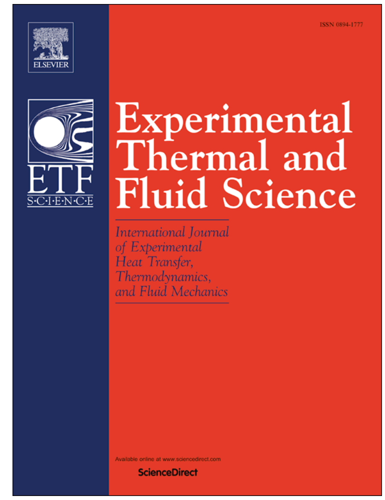

Experimental analysis of spallation particle trajectories in an arc-jet environment

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Experimental analysis of spallation particle trajectories in an arc-jet environment

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Abstract

Spallation is a phenomenon in which solid particles are ejected off the surface of an ablative material in a high-enthalpy, high-shear flow field. The main contributor to this phenomenon in carbon-based heat shields is the mechanical erosion of carbon fibers weakened by oxidation decomposition. The dynamics of this phenomenon, which are poorly characterized in the literature, strongly affect the ablation rate of the material. In state-of-the-art codes, ablation by spallation is modeled using a "failure" ablation rate that is empirically determined. The present study aims at understanding the rate of ablation of low-density carbon materials. Results from a test campaign at the NASA Langley Hypersonic Materials Environmental Test System (HYMETS) arc jet facility are used to examine spallation. High-speed multi-camera imagery at 44,000 fps is used to generate velocity vectors of spalled particles emitted from carbon-fiber samples exposed to an arc jet airflow. The imagery recorded approximately 4×10^6 unique particles, indicating that spallation is a potentially non-trivial process. The velocities of the particles ejected from the surface were found to be between 10 m/s and 20 m/s, accelerating to velocities as high as 250 m/s further away from the sample surface. Although the particle diameters were not directly observable, estimates suggest anywhere from 0.06% to 5.6% of the mass loss from the sample occurred due to spallation.

Keywords: Spallation, Ablation, Atmospheric entry, Thermal protection systems

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