Particle-based fiber models of woven materials for earth entry thermal protection
(PARTICLES 2023)

Andrew P. Santos*, Lauren J. Abbott† and Justin B. Haskins†

* AMA Inc., Thermal Protection Materials Branch, NASA Ames Research Center,
Moffett Field, CA, USA
Email: andrew.p.santos@nasa.gov

† Thermal Protection Materials Branch, NASA Ames Research Center,
Moffett Field, CA, USA

ABSTRACT

Applications requiring materials with layer-to-layer strength, from basketry to thermal protection systems, use interlaced, three-dimensional woven materials. NASA is developing and deploying woven material heat shields for missions, including Artemis I (3D-MAT for compression pads) and potentially Mars Sample Return - Earth Entry System. These materials are complex, hierarchical and must protect from extreme environments and phenomena, such as deformation, impact and high-enthalpy heating. Woven material performance depends on microstructure, damage and weave geometry. Therefore, fiber-specific models are needed to simulate fiber contacts within the weave hierarchical geometry (fiber to tow to yarn to weave) and the inherent directionality of fibers.

Explicit fiber models can simulate how weave microstructure evolution affects thermal and mechanical properties. We parameterize a discrete element bonded particle models (DEM-BPM) of fibers to capture thermal and mechanical behavior within and between fibers, with bonded and contact forces, respectively. We study the proportion of heat transfer and stress via the contact network, fiber bonds and the weave geometry, for example, with respect to yarn warp-weft identity (whether it interlaces weave layers). Our results demonstrate the importance of explicit fiber modeling for connecting microstructure with thermal and mechanical properties.