NASA SBIR 2020 Phase I Solicitation

Z7.05 3D Weaving Diagnostics

Lead Center: ARC

Technology Area: TA9 Entry, Descent and Landing Systems

Scope Title

3D Weaving Diagnostics for Validation of Uniform Weaving Processes

Scope Description

NASA is utilizing 3D woven materials to develop Woven Thermal Protection Systems (W-TPS). Examples of recent 3D woven Thermal Protection Systems (TPS) projects include: 3D Multifunctional Ablative TPS (3D-MAT) for compression pads on Orion, Adaptive Deployable Entry Placement Technology (ADEPT) looking at a mechanically deployable aeroshell (similar to an umbrella) that utilizes 3D woven carbon fabric between the ribs, and Heatshield for Extreme Entry Environment Technology (HEEET), containing dual-layer 3D weaves to provide mass efficient TPS solutions for extreme entry environment missions such as to Venus, Saturn and the outer planets. The specialized equipment used to weave 3D woven preforms is based on standard textile equipment that is substantially modified to allow hundreds of layers to be interwoven together. As these complex woven structures are scaled up, it is critical to understand the dynamics of the 3D weaving equipment/hardware and how interactions between different components affect the unit cell of the woven structure and ultimately the material properties.

This subtopic area solicits innovative technology solutions applicable to 3-D woven materials. Specific technology development areas include:

1. Advancements in the understanding of the impact of weaving parameters on the properties of the final weave itself. Looking at developing methods to associate measured weave diagnostics (such as warp tension and beat up force) to understand the effects of woven material parameters (such as fiber volume fraction and yarn crimp), to develop tools to predict the impacts of changes in weaving parameters on final material properties (such as stiffness and strength).
2. Understand what damage may be introduced into the yarns during the weaving operation and the impact of that damage on material performance (such as strength). Objective is to further improve the understanding of how/if key aspects/parameters in the weaving operation (warp tension, beat up force, warp or fill yarns per inch) lead to damage of the yarns and develop methods to reduce weaving damage and/or guidelines to reduce the level of damage induced in the yarns.

References

More info for 3D-MAT, ADEPT, HEEET can be found at: https://gameon.nasa.gov/publications/

Expected TRL or TRL range at completion of the project: 3 to 6

Desired Deliverables of Phase II

Prototype, Analysis

Desired Deliverables Description

Phase I: Assessment study of potential diagnostic techniques
Phase II: Prototype instrument demonstration on a weaving machine demonstrating increased control capability

State of the Art and Critical Gaps

NASA is investing in woven thermal protection systems, both rigid and mechanically deployable, which both come from a 3D weave. The mechanical/structural properties of these weaves are a strong function of nuances in the resultant weave microstructure; nuances such as fiber volume fraction and the level of crimp in warp versus weft direction or damage induced in the yarns during weaving. An enhanced understanding of the effects of the weaving operation parameters on the final weave itself would better enable scale-up of weaving processes (thickness and width) and tailoring of weaves to meet specific mission needs (how does a change in warp tension to reduce fiber volume fraction manifest itself in changes to crimp or other parameters). There is also value in understanding if/where the weaving operation induces damage into the yarn and its impact on material properties. The current state of the art is very empirical for understanding the effects of weaving parameters on material performance/damage. For example, it is recognized that increasing crimp can decrease stiffness in a material, but there are not good tools to predict the impacts of changes in weave parameters (such as warp tension) are on the crimp level in a weave and how that will impact the properties of the final material. This makes it difficult to predict the impacts of changes in weave on properties and understand how sensitive the relationships are. The end result is that this lack of knowledge limits the flexibility end users have, and requires substantial amounts of testing to understand if a given change is important or not.

Relevance / Science Traceability

Several potential future missions, outlined in decadal surveys, crewed exploration mission studies, and other supporting analyses, have Entry and Descent (ED)/ Entry, Descent and Landing (EDL) architectures: Mars sample return, high speed crewed return, high mass Mars landers, Venus and gas/ice giant probes. With few exceptions, entry vehicle TPS (Thermal Protection System) for these missions will be composed of materials currently under development and without certification heritage.

NASA planetary exploration programs supporting ED/EDL missions are the intended beneficiaries of this subtopic.