Measurement of Thermophysical Properties for the Development of a Flexible Thermal Protection System (FTPS) for Mars Entry

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A flexible thermal protection system (FTPS) is needed to enable the use of deployable and inflatable hypersonic decelerators on aerocapture, entry, descent, and landing missions. These decelerators could increase entry vehicle drag area beyond that of conventional rigid heatshields, enabling Mars missions with greater landed masses and/or higher-elevation landing sites. An ESA technology development study was completed to define an FTPS that may be integrated with a Mars-entry inflatable hypersonic decelerator.

The FTPS consists of three functional layers: (i) a protective outer layer, resistant to high heat flux; (ii) an insulation layer to delay the entry heat pulse; and (iii) a gas barrier layer to prevent hot gases/decomposition products from damaging the underlying structure. The individual materials must comply with a series of requirements, e.g., thermophysical and -mechanical properties, flexibility, handling and manufacturability. Insulation materials with high-temperature performance, flexibility and low thermal conductivity were selected and characterized, including Nextel 440 BF-20 (an alumina-silica-boria ceramic fiber woven fabric), Sigratherm GFA (a graphite felt), and Pyrogel XTE (a silica-based aerogel).

This work reports measurements of thermophysical properties of selected individual layer materials as well as heat transfer through layered stacks. The basic measurements were performed with classical laboratory means, e.g., laser-flash, DSC, or thermogravimetry. The fabric and felt structure, as well as the low thermal conductivity of these materials posed some measurement challenges. Additionally, thermal conductance tests on 120 mm x 120 mm stacks, instrumented with thermocouples between the individual layers, were performed by applying a graphite crucible containing solidifying copper at one surface.

The obtained thermophysical data was incorporated in a numerical model to describe the temperature development in the FTPS during atmospheric entry, which in turn was tested by plasma arc-jet testing.