EXPLORATION OF A NEW AFFORDABLE THERMAL PROTECTION SYSTEM UTILIZING NEEDLE-PUNCHED (2.5D) FABRIC COMPOSITES

by

Ryan McDermott, B.S.

ABSTRACT

Thermal protection systems (TPS) designed for solid rocket motors (SRMs) and reentry vehicles employ ablative composites. Phenolic and cyanate ester are state-of-the-art (SOTA) resin systems used in many of the ablative composites today, including MX-2600 from Cytec Solvay Group. While these ablatives have worked well, more demanding requirements drive the need for affordable lightweight advanced composites capable of handling high heat fluxes with less mass loss. These advanced ablative composites result in lighter heat shields and solid rocket motors, increasing payload capabilities of rockets and missiles. Molding compound made of aerospace grade 99% SiO_2 fabric and polysiloxane resin showed considerable improvement over MX-2600 in ablative properties in recent studies. Also, to meet increased mechanical strength demands, NASA recently developed an ablative composite using a 3D quartz woven material designed for the Orion spacecraft. While 3D woven composites provide excellent out-of-plane mechanical and ablation properties, they are very expensive, which limits their application. This research explores needle-punched silica fabric, sometimes referred to as 2.5D, which provides similar out-of-plane mechanical benefits to 3D woven composites in a more flexible VARTM manufacturing process at a much lower cost. The needle-punched silica fabric was infiltrated with polysiloxane resin, and mechanical tests were performed. The needle-punched composites showed a 181% increase in flexural strength and a 27% increase in interlaminar shear strength. In ablation tests, the 2.5D

out-performed the 2D laminate in char yield, mass loss, and recession rate; and in char yield and mass loss (%), the 2.5D out-performed the industry standard MX-2600 molding compound. The increased out-of-plane strength and char yield make it a promising and affordable candidate for ablation performance with enhanced mechanical properties.

Key Words: Ablation, thermal protection systems, needle punched, 2.5D, high-temperature, and polysiloxane