Paper ID: 52477
oral

IAF MATERIALS AND STRUCTURES SYMPOSIUM (C2)
Advanced Materials and Structures for High Temperature Applications (4)

Author: Mr. Peter Valentine
National Aeronautics and Space Administration (NASA), United States

Mr. Paul Gradl
National Aeronautics and Space Administration (NASA), United States

EXTREME-TEMPERATURE CARBON- AND CERAMIC-MATRIX COMPOSITE NOZZLE EXTENSIONS FOR LIQUID ROCKET ENGINES

Abstract

The United States (US) National Aeronautics and Space Administration (NASA) and its US industry partners are developing extreme-temperature composite nozzle extensions for a variety of cryogenic liquid rocket engine propulsion systems. Applications under consideration at the NASA Marshall Space Flight Center (MSFC) include launch vehicle (upper stage), in-space, and lunar lander descent/ascent propulsion systems. Composite material systems of interest include carbon-carbon (C-C) and carbon/silicon-carbide (C-SiC) composites, as well as modified versions of such composites (coatings, mixed matrices, oxidation inhibitors, etc.). Missions addressed include access to low Earth orbit, the lunar surface, and more distant destinations.

Cryogenic liquid rocket engines are optimized for performance through the use of high area ratio nozzles to fully expand combustion gases to low exit pressures, increasing exhaust velocities. As a result of the large size of such nozzles, and the related engine performance requirements, composite nozzle extensions are being considered to reduce mass impacts. Currently, the metallic and foreign composite nozzle extensions used on the Atlas V, Delta IV, Falcon 9, and Ariane 5 launch vehicles represent the state-of-the-art. Such extensions are limited to use at or slightly above 1093C (2000F). Materials under development by MSFC and its industry partners have the potential to operate at temperatures up to (or above) 2204C (4000F).

Marshall Space Flight Center efforts are aimed at (a) further developing the technology and databases needed to enable the use of composite nozzle extensions on cryogenic liquid rocket engines, (b) developing and demonstrating low-cost capabilities for testing and qualifying such nozzle extensions, and (c) advancing the domestic supply chain for nozzle extensions. Through the Small Business Innovative Research (SBIR) program, low-level internal MSFC research projects, and teaming arrangements with domestic industry partners, composite material design, development, hot-fire test, and evaluation efforts are progressing. Hot-fire engine tests of subscale hardware have been conducted using both oxygen/hydrogen and oxygen/methane propellants. These engine tests at MSFC have enabled the evaluation of both heritage and state-of-the-art material systems, demonstrating the initial capabilities of the extreme temperature materials and their fabrication methods.

Recent, ongoing, and potential future work supporting cryogenic propulsion systems development will be presented. The composite nozzle extension technology and test capabilities being developed are intended to support both NASA and US Department of Defense requirements, as well as those of the broader Commercial Space industry.