Paper ID: 72587
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student

IAF SPACE PROPULSION SYMPOSIUM (C4)
Liquid Propulsion (2) (2)

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DEVELOPMENT OF A METHOD FOR THE QUANTITATIVE ASSESSMENT OF FOULING BY THERMO-CATALYTIC FUEL DECOMPOSITION IN ROCKET COOLING CHANNELS

Abstract

Hydrocarbon fuels have long been favored for many liquid propulsion systems, owing largely to their high energy density and storability at ambient conditions. However, in contrast to e.g. hydrogen, hydrocarbon fuels are subject to thermo-catalytic decomposition at elevated temperatures. This decomposition, which can occur e.g. in rocket engine cooling channels, causes the deposition of solid carbon on channel walls, which alters the cooling capabilities of the system. This can result in thermal degradation of the hardware and even catastrophic failure. For reusable systems, thermal degradation will contribute to component life limits and maintenance costs. Methane has received significant attention as a fuel for future reusable liquid propulsion systems such as ESA's Prometheus engine. This, in part, is due to the higher theoretical thermal stability compared to fuels such as kerosene.

Research on the subject of methane as a rocket fuel has focused on important factors such as the heat transfer characteristics; however, limited work has focused on investigating the thermo-catalytic stability characteristics under representative conditions. A challenge in the research of this decomposition of methane in rocket systems is the fact that not only the wall material, but also the deposited carbon itself can catalyze the decomposition reaction. Therefore, cleaning and inspection methods are necessary, which facilitates the removal of carbon depositions between tests, and quantify the remaining carbon fouling in test sections. In future applications, such methods may be translatable to procedures for the inspection and maintenance of operational, reusable rocket engines.

This work discussed the development of a method for the quantitative assessment of fouling by thermo-catalytic fuel decomposition in rocket cooling channels. This effort is part of the MERiT project, a collaboration between KTH Royal Institute of Technology and GKN Aerospace Sweden AB, and supports the wider research into the characterization of methane as a fuel for reusable rocket engines. The method is based on the quantification of the differences in imagery of fouled samples when compared to uncontaminated controls. The samples are made of common high-temperature alloys and will include different surface conditions, including those representative of additive manufacturing processes. The carbon fouling will be deposited by means of a dedicated experimental setup, under controlled conditions of temperature (723 K - 1073 K), pressure and exposure time (10 min. - 60 min.). Finally, the method is tested by assessing the residual fouling in a rocket nozzle cooling channel, after it has been treated by an ozone-based cleaning procedure.