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METAL ADDITIVE MANUFACTURING FOR ELECTRIC PROPULSION

Abstract

Electrothermal propulsion systems for spacecraft consist of an electrically powered heat exchanger, which increases the enthalpy of a propellant. Enthalpy is traded for kinetic energy through a gas dynamic expansion process to produce a high velocity exhaust jet via a converging-diverging nozzle producing thrust. The performance is quantified by the specific impulse (ISP), which increases proportionally to the square root of the stagnation gas temperature. By increasing the stagnation temperature, the amount of propellant required on board of the spacecraft to accomplish a specific mission decreases or greater total impulse is provided for a fixed quantity of propellant.

Surrey Satellite Technology Limited (SSTL) has used a low power hot gas system, known as a resistojet, since 2002, which uses either butane or xenon as propellant. This system has flown on 20 spacecraft including the European GPS Galileo Testbed GIOVE-A validation satellite. A collaborative development programme between the University of Southampton and SSTL is currently proceeding to develop a High Temperature Xenon Resistojet (HTXR), which nearly doubles current ISP performance. Selective Laser Melting (SLM) manufacturing is being utilised to build a novel complex thin-wall concentric tubular heat exchanger as a single component, for this reason this thruster has been named Additively Manufactured Resistojet with Xenon (AMR-X). The AMR-X is designed to increase the stagnation temperature of the propellant to approximately 3,000K with a resulting ISP for xenon propellant is above 80s.

Presently, the primary driver of resistojet technology is a requirement for the all-electric propulsion spacecraft bus. Geostationary telecommunication satellites typically use chemical propulsion for attitude control as well as orbit–raising and station-keeping. The benefit of using an AMR-X is in fuel mass savings, cost savings in launch vehicle option for lighter spacecraft and further reduction of costs by eliminating the use of hazardous propellants.

This paper presents the design and performance evaluation of the first AMR-X breadboard model (BM) thruster through vacuum testing at the University of Southampton. The BM is made by stainless steel, which limits the maximum gas temperature to about 1,000K, for an expected ISP in the region of 50s with xenon. High-resolution micro Computed Tomography (CT) is used as a tool for non-destructive inspection, since the concentric tubular heat exchanger of the thruster is closed not allowing visual inspection. The CT volume data is used to determine a surface mesh to perform coordinate measurement, nominal/actual comparison and wall thickness analysis.