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DEVELOPMENT AND TESTING OF A HIGH-PERFORMANCE 3D PRINTED INCONEL RESISTOJET

Abstract

Currently available propulsion technologies for high Δv orbital maneuvers impose a tradeoff between high thrust – low I_sp (chemical rocket engines) and low thrust - high I_sp (Hall and ion thrusters). Recent examples of commercial all-electric GEO satellites, while substantially reducing fuel consumption, have increased the transfer time to 4-6 months, which may not be the optimal choice for commercial operators when satellites cost in the hundreds of millions USD. A potential alternative would be the use of a high-temperature hydrogen resistojet, which would be theoretically capable of exceeding 800s of I_sp while maintaining a thrust/power ratio of 200 mN/kW. The development and utilization of such thrusters, however, has been limited by the need of manufacturing complex shapes at very small scales capable of withstanding temperatures in excess of 1500K. With the recent developments of 3D printing technologies for metallic materials (selective laser melting), however, manufacturing of such components has become possible. Our design involves a single block multi-layer cylindric heater element with integrated flow channels, manufactured in Inconel for simplicity. The first demonstration prototype, with 6 heating layers with 0.2mm thickness, had a total resistance of 20mΩ, while the improved variant, packing 14 layers in the same volume, offers a 80mΩ resistance, increasing its capability of depositing electrical power to the propellant. Testing of the new model on N2 as propellant is been performed in thermal vacuum (same as for the 20 mΩ version), with positive results in terms of performance. Nitrogen operation offers up to 110s of I_sp and 390mN at 290W power input, with no performance decay observed through the performance curve. Operation on H2, which has a 14 times higher heat capacity, allow us to deposit substantially more power to the propellant, nearing the limits of the resistor, obtaining 410s of I_sp at the same thrust and 1.2kW power input. In this proof-of-concept, performance is limited by the operational temperature of Inconel, which loses yield strength above 900K. As our concept of 3D printed resistojet has been proved to have high performance capabilities while remaining easy to manufacture, the next logical step will be to manufacture a higher temperature variant of the current design. This will be manufactured in tungsten, allowing a wall temperature of 2000K and hence an I_sp up to 750-800s at 390mN with about 2.5kW power input.