Paper ID: 34886
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SPACE PROPULSION SYMPOSIUM (C4)
Electric Propulsion (4)

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DISCHARGE AND PHYSICAL CHARACTERISTICS OF AN ABLATIVE LIQUID-FED PULSED PLASMA THRUSTER FOR SMALL SATELLITES

Abstract

The miniaturization of technology has enabled the development of increasingly smaller satellites, and there has been increasing interest in small satellites weighing <100 kg. A major limitation of small satellites, especially those in the range of 1 – 10 kg, is the lack of a suitable propulsion system for performing large ΔV maneuvers. A suitable propulsion system can enable orbital transfers and provide de-orbiting capabilities. It can also potentially enable the use of lower orbital altitudes by compensating for atmospheric drag.

Pulsed plasma thrusters (PPTs) are a simple form of electric propulsion that have been used in orbit many times since the onset of space exploration. A solid propellant is ablated by an electric arc, producing plasma that is propelled between two electrodes. A capacitor periodically stores and discharges the required energy. These thrusters are very attractive for use in small satellites due to their inherently simple design. However, despite the design simplicity, many operational aspects are complex and are still being investigated. Furthermore, issues such as carbon deposition contribute to a reduction in the thruster lifetime.

The use of liquid or gaseous propellants is able to resolve some drawbacks, usually at the expense of increasing the complexity of the design. Gaseous propellants usually require high pressurization for propellant storage and high-speed valves for delivery. Alternatively, liquid propellants can potentially be stored and delivered using simpler concepts derived from microfluidics.

We present here investigation results for liquid-fed PPTs operating under principles similar to conventional ablative solid propellant PPTs. The simple and novel design maintains most of the simplicity of conventional PPTs while utilizing a non-volatile liquid propellant (a perfluoropolyether). Carbon deposition on the exposed ablation area was examined over thousands of pulses both macroscopically and with a scanning electron microscope. While conventional polytetrafluoroethylene (PTFE) propellant exhibited carbon deposition that is typical of PPTs, the ablation area of the liquid-fed PPT remained completely clear of carbon deposition, solving one of the major problems that can limit the lifetime of a PPT. Comparisons between the discharge characteristics of PTFE and the liquid propellant were also performed, with the liquid propellant shown to be equal to or even superior to PTFE in some aspects.

The results here will aid in the development of liquid-fed pulsed plasma thrusters with a simple design aimed towards reliable long-term use in small satellites.