Low and High-Power Inductive Pulsed Plasma Thruster Development Testing at NASA-MSFC

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I. Abstract

The inductive pulsed plasma thruster (IPPT) is an electromagnetic plasma accelerator that has been identified in NASA roadmaps as an enabling propulsion technology for some niche low-power missions and for high-power in-space propulsion needs. The IPPT is an electrodeless space propulsion device where a capacitor is charged to an initial voltage and then discharged producing a high current pulse through a coil. The field produced by this pulse ionizes propellant, inductively driving current in a plasma located near the face of the coil. Once the plasma is formed it can be accelerated and expelled at a high exhaust velocity by the electromagnetic Lorentz body force arising from the interaction of the induced plasma current and the magnetic field produced by the current in the coil.

Thrusters of this type possess many demonstrated and potential benefits that make them worthy of continued investigation. The electrodeless nature of these thrusters eliminates the lifetime and contamination issues associated with electrode erosion in conventional electric thrusters. Also, a wider variety of propellants are accessible when compatibility with metallic electrodes in no longer an issue. IPPTs have been successfully operated using propellants like ammonia, hydrazine, and CO₂, and there is no fundamental reason why they would not operate on other in situ propellants like H₂O. It is well-known that pulsed accelerators can maintain constant specific impulse (Iₚ) and thrust efficiency (ηₜ) over a wide range of input power levels by adjusting the pulse rate to hold the discharge energy per pulse constant. It has also been demonstrated that an inductive pulsed plasma thruster can operate in a regime where ηₜ is relatively constant over a wide range of Iₚ values (3000-8000 s). Finally, thrusters in this class have operated in single-pulse mode at high energy per pulse, and by increasing the pulse rate they offer the potential to process very high levels of power using a single thruster.

There has been significant previous research on IPPTs designed around a planar-coil (flat-plate) geometry. The most notable of these was the Pulsed Inductive Thruster (PIT), with the PIT MkV presently representing the state-of-the-art in pulsed high-power IPPT technological development. In this paper, we focus on two planar-geometry devices that operate at significantly different power levels. Most work performed at NASA-Marshall Space Flight Center (MSFC) has, to date, focused on lower power thruster operation (≈ 10s to 100s of J/pulse, up to 2-2.5 kW average power throughput) and previously described in Refs. In the present work, we present results from testing of both the small IPPT and the larger MkVI thruster. The smaller device (Fig. 1) is tested on a thrust stand on multiple gases to demonstrate its capability to operate in a repetition-rate mode and serve as an IPPT technology-development testbed. The larger MkVI (Fig. 2) is operated
for the first time in its newly reconstituted state, demonstrating full-power pulsed operation and, for the first time, repetition-rate operation of a high-power IPPT. The additional upgrades required for synchronous operation of all the pulsed systems in single-pulse and repetition-rate mode are described in detail.

![Image](image1.png)

**Figure 1.** (left) The assembled small IPPT and (right) the small IPPT operated in single-pulse mode at a charge of 2 kV.

![Image](image2.png)

**Figure 2.** Front and rear views of the PIT MkVI thruster during the re-assembly process.

**References**

