PULSE INDUCTIVE THRUSTER USING MARTIAN ATMOSPHERE AS PROPELLANT

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Introduction: Utilizing in-situ resources to avoid hauling the resources from Earth has always been an attractive strategy. However, processing the in-situ resources to get one type of product is very challenging. Pulse Inductive Thrusters (PIT) can use the Martian atmosphere as is for propellant used on the return orbit transfer vehicle, or as refill propellant for other science missions in the solar system.

Background: The Pulse Inductive Thruster (PIT) is an planar electrodeless electric propulsion device in which energy is capacitively stored and then discharged through an inductive coil. The time varying current in the coil interacts with propellant covering the coil face, first ionizing the gas and then inducing a plasma current. The propellant is accelerated by the Lorentz body force that arises from the interaction of the magnetic field and the induced plasma current. This process is illustrated schematically in Fig. 1. Shown in Fig. 1 is the basic operation of a PIT with a planar inductive coil while shown in Fig. 2 is a picture of the full-scale 1-m diameter PIT MkVI test article.

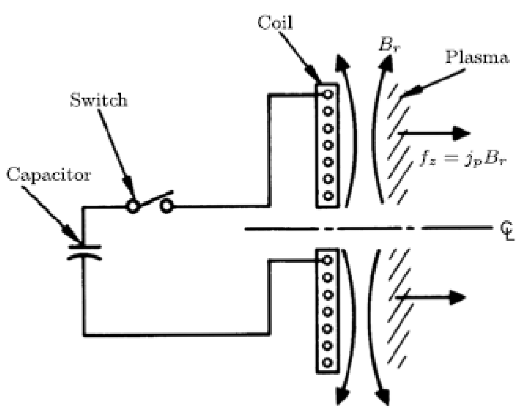

Figure 1. Schematic illustrating the basic operation of a planar pulsed inductive thruster [1].

Figure 2. PIT Mk VI

The PIT is attractive as a propulsion system for several reasons. It is electrodeless, which eliminates the lifetime and contamination issues associated with electrode erosion in conventional electric thrusters. PIT operation has been demonstrated using argon, ammonia, hydrazine, helium, nitrogen, xenon, and CO_2. Test results are shown in Fig. 3 for operation on argon, CO_2 and helium. The repetition rate of the PIT can be varied, providing constant performance per pulse (efficiency and I_{sp}) over a wide range of input power. The PIT has the potential to operate at high power (much greater than 50 kW) and provide thrust far in excess of 1-N. Additionally, because it is a pulsed electromagnetic thruster, PIT has a higher thrust-to-power ratio than conventional SOA Hall and ion thrusters.

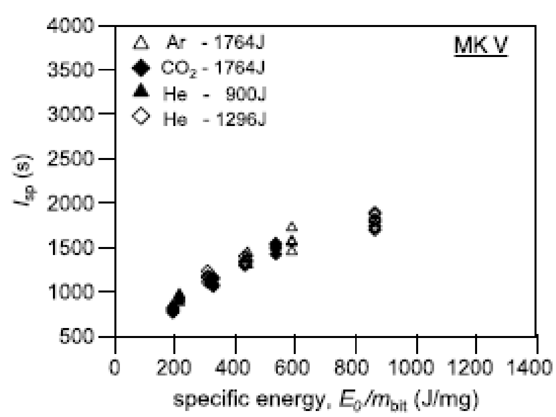

Figure 3. Performance of PIT Mk V operating on various propellants [2].

A variety of pulsed inductive plasma accelerator-concepts have been investigated. The planar PIT, where the inductive coil takes the shape of a flat spiral, was primarily investigated by TRW (later Northrop-

Grumman). Presently, NASA-MSFC is establishing a partnership with Georgia Tech to obtain and test the PIT MkVI, which was the last iteration of the PIT. Work at NASA-MSFC has also aimed at exploring the use of a conical-shaped coil, investigating pulsed inductive accelerators and field-reversed configuration (FRC) thruster concepts. The Air Force has recognized the potential to usepulsed inductive acceleration for high-power thrusters producing high thrust levels. This work has primarily centered around different variants of the FRC concept.

Concept: It may be advantageous to use the Martian atmosphere as propellant for the PIT, which could power Earth-to-Mars and Mars-to-Earth orbit transfers. The martian atmospheric composition is 95.32% carbon dioxide, 2.7% nitrogen, 1.6% argon, and 0.13% oxygen. If a thruster can operate on CO2 (as the PIT can), then the Martian atmosphere appears to be a simple and useful ISRU option. Assuming the performance operating on the martian atmosphere is acceptable, future Mars acent vehicles could easily be used to collect the Martian atmosphere with a small compressor and fill a COPV tank with the propellant required for a return trip to Earth. In additionn, the spacecraft wouldn't have to return to Earth but, instead, it could refuel at Mars and then proceed to other destinations in the solar system powered by PIT.

We propose an investigation of PIT performance using the Martian atmosphere as propellant. This investigation would be conducted at the thruster power levels commensurate with a Martian transfer stage is recommended.

References:

[1] Lovberg, R.H. and Dailey, C.L., "Large Inductive Thruster Performance Measurements," *AIAA Journal*, Vol. 20, No.7, 1982, pp. 971-977.

[2] Polzin, K.A., "Comprehensive Review of Planar Pulsed Inductive Plasma Thruster Research and technology," *Journal of Propulsion and Power*, Vol 27, No.3, May-June 2011, pp. 513-531.