Comparison of Computed and Measured Performance of a Pulsed Inductive Thruster Operating on Argon Propellant

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I. INTRODUCTION

Pulsed inductive plasma accelerators are electrodeless space propulsion devices where a capacitor is charged to an initial voltage and then discharged through a coil as a high-current pulse that inductively couples energy into the propellant. The field produced by this pulse ionizes the propellant, producing a plasma near the face of the coil. Once a plasma is formed if can be accelerated and expelled at a high exhaust velocity by the Lorentz force arising from the interaction of an induced plasma current and the magnetic field. A recent review of the developmental history of planar-geometry pulsed inductive thrusters, where the coil take the shape of a flat spiral, can be found in Ref. [1]. Two concepts that have employed this geometry are the Pulsed Inductive Thruster (PIT)[2, 3] and the Faraday Accelerator with Radio-frequency Assisted Discharge (FARAD)[4].

There exists a 1-D pulsed inductive acceleration model that employs a set of circuit equations coupled to a one-dimensional momentum equation. The model was originally developed and used by Lovberg and Dailey[2, 3] and has since been nondimensionalized and used by Polzin *et al.*[5, 6] to define a set of scaling parameters and gain general insight into their effect on thruster performance. The circuit presented in Fig. 1 provides a description of the electrical coupling between the current flowing in the thruster I_1 and the plasma current I_2. Recently, the model was upgraded to include an equation governing the deposition of energy into various modes present in a pulsed inductive thruster system (acceleration, magnetic flux generation, resistive heating, etc.)[7]. An MHD description of the plasma energy density evolution was tailored to the thruster geometry by assuming only one-dimensional motion and averaging the plasma properties over the spatial dimensions of the current sheet to obtain an equation for the time-evolution of the total energy. The equation set governing the dynamics of the coupled electrodynamic-current sheet system is composed of first-order, coupled ordinary differential equations that can be easily solved numerically without having to resort to much more complex 2-D finite element plasma simulations.

Solving for the total energy contained in the system permits the calculation of a time-varying plasma temperature, which then allows for the self-consistent determination of several thermodynamic and plasma parameters and relationships relevant to the specific propellant employed in the thruster. These include the ionization fraction (using the Saha equation), the specific heat ratio, the real-gas equation of state relationship between plasma pressure and temperature, and the plasma resistivity found using collision cross-section date. Customizing the model by incorporating these features allows for the comparison of calculations with actual performance data from previous measurements. In this paper, we compare to experimental data obtained using argon propellant in the PIT MkI, MkV, and MkVa devices. While not included in the present efforts, the existing formulation shows the path for inclusion of more complex physics in the model. These include a plasma radiation model and the use of two (or more) temperatures in the model to separately track the electron and ion temeperatures in non-equilibrium situations.

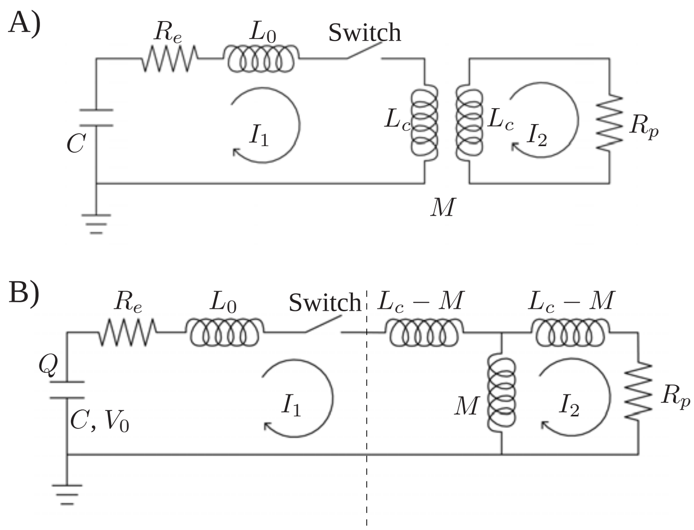

FIG. 1: A) General lumped element circuit model of a pulsed inductive accelerator. B) Equivalent electrical circuit model. (After Ref. [2])

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