

SPACE PROPULSION SYMPOSIUM (C4)
Electric Propulsion (4)

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COILGUN ACCELERATION MODEL CONTAINING INTERACTIONS BETWEEN MULTIPLE
COILS

Abstract

Electromagnetic (EM) accelerators have the potential to fill a performance range not currently being met by conventional chemical and electric propulsion systems by providing a specific impulse of 600-1000 seconds and a thrust-to-power ratio greater than 200 mN/kW. A propulsion system based on EM acceleration of small projectiles has the traditional advantages of using a pulsed system, including precise control over a range of thrust and power levels as well as rapid response and repetition rates. Furthermore, EM accelerators have lower power requirements than conventional electric propulsion systems since no plasma creation is necessary.

A coilgun is a specific type of EM device where a high-current pulse through a coil of wire interacts with a conductive projectile via an induced magnetic field to accelerate the projectile. There are no physical or electrical connections to the projectile, which leads to less system degradation and a longer life expectancy. Multi-staging a coilgun by adding multiple turns on a single coil or on the projectile increases the inductance, thus permitting acceleration of the projectile to higher velocities.

Previously, a simplified problem of modeling an inductively-coupled, single-coil coilgun using a circuit-based analysis coupled to the one-dimensional momentum equation through Lenz's law was solved; however, the analysis was only conducted on uncoupled coils. The problem is significantly more complicated when multiple, independently-powered coils simultaneously operate and interact with each other and the projectile through induced magnetic fields. This paper presents a multi-coil model developed with the magnetostatic finite element solver QuickField. In the model, mutual inductance values between pairs of conductors were found by first computing the magnetic field energy for different cases where individual coils or multiple coils carry current, then integrating over the entire finite element domain for each case, and finally using the definition of inductive energy storage to solve for the self and mutual inductance. The electric circuit model is coupled to the projectile through Lenz's law, with the coils coupled through mutual inductance but able to be independently triggered at different times to optimize the acceleration profile.

This initial model to predict the behavior of a projectile's acceleration through a coupled, multi-coil coilgun increases the potential of building a highly efficient coilgun thruster with key advantages over other EM thruster systems, thus making it a promising candidate for satellite main propulsion or attitude control thrusters.