CALIFORNIA STATE SCIENCE FAIR
2016 PROJECT SUMMARY

Name(s)

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Project Number

36627

Project Title

Improving the Efficiency of a Coilgun with the Use of Non-Uniform Coil Density and Current Reversal via H-Bridges

Abstract

Objectives/Goals

The coilgun is a device that launches a projectile through coils used as electromagnets. Although coilguns are quite durable, they typically only achieve efficiencies between 0.3% and 1%. A typical coilgun dumps all of the energy in a capacitor into a uniform coil, resulting in an acceleration when the projectile is in the first half of the coil and a deceleration when the projectile is in the second half. In this project, I propose three novel approaches to substantially improve the efficiency and velocity of a projectile.

Methods/Materials

I used an (open-source) Arduino controller to build my instrumentation, which included a DC current logger to log real-time coil current, a speedometer, consisting of two photogates to measure projectile velocities, and a firing control board employing solid-state relays to generate the current pulses. I bought a 50V, 120000μF capacitor as the power supply and built a charging circuit for it with a boost converter power supply that I bought. I also used PSpice (free online circuit simulator) to model RLC circuits with appropriate design parameters. I built five different types of coils, each hand-wound around styrene tubes, with varying coil densities. For the experimentation, a magnet was launched through the coils and velocities maximized with a single forward pulse. I added a reverse current pulse of the same duration when the projectile was close to the exiting end of the coil, along with varying delays placed between the two pulses to ensure the reverse current pulse was as close to the exit edge of the coil as possible. I then recorded the maximum velocities and corresponding efficiencies as functions of the delay.

Results

In my pulsed current system, the maximum velocity of a ferrite rod is 3m/s with an efficiency of only 0.02%. However, optimizing forward and reverse current pulses with non-uniform coil density increased the velocity up to 11.92 m/s and the efficiency up to 4.711%.

Conclusions/Discussion

The results demonstrate that varying coil density, using an H-bridge to reverse current, and using a magnet as the projectile can drastically improve the performance of a coilgun. I believe this is the highest recorded efficiency of a single-stage coilgun in the literature. Potential applications of this electromagnetic propulsion technology include high-speed trains, weaponry, and launch systems, and may even replace railguns if efficiency is further improved.

Summary Statement

I demonstrated that changing coil density, using a magnet as a projectile, and reversing current could dramatically improve the efficiency of a single-stage coilgun.

Help Received

My physics teacher Dr. Roy Rocklin gave me valuable advice for my poster and presentation.