Electromagnetic Railgun

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December 4, 2017

Abstract

A railgun is a device that uses electromagnetic force to launch high velocity projectiles, by means of a sliding armature that is accelerated along a pair of conductive rails. Railguns rely on electromagnetic force to propel a projectile at very high velocities(more than $3km/s$).

I. Introduction

A railgun is a device that uses electromagnetic force to launch high velocity projectiles, by means of a sliding armature that is accelerated along a pair of conductive rails. Railguns rely on electromagnetic force to propel a projectile at very high velocities(more than $3km/s$).

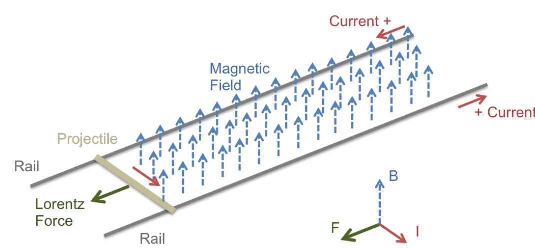
II. Potential Applications

- Railguns are being researched as weapons that would use neither explosives nor propellant.The absence of explosive propellants or warheads to store and handle conventional weaponry come as additional advantages.
- In addition to military applications, NASA has proposed to use a railgun to launch wedge-shaped aircraft with scramjets to high-altitude at Mach 10, where they will then fire a small payload into orbit using conventional rocket propulsion.
- Railguns can potentially be used to aid mining, as a substitute for dynamite for clearing tunnels.

III. Principle

The magnetic force on a current carrying conductor can be modelled by the equation.

Figure 1: *Working principle of railgun*



$$\vec{F} = I_r \vec{l} \times \vec{B} \tag{1}$$

Where F is force, B is magnetic field and I_r is current passing through the rails.

We notice that the direction of force is always outward as shown in $figure 1$, regardless of whether the power supply is AC or DC.

We apply the magnetic field as seen in Figure 1 using a current carrying coil. The magnetic field intensity of a current carrying coil with N turns is given by the equation

$$B = \frac{\mu_0 N I_c}{2r} \tag{2}$$

Where r is the radius of the coil, B is magnetic field intensity and I_c is current passing through the coil.

As the magnetic field is perpendicular to the current carrying projectile, $Eq(1)$ simplifies to $F = I_r l B$. Substituting equation 2 into 1, we get

$$F = \frac{\mu_0 N l I_c I_r}{2r} \tag{3}$$

IV. Approach

We began by deciding the architecture of our gun. After brainstorming many different setups, we settled on

- A set of 2 parallel rails
- A cylindrical graphite rod, which is conducting yet non-ferromagnetic.
- Strong Permanent magnets to generate an external magnetic field
- A capacitor bank in order to deliver high currents in a short amount of time to the rails.

Current progress

We began by designing the Capacitor bank charging circuit, using simulink (A MATLAB simulation software).

A detailed schematic of the circuit can be found below in Figure 1.

Figure 2 shows the voltage vs time plot of the charging capacitors.

Figure 2: *Circuit Diagram of simulated charging circuit*

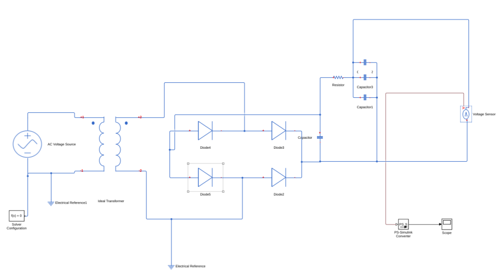
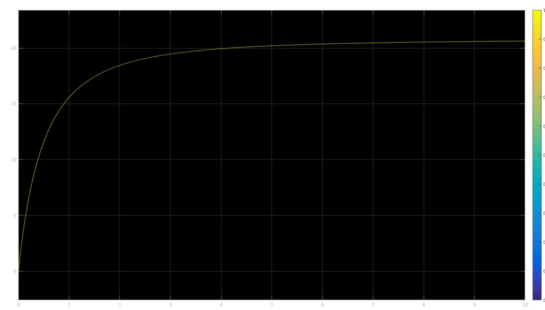
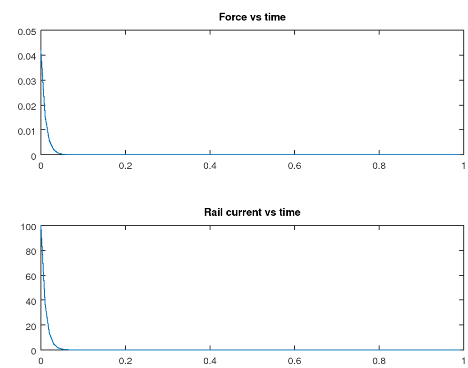


Figure 3: *Plot of voltage across capcitor bank vs time*



We ran calculations using a matlab script and plotted the force on the projetile vs time along with the rail current vs time.(Figure 3)

Figure 4: *Plots of rail current vs time and force vs time*



The script and all other code used in this project can be found in the project github repository. **https://github.com/AravindGanesh/IDP-Sem3**

Parameters

The following are the parameters in our matlab program to be used in our circuit with self explanatory names.

```
capcitance = 0.0010000
Voltage = 100
n_capacitors = 10
capacitor_rating = 100
Series_resistance = 1000
projectile_length = 0.020000
```

```
external_resistance =  1
mass =  0.010000
mu0 =     1.2566e−06
radius =  0.030000
turns =  200
coil_current =  5
B_coil =  0.020944
eff_capacitance =  0.010000
charging_Time_constant =  10
discharging_Time_constant =
0.010000
B_rails = 0
Energy_stored =  50
```

Testing the Prototype

We went to power electronics lab, charged capacitors(2.2mF, 25V) using charging circuit which was available in lab itself and tested the prototype.

As we used low valued capacitors, it couldn't supply enough voltage and hence it couldn't generate enough force to move the projectile.

So, now we are planning to make charging circuit according to our calculation.

V. Bibliography

- https://www.allaboutcircuits.com.
- electronics-course.com/ripple-counter.
- https://www.eecs.tufts.edu/ dsculley/tutorial