Enhanced Electromagnetic Railgun

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Abstract—Railguns are expected to reach higher muzzle velocities and fire rates than conventional guns. Due to the muzzle velocity and fire rate, railguns will perform much better against the future threats. The device is simple in construction. It has to parallel rails and a movable projectile. An electric current goes down through one rail and then through the project, returning back from the other rail. The magnetic field thus created in between the rails, pushes on the projectile with the current running through it to propel it out of the railgun. In an attempt to increase the efficiency of such a kind of railgun, we developed a simulation model calculating the maximum capacitor and system current. Also the model was revised to calculate the maximum system frequency. Thus the velocity at the barrel exit was about 53.5 m/s. Moreover the kinetic energy to be delivered by the electromagnetic railgun (EMRG) ask for the requirement of a pulsed power supply, and due to the repetitive experiments, need for thermal management has to be considered. Thus we carried out simulations many times to study mainly the electrical behavior of the EMRG and compared their advantage and disadvantages.

Keywords – Barrel exit velocity, capacitor bank supply, simulation, system study.

I. INTRODUCTION

Electro Magnetic Rail Guns, EMRGs for short, are systems that propels the projectile by using the electrical energy and transforming electrical energy into kinetic energy. With the EMRGs, the projectile is accelerated at a very high velocity. Before the EMRG came into existence, the conventional or light gas guns were popularly used. The only reasons they were discarded was due to the limitation of the acceleration of the expanding gas. The projectiles in those systems can never exceed the acceleration of the gas it uses. Thus EMRGs are not limited due to the acceleration as they convert electrical energy into kinetic energy. Though EMRGs themselves tend to only be about 2% efficient, theoretically they have no limit to how much energy can be input to the system. Due to this there is no maximum velocity that the design can obtain. In order to get the pulsed power supply for the EMRG, the capacitor banks are arranged thus using series of capacitors in to supply system. The capacitor bank discharge the electric potential built up through the projectile, inside the rails in order to create the EMRG’s force. Also an effort is made to built a protection circuit to prevent projectile getting stuck in between railguns.

II. PRINCIPLE

The basis for the railgun technology is found on the principle of Lorentz Force, which describes the interaction between electric current and magnetic fields, and is it is given by

\[ F = q (V_d \times B) \]

Where, \( q \) – is the charge, \( V_d \) – is drift velocity, \( B \) – is magnetic field and \( F \) – is force exerted on the charge. Electric current flows down the rail creating a magnet field between the rails. The projectile completes the circuit path resulting in current flow with a drift velocity \( (V_d) \) and a perpendicular component to the magnet field \( (B) \) resulting in a force \( (F) \) on the projectile.
III. BLOCK DIAGRAM:

**BLOCK DIAGRAM EXPLANATION:**

**Autotransformer:**
Auto transformer is kind of electrical transformer where primary and secondary shares same common single winding. So basically it’s a one winding transformer and here we are using Autotransformer to vary the voltage level. So that it would be convenient for as to supply it through lab autotransformer.

**Rectifier:**
It is an electrical device which converts an alternating current into a direct one by allowing a current to flow through it in one direction only. Due to some following advantages like the rectification efficiency of full-wave rectifier is double of that of a half-wave rectifier, so we decided to use full wave rectifier instead of half wave rectifier. Also, other key points like higher output voltage, higher output power and higher Transformer Utilization Factor and low ripple voltage make it more advantageous compared to full wave rectifier and in case of higher frequency it doesn’t required complex filtering circuit.

**Monitoring circuit:**
This circuit will consists of meters which will keeps eye on charging and discharging of capacitors.

**Switch:**
A device for making and breaking the connection in an electric circuit.

**CIRCUIT DIAGRAM**

**Storage devices:**
To achieve main objective of producing a pulse powered supply. We found that capacitors could be used and by comparing all the basic types of capacitors (based on construction). We came to know Electrolytic Capacitors are generally used when very large capacitance values are required. Here, instead of using a very thin metallic film layer for one of the electrodes, a semi-liquid electrolyte solution in the form of a jelly or paste is used which serves as the second electrode (usually the cathode). The dielectric is a very thin layer of oxide which is grown electro-chemically in production with the thickness of the film being less than ten microns. This insulating layer is so thin that it is possible to make capacitors with a large value of capacitance for a small physical size as the distance between the plates, d is very small.

**Injector:**
The injector subsystem is required to accelerate the projectile before it reaches the electric rails. If projectile enters the electric rails with no or low initial velocity, the projectile will weld to the rail. To combat this, an injector must be used it give the projectile an initial velocity (muzzle velocity). The more initial velocity obtained using the injector is also energy that the electrics rails do not have impact onto the projectile; ideally an injector that provides as much velocity as possible should be used.
Discharging Circuit:
IV. EQUATIONS

It consists of high value resistance to discharge the capacitance and inductor through it. As soon as the capacitor discharges, the projectile moves faster in the forward direction following the principle of Lenz’s law.

For cuboidal rails:

\[
\text{Energy of the capacitor bank} \quad \text{Number of capacitors} = 12 \quad \text{Capacity of capacitors} = 3300
\]

\[
= 3300 \times 10^{-6}
\]

Total capacity when connected parallel to each other then, Total capacitance = \(\frac{1}{2} \times (3300 \times 10^{-6}) \) F = 33000 \(\times 10^{-6}\) F

Then the energy developed by each capacitor is given by,

\[
\frac{1}{2} \times 12 \times 3300 \times 10^{-6} \times 350^2
\]

\[
\text{Input E} = 2021.25 \text{ Joule}
\]

The efficiency of the system is only 2% so, \(\frac{\text{Output}}{\text{Input}} = \eta\)

\[
\text{Output E} = \frac{2}{100} \times 2021.25 = 40.425 \text{ Joule}
\]

\[
\text{Dimensions of rails}
\]

Height of rail = 0.0622 m Length of rail = 50 \(\times 10^{-2}\) m

\[
\text{Calculation of inductance gradient}
\]

\[
L' = \frac{4}{2} \times \left\{ \frac{(0.0622 + 7.5 \times 10^{-3})^2}{(0.0622)^2} \right\} \quad L' = 0.0048 \times 10^{-6} \text{ H/m}
\]

\[
\text{Resistance of rails}
\]

\[
= \frac{1.72 \times 10^{-8} \times (50 \times 10^{-2}) \times (50 \times 10^{-2} \times 0.0622)}{(8 \times 10^{-3}) \times 2}
\]

\[
= 1.7338 \times 10^{-5} \Omega
\]

\[
\text{Calculation of force}
\]

Voltage applied = 350V Approximated current = 1000 A F = \(\frac{1}{2} \times \frac{1}{2}\)

\[
F = \frac{1}{2} \times 0.0048 \times 10^{-6} \times 1000^2 = 9.7
\]

F = m \(\times\)

Taking, mass of projectile m = 10gm = 10 \(\times 10^{-3}\) kg

\[
= \frac{a}{a} = 970 \text{ m/s}^2
\]

\[
\text{Calculation of velocity}
\]

\[
v = u + at
\]

Where, \(u = \) initial velocity imparted by injector

\[
t = \text{time elapsed by projectile to move outside the launcher} v = 5 + (970 \times 50 \times 10^{-3})
\]

Velocity = 53.5 m/s.
IV. SIMULATION

The Simulink diagram below shows how the electricity is taken from the charged capacitors and converts its current into required forces, acceleration and velocity. Thus the simulation helps in getting the actual values required for the EMRG. This models the physical rails, projectile and capacitor bank. These simulations allow us to make even the smallest of the changes in the design and note the changes that took place. The following are the graphs obtained of position, acceleration and velocity.

Figure 1: Simulation Model of Full EMRG System

Figure 2: Simulation Model of Subsystem Output of Simulation
Figure 3

Figure 4
Figure 5

REFERENCE


