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Electromagnetic Coil Gun Launcher System

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ABSTRACT: In our present time, a study was undertaken to determine if ground based electromagnetic acceleration system could provide a useful reduction in launching cost with current large chemical boosters, while increasing launch safety and reliability. An electromagnetic launcher (EML) system accelerates and launches a projectile by converting electric energy into kinetic energy. An EML system launches projectile by converting electric energy into kinetic energy. There are two types of EML system under development: rail gun and coil gun. A coil gun launches the projectile by magnetic force of electromagnetic coil. A higher velocity needs multiple stages of system, which make coil gun EML system longer. As a result installation cost is very high and it required large installation site for EML. So, we present coil gun EML system with new structure and arrangement for multiple electromagnetic coils to reduce the length of system

KEYWORDS: EML, coil gun, Electromagnetic launcher, suck back effect

I. INTRODUCTION

In chemical launcher systems such as firearms and satellite launchers, chemical explosive energy is converted into mechanical dynamic energy. The system must be redesigned and remanufactured if the target velocity of the projectile is changed. In addition, such systems are not eco-friendly. In contrast, electro-magnetic launcher (EML) systems convert electric energy into mechanical energy. Thus, such systems are very eco-friendly and can control the muzzle velocity of the projectile by controlling the electric current in the electromagnetic coils. EML systems are under active research and development for a variety of applications worldwide. Two types of EML systems have typically been studied in past years. The first type is the rail gun EML system, wherein a projectile is placed between a pair of rails connected to a direct current (DC) power supply. The current flows through the brush of the projectile by passing the current on the rail. Two rails and conductive projectile form a strong magnetic field by creating a loop in the top and bottom of rails. This field generates a Lorentz force with flowing current in the projectile. A force $F = J \times B$ occurs, where J is the current density on the rail and B is the magnetic flux density. The projectile is propelled by the force. In this way, it has good efficiency in high-speed driving. Figure 1 shows a schematic diagram of a rail gun. Massive heat is created due to the friction of the projectile leaving the device. It is possible for the rails, barrel, and all equipment attached to melt or be irreparably damaged [2, 3]. The second type of system is the coil gun EML system, which propels the projectile by electromagnetic force caused by Fleming's right hand rule when the electric current energizes the electromagnetic solenoid coils. That is, the electromagnetic force of the coils attracts and launches the projectile. The projectile may has the contact to the flywheel tube if it is not guided at center of flywheel tube. When the projectile is launched in the coils, the projectile has radial force (F_r) by gravity to the mass of projectile. Currently, various studies to minimize the radial force are under way. If the projectile is centered on the axis of the flywheel tube, the coil gun EML system has no friction and thus no problem with heat generation [4-7]. But, a coil gun EML system has difficulty producing a high muzzle velocity for the projectile using one coil stage because of the resistance and inductance of the coil. Thus, multiple stages of coils are required to accelerate the projectile sequentially in order to obtain a high muzzle velocity. Accordingly, the size of the coil gun system is lengthened, and the cost for the installation of a coil gun EML system (such as for a satellite) is very high due to the large installation site. We introduce a coil gun EML system that has a new structure and arrangement of multiple electromagnetic coils to reduce

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the length of the gun. We developed a mathematical model and simulated the device in order to demonstrate its performance. The proposed coil gun EML system is 31% shorter compared to a conventional coil gun EML system for the case of a target muzzle velocity of over 100 m/s for the projectile.

Coilgun is an electromagnetic projectile launching system. Electromagnetic launching (EML) system is advantageous over existing chemical launch system [1]; it's a fuel-free launching technology. EM launchers are eco-friendly and can have easily adjustable range by controlling the muzzle velocity through electrical current. It has higher repetition rate, it's smoke-free, silent and has low frictional losses. EMLs are mainly constructed as railguns or coilguns [2]. They both differ from conventional weapons; they use electromagnetism to propel the projectile rather than using an explosive charge. A coilgun is a type of projectile accelerator having one or more coils which when energized behave as electromagnets in

the configuration of a linear motor that accelerate a ferromagnetic or conducting projectile to high velocity. Construction of coilgun is simple but it is conceptually complex to analyse. Coilgun is mainly divided into two categories:

1. Induction type coilgun.
2. Reluctance Type coilgun

In induction type coilgun, the projectile is repelled out of the coil through the action of eddy currents induced in the projectile. The projectile must be non-ferromagnetic in nature. The force experienced by the projectile depends on mutual inductance and magnetic diffusion processes. While in reluctance coilgun a ferromagnetic projectile is placed near the coil and then coil is magnetized by carefully timing the coil current. Attractive forces pull the projectile towards it and hence projectile is accelerated. Both are similar in terms of their general construction. Though the practical usage of coilgun is not given much consideration till now, but its potential future applications can be very attractive. The potential applications of this concept can range from firing a bullet to launching big space payloads. Hence it is gradually becoming more popular and various studies are being carried out in this field. In this paper the focus will remain on single-stage reluctance type coilgun.

II. LITRATURE REVIEW

In research paper describe the New system of EML with its structure & arrangement to reduce length of the system. Mathematically proved the length of barrel is 31% decreases of electromagnetic coil gun as compare to the convection system.[1]

In paper, the detailed study about self-consistent control strategy of the multistage induction coil gun. Also length and thickness of armature & driving coil can improved the coupling relationship. The length is depending upon the change in turn of coil.[2]

The paper shows the design and development of single stage type coilgun. [3]

III. COILGUN THEORY

The coilgun works on the simple principle of electromagnetism. In coilgun a quick current pulse is to be provided. In a reluctance type coilgun current pulse is passed through a solenoid which then magnetizes and creates a magnetic field. This field attracts magnetically active (material with positive susceptibility) projectiles with high velocity and thus they get accelerated along the axis of the solenoid (coil). The current through the coil should be quenched before the projectile reaches its center otherwise the coil tries to draw the projectile in opposite direction; this phenomenon is called suckback effect.

This suckback action exerts force to pull the projectile back into the coil and decreases the speed. But if the current pulse is too short it will affect the efficiency of the system. Therefore, timing the current pulse is critical for the performance of the coilgun. Single stage coilgun launching system is shown in Fig.1. In reluctance coilgun dc voltage supply is needed in order to charge the capacitor bank. This can easily be done using a dc voltage supply or a battery, but to obtain high voltage Switched Mode Power Supply (SMPS) is used after charging the capacitor it is then discharged across the coil using a fast response high rating power switch. When current flows through the coil it becomes an electromagnet and draws the projectile which is kept little off from the center of the coil along its axis. The

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current carrying coil pulls the projectile with a high speed such that it accelerates further into the coil due to initial inertia.

Principle of Magnetic system: The coils wound in the flywheel tube were simply modeled.

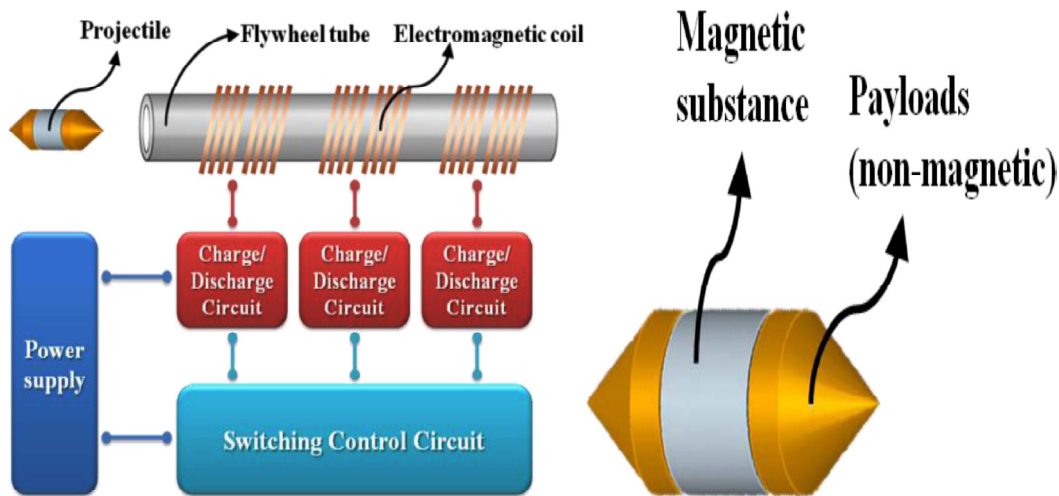


Figure 1 Structure of the multi-stage coil gun Figure 2 Projectile structure

IV. DESIGN PARAMETER

1. Capacitor Bank:

A bank of electrolytic capacitor is needed in order to charge. Here batteries are not used because the internal resistance of a battery is much higher than a capacitor. It takes much longer time to get the same amount of energy from a battery, and the timing is very important. In fact, using a different combination of capacitors can give the exact control needed over this delicate issue. Capacitor should have low ESR and high voltage rating and they are connected in parallel.

2. Coil:

Experimental results show that for getting satisfactory speed, the ratio of coil to projectile length should be in the range. The coil should have low resistance so that higher current can be drawn therefore the coil is designed. More the number of turns higher will be the magnetic field but the resistance also increases. Fig. 2 shows the design layout of the coil.

3. Projectile:

Material should be ferromagnetic and electrically non-conductive in nature. Mild Steel is selected having relative permeability, $\mu_r = 200-5000$. The diameter of projectile is decided according to barrel's inner diameter such that air gap between projectile and barrel is minimum i.e. it should be a snug fit.

4. Switch:

The switch should be selected such that it is capable of withstanding high values of peak currents also switching should be faster. IGBT switch meets both the criteria. This device offers the ease of control of the MOSFET with the higher current capacity of the bipolar transistor. The IGBT does require a slightly higher gate voltage to ensure that it is fully turned on. IGBT is used having Voltage rating of 1200 V and peak current rating of 400 A.

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V. SPEED MEASUREMENT OF MOVING PROJECTILE

Determining the muzzle speed can be challenging. Speed measurement of the moving projectile can be done mainly by two methods.

1. Parabolic method (kinematic method)
2. Light gate method

The parabolic method and light gate method for velocity measurement is discussed in detail. Parabolic method is basic kinematics calculations but there can be errors of approximately 15% or more. The validity of this method diminishes as the target range increases. With light gate method using IR sensors and electronic circuit higher accuracy can be obtained. The Fig.4 shows the block representation of speed measurement circuit using Light-gate method. In this assembly two pairs of optical transmitter and receiver are mounted on a frame such that they are aligned in parallel 10 cm apart. When bullet interrupts the first pair the timing pulse starts and ends when bullet passes through the second pair. The time to travel 10 cm for a projectile can be determined and thus speed can be calculated. The display records the time (millisecond) taken for the projectile to travel between the pair of opto-couplers. The speed can therefore be easily calculated. This circuit estimates the speed lower than the actual muzzle speed.

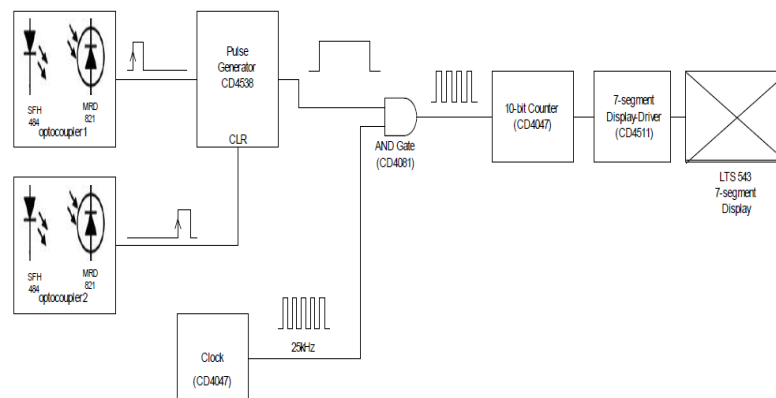


Figure 3 Block representation of speed measurement circuit

VI. CONCLUSION

A coil gun EML system uses multi-stage electromagnetic coils to accomplish a high muzzle velocity of the projectile. A multi-stage electromagnetic coil gun structure grows in length in proportion to the number of stages. We describe a coil gun EML system with new electromagnetic coil structure and arrangement to reduce the length of the system. Our mathematical simulation shows that the new system achieves the target muzzle velocity of the projectile with a 31% decrease in length size of system compared to a conventional system. The design and development of single-stage reluctance type coilgun. The parameters and considerations while designing a reluctance coilgun are also discussed. Also, Light-gate method for obtaining the speed of the moving projectile is also explained.

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