International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 05 | May 2021 www.irjet.net p-ISSN: 2395-0072

Electromagnetic Railgun with Targeting System

Preeti Samdani[1], Chinmay Nivaskar[2], Shreyas Newale[3], Vedant Rupe[4], Omkar Khade[5]

[1]Professor, Dept. of Mechatronics Engineering, New Horizon Institute of Technology & Management, Maharashtra, India

[2-5]Student, Dept. of Mechatronics Engineering, New Horizon Institute of Technology & Management, Maharashtra, India

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Abstract - *Modern day ammunitions such as missiles and rockets are effective. But there are a few drawbacks to the traditional missiles. Missiles are explosive projectiles and are very expensive. Also the storage and maintenance of missiles is expensive. These problems countered by the modern day ammunitions are solved by the Electromagnetic Railguns. Railguns have been proven as a safer launching weaponry system. The proposed system focuses on launching of a metallic projectile at high speeds using electromagnetic force. For the aiming of the target a targeting system is designed which will be mounted upon the railgun setup. It is a very stable system and does not use any explosive materials in the projectile or not even in the launching process of the projectiles. It completely utilizes strong electromagnetic forces which makes it less expensive as compared to the missiles. Less Technology is used in railguns than missiles. Therefore chances of having a technological glitch in the launching mechanism are very less.*

Key Words*: *Railgun, Lorentz Force, Electromagnet, Micro-controller, Rails, Defense Artillery, Targeting System

1. INTRODUCTION

A Railgun is a type of artillery weapon that uses electromagnetic force to launch solid iron cores at very high speeds, over large ranges. It is a type of linear motor device. In an electromagnetic railgun, an armature which slides and moves forward due to the acceleration caused due to the electromagnetic force. The factor that determines the power of a railgun is the current flowing through the rails.

The basics of the electromagnetic railgun technology is the Lorentz Force. Lorentz force characterizes the interaction between a current and a magnetic field. As of 2020, the railguns have been under research and development as weapons that utilise electromagnetic forces to release a very high kinetic energy to a projectile instead of use of conventional propellants. Normal guns cannot achieve a muzzle velocity of more than or equal to 2 km/s, whereas, railguns can readily exceed 3 km/s.

The destructive force caused due to the projectile depends upon the projectile's kinetic energy and mass at the point of impact. Due to the high velocity of a launched projectile from the electromagnetic railgun, their destructive force may be many times larger than usually launched projectiles of the same size. Low cost of the projectiles as compared to the conventional weaponry and no use of warheads and explosive propellants are the additional advantages of the electromagnetic railgun. After decades of Research and Development, it remains to be seen that whether the railguns will ever be deployed for practical use as a weaponry.

In current railguns, massive heat is generated, because of the electricity flowing through the rails, as well as the friction caused from the launching of a projectile. For this purpose, the selection of the rail material is a very crucial element of the railgun. The stresses caused due to launching of projectile in this manner requires an extremely heat-resistant material. Otherwise, the rails, the barrel, and all the equipment attached along with the setup would melt and get damaged.

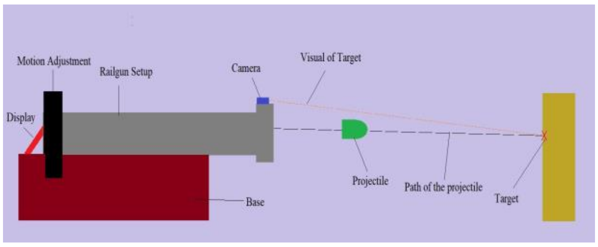

Fig. 1. Electromagnetic Railgun with Targeting System

The main building blocks of the targeting system are a small action camera, a microcontroller, a diplay unit and a hydraulic system for movement of the railgun. The action camera is used for input of the viewed target to aim, a microcontroller is used to process the data and give output to a Display to view the target. The railgun can be moved in two axis to adjust according to the target. A joystick will be used to control the movement of the railgun.

1.1 History of Railgun

Andre Louis Octave Fauchon-Villeplee, a French inventor, initially, had introduced the idea of a railgun in the year 1917. With the help of the Société anonyme des accumulateurs Tudor, he created a small working model. Fauchon-Villeplee filed for patent in US on 1 April 1919, later it was issued in July 1922 with the name "Electric Apparatus for Propelling Projectiles".

Later in the year 1923, A. L. Korol'kov, a Russian scientist, gave a detailed statement criticising Fauchon-Villeplee's design. Korol'kov eventually said that although long range electric gun was possible but, the Fauchon-Villeplee's railgun made it difficult as it required enormous electric energy, which was not possible without a dedicated special electric generator having considerable capacity to power it.

In 1950, an Australian physicist, Sir Mark Oliphant, at the Australian National University, started the designing and construction of the world's largest homo-polar generator. From the year 1962 it was used to power a large-scale railgun which then was used as a scientific experiment.

In the year 1980, a long-term theoretical and experimental program began research on railguns under the Ballistic Research Laboratory. In 1990, in a view of establishing the Institute for Advanced Technology (IAT), the U.S. Army made collaboration with the University of Texas at Austin. Since 1993, the British Government and the American governments came together for collaboration on a railgun project at the Dundrennan Weapons Testing Centre. In the year 2010, while testing the BAE Systems fired a projectile of weight 3.2 kilograms at 18.4- megajoules at a speed of 3,390 m/s.

In the year 1994, India's DRDO's Armament Research and Development Establishment developed a railgun. It had a low inductance capacitor bank of 240 kJ, which was operating at 5 kV power supply. It was able to launch projectiles having a weight of 3–3.5 g at a velocity of more than 2,000 m/s. In the year 2017, DRDO officials made a claim that they have performed testing in a 12 mm square bore electromagnetic railgun which launched a projectile at around 2000 m/s. Low powered, small scale railguns have also made popular amateur and college projects and researches on railguns.

2. Methodology

The Electromagnetic Railgun with Targeting System is having two sub-systems, one is the railgun setup and the other is the targeting system. The block diagram of the complete system is given in the Fig. 2

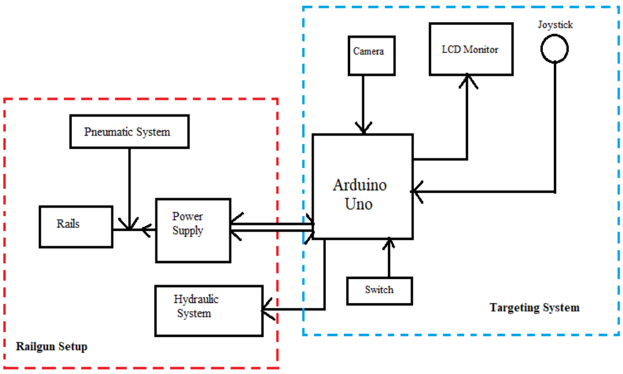

Fig -2: Block Diagram of the System

2.1 Working

An electromagnetic railgun is a large electric circuit which is basically made up of three parts: a power source, a pair of parallel rails and a moving armature.

Power supply: It is simply a source of large electric current. Typically, millions of amperes current is used in medium caliber to large caliber rail guns.

Rails: A pair of parallel conductive metal, such as aluminium, copper is used for rails. They can range from about 4 to 30 feet in length.

The armature: It is used to bridge the gap between the two rails. It can be a solid piece of conductive metal or a carrier that houses a dart or other projectile. Sometimes, a plasma armature is used in few models of rail guns.

A railgun basically consists of two parallel metal conductors called as rails (hence the name). One end of these rails are connected to an electrical power supply. As the rails are parallel to each other, there is no connection in between the rails. Hence, even if one terminal is connected to the supply, no current will flow through the other rail. It becomes an open circuit. If a conductive projectile is inserted between the rails, it will complete the circuit.

Now, as the current is applied, it will generate a flow of electrons starting from the negative terminal of the power supply travelling through the rail connected to the negative terminal, then across the projectile, further to the rail connected to the positive terminal and then back to the power supply through its positive terminal.

Current that flows through any wire creates a magnetic field around it -- a region where a magnetic force is felt. The magnetic force has both a magnitude and a direction. In an electromagnetic railgun, the two rails act like wires, with a magnetic field circulating around each rail up to the position of the armature. The magnetic lines of force of the magnetic field run in a counter-clockwise circle around the positive rail and in a clockwise circle around the negative rail.

The net magnetic field created between the rails is directed in vertical direction. Just as same as a charged wire in an electric field, the projectile experiences a force known as the Lorentz force named after the Dutch physicist Hendrik A. Lorentz.

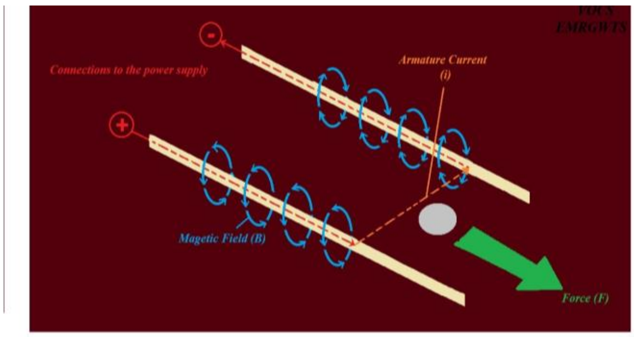

Fig -3: Basic Principle of the Railgun

A particle of charge q, which moves with a velocity v, in a magnetic field B and an electric field E experiences a force of:

$$F= qE+ qv \times B$$

The force F in the equation is the Lorentz force. It is directed perpendicularly to the direction of current flowing across the armature and the direction of magnetic field. This makes the projectile accelerate along the rails out of the loop and away from the power supply, through the end of the rails. As the circuit is broken, the flow of current ends. There are also Lorentz forces that act on the rails and attempt to push each other apart. But the rails are fixed on a base firmly, so they cannot move.

The Lorentz force is parallel to the rails. It acts away from the power supply. By magnitude, the Lorentz force can be determined by,

$$F = (i)(L)(B)$$

Where, F is the net force, i is the current applied, L is the total length of the rails and B is the magnetic field induced.

The lorentz force in the railgun can be boosted by increasing either increasing the amount of current or by increasing the length of the rails. As increasing the length of the rails is a designing challenge, most of the railguns use large currents (in the order of a million amperes) to generate a tremendous force.

The targeting system mainly comprises of a small action camera, a microcontroller (Arduino), a LCD screen and hydraulic system for movement. For accuracy in launching the projectile, a Targeting system plays an important role. A camera is used to locate the target. The camera is the input device for the targeting system. The image data generated from the camera is passed on to the Arduino ATmega328 microcontroller.

The Arduino acts as the brain of the system providing all the data to the input & output. It processes the data from the camera and passes it to the LCD screen. The LCD screen shows the view of the target captured from the action camera. This helps the operator to decide the movement of the electromagnetic railgun system. A joystick is connected to the arduino which instructs the movement of the Railgun in up-down and left-right directions for accurate targeting. As the joystick is moved in any of the up-down or left-right direction, the double acting cylinder gets actuated and moves the position accordingly.

The Arduino uses a program to instruct the moving of the railgun in accordance to the input provided tough the joystick. When the railgun is aimed at the target perfectly, a separate switch is used to launch the projectile.

2.2 Flow Chart

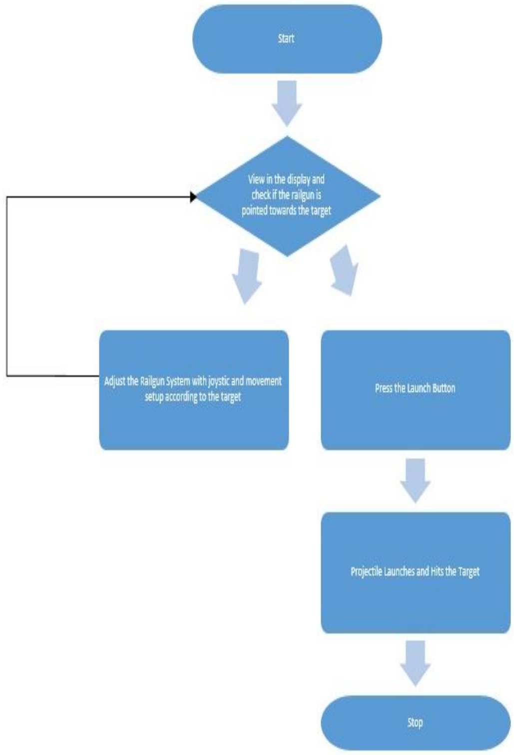

Fig -4: Flow Chart of the Process

2.3 Components

Rails: Rails are the most important component of the Electromagnetic Railgun. The rails in the railgun setup are forced to large electrical currents, high temperatures, large electromagnetic loads, and high sliding velocities. While a rail material has to be chosen, two objectives for railgun must be considered, one is maximizing magnetic efficiency, and the other is maximizing durability. The performance requirements for the rail material: high electrical conductivity, high thermal conductivity and high resistance to abrasion and arc ablation. Various materials like steel copper or iron can be used as a rail material.

Aluminium Electrolytic Capacitors: Capacitors are devices which store electrical energy in an electrifield. A capacitor is a passive electronic component having two terminals. The battery cannot put out current that is fast enough to launch a projectile at high speeds. Therefore, electricity is stored in capacitors. For this purpose aluminium electrolyte capacitors are used for the railgun setup.

Battery: .For efficient functioning of the electromagnetic railgun, a battery of high power supply is required for such type of functioning. A battery of around 4200 mAh, 12V output is suitable for the railgun.

DC-DC Converter: For charging of the capacitors of high voltage, the supply voltage needs to be converted and increased to the high voltage. Therefore, a dc-dc converter is required which converts and increases the supply voltage while charging the capacitors.

Acrylic sheet: Acrylic is a generally used name for Polymethyl Methacrylate (PMMA). It is used in this system as an insulating material. It is used to cover the railgun setup.

Pneumatic Cylinder System: The metal projectile cannot simply be inserted into the rails, as one may get electrocuted, and the projectile will get spot welded onto the rails by the large electrical charge suddenly jumping across the projectile. To prevent both of these things happening, the projectile must already be moving before it meets the rails at a sufficient speed to prevent it stopping. For this a Pneumatic Cylinder system is used. With pneumatic pressure, the projectile is pushed upto the rails.

Pneumatic Pipes: Pneumatic pipes are used for the connection purposes in pneumatic cylinder system.

Carbon Dioxide Cartridges: CO2 cartridges are highly compressed cylinders of liquid carbon dioxide. These are used as a source for the pneumatic cylinder system.

Gas Valves: Gas valves are used for regulating the air power through the pneumatic cylinder system

Projectiles: The projectile which has to be fired through the railgun should be extremely small, highly conductive and highly heat resistant. For this a small spherical ball of diameter approximately 10 mm of materials like aluminium is very suitable.

Joystick: The main purpose of the joystick is to give input to the solenoid valves for the up-down and left-right movement.

Two Double acting cylinders: The movement of the railgun towards the desired target is a crucial element of the targeting system. It is necessary for the railgun to move in up-down and left-right directions. One double acting cylinder is required for the up-down movement, and one for the left-right movement of the electromagnetic railgun.

Two 5/2 Solenoid Valves: Solenoid valves controls the double acting cylinder. Hence we require two 5/2 solenoid valves for giving input to the double acting cylinders.

Small Action Camera: For the exact positioning of the target, a visual view of the target needs to be achieved. For this purpose a small action camera with considerable amount of zoom is required. Hence it is one of the input devices for the targeting system. The camera module used for capturing the target is OV7670 Camera Module.

Fig -5: OV7670 Camera Module

LCD Screen: It is one of the output devices of the targeting system. To view the target input obtained from the action camera, a LCD screen is required. Here, we have used a 2.4 inch TFT LCD screen for the targeting system.

Fig -6: 2.4 inch TFT LCD

Arduino Module: For processing of the input and giving output, a microcontroller is required. It takes input from the Camera, provides output from the LCD Screen. It also takes input from the joystick for the movement of the setup with the help of hydraulic system. Here, for the targeting system, we are using Arduino Uno module which is based on the ATmega328 microcontroller chip.

Fig -7: Arduino UNO

Resistors: Resistors are required in the circuit of the targeting system.

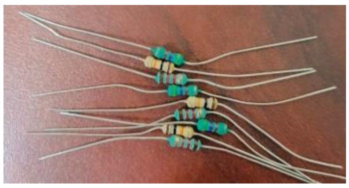

Fig -8: Resistors

3. CONCLUSIONS

Electromagnetic Railguns are a very intriguing technology and have a large scope for advancements through research and development. It has several potential and exciting applications. The principle of electromagnetism used in this system is very simple but its implementation in the system is quite difficult as the electromagnetic force required to launch the projectile is very high. For increasing the speed of the projectile, either the number of capacitors can be increased or the length of the rails can be increased. Mass of the projectile also affects the distance to be travelled by the projectile.

A target at certain distances can be viewed through the targeting system. The Arduino Uno microcontroller is the most significant part of the Targeting System. It acquires the input from the user and provides signal to the system accordingly. The targeting system helps the personnel to adjust the railgun setup according to the target. The proposed system functions properly and launches projectiles at very high speeds. The future of railgun development depends on continued technological development and also on financial support provided for R&D.

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