The Rail Gun

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***Abstract*- The rail gun is one of promising ways of launching projectiles. Recently, many experiments show that they have impressive abilities and advantages over the traditional ways of projections. In this project, I am going to investigate the construction of electromagnetic rail guns, the way the function and the science behind them.**

I. Introduction

The most commonly used way of projection in military, by means of gunpowder, has many disadvantages including additional weight, volatility and limited velocity. This fact enhanced scientists to look for more efficient way to launch projectiles. The electromagnetic rail gun has appeared as a promising propellant with a velocity of 16,000 m/s, about 12 times that of gunpowder, and a range of about 400 km. These features are so attractive to the extent that the concept of launching projectiles with electric energy was introduced more than 90 years ago.

II. History

A French inventor, called Louis Octave Fauchon-Villeplee, invented an electric cannon ,in 1918, with two parallel bars connected by the wings of a projectile, and the whole apparatus surrounded by a magnetic field. By passing current through bars and projectile, a force is induced which propels the projectile along the bars and into flight.

During World War II the idea was revived by the German scientist Joachim Hänsler and an electric anti-aircraft gun was proposed. The guns were to be mounted in batteries of six firing twelve rounds per minute, but it was never built. When details were discovered after the war it aroused much interest and a more detailed study was carried out, culminating in a 1947 report which concluded that it was theoretically feasible, but that each gun would need enough power to illuminate half of Chicago.

III. Construction

"A rail gun is a purely electrical gun that accelerates a conductive projectile along a pair of metal rails". It contains two parallel metal rails with a sliding conductive armature. The acceleration of the projectile, which is driven be the armature, is achieved by a power supply acting mainly as a current source and providing a huge current.

IV. Functionality

One terminal of the power supply is connected to one rail and the other terminal is connected to the other parallel rail.

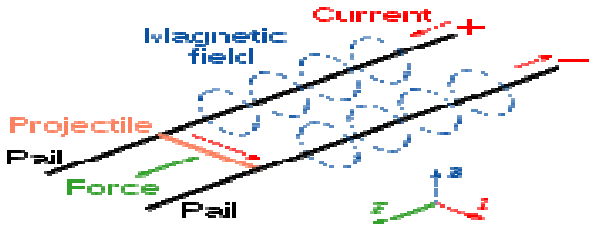

Fig. 1: Lorentz Force.

Due to the existence of the conductive armature, a closed circuit will be formed and current will flow from the positive terminal of the power supply to the negative one. The flow of current generates a magnetic field around the rails and the armature according to the right hand rule. The net magnetic field between the rails is vertically perpendicular to the armature as shown in Figure 1.

Since the magnetic field is perpendicular to the current in the armature, a force, known as Lorentz force, perpendicular to both current and magnetic field will act on the armature. Lorentz force is directed away from the power supply and parallel to rails pair. The force can be increased by either increasing the current or the length of the rails. Usually, a current in Mega amperes is needed. At the end of the rails, the armature and the projectile exist through a hole causing the current in the rails to vanish because the circuit is now open.

V. The Electromagnetism Behind Rail Guns

The current in a wire produces a magnetic field as Oersted noticed. The magnitude and direction of the magnetic field is governed by Biot-Savart's Law:

$$\mathbf{dH} = \frac{\mathbf{I\,dl \times R}}{4\pi R^3} \qquad (1)$$

Since we have moving charges, the current, a magnetic force will act on the armature. For a closed loop, the net force, Lorentz force, is given by:

$$\mathbf{F} = \oint_l \mathbf{I\,dl \times B} \qquad (2)$$

VI. Applications

Rail guns are of particular interest to the military, as an alternative to current large artillery. Rail gun ammunition, in the form of small tungsten missiles, would be relatively light, easy to transport and easy to handle. And because of their high velocities, rail gun missiles would be less susceptible to bullet drop and wind shift than current artillery shells.

They have also been proposed as important components of the Strategic Defense Initiative, popularly known as Star

Wars. Star Wars is a U.S. government program responsible for the research and development of a space-based system to defend the nation from attack by strategic ballistic missiles. Rail guns could fire projectiles to intercept the incoming missiles. Some scientists argue that rail guns could also protect Earth from rogue asteroids, by firing high-velocity projectiles from orbit. Upon impact, the projectiles would either destroy the incoming asteroid or change its trajectory.

Besides Rail guns have some interesting non-military applications as well. For one thing, they could potentially launch satellites or space shuttles into the upper atmosphere, where auxiliary rockets would kick in. On bodies without an atmosphere, such as the moon, rail guns could deliver projectiles to space without chemical propellant, which requires air to function.

Many of these applications remain in the realm of theory, experimentation and development. It will likely be 2015 before an all-electric battleship uses a rail gun to launch projectiles at an enemy.

Still, the technology is promising. In 2003, the British Ministry of Defense hosted a one-eighth-scale test of an electromagnetic rail gun that achieved a muzzle velocity of Mach 6, or approximately 2,040 meters per second. With continued successes such as these, the rail gun may one day be the weapon of choice on the battlefield and the propellant of choice on the launch pad.

VII. Problems With Rail Guns

In theory, rail guns are the perfect solution for short- and long-range firepower. In reality, they present several serious problems:

A. Power supply

Generating the power necessary to accelerate rail gun projectiles is a real challenge. Capacitors must store electric charge until a sufficiently large current can be accumulated. While capacitors can be small for some applications, the capacitors found in rail guns are many cubic meters in size.

B. Resistive heating

When an electric current passes through a conductor, it meets resistance in the conductive material -- in this case, the rails. The current excites the rail's molecules, causing them to heat. In rail guns, this effect results in intense heat.

C. Melting

The high velocity of the armature and the heat caused by resistive heating damages the surface of the rails.

D. Repulsion

The current in each rail of a rail gun runs in opposite directions. This creates a repulsive force, proportional to the current, which attempts to push the rails apart. Because the currents in a rail gun are so large, the repulsion between the two rails is significant.

VIII. Suggested Solutions

A. Power Supply

Nuclear power may be use to enhance the power generation especially in military ships.

B. Heating

Cooling techniques should be used effectively to prevent intense heating. In addition, materials used to build rail guns have to be chosen such that it gives optimum resistance to heating.

C. Repulsion

The rails of a rail gun should be fixed firmly such that minimum repulsion takes place.

VIIII. Conclusion

Rail guns are plausibly one of the most promising ideas in the field of projection. Although they are still theoretical with limited practical experiments conducted, rail guns have opened new horizons in the field. With increasing scientific discovery, they may be the most commonly used way of projection in future.

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