International Journal of Emerging Technology in Computer Science & Electronics (IJETCSE)
ISSN: 0976-1353 Volume 7 Issue 1 –MARCH 2014.

ELECTROMAGNETIC ROCKET LAUNCHER

Nirmal.A.S[1#], Romanuse.R[#]
[#] *UG Scholar,*
Department of Electronics and Communication Engineering,
Karunya University, Coimbatore, Tamil Nadu, India.

***Abstract*— Electricity has greater amount of energy than that of the conventional fuels. Here is a machine that uses the electricity to launch rockets at a speed ranging from 6Km/sec to 10Km/sec with minimum turn over time and at low cost. It is the Electromagnetic Launching Machine or Electromagnetic Launcher (EML). In this paper, we have concentrated in the satellite launching using coilgun. By building this, the rockets can be launched with more efficiency; the payload to mass ratio can be increased and the cost of launching can be decreased. The main advantage of using this machine is that it replaces the initial huge fuel boosters used in the conventional rockets. The challenges faced by EML are thermal effect, air drag, high gravitational attack etc. This paper reveals the various ways to overcome these challenges.**

***Keywords*— Launch, coilgun, rocket, projectile, coil, fuel**

I. INTRODUCTION

Conventional rockets are driven by the combustion of liquid and solid chemicals-a propellant and an oxidizer. The speed and acceleration of the rocket are relatively low after liftoff, but they are continuously increased over a long time period until the rocket reaches the required end velocity. The disadvantage of all the staged rockets employed so far is their non-reusability and the very small ratio of the payload to the fuel mass which is generally termed as propellant mass fraction which is less than 1%. To overcome these constraints, worldwide efforts has been taken to establish programs for commercially competitive and reusable engines and rockets. However, the payload to takeoff mass ratio of these new launch vehicles may be even worse.

This can be rectified by employing a new propulsion technique based on an electromagnetic coilgun launching machine using electromagnetic force for acceleration of the projectile. By using this electromagnetic (EM) coilgun, the major disadvantage of the conventional rockets can be overcome. The reusability of the entire propulsion part and an improved payload to takeoff mass ratio can be achieved. The EM-coilgun technology has reached a level that makes it a potential medium for the launch of small payloads into suborbital and even orbital altitudes. The development of such innovative concept requires key technology that could also be of benefit to other space application like the atmospheric re-entry, the miniaturization of payloads, high performance materials etc. The reusability of the entire propulsion part at low recurring costs, resulting in launch prices are expected to be very competitive in the corresponding market segments.

II. OVERVIEW OF CONVENTIONAL ROCKETS

In conventional rockets, there are various stages of launching. The liquid and solid booster occupies the major part. Their main job is to lift the whole rocket to higher altitude above the earth's atmosphere. In the initial stage of rocket liftoff, the gravitational force is of maximum attraction. Hence maximum liftoff force is required at the initial stage. To achieve this force, huge conventional fuel (liquid hydrogen and liquid oxygen) boosters are used. These boosters occupy a considerable mass of the rocket. Due to this, the payload to mass ratio is 1:100. Thus for launching even small payloads a large quantity of fuel is required. Also, these conventional boosters are not reusable. All these things make rocket launching too expensive (launching of 1Kg payload to space costs around 20,000$).

III. ELECTROMAGNETIC LAUNCHING MACHINE

The use of electromagnetic energy to controllably propel objects in extremely high speed has many applications in our society, including transportation (Bullet trains), communication, energy storage, national defense and space research. The Magnetically levitated trains and hybrid electric automobiles leads to an efficient transportation and energy conservation. The technology for using electromagnetic energy pulses to accelerate materials to extremely high speed is now sufficiently advanced to evaluate the survivability of space structures. In fact, electromagnetic launchers are now capable of accelerating objects to travel many hundreds of kilometers and have even reached sufficiently high speed to put objects in orbit around the earth. Basically there are two types EM-launching machines - Railgun and Coilgun.

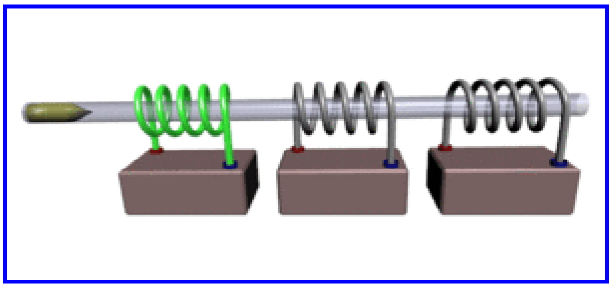
A. Fundamental principle

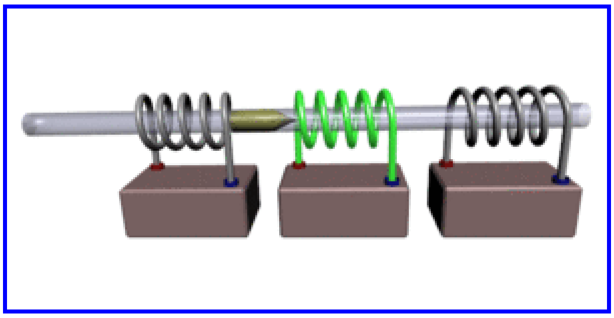
The fundamental principle of all electromagnetic launchers is that a conducting wire carrying an electric current (I) when subjected to a magnetic field (B), will experiences a force called the Lorentz force (F). This interaction between electric and magnetic field is the fundamental relationship that governs all types of electromagnetic launching machines.

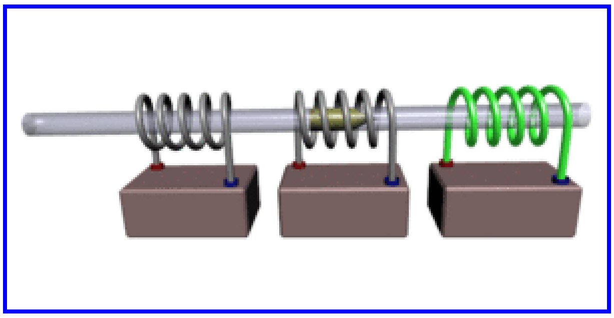
The projectile is placed in between the coil of wires where alternate excitation of the coils will propel the projectile forward, and this is the principle of the EM-coilgun launching machine.

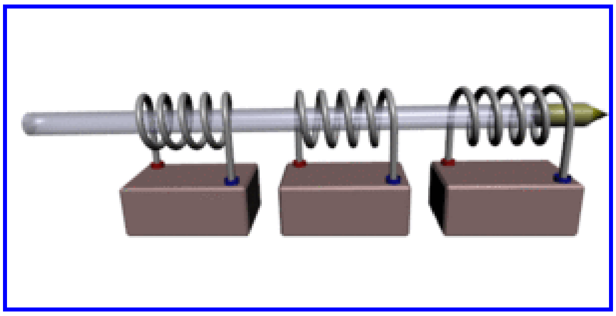
IV. COILGUN LAUNCHER

A coilgun, as the name implies, consists of a coil of wire (or solenoid) with a ferromagnetic projectile placed at one of its ends. A single-stage coilgun uses one electromagnet to propel a projectile. A large current is pulsed through the coil and a strong magnetic field forms, pulling the projectile to the center of the coil. When the projectile approaches the center, the initial coil is switched off and a next coil will be switched on, progressively accelerating the projectile to successive stages [2].



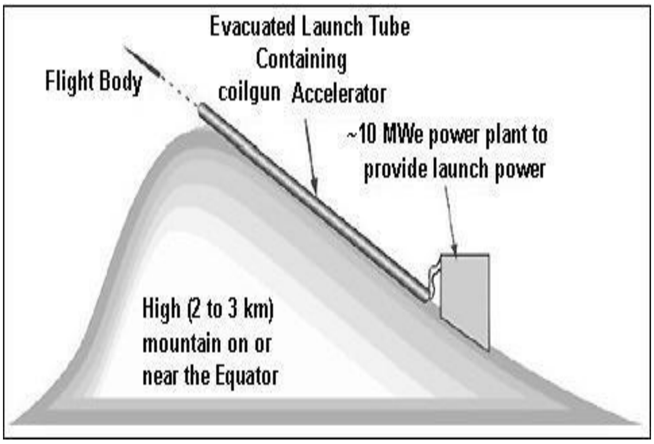






A. Launch Station

For a projectile launched from the surface of the earth by this EML Machine carrying a 100Kg payload, about 10 km/s launch velocity is necessary to reach the specific orbit. This required launch velocity can be reduced if the launching machine (station) is located at higher altitudes. For example, if the launching takes place at an altitude of 4 km, then the launch velocity to achieve the orbit is reduced to 9.1 km/s. Also, establishing launch stations at high altitude will reduce the air drag on the rocket which in turn reduces the heat production on the surfaces of rocket, due to aero-thermodynamic effect.



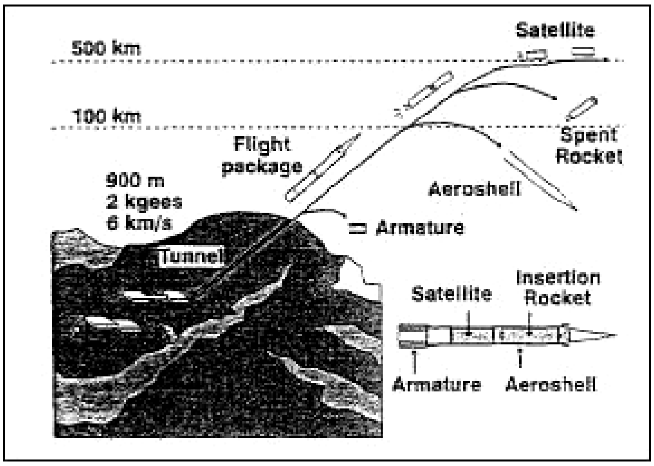
Constructing the EM-Launch station along the mountain slides has lot of advantages. By constructing the launcher at an inclined angle of 25 degrees [3] enables us to eliminate the booster rockets from guiding work. In addition to these things, the mountain will be a good absorber of vibration and sound, which were produced during the launching.

B. Launch Package

The launch package consists of the armature, aero-shell, orbital insertion rocket (guiding rocket), satellite, and nose bore-rider (sabot). The flight package is the launch package excluding the armature and the bore-rider. The flight package is designed for atmospheric penetration, essentially a low drag supersonic projectile shape with ablative heat shield [1]. The aero-shell protects the package from atmospheric heating. While launching from an EM-Launcher which is kept sliding on a mountain, we can reduce the required muzzle velocity to 6 or 7Km/s.

C. Stages of Launching

To reduce drag and shock effects of supersonic flight within the launcher, the launch package travels through an evacuated flyway tube to an exit velocity of 6 km/s [3]. This flyway tube is constructed of fiber-reinforced plastic, and serves the added function of alignment and stabilization during launch. A thin foil breakaway window is located at the exit. The flight package consisting of the satellite, an orbital insertion rocket, guidance and an aero-shell is pushed through the coilgun by an armature.



After launching, the armature separates, slows and falls to the earth within a few miles because of its poor aerodynamic shape. The flight package penetrates into the atmosphere and the aero-shell is pealed open and ejected at a height of 100Km. Once open, the pieces of the aero shell are much less robust against atmospheric heating and thus burn up upon re-entry. The insertion rocket then ignites and circularizes the orbit of the satellite. The rocket detaches from the satellite at a height of 500Km and makes a final small braking burn to assure that it re-enters the atmosphere.

V. BASIC CHALLENGES

The key basic challenges and the ways to face the challenges in this electromagnetic launching machine and the projectile (rocket) are detailed below:

A. Thermal Effect

One of the main issues to be investigated is the extreme thermal conditions the projectile's surfaces are exposed to. These are caused by friction and turbulent flow properties, when the projectile rushes through the dense Earth's atmosphere in less than 30sec. The important factors to be considered are the design of a hypersonic projectile - the determination of the duration, magnitude and location of the maximum temperatures with respect to the projectile's surface and its corresponding internal structure.

The thermal effect can be reduced to a great extent by launching the projectile at low velocity, by mounting a guiding rocket on it. Thus the production of heat on the projectile due to its rapid velocity in the denser atmospheric region is eliminated. The earth's rotational velocity [5] at the equator is approximately 464 m/s, therefore if launch is in the correct direction, and then the required muzzle velocity will be reduced greatly which in turn reduces the thermal effect.

B. Power Required for Launching

For a satellite payload of 10-100 kg, the electrical energy requirement of a launcher is 2-12 GJ, and the peak power requirement is 6- 30 GW. At these power levels, a system of energy storage and fast switching will be needed. This amount of energy can be produced using the conventional power stations. But the question here is, how and where are we going to store this energy and how are we going to distribute it to the coils.

In the baseline concept, the temporary energy storage is accomplished with capacitors. Energy from the capacitors is switched into the propulsion coils on the microsecond time scale. With 9000 propulsion coils, each coil is energized with 1MJ of energy (1MJ energy capacitors are available in Institute of Advanced Technology).

The technology for such capacitor-coil combinations is available now, and has been demonstrated in high-velocity launcher experiments at the level of 60 kJ. This method of storing energy is known as Distributed Energy Storage (DES) principle. Also, Superconducting Magnetic Energy Storage (SMES) can be used.

C. Air Drag

As the projectile has achieved a great velocity at the beginning of the launch, there will be maximum air drag on the projectile as it has to penetrate through the dense atmospheric level. In order to reduce this air drag, the projectile must have a minimum air drag structure.

The projectile can be designed in such a way that it has minimum air drag. The nose tip of the projectile is made of tungsten and is given a suitable angle to tear through the dense atmosphere. Using Computational Fluid Dynamics (CFD), the projectile can be designed giving a slim and good air penetrating structures.

D. High Gravitational Attack

As the highest acceleration is given to the rocket at the initial stage, the escape velocity and the gravitational force acting opposite to each other will have a great difference. This difference is felt on the rocket in terms of increase in weight.

The effect of gravitational force on the projectile cannot be eliminated but we can manufacture the satellite and the flight package to withstand about a thousand times the force of gravity (one kilogee). This can be done by proven techniques such as avoiding cantilevered elements, tying down loose wires, potting electronics in plastic and making the structure as compact as possible. Military shells are moving towards greater complexity and it is said that they have already demonstrated the ability to be hardened against acceleration at levels of more than 10 kilogees.

E. Synchronization of the Coil Excitation

In order to propel the armature continuously forward, each coil must be energized simultaneously with the armature. The propulsive force is created by the mutual repulsion between a pulsed solenoid magnetic field and the induced currents in a conductive armature. Continuous acceleration of the armature is achieved by sequential switching of energy storage modules into successive coils to create a magnetic traveling wave that propels the armature and the entire launch vehicle forward. Achieving this synchronization in coil excitation is major challenge to be faced.

One main obstacle in coilgun design is switching the power through the coils. There are several common solutions—the simplest is the spark gap, which releases the stored energy through the coil when the voltage reaches a certain threshold. A better option is to use solid-state switches; these include IGBTs or power MOSFETs and SCRs

Switch Synchronization and control can be achieved by a sense and fire control system [4], such as a laser range based system. This sense and fire control system is based on a laser range-finding beam injected through the gun to determine the location of the launch package. A benefit of this real-time sensing and firing technique is the ability to accurately control the exit velocity of the flight package. Given the high degree of repeatability achievable with the system, however, a preprogrammed firing sequence may be adequate.

VI. ADVANTAGES

- One of the main advantages of this launch system is its reusability. The same launching machine and the energy systems are used for launching of many satellites.
- Rapid launching of rockets is possible; the turnaround time between the launchings is very less. It has been estimated that 200 satellites launching per day is possible.
- Over-night delivery of small packages to the space station, launch of station-keeping fuel and other supplies for the space station, and launch of low-altitude, rapid-response military sensors or environmental monitors can be launched with quick and minimum preparation.
- The cost of launching 1Kg payload using conventional rockets is about 20,000$ but in this system we can launch 1Kg payload at some 2,000 to 10,000$. This cost is for the fuel or electric energy which is used.
- In terms of maintenance, the launcher is modular; the launcher pieces can be mass-produced in large numbers, which will reduce their cost and risk. Maintenance of a damaged section or coil also is simplified by this modularity [3].
- There is very less pollution in this system compared to the conventional launching. The pollution in this system is due to the usage of insertion rocket.
- Inter planetary satellites also can be launched using this EM-Launching machine.
- The fuel consumption is greatly reduced in this EM-Launching machine.

VII. RECENT HAPPENINGS

- The recent interest by the Air Force Office of Scientific Research (AFOSR) in much smaller launch masses (1 to 10 kg) offers the possibility of a feasible air-lift system. If one could launch from an aircraft at 16 km (10 miles) altitude, then the required launch velocity would be reduced to 8.1 km/s whereas 9.1 km/s for the 4 km launch altitude
- Our ISRO is having a R&D in this Electro-Magnetic Launching field.
- Many foreign institutes have started launching trial projectiles using this launching machine. Soon those trial projectiles are going to be conventionally possible.

VIII. CONCLUSION

The conventional fuel level in the world is declining day by day even we can say minute by minute. So the conventional fuel launching system for the rocket launchers is not going to be the perfect way of launching anymore. From the above discussions it is clear that the fuel launching system can be replaced with the Electromagnetic Launching Machine. The total cost estimate is thus about $760 M for a 10 kg launcher, and about $1380M for a 100 kg launch capability. The facility cost is prorated over a 50,000 shot lifetime assumption. In this case, then, the cost per launch is in the range of $2000/kg for a 100 kg satellite, and $ 10,000/kg for a 10 kg satellite.It will be still more efficient if many new studies and researches are conducted in this field.

REFERENCES

[1] Ryan C. Gosse, *Ablation Modeling of Electro-Magnetically Launched Projectile for Access to Space.*

[2] Levi, E.; He, L, Zabar, H and Birenbaum L (January 1991). "*Guidelines for the Design of Synchronous Type Coilguns*". *IEEE* Transactions on Magnetics 27 (1): 628–633.

[3] B.N.Turman, "*Coilgun Launcher for Nanosatellites"* in 2nd International Conference in Integrated Micro/Nanotechnology for Space Applications 1999.

[4] Kaye, R. J., 1. R. Shokair, R. W. Wavrik, J. F. Dempsey, W. E. Honey, K. J. Shimp, G., M. Douglas, (1994) "Design and Evaluation of Coils for a 50 mm Diameter Induction Coilgun Launcher," presented at the 7th Symposium on Electromagnetic Launch Technology, San Diego, CA, April 20-24, 1994.

[5] Wikipedia website[online] Available: http://en.wikipedia.org/