A Review on Capacitor Driven Coilgun

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Abstract: A recent trends in electromagnetic launcher (EML) is the improvement in design of the coilgun. It has many advantages over chemical and mechanical type launchers. Present study is carried out on coil gun about its working and design consideration. Review has been made on parametric variation of projectile and coil to achieve higher force, velocity and efficiency.

Keywords: coilgun, electromagnetic launcher, capacitor driven, finite element analysis (FEA), EMTP-RV.

I. INTRODUCTION

In recent years, main focus is made on improving the efficiency of coilgun as electromagnetic launcher (EML). This is also known as Gauss gun, gauss rifle, electromagnetic gun, etc. Coilgun is a device in which projectile which is also known as muzzle or nails or bullet can be launch through excitation of coil which is supplied by charged capacitor. Coilgun has many applications, e.g. launching mechanism for missile in Navy or army applications, as armour for tank, can be used in high speed actuators, for launching satellite in space, etc. As these coilgun is having many advantages over conventional chemical propulsion based or mechanical system based launcher, it is having wide applications worldwide. Also, coilgun is frictionless compared to railgun which is major advantage [1]. Careful design is required to make coilgun otherwise it has to face problems like, less velocity and impact of projectile, response of the projectile may be slow; coil or barrel on which coil is wound can be melt, projectile can be overheated; capacitor can be recharged due to electromagnetic energy stored in coil [6]. So, to overcome above difficulties, an attention is required to make properly designed coilgun.

II. DESIGN CONSIDERATION OF COILGUN

Capacitor driven coilgun is a simple device which is supplied by charged capacitor. Many advancement has made to supply the coilgun like pulsed power technology, MOSFET, IGBT driven. But capacitor driven technology is simplest one [2] [3]. First electrolytic capacitor is charged using DC source which should be ripple free. One can also use simple rectified output with filter. Here, design to get DC supply for capacitor charging is not necessarily based on heavy charging current but based on supply voltage. Because after charging capacitors, they will be disconnected from this DC source and they are made to discharge in coil. So, on supply side simple single pole single through switch with low current capacity upto the charging current level is used. Here the capacitors are connected in parallel go get more current.

One coil, with required number of turns and size is used. It can be wound as simple air cored or wound on some barrel of non-magnetic material, so that magnetic flux can be properly linked with projectile which is inside the coil. Different approaches have been noticed for different design of coilgun but this simple design: projectile inside the coil is best suitable configuration. To get higher response of coilgun i.e. to get fast acceleration of projectile, time constant of R-L-C series circuit formed due to charged capacitor and it's resistance, coil resistance and it's resistance, switch resistance and wire resistance should be properly designed and can be as minimum as possible show that projectile can move faster.

When the capacitors are made to discharged through coil, it will first of all disconnected from the main DC source and then after made to discharged through the coil. Here the switch which is used for discharging purpose should have higher insulation and high current capacity as heavy DC discharging current will flow it which can melt the switch. It was observed in the literatures while performing the coilgun experiments, negative current was flowed through capacitor which can charge capacitor negatively. So to avoid this difficulty, a freewheeling diode is place in reversed direction in parallel with the coil. A multistage coilgun can be made by placing coil one after another. They are operated in similar manner as single stage coilgun. Here, projectile passed through first stage and going in another stage at that at the starting edge of the another stage coil IR sensor is placed which can detect the position of the projectile and trigger the another stage. Similarly followed for another stages [4].

III. METHODOLOGY TO ANALYSE

This paper discuss, about the methodology to analyse the coilgun. Here the coil is showing the dynamic behaviour. But for analysis purpose steady state behaviour is to be considered. When the coil is supplied by DC transient current generated through charged capacitor, it will dissipate the electrostatic energy into electromagnetic energy. Here the losses occur in switches and connecting wires as well as coil. Then after the magnetic field generated by the coil will link up with the projectile, so it experiences the Lorentz force and it will move. As when this current will die out after that this projectile will starts to move. So, maximum

value of the transient current is responsible to move the coil. This peak value is simulated to generate and find the force on projectile. So, a kind of software is required which can do above mentioned simulation simultaneously. ANSYS Maxwell with Simplorer can do this job easily. ANSYS Maxwell is Finite Element Analysis (FEA) based Approach and Simplorer is Circuit based approach [4]. A combination of FEMM 4.2 (FEA) and EMTP-RV (Circuit) approach can also work with better accuracy.

IV. PARAMETRIC VARIATION

Many literature found on parametric variation which shows the behaviour of the coilgun. Parametric variation of the projectile can be done for length, width (diameter), material, position and shape. Also, the parametric variation can be followed coil with respect to its length, width (diameter), number of turns, material and wire gauge of the coil [6]. If coils are charged for particular voltage with different number of turns then as turns increases force and velocity of projectile will increases. If voltage is increases for particular number of turns of coil then also velocity will increases. Trigger position also affects the projectile motion. If projectile is far away from the coil then force is less. But as it placed nearer to coil force will increases but as projectile is placed nearer to centre of the coil, force on the will reduce. And at the center of the projectile force is zero. So, proper position of the projectile is at the edge of the coil. Due to this efficiency of the coilgun will increases [2] [4]. From the parametric variation as per the literatures, as length of the projectile changes with respect to coil length, maximum force can increase as well decreases. It is found that best size of the projectile is when length of projectile is equal to length of the coil. At this time, projectile will achieve maximum force and speed. Material with higher permeability will link with maximum flux. So, such material can be used for projectile.

V. CONCLUSION

It is concluded from the study that by obtaining proper diameter of the projectile, diameter of the coil, material, proper current and voltage one can achieve higher efficiency. Also, tools based on circuit and finite element analysis can be helpful to analyse the coil gun electromagnetic field and transient current.

VI. REFERENCES

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