Modelling and Analysis of Electromagnetic Coilgun with Two Coils

Rahul Abhyankar[1], Tejas Sakpal[2], Dr. Pawan Tapre[3]
[1, 2, 3] Dept of Electrical Engineering
[1, 2] Viva Institute of Technology, Virar.
[3]S.N.D college of engineering, Yeola

Abstract- *This paper presents modelling and simulation of electromagnetic coilgun with two coils.Two different models were analyzed in the simulation process. First model is made with Ansys Maxwell to get forces, moving position of projectile within the coilgun and the speed at various points and muzzle velocity as well. The model is developed in the MATLAB with basic programing and the mathematical modelling of the projectile motion to get range and velocity graph of the projectile motion.*

Keywords- Ansys Maxwell, Graphical presentation of Projectile motion, Muzzle velocity, Projectile motion mathematical modelling.

I. INTRODUCTION

The coilgun is a next generation weapon which operates on the basic principles ofelectromagnets and the ferromagnetic projectiles. Two or more coils are excited in the proper sequence to fire the projectiles. Fast switching device such as MOSFETs, IGBTs are used for switching. Capacitors are used to store and release the electrical energy for short duration. Each coil is energized with the help of its own capacitor bank. The duration for which coil is kept energized, plays a vital role in the projection. For better projectile motion, once the projectile reaches the center of coil, the next coil must be energized to attract then projectile into the next coil to avoid the suck back effect. A detection circuit with infrared lights in each coil can be used to detect the motion and position of the projectile.

II. SIMULATION MODEL WITH ANSYS MAXWELL

This model is developed in Ansys Maxwell to find out the muzzle velocity of the projectile which is necessary for the MATLAB model to find out the projectile motion graph.
Model details are: length of bullet is 22mm,radius of bullet is 4.9mm, total length of barrel is 70mm, inner and outer diameter of coil is 7.05mm and 10mm respectively. Each coil has length of 15mm, and number of turn on first and second coil is 350 and 400 respectively.

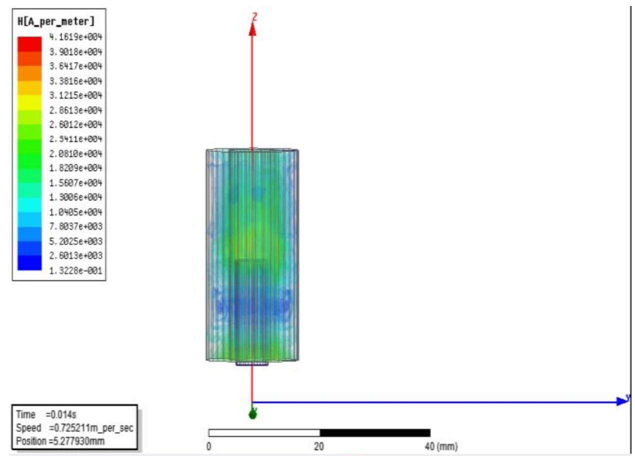

Fig. 1. Simulation model with one coil

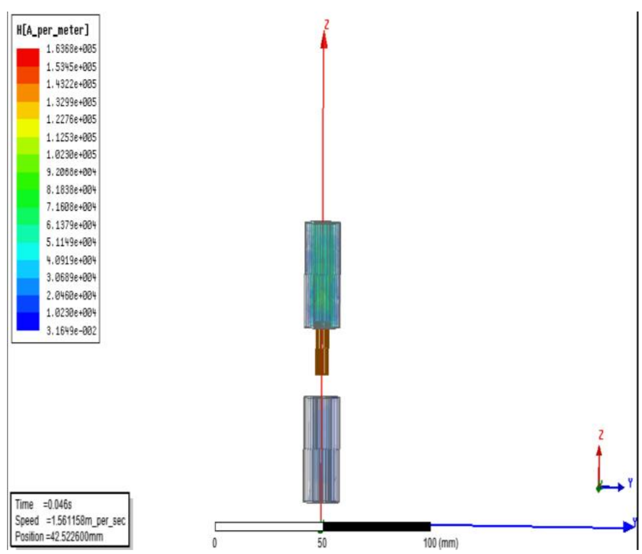

Fig. 2. Simulation model with two coils

Figure 1 and figure 2 shows the simulation model of electromagnetic coilgun with one and two coils respectively. Coil 1 is excited with 3 A and coil 2 is excited with 6 A current. This model gives a very detailed simulation of two coils.

Ansys simulation is based on transient dynamic analysis and it provides detailed information on the fractional time of the simulation. The projectile should keep half so it can pull it and forward direction. The direction was chosen according to Fleming's right-hand rule. Coil winding is chosen as stranded to decrease eddy current losses. Magnetic field intensity (H) i.e. the strength of the magnetic field of a coil is shown in the left spectrumbar.

Table 1. Observation of Simulation Model Parameters

Time [ms]	FORCE (N)	Speed (m/s)	Moving Position (mm)
0	0.095852821	0	0
1	0.102579336	0.078572	0.0611117
2	0.097775998	0.132842	0.167343
3	0.103914717	0.186869	0.327307
4	0.104673347	0.242925	0.542803
5	0.111489243	0.298886	0.813883
6	0.11340754	0.35773	1.14305
7	0.116743314	0.416492	1.53042

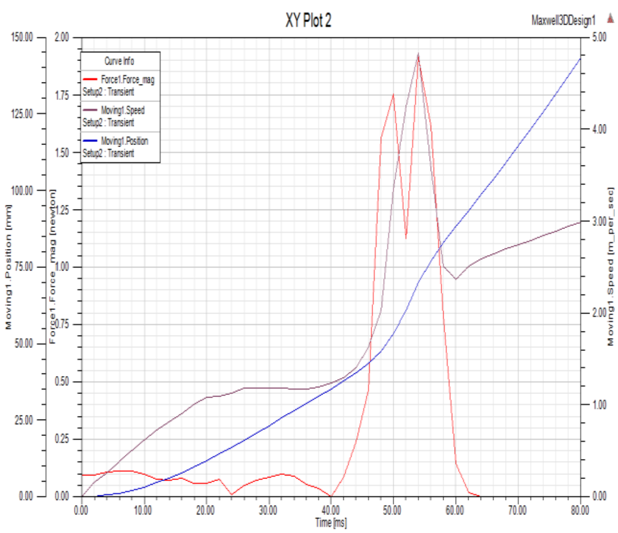

Fig 3. Graphical Representation of The Forces, Speed and Position of The Projectile

III. MATHEMATICAL MODELLING

For initial velocity:

$$u_x = u\,.\,cos\theta \text{ ..... (1)}$$

$$u_y = u\,.\,sin\theta \text{ ..... (2)}$$

Time of Flight

$$T = \frac{2usin\theta}{g} \text{ ..... (3)}$$

Displacement

$$x = u.t.cos\theta \text{ ..... (4)}$$

$$y = u.t.sin\theta - \frac{1}{2}\,g.t^2 \text{ ..... (5)}$$

Maximum Height

$$h = \frac{u^2.sin^2\theta}{2g} \text{ .....(6)}$$

Range

$$R = \frac{u^2sin2\theta}{g} \text{ .....(7)}$$

All above mentioned formulas were used to create mathematical model of projectile motion of the projectile being fired with the help of the coilgun. MATLAB programming is used to create the model and analysis can be made with the help of graph. Also program provides important parameters such as time of flight, maximum height and range of the projectile directly.

IV. MATLAB SIMULATION

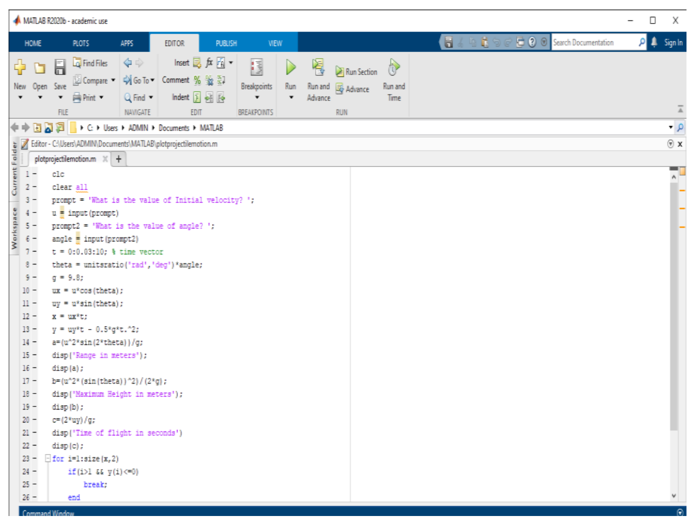

Fig 4. MATLAB programming simulation with mathematical modelling

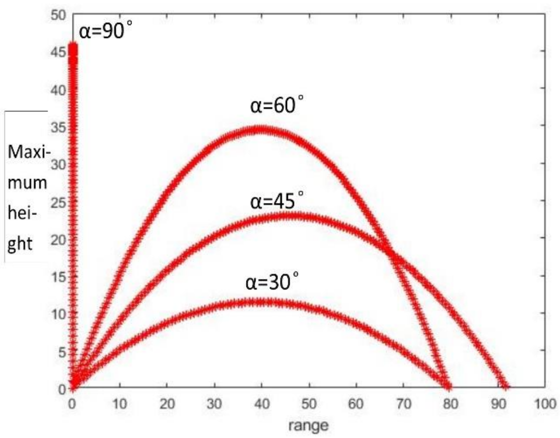

Fig 3. Graphical representation of projectile motion from MATLAB simulation and mathematical modeling

Table 2. Simulation Parameters for various angles with same muzzle velocity

Angle	Maximum Height (m)	Range (m)	Time of Flight (s)
30	11.4796	79.5329	3.0612
45	22.9592	91.8367	4.3292
60	34.4388	79.5329	5.3022
90	45.9184	0	6.1224

Table 2 shows that for same velocity of 30 meters per seconds, there will be difference in the maximum height, range and time of flight. For theta angle 45, the projectile covers maximum range, for higher value of theta angle maximum height and time of flight is more and vice versa.

V. CONCLUSION

From the simulation model of Ansys Maxwell, the initial velocity or muzzle velocity can be found. The mathematical modelling and MATLAB programming model will be helpful to find out the maximum height, range and time of flight. Also the graphical representation can be analyzed to understand the nature of the projectile motion.

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