iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 3 **Issue:** III **Month of publication:** March 2015

DOI:

www.ijraset.com Volume 3 Issue III, March 2015
IC Value: 13.98 ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Design a Novel Plasma Launcher in Railgun

P.Balamurali[1], G.Vijila[2], D.Saravanakumar[3]
[1]PG Scholar, [2] Assistant Professor, [3]PG Scholar, [1,2,3] Department of ECE, Karunya University

Abstract—An Electro Magnetic (EM) launcher can be utilized as an observational tool to accelerate low-mass specimens up to 350 m/s to study impact phenomena. A plasma armature is used to avoid the friction developed by a sliding metal armature. High current flows are applied to achieve high accelerations, resulting in high plasma temperatures. Yet to our knowledge, there are no existing design methods to control the plasma temperature so we propose a new model using gold coil and plasma gases to reduce the plasma temperature and armature friction. For this purpose, 2-D and axisymmetric plasma models are widely used as these are less complicated and fairly available. This proposed model solves the drawbacks of rail guns, these simulations are performed using Comsol Multiphysics version 4.3b software.

Keywords t— Electro Magnetic(EM) launcher, plasma, armature friction, copper and gold coil.

I. INTRODUCTION

Rail guns feature to be one of the most prominent technique that can be used in integrated air and missile defense. Rail guns have established their role as projectile launchers, used for propelling missiles. Rail gun's harness electromagnetic energy to launch the projectiles between two conductive rails. A Rail gun comprises of a pair of parallel conducting rails, along which a sliding armature is accelerated by the electromagnetic effects of a current that flows down one rail, into the armature and then back along the other rail[1]. Rail guns on electromagnetic forces to shoot projectiles with a velocity almost seven times greater than the speed of sound. Greater efforts are made by US NAVY, in the recent years to make rail guns a feasible military technology. It is also suggested that rail gun can be used from a high altitude aircraft to fire a small payload into orbit. The rail gun discussed in this paper, uses Lorentz force to accelerate the launch package[2]. The armature used is plasma armature amidst other types of armatures because of high velocity applications[3]. The Lorentz force is created by the interaction of the armature current with the magnetic field generated by the current in the rails, accelerates the launch package down the drill. Various types of armatures are used in rail gun launchers, only the most common armature for hypervelocity applications is the plasma armature [4]. Of course, plasma armatures can be applied in other EM launchers. At that place are groups of EM launchers that do not use rails. The social system of presenting EM launcher that will be discussed in this paper is different and uses plasma armature in hypervelocity applications. Cognition of the thermodynamic characteristics, transport properties and drift–diffusion theory of the armature is important for both the design of presenting EM launcher and supporting the reading of diagnostic information. In this report, a methodology for estimating key armature characteristics has been presented, which admits the average armature temperature, force per unit area, electrical conductivity, diffusion, and radiation mean free path as functions of the launcher geometry. The methodology is grounded in the 2-D, axial symmetry transient form of the governing equations for the plasma armature. In universal, these equations must be measured numerically. The methodology presented here is rather universal and can be applied to armatures with any elemental composition or even mixtures [5]. The existing models are employed by copper coils it has less temperature resistance, melting point and conductivity is low compared to gold, so our proposed model gold coil is used to reduce these existing limitations[6]. A detailed analysis of the thermo dynamo characteristics and transport properties of the EM launcher is done using COMSOL Multi Physics 4.3b.

II. DEVICE MODEL EQUATION

For a 2-D, axial symmetry EM launcher MHD model is used to model the Plasma. The different equations that has formulated the means to design the EM launcher is in this section.

The electron density and mean electron energy are computed by solving a pair of drift-diffusion equations for the electron density and mean electron energy. Convection of electrons due to fluid motion is neglected. For detailed information on electron transport see Theory for the Drift Diffusion in the plasma.

$$\frac{\partial}{\partial t}(n_e) + \nabla.[-n_e(\mu_e.E) - D_e.\nabla n_e]=R_e \quad (1)$$

$$\frac{\partial}{\partial t}(n_e) + \nabla.[-n_e(\mu_e.E) - D_e.\nabla n_e] + E.r_e = R_e \tag{2}$$

The electron source *Re* and the energy loss due to inelastic collisions *R*ε are defined later. The energy, mobility, electron and energy diffusivity are computed from the electron mobility using:

$$D_e = \mu_e T_e.\mu_\varepsilon = \left(\frac{5}{3}\right)\mu_e.D_\varepsilon = \mu_\varepsilon T_e \tag{3}$$

The rate coefficients are used in the plasma chemistry to find the source coefficients in the above equations. Suppose that there are M reactions that contribute to the growth or decay of electron density and P inelastic electron neutral collisions normally *P>>M* in the case of rate coefficients, the electron source term is made by:

$$R_e = \sum_{j=1}^{M} x_j k_j N_n n_e \tag{4}$$

Where x_j is the mole fraction of the target species for reaction *j*, k_j is the rate coefficient for reaction *j* (SI unit: m3/s), and *Nn* is the total neutral number density (SI unit: 1/m3). By summing the collisional energy loss of the overall reactions will give the electron energy loss.

$$R_\varepsilon = \sum_{j=1}^{P} x_j k_j N_n n_e \Delta\varepsilon_j \tag{5}$$

Where Δε*j* is the energy loss from reaction *j* (SI unit: V). The rate coefficients can be worked out from cross section data by the following integral:

$$k_k = \gamma \int_0^\infty \epsilon\, \sigma_k(\varepsilon) f(\varepsilon) d\varepsilon \tag{6}$$

Where γ = (2*q*/*me*) 1/2 (SI unit: C1/2/kg1/2), *me* is the electron mass (SI unit: kg), ε is energy (SI unit: V), σ*k* is the collision cross section (SI unit: m2), and *f* is the electron energy distribution function in this case a Maxwellian EEDF is assumed.

$$\rho\frac{\partial}{\partial t}(w_k) + \rho(u.\nabla)w_k = \nabla.i_k + R_k \tag{7}$$

The electrostatic field is calculated utilizing the following equation:

$$-\nabla.\varepsilon_0\varepsilon_r\nabla V = \rho \tag{8}$$

The space charge density ρ is automatically worked out based on the plasma chemistry specified in the example using the pattern:

$$\rho = q\left(\sum_{k=1}^{N} Z_k n_k - n_e\right) \tag{9}$$

III. DEVICE DESIGN MODEL

In this section the railgun model is designed using 2-D axial symmetry and it is shown in Fig 1. For this design model of this device the physics, which are involved inductively coupled plasma, laminar flow and heat transfer in fluid. Time dependent studies used to get the result in different time instance.

IV. RESULTS AND DISCUSSION

The proposed model deals with the limitations like high friction and high temperature inside the plasma chamber. The existing model uses copper coil which causes high friction in the plasma chamber which in turn lead to low acceleration. The 2D axis design involves variation in outlet diameter, working pressure, winding current, armature distance, number of winding & armature width. The design parameter of the various models is enlisted in the table 1. Some physical properties are used to measure the functions of plasma temperature and pressure, using these measures we compare our proposed work with existing. The physical properties are viscosity, thermal conductivity, specific heat, electrical conductivity and density. The comparison of the result obtained term gold coil and copper coil 2D axis symmetry design model shown in table 2 and their corresponding values is shown in table3.

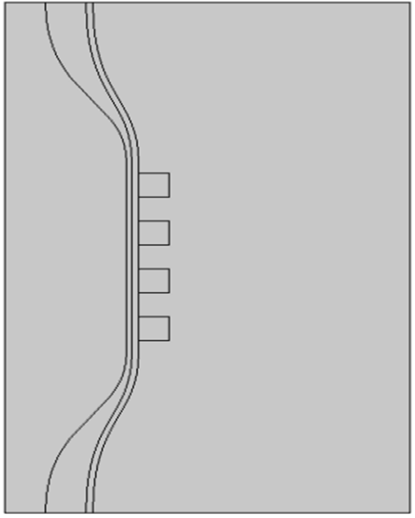
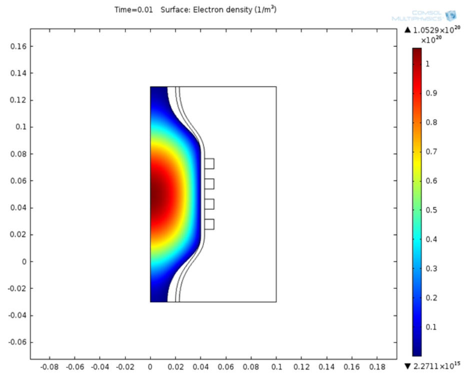
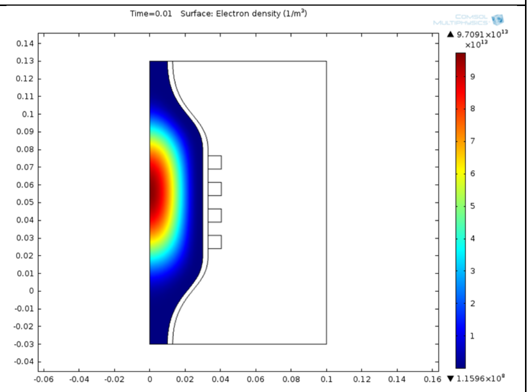


Fig. 1 2-D axisymmetry model designed using COMSOL multiphysics 4.3b

Table I: The model parameters

Model	Out let diameter (cm)	Working pressure (torr)	Winding current(A)	Armature distance(cm)	Number of winding	Armature width
Model1	2	1	15	2.8	4	0.5
Model2	3	0.7	15	3.2	4	0.5
Model3	3	1	50	3.2	4	0.2
Model4	2	1	50	2.8	20	0.5
Model5	2	1	50	2.8	16	0.5

Table II: comparison of gold and copper coil 2-D axisymmetry

Properties	Copper coil	Gold coil
Density		

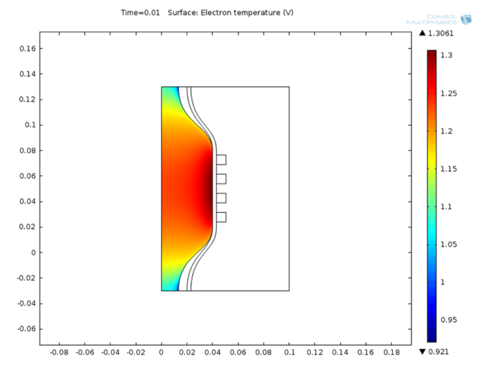
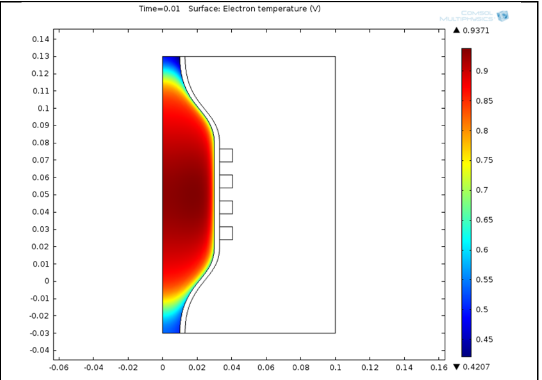
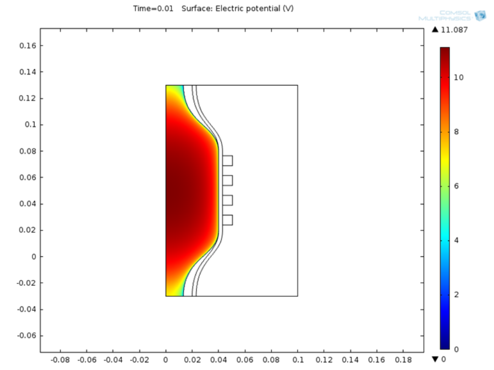
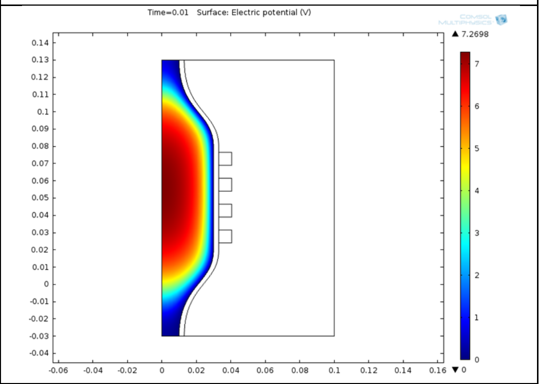
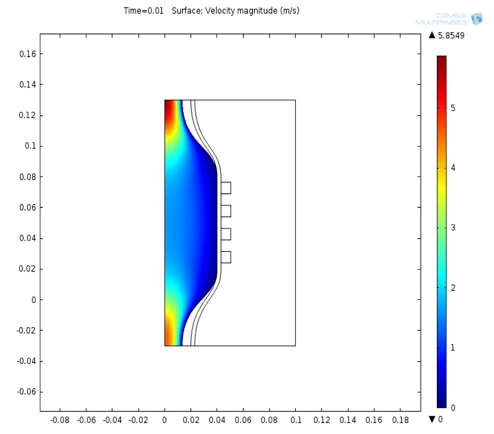
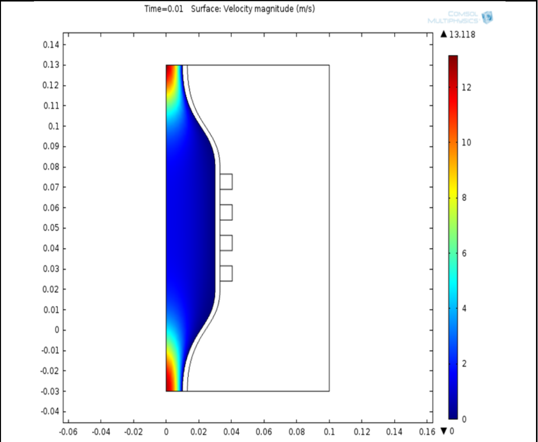
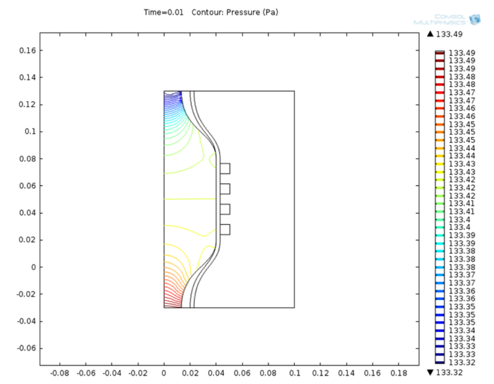
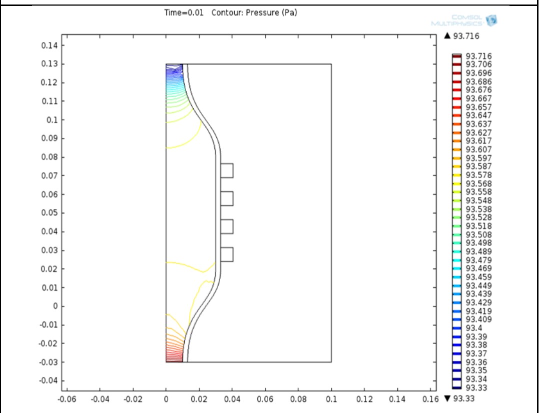
Temperature		
Potential		
Velocity		
Pressure		

Table III: comparison of various performance measures of gold and copper coil designed according to model2

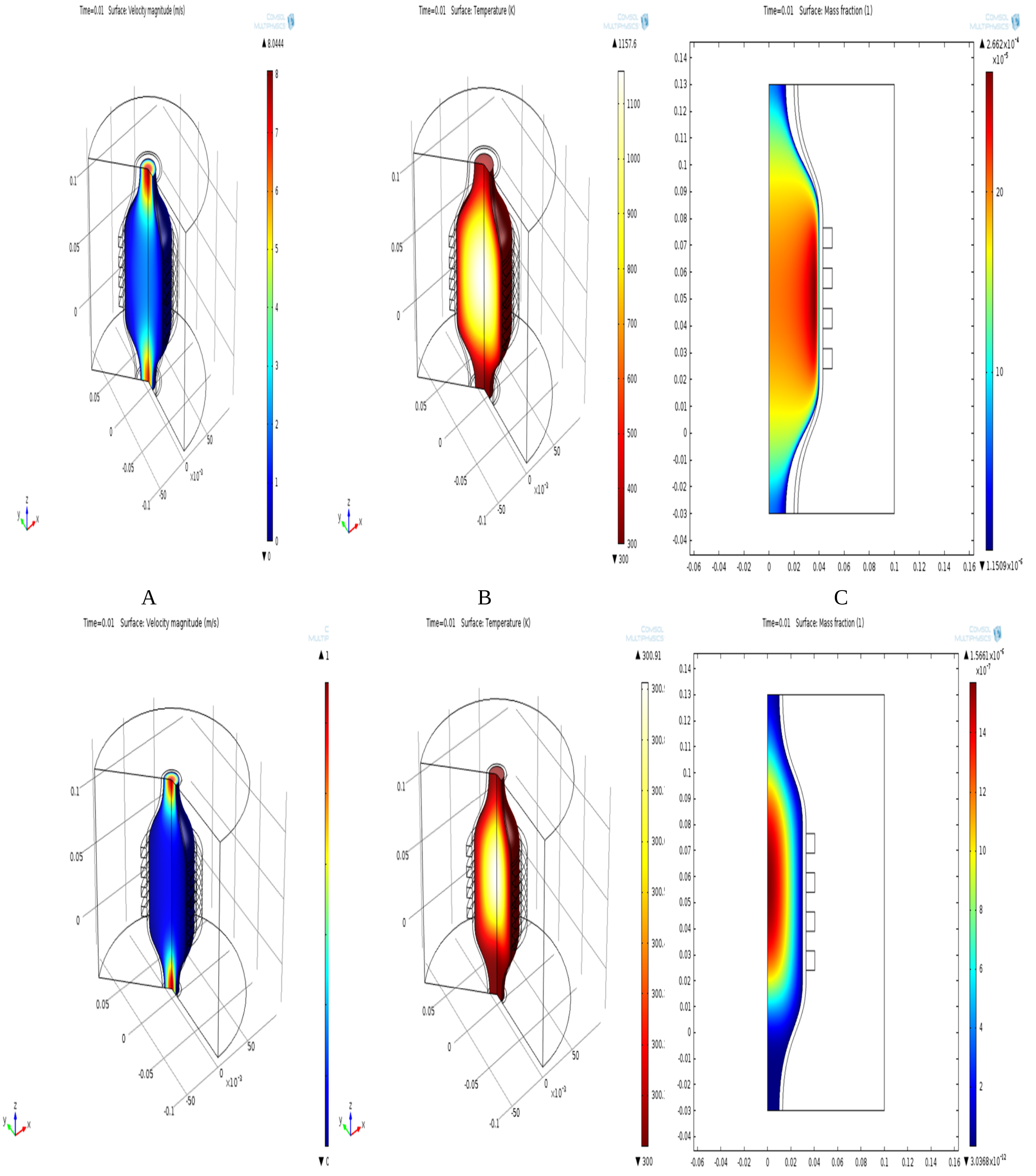
Properties	**Copper coil**	**Gold coil**
Density$(1/m^3)$	1.0523×10^{20}	2.0498×10^{14}
Temperature(v)	1.3061	0.9213
Potential(v)	11.087	7.3868
Velocity(m/s)	5.8549	9.1853
Pressure(Pa)	5.8549	133.6

Our proposed model produces low friction and low temperature inside the plasma chamber which is described by 3-D model and the results are shown in fig 2. Also, the results obtained for different design parameter is shown in table 4. The model parameters are armature distance and width, number of armature windings, pressure, current, diameter of plasma chamber. In order to have a proper analysis of the model which produces high velocity, low temperature & low mass friction the result obtained for the above parameters for existing models and proposed model are listed in table 4. Fig 3 shows the armature mass friction value between copper coil and gold coil in the form of a graph.

Table IV: The results of different models of EM launcher

Parameters	**Model1**		**Model2**		**Model3**		**Model4**		**Model5**	
	copper	gold	copper	gold	copper	gold	copper	gold	copper	Gold
Velocity(m/s)	5.031	1.1853	10.8549	9.0496	10.061	10.859	10.024	13.12	10.028	13.12
Temp(k)	1275.2	301.77	1368.1	303.3	1275.1	303.7	1265.3	303.14	1269.1	302.29
Mass friction	2.4439×10^{-4}	3.8669×10^{-6}	1.9504×10^{-4}	1.5661×10^{-6}	2.4428×10^{-4}	3.5460×10^{-6}	2.4179×10^{-4}	4.9997×10^{-6}	2.4256×10^{-4}	3.6809×10^{-6}

.



A B C

D E F

Fig. 2 A. Velocity of copper coil plasma chamber, B. Temperature of copper coil plasma chamber, C. Friction inside the copper coil plasma chamber, D. Velocity of gold coil plasma chamber, E. Temperature of gold coil plasma chamber, F. Friction inside the gold coil plasma chamber.

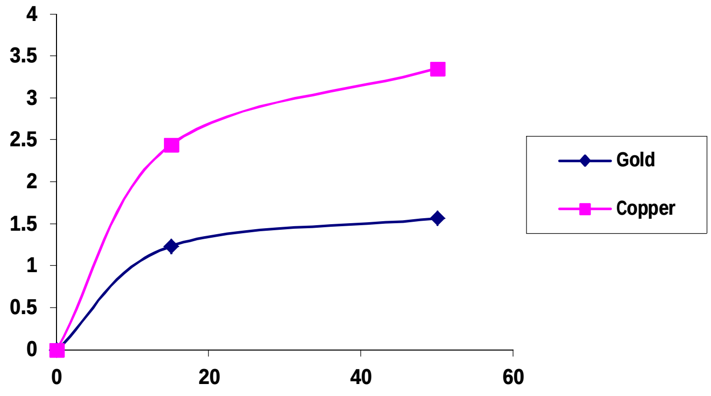


Fig. 3 Graph between copper and gold coil (Mass friction)

V. CONCLUSOIN

The proposed model is found to eliminate the drawbacks of existing model such as high friction and high temperature produced by the conventional copper coil. It is found that the rail guns designed using plasma armature and gold coil produces lesser friction and the temperature exerted to the surrounding chamber is also found to be less for the different models designed. Model2 is found to give the best result with the friction of 1.5661×10^{-6} and the temperature exerted is 303.3k. The main drawback of the proposed scheme is the cost of gold coil.

REFERENCES

[1] Lindsey D. Thornhill and Jad H. Batteh, Scaling Laws for Plasma Armatures in Railguns, IEEE TRANSACTIONS ON PLASMA SCIENCE, VOL. 21. NO. 3, JUNE 1993.

[2] F. Azhar, M. Norhisam, N. F. Mailah, M. R. Zaire, H. Wakiwaka, and M. Noir, “Thrust optimization of linear oscillatory actuator using performance analysis method,” Int. Rev. Electr. Eng., vol. 6, no. 5, pp. 2929–2938, 2011.

[3] D. Azizi and A. Gholami, “Optimization algorithm for improvement insulation system in HV generator based Multiphysics analysis using FEM,” Int. Rev. Electr. Eng., vol. 6, no. 3, p. 1223, 2011.

[4] A. I. Egaña, I. Elosegui, J. M. Echeverría, and M. Martínez-Iturralde, “Analytical calculation of the flux distribution and demagnetization in spoke interior permanent-magnet machines with non-magnetic shaft,” Int. Rev. Electr. Eng., vol. 6, no. 3, p. 1228, 2011.

[5] P. Flesch and M. Neiger, “Numerical simulation of a dc high-pressure discharge lamps including electrodes,” J. Phys. D, Appl. Phys., vol. 35, no. 14, pp. 1681–1694, 2002.

[6] Diako Azizi and Mohammad Reza Alizadeh Pahlavani, Evaluation of a Novel Plasma Launcher Behavior Using Magneto Hydro Dynamic Modeling-Coupled Time Varying Electron Energy Distribution Function, IEEE TRANSACTIONS ON PLASMA SCIENCE,