MATHEMATICAL MODELING AND CONTROL OF MAGLEV

Harish Desai[1], Akash. S[2], Santosh Kumar Choudhary[3]

[1]Manipal Academy of Higher Education, Manipal Institute of Technology, Manipal, Karnataka, India

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Abstract – *The main objective of this paper is to evaluation of the mathematical modeling and control of the magnetic levitation. Maglev is a electrochemical system which overcomes gravitational force by appling counter magnetic force. Using the Maxwell's equation and Lorentz force law the equation of motion of ball is obtained. Controller design for the maglev is done using Root locus technique. Open loop and close loop state response is obtained. The exhibitions of the proposed regulator are anticipated by a few reenactments, and rules for planning the levitation control will be given.*

Key Words: Mathematical model, control, Lorentz force law, root locus technique.

1. INTRODUCTION

The attractively suspended framework (MAGLEV) is a situation benevolent transportation framework that has picked up expanding enthusiasm as an appealing transportation innovation. The MAGLEV innovation offers favorable circumstances, for example, high effectiveness, rapid, low upkeep, and light-weight and is, henceforth, being effectively evolved [1]. Actually, following broad research,MAGLEV innovation has arrived at commercialization in a few nations. For example, China, as a team with German-Transrapid, actualized and started tasks of the Shanghai Maglev Train, which can accomplish velocities of more than 400 Km/h [2], [3].

When all is said in done, three sorts of levitation advancements are utilized in MAGLEV: electromagnetic suspension, electrodynamic suspension, and electromagnet/perpetual magnet half and half electromagnetic suspension. Electromagnet/perpetual magnet crossover electromagnetic suspension frameworks are regularly alluded to as controlled-perpetual magnet (CPM) levitation frameworks. In the CPM levitation framework, electromagnets are controlled to keep up the levitation airgap so that the appealing power by the lasting magnet adjusts the all out weight of the vehicle and its heap [5], [6].

The CPM levitation framework has been viewed as a successful vitality moderating MAGLEV framework. In this framework, as the CPM utilizes electric force just in the transient condition, the DC power loss of the CPM with load variety can be definitely diminished utilizing the zero-power-control technique proposed by Morishita, et al. [7]. Along these lines, fathoming the levitation power is basic for deciding the reasonable airgap in a MAGLEV [8]. In spite of the fact that the limited component strategy (FEM) is broadly utilized for dissecting the electromagnetic presentation of electric machines, equivalentmagnetic circuit (EMC) models are regularly pre-ferred at the structure stage to decide, among different boundaries, the airgap motion thickness, back-EMF, and static power Characteristics [9], [10].

1.1 Mathematical model

maglev framework is an electromechanical framework which defeats gravitational power by applying counter attractive power. MAGLEV frameworks utilizes electromagnet to suspend a steel ball in air by attractive power.

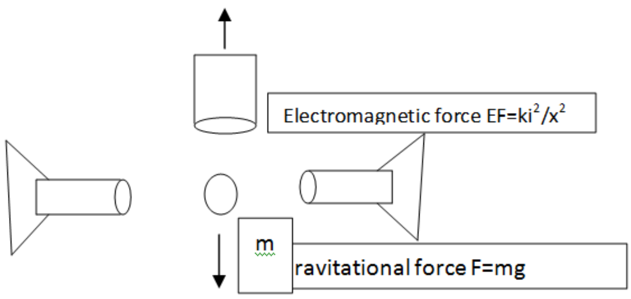

Figure 1: block diagram of maglev

The block diagram of MAGLEV is shown in above figure 1. which consist of ball of mass m, electromagnetic force, and gravitational force F.

When charge is in space:

Maxwell equation: Electric field due to charge: . E ▽

When there is current, (magnetic field):

Δ * B

Δ * B α -2E/2t

dB/dx = -2E/2t

dB = -dE/dt * dx

Electric field strength EF = force/charge = F/q = kQ/x^2

Where, F = kqQ/x^2 k = 9 *10^9 Nm^2/c^2

X = separation between charges (m)

Where, q is test charge and Q is the source charge by using the derivation,

Also, $dE/dt = d/dt\ (Kq/x^2)$

Also, $dQ/dt = -i$

$dE/dt = -ki/x^3 * x\^{}$

$\int dB = \int ki/x^3\ dx$

$B = ki/x^3$

Also, by using Lorentz force law:

For a moving charge q, force F is given by:

$F = qvB$

$F = q\ .\ x/t\ .\ B$

$F = I\ .\ x\ .\ B$

$F = I\ .\ x\ .\ ki/x^3\ ki^2/x^2$

$F = ki^2/x^2$

From Newton's second law equation of motion of ball is given by,

$m\ddot{x} = mg - ki^2/x^2$

from the above equation m is given by (mass * acceleration) (weight due to gravity)

Equating derivative to zero : $m\ddot{x} = 0$

$mg = ki^2/x^2\ (g = ki^2/(x^2.\ m)$

$k = mg/ki^2\ .\ x^2$

by using Taylor – series approximation for linearizing:

$\ddot{x} = -\ \{\ db\ (I, x)/2i\ |_{i0\ x0}\ \Delta I + 2b\ (I,x)/2x\ |_{i0\ x0}\ \Delta x\ \}$

$= -\ \{\ 2ki/x^2\ \Delta I + (-2)/x^3\ .\ ki^2\ \Delta x\ \}$

$R^2\ \Delta x = -ki\ \Delta I\ -kx\ \Delta x$

$\Delta x\ \{r^2 + kx\} = -ki\ \Delta i$

$\Delta x/\Delta I = -ki/(s^2 + kx)$

$\Delta x/\Delta I = G(s) = -ki/\ (s^2 + kx)$

Where,

$Ki = 2i/x^2\ .\ k = 2i/x^2\ .\ mg\ x^2/i^2|_{i0\ x0} = +2mg/i_0$

$Kx = -2/x^3\ .\ i^2\ .\ k = -2/x^3\ .\ i^2\ .\ mgx^2/i^2 = -2mg/x_0$

If $x_0 = -1.5v$

$I_0 = 0.8\ A$

$m = 0.02\ kg : g = 9.8\ ms^{-2}$;

$G(s) = -(+\ 2*0.02*9.8/0.8/s^2 + (\ +2*0.02*9.8/+1.5)$

$= -0.49/s^2 + 0.2613$

$G(s) = -0.49/s^2 + 0.2613$

1.2 Open loop and Close loop analysis

The open loop reaction of a control framework is the consolidated reaction of the plant and the regulator, barring the impact of the input loop. Practical analysis of the maglev is done using open loop and close loop response. Open loop step response is shown in below figure.

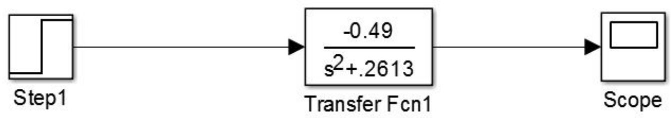

Figure 2: open loop transfer function

Open loop transfer function is shown in above figure. Step response of the open loop response is shown in below figure.

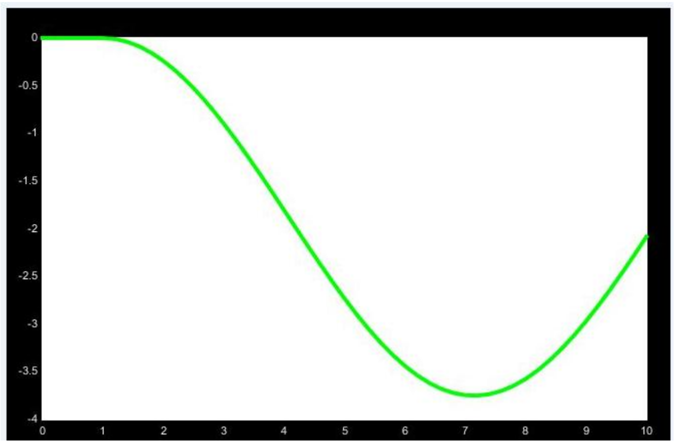

Figure 3: step response of open loop transfer function

Close loop response will be used because Shut circle frameworks are intended to naturally accomplish and keep up the ideal yield condition by contrasting it and the genuine condition. It does this by producing a mistake signal which is the distinction between the yield and the reference input. The block diagram of close loop response is shown in below figure.

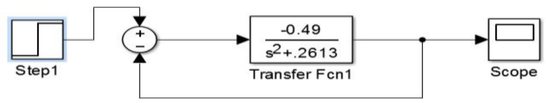

Figure 4: close loop block diagram

Close loop transfer function is shown in above figure. Step response of the Close loop analysis is shown in below figure.

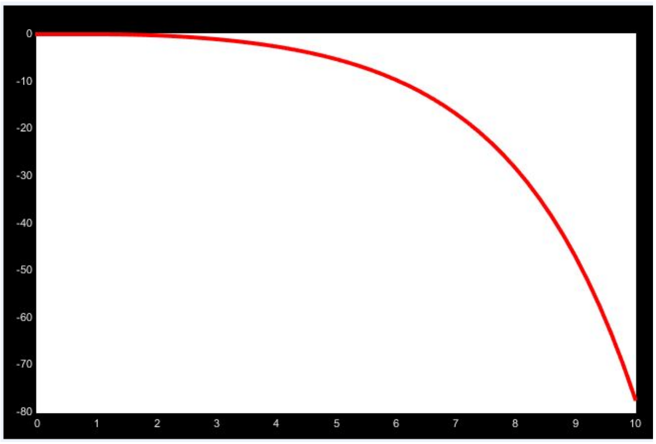

Figure 5: step response of close loop transfer function

2. CONCLUSION

Mathematical model for the system is obtained.

The open loop and close loop response of the system is obtained as expected. From the results we can analyse that system is stable. And control system for the maglev is obtained.

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BIOGRAPHIES

Harish Desai. Author from india was born in january 22 1995. He graduated with M.Tech degree in AeroSpace Engineering from Manipal Institute of Technology at Manipal Academy of Higher Education, Manipal, Karnataka in 2020.

Akash S. Author from india was born in may 7 1995. He graduated with M.tech degree in aerospace engineering from Manipal Institute of Technology, Manipal academy of higher education in 2020.

Santosh Kumar Choudhary. Author is currently Assistant Professor at Manipal Institute of Technology, Manipal, Karnataka, India. He graduated with M.tech degree in Astronomy and Aerospace Engineering from Manipal Institute of Technology at Manipal academy of higher education, Karnataka. He is an Applied Mathematician and actively involved in research work related to Mathematical Modelling and Control of dynamical systems with an emphasis on Aerospace dynamic systems.

Asst Prof. Choudhary is also the member of Institution of Engineers (India), Indian Society of Technical Education (ISTE) and Indian society of systems for Science and Engineerin (ISSE).