Applied Mechanics and Materials

Country	Switzerland
Subject Area	Engineering
Subject Category	Engineering (miscellaneous)
Publisher	Trans Tech Publications Ltd.
Publication type	Book Series
ISSN	16609336
Coverage	2005-ongoing

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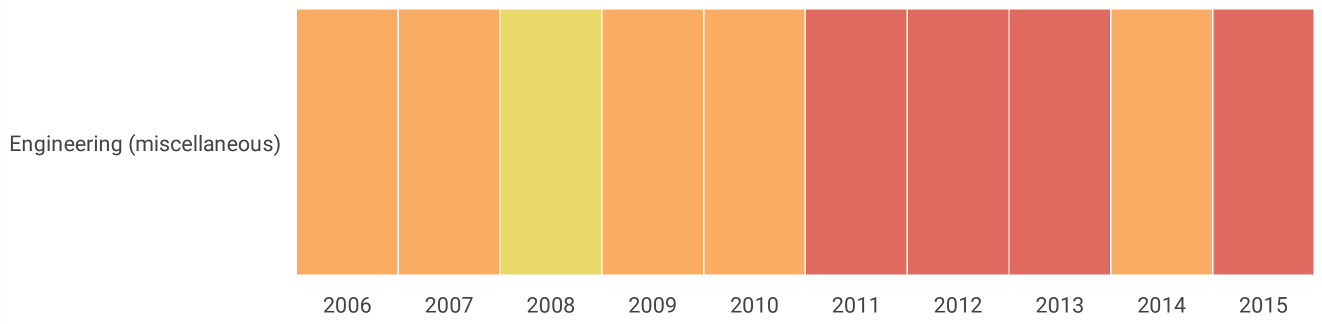

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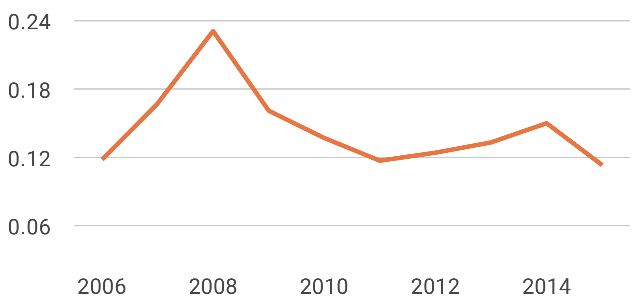

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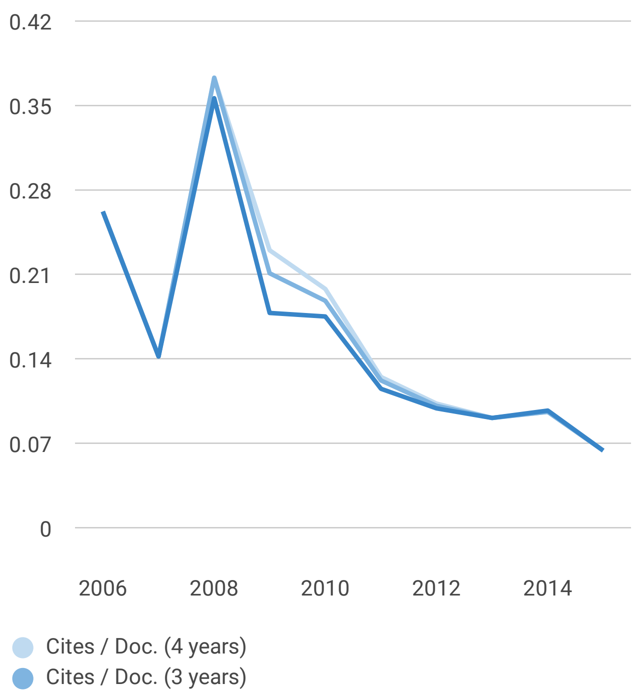

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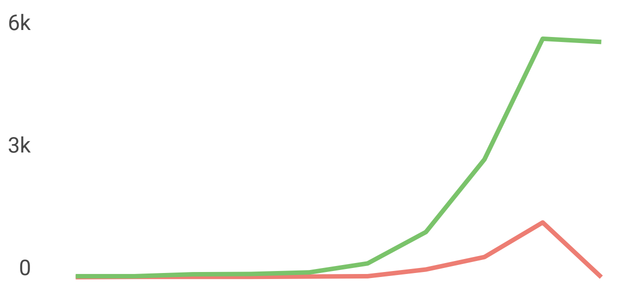

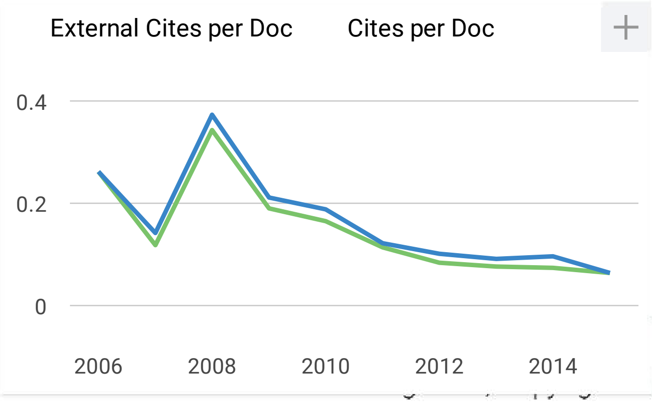

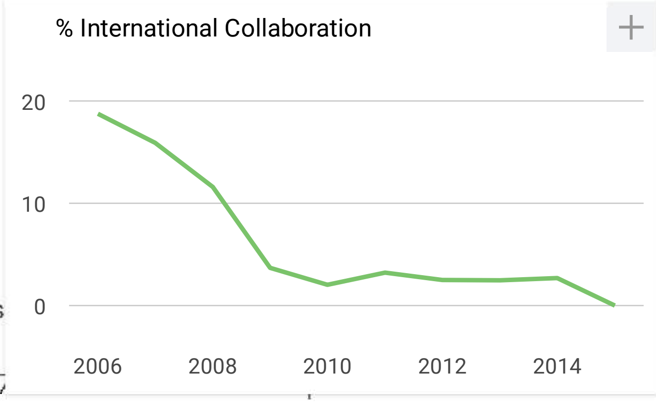

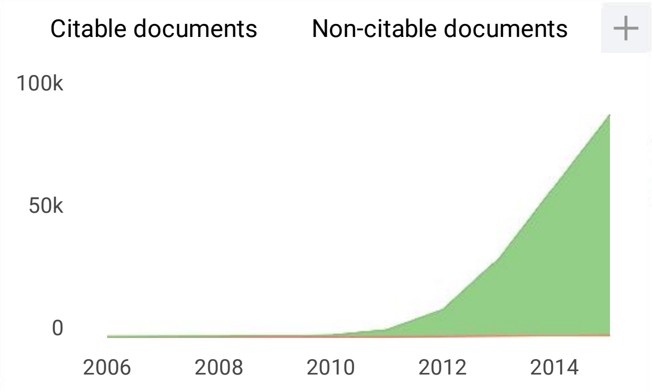

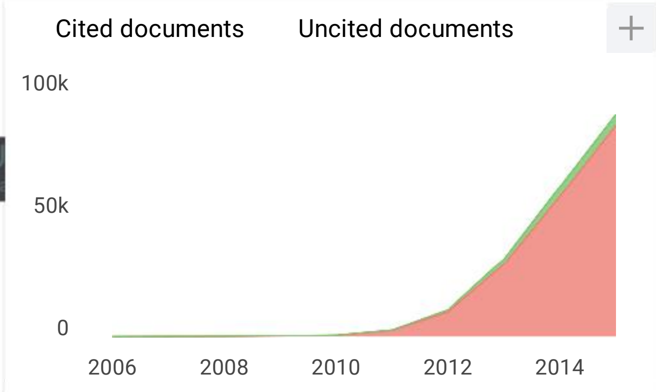

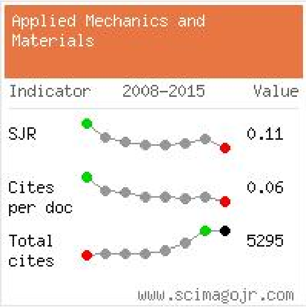

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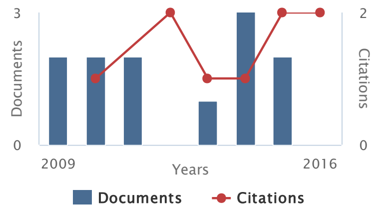

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doi:10.4028/www.scientific.net/AMM.493.517

Preliminary Study on Magnetic Levitation Modeling Using PID Control

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Keywords: modeling magnetic levitation, PID control, gap, electromagnet

Abstract. This paper proposes to understand about basic magnetic levitation model. Magnetic Levitation is repulsive or attractive force resulting gap from magnetic field. Characteristic of the magnetic levitation model is used permanent magnet and electromagnet with PID control to maintain wide gap between levitator and object levitation. Mass addition is used to analysis the model of the Maglev with PID control to maintain wide gap. Calculation result show that the maglev with PID control has sufficient levitation force in the maintain wide gap. Comparison between calculated and measured values can be done to build a another complex model magnetic levitation.

Introduction

Development modern transport systems has been something important. Condition transportation system that today are cause various problems, such as pollution increases, limited energy source and expensive for daily operation. Magnetic levitation (maglev) is a one of new method that used for modern transportation system. The system is made a vehicle lifted from the road way or guide way by a magnetic field. The high magnetic levitation force makes possible various applications, not only transportation system, but magnetic bearing, flywheel and motors or generators.

Superconductor YBa2Cu3O7-x (YBCO) and electromagnet can produce magnetic levitation, which this system resulting equations for lift to weight, suspension stiffness and lateral stiffness [1][2]. However, using the superconductor it be difficult to applied in the form real vehicle, because the superconductor only work at temperatures -197^0 C.

Source magnet field (flux) has a different character depending on the type of field. There are three types of fields, the uniform, non uniform and variable [3]. In research to determine the costs is an important part, especially to reduce the costs required to make magnetic levitation equipment with low cost [4].

Research on magnetic levitation has been developed, to create a new conveyor passive systems based on magnetic levitation bearings [5], maglev car with a miniature model of YBCO superconductor [6], the trajectory of permanent magnet made in the form of a "V" [7] and to observe the effects of dynamics and response learning physics with this method [8]. Setting gap of the maglev is an important, because the gap of the maglev needs to be constant and stable. Therefore the control of the maglev system using electromagnets can be well controlled. Arrangement with zero-power controller to produce maglev and the proportional-integral-derivative (PID) controller is used to adjust the electrostatic levitation [9].

Design of Experiments

This paper describe of modeling magnetic levitation system, also controller and mass additions. Data obtained from Matlab simulation, the results can be used to make the maglev system. There needs to some factors that must be considered. Permanent magnet is the part of a factors. There are various types of the permanent magnets that are now used. In table 1 we can see various types of magnets with commercial characteristics.

Table1. Commercial characteristics of the magnetic [3].

	B_r (T)	J_S (T)	$_iH_c$ (kA m^{-1})	$_BH_c$ (kA m^{-1})	$(BH)_{max}$ (kJ m^{-3})
$SrFe_{12}O_{19}$	0.41	0.47	275	265	34
Alnico	1.25	1.40	54	52	43
$SmCo_5$	0.88	0.95	1700	660	150
Sm_2Co_{17}*	1.08	1.15	800	800	220
$Nd_2Fe_{14}B$	1.28	1.54	1000	900	300

From Table 1 it can be seen that the Nd2Fe14B or neodymium has greater value when compared to other types of permanent magnets, so the modeling will be using neodymium material.

Figure 1 show magnetic levitation system. Permanent magnets used have cylindrical shape where r_1 is the inner radius and the r_2 is the outer radius of the cylinder. Pole located at the center of the magnet is used to keep the magnet does not move left or right.

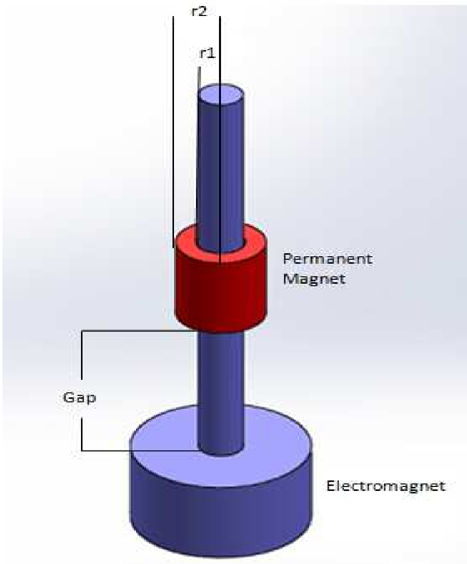

Figure 1. Magnetic levitation system.

From cylindrical shape used in maglev systems, the resulting magnetic field can be written [3]:

$$B_{PM} = B_r \ln\left({}^{r_2}/_{r_1}\right) \quad (1)$$

when B_r is permanent flux density of the permanent magnet and B_{PM} is magnetic field permanent magnet. While electromagnets used is the solenoid, the equation can be written:

$$B_{EM} = \mu_0 i_0 n \quad (2)$$

μ_0 is permeability current, i_0 is current through the solenoid and n is the number of turns per unit length to solenoid.

Form equation 1 and 2 found that the magnetic force. Equation of magnetic force is obtained from the Lorentz equation, for the force generated from the permanent magnet can be written:

$$F_{PM} = qv.B_{PM} \quad (3)$$

Particle of charge q moving through the uniform field with velocity v. To electromagnet with the electron are confined to conductor of length L aligned perpendicular to the field as in the armature or actuator, they constitute a current I and the Lorentz force lead to expression

$$F_{EM} = B_{EM} I L \tag{4}$$

To get the lift force between the electromagnet (levitators) with permanent magnet $F_{EM} = F_{PM}$ with the same polar direction. However, due to the permanent magnet are the masses and is also affected by gravity. The general setup of these levitation system is presented in Fig 2, where levitator has an attractive force $\tilde{F}(\tilde{u},\tilde{z})$ that is realized through input $\tilde{u}$ and also depends on the air gap $\tilde{z}$.

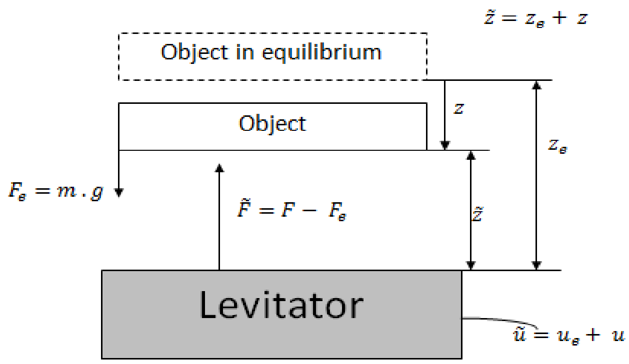

Figure 2. Free block diagram of maglev (input $\tilde{u}$, gap $\tilde{z}$, $\tilde{F}$).

The general setup of a levitation system is shown in Figure 2, General setup of a levitation system is shown in Figure 1.b, with levitators having an active force $\tilde{F}\ (\tilde{u}\,,\tilde{z})$, which is expressed through the inputs $\tilde{u}$ and depends by the air gap $\tilde{z}$. Then made a linear force equation at the point (u_e, z_e, F_e) where the attractive force equal to the force of gravity $(F_e = mg)$. With deviations from operating point defined by the image, with the following linear equation:

$$m\ddot{z} = k_u u - k_z z \tag{5}$$

Where m is a object levitation mass, k_u is a factor of the input force, k_z is the force displacement factor and

$$k_u = \frac{\Delta\tilde{F}}{\Delta u}(u_e, z_e),\ \ k_z = \frac{\Delta\tilde{F}}{\Delta z}(u_e, z_e),\ \ F_e = \tilde{F}(u_e, z_e). \tag{6}$$

$$\tilde{F} = F_{EM} - (F_{PM} + mg) \tag{7}$$

The transfer function of H_{SYS} levitation system, which is obtained from the equation (5) in the Laplace domain conjugates, wherein each variable is has a large influence and assume zero initial conditions:

$$H_{SYS} = \frac{Z_{(s)}}{I_{(s)}} = \frac{k_u}{ms^2 + k_z} \tag{8}$$

Equations of the system and the controllers has been obtained, the next step is to determine the values of model parameters. Values of the parameters are:
magnetic field from permanent magnet = 1.25 T, permanent magnetic force = 69,42 N, permeability constant = 1,26 x 10^{-6} N/A^2, magnetic field from electromagnet = 0.441 T, electromagnetic force = 563.95 N, number of coil windings = 50000, coil current = 7 A, air gap = 10 mm, mass = 100g

Simulation Result

The parameters obtained are then used to perform simulations. In Figure 3 is the simulation of maglev system with parameters obtained without using a controller.

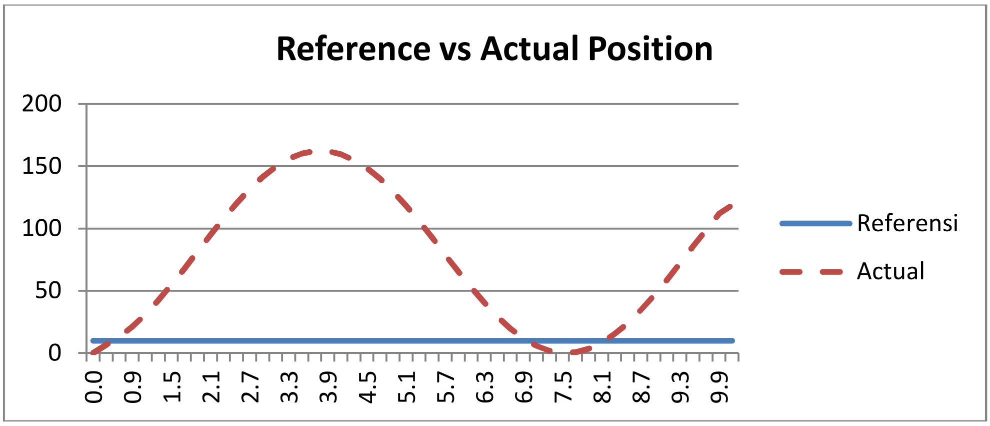

Fig 3. Graph the position of the maglev system without a controller.

Figure 3 shows that the gap resulting from the maglev system is different from the reference position. Reference gap position is 10 mm between and the actual position can't maintain the gap between levitator with object levitation. Actual position need to improved, because the position of actual must be stable, when actual position stable giving mass addition can be simulated.

Given active controller is used to make the actual position stable or same with reference position and maintain the gap position when maglev system is given mass addition. PID control system is used to generates a better response. Tuning of the PID controller using the Ziegler-Nichols rules. Ziegler and Nichols method is proposed a rule to determine the value of the proportional gain K_P, the integral time T_I and derivative time T_D based on the character of the transient response obtained from the plant. PID control and the plant can be seen in Figure 4.

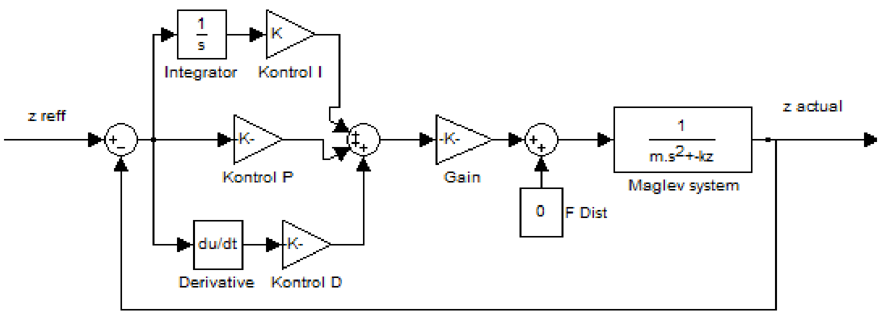

Fig 4. Magnetic levitation system with PID controller.

By given PID control and tuning value for $K_P = 2.16$, $K_I = 0.3$ and $K_D = 0.9$, result has shown at Fig 5. Figure 5 shows the actual position of the maglev system is able to follow the reference position with a small difference and the response time. The results are used to simulate the system with the addition of mass.

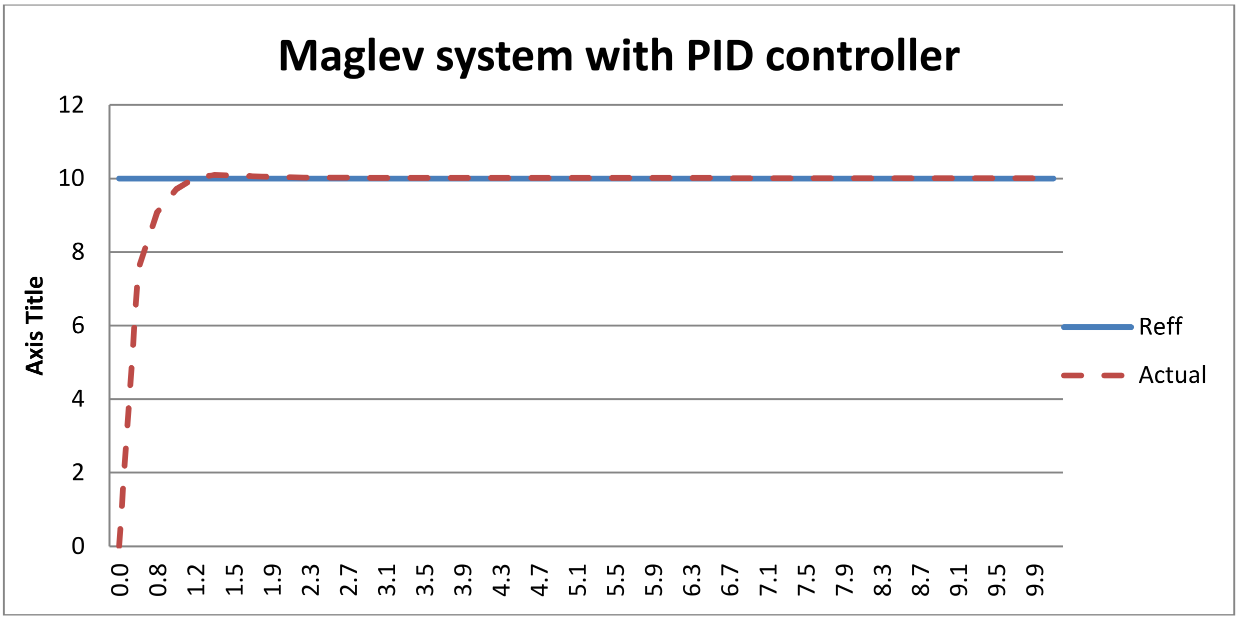

Fig 5. Graph the position of the maglev system with PID controller.

The stability test of the system is by adding mass. This measure is used as an illustration if there is additional mass does maglev system can keep the width of the gap is determined, the application is as a conveyor or maglev transportation system can maintain the gap width when given the addition or subtraction of mass.

The addition of a given mass in the form of mass system static. Where the addition of the load is given in stages, with 25 g, 50 g, 75 g, 100 g, and 150 g. Given load gradually to see if the system of maglev and the controller can keep a wide gap remains with references. Results of the maglev system given the addition of mass has shown in Figure 6.

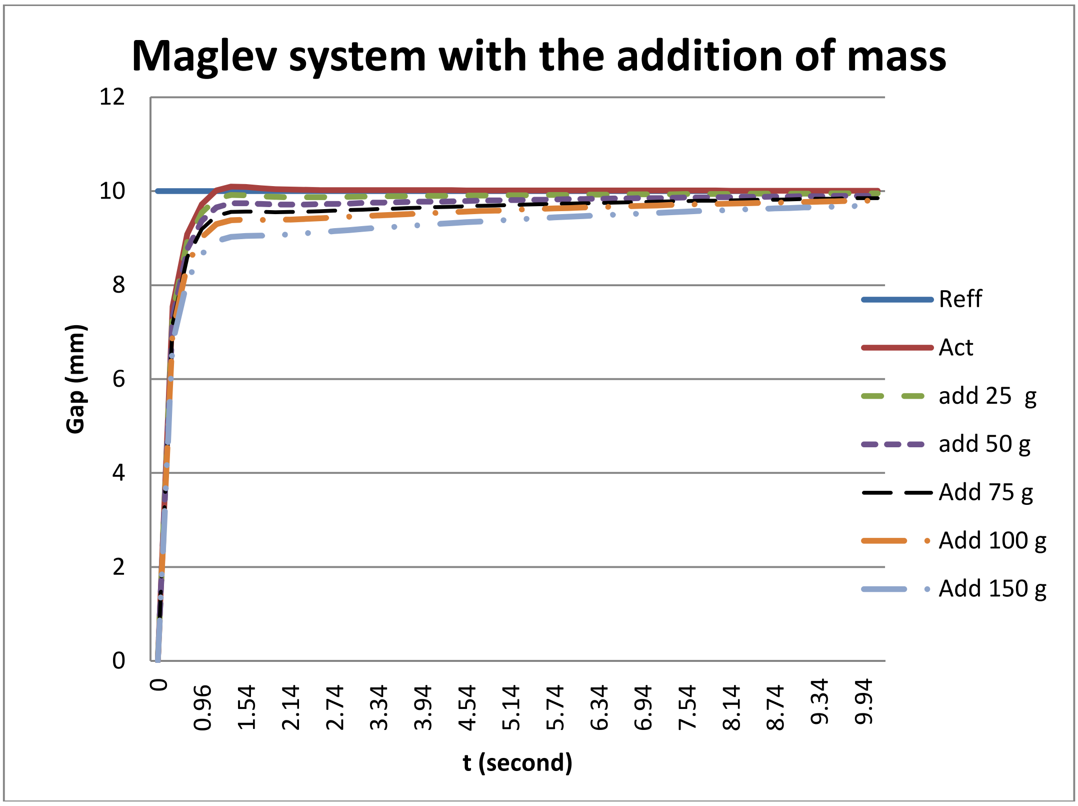

Fig 6. Graph the position of the maglev system with the addition mass.

Figure 6 it shown that the maglev system with PID control is help to maintain a wide gap. However, still have small difference between reference position and maglev system with mass addition. The result shown if maglev system given more mass addition the system is difficult to control the difference gap between actual position with reference position.

Conclusion

Research results be obtained that the maglev system is being designed and tested by simulation is not able to maintain a wide gap between the object in levitators. By the addition of the PID controller simulation results show that the maglev system can follow from the position of the reference.

The addition of a given mass on maglev system is also not very influential, although the addition of the masses to make the position of the levitated object moved by 1 mm from the reference position. This study as a simulation of a maglev system to be developed, so that when there is the addition of the actual mass of the system can maintain the expected gap.

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