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Tuning of PID controller using genetic algorithm for an electromagnetic semi-active suspension system

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ABSTRACT
Electromagnetic suspension of vehicles has advantage of improved ride comfort and drivability. Electromagnetic levitation has been in use in Maglev trains for smoother transportation. However, application of electromagnetic suspension system was limited by its cost and weight. This paper focuses study on use of an electromagnet and permanent magnet hybrid magnet setup and compares the control method to stabilize the suspension system by genetic algorithm optimization, auto tuning technique and fuzzy logic controller for tuning the Proportional-Integral-Derivative (PID) controller for making the system stable. MATLAB-Simulinkanalysis of hybrid magnetic suspension system show stabilization by reduction of the errors in the closed loop control system. Realization in a real time setup may be possible by varying the magnetic field developed in the electromagnet to control the force of repulsion between the electromagnet and permanent magnet.
Keywords— Electromagnet, Levitation, Control, Genetic Algorithm, PID controller, Suspension

1. Introduction
Suspension systems are classified based on the ability to provide reaction force by using an external device such as a motor or the system can by itself provide a reaction force without using an external device [1]. A passive suspension system is a basic system that relies on mechanical components, such as springs and shock absorbers, to absorb shocks and vibrations from the road [3]. The stiffness and damping force of a suspension can be changed using electrical components in a semi-active suspension system[2]. These systems employ sensors to assess the road profile and instantly modify the suspension. An active suspension system is a highly sophisticated system that uses electronic and computer-controlled components to adjust the stiffness and damping force of the suspension. This type of system can change the suspension's characteristics in real-time according to the road conditions and driver inputs [5] [6].

2. Mathematical modelling
Using Equation 1, relation between inductance, $L(z)$, number of windings(N) and reluctance of the electromagnet can be known i(t) is the instantaneous current, ΦT is the flux, RT is the reluctance and N is the number of windings[4].

$$L(z) = N^2 / R_T \qquad (1)$$

Equation 2 represents the force of repulsion of the electromagnet which relates inductance and current to the electromagnet

$$F(i) = [\mu(N^2)A]/4 \ (i(t))/(z(t)) \qquad (2)$$

The final transfer function is obtained by substituting the numerical specifications of the electromagnet and solving the equations and is represented in Equation 3. The mathematical model was realized using the physical setup shown in Figure 1.

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$$G(s) = \frac{0.0475}{s^2+0.2} \quad (3)$$

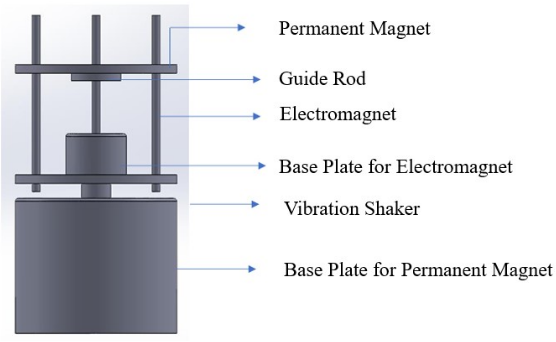

Fig 1. Physical Setup

3. Simulink Model

MATLAB-Simulink was used to observe the response of the suspension system under no control, controlled with Genetic algorithm tuned PID controlled, Auto-tuned PID controller. Figure 1 shows schematic diagram physical hybrid system.

Table 1 shows the disturbance data collected from a typical vibration shaker and provided as an input to the model to observe the response of the electromagnetic suspension.

S.NO	Data	S.NO	Data
1	460	**11**	358
2	460	**12**	-427
3	-532	**13**	325
4	395	**14**	-370
5	-508	**15**	308
6	1568	**16**	-399
7	-2099	**17**	289
8	1104	**18**	-392
9	-1022	**19**	248
10	677	**20**	-365

Table 1 Displacement Data (x10^{-3}mm)

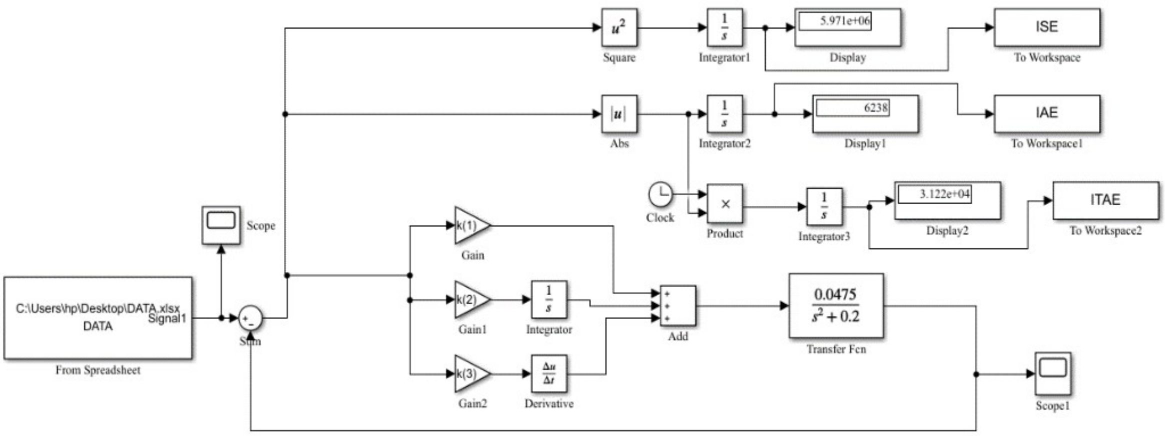

Fig. 2. Simulink model of the electromagnetic suspension system with error display

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The electromagnetic suspension was modelled Simulink along with performance measures without any control being implemented. Figure 2 shows the Simulink model of the electromagnetic suspension.
Figure 3 shows the response of the system without any controller and disturbance can be observed in the electromagnetic suspension.

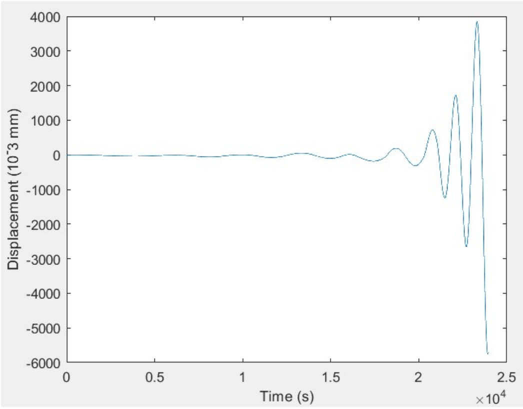

Fig. 3.Simulink model of the electromagnetic suspension system with error display

Genetic algorithm was used to optimize PID parameter values for stabilizing the system. It was observed that Genetic algorithm tuning was effective in stabilizing the system when disturbance is provided as an input to the system. The response of the system after tuning using Genetic Algorithm is shown in Figure 4, in which steady state of the electromagnetic suspension can be observed.

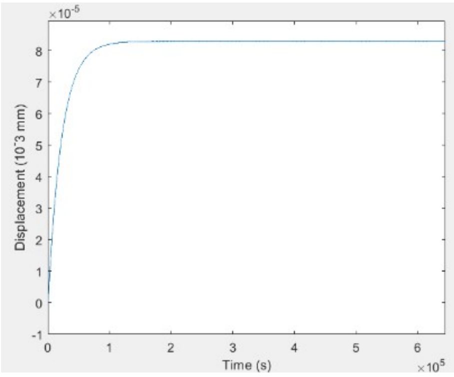

Fig. 4. Response of the electromagnetic suspension system after optimization

4. Results and Discussion

ISE, IAE and ITAE are Integral Squared Error, Integral Absolute Error and Integral Time Absolute Errors respectively. They are the performance indicators of the system. Lower the values, more stable the system. It can be observed that there is a decrease in error when a PID controller tuned using Genetic Algorithm is used.

	Before tuning	GA tuned PID	Auto tuned PID
ISE	5.07	1.7	2.9
IAE	6.2	2.5	3.1
ITAE	7.1	6.2	7.7

Table 2 Errors after controller optimization

Table 2 represents the error values before and after tuning the PID controller using Genetic Algorithm and it was compared with Auto tuned PID controller.

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CONCLUSION

Using the steady state response of the system and the error values i.e., ISE, IAE and ITAE, it can be concluded that, Genetic Algorithm tuned PID controller provides good controlled response with stabilized output and reduced error values. The comparison with auto-tuning method for PID controller in MATLAB-Simulink and replacing PID controlled with Fuzzy logic controller with Genetic Algorithm tuned PID controller was effective in stabilizing the system.

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