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Modelling and Control System Design for Electro Magnetic Suspension System

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***Abstract:** when any vehicle runs on the road, it is subjected to bump and potholes which result in vibration that affects the passenger comfort and vehicle handling. The suspension system is an assembly of tires, springs, shock absorbers and linkages that connect a vehicle to its wheels and is used to absorb and damp out the road shocks. In designing of suspension, it is characterized by the suspension which has low spring stiffness, low damping rate which results in large suspension travel, while suspension having high damping rate is good for better handling that results in small suspension travel. These two contradictory needs the requirement of suspension with varying damping rate.*

This paper describes the design and simulation of a magnetic suspension system for the quarter car. Here in the designed suspension system, the damping value can be varied by changing the electric current supply in the electromagnet. Basically, this system works on Levitation technology, in which pre-defined air gap is maintained due to magnetic repulsion. Here two types of the controller are designed that is look-up table and fuzzy rules to maintain the predefined air gap. Here, when the bump comes, the air-gap fluctuation is sensed by the air sensor and this changed value of gap send to the controller and with respect to this air-gap value the current value from the look-up table or from fuzzy is decided by the controller and sends to voltage amplifier. Voltage amplifier should send that much current toward the electromagnet to vary the repulsion force which results in maintaining the predefined required air gap. Both Look-up tables and fuzzy rules are compared and validate the results.

***Keywords:** Electro-Magnetic Suspension, Levitation Technology, Controllers.*

I. INTRODUCTION

The suspension system is a mechanical system consists of tires springs, shock absorbers connecting wheels to the chassis of the vehicle and allows relative motion between them. The three main functions of the suspension are road isolation, road holding, and cornering. A suspension system in automobiles provides the friction between the tires and road surface, to provide steering stability with good handling and comfort of the passengers.

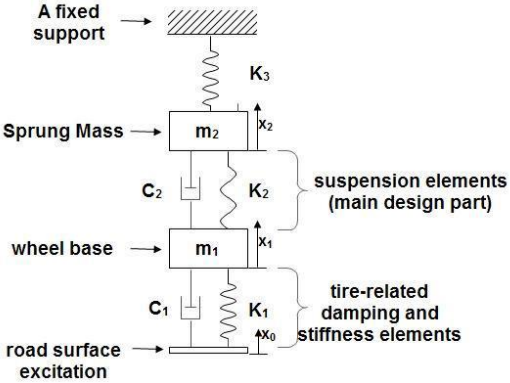


Fig.1 Suspension System of Quarter Car Model

ELECTROMAGNETIC SUSPENSION SYSTEM

Electromagnetic suspension works on the principle of levitation technology that enables the object to float in the air. The electromagnetic actuator replaces the damper and the hydraulic actuator, forming with the spring an oil-free suspension. Here the magnetic force is used to counteract the effects of gravitational acceleration.

II. LITERATURE SURVEY

Bart L.J.Gysen [1] adopted a new active suspension system additional stability as well as maneuverability by performing active roll and pitch control while cornering and braking and eliminating road irregularities, thereby increasing vehicle and passenger's safety and driving comfort. Here various technologies are compared with the proposed active electromagnetic suspension system that uses tubular permanent – magnetic actuator with passive spring. Here various on-road measurements and results from literature and several specifications for the design of an electromagnetic suspension system are derived. The measured on-road moment of a passive suspension system is reproduced by electromagnetic quarter car model, proving dynamic capabilities of designed electromagnetic suspension system

Musaab Hassan [2] in this paper various characteristics to model an electromagnetic suspension system are considered. To model an electromagnetic suspension system it requires modeling a magnetic force characteristics together with the current and the position of the object. So, 1D look-up tables from measured data are used to represent inductance as a function of the air gap. A 2D look-up table was also generated to represent electromagnetic force as a function of current and airgap. By using these Look-up tables the electromagnetic suspension system is modeled in MATLAB/SIMULINK. The designed model accounts both inductance and current variation as airgap are changing.

Pankaj Madharia [3] discussed the shocks due to rumble strips on the road that is not absorbed by the suspension system and passes to the passengers directly. When any bump comes on the road have the height of 3 to 4 inches but rumble strips are only 0.5 inches shock due to these are not absorbed by the normal suspension system. So a new suspension system is developed in which it consists of a permanent magnet as well as an electromagnet, thus this changes the current supply in the electromagnet and damping value of the suspension can be changed. The developed new magnetic suspension system assists the sensors and controllers to response fast in case of rumble strips thereby avoiding shocks from these strips.

IsmenioMartins[4]In this paper author compared the layouts of both hydraulic and electromagnetic active suspensions. In order to improve the performance of active suspension system without excessively increasing complexity and cost, he analyzed the implementing of the electromagnetic actuator into active suspension system. The actuator requirements are calculated, and some experimental results proving that electromagnetic actuator increases the performance of the suspension system.

Yen-Chen Chang [7] modeled the electromagnetic suspension system as a neural based linear T-S fuzzy system and then optimized fuzzy control design is proposed to control current and voltage control system with minimum current and voltage consumption. Here a six layer network with linear self-constructing neural fuzzy inference network is modified from the SONFIN network, which can construct the linear T-S fuzzy model just by input and outputs information. Based on this the author constructed the optimum fuzzy control network to efficiently regulate the non-linearity, complex electromagnetic suspension system to an equilibrium state.

III. METHODOLOGY

Based on the objectives, the following methodology was adopted for designing model of electromagnetic suspension in Matlab/Simulink with look-up tables and fuzzy logic controller. Initial studies were conducted on the various equations of the electromagnetic suspension system. A mathematical model of the electromagnetic suspension system using these equations modeled in Simulink. Various controllers like look-up tables, fuzzy, neural fuzzy were studied for designing the controllers Then to design look-up tables to this suspension system various design considerations were taken from previous papers and look-up tables are designed for inductance and repulsion force as a function of the air gap. Then graphs generated using the electromagnetic suspension model with look-up tables.

Fuzzy logic rules were formed in Matlab using mamadani method and imported this rules to Simulink fuzzy logic controller in Simulink.

Look-up tables were replaced with the fuzzy logic controller and simulated. Then graphs from Fuzzy logic controller also generated.

Both the results from lookup tables and Fuzzy are compared to decide the optimal controller.

MATHEMATICAL MODELLING OF ELECTROMAGNETIC SUSPENSION SYSTEM

- When DC voltage is supplied to electromagnet then, the relation between current and voltage is

  V = [R*i*+ *(L)*]……………….. Eq (1)

- From eq. (1) current *i* can be written as below: *i* = [V- *(L)*] x ^{1} ……………. Eq (2)

- The EMF (F) is expressed as:

L = 0 2 .... Eq (3)

- The EMF (F) is expressed as:

F = 0 2 ( )2..................... Eq (4)

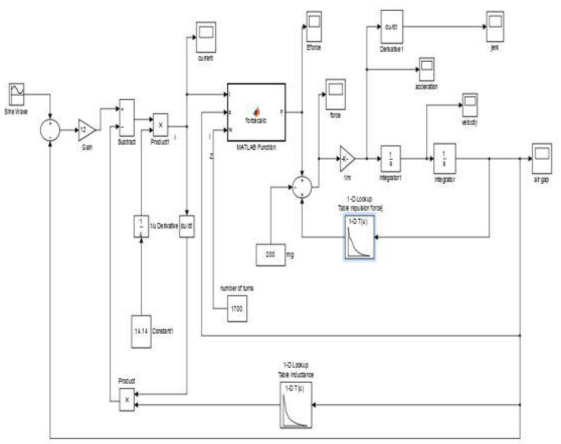
Using all the above equations the simulink models of the electromagnetic magnetic system were modeled. In the first model look-up tables used in first model both tables (1) & table (2) is used to calculate inductance and repulsion force as a function of air gap and in second fuzzy logic controller is used

. SUSPENSION SYSTEM SIMULINK MODEL WITH LOOK UP TABLE

Airgap (Z) in m	Inductance (L) in H
0.001	2.56
0.002	1.28
0.003	0.857
0.004	0.643
0.005	0.514
0.006	0.428

Table (2) Repulsion force 1D look-up table

Airgap (Z) in m	Repulsion force (N)
0.010	18.84
0.013	16.62
0.014	15.39
0.015	12.71
0.016	10.30
0.018	9.23



USPENSION SYSTEM SIMULINK MODEL WITH FUZZY CONTROLLER

Fuzzy rules used in the controller is given below

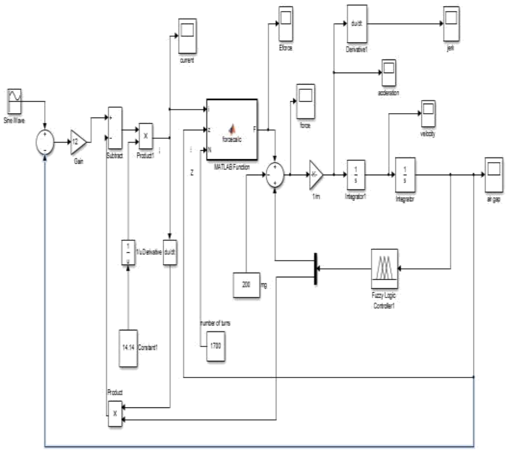
- If (Z) is small then (H) is high and (N) is high.
- If (Z) is medium then (H) is medium and then (N) is medium.
- If (Z) is high then (H) is small and (N) is small.

Here Z – air gap

H – Inductance

N – Repulsion Force

Table (1) Inductance 1D look-up table

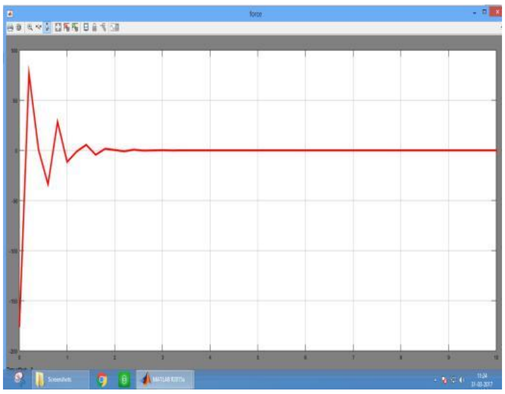


RESULT AND DISCUSSION

The simulation results of suspension system Simulink model with look-up tables are below:

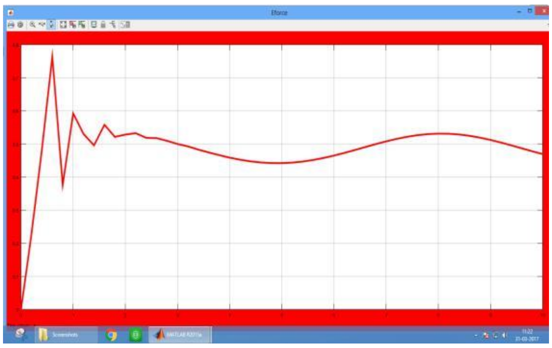
1. Force vs. time

Here the permanent magnet force and electromagnetic force balances the vehicle mass initially thus the suspension system in an equilibrium position. When input bump comes and the vehicle mass is an unbalanced and negative force is imparted on the suspension system. The resultant force is applied on the suspension system to nullify the imparted negative force. Due to which the remaining force becomes zero after 2 seconds



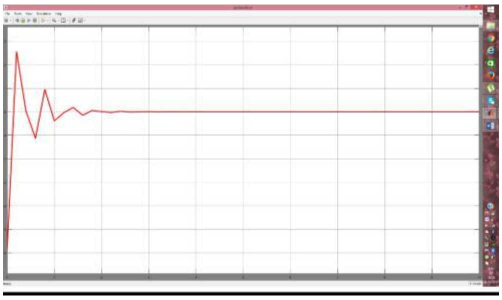
2. Electromagnetic force vs. time

Initially, no current is supplied when the body is in equilibrium state to the electromagnet, so at t=0 electromagnet force is zero. The current and electromagnetic increases when the input bump comes due to fluctuation in airgap. The electromagnetic force decreases to normal with in two seconds.



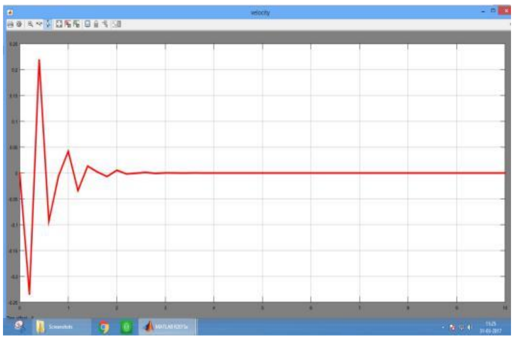
3. Acceleration vs. time

When bump input comes due to inertial force the body is accelerated, thus within the suspension, some negative acceleration comes. Within 2 seconds this acceleration is damped out.



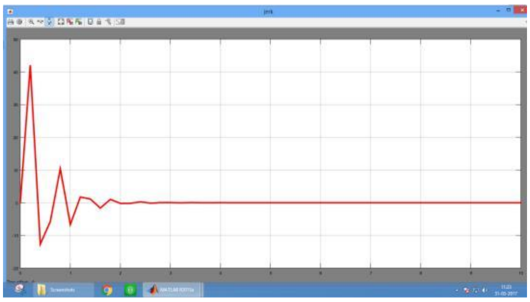
4. Velocity vs. time

From sine wave when input bump comes, the initial displacement is zero, the resultant velocity at time t=0 in the suspension system. This shows that there is no initial movement in the suspension system. The system moves with some velocity after the bump and within 2seconds it is nullified.



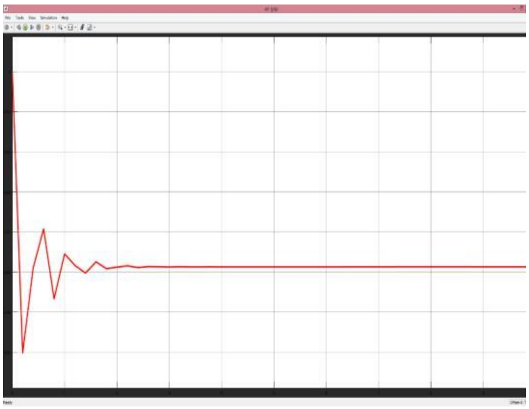
5. Jerk vs. time

No jerk is present in suspension system at time t=0 so the body is not vibrating initially. Large jerks come to the body after the bump which is damp out within 2seconds.



6. Airgap vs time

The permanent magnet force maintains an initial air gap in the suspension system. The airgap fluctuates when the bump input comes. This fluctuation in the air gap can be damped out by applying both magnetic force and the electromagnetic force. The fluctuation in airgap is damped out within 2seconds as EMF is increasing continuously.



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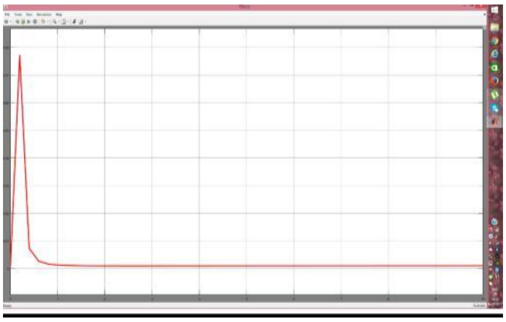
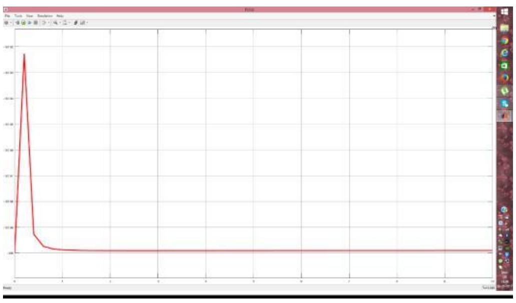


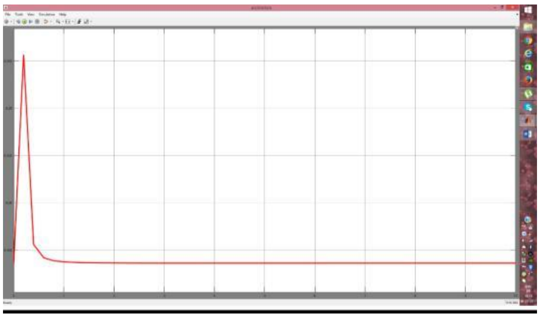
2. Force vs. time

Here the permanent magnet force and electromagnetic force balances the vehicle mass initially thus the suspension system in an equilibrium position. When input bump comes and the vehicle mass is an unbalanced and negative force is imparted on the suspension system. The resultant force is applied on the suspension system to nullify the imparted negative force. Due to which the remaining force becomes zero after 1 second.



3. Acceleration vs. time

When bump input comes due to inertial force the body is accelerated, thus within the suspension, some negative acceleration comes. Within 1 second this acceleration is dumped out



4. Velocity vs. time

From sine wave when input bump comes, the initial displacement is zero, the resultant velocity at time t=0 in the suspension system. This shows that there is no initial movement in the suspension system. The system moves with some velocity after the bump and within 1.5seconds it is nullified.

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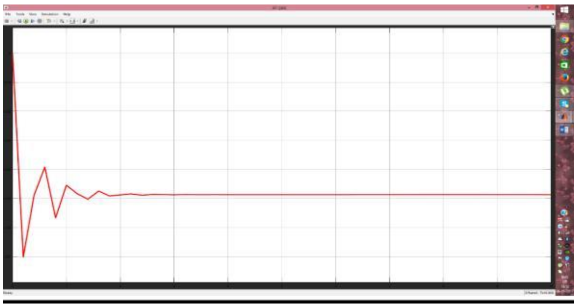

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The permanent magnet force maintains an initial air gap in the suspension system. The airgap fluctuates when the bump input comes. This fluctuation in the air gap can be damped out by applying both magnetic force and the electromagnetic force. The fluctuation in airgap is damped

CONCLUSION

A new suspension system is designed with the optimized controller to overcome a few shocks that cannot be damped out using conventional suspension system. After comparing both looks up tables and fuzzy logic controller, the fuzzy controller has given best output compared to look up tables. Comparison of various parameters between two controllers is given below in table (1).

Table (1) Comparison between look-up tables and fuzzy controller

S. No	Various parameters	Look up table settlingg time(s seconds)	Fuzzy logic controller settling time(sec one)
1	Electromagnetic force	2	1
2	Force	2	1
3	Acceleration	2	1
4	Velocity	2	1.5
5	Jerk	2	1
6	Air gap	2	1.8

REFERENCES

1. Gysen, Bart LJ, et al. "Active Electromagnetic suspension system for improved vehicle dynamics." *IEEE Transactions on Vehicular Technology* 59.3 (2010): 1156-1163.
2. Gysen, B. L., Janssen, J. L., Paulides, J. J., & Lomonova, E. A. (2009). Design aspects of an active electromagnetic suspension system for automotive applications. *IEEE transactions on industry applications*, *45*(5), 1589-1597.
3. Hassan, M. (2012). Modeling electromagnetic suspension force using
4. Measured inductance-air gap data. *Electrical and Electronic Engineering*, *2*(2), 64-7.
5. Ali, K. A., Abdelati, M., & Hussein, M. (2010). Modeling, Identification, and Control of A" Magnetic Levitation CE152. *Al-Aqsa University Journal (Natural Sciences Series)*, *14*(1), 42-68.
6. Hio, KojiZama-ShiKangawa, "Electromagnetic Suspension System", European Patent 1445132A2.
4. Fujita, M., Namerikawa, T., Matsumura, F., & Uchida, K. (1995). μ-synthesis of an electromagnetic suspension system. *IEEE Transactions on Automatic Control*, *40*(3), 530-536.