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Vibration Comparison in Active Quarter Car System Using Electromagnetic Suspension System

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Abstract: *Suspension system plays a vital role in vibration control of vehicle structure as well as in improving ride comfort and safety of travelling passengers. Active suspension system can successfully provide best results in vibration suppression of road induced vibrations in vehicles compared to passive and active type. In present project work, a quarter car test rig is developed using electromagnetic damper in active suspension system. The developed active and passive test rig with two degrees of freedom is tested on vertical shake table to obtain experimental results in terms of sprung mass acceleration and displacement response. The experimental results for sprung mass acceleration and displacement response in time and frequency domain showed that active suspension is highly successful in vibration control compared to passive one. Thus, based on the experimental results it can be finalized that active suspension with electromagnetic damper can be used to get enhanced ride comfort and safety of travelling passengers.*

Keywords: *Electromagnetic Suspension system; FASMA Soft;*

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I. INTRODUCTION:

Every vehicle model has got its own designed and assembled suspension system, which is responsible for comfortable ride on different road conditions varying from smooth to rough. A vehicle suspension system structure consist the assembly of various parts such as dampers, springs, torsion bars and arms etc. The two main assembled parts in suspension system are spring and damper. Technically, during the vehicle vibration duration, the spring element stores the energy in potential form, which is instantaneously converted into kinetic energy of vehicle body and dissipated to the environment in the form of thermal energy through the outer walls of the damper. The suspension system must be designed and developed in such a way so as to keep wheels in contact with road surface i.e. wheel lifting must be avoided during turning, braking and in accelerating conditions.

Electromagnetic suspension works where two or more electromagnets of the same polarity absorb all the bumps. As the magnets of same polarity repel, this property is used to maintain the clearance between the magnets. And this clearance is used to provide the damping and absorbs the vibration. The major components for design of electromagnetic suspension system are a linear damper, Magnets, Iron plates, Iron rod, Steel rod, Hydraulic Damper and Helical springs. In the designing of this type of suspension system the damping value can be varied by changing the current supply in the magnet. The different values obtained by changing the current supply will be used to analyze the behavior of this suspension system under different road condition. Using the approximate technique the design can be used to predict the analysis. With comparison to the other types of suspension system, electromagnetic suspension system provide totally comfortable ride. The developments of the electromagnetic suspension system leads to absorb the shock, reduces the effects of travelling over rough ground and also improve the ride quality and the vehicle handling.

II. LITERATURE REVIEW:

Literature review was done for the application of electromagnetic damper in active suspension system with the help of different research paper are as follows:

Fischer et al in 2004 gives many suspension principle with different dampers and springs, also derive active component and mathematical model of the system and mathematical model also used for detecting fault and diagnosis of the damper.[1] Allegne et al in 1995 gives reduction error in model of previous developed electro-hydraulic suspension system through adopting standard parameter scheme. Which is based on the principle of Lyapnov analysis.[2] Kim et al in 2004 gives a proposal of new type of electro-rheological dampers. In which damper contain flow orifice which is controlled by intensity of electric field and for piston motion.[3]

Xu et al in 2003 gives Magnet Ortheological (MR) dampers of bingham model. Which semi- active control the building and structure in earthquake.[4] Wilson et al in 2010 gives a option of using self turning fuzzy controllers in Magnet Orheological (MR) dampers for reduction in structural vibration.[5] Song et al in 2005 gives adaptive semi active control algorithm, Which is non linear model used for Magnetic Ortheological (MR) suspension system.[6]

Martins et al. in 2006 compared the performance of hydraulic and electromagnetic active suspension systems using experimental work. Experimental results proved the effectiveness and superiority of electromagnetic suspension system in vibration control of sprung mass.[7] Kawamoto et al. in 2007 presented electromagnetic damper for application in automotive suspension. The simulation results were compared with the test results obtained using shaker.[8] Gysen et al. in 2009 applied a brushless tubular permanent-magnet actuator in active suspension for application in automotive. The performance of active suspension was compared with passive one using experimental quarter car test rig.[9]

Zhu et al in 2010 studied the influence of time varying flotor position on the capability of damper to produce electromagnetic force as well as proper development of model voltage-mode in active suspension system.[10] Gysen et al. in 2010 proposed a new electromagnetic suspension system with tubular permanent-magnet actuator in combination with a passive spring. The performance of active suspension system was compared with passive suspension system using a quarter car set up to study the dynamic capabilities of electromagnetic suspension.[11] Amati et al. in 2011 presented the modeling and design of electromechanical damper for application in suspension system. The performance of designed suspension was evaluated under C class road profile considering size and weight criterion.[12]

Montazeri-Gh et al in 2014 studied the performance of active electromagnetic suspension system using hybrid control strategy. The proposed hybrid control strategy is the combination of skyhook and groundhook control concept. The simulation results demonstrated the effectiveness of proposed active suspension system compared to other cases.[13] Vhanamane et al in 2015 manufactured electromagnetic damper for application in active suspension system and studied its performance against passive damper in quarter car model.[14] Ping et al. in 2017 studied the working performance of active suspension using -magnet maaagnetic-valve magnetorheological damper (PMMVMD). The LQG control algorithm was designed using fruitfly optimization algorithm whereas simulation and experimental work was performed on quarter car model.[15]

III. FUNDAMENTAL AND DESIGN MODEL OF ACTIVE QUARTER CAR TEST RIG :

A quarter car test rig is developed to study the dynamic behavior of sprung mass under random road excitation using experimental work. The design and manufacturing of quarter car test rig is easy and less costly compared to half car or full car model. This system contains sprung mass, unsprung mass, helical springs, rods, passive damper and electromagnetic damper as main components. This test rig can work as passive suspension when the power supply to EM damper is zero and it can work in active mode when the power supply to EM damper is not zero. In present case, only vertical movement of the attached masses is considered by neglecting rolling and pitching motion of vehicle.

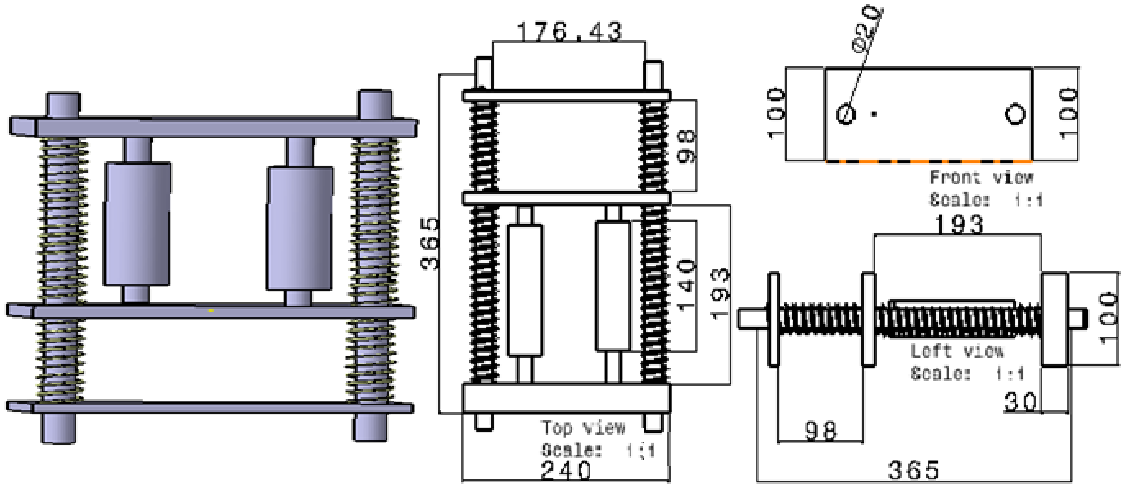

Fig. 1 Design of Test rig assembly 2-D view and Test rig assembly dimension in draft view.

In this Active electromagnetic Quarter car model we use to design the model in Catia V5 R20 software. In this design represents Test rig assembly 2-D view and Test rig assembly dimension in draft view. Design contains electromagnetic quarter car model contains different types of components which are electromagnetic damper, hydraulic damper, permanent magnet of different dimension which are mentioned in table 1. The specification of electromagnetic damper is represented is table 2 also contain the plate which are upper, middle and lower plate of different dimension represented in table 3 and the rod which are right rod and left rod with dimension is represented in table 4.

Table 1: Dimensions of Electromagnetic Damper

S. No.	Parts Name	Dimensions (mm)
1	Electromagnetic damper outer diameter	45
2	Electromagnetic damper inner diameter	14
3	Hydraulic damper diameter	39
4	Electromagnetic damper rod diameter	13
5	Permanent magnet inner diameter	12
6	Permanent magnet outer diameter	25
7	Permanent magnet thickness	7

Table 2: Specifications of electromagnetic damper prototype

Item/ Symbol	Value/Unit		Item/ Symbol	Value/Unit
Mover			Stator	
Number of poles	10		Stator height	86 mm
Number of magnets	10		Stator weight	285 gm
Magnets thickness	7 mm		Stator material	PVC
Magnet weight	15 gm		Stator inside diameter	27 mm
Magnets outside diameter	25 mm		Conductor	
Rod material	Nylon		Conductor material	Copper
Rod diameter	13 mm		Diameter of conductor	45 mm
Maximum stroke	36 mm		Number of turns	300
Mover weight	165 gm		Conductor weight	246 mm
Magnet material	Hard Ferrite		Density	----

Table 3: Dimensions of Plates

S.No.	Name	Length (mm)	Width (mm)	Thickness(mm)
1	Upper Plate (P1)	240	100	8
2	Middle Plate (P2)	250	100	5
3	Lower Plate (P3)	250	100	4

Table 4: Dimensions of Rods

S. No.	Rods No.	Diameter (mm)	Length (mm)
1	Right Rod (R1)	20	365
2	Left Rod (R2)	20	365

IV. TESTING SETUP OF AEQCM USING VERTICAL SHAKE TABLE:

To investigate the effectiveness of Electromagnetic suspension system in reducing sprung mass acceleration, experimental work is performed using quarter car models having two degrees of freedom. A vertical shake table is used as experimental test bed which is controlled by control unit. A motor is attached to provide vertical movement to the fixture on which test rig is assembled. One accelerometer is attached to the sprung mass to measure the acceleration response of sprung mass under various excitation frequencies.

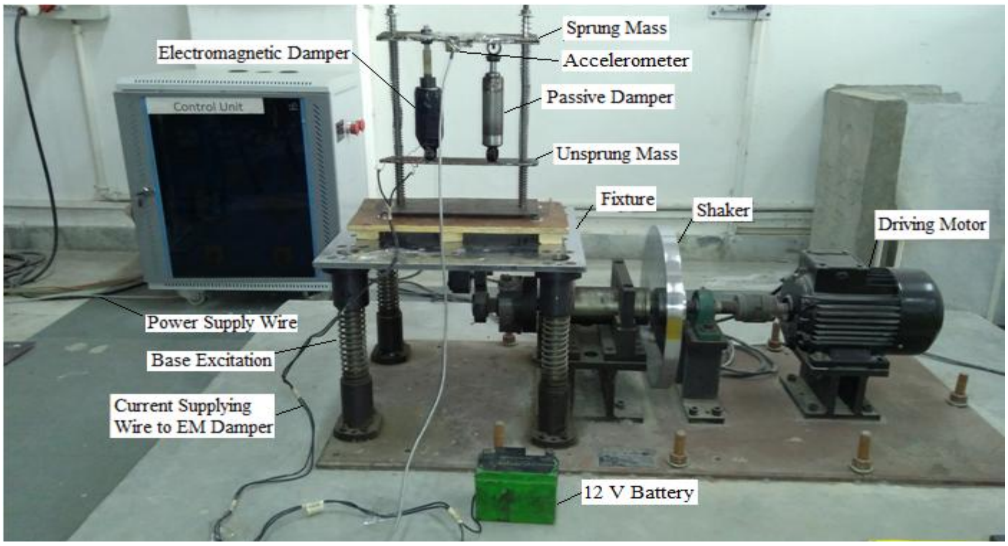

Fig.2 Testing setup of Active Electromagnetic Quarter Car Model using vertical Shake Table

The control unit used for supplying excitation frequency to base structure. It can supply varied excitation frequency resulting into generation of various magnitudes of vibrations in vertical direction. The control unit contains on-off signal for running the base excitation unit. The data from test rig was taken using assembled accelerometer using FASMA Soft software. The function of various assembled parts in quarter car test rig is shown in Table.

Table 5 Mechanical Parts Functions

S.No.	Name of Parts	Material	Quantity	Function
1	Passive Damper	-----	1	1. It is used for controlling vibration efficiently. 2. It will extend and release the energy it absorbs from the road profile.
2	EM Damper	-----	1	1. It is used for control the vibration. 2. Used for giving quick reaction according to the vibration.
3	Plates	Iron	3	It acts as sprung and unsprung masses.
4	Rods	Steel	10	1. To support the structure. 2. Helps in the movement of the plate up and down.
5	Helical Springs	Steel	4	1. It is used to store energy and subsequently release it. 2. Used for absorbs shocks and maintain a force between contacting surface.
6	D. C. Battery (12V)	-----	1	It is responsible for power supply.

V. ANALYSIS ON AEQCM USING VERTICAL SHAKE TABLE AND TEST RESULT :

Analysis on Active electromagnetic quarter car model using vertical shake table is done in FASMA software. In this we use to analysis the sprung mass acceleration response and displacement response in time domain and power spectral density for active and passive one.

Time Domain

Experimental results of active and passive quarter car test rigs are shown in Fig.3 for sprung mass acceleration response while the displacement response for same is presented in Fig.4. The mathematical results for the same are shown in Table 6. It can be seen from Figs. and tabular values that active suspension with electromagnetic damper shows much improved results of sprung mass response compared to passive one.

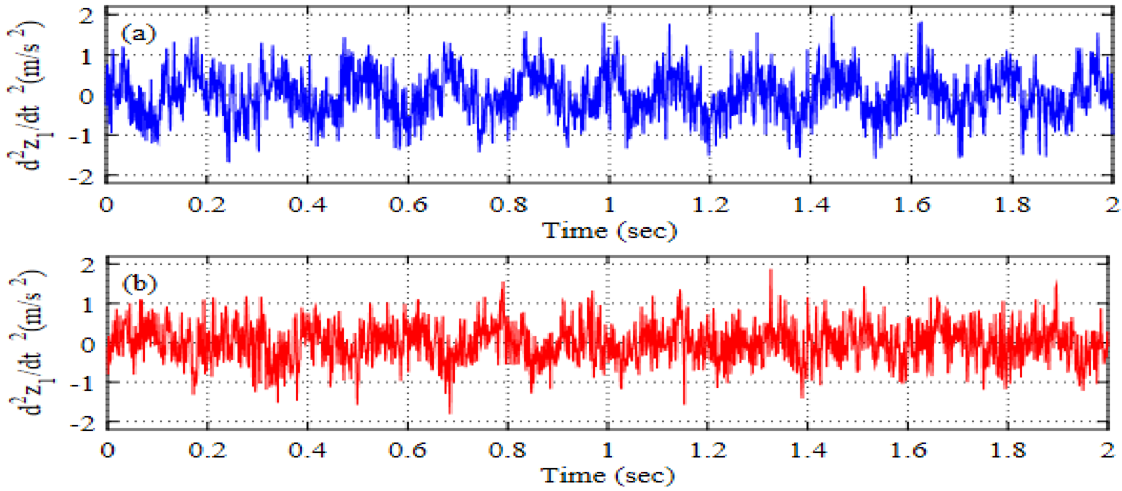

Fig. 3 Acceleration response of sprung mass (a) Passive suspension (b) Active suspension

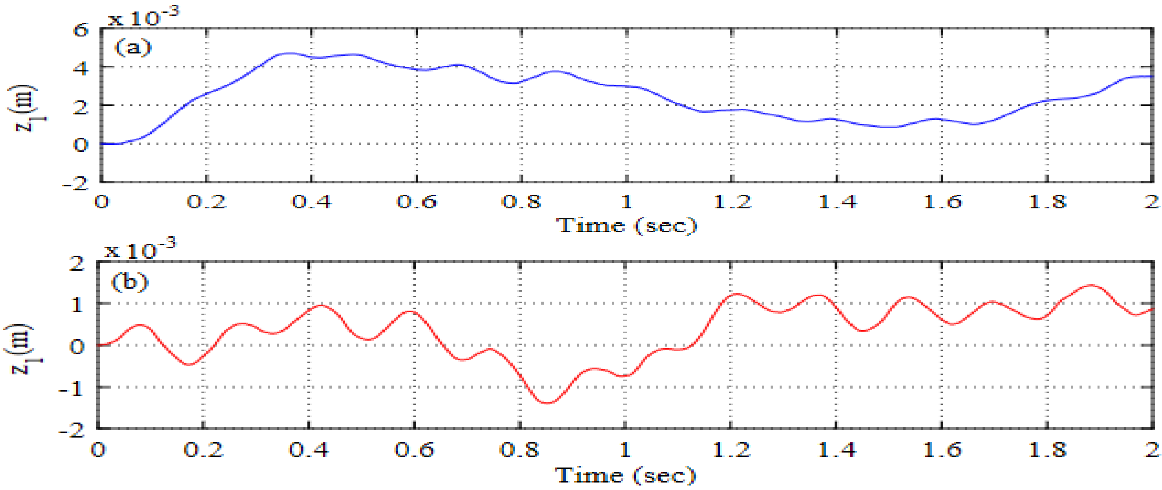

Fig. 4 Displacement response of sprung mass (a) Passive suspension (b) Active suspension

Table 6 Sprung mass response comparison using passive and active suspension

Suspension Type	Max Accel. (m/s^2)	RMS Accel. (m/s^2)	Max Disp. (m)	RMS Disp. (m)
Passive	1.9750	0.5760	0.0047	0.0028
Active	1.8740	0.4887	0.0014	7.2893e-04

Power Spectral Density Analysis

The power spectral density represnts the power contained in the signal in frequency domain. The power spectral dentity response of sprung mass behaviour is calculated from time domain data of sprung mass acceleration and displacement results. The power spectral density response is shown in Fig.5 while the calculated values for the same is shown in Table 7. It can be observed that active suspension supresses the power spectral density acceleration and displacement response in much better way compared to passive one showing its superior performance in frequency domain.

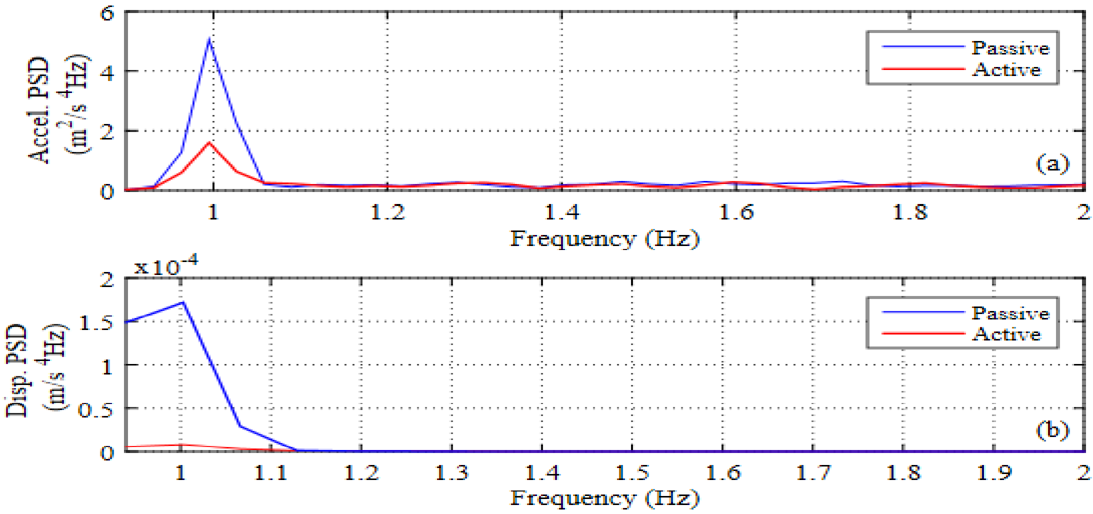

Fig. 5 PSD response (a) Sprung mass acceleration (b) Sprung mass displacement

Table 7 PSD sprung mass response comparison using passive and active suspension

Suspension Type	Max Accel. PSD (m/s^2)	Max Disp. PSD (m)
Passive	5.0520	1.7216e-04
Active	1.6004	8.3124e-06

VI. CONCLUSION:

In present work, we have developed an electromagnetic suspension system with two degrees of freedom. The developed suspension system was tested on vertical shake table under random road excitation for passive mode and active model. The graphical and mathematical results show that the vibration control using electromagnetic damper is high for sprung mass response compared to passive one under random road excitation. Increase the effectiveness of Electromagnetic suspension system in reducing sprung mass acceleration, Using Quarter car model with two degree of freedom with the help of vertical stake table (used as bed). In analysis of time domain the active suspension type have less maximum acceleration as difference of 0.1010 m/s^2, RMS acceleration of difference 0.0873 m/s^2, Maximum displacement difference is 0.0033 m and RMS displacement difference is of 0.0020711 m. While in power spectral analysis Active suspension type have less maximum acceleration PSD as difference of 3.4516 m/s^2 and Maximum displacement PSD is 1.638e-04 m. As it also leads to high ride comfort and safety of travelling passengers in running vehicles.

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