IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
ISSN: 2278-1684, PP: 01-06
www.iosrjournals.org

Analysis of Semi active Suspension System with Bingham Model Subjected to Random Road Excitation Using MATLAB/Simulink

Mr. Amit A.Hingane[1], Prof. S. H. Sawant[2], Prof.S.P.Chavan[3],Prof. A.P.Shah[4]
[1]*(PG Student,Mechanical Engineering Department, Dr. J.J. Magdum College of Engg. Jaysingpur, India)*
[2]*(Asso.Professor, Mechanical Engineering Department, Dr. J.J. Magdum College of Engg. Jaysingpur, India)*
[3]*(Asst.Professor,Mechanical Engineering Department, Dr. J.J. Magdum College of Engg. Jaysingpur, India)*
[4]*(Asso.Professor, Mechanical Engineering Department, Dr. J.J. Magdum College of Engg. Jaysingpur, India)*

ABSTRACT: *In this paper, a brief introduction to vehicle primary suspension system is presented along with analysis of a semiactive suspension system with Bingham model for MR damper.Isolation from the forces transmitted by external excitation is the fundamental task of any suspension system. The heart of a semiactive suspension system is the controllable damper. In this paper, the ride and handling performance of a specific vehicle with passive suspension system is compared to semiactive suspension system. The body suspension wheel system is modeled as a two degree of freedom quarter car model. Simulation is carried out using MATLAB/Simulink. The developed design allows the suspension system to behave differently in different operating conditions, without compromising on road-holding ability. Controller has been developed for semi active suspension. The result shows improvement over passive suspension method.*

KEYWORDS:*Bingham model,MR damper,Passive, Ride comfort, Road handling, Semiactive*

I. INTRODUCTION

Suspension is the term given to the system of springs, shock absorbers and linkages that connects a vehicle to its wheels and allows relative motion between the two. Isolation from the forces transmitted by external excitation is the fundamental task of any suspension system.

The automotive suspension on a vehicle typically has the following basic tasks:

1. To isolate a car body from road disturbances.
2. To keep good road holding, and
3. To support the vehicle static weight[1].

Primary suspension is the term used to designate those suspension components connecting the axle and wheel assemblies of a vehicle to the frame of the vehicle. This is in contrast to the suspension components connecting the frame and body of the vehicle, or those components located directly at the vehicle's seat, commonly called the secondary suspension. There are two basic types of elements in conventional suspension systems. These elements are springs and dampers. The role of the spring in a vehicle's suspension system is to support the static weight of the vehicle. The role of the damper is to dissipate vibrational energy and control the input from the road that is transmitted to the vehicle. The basic function and form of a suspension is the same regardless of the type of vehicle or suspension. Vehicle Primary Suspensionsis divided into passive, active and semi-active systems.

In Semiactive suspension system, the conventional spring element is retained, but the damper is replaced with a controllable damper.Magnetorheological (MR) damper is a kind of semiactive device. A wide range of Magneto-rheological (MR) fluid based dampers are currently being explored for their potential implementation in various systems, such as vibration control devices and suspension system.The main function of vehicle suspension systems are to minimize the vertical acceleration transmitted to passengers to provide ride comfort and to maintain the tire road contact to provide holding characteristics, and to keep suspension travel small. In this paper, performance of semiactive suspension model (2DOF) based on the **Bingham**model subjected torandom road excitation is compared with passive suspension system. This semiactive vehicle suspension shows improvement over passive vehicle suspension.

II. MODELLING OF SYSTEM

2.1 Quarter Car Model with Passive Suspension System

To simulate the performance of vehicle subjected to random road surface the passive quarter car model asa shown in Fig.1 is taken for study.

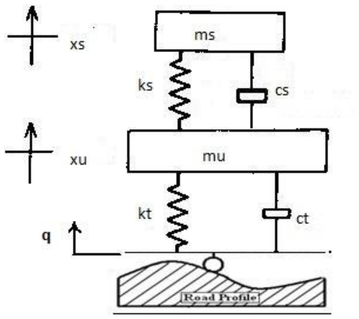

Fig.1:TDOF Passive Quarter Car Model.

The equations of motion for this linear model is

$$m_S\ddot{x}_S = -\left[\left[k_S(x_S - x_u) + c_S(\dot{x}_S - \dot{x}_u)\right]\right] \tag{1}$$

$$m_u\ddot{x}_u = -\left\{-\left[k_s(x_s - x_u) + fa\ \right] + \left[k_s(x_u - q) + c_t(\dot{x}_u - \dot{q})\ \right]\right\} \tag{2}$$

2.2 Quarter Car Model with Semiactive Suspension System

The proposed system is 2DOF quarter car vehiclewith a MR damper. The dynamics of the damper are modeledwith the Bingham model i.e. first model used to describe the behavior of MR damper [2]. The Bingham model contains thenonlinear behavior of a viscous fluid going through an orifice.

Bingham model

The idealization of the visco-plastic MR damper model presented in [2] uses similarities in the rheological behavior of ER and MR fluids and the similar techniques in the modelling of ER dampers.

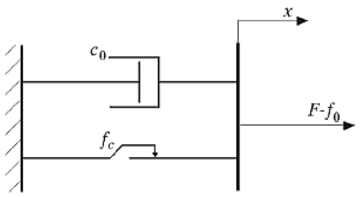

Fig. 2: Rheological Structure of a MR Damper for the Bingham Model.

In the rheological structure in Fig.2, on which the Bingham model is based, there is a Coulomb friction element *fc* placed parallel to the dashpot c_0. According to Bingham's MR damper model, for non-zero piston velocities $\dot{x}$, the damping force *fa* can be expressed as

$$f_a = f_c \operatorname{sgn} \dot{x} + c_o \dot{x} + f_o \tag{3}$$

Where *fc* is the frictional force, c_0 is the viscous damping parameter; f_0 is the force due to the presence of the accumulator. This last simplification in the model results from the assumption that the elasticity replacing the accumulator activity has a low stiffness and linear characteristics.

Fig.3 shows the semi active quarter carmodel with MR damper and controller.In Fig. 3, m_s represents one quarter of sprung mass; m_u represents unsprung mass (wheel, damper and spring etc.); $x_s$and x_t are the masses displacement and q represents the road disturbances, $k_t$is the tire stiffness; k_s is the spring betweenwheel and chassis.

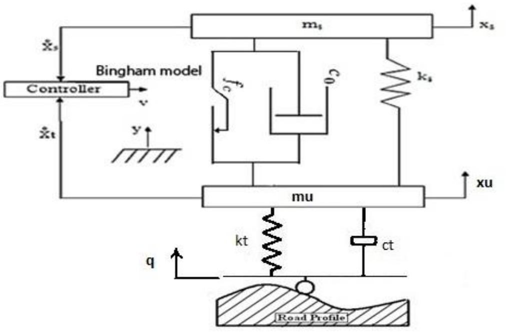

Fig.3: Quarter Car Vehicle Model with MR Damper [3].

For the controller, ($\dot{x}_S$) and ($\dot{x}_t$)represents absolute velocityof sprung mass and unsprung mass respectively. Controller generates the voltage v in the MR damper and it modifies the force *fa*of semi active suspension.

The motion equations of the car body and wheel of this model areas follows,

$$m_S \ddot{x}_S = -[k_S(x_S - x_u) + fa] \tag{4}$$

$$m_u \ddot{x}_u = -\{-[k_S(x_S - x_u) + fa] + [k_t(x_u - q) + c_t(\dot{x}_u - \dot{q})]\} \tag{5}$$

The values for parameters for Bingham model are adopted from the [3].Table 1 shows the values of parameters for different currents.

Current	Value of the parameter		
I [A]	f_c[N]	c_0[Ns/m]	f_0[N]
0.0	43.95	735.90	195.51
0.4	262.13	3948.70	186.28

Table 1: Parameters of Bingham Model.

III. ANALYSIS

The MATLAB/Simulink models for passive and semiactive suspension system are prepared and the sprung mass acceleration forrandom road excitation is obtained for suspension parameters given in Table 2.

3.1 MATLAB/Simulink Models

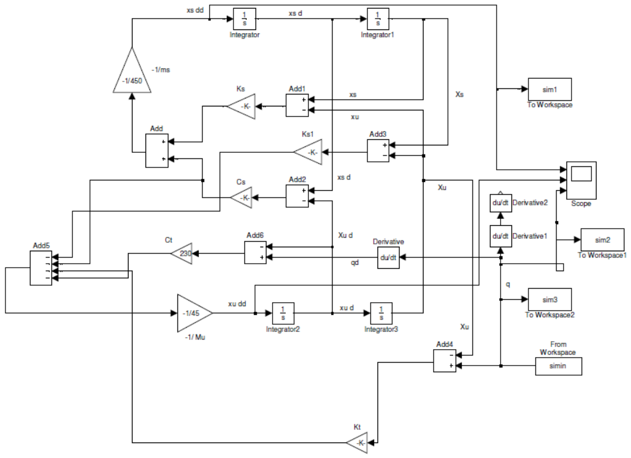

Fig.4: MATLAB/Simulink Model of Passive Suspension System.

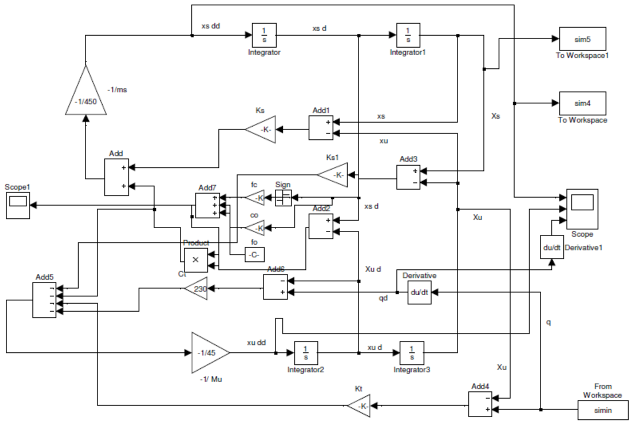

Fig. 5: MATLAB/Simulink Model of Semiactive Suspension System based on Bingham Model.

System Parameter	**Value**
Sprung Mass (m_s)	450 Kg
Unsprung Mass (m_u)	45 Kg
Suspension Stiffness (k_s)	22000 N/m
Passive Suspension Damping Coefficient (c_s)	2300 N-sec/m
Tire Stiffness (k_t)	176000 N/m
Tire Damping Coefficient (c_t)	230 N-sec/m

Table2: Suspension Parameters of Quarter Car Model [4].

3.2 Random Road Excitation

Road data used as input is adopted from [5] which were measured by mounting accelerometerat the axle level of the vehicle. Fig.6 shows the simulation of random road excitation.

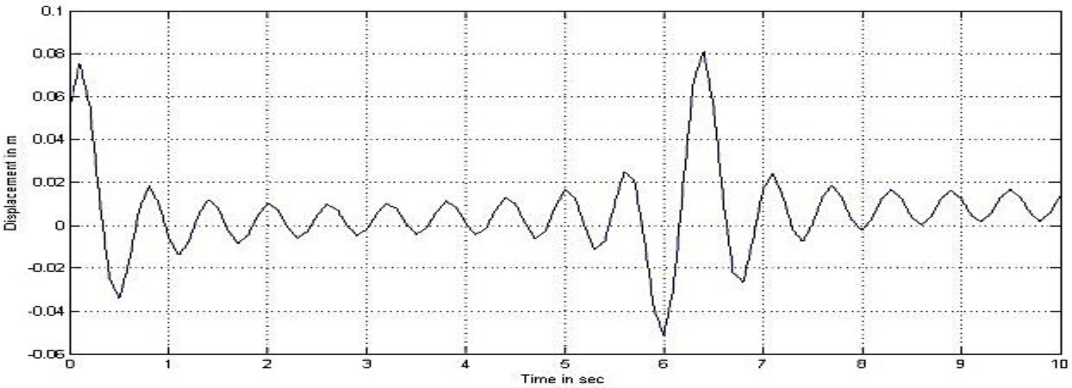

Fig.6: Random Road input

3.3 Simulation Results

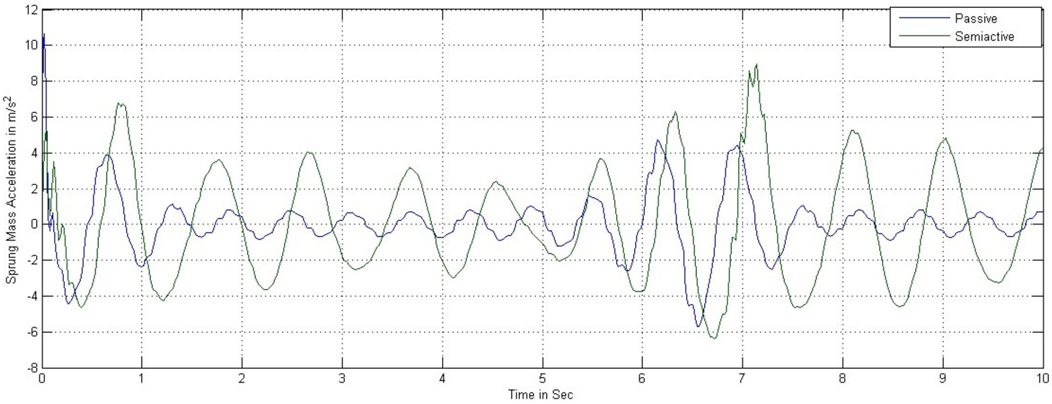

Fig.7: Sprung Mass Acceleration of Passive and Semiactive Suspension System

Table 3 shows the difference in maximum value of acceleration response for passive and semiactive suspension system.

Suspension System	**Maximum Sprung Mass Acceleration (m/s^2)**
Passive Suspension System	11.01
SemiactiveSuspension System	8.75

Table 3: Maximum Value of Sprung Mass Acceleration Response for Passive and Semiactive Suspension System.

IV. DISCUSSION OF RESULTS

The percentage variation in maximum sprung mass acceleration of semiactive suspension system based on Bingham model is 20.52% from passive suspension system. So it shows that semiactive suspension system gives lower value of maximum sprung mass acceleration for given random road excitation.

V. CONCLUSION

The passive suspension system and semiactive suspension system with MR damper (Bingham Model) is simulated. The simulation results shows that semiacive suspension system with Bingham model gives lower value of maximum sprung mass acceleration for given random road excitation. Hence suspension model with semiactive suspension provides good passenger comfort and vehicle stability than passive suspension system.

REFERENCES

[1] Yi, K. and Hedrick, K., "Dynamic Tire Force Control by Semiactive Suspensions",*Journal of Dynamic Systems, Measurements, and Control*, Vol. 115, No. 3, pp. 465-474, September 1993.

[2] Sapiński B.,Filus J.2003, “Analysis of parametric models of MR linear damper”, *Journal of Theoretical and Applied Mechanics,* 41, 215-240.

[3] Luis C. Felix-Herran, Jose de Jesus Rodrigues-Ortiz, RogelioSoto, Ricardo Ramirez-Mendoza, “Modeling and control for asemiactive suspension with a Magnetorheological Damperincluding the actuator dynamics”, Electronics, Robotics andAutomotive Mechanics Conference 2008, pp 338-343.

[4] H.F.Lam,W H Liao and C Y Lai, “Automobile Suspension Systems with MR fluid Dampers”, Smart Materials and Structures, 11 (2002)

[5] Prof. Sanjay H. Sawant, Dr. J. A. Tamboli, “*Comparative study of passive and semi-active suspension system subjected to random excitation”,* International Journal on Mechanical and Automobile Engineering, *ISSN 0974-231, (2011).*