JJMIE

Volume 5, Number 3, June 2011
ISSN 1995-6665
Pages 261 - 265

Jordan Journal of Mechanical and Industrial Engineering

Performance Analysis and Behaviour Characteristics of CVD (Semi Active) in Quarter Car Model

K. Kamalakannan*[,a], A. ElayaPerumal[b], S. Mangalaramanan[c], K. Arunachalam[d]

[a]Faculty, Automobile Engineering, Hindustan University, India..
[b]Faculty Mechanical Engineering , Anna University, India..
[c]Section Head, Advanced Engineering, Ashok Leyland, India..
[d]Faculty Automobile Engineering –Anna University, Chennai , India..

Abstract

Semi-active suspension uses a special adaptive damper whose damping properties vary with road conditions under the influence of an electromagnet. The adaptive damper is used along with a sophisticated electronic circuit which constantly monitors the changing road conditions and adapts accordingly. The aim of this paper is to simulate and analyze a simple and low-cost semi active suspension system using 'MATLAB and SIMULINK' platform and establish its superiority, and also involves the development and simulation of a virtual quarter car model. Thereafter the graphical results obtained are analyzed. The model is developed using equations of motion involving stiffness, damping ratio and displacement. These equations are translated into a simple data flow circuit in the simulation software to obtain definite results in the form of graphical output .This paper aims at the development of a simpler and cheaper semi active suspension system which will allow its fitment in comparatively affordable cars.

Keywords: CVD (continuous Variable Damper); Semi Active; MATLAB; Suspension; SIMULINK

1. Introduction

In the interest of improving the overall performance of automotive vehicles in recent years, suspensions incorporating active components have been developed and the process moves to further developments and improvements.

SUSPENSION systems are classified in to three groups: Passive, Semi Active and Active suspension systems. Passive suspension system consists of an energy dissipating element, which is the damper, and an energy-storing element, which is the spring. Since these two elements cannot add energy to the system this kind of suspension systems are called passive, Figure 1 shows passive suspension system and Figure 2 shows semi active suspension, both differs in particular aspect (damper stiffness) which former is a fixed one and a secondary consists of a continuous variable. Sensors continuously monitor the operating conditions of the vehicle body, according to the base excitement the signals obtained by the sensors and prescribed voltage applied across the flow (Rheological Fluid)of the fluid in a shock absorber, the damping force can be controlled(Varied).Control strategy, the force in the actuator is modulated to achieve improved ride and handling. It should be noted, that the semi-active suspension system requires external power, of minimum requirement from the battery. It is greater advantage than active suspension for its higher power requirement, and also a considerable penalty in complexity, reliability, cost and weight.

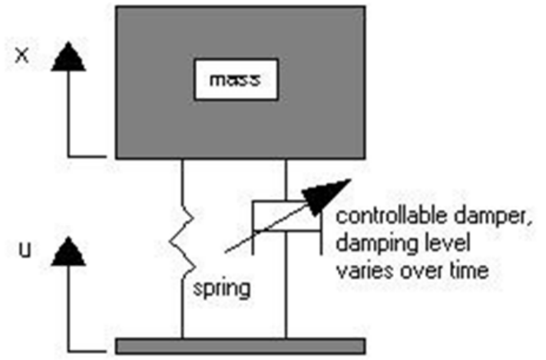

Figure 1: Passive Suspension.

Semi-active systems can only change the viscous damping coefficient of the shock absorber, and do not add energy to the suspension system. Though limited in their intervention (for example, the control force can never have different direction than that of the current speed of the suspension), semi-active suspensions are less expensive to design and consume far less energy.

In recent years, many investigators have predicted that with a semi active suspension it is possible to attain performance gains comparable to those possible with a fully active suspension. Semi active suspension control has been studied widely since Crossby and Karnopp [1] developed skyhook control system. The method by which the damper is controlled is one of the crucial factors that ultimately determines the success or failure of a particular semi active suspension. This study is an investigation into

* Corresponding author. e-mail: kamalakannan.ka@gmail.com

the effectiveness of a number of basic control strategies at controlling vehicle dynamics, particularly vehicle roll by Chalasani , R.M [2,3] .

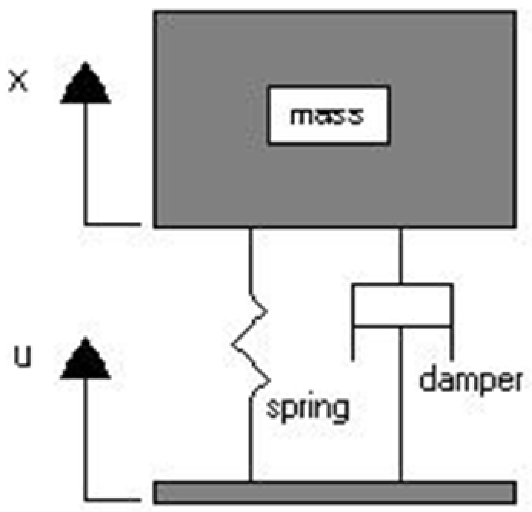

Figure 2: Semi active Suspension.

2. Basic Model of the Quarter Car Model

For the purpose of simulation and analysis of a semi active suspension system a quarter car model was taken into consideration .This is done to simplify the calculations involved in the modeling. The results obtained can then be scaled up and adjusted accordingly for the entire car. A quarter car as the name suggests comprises of the quarter portion of the car .It consists of a wheel, a variable damper and spring set.

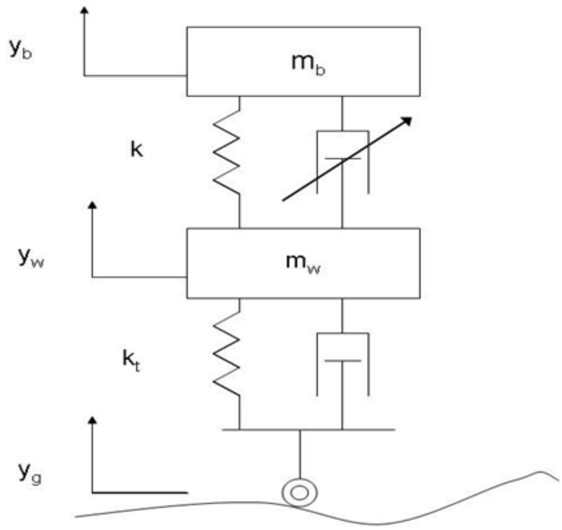

Figure 3: A Quarter car model of semi active suspension.

As shown in the Figure 3 the mass acting on the suspension system can be classified into sprung (m_b) and unsprung mass (m_W). The sprung mass comprises of the mass of the body which is damped by the suspension system (in case of quarter car model the value is $1/4^{th}$ the total sprung mass value). The unsprung mass comprises the mass of the wheels, brakes, suspension components etc.

3. Simple Equation of Motion For Suspension System

$$\mathbf{K}\,(\mathbf{y_W}-\mathbf{y_B})+\mathbf{b}\,(\dot{\mathbf{y}}_\mathbf{W}-\dot{\mathbf{y}}_\mathbf{b})=\mathbf{m_b}\ddot{\mathbf{y}}_\mathbf{b}$$

$$K_t\left(y_g-y_W\right)+b_t\left(\dot{y}_g-\dot{y}_W\right)+$$
$$K\,(y_b-y_W)+\,b\,(\dot{y}_b-\dot{y}_W)=m_W\ddot{y}_W$$

These equations can be further simplified and written as
$$\mathbf{f_k}(\boldsymbol{\Delta})+\,\mathbf{f_b}\,=\mathbf{m_b}\ddot{\mathbf{y}}_\mathbf{b}$$

Where
$$\boldsymbol{\Delta}=(\mathbf{y_W}-\mathbf{y_b})$$

For passive suspension
$$\mathbf{f_b}\,=\mathbf{f}(\dot{\boldsymbol{\Delta}})$$

Where
$$\dot{\Delta}=(\dot{y}_W-\dot{y}_b)$$

For semi active suspension
$$\mathbf{f_b}\,=\mathbf{f}(\dot{\boldsymbol{\Delta}},\mathbf{i})$$

Where
$$\dot{\Delta}=(\dot{y}_W-\dot{y}_b)$$
i = control current.

The above mentioned equation clearly depicts the difference between the variables that affect the shock damping force (fb) in both the cases .In case of a semi active suspension it also depends on the control current along with the velocity function .This clearly suggests that the damping force can be controlled by controlling the current input to the electromagnet around the damper.

4. Virtual Designing and Modeling

For the purpose of performance analysis the semi active suspension system's quarter model was developed. The basic model can be divided into the three sub parts for simplification of calculations, namely

- SEAT AND DRIVER
- SPRUNG MASS
- UNSPRUNG MASS

The model is based on equation of motion involving parameters like

- STIFFNESS
- DAMPING RATIO
- DISPLACEMENT
- MASS
- ACCELERATION
- VELOCITY

5. Equation of Motions

5.1. Equations for seat and driver:

$$M_{SE}\,\ddot{Z}_{SE} + K_{SE}\,(Z_{SE} - Z_S) + b_{SE}\,(\dot{Z}_{SE} - \dot{Z}_S) = 0$$

Or

$$\ddot{Z}_{SE} = \{-K_{SE}\,(Z_{SE} - Z_S) - b_{SE}\,(\dot{Z}_{SE} - \dot{Z}_S)$$

5.2. Equations for sprung mass:

$$M_S\,\ddot{Z}_S - K_{SE}\,(Z_{SE} - Z_S) - b_{SE}\,(\dot{Z}_{SE} - \dot{Z}_S) + K_S(Z_S - Z_U) + b_S(\dot{Z}_S - \dot{Z}_U) = 0$$

Or

$$\ddot{Z}_S = \{K_{SE}\,(Z_{SE} - Z_S) + b_{SE}\,(\dot{Z}_{SE} - \dot{Z}_S) - K_S(Z_S - Z_U) - b_S(\dot{Z}_S - \dot{Z}_U)\}/M_S$$

5.3. Equations for unsprung mass

$$M_U\,\ddot{Z}_U - K_S\,(Z_S - Z_U) - b_S\,(\dot{Z}_S - \dot{Z}_U) + K_t(Z_U - Z_r) = 0$$

Or

$$\ddot{Z}_U = \{K_S\,(Z_S - Z_U) + b_S\,(\dot{Z}_S - \dot{Z}_U) - K_t(Z_U - Z_r)\}/\,M_U$$

These equations are combined in the simulation software in such a way that they form a feedback loop or in other terms any alterations in any of the values results in a change in the behavior of the system as a whole. These results are obtained in the form of graphs for each system separately depicting the effect of road input in the form of change in velocity and displacement from the mean position. These graphs are also dependent on the values of different constants as mentioned above. This property of the experimental model allowed the variation in damping coefficient (bs) of the suspension system, which differentiates semi active suspension system from passive suspension system, for which the damping coefficient is constant under all conditions.

6. Values of Parameters Used for Modeling

The values considered below are used only for the purpose of modeling and are reference values obtained from various related literature. A provision has been made within the model itself to make changes to these values to obtain corresponding graphs.

- M_{se} =90kg
- b_{se} =3000Ns/m
- K_{se} =8000N/m
- M_s =250kg
- b_s =2000Ns/m
- K_s =28000N/m
- M_u =40kg
- K_u = 12500N/m

7. Steps Involved in Modeling

After the initial calculations were done and parameters were established, the system was modeled using MATLAB and SIMULINK platform .The modeling was done in logical steps of the above mentioned equations ,were converted into a logical data flow circuit loop using predetermined logic boxes and connectors available in these platforms .Complete semi active suspension circuit consists of sub circuits like sprung mass circuit, seat and driver circuit and unsprung mass circuit.

As the damping coefficient of a semi active suspension varies with respect to the road conditions, a special sub circuit was developed for varying the damping coefficient with the change in road input.

8. A Complete Circuit of a Semi Active Suspension System

The figure below shows a complete circuit of a semi active suspension system:

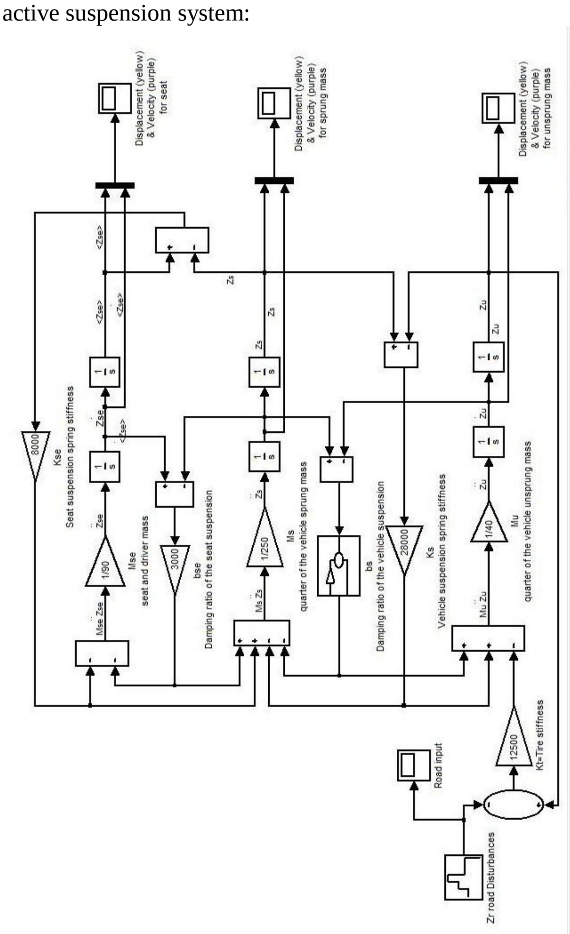

Figure 4: Complete Circuit of the Semi Active Suspension.

9. Simulation Parameters Considered in Modeling

Table .1: Simulation Parameters Varying with Zr.

Sl.No	Z r	Time Delay	b s
1	0.05	0	1500
2	0 . 1	8 0	3000
3	0.15	1 5 0	4500
4	0.07	2 3 0	2100
5	0.00	4 0 0	1200

The table given above shows the various parameters which were used for modeling for example the road input and its corresponding time delay and damping coefficient.

10. Simulation Results

The results are obtained in the form of graphs which consist of two variables with respect to time .These variables are velocity and displacement from the mean position the graph is in the form of an oscillating wave. These waves are almost similar in shape for the three parameters i.e. seat, sprung mass and unsprung mass but differ in amplitude and linearity. On the vehicle operation, payload varies from time to time. It is observed that a small mass makes the difference in peak harmonics. In practice, the excitation on the vehicle suspension depends on the road roughness, mass of the vehicle, inertia of the vehicle and vehicle speed.

11. Conclusion

The aim of this paper was to establish the superiority of a low cost semi active suspension model. From the results obtained it was concluded that the semi active suspension system offered superior damping properties over a wider load range. It also eliminated the need to compromise between ride comfort and handling which is a major drawback with the present passive suspension system. The low cost model developed will have a wider application in more economical vehicles making this technology available to everyone around the globe, which right now is restricted to a few expensive vehicles.

References

[1] D.C. Karnopp, M.J. Crosby, and R.A. Harwood, “Vibration Control Using Semi- Active Force Generators” ASME Journal of Engineering for Industry, Vol. 96, No. 2, 1975, 619-626.

[2] R.M. Chalasani, “Ride Performance Potential of Active Suspension Systems-Part I Simplified Analysis Based on a Quarter-Car Model,” Proceedings of 1986 ASME Winter Annual Meeting, Los Angeles, CA,1986.

[3] R.M. Chalasani, “Ride Performance Potential of Active Suspension Systens-Part II: Comprehensive Analysis Based on a Full-Car Model,” ASME Symposium on Simulation and Control of Ground Vehicles and Transportation Systems, AMD-Vol. 80, DSC-Vol. 2, 1986, 187-204.

[4] P. Barak, “Design and Evaluation of an Adjustable Automobile Suspension,” Auto technologies Conference and Exposition, Vol. 98, Section 6, 1989.

[5] Lord Corporation Web Page; www. Rheonetic.com.

Appendix

Graphs for semi active suspension model

Seat and driver circuit

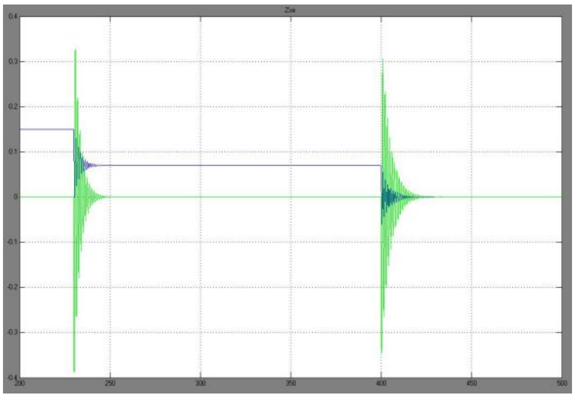

Figure 5: Seat and Driver Circuit Simulation.

The green line shows the velocity whereas the blue line shows the displacement of the seat and driver from the mean position and X axis in second (Actual Simulation).

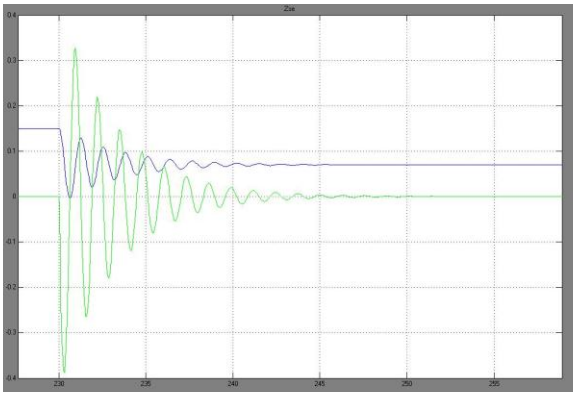

Figure 6: Zoomed view Seat and Driver Circuit Simulation.

Sprung mass circuit

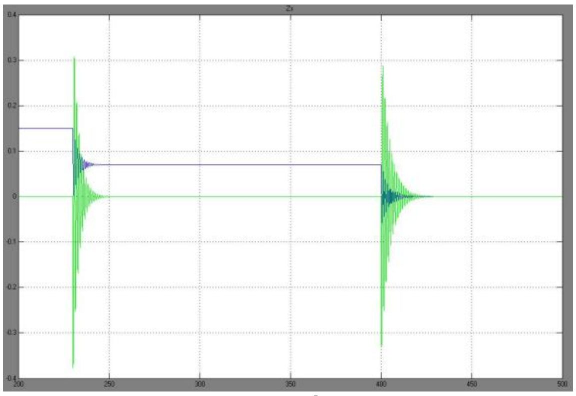

Figure 7: Sprung Mass Circuit Simulation.

The green line shows the velocity whereas the blue line shows the displacement of the sprung mass from the mean position. Although it is similar in shape to the seat and driver graph but the peak values clearly differ from each other in the two cases. This is because of the different values of the parameters involved. The most noticeable difference is the peak value of velocity.

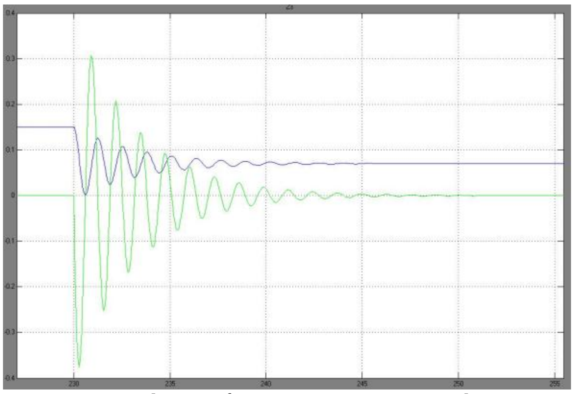
Figure 8: Zoomed View of Sprung Mass Circuit Simulation.

Unsprung circuit

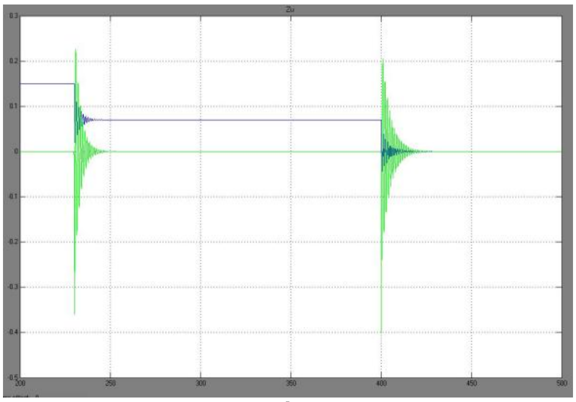
Figure 9: Unsprung Circuit Simulation.

The peak value of velocity is the least for this system when compared to the other two this shows that the unsprung mass gains the least velocity in any suspension system.

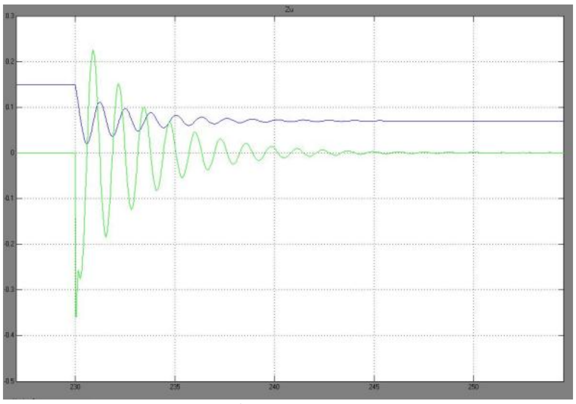
Figure 10: Zoomed View of Unsprung Circuit Simulation.