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Analysis of Active and Passive Suspension System of Half Car model using Matlab™ - Simulink®

Ajay Dusane, Akshay Jadhav, Abhijit Gaikwad, Pratik Ingle & Dr. K. R. Borole
jadhav.akshay@rocketmail.com

Abstract

The concept of using an active suspension system for vehicles is to provide the best performance of car controlling. A fully active suspension system aim is to control the suspension over the range of excitation signals. It is considered to be the way of increasing load carrying, handling and ride quality. The purpose of this research paper is to construct a half car model with a linear control design which is the Proportional Integral Derivatives (PID).This paper compares the passive suspension response with active suspension response. The response of the system is simulated by MATLAB™ Simulink®. To evaluate the performance of this system, PID is chosen as a control strategy and will be compared with the uncontrolled, by performing a MATLAB™ Simulink® simulation.

Keywords: Half car, Active suspension, Passive suspension, PID Controller.

Introductions

The passive suspension have inherent limitations as a consequence of the choice of elastic and damping characteristics to ensure an acceptable behavior for the entire range of road conditions. The need to obtain a compromise between the conflicting requirements, ride handling and passenger comfort, among different vibrations modes of the vehicle gives rise to the research of the active suspension systems. The response is determined by the controller by taking input of vehicle dynamics. The response of passive suspension system is not dynamic, i.e. it does not take into account the varying road conditions. Active suspension however overcomes this problem as its response changes according to varying road conditions. Hence we get optimal performance of the vehicle.

Active suspensions use separate actuators for each wheel, which exert an independent force on the suspension for improving the dynamic behavior. The magnitude of the force is decided using a controller (here PID). When designing an active suspension, two important issues must be considered: the possible failure of the actuator, and the transfer of a large quantity of mechanical energy in a structure that has the potential to destabilize the controlled system. However, the active suspension systems significantly improve car comfort, handling performance and driving safety, realizing an improved performance among different vibration modes of the vehicle.

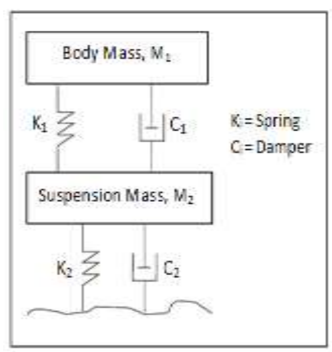

Fig a

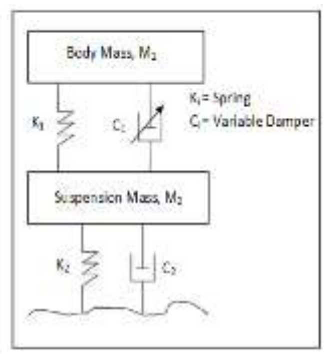

Fig b

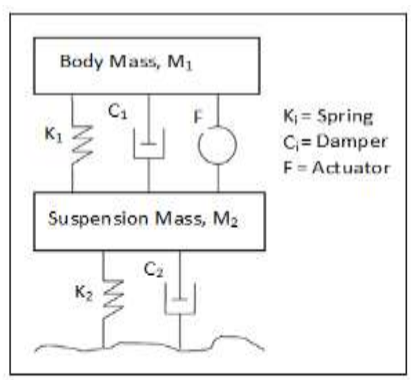

Fig c

Modeling of SUSPENSION SYSTEM

We have used half car model as a representation of the vehicle for the analysis. Fig d shows the half car system. m_1 and m_2 are the

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unsprung masses at front and rear respectively. m3 is the sprung mass of the system. q_1 and q_2 are the excitation forces at front and rear wheel respectively. k and c are spring constant and damping constant respectively. l_1 is the length of C.G. from front suspension arrangement. l_2 is the length of C.G. from rear suspension arrangement.

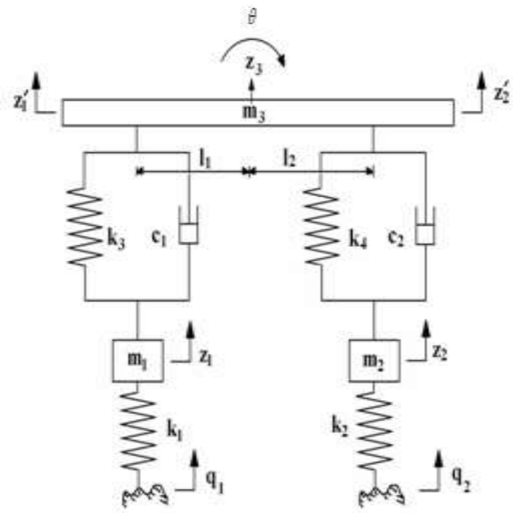

Fig d

The equations of motion can be obtained by applying Newton's second law of motion to sprung mass and unsprung masses.

$$\mathbf{m_1\ddot{z}_1 = k_1(q_1-z_1) + k_3(z_1'-z_1) + c_1(\dot{z}_1'-z_1)}$$
$$\mathbf{m_2\ddot{z}_2 = k_2(q_2-z_2) + k_4(z_2'-z_2) + c_4(\dot{z}_2'-\dot{z}_2)}$$
$$\mathbf{m_3\ddot{z}_3 = k_3(z_1-z_1') + c_1(\dot{z}_1-\dot{z}_1') + k_4(z_2-z_2') + c_2(\dot{z}_2-\dot{z}_2')}$$
$$\mathbf{J\ddot{\theta} = k_3(z_1-z_1')\,l_1 + c_1(\dot{z}_1-\dot{z}_1')\,l_1 + k_4(z_2'-z_2)\,l_2 + c_2(\dot{z}_2'-\dot{z}_2)\,l_2}$$

All these equations have been obtained by analyzing the free body diagrams of all the masses shown in the schematic. The displacements of the car body mass due to one signal alone can be determined by using the geometry of the arrangement. The concept utilized is – Angle * Radius = Arc

Thus the following relations can be obtained

$$\mathbf{z_1 = z_3 + \theta l_1}$$
$$\mathbf{z_2 = z_3 - \theta l_2}$$

Solving these equations is quite difficult hence MATLAB™ Simulink® is used for modeling and simulating the results. Following system parameters are input to the half car model,

m1 = 59 kg
m2 = 59 kg
m3 = 750 kg
k_1 = 190000 N/m
k_2 = 190000 N/m
k_3 = 35000 N/m
k_4 = 38000 N/m
c_1 = 1000 Ns/m
c_2 = 1100 Ns/m
J = 1080 kg.m^2
l_1 = 1.4 m
l_2 = 1.7 m

It is assumed that vehicle is travelling at constant speed of 40 km/hr and speed remains the same while travelling over obstacles.

Assumptions made:

- The vehicle travels along a straight line path without negotiating curve.
- The vehicle runs at a constant velocity of 40kmph.
- The gravity forces are not considered for analysis.
- Friction forces at the contact connections are neglected.

PID Controller

Proportional Integral Derivative controller is used for as a control strategy for active half car suspension model. PID block has three gains kp, ki, kd which determine the response of the controller. Hence it becomes imperative to have optimal values to get better performance. Tuning of PID is required for every excitation signal input to the suspension system. Hence for different bump profiles we have different values of gains. Following table gives PID controller characteristics.

Controller Response	**Rise Time**	**Overshoot**	**Settling Time**	**Steady-state error**
Kp	Decrease	Increase	Small Change	Decrease
Ki	Decrease	Increase	Increase	Eliminate
Kd	Small Change	Decrease	Decrease	Small Change

It can be seen that gains are dependent on each other. Any change in magnitude of one gain will require change in magnitude of other gains. Thus we have to choose the gains very carefully to get optimal performance.

Observations

Different bump profiles are input to the model and response of passive and active suspension systems are compared.

1. Bump profile

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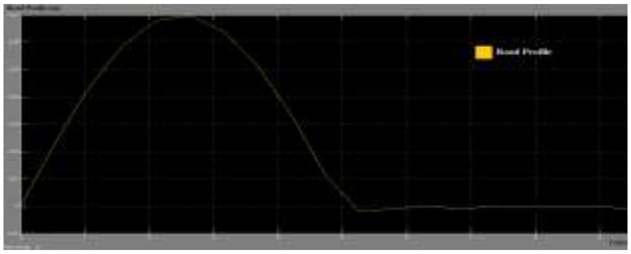
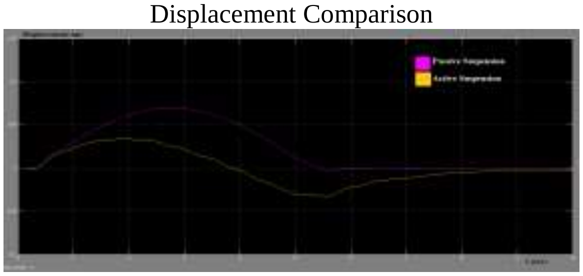
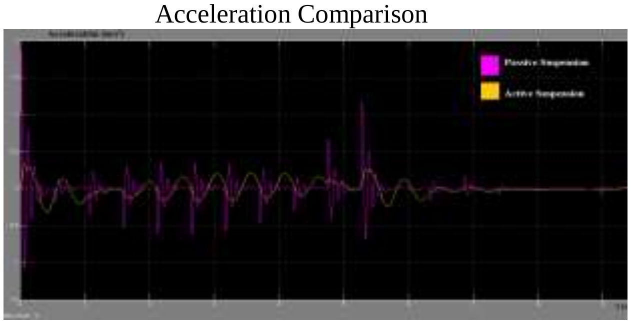


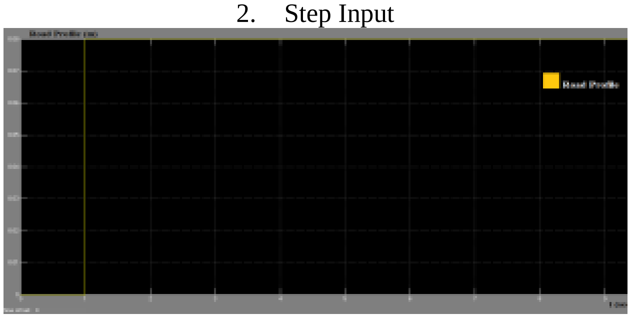
Displacement Comparison



Acceleration Comparison

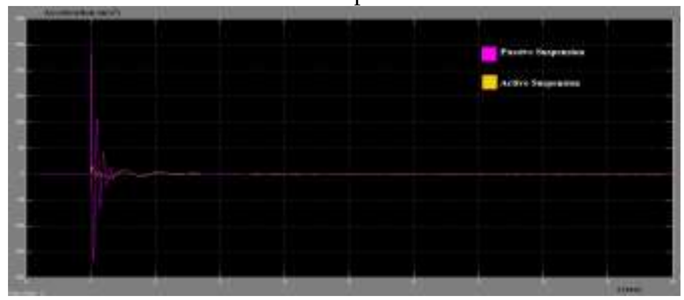


2. Step Input



Displacement Comparison

Acceleration Comparison



Conclusion

From the comparative figures it is clear that active suspension model gives better performance than passive system. Active suspension model is adaptive to the road conditions. It can change its response according to the varying bump profiles. PID controller reduces the suspension travel by providing necessary actuating force. Further vertical acceleration is also reduced which ensures comfort driving conditions. PID controller's response time can be varied, so according to the road conditions we can have different response and choose which is best for passenger and commercial vehicles.

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