



Simulation Analysis of Car Semi-Active Suspension System to Improve Ride Comfort

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ABSTRACT: For investigating the performance of semi-active suspension system a quarter car model with two degree of freedom has been used. Many analytical studies on semi-active suspension have been performed to improve ride comfort. Skyhook control strategies and PID controller now widely used to vehicle suspension system. In this paper overview of various works are done. This paper tries to give an importance about the previous research findings about study of Simulation of 2dof Semi-Active Suspension System to Improve Ride Comfort.

KEY WORDS -active suspension system, quarter car model, MR damper, Fuzzy-PID.

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 which is a fixed one and a secondary consists of a continuous variable damper.

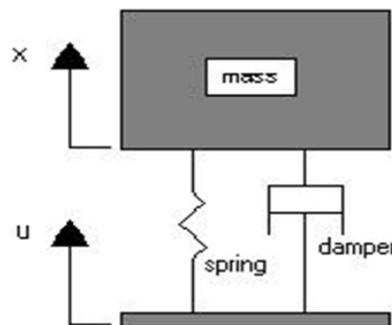


Figure 1: Passive Suspension.

Semi-active systems can only change the Damping coefficient of the shock absorber, and do not add energy to the suspension system. Semi-active suspension is less expensive to design and consume less energy. 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.

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.

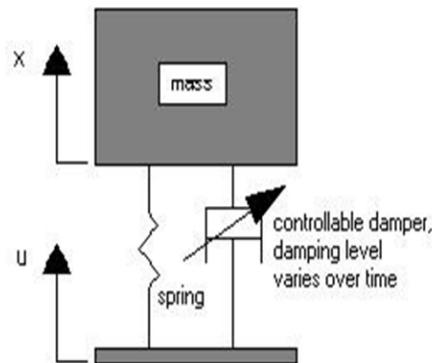


Figure 2: Semi active Suspension.

II. BASIC MODEL OF THE QUARTER CAR

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.

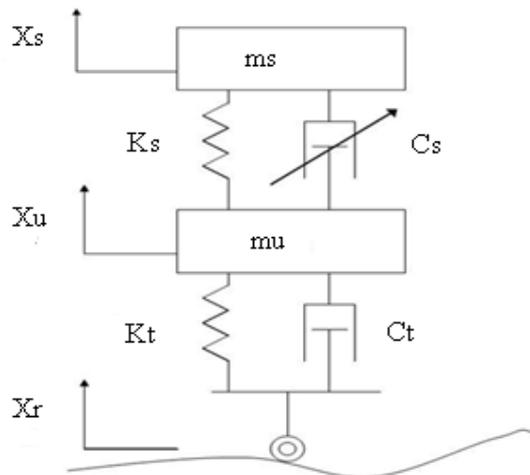


Figure 3: A Quarter car model of semi active suspension.

As shown in the Figure 3 the mass acting on the suspension system can be classified into sprung and unsprung mass. 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 1/4th the total sprung mass value). The unsprung mass comprises the mass of the wheels, brakes, suspension components etc.

III. EQUATION OF MOTION

The equations of vertical direction motion for the quarter car suspension system i.e. sprung mass (quarter car (body mass) and unsprung mass (suspension parts) can be represented by applying Newton's second law of motion with the help of following mathematical equations

A. For sprung-mass motion:

$$m_s \ddot{x}_s - c_s \dot{x}_s - x_u - k_s x_s - x_u = 0$$

B. For unsprung-mass motion:

$$m_u \ddot{x}_u + c_s \dot{x}_s - x_u + k_s x_s - x_u - c_t \dot{x}_u - x_r - k_t x_u - x_r = 0$$

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 of the suspension system, which differentiates semi active suspension system from passive suspension system, for which the damping coefficient is constant under all conditions.

IV. EFFICACY OF ROAD DISTURBANCE AMPLITUDE AND SPEED INCREASING ON PERFORMANCE OF SEMI ACTIVE SUSPENSION SYSTEM

Mohammad Zehsaz [1], designed semi-active suspension for a passenger car and studied at different road conditions at different speeds. For investigate performance of semi-active suspension system a quarter car model with two degree of freedom has been used. Parameters of the Renault Megane Coupe has been used for modeling and simulation of vehicle moving at speeds of 80, 108 and 130 [km/hr] in a rough road with amplitudes of 0.02, 0.05 and 0.08[m]. In different damping coefficients from 1000 to 6000 [N.s/m]. The increasing disturbance should be controlled which has direct influence on transmitted acceleration to the passengers. The frequencies below 5 [Hz] and amplitude less than 0.06 [m] are most appropriate range and semi-active damper with damping coefficient of 1000-2000 [N.s/m] produce suitable condition, with low transmitting acceleration to the passenger and therefore good handling of vehicle. The handling of vehicle is good because disturbance transmitted to the passengers are controlled using optimizing parameters of vehicle. The following figure shows the comparison of amplitude at different speeds.

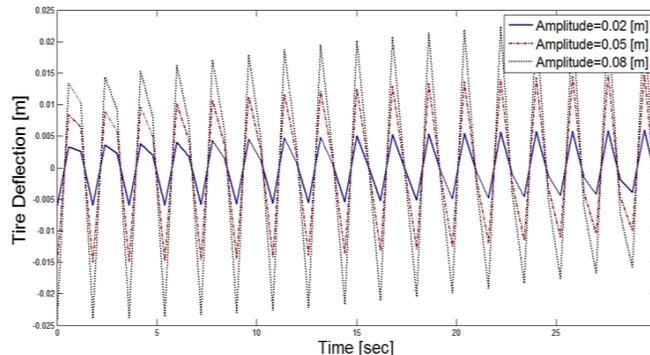


Figure 4. Comparison of amplitude increasing on tire deflection for $C_s=2000$ [N.s/m] and $V=80$ [km/hr]

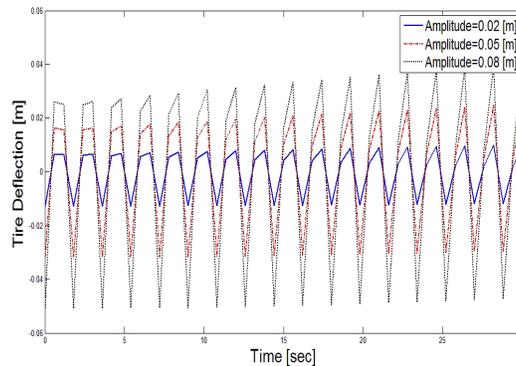


Figure 5. Comparison of amplitude increasing on tire deflection for $C_s=2000$ [N.s/m] and $V=108$ [km/hr]

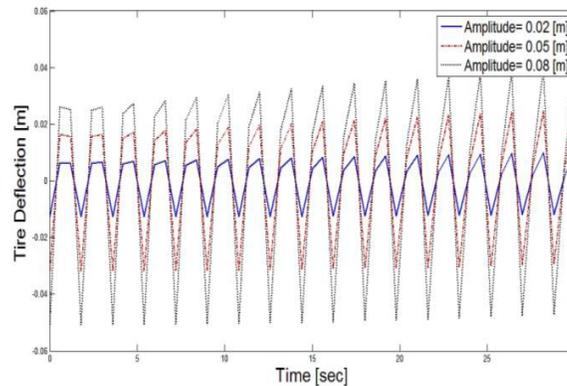


Figure 6. Comparison of amplitude increasing on tire deflection for $C_s=2000$ [N.s/m] and $V=130$ [km/hr].

V. SEMI ACTIVE SUSPENSION SYSTEM SIMULATION USING SIMULINK

S Abramov [2] used an 2DOF semi-active quarter car model with skyhook control. The road profile is generated from power spectral density (PSD) to represent a road. To get vehicle ride comfort and handling performance root-mean-square values of sprung mass acceleration and tyre road forces are used.

The skyhook control improves characteristics comparison with passive suspension system. A semi-active suspension using skyhook control strategy improve comfort index by 14% to 34% with 10% degradation in handling performance with acceptable range.

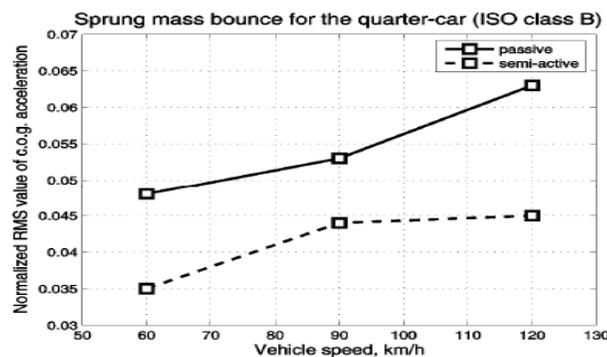


Figure 7. Normalized RMS values of sprung mass vertical acceleration for the quarter-car model, travelling at different velocities (ISO class B).

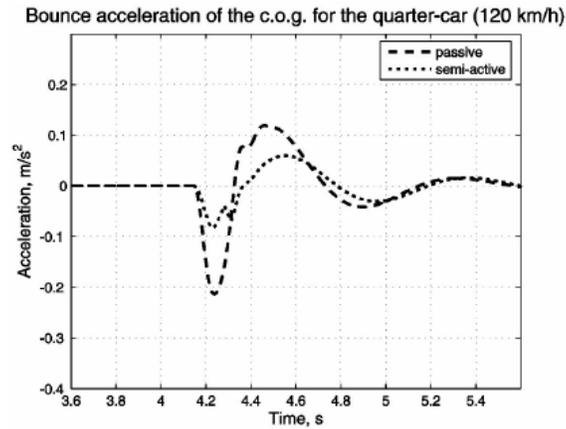


Figure 8. Quarter-car model under sine wave hole test at 120 km/h.

The comparison of bounce of sprung mass shows the difference between passive and semi-active i. e. using semi-active system improve comfort. These are also shown in figure 7, 8 and 9.

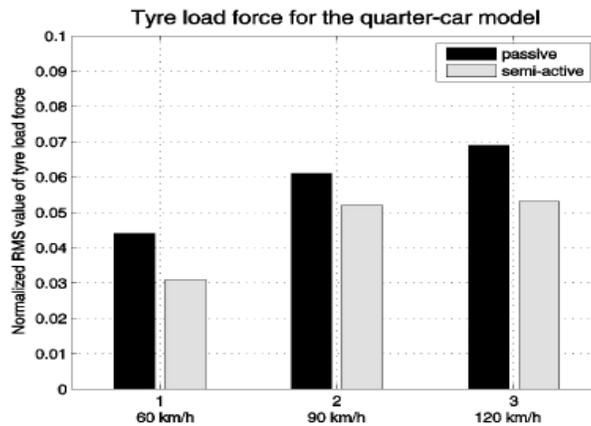


Figure 9. Tyre load force for the quarter-car model under sine wave hole test.

VI. FUZZY CONTROL OF SEMI-ACTIVE QUARTER CAR SUSPENSION SYSTEM WITH MR DAMPER

Devdutt [3], examined MR damper and fuzzy controller suitable for passenger ride comfort and vehicle handling. A semi-active suspension quarter car model having MR damper with fuzzy controller compared to passive suspension system.

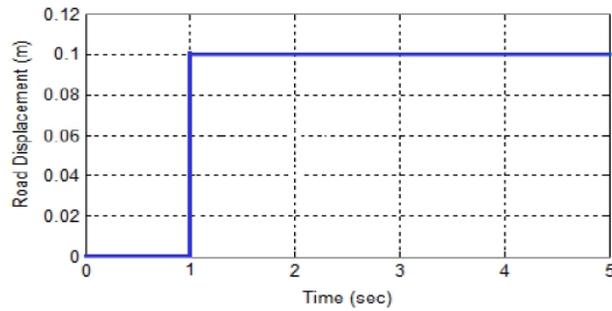


Figure 10. Road disturbance with step having amplitude 10cm.

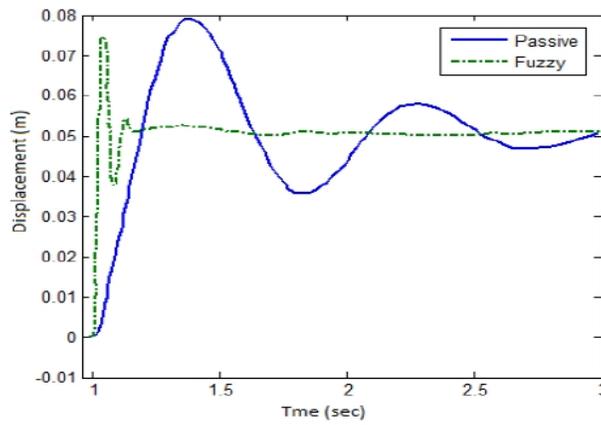


Figure 11. Displacement of sprung mass.

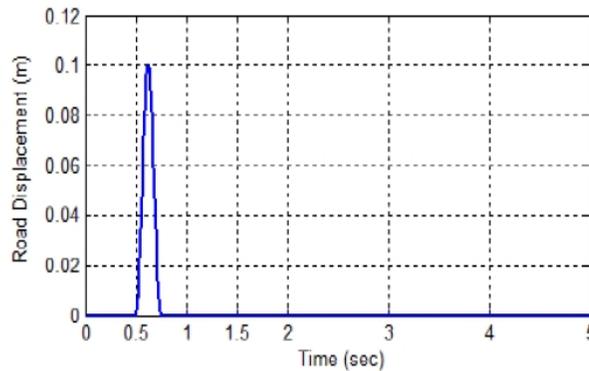


Figure 12. Road disturbance with bump having amplitude 10cm.

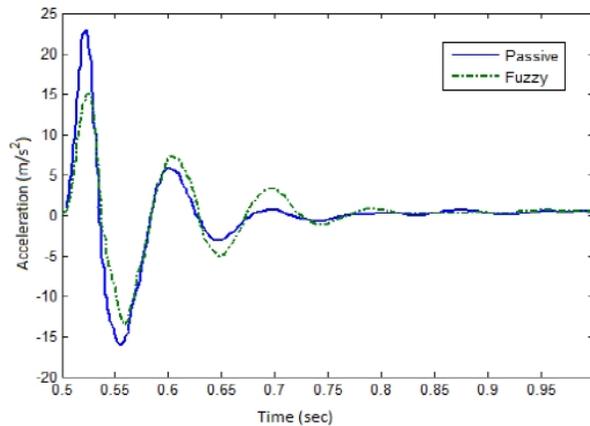


Figure 13. Acceleration of sprung mass.

VII. SKYHOOK CONTROL FOR SEMI-ACTIVE VEHICLE SUSPENSION

Xubin Song [4] designed cost effective skyhook control for semi-active suspension applications. In skyhook control require two sensors to measure sprung mass acceleration and relative displacement. A change is made by eliminating one sensor instead of using two. For comparison purpose a passive suspension is also simulated these are shown in following figures,

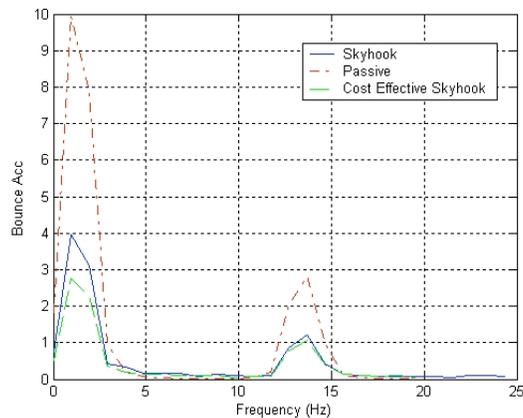


Figure 14. Comparisons of Bounce acceleration.

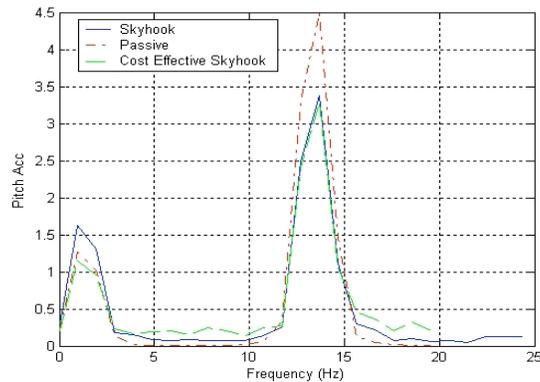


Figure 15. Comparisons of Pitch acceleration.

In automobile industry, both cost and reliability big matter. It is challenge to the engineers to develop more cost-effective control algorithms but maintain a high quality for production.

VIII. FUZZY-PID CONTROLLER FOR SEMIACTIVE VIBRATION CONTROL USING MAGNETO RHEOLOGICAL FLUID DAMPER.

Banna Kasemi [5], analysed semi-active quarter car suspension model. A MATLAB/Simulink model is developed for quarter car. A PID controller is developed and compared with uncontrolled output. A PID controller tuned for single frequency does not work for other excitation frequencies. To overcome this limitations an adaptive PID controller is developed using fuzzy logic. The fuzzy based PID controller shows improved results.

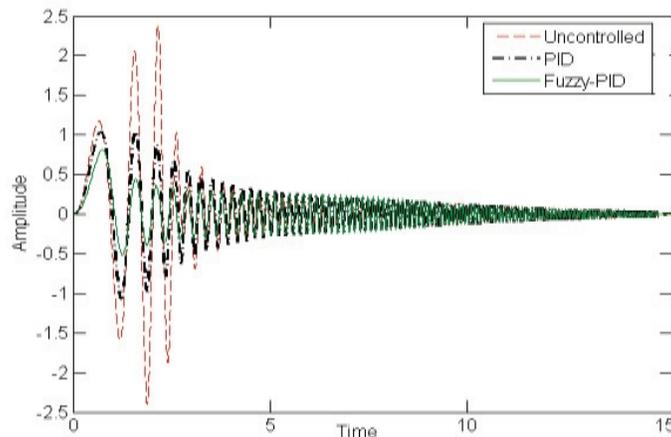


Figure 16. Controller response for Chirp signal

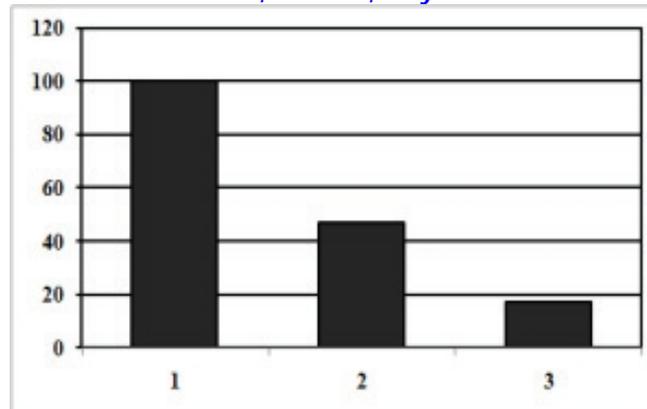


Figure 10. Peak reduction: PID controller vs Fuzzy-PID controller.

IX. CONCLUSIONS

This paper presents an overview of Simulation of 2DOF semi-Active Suspension System to Improve Ride Comfort of a road vehicle. The following conclusions can be drawn from the literature review,

1. Ride comfort and handling characteristics of Semi-active Suspension system is better as compare to conventional passive suspension system and less expensive than the Active Suspension system.
2. The suspension strategy of combination of adaptation of Fuzzy controller with MR damper gives better results in terms of passenger ride comfort and vehicle handling.
3. Fuzzy-PID controller work better than the PID controller having fixed gain parameters.

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