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Review Paper

Effects of Electronic Control Techniques on Performance of Automotive Suspension: A Review

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Abstract

Precise and accurate control of processes and dynamic system is becoming the need of modern industry. This need has made it possible for the engineers to come out with the different types of electronic controllers e.g. single loop controller, multi loop controller, real time, P, I, PI, PD, PID etc. Electronic control units have made great innovation possible in the field of Automotive Engineering. One of them is electronically controlled suspension system known as semi active and active suspension system. This paper deals with the review of different control techniques used in suspension and their effect on ride quality of vehicle.

Keywords: Electronic controllers, ride quality, suspension.

Introduction

Suspension System: An arrangement of spring along with different linkages in a vehicle when used to connect wheels to vehicle body is known as suspension. It ensures relative movement between wheels and body of vehicle. Suspension system is a critical part of an automobile engine. It is used to prevent the road shocks which causes bounce in the vehicle body. It consists of springs, and damper. The energy of road shock causes the springs to oscillate. These oscillations are restricted by a damper. Functions performed by the components of the suspension system are as follows: i. Vehicle's correct ride height is maintained by them. ii. Shock forces are reduced by them. iii. Wheel alignment is maintained at correct level. iv. Vehicle's weight is supported by them.

Types of Suspension System: Automotive suspension system is divided into following types:

Passive: A passive suspension system shown in figure 1 is that which has conventional arrangement of spring and damper. In this suspension vertical movement of vehicle is entirely governed by the road surface.

Semi Active: Semi-active system changes the damping coefficient of viscous fluid in absorber and no energy is being added to the suspension system. They are less expensive to design and energy consumption is also very less in these systems. Figure 2 shows its arrangement.

Active: A separate actuator is an integral and important part of active suspension. An independent force is exerted by actuator on the suspension which in turn improves ride characteristics of vehicle by controlling its vertical motion. An active system is shown in Figure 3.

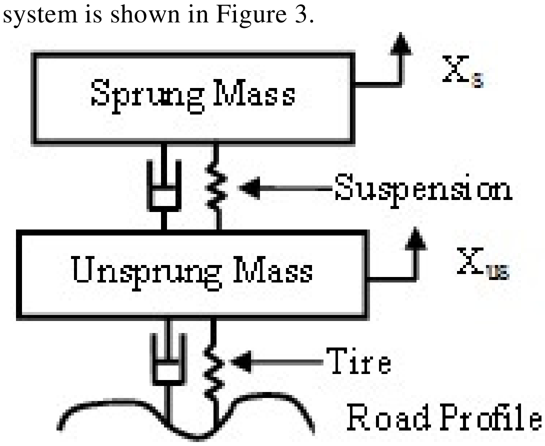

Figure-1
Passive Suspension

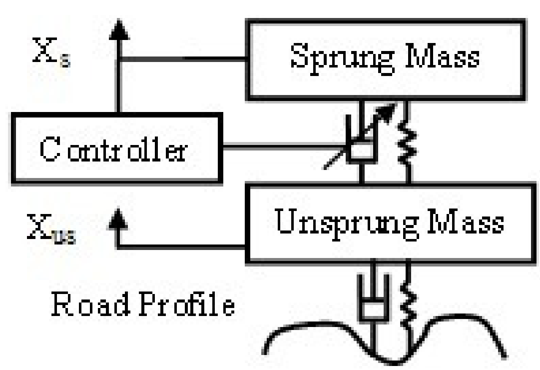

Figure-2
Semi Active Suspension

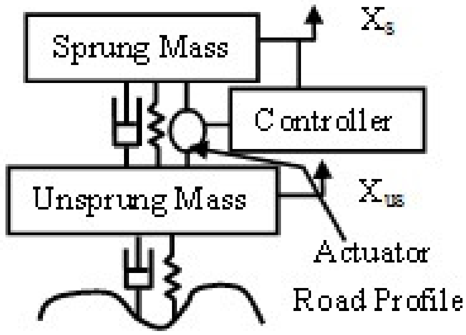

Figure-3
Active Suspension

Control Techniques and Their Performance

To achieve high ride quality a number of control techniques are used by researchers. The techniques and their effect have been reviewed in this study.

M.J. Crosby and D.C. Karnopppresented concept of semi active suspension for vibration along with shock isolation. A lot of work and study has been done since then on semi active dampers in automobiles. They designed this system which makes the damper itself as a controllable force generator. Simulation of their model showed that performance of semi active was better than passive and close to full active system[1].

D. Cebon, F.H. Besinger and D.J.COLE presented a work to reduce the dynamic force on tire and body acceleration of a heavy truck. The root mean square values of the two factors under study were minimized. Two control strategies used for this work were skyhook damping with modification and linear control with feedback in full state optimal value. The simulation work showed that FSF control strategy performed better in reducing rms values of tire force and body acceleration. These two parameters were reduced by 28 and 21 per cent respectively by using this approach of semi active damping[2].

M.S. Kumar, S. Vijayranganworked on designing a car's active suspension system to improve ride quality of a passenger car light in weight. A 2DOF one fourth model was considered in the analysis. A PID controller was designed and tuned to get optimum value of ride quality. The active system improved ride quality by 78 per cent by reducing the acceleration. The road holding ability showed not much improvement for active system. It has also been observed that when controller gain goes beyond 4.915 amplitude of sprung mass displacement increases instead of decreasing, thus showing that increase in gain may not give better ride performance[3].

M.K. Hada, A. Menon and S.Y. Bhavepresented a paper for the control in a 4DOF half vehicle model. Control scheme presented is based on force cancellation. It isolates the unsprung mass and sprung mass. To provide stability to unsprung and sprung mass a virtual damper along with a sky hook damper is used. The parameters like damping coefficient and spring stiffness are optimized by Genetic Algorithm in order to obtain best trade off among quality of handling, suspension travel and ride comfort under random road profile. The GA approach has improved ride quality a lot[4].

A. Shirahatt, P.S.S. Prasad, P. Panzade and M.M. Kulkarnipresented a paper on design and analysis of suspension for complete car full active and 8DOF model. Genetic algorithm approach is used to optimize ride quality of vehicle and compared with simulated annealing technique. The simulation results showed that GA is giving results similar to annealing approach. The driver's seat displacement has been reduced by 74.2% and settling time dropped from 6 sec to 3.5 sec. In case of active suspension travel has been increased by an amount of 56 to 60% thus giving more ride comfort. The tire displacement has also been reduced by 28.5 per cent[5].

L. Li and Q. Lipresented a paper on the analysis of a 20 degree of freedom model. The model considered is with full active suspension and created in the virtual window using ADAMS software. The effect of outside disturbance over the suspension has been analysed numerically and compared with simulated response. The peak in transfer function, frequency response can be optimized by parameterization of springs and bushings[6].

A. Kruczek, A. Stríbrsky, J. Honcu and M. Hlinovskydesigned electric motor integrated full active suspension as an actuator. A comparative study was done for different types of H infinity controllers designed for the system. The stability remained unaffected for different controllers[7].

H.S Amir and A.T Zahra developed a method of robust PID control suspension strategy for one fourth model active system. PID controller as a function of mass and velocity checks the performance of suspension against different road profiles. Robust PID control has given average reduction of 78% in comparison to passive system[8].

M. Senthildeveloped active suspension with PID control for one fourth car model. Controller wastuned by Ziegler Nicholas rules. Sprung mass overshoot was reduced by 47.79% for step input and 87.22% for random road profile in PID controlled system as compared to passive system, giving high ride comfort[9].

A.M Tawwabexperimentally and theoretically analysed the performance of PID and Fuzzy control pneumatic suspension system. Fuzzy and PID controlled system showed much improved performance in comparison to passive system whereas Fuzzy controlled system showed better result than

PID controlled system in terms of overshoots reduction for road profile of sine wave[10].

M.N. Khajvi and V. Abdollahianalysed performance of Fuzzy controlled suspension with passive system. Fuzzy controller was designed for velocity of suspension and sprung mass velocity as input. Varyingdamping coefficient is taken as output of Fuzzy control. Fuzzy system showed a remarkable reduction in overshoot of system[11].

K.T.K. Teo, G. Sainarayanan and C.S.X. Lohdesigned a Fuzzy PID controller for temperature control of exothermic process during polymerization of resin adhesive using GA approach. GAFPID controller provided better temperature control in nonlinear exothermic process[12].

Y. Shiao, Q.A. Nguyen and C.C. Laideveloped a self-tuned fuzzy logic controller for quarter car suspension. Performance of controller was analysed for pulse and step road conditions by simulation. Self-tuned fuzzy controller for air spring suspension showed an improvement of 63% magnitude of sprung mass displacement[13].

J. Wang, H. Wang and L. Guoformulated a Fuzzy PID self-adaptive controller. In this active suspension system dynamic deflection, vehicle speed, vehicle body acceleration, dynamic deflection of suspension integrated feedback was used. Simulation of suspension with self-adapt Fuzzy PID showed remarkable improvement in ride comfort and driving stability under random road excitation[14].

M.M. Rashid, M.A Hussain, N.A. Rahim and J.S. Momohdeveloped semi actives MR damper system control using PID and Fuzzy approach. A nonlinear 2DOF one fourth model was analysed for various road profiles. Fuzzy rule used for the system was two input one output. Controller performances were measured in terms of amplitude displacement and IAE of displacement. It has been found that fuzzy controller reduced the amplitude disturbance from 87 to 90% and IAE from 73 to 81% and Fuzzy hybrid controller was able to reduce them by 90 to 92% and 78 to 80% respectively. Their performance was much better than PID controller[15].

H. Liestablished a mathematical model of adaptive nonlinear suspension by T-S fuzzy approach. They used T-S fuzzy system and simulated one half model with active suspension. They analysed effectiveness of control techniquesover conventional schemes[16].

K. Kamalakannan, A. E. Perumal, S. Mangalaramanan, K. Arunachalamsimulated a semi active one fourth suspension model. They analysed performance and behaviour characteristics of CVD (continuous variable damper) in virtual window of MATLAB/SIMULINK. The work shows that CVD suspension has better ride improvement quality. The excitation of suspension depends on profile of road, vehicle mass, speed of vehicle and inertia[17].

Conclusion

The control of suspension is very complicated problem because of complicated relationship among the suspension parameters and components. The various control techniques used are showing improvement in the ride quality of system but in varying proportions. PID control system are showing significant reduction in overshoot of sprung mass for step input and even better reduction when road profile is random. A Fuzzy control is even better than PID controlled system. Genetic algorithm approach is showing great promise in improving overshoot and settling time. When GA combined with with conventional PID or Fuzzy with PID are giving very interesting results for ride quality and are makinf semi active system approaching towards full active in performance. A scope is arising there to look for performance of other hybrid controllers designed using convention controllers with other intelligent controllers.

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