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An Overview of Disarray in Active Suspension System

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ABSTRACT

When designing a suspension system, the dual objectives are to minimize the Vertical forces transmitted to the passengers and to maximize the tire-to-road contact for handling and safety. Comfort ability of passenger is very much related to the vertical forces that transmitted from the car body. This objective can be achieved by minimizing the vertical car body acceleration. An excessive wheel travel will result in non-optimum attitude of tyre relative to the road that will cause poor handling and adhesion. Furthermore, to maintain good handling characteristic, the optimum tyre to-road contact must be maintained on four wheels. In conventional suspension system, these characteristics are conflicting and do not meet all conditions. So there are various investigations are going on for the study of improvement in active suspension over passive suspension system.

In this paper overview of various works are done. This paper tries to give an idea about the previous researches & their finding about study of passive and active suspension system parameters by considering quarter car model.

Keywords – **Active suspension system, control system, dynamics, passive suspension, vehicles.**

I. INTRODUCTION

The purpose of a car suspension system is to improve ride quality while maintaining good handling characteristics subject to different road profile. Different suspensions satisfy the above requirements to different degrees. Although significant improvements can result from designers ingenuity, on the average, suspension performance mainly depends on the type or class of suspension used. Here one distinguishes, in an ascending order of improved performances, between passive, semi active and fully active suspension system, the force input usually provided by hydraulic actuators. As an alternative approach to active suspension system design electromechanical actuators would provide a direct interface between electronic control and suspension system.

There are two forms of active suspension which are commonly recognized as the first, high bandwidth active suspension in which the actuator sits in parallel with the road spring. Between the body and the unsprang mass, and controls both, the body and the unsprang mass with a frequency around 1 Hz and around 12Hz respectively. Second the low bandwidth active suspension in which the actuator sits in series with the road spring and controls the body motion, while the unsprang mass is controlled by the passive damper. The active control of automobile suspensions gives improved performance over conventional suspensions. Active suspension, that includes the hydraulic actuators which create a force in the suspension system. The force generated by the hydraulic actuator is used to control the motion of the sprung mass and relative velocity between sprung and unsprung masses. To get improved vehicle characteristics, researches going mainly on high bandwidth type of active suspension.

By considering all above facts, this paper tries to cover literature which deals with an active suspension system with quarter car model by considering suspension nonlinearities, ride comfort and car holding as parameter. In this paper overview of various works are done.

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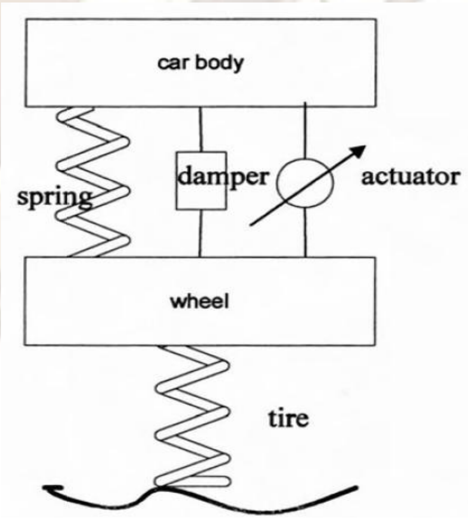


Figure 1 High bandwidth system [6]

II. Modified Skyhook Control of Semi-Active Suspensions

Keum-Shik Hong & Hyun-Chul Sohn al [2] in year 2002 studied the Modified Skyhook Control of Semi-Active Suspensions.demonstrates the connection between optimal one and two degree of freedom vehicle structure incorporating active suspensions. It is shown that the resulting, special one DOF structure represents the limits of the best possible performance attainable with two degree of freedom counterparts.

III. Alternative Control Laws for Automotive Suspensions

C.Yue et al. [3] discussed on the alternative control laws for automotive active suspension system. They evaluate the control laws by using 2DOF quarter car model. The control laws considered are full state feedback sprung mass absolute velocity feedback and LQG regulator using suspension deflection measurement. They found that, all three yields improved performance but overall the LQG regulator using suspension deflection provides the best compromise between ride comfort, suspension travel and tire force variation.

As a baseline case for comparison purposes is given for the passive system acceleration with standard values of vehicle parameters.

In full state feedback control law the linear optimal control theory has been used for design. They found that several interesting characteristics.

It is shown that the transfer functions for a design that emphasized ride comfort. The active suspension greatly improves the l Hz region while the invariant point (10.6Hz) eliminates any effect at the tire hop mode. Also they found that the high frequency performance of the active system is worse than the passive System. They also found that the tire deflection transfer function has been improved at 1Hz only. The absolute velocity feedback gives the same performance and also eliminates the problem of high frequency harshness. The best overall designs were achieved by the LQG compensator using the easiest and most inexpensive variable to measure, suspensions deflection

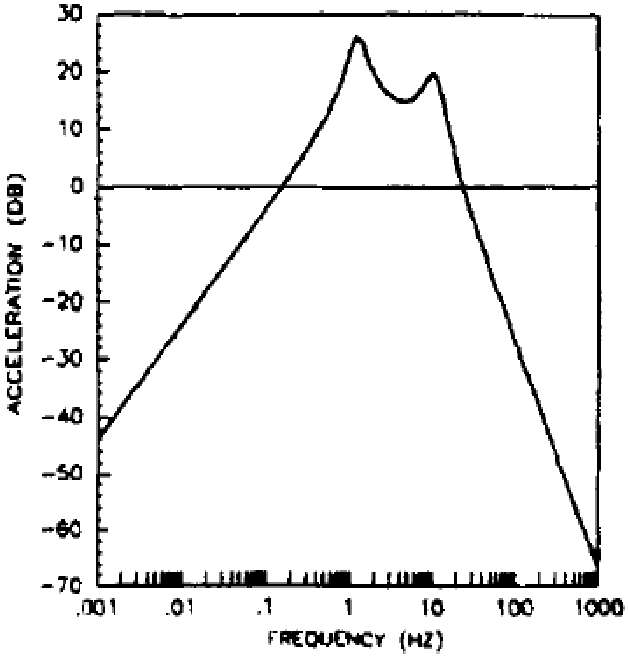
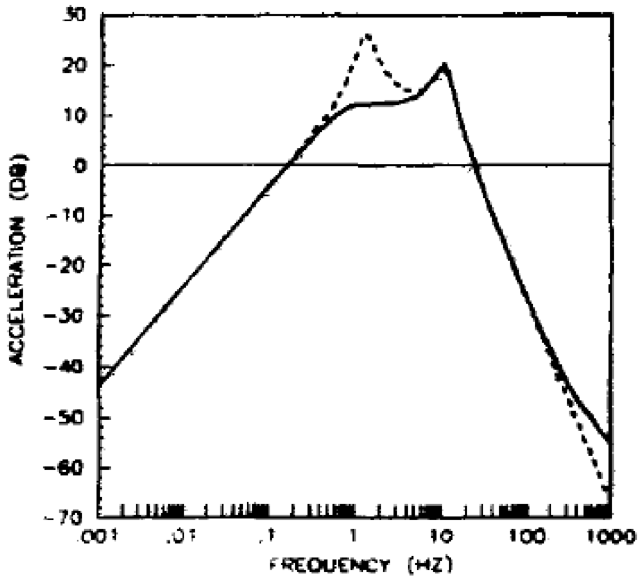


Figure 2 passiveacceleration [2]



Figures 3 passive acceleration [2]

In a controls sense the system using actuator force as the control and suspension deflection as the measurement is both controllable and observable thus we can design for either ride quality or road holding. It was shown that the design for ride quality captured all the nice features of the full state design and eliminated or reduced some of the bad features.

IV. Non Linear Adoptive Control of Active Suspensions

Andrew Alleyne et al [4] investigated on a previously developed nonlinear "sliding" control law and which is applied to an electro-hydraulic suspension system. In the most of the earlier researches the optimal control law for the suspension and does not consider the dynamics of the actuator. Hear they considered the nonlinear dynamics of an electro-hydraulic actuator in a quarter-car active suspension model and used these dynamics to formulate a nonlinear control law.

In this paper standard method based on lyapunov analysis is introduced for reducing the error in the model. The model used for the analysis is shown in figure 4.for the performance comparison purpose simulation and experimental results are usedin this paper the investigation is carried out to increase the ride qualityof the automobile.

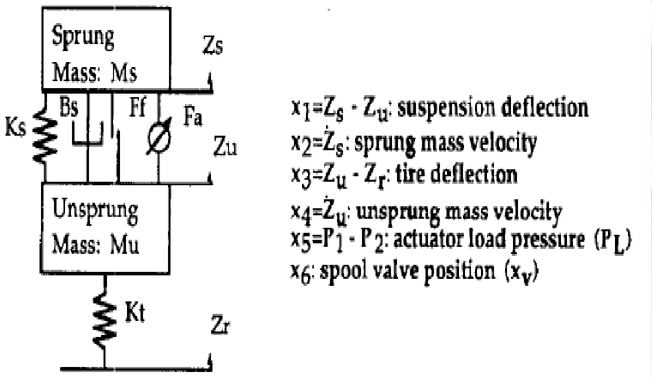


Figure 4 Quarter car model and state equation [3]

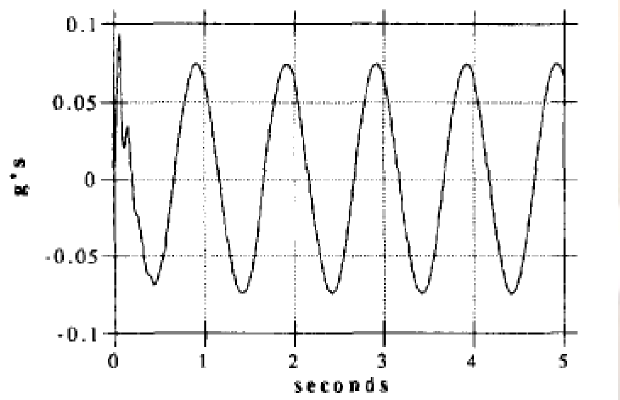


Figure 5Skyhook sprung mass acceleration (simulation).[3]

Since the ride quality is linked to the acceleration felt in the passenger compartment, so the task is to reduce the acceleration while remaining within the constraints of the suspension system. The method used to achieve this goal is “skyhook damping”. The performance of the controller is defined as the ability of the active element to track a given “skyhook” force, which is determined from the states of the system. The performance of the active systems, under various nonlinear controllers, is compared with each other and with a passive system. The actuator, the force producing element is a conventional hydraulic actuator with a four way spool valve. The four way spool valve is controlled by a flapper valve with a direct current input. The flapper valve uses the input current and a hydraulic assist to control the motion of the spool valve. The dynamics of the servo valve, including both the flapper and spool valves, are third order.

In simulation the A modified adaptation scheme is used in whichparameters are not restricted to being slowly time-varying as in the standard adaptation scheme; however, they are restricted to being constant or slowly time varying within regions of the state spaceFig. 5 shows the Skyhook sprung mass acceleration in simulation.

Figure**6** show the experimental results of the systemunder the dual surface sliding controller developed in adoptive control.

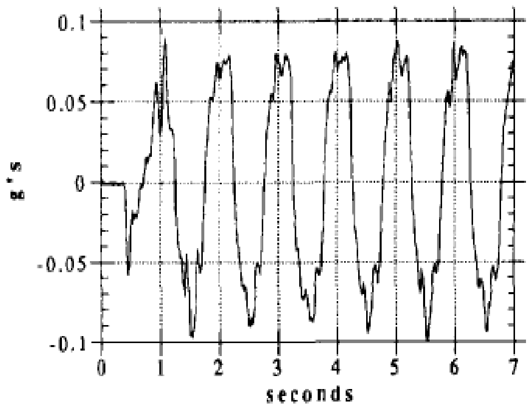


Figure 6 Sprung mass acceleration (experiment).[3]

Figure 6 shows that the accelerations are greatly reduced from those of the simulation in Figure 6.

V. DRIVE BY WIRE CONTROL OF AN ELECTRO-HYDRAULIC ACTIVE SUSPENSION A BACKSTEPPING APPROACH

Claude Kaddissi, et al [5] have studied the control of an electro-hydraulic active suspension based on back stepping approach. The active suspension model is highly non liner and non-differential due to the hydraulic components, especially the servo-valve, therefore the powerful control strategy is needed, and the back stepping is used here for being powerful non-liner approach, which able to overwhelm all these facts. Here the electro-hydraulic actuators are used to ensure the passenger comfort.

Figure 8 Quarter car electro-hydraulic active suspension

For any type of suspensions, the main objective is to minimize the vertical motion, of the body, due to road imperfections. This consequently means reducing the force which is transmitted to the passenger’s comportment. Electro-hydraulic actuators are typically chosen for this purpose in the suspension control. Hear, the drive by wire control of electro-hydraulic active suspension is studied using the back stepping approach. The main focus of this work is that to account for all system non-linearity's, including the one induced by the variation of the actuator chamber volume and the stability of zero dynamics.

Figure 8 shows an electro-hydraulic active suspension of a quarter car model. The suspension is composed of the hydraulic system; spring-damper system which constitutes the classic passive suspension. With concerning the car dynamics, the tire with a spring are modeled it as a spring and damper in parallel. Hear the main aim is ensures a stable zero dynamics. Concerning the hydraulic system, the electric motor drives the hydraulic pump at constant speed. Then, the pump delivers oil flow from the tank to the rest of the components. Normally, the pressure *Ps* at the pump discharge depends on the load (car and passengers weight); but in any case it is steady due to the presence of an accumulator and a relief valve. In fact, the accumulator acts as an additional source of pressure in case it is needed. On the other hand, the relief valve compensates the increase in pressure, due to big loads, by returning the additional amount of flow to the tank.

The hydraulic actuator carries the suspensions; its motion and speed that determine the suspension travel is settled on by the oil flow and pressure that comes from the servo-valve. The control law, generated by the back stepping controller designed in an electric signal. It actuates the servo-valve spool to the right position depending on road perturbations. This in turn determines the action the actuator has to take in order to drive the vertical motion of the car body to zero, which gives a drive by wire aspect to this control strategy.

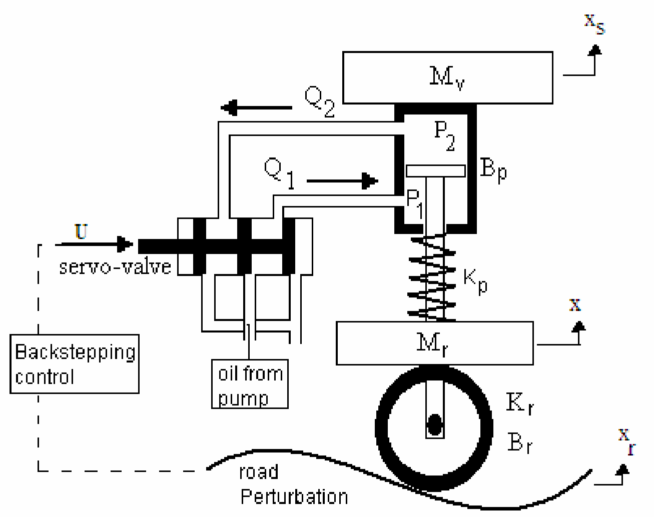


Figure 8 Quarter car electro-hydraulic active suspension [5]

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Figure 5 shows the same data for a classical passive suspension. Figure 6 presents the vertical motion of the car body and the transmitted force to the passengers for an electro hydraulic active suspension using the Backstepping nonlinear control. In this paper, they presented a nonlinear, drive by wire, control strategy for an electro-hydraulic active suspension. This control law is based on the non-linear backstepping. From figure 6 it is seen that the designed controller succeeded in stabilizing the vertical motion of the car body and the force transmitted to the passengers. The hydraulic actuator is linear, which increases the nonlinearity in the system since the oil volume varies with the piston position. This discontinuity generates mathematical and numerical problems when the valve spool has to switch from a positive to a negative position and vice versa. In the mathematical model we introduced a damping coefficient to the tire model; this ensures a stable zero dynamics independently of the control variable choice. The results were compared to those obtained with a classic passive suspension and with a PID controller.

Claude Kaddissi et.al[7]have studied the real time position control of an electro hydraulic system using indirect adaptive back stepping, the hydraulic parameters prone to variations, it is therefore useful to employ an adaptive control strategy in order to update the controller with parameter variations. For this purpose adaptive control is useful.

When dealing with electro hydraulic system the important factors are considered are first the accuracy of the mathematical model and effectiveness of control strategy. in this paper dynamics of the hydraulic parameters taken in to consideration .which gives several improvements in the existing system. regarding the control issue, the most effective indirect adoptive control system is used. this propose the position control of an electro hydraulic servo system which gives the advantages of robust backstepping strategy and also consider the system parameter variations In this paper the main concern is the identification and the variation of the system parameters with the operating system conditions .its benefit is that it guarantees the convergence of the system parameters to the real physical parameters value which simultaneously ensure the system stability.

The electro hydraulic workbench is used for the experimentation purpose with an indirect adaptive backstepping controller. as the electro hydraulic components are subjected to the variations depending upon load temperature and pressure the results were compared to those obtained with the real-time non adaptive back-stepping controller. It found that during parameter variations, the adaptive controller was able to track the desired reference signal with a slight transient behavior after the parameter variation. From this paper it is prove that indirect adoptive controller is ideal option for the hydraulic control system, it leads to the real physical values of the system parameters, which allows a good system monitoring

VI. CONCLUSION

This paper presents an overview of the recent developments in the study of control system design for active vehicle suspension. The following conclusions can be drawn from the literature review of the active suspension system.

1. Electro-hydraulic actuators can be effectively used for active vehicle suspension .
2. The back stepping is the powerful strategy for vehicle suspension control as it controls the nonlinearities of the hydraulic components especially servo valve.
3. As in the back stepping approach the main objective is to control the vertical motion so it gives improved performance of the passenger's compartment over the other approaches.
4. Indirect adoptive controller is ideal option for the hydraulic control system, since it leads to the real physical values of the system parameters, which allows a good system monitoring.

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