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Simulation and Analysis of Active Suspension System for Passenger Vehicles

Mr. Ashishkumar A Jain[1], Mr. Akshay Patel[2], Mr. Bhargav Patel[3], Mr. Gunjan Desai[4]

[1,2,3,4] Department of Mechanical Engineering, ITM-Universe,Vadodara, India

Abstract— *Suspension system is the most significant part which heavily affects the vehicle handling performance and ride quality. Because of its structures limit, the passive suspension system can hardly improve the two properties at the same time. Since the advent of active suspension system, it has become the research hot spot. In this review paper we shall see the advantages of the active suspension system over the passive suspensions systems and its incorporation in passenger vehicles.*

Keywords—*Passive, Active, Suspension, system.*

I. INTRODUCTION

Suspension is the system of tires, tire air, springs, shock absorbers and linkages that connects a vehicle to its wheels and allows relative motion between the two[1]. Suspension systems serve a dual purpose — contributing to the vehicle's road holding/handling and braking for good active safety and driving pleasure, and keeping vehicle occupants comfortable and a ride quality reasonably well isolated from road noise, bumps, vibrations, etc. It is important for the suspension to keep the road wheel in contact with the road surface as much as possible, because all the road or ground forces acting on the vehicle do so through the contact patches of the tires. The suspension also protects the vehicle itself and any cargo or luggage from damage and wear.

Traditional suspension systems use a combination of sets of springs and sets of dampers to decrease the vehicle vibration. The passive suspension system, which has the largest amount equipped on current vehicle, its spring and damper coefficient is constant and cannot adjust itself along with its road surface situations. This has certain advantages and disadvantages. On the plus side, the system is very predictable. Over time, the owners, will develop a familiarity with the car's suspension. They will understand its capabilities and its limitations. On the down side, once the system has reached these limits, it has no way of compensating for situations beyond its design parameters. There are various passive suspension systems like:

- Macpherson strut
- Double wishbone
- Trailing-arm suspension
- Moulton rubber suspension
- Solid-axle, leaf spring
- Solid-axle, coil spring
- Beam axle

The front and the rear suspension are usually different. In most vehicles for front suspension macpherson and double-wishbone suspension systems are used and for rear suspension leaf spring and beam axle are used.

An active suspension system, on the other hand, has the capability to adjust itself continuously to changing road conditions. It artificially extends the design parameters of the system by constantly monitoring and adjusting itself, thereby changing its character on an ongoing basis. With advanced sensors and microprocessors feeding the information all the time, its identity remains fluid, contextual and amorphous. By changing its character to respond to varying road conditions, active suspension offers superior handling, road feel, responsiveness and safety.

Active suspension systems are mainly of two types:

- Hydraulic actuated
- Electromagnetic recuperative

II. LITERATURE REVIEW

Mats Jonasson et al.[2] have developed the active suspension, based on Autonomous Corner Module (ACM), by making damper entirely electrochemical. The upper arm of the wheel suspension, which is normally passive and bounded by suspension kinematics, has been provided with an active function. The function has been implemented by attaching two actuators to the end of the upper arm. Since the existing arm can be used for actuation, additional suspension linkages are not needed to incorporate the active function and, in turn, fewer parts are required. For controlling the system they have adopted the skyhook algorithm. At the end of their research they found out that the heat generated in the electric damper is lower than the conventional passive suspension.

With ECU being the main component of the active suspension system therfore it has become very important to find various control systems for the ECU which will make the working of the system more efficient. Chiou-Jye Huang et al.[3] have shown the application of a road-adaptive nonlinear control integrated with active suspension into a half-car model by employing road adaptive algorithm schemes. By their research they found that the non-linear back-stepping designs feature significant flexibility, which can be used to successfully resolve many of the tradeoffs inherent in real-world control applications. This was achieved by appropriate choice of the critical non-linear filter parameters.

G. Priyandoko et al.[4] have developed the novel hybrid control technique for a vehicle active suspension system by using skyhook and adaptive neuro active force control. In this control system there are overall four feedback control loops, namely the innermost proportional-integral (PI) control loop for the force tracking of the pneumatic actuator, the intermediate skyhook and active force control(AFC) control loops for the compensation of the disturbances and the outermost proportional–integral–derivative(PID) control loop for the computation of the optimum target/commanded force.

Weichao Sun et al.[5] have suggested a constrained adaptive back-stepping control scheme for active suspensions to achieve the multi-objective control, such that the resulting closed-loop systems can improve ride comfort and at the same time satisfy the performance constraints in the presence of parametric uncertainties. Compared with the classic Quadratic Lyapunov Function (QLF), the barrier Lyapunov function employed in this paper can achieve a less conservatism in controller design.

Keiwan Kashi et al.[6] have developed a fault diagnosis system for the active suspension control system. They have taken a model based approach for gaining more and more grounds for the fault diagnosis purpose which rely on a mathematical description of the system. For diagnosis they have used the fuzzy logic method. By this method they found out that the system was able to detect faults that were classified as hazardous, which enhanced the feasibility of the system.

Christian Graf et al.[7] Have designed pneumatic push pull actuator which is used for vibration isolation. They evaluated the influence of active controllable forces in pull-direction in addition to forces in push direction, in order to prevent the system from hitting into the bumpers in case of large excitations. They have first designed the pneumatic cylinder and the valve, then the strategy to control the force of the pneumatic actuator is shown. To control the vibrations in the system vibration controller is designed for a one degree of freedom model of a quarter car cabin of a commercial vehicle based on the skyhook-principle. The concepts are evaluated in a hydraulic test bench. The results of the test show a very little increase in the comfort level because of the high friction, so the system setup is changed to an actuator configuration consisting of an air spring and two parallel assembled fluidic muscles. By using the hybrid pneumatic actuator both a good comfort and also the possibility to prevent the system from hitting into the bumpers in case of very large excitation can be achieved.

K El. Majdoub et al.[8] have developed a control system for semi-active suspension system which is using a magnetorheologic damper featuring hysteretic behavior captured through Dahl model. The control problem is dealth with backstepping control design. They have designed an observer which gets online estimates of the hysteresis internal state. Then, an adaptive state-feedback controller, that ensures tight regulation of the chasis vertical position, is designed assuming all internal state variables to be accessible to measurements. An adaptive feedback controller is obtained combining the previous designed observer and state feedback controller. By using extensive time response with different road profiles it was found that the designed controller performed efficiently resulting in improved ride comfort of the passengers.

III. PASSIVE SUSPENSION SYSTEM

Passive suspension cannot change stiffness and damping coefficient, and it has no additional power and actuator. It consists of springs, dampers and oriented institutions. It has simple structure, reliable performance, low cost and no additional energy, which is currently the most widely used on the vehicles. Passive suspension cannot adjust stiffness and damping, according to the random vibration theory, it can only ensure the specific operating conditions to achieve optimal damping effect, it is difficult to adapt to different road and tough use; while taking passive suspension is also difficult to acquire good ride comfort and handling stability at the same time, because these two requirements is a pair of contradiction.

Due to the structure itself, the traditional passive suspension summed up in the following defects:

1. Due to the suspension travel stroke and is inversely proportional to the square of the system natural frequency, when the frequency is reduced, it has prone to large travel stroke;
2. The suspension components are limited by the stiffness and damping, which restricts the range of its parameters.
3. Suspension system parameters are fixed and cannot meet the load, road conditions, speed and other changes in circumstances.

Passive suspension is mainly used in middle and low end cars. Research to improve the passive suspension performance hit in three aspects: First, how to find the optimal suspension parameters, mainly through modeling and simulation; Second, gradient stiffness springs and mechanical variable-damping shock absorbers, so that suspended frame parameters to adapt to different conditions within a certain range; The third, suspension-oriented institutions, in this area focus on the multi-link suspension with stabilizer bar.

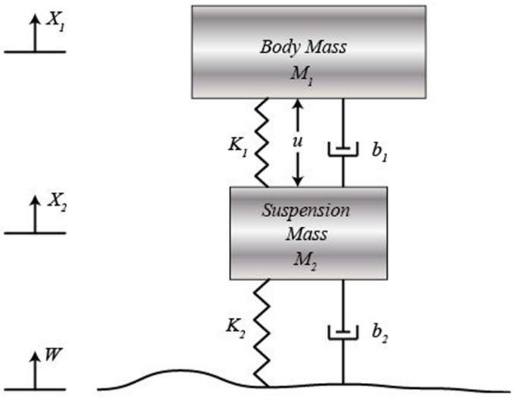


Figure: (i) Passive Suspension System

IV. ACTIVE SUSPENSION SYSTEM

Active suspension systems, also known as Computerized Ride Control, consist of the following components: a computer or two known as Electronic Control Unit (ECU), adjustable shocks and springs, a series of sensors at each wheel and throughout the car, and an actuator or servo atop each shock and spring. The components may vary slightly from manufacturer to manufacturer, but these are the basic parts that make up an active suspension system.

Active suspension works by constantly sensing changes in the road surface and feeding that information, via the ECU, to the outlying components. These components then act upon the system to modify its character, adjusting shock stiffness, spring rate and the like, to improve ride performance, drivability, responsiveness, etc.

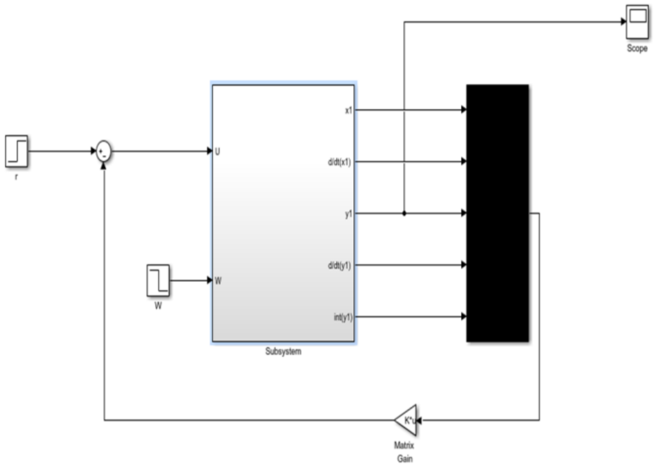


Figure: (ii) MATLAB model of Active Suspension System

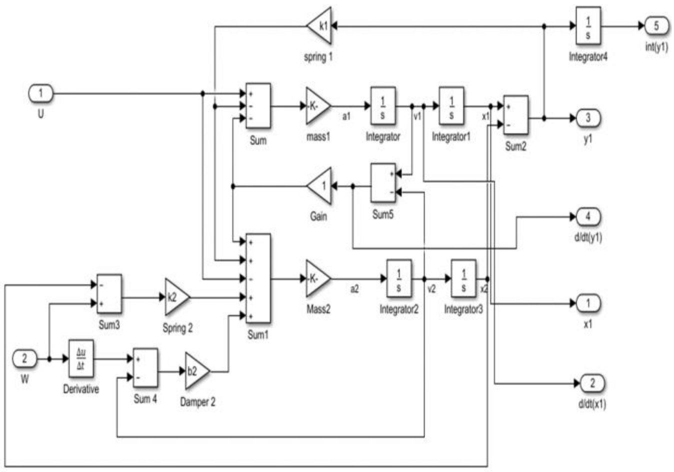
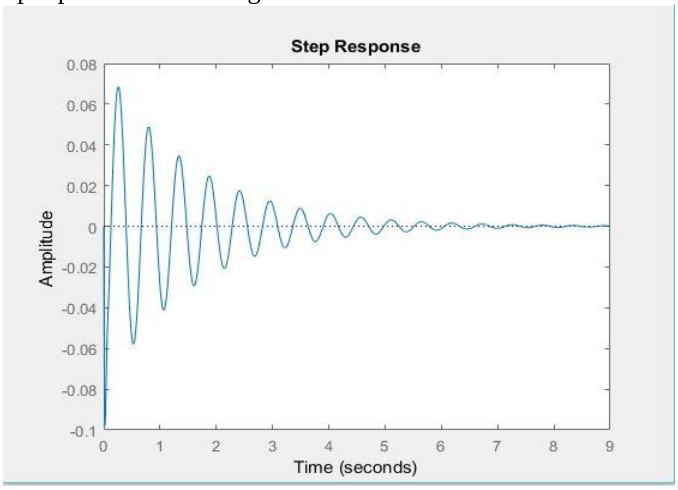


Figure: (iii) Subsystem of Active Suspension System

V. SIMULATION RESULTS

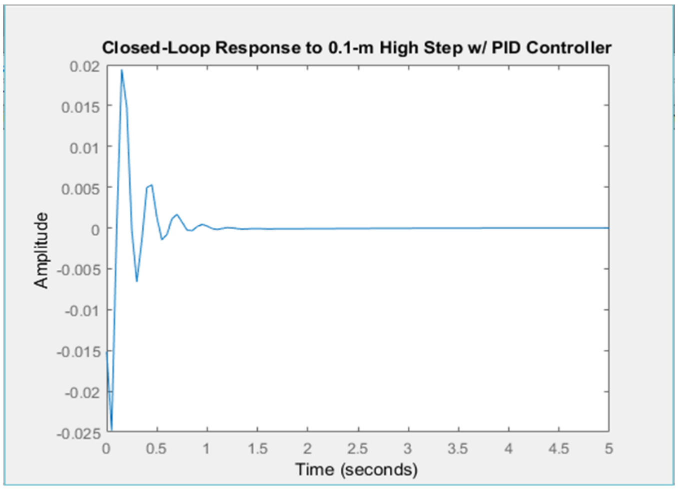
For simulation, we gave both the systems a 10cm step input.

The first graph shows the simulation of the passive suspension system, in which the car body travels to a maximum amplitude of 7cm for 10cm step input and the settling for the car is 9sec.



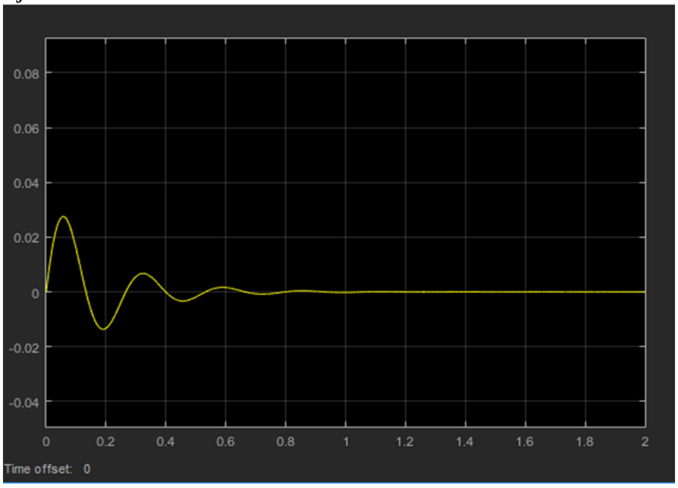
Graph: (i) Car body displacement for 10cm step input for passive system

For active suspension system a PID controller was designed to control the system and stabalize the car during variable road conditions.



Graph: (ii) Close loop response to 10 cm high step w/ PID controller

When this PID controller was applied to the active suspenison system, the suspension travels to maximum amplitude of 3cm and stabalizes within a second. So by implementing the active suspension system the overshoot is decreased to 30% and settling time is reduced to just 1 second.



Graph: (iii) Car body displacement for 10 cm step input for active system

CONCLUSION

In this study we found out that the performance of active suspension system is very high compared to the passive suspension system. It provides greater comfort and ride quality. And with increasing research on the control systems for the active suspension there is increase in its efficiency and cost effectiveness.

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