Experimental Analysis of Passive/Active Suspension System

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Abstract - *The suspension system classified as a passive, semi-active, and active suspension, according to its ability to add or extract energy. Active suspensions have recently attracted increased attention in automobile industry because they can significantly improve vehicle ride and handling performance. The control object of an active suspension system is to produce excellent ride comfort and good holding ability. Optimal control theory was used to investigate potential benefits of active suspensions. This study addresses the main characteristics of optimal active suspension based on two degree-of-freedom quarter car vehicle models. In this study MATLAB software is used for see the results of active and passive suspension system. Modeling of quarter car suspension system with the help of 2 DOF model of vibratory system such as mass, spring and damper arrangement done. Mathematical analysis done here by using Laplace transform because it is very simple to use in MATLAB and results taken. Simulation is also done here by using simulink library of matlab, sources, sinks and continuous library used for simulation. Also experimental set up done, for this used masses and shock absorbers in vertically arrangement. Here also design of active control strategy such as Proportional Integral Derivative controller. In addition, the study puts into perspective the optimal active suspension performance through comparison with corresponding passive counterparts. The simulation results indicate that the proposed active suspension system proves to be effective in the vibration isolation than passive suspension system*.

Key Words: **Active and Passive Suspension System, DOF model, PID, Vibration**

1. INTRODUCTION

The main functions of an automotive suspension system are to provide vehicle support, stability and directional control during handling maneuvers and to provide effective isolation from road disturbance. These different tasks result in conflicting design requirements, directional control and stability requires a stiff suspension, whereas good ride comfort demands a soft suspension. In conventional passive suspension system, the designer is faced with problem of choosing the suspension stiffness and damping parameters, which inevitably involves a difficult compromise in view of the wide range of conditions over which a vehicle operates. This type of active suspension system has proven capable of achieving improvement over passive systems. The primary thrust of the commercial research and development in active suspension has been improved ride handling and stability in the on-road environment while minimizing system cost and mean time between failures. Much of this work was pioneered by lotus engineering, located in Norwich, England and has been continued by several major automotive manufactures, including U.S. based ford and GM. Though the performance results have been quite promising, cost, reliability and potential safety issues have limited the production commitments for active suspension to only Toyota and Nissan. With recent advances in microelectronics and actuators, there has been an upsurge in the concept of active suspension control. Active suspension offers the potential of being adapted to the quality of the road surface, vehicle speed and different safety and comfort requirements, with the choice being selected either by the driver or by an adaptive control algorithm embodied in a microcontroller. The issue of vehicle suspension damping is the conflict between vehicle safety and ride comfort. The safety of a vehicle is typically measured by the vertical motion of the vehicle tires (wheel hop) and by the rotational motions of the vehicle body, such as the roll and pitch of the vehicle during cornering and braking. These measures are also considered as road handling and stability characteristics by providing information on the vehicle tire contact to the road and the location of the vehicle's center of gravity. The degree of ride comfort of a vehicle is obtained by evaluating the displacements and accelerations of the vehicle body. This provides a measure of the movement and forces transmitted to the vehicle passenger, which cause discomfort. Two common types of vehicle suspension dampers are passive and semi active dampers. With each of these dampers, the magnitude of damping is dependent on the relative velocity across the damper. The force versus velocity curves of each type of damper, however, is not identical.

2. ACTIVE SUSPENSION SYSTEM

Traditionally automotive suspension designs have been a compromise between the three conflicting criteria of road holding, load carrying and passenger comfort. The suspension system must support the vehicle, provide directional control during handling manoeuvre and provide effective isolation of passengers/payload from road disturbances. Good ride comfort requires a soft suspension, whereas insensitivity to applied loads requires stiff suspension. Good handling requires a suspension setting somewhere between the two. Due to these conflicting demands, suspension design has had to be something of a compromise, largely determined by the type of use for which the vehicle was designed. Active suspensions are considered to be a way of increasing the freedom one has to specify independently the characteristics of load carrying, handling and ride quality. A passive suspension system has the ability to store energy via a spring and to dissipate it via a damper. Its parameters are generally fixed, being chosen to achieve a certain level of compromise between road holding, load carrying and comfort. An active suspension system has the ability to store, dissipate and to introduce energy to the system. In an active suspension the interaction between vehicle body and wheel is regulated by an actuator of variable length. The actuator is usually hydraulically controlled and applies between body and wheel a force that represents the control action generally determined with an optimization procedure. Active suspensions have better performance than passive suspensions. Then, we propose an optimal control law for active suspensions that aims to optimize the system performance while ensuring that the magnitude of the forces generated by the actuators never exceed a desired value, on the active forces limits the maximal force required from each controller i.e., it leads to the choice of suitable actuators

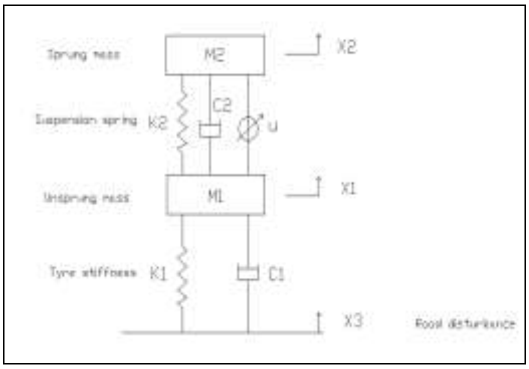


Fig 1: 2DOF model of quarter car active suspension system

3. EXPERIMENTAL SET UP:

In this study we have fabricated an experimental model of vehicle suspension system. This model is an example of two degree of freedom vibration system (quarter car model). In the construction of the model firstly did the frame base, it has very important role, for this used the I channel give the sufficient support to all components mounted on that, it has big role to locate the components and fixed on base. Two shock absorbers are used having different stiffness mounted vertically on the ramp using frame made up of two columns such as circular bar, bushes are used here to give the support to shock absorber and smooth vertical motion over the bar, connection of bushes with the help of beam there will be mounted of mass. Two columns are welded by arc welding on the base and inclined plate also weld at lower level to stay the bar vertically and carry the maximum load without tilt. There will be the one bearing use, it connect with the lower level of lower shock absorber with the help of nut bolt arrangement and it mounted on rounded plate having sinusoidal bump made up of wood or steel having height range 5-15mm, the ramp is fitted on the disc. This plate holds by one shaft which is pass through the gearbox hole. Rotary motion to the plate give by gear box using single phase D.C. motor. Worm and worm wheel gearbox using here having gear ratio 64:1. In actual case road is stationary and wheel of vehicle is moving. In this model we are assumed that earth is moving and vehicle is stationary. A provision has been made that mass is applied in such way that on two shock absorbers different mass is acting. There is drum and pen arrangement has been made to plot two separate graphs of displacement of the shock absorbers. When disc is rotary motion it causes the displacement of shock absorber in the upward direction. This displacement is directly depending upon the shape of a road surface (ramp). Linear 2DOF system is used as model for a road vehicle. Complete vehicle mass divided into two masses unsprung and sprung instead of that two particular masses used here and instead of suspension spring and tyre two shock absorber used here of different stiffness and damping coefficient.

Fig:2 Experimental set up of Suspension System

Experimental Procedure

Set up including motor, gearbox and shock absorbers are significant component. Firstly we should check all elements are in working or not then go further for readings of experimental set up. Firstly take reading without using PID controller for Passive suspension and then take reading of set up for active suspension with the help of PID controller then compare both reading, active suspension should be less than the passive suspension.

- Start the motor which supplies the power to gearbox, decrease in speed by gear box, reduction ratio is 64:1.
- Rotation of round pillar directly moves to circular plate because of welding in the pillar and circular plate. Here contact of circular plate and bearing, so circular plate move to bearing, all sprung and unsprung mass is directly on the bearing so bearing touch to circular plate. Bearing roll over a circular plate and converts rolling motion of bearing in to linear motion of shock absorber.
- Displacement of sprung and unsprung mass occur here we should take reading of displacement and acceleration of masses with the help of vibration measuring instrument, measure the speed of motor simultaneously at each reading.
- Graph plotting easily by SVAN software, SVAN software directly gives the graph frequency verses displacements, velocity and acceleration.

Shock Absorbers

Fig 3 Shock Absorbers

Two shock absorber is used in this experimental set up, one for sprung mass suspension and other for unsprung mass suspension. Scooty pep rear shock absorber is used for sprung mass suspension and M80 front shock absorber is used for unsprung mass suspension. In the above figure the hole on both side is shown is used for fitting of shock absorber with masses by nut and bolt arrangement. The detail data of shock absorber is mentioned in mathematical modeling viz. stiffness, damping coefficient. Scooty pep shock absorber having length 300mm and diameter is 50mm while M80 front shock absorber length is 270mm and diameter is 40mm.

PID Controller :

Fig: 4 Actuator

Fig: 5 PID Controller Control box

In the figure 4 and 5 Actuator and PID Control box shown here, Actuator is situated above the pillar and its function to minimize the displacement of masses when PID is ON. In the PID control panel set the value of PID, if value of PID changes it affects directly on the motion of Masses and thus active suspension displacement is less than the passive suspension. When PID is in off condition then taken readings for passive suspension.

Vibration measuring instrument:

The SVAN 954 is digital, Type 1 vibration level meter along with analyser. The instrument is intended to general vibration measurements, machinery condition monitoring. It can be used by consultants, maintenance services and industry R&D departments etc. Instrument allows the parallel acceleration, velocity and displacement measurements.

5. RESULTS AND DISCUSSIONS:

Below Table no.1 and 2 results of 2DOF quarter car model experimental setup of Active and passive suspension, in this used a PID controller for active suspension for improve the ride and handling performance.

Table 1 2DOF quarter car model experimental setup of Active suspension system

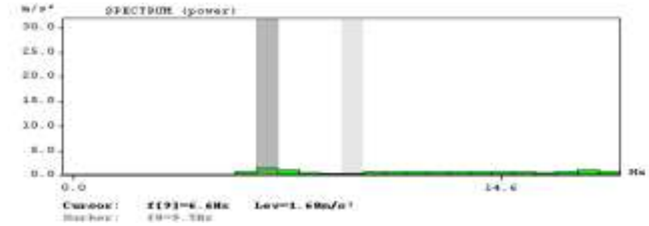
Active Suspension (PID Controller)		
When	P=2 I=20 D=0	
Speed(rpm)	's' (µm)	'a' (m/s2)
372.2	646	1.68
492.3	776	1.07
612.2	813	1.4
When	P=10 I=20 D=20	
Speed(rpm)	's' (µm)	'a' (m/s2)
372.2	610	2.37
492.3	617	2.45
When	P=2 I=20 D=10	
Speed(rpm)	's' (µm)	'a' (m/s2)
372.2	700	1.06
492.3	741	1.36

Table 2 2DOF quarter car model experimental setup of Passive suspension system

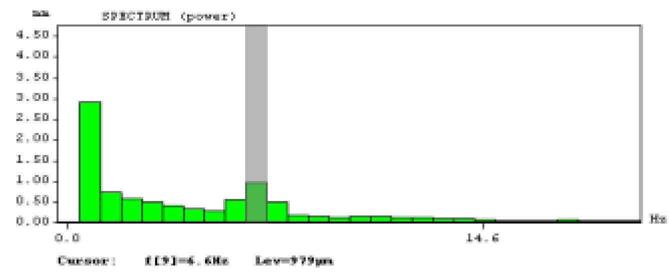
Passive Suspension		
When	P=2 I=20 D=0	
Speed(rpm)	's' (mm)	'a' (m/s2)
372.2	5.89	19.7
492.3	9.66	18
When	P=10 I=20 D=20	
Speed(rpm)	's' (mm)	'a' (m/s2)
372.2	5.56	18
492.3	9.66	18.8
When	P=2 I=20 D=10	
Speed(rpm)	's' (mm)	'a' (m/s2)
372.2	5.69	15.8
492.3	9.12	14.6

In comparison of Acceleration active suspension shows 1 to 3 m/s2 nothing more than that, but in case of passive suspension it becomes 14 to 20 m/s2. Similarly if compare the displacement, for active suspension 600 to 900 micrometer but passive suspension shows in 5 to 10mm.

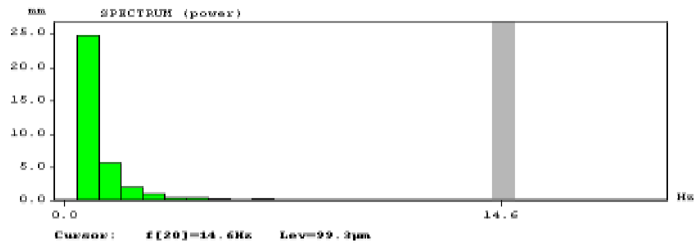
Graph: 1 (Experimental)



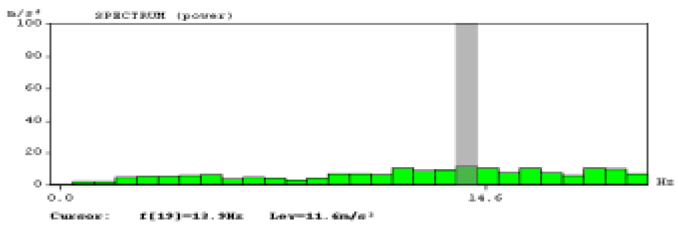
Graph: 2 (Experimental)



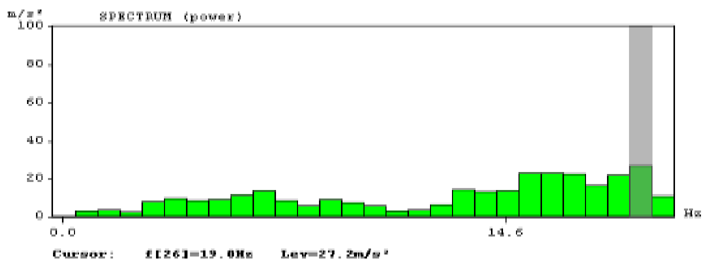
Graph: 3 (Experimental)



Graph: 4 (Experimental)



Graph: 5 (Experimental)



6. Conclusion:

A detailed experimental study of a quarter car model is presented. We study PID controller approaches in the active suspension system. A controllers used in suspension system we have designed such as Proportional Integral Derivative controller. In the passive suspension uses controller with the spring and damper, we will control on suspension deflection, acceleration of body and velocity of suspension masses. Active suspension system shows better control over displacement of system from the graphs. Comparison of active and passive suspension system result we conclude from that the active suspension system improve vehicle isolation properties and handling performance than the passive suspension system.

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