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STUDY ON PERFORMANCE OF SEMI ACTIVE VARIABLE DAMPING RIDE COMFORT SUSPENSION FOR AUTOMOBILES

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Abstract — *for comfort ride, handling, and safety of road vehicles suspension systems are of high importance. Conventional passive type suspension systems do not offer ride comfort on uneven road surfaces, corners, long bumps and short bumps. For a comfortable ride, all the conditions mentioned above require different damping ratios thereby to overcome these conditions a variable damping system is needed. A magneto rheological system for control of damping is introduced in the majority of high-end cars and recreational vehicles. The magneto rheological systems are effective but these systems are extremely costly and hence for budgetary reasons it cannot be applied to small cars and vehicles. The objective of this paper is to analyse the performance of a variable damping system at all above conditions of a ride by application of hydraulic dampers with orifice control system that will enable to control the damping ratios. Prototype of semi-active damper has been developed and experimentation was carried out. To analyse performance of system trial of developed system was taken.*

*Keywords- Hydraulic Damper, Orifice Control System, Semi-Active Suspension, Variable Damping, comfort ride***.**

I. INTRODUCTION

The purpose of a suspension system is to isolate the body and its occupants from the irregularities of the road surface. Ideally the body should ride level and without vertical motion however bumpy the road surface. Another important feature of suspension is that it should keep the tires on the ground all the time. If there were no suspension the tires would tend to lift off the ground every time they passed over a bump at the same time, the shock as the wheels left the ground and then came down again, would be transmitted directly to the passengers. Ideally the suspension should allow the wheels to move up and down so that they follow the undulations in the road while the body rides level. The first requirement therefore is that the wheels should be able to move vertically relative to the body.
The job of a car suspension is to maximize the friction between the tires and the road surface, to provide steering stability with good handling and to ensure the comfort of the passengers. If a road were perfectly flat, with no irregularities, suspensions wouldn't be necessary. But roads are far from flat. Even freshly paved highways have subtle imperfections that can interact with the wheels of a car. It's these imperfections that apply forces to the wheels. According to Newton's laws of motion, all forces have both magnitude and direction. A bump in the road causes the wheel to move up and down perpendicular to the road surface. The magnitude, of course, depends on whether the wheel is striking a giant bump or a tiny speck. Either way, the car wheel experiences a vertical acceleration as it passes over an imperfection. Without an intervening structure, all of wheel's vertical energy is transferred to the frame, which moves in the same direction. In such a situation, the wheels can lose contact with the road completely. Then, under the downward force of gravity, the wheels can slam back into the road surface. Thus we need a system that will absorb the energy of the vertically accelerated wheel, allowing the frame and body to ride undisturbed while the wheels follow bumps in the road.

Traditionally springs and dampers are used which referred as passive suspensions. Passive suspension system consists of either leaf spring, torsion beam suspension or coil spring and dampers or shock absorbers. The Function of Spring is to absorb shock energy from road bump and convert it into potential energy of spring. The Function of Shock Absorber is to dissipate shock energy from road bump without causing undue oscillation in the vehicle. Passive suspension has significant limitation in structural applications. The disadvantage of passive suspension system is it has fix characteristic, for example if the designer designs the suspension heavily damped it will only give good vehicle handling but at the same time it transfer road input (disturbance) to the vehicle body. The result of this action is if the vehicle travel at the low speed on a rough road or at the high speed in a straight line, it will be perceived as a harsh road. Then, if the suspension is design lightly damped, it will give more comfortable ride. Unfortunately, this design will reduce the stability of the vehicle in make turn and lane changing. Active suspension is a type of automotive suspension that controls the vertical movement of the wheels relative to the chassis or vehicle body with an on board system, rather than in passive suspensions where the movement is being determined entirely by the road surface. In Active suspension system, the damper or spring is interceding by the force actuator. This force actuator has its own task which is to add or dissipate energy from the system. The force actuator is control by various types of controller determine by the designer. The correct control strategy will give better compromise between comfort and vehicle stability. Therefore, active suspension system offers better riding comfort and vehicle handling to the passengers. But the active suspension systems are expensive and require frequent maintenance. Hence semi-active suspension systems are introduced. Semi-active suspension system was first proposed in 1970's. It provides a rapid change in rate of springs damping coefficients. It does not provide any energy into suspension system but the damper is replaced by controllable damper. The controllers determine the level of damping based on control strategy and automatically adjust the damper to the desired levels. This type of suspension system used external power to operate.

II. PROBLEM DEFINATION

The power required for totally active system is very high. Power consumption is lowest when the system is least active, as when driving on smooth road. Rough road and hard maneuvers, on the other hand, put more of a demand on the system. The hydraulic pump works harder and thus requires more power. Power consumption can be reduced by going with a semi-active suspension. Though the active suspension systems provide better ride, comfort and stability, but separate actuators are required which exert an independent force on the suspension to improve the riding characteristics. Other drawbacks of active suspension system are high cost and complication while installation. Also, this system need frequent maintenance after implementations. Maintenance of the active suspension system requires specialized tools and some problems can be difficult to diagnose. Currently using semi-active suspension system is MR Damper suspension system. It is found that in absence of particular additives MR fluid faced problem of sedimentation and formation of hard cake. Clamping effects in MR fluid have been discovered which leads to fluid particle separation. Though effective these MRF systems has above stated defects and are extremely costly, hence cannot be applied to small cars and vehicles. For these budgetary reasons, there is need to do research on another type of semi-active suspension system which is low cost system namely orifice variable damping suspension system (OVDSS) which will make variable damping possible with least system components and simple arrangement.

III. PROTOTYPE MODEL

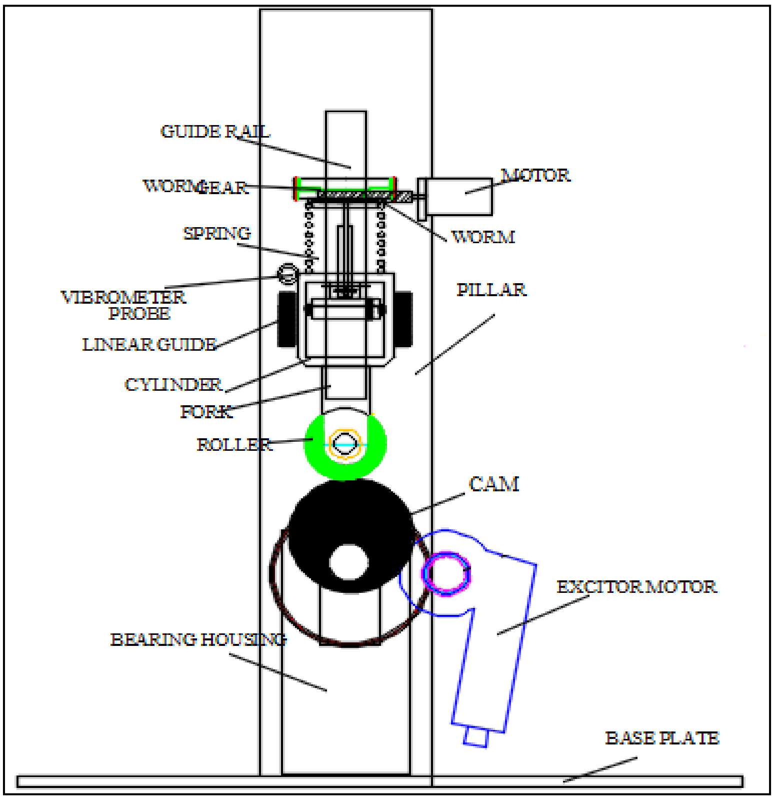

Figure 1. Variable damping comfort suspension test rig

The actual model of semi-active variable damping suspension system will get driven by 12 volt 2300 rpm DC Motor. On the motor shaft standard worm will get fitted which will drive the worm gear fitted on damper shaft with bush. The damper shaft will be placed inside the piston and Piston with piston ring will get placed into hydraulic damper body i.e. cylinder. The operating principle of the set-up is as follows; Geared motor is used to drive the cam which will move the roller either up or down, this used to change a) The motion of the cam driven by motor mounted on the exciter mechanism will make the shock absorber to move upwards or downwards, depending upon the speed and amplitude settings of eccentric cam and motor speed & the resultant displacement (δ), velocity (v) , acceleration (a) of the system in response to the excitation

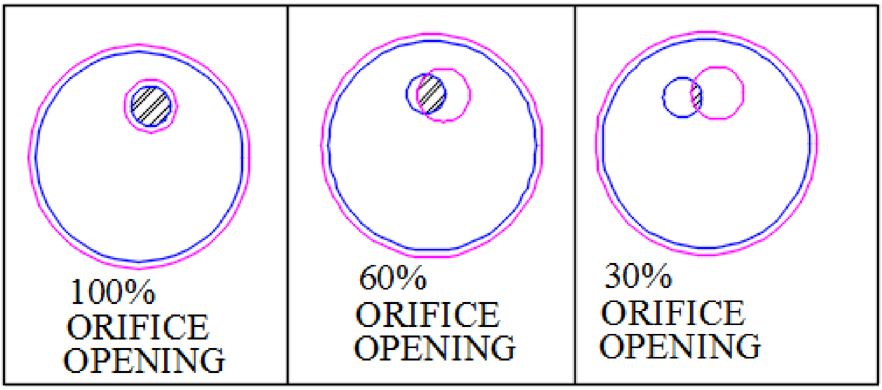

Figure 2. Orifice opening

To change the damping coefficient of the system by changing the damper hole size using the variable pitch disk. The rotary motion of the orifice disk changes the percentage opening of the orifice for example, 100% Orifice opening, 60% orifice opening and 30% Orifice opening The holes of damper thereby allowing oil to easily pass through system disks thus enable a smooth descent of the suspension in large bump where as the upward motion of the helical cam to close holes of the damper to allow reduded oil flow to provide better damping in case of short but series of bump.

IV. METHODOLOGY

A) System design

1. System Selection Based on Physical Constraints
2. Arrangement of Various Components
3. Components of System
4. Weight of Machine

B) Mechanical Design

1. Design of Piston
2. Design of Hydraulic Damper Body (Cylinder)
3. Design of Worm Wheel to operate the variable damping disk
4. Design of Damper Disk
5. Design of damper shaft
6. Selection of Damper Oil

V. EXPERIMENTAL SIMULATION

Vibrometer is used to test the dynamic performance of the OVDSS. The vibrometer is also called as seismometer and it is used to measure the displacement of vibrating machine or structure. The damper disk which turned in response to control to various rotated positions to register and select orifice sized to further control the flow through piston was get driven by worm and worm gear. Here we were considering the 30%, 60% and 90% opening of orifice due to gear rotation limits the rotation of damper disk. To control the position of gear rotation push button were used. For variation in excitation the center of slotted cam was shifted and to measure the actual excitation or eccentricity the Digital Vernier Caliper was used seismometer and it is used to measure the displacement of vibrating machine or structure. Experimentation During the actual experiment, the OVDSS obtain excitation from slotted cam. The various excitation paths provided during experimentation as shown in below fig.

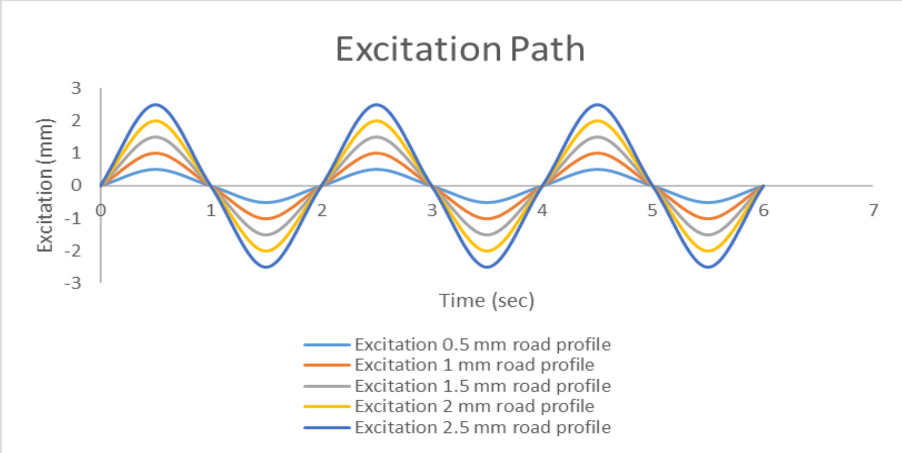

Figure 3. Excitation Path

For given experimental condition the equation of motion is written as

$$x = X\, e^{-\xi\omega t}\, \mathrm{Sin}\, (\omega_d t + \emptyset)$$

When system start disturbing i.e. at t=0, initial displacement x=0 and velocity were v. for x = 0, X ≠ 0 therefore ϕ = 0. Considering energy conversion, the simplified equation of motion was written as follows

$$x = \frac{\sqrt{2gh}}{\omega_d} e^{-(C/2m)t}\, \mathrm{Sin}\, (\omega_d t)$$

Using this equation different values of damping coefficient (C) were found. Firstly, the excitation was set to 0.5 mm and orifice opening was kept at 90%. At this condition, the values of x & X were measured. Keeping 90% opening constant the various readings of x & X were taken at various excitation. As absolute vibration amplitude (X) at vehicle body measured experimentally with vibrometer, theoretically it was calculated by using following relation

$$X = \frac{Y\sqrt{1 + (2\xi\frac{\omega}{\omega_n})^2}}{\sqrt{(1 - (\frac{\omega}{\omega_n})^2)^2 + (2\xi\frac{\omega}{\omega_n})^2}}$$

Same set of readings were taken for 60% opening and 30% opening.
For the validation of system the experiment result were compared with the therotical results. The main parameter which was measuerd experimentally and therotically was the vibration amplitude at vehicle body. Sufficient cycles have been measured for each single loading case to ensure the performance stability and uniformity

VI. RESULTS

Case I : 90% orifice opening

In this case the orifice opening was 90% which allow oil to easily pass through damper disk thus enable smooth descent suspension. From Fig. we can say that the large orifice size is optimized for soft ride as the damping characteristic of shock absorber is reduced.

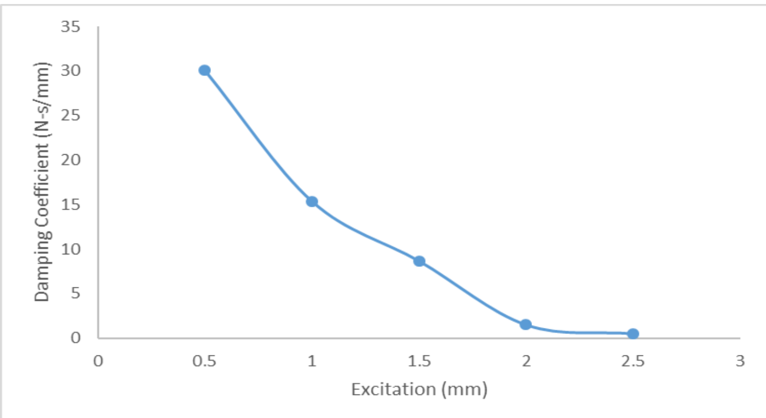

Figure4.Damping coefficient vs Excitation having 90% orifice opening

Case II: 60% orifice opening

In this case 60% orifice opening was considered, means there was decrease in orifice opening. This was second or intermediate position of orifice opening. As the orifice opening is decreased it offer more restriction to flow through orifice. From Fig it is evaluated that 60% orifice opening provide medium or intermediate damping action.

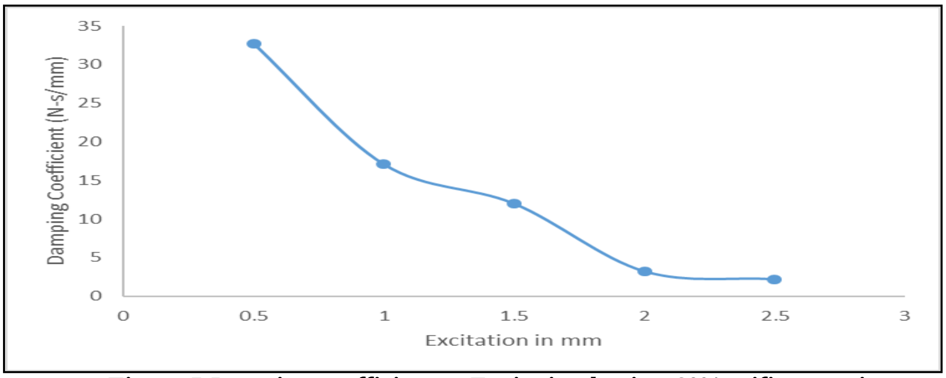

Figure 5.Damping coefficient vs Excitation having 60% orifice opening

Case III: 30% orifice opening

In this case 30% orifice opening provided high flow restriction through orifice. Due to more flow restriction, the damping characteristic of shock absorber is increased which provide stiff or hard ride at all excitation condition as compare to 60% & 90% orifice opening

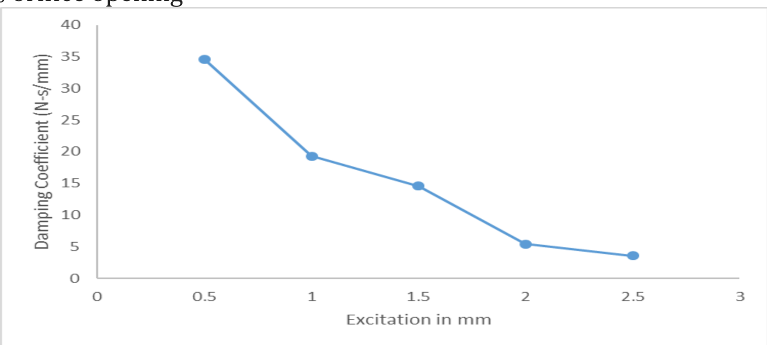

Figure 6.Damping coefficient vs Excitation having 30% orifice opening

Comparison of all cases

The same condition of excitation provides relation of damping coefficient to velocity and % orifice opening. The damping coefficient of OVDSS against velocity under various excitation condition and orifice opening condition is shown in Fig

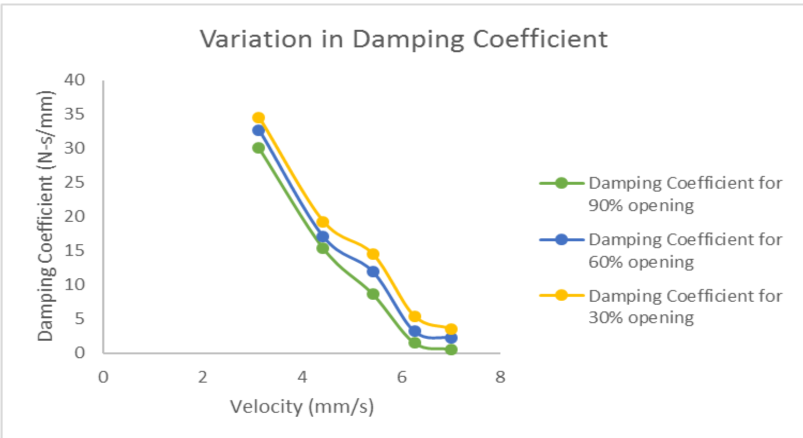

Figure 7. Comparisons of Damping coefficient vs Excitation having

30% , 60% & 90% orifice opening

VII. CONCLUSION

To develop continuous variable damper for semi-active suspension of a passenger cars i.e. OVDSS, variable damping mechanisms were analyzed and a damper is designed and developed.

The performance was confirmed through experiments. From experimentation, it is observed that the damping coefficient changes according to percent orifice opening.

It has been found that as orifice opening decreases, the restriction to flow through orifice increases accordingly the damping coefficient also increases.

It has also found that for better ride comfort the 90% orifice opening is suitable for large bumps, for short series of bumps the 30% orifice opening is suitable and for intermediate bumps 60% orifice opening provide good results.

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