VARIABLE DAMPING FORCE SHOCK ABSORBER

D.Mohankumar1, R. Sabarish1, Dr. M. PremJeyaKumar2,
1 Research Scholar, Department of Automobile engineering, BIST, BIHER, Bharath University, Chennai.
2 Supervisor, Department of Automobile engineering, BIST, BIHER, Bharath University, Chennai.
mohankumar.auto@bharathuniv.ac.in, Sabarish5041@gmail.com, prem.auto@bharathuniv.ac.in.

Abstract: The automobile chassis is mounted on the axles, not directly but through some form of springs. This is done to isolate the vehicle body from the road shocks which may be in the form of bounce, pitch, roll or sway. These tendencies give rise to an uncomfortable ride and cause additional stress in the automobile frame and body. All the parts which perform the function of isolating the automobile from the road shocks are collectively called a suspension system. It includes the springing device used and various mounting. The present shock absorber damping force will remain same for shocks of different magnitude. The result of using the present shock absorber is more vibration for shocks of smaller magnitude, which result in lesser comfort for the passengers. The aim of the project is to provide better comfort for the passengers, when the vehicle experiencing shocks. The comfortability can be increased by varying the damping force. In order to achieve better comfort, shock absorber damping is increased by having grooves in the inner cylinder of the shock absorber. The fluid can pass through both piston nozzles and through grooves for average shocks. Once the piston gets past the grooves, the shock absorber will behave like a conventional shock absorber. Since the force experienced by a piston varies, the name has given as variable damping force shock absorber. This result in a cushioning of average shocks and at the same time because of friction experienced by a fluid in grooves, damping of vibrations will be faster. The analytical solution has been given for the vehicle. The cutting of grooves indirectly reduces the unsprung weight of the vehicle which also result in a reduced vibrations. The testing of the modified shock absorber shown better results while, comparing with the present shock absorber.

I INTRODUCTION

Inventions are made to ease the effort of people. Among the inventions, the most important in the last century is a vehicle. In order to ease the road transport it has been invented. Since its invention lot of changes has been made to increase the comfort of passengers. A vehicle contains lot of systems to add comfort to the passengers. The vital one is a suspension system, which is used to connect chassis and the vehicle wheels. A suspension system is used to suspend the chassis from responding to road irregularities. In the suspension system the most important one is damper and helical spring[1-4].

A lot of research has been going on over optimization of suspension system. Each researcher has their own ideas in enhancing the performance. A.M.A. Soliman proposed an adaptation algorithm to maintain optimal performance over the wide range of input conditions typically encountered by a vehicle. Richard van kasteel, proposed a new shock absorber model with an application in vehicle dynamics. Peter Holen and Boris Thorvald given an analytic expression with simulations of a 3-d truck model to study roll and bounce damping for heavy vehicles to illustrate the limits in performance resulting from the choice of dampers and mounting positions. The damper is used to absorb shocks, when vehicles run over a pit or irregular surface. This is done to avoid fatigue to the passengers. The energy of road shocks causes the spring to Oscillate[5-9]. These oscillations are restricted to a reasonable level by a damper, which is more commonly called a shock absorber.

Objects of the suspension are:

a. To prevent road shocks from being transmitted to the vehicle components.
b. To safeguard the occupants from road shocks.
c. To preserve the stability of the vehicle in pitching or rolling in motion.

Nowadays, the most used damper is twin tube shock absorber. To modify the present damper, description and working should be known. So it has been given below with the dimensions.

II PRINCIPLE BEHIND SHOCK ABSORBER

Dampers / Shock absorber are designed to work in concert with the spring to keep the tyre contact patch on the racing surface. In bump, the damper compresses to help control the wheel travel and prevent "overshoot", and in rebound, the damper helps absorb the energy stored in the spring.

Good damper control is the most significant contributor to the "mechanical grip" we hear so much about. Mechanical grip is all about keeping the tyre patch in contact with the racing surface with as little excitation as possible. It is the task of the damper to dissipate that excitement. Thus Shock absorber can be better called as an energy-absorbing device that works on the conversion of energy principle for stopping moving load with minimum load rebound and shock to the load and to surrounding equipment. To stop a moving load smoothly, is necessary in motion control. Different types of instruments like rubber snubber, a compression spring, and a dashpot is used for stopping the moving load. These instruments accomplished their tasks by absorbing energy[10-15].

In spring and snubber, energy is stored and when they are compressed the energy is released thereby resulting in a rebound. In a dash pot on the other hand if a force acts against
the piston, it encounters high resistance from the fluid at the beginning of the stroke, then much less as the piston retracts. However, there is a limitation in working of springs, snubbers, and dashpots. These instruments do not dissipate the energy uniformly. The energy is transferred to the load uniformly only in the case of shock absorbers. Take the case when in all the above mentioned instruments (snubber, dashpots, springs, and shock absorber) the same amount of kinetic energy is absorbed. In this situation the energy will be dissipated at differing rates [16-20].

The kinetic energy of the load is converted into heat by the shock absorbers which is transferred into the atmosphere. There is no rebound in shock absorbers. The potentially dangerous shocks are prevented from reaching to the equipment.

The design of a normal shock absorber is quite simple to understand. Generally speaking, a shock absorber contains double-walled cylinder. There is space between the concentric inner and outer walls, a piston, some means of mechanical return for the piston, and a mounting plate. The piston can be mounted externally around the piston rod or internally on the inside of the cylinder body. In the inner cylinder wall many orifices are drilled. The cylinder contains the fluid which is void of air as the bubbles may reduce the efficiency of the shock absorber. The movement of the piston inside, forces the fluid through the orifices in the inner cylinder wall. The orifice is closed as the the piston retracts thereby reducing the effective metering area, and maintaining a uniform deceleration force as the load loses its energy.

The pressure of the fluid remains constant which provides constant resistance to the load. Since the kinetic energy of the load becomes zero, the load slows to a stop. Also as the shock absorber stores no energy, there is no rebound. The shock absorber returns to its position after the load is removed. The piston is pushed by the spring outward and open a check valve. This permits the flow of fluid from behind the piston to the space the piston was in its retracted position.

While mounting care must be taken to bolt the shock absorbers to a non-flexing mounting structure. External stop is also necessary for providing a firm positioning point, and for preventing the shock absorber piston from bottoming out at the end of its deceleration stroke. Usually an external stop is required to prevent damage both to their product and to the user's equipment. Shock absorber can be mounted through a drilled hole. The mounting can be secured by using stop collar.

Shock absorbers work on the principle of fluid displacement as you consider them a working piston, having hydraulic fluid in it. The hydraulic fluid in the piston, is forced through tiny holes -which are called 'Orifices'- in the piston as the suspension travels through jounce and rebound. However, the orifices let only a small amount of fluid through the piston, which in turn slows down spring and suspension movement. Shock absorbers are velocity sensitive hydraulic damping devices, meaning the faster the suspension moves, the more resistance the shock absorbers provide. Because of this feature, shock absorbers adjust to road conditions. As a result, shock absorbers reduce bounce, roll or sway, brake dive and acceleration squad

The basic principle of a shock absorber is that as the unit compresses or rebounds, valves within the oil-filled tube restrict the flow of oil to reduce the movement of the piston. This reduces oscillation of the road spring, keeping the tyre in contact with the road and improving ride comfort.

Monotube and twin-tube shock absorbers perform the same tasks but differ in design.

A monotube gas shock is filled with oil and gas at 25-30 bar pressure, and a movable separator piston separates the two substances. A piston valve attached to the piston rod controls oil flow and damping effect [21-26].

Monotube shock absorber schematic

A twin-tube shock absorber has two concentric chambers: the oil-filled working chamber housing the piston rod and piston valve; the compensation chamber formed of the space between the working cylinder and the outer tube; this is filled with two-thirds oil and one third air. In a gas-pressurised shock, gas at 6-8 bar pressure replaces the air. The piston valve and a valve in the base of the working chamber control oil flow and damping effect [27-31].
III TWIN TUBE-DAMPER

A. Principle

In hydraulic dampers, pumping fluid through an orifice converts energy to heat which can then be dissipated into atmosphere. The objective in a damper valve design is to maintain consistent laminar flow characteristics through operating range of loads.

B. Description

The outer tube is connected at the bottom of the axle or suspension member with the help of an eye. The inner tube has an end blank at the bottom. It acts as a non-return valve. It allows the oil to pass from the cylinder to reservoir during rebound stroke. The compression disc, washer, orifice disc, conical springs are all riveted to the end blank. The upper part has a dirt excluder, a bearing with an oil return channel within it, a seal for piston rod and piston have two non-return valves with an eye welded to upper end of the piston rod. The cylinder is fully filled with hydraulic fluid while reservoir is partially filled. The piston rods are chrome plated and super finished for improved wear corrosion resistance. The piston is of sintered iron which has got good self lubricating properties and reduces wear due to friction[32-36].

C. Working

When the piston descends, causing the central rebound valve to close and the piston bump valve opens. So the fluid is transferred from the lower to upper cylinder chamber. At the same time, the outer base rebound valve closes and the central base bump valve opens, displacing a quantity of fluid to the outer reservoir. The flow of fluid through the orifice provides the necessary damping force.

Fig 1 Schematic representation of a Damper

During rebound stroke, the piston is pushed up towards the cylinder. The fluid above the piston passes through to lower part of cylinder as rebound valve opens. Due to volume occupied by the piston rod, there is not enough fluid above the piston to completely fill the volume of the cylinder below the piston. Hence the lower portion of the cylinder develops the slight vacuum and extra fluid flow from the reservoir to lower portion of the cylinder. This happens only when foot valve opens.

In this way, the shock absorbers successfully perform two main functions. They are

1. To control quick bouncing of wheels on road surface.
2. To control slow bouncing of the body on the
suspension springs.

**IV DESIGN OF VARIABLE DAMPING FORCE SHOCK ABSORBER**

To vary the dampers damping characteristics grooves can be cut in the inner cylinder of damper.

**A. Determination of shape and size of grooves**

To increase the comfort of passengers for average shocks of smaller magnitude, nature and dimensions of grooves are to be determined. So, the grooves can be easily machinable. These constraints lead to v-groove. Apart from these, there are some more constraints like

a. Inner cylinder thickness (of1mm.)

b. Depth and width of grooves.

c. Position of grooves.

The above three constraints will directly affect the working of damper. On taking the account of the first two, three v-grooves of 0.5x0.5x25 are taken. Since the grooves should be placed without affecting the strength of the damper cylinder. So the grooves are placed at an angle of 120 degree difference. The sectioned view of the modified damper is shown in the figure below.

![Fig 2 Schematic representation of Modified Damper](image)

To design the variable damping force shock absorber the following assumptions are made through the guidelines of EUROPEAN SHOCK ABSORBER ASSOCIATION.

**Design procedure consist of following determination**

- Determination of Diameter of the piston.
- Determination of Diameter of the rod.
- Determination of Length of the cylinder.
- Determination of Outer diameter of the shock absorber.
- Determination of working Temperature of the fluid.
- Determination of Damping forces
- During Rebound
- During Compression
- Determination of damping co-efficient.
- Conventional shock absorber
- Variable damping force shock absorber

**Assumptions**

- Piston velocity = 1m/s
- Density of fluid (Turbine oil) = 9000N/m³
- Rebound pressure = 5 MPa

**Design Calculation**

**Diameter of the piston (dp)**

According to EuSAMA (European Shock Absorber Manufactures Association) the standard piston diameters for light vehicles are:

<table>
<thead>
<tr>
<th>Diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
</tr>
<tr>
<td>22</td>
</tr>
<tr>
<td>27</td>
</tr>
<tr>
<td>30</td>
</tr>
</tbody>
</table>

Here we have selected a piston of diameter, dp = 30 mm.

**Diameter of the rod (dr)**

The diameter of the rod, dr = (3 to 7)* dp

The diameter of the rod, dr = 0.4* 30

The diameter of the rod, dr = 12 mm.

**Outer diameter of shock absorber (D) (Dust cover)**

D0.3 = (3.4*[V0.7 (air)])/ Kt

D = (3.4 *[60 * 1000)/36000.7])/60

Diameter (D) = 0.0498m.

Diameter (D) = 50mm.

**chosen viscosity of the fluid**

The viscosity of the fluid with temperature variation is given below.

<table>
<thead>
<tr>
<th>S.NO</th>
<th>Temperature (°C)</th>
<th>Time (Seconds)</th>
<th>Kinematic viscosity (Cs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>90</td>
<td>52</td>
<td>6.8</td>
</tr>
<tr>
<td>2.</td>
<td>80</td>
<td>47</td>
<td>10.0</td>
</tr>
<tr>
<td>3.</td>
<td>70</td>
<td>54</td>
<td>11.5</td>
</tr>
<tr>
<td>4.</td>
<td>60</td>
<td>62</td>
<td>13.0</td>
</tr>
</tbody>
</table>

**Determination of design Temperature of working fluid**

\[ T = Ta + \left[ \frac{N}{427} \times Kt \times So \right] \]

Temperature, T = 36°C

**Determination of design compression force – F(r)**

\[ Fc = \left( Ap - Ar \right) * Pr \]

\[ Fc = \pi/4[dp^2 - dr^2]*Pr \]

Fc = 2388N

**Determination of design rebound force – F( e )**

\[ Fr = \left( Ap + Pr \right) \]

\[ Fr = \pi/4[dp^2]*Pr \]

Fr = 716N

**Determination of damping coefficient (conventional)**

\[ \frac{4A_p^2}{\mu Fc \sqrt{vP_e/2g}} \]
Conventional Compression

\[ K_c = 2092.92 \text{ N/s/m} \]

Rebound

\[ K_r = \frac{4(A_p - A_r)^2}{\mu Fr} \sqrt{\frac{Pr}{2g}} \]

Determination of damping coefficient (variable)

**Compression**

Where, \( F_c = F_{c1} + (b^2d) \)
\( b = 5*10^{-3} \text{ m}. \)
\( d = 0.5 *10^{-3} \text{ m}. \)
\( F_c = 30*10^{-6} \text{ m}^2 \)

\[ K_c = \frac{4A_p^2}{\mu F_c} \sqrt{\frac{Pr}{2g}} \]
\[ K_c = 1932 \text{ N/m} \]

**Rebound**

\( F_r = Fr1 + (b^2d) \)
\( b = 5*10^{-3} \text{ m}. \)
\( d = 0.5 *10^{-3} \text{ m}. \)
\( Fr = 12*10^{-6} \text{ m}^2 \)

\[ K_r = \frac{4(A_p - A_r)^2}{\mu F_r} \sqrt{\frac{Pr}{2g}} \]
\[ K_r = 7136 \text{ N/m} \]

**Fig. 3 Schematic arrangement of set up**

The experimental set up for testing the shock absorber is shown in figure 4.1 consists of frame connected to the axle through damper, an AC motor coupled to the axle and a variable transformer to maintain speed of motor.

**Motor**

The motor used for the project is a three phase induction type, 7.5 HP motor with 1500 rpm. It is used to transmit rotary motion to the wheels of the set up for simulation.

**Variable Transformer**

Variable Transformer is used to maintain constant power supply to a motor to maintain constant speed. It consists of primary and secondary coils. Primary coils are connected to 230V regular power supply and the secondary coils are stepping up the voltage to run the motor. The multiplication factor of 60 is maintained.

**Vibration Analyzer**

It is used to measure and analyze the vibration characteristicslike displacement, acceleration and velocity with respect to the frequency of it. The sensing material is a piezo-electric transducer, which will send electric signal to the instrument after sensing vibrations.

**Experimental Procedure**

The experimental set up is shown in the above figure 6.1. The power supply is given to the variable transformer and multiplication factor is increased still the motor speed is constant to take on the load of set up. Using vibration analyzer the readings are taken for various loads and the displacement, velocity and acceleration are noted down.

From the experimental data bound damping coefficient and rebound damping coefficient are calculated. Graphs are drawn by substituting the values in the proposed model equation.

**Calculation of damping Co-efficient**

Based on the experimental set up, model has given below to find the damping co-efficient through the principle of forced damping.

**Fig-4 schematic representation for calculating damping co-efficient**

By Newton law

\[ F_c = -M_1 \ddot{X}_1 + K_1 X_1 + C_1 \dot{X}_1, \]
\[ F_c + F_s = F_r = -M_2 \ddot{X}_2 + K_2 X_2 + C_2 \dot{X}_2 + K_s(X_2 - X_1) + C_s(\dot{X}_2 - \dot{X}_1) \]
\[ M \ddot{X}_c = \frac{M_2}{M_1 + M_2} \ddot{X}_1 + \frac{K_1}{M_1 + M_2} X_1 + \frac{C_1}{M_1 + M_2} \dot{X}_1 + \frac{K_s}{M_1 + M_2} (X_2 - X_1) + \frac{C_s}{M_1 + M_2} (\dot{X}_2 - \dot{X}_1) \]

Where,

\( M_1 = \text{sprung Mass of the vehicle (Kg)} \)
\( C_1 = \text{Damping co-efficient (N/s/m)} \)
\( K_1 = \text{Stiffness of spring (N/m)} \)

\[ \ddot{X}_1 = \text{Acceleration of the body (m/s}^2) \]
\[ \dot{X}_1 = \text{Velocity of the body (m/s)} \]
\[ X_1 = \text{Displacement of the body (m)} \]
\[ F_1 = \text{forced due to the applied mass (N)} \]
\[ \ddot{X}_2 = \text{Acceleration of the body (m/s}^2) \]
\[ \dot{X}_2 = \text{Velocity of the body (m/s)} \]
\[ X_2 = \text{Displacement of the body (m)} \]
\[ F_2 = \text{forced due to the shock (N)} \]
\[ F_2 = \text{ground reaction (N)} \]
\[ M_1 = \text{sprung mass (Kg)} \]
By knowing the above parameters of sprung and unsprung masses we can calculate the damping co-efficient of the damper using the above equation (i).

RESULTS AND DISCUSSIONS

In this chapter the experimental readings are tabulated, graphs are drawn using these data and the discussions are carried out for the obtained results.

DISPLACEMENT

Displacement of the damper found to be increasing during rebound and decreasing during bound for various loads.

VELOCITY

Velocity of the damper found to be increasing during rebound and decreasing during bound for various loads.

ACCELERATION

Acceleration of the damper found to be increasing during rebound and decreasing during bound for various loads.

REBOUND DAMPING CO-EFFICIENT

Rebound Damping co-efficient of the damper find to be increasing during rebound with increase in loads.

Fig. 2 shows the variation of Rebound Damping co-efficient with respect to different frequency for both present and modified shock absorber at no load. The maximum rebound damping co-efficient is of present shock absorber is 1819 N-s/m, where as for modified damper is 1800.90 N-s/m.

Fig. 4 shows the variation of Rebound Damping co-efficient with respect to different frequency for both present and modified shock absorber at no load. The maximum rebound damping co-efficient is of present shock absorber and it is 2601.50 N-s/m, where as for modified damper is 2550.85 N-s/m.

Fig. 6 shows the variation of Rebound Damping co-efficient with respect to different frequency for both present and modified shock absorber at no load. The maximum rebound damping co-efficient is of present shock absorber and it is 4195.00 N-s/m, where as for modified damper is 4167.64 N-s/m.

Fig. 8 shows the variation of Rebound Damping co-efficient with respect to different frequency for both present and modified shock absorber at no load. The maximum rebound damping co-efficient is of present shock absorber and it is 5512.75 N-s/m, where as for modified damper is 5462.80 N-s/m.

BOUND DAMPING CO-EFFICIENT

Bound Damping co-efficient of the damper found to be increasing during bound with increase in loads.

Fig. 1 shows the variation of Bound Damping co-efficient with respect to different frequency for both present and modified shock absorber at no load. The maximum bound damping co-efficient is of present shock absorber and it is 1974.11 N-s/m, where as for modified damper is 1950.00 N-s/m.

Fig. 5 shows the variation of bound Damping co-efficient with respect to different frequency for both present and modified shock absorber at no load. The maximum bound damping co-efficient is of present shock absorber and it is 2531.20 N-s/m, where as for modified damper is 2483.17 N-s/m.

Fig. 7 shows the variation of bound Damping co-efficient with respect to different frequency for both present and modified shock absorber at no load. The maximum bound damping co-efficient is of present shock absorber and it is 2888.20 N-s/m, where as for modified damper is 2861.19 N-s/m.

GRAPHS

The readings are noted down while testing the conventional & variable shock absorber for different weights and by using these readings, graphs are plotted with bound & rebound damping co-efficient in y-axis.

FOR No Load

At 25Kn/hr

![Graph 5](image-url)

![Graph 6](image-url)
FOR 5 Kg
At 25Km/hr

Fig7

FOR 10 Kg
At 25Km/hr

Fig8

FOR 15 Kg
At 25Km/hr

Fig9
CONCLUSION& FUTUREWORK

The modified damper has more displacement, less compression damping co-efficient & less rebound damping co-efficient when compared to the present damper for average shocks. It’s all due to reduced unsprung mass, friction of grooves, increased oil passages and increased heat dissipation due to the machined grooves. The modified damper provides better comfort, stability to the vehicle with reduced vibrations. Further modification can be done by drilling holes circumferentially to vary the damping co-efficient.

REFERENCES

36. Lakshmi C., Ponnavaikko M., Sundararajan M., Improved kernel common vector method for face recognition varying in background conditions, Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), V-6026 LNCS, PP-175-186, 2010


