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Development of Pneumatic Shock Absorber by Variable Damping

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Abstract*: *In commercial models and premium vehicles the damping is varied by sensing the road conditions, driver's action etc. using ECU's and damping properties are varied every second. This advanced technology is very costly and complicated for middle class consumers who also need some comfort with low cost. The main issue here is to vary the damping of hydraulic shock absorbers according to the shock to which it is subjected. Thus by sensing the speed of the shock absorber and changing the vibration absorbing capacity of the damper with respect to it will surely be useful. In this project we used a spring valve to sense the speed of the Shock absorber and controlling the valve which is fitted inside the damper. By Variable damping pneumatic shock absorber we can get enough comfort with a simple and cost efficient setup.

Keywords: Variable damping Pneumatic Shock Absorber; Vibration Capacity; Hydraulic Shock Absorber; Damper.

I. INTRODUCTION

The suspension is a major component of any automobile as it absorbs the vibrations produced due to road conditions and sudden acceleration or deceleration. It comprises of tire, wheels, shock absorber and other linkages. It is designed not only to handle the bumps but also the turning and breaking forces. **Bauer W** et.al [2] Defines in the small cross sections the increased velocity is obtained. This cross section must not be lower than the minimum value. Smaller the cross section damping value will be more and this result in the property loss of the suspension oil used which is unfavorable. **Bhandari V B** et al [3] Explains that suspension is not only designed to absorb disturbances but also to handle the turning and braking of the vehicle. The main aim of any shock absorber is to isolate the road conditions from passengers. Usually a pair of telescopic fork is present in the front wheel of the vehicle and one or two on the rear side. The general principle used in the making of the shock absorber may be mechanical, hydraulic or it may be pneumatic way of approach. **Chavan D K** et al [4] proposed that in an air shock absorber air chamber and a piston is reciprocated to compress the air to do the damping action. The presence of compressed air in it makes it Stiffer. Pneumatic shock absorber has the tendency to adjust the loading conditions, height of the Vehicle, pressure and high speed settings are also made easily. Since the damping is taken place by the usage of compression the noise problems does not occur in this suspensions. Likewise pneumatics is applied in many fields to convert the motions from one place to another due to its following advantages **HrishikeshDeo**et.al. [7] Establishes that unlike hydraulic shock absorbers the stiffness value can be changed in pneumatic suspensions. This is done by changing the volume of air stored in the suspension. Advanced technologies use variable stiffness for different speed and road applications. It is done by a high pressure compressor. **Kommalapati**et.al. [8] says that the main duty of a shock absorber is to absorb and dissipate energy. One thing to be kept in mind according to him is that design considerations must say about the time it usually takes to dissipate the energy into heat. The dashpots are designed in a way to get the energy to go into the viscous fluid. Some shock absorbers of electromagnetic type store the energy for later use. It is responsible for comforting in many uneven roads. **Maxwell J C** et al [9] Makes it clear that the viscosity of a liquid decreases with increase in the temperature whereas the viscosity of air increases with the increase in temperature. The pressure of air is directly proportional to the viscosity values. This makes the two fluids directed in a different way and to serve multiple applications. **Prof. D. A. More** et al [12] Describes that air-suspension system is used in the place of helical spring in the vehicle which are traditionally used to absorb shock and comfort. The heavy duty rubber is employed to manufacture the air springs. Various parts involved in this air suspension system is on-board compressors, air bags, solenoids valves and lines to balance heavy preload improves vehicles ride. **Pranav Badole**et.al. [14] Describes the better ride comfort is achieved through bellow tube air suspension to both riders and passengers. The on-board compressor and off-board compressor are mounted to the mudguard of the rear wheel. The off-board compressor helps in the inflation of the bellow tube. Pressure relief valve is also used during compression to adjust pressure..

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II. DESIGN AND ANALYSIS

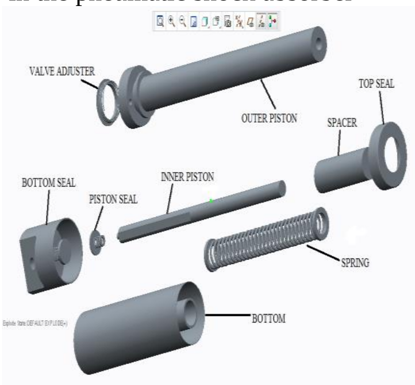
The design of variable damping pneumatic shock absorber is been created using CERO.

2.1 Prototype Model in 3D view:

The design of the variable damping pneumatic shock absorber is carried through cero software. And the assembly of the suspension is also done with the help of cero software.

2.2 Exploded View of Prototype Model

The exploded view the variable damping pneumatic shock absorber is been shown below to understand the clear view of every parts in the pneumatic shock absorber



III. CALCULATION

3.1 Natural Frequency (ω_n) Of Old Suspension

Dual pitch spring,

$D_1 = 20mm \quad N_1 = 28$

$D_2 = 18mm \quad N_2 = 38$

$P_1 = 7mm \quad D = 4mm$

$P_2 = 4mm \quad L = 348$

$m = 300kg$

$$K_1 = \frac{(0.003)^4 (77 \times 10^9)}{8 \times (0.02)^3 \times 28}$$

$$\mathbf{K_1 = 3481 N/m}$$

$$K_2 = \frac{(0.003)^4 (77 \times 10^9)}{8 \times (0.018)^3 \times 38}$$

$$\mathbf{K_2 = 3518 N/m}$$

$$\frac{1}{K} = \frac{1}{K_1} + \frac{1}{K_2} = 1750 \text{ N/m}$$

$$\omega_n = \sqrt{k/m}$$

$$\mathbf{\omega_n = 4.18 \text{ rad/s}}$$

$C_c = 2mWn$

$\mathbf{Cc = 836}$

3.2 Natural Frequency (ω_n) Of New Suspension

Dual pitch spring,

$D = 20mm \quad N = 38$

$P = 8mm \quad L = 300$

$d = 3mm \quad m = 300kg$

$$K = \frac{(0.003)^4 (77 \times 10^9)}{8 \times (0.02)^3 \times 38}$$

$$\mathbf{K = 2565 N/m}$$

$$\omega_n = \sqrt{k/m}$$

$$\mathbf{\omega_n = 2.92 rad/s}$$

$$C_c = 2m\omega_n$$

$$\mathbf{C_c = 1752}$$

IV. FABRICATION

This prototype model for Variable Damping Pneumatic Shock Absorber consists of

1. Outer Piston
2. Bottom Seal
3. Inner Piston
4. Bottom
5. Piston Seal
6. Spring
7. Spacer
8. Top Seal
9. Valve Tighter
10. Fork Cap

4.1 Outer Piston

This component uses the viscosity of the compressed air present the outer ring of the bottom. The outer piston head is made with 2 holes each of 5mm in diameter. The air flows through these valve to create resistance. The outer piston is hollow and this carries the spacer, inner piston and the compression spring. It is manufactured by CNC machine with the tolerance of ±0.01 to obtain better clearance with the bottom part.

4.2 Bottom Seal

The bottom seal is an important part which is designed to maintain the air pressure during every stroke of the suspension. It comprises of a check valve which allows the compressed air from the piston seal to enter into the outer ring and seals the leakage of air back into the inner piston

4.3 Inner Piston

It is a 13mm rod used to fix the piston seal. The inner piston is designed with a thread at one end to adjust the clearance volume in the inner bottom part. The other end has a small projection to close the piston seal at the compression stroke.

4.4 Bottom

It is the most complicated part in the total product, which is made by the CNC operation. The coding is created by observing the dimensions in the design of the suspension and it is made with the tolerance valve of ±0.01. It maintains a clearance between the outer pistons to provide resistance.

4.5 Piston Seal

This component is responsible for maintaining the pressure of air inside the outer ring of the bottom. The piston seal is mated with the inner bottom to compress the atmospheric air to a very high pressure. The seal is designed in a manner to suck air from the center hole during suction stroke and closed by the inner piston during compression stroke.

4.6 Spring

The suspension system uses the open coil helical spring made of steel. It is responsible for the carrying of load created by the bump, sway and steering the vehicle. The energy is stored in the spring as compression energy and this is dissipated by the damping action of the shock absorber.

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4.7 Spacer

This component is used to fill the remaining gap in the suspension fork to maintain spring in tight fit. The spacer also has internal threads which holds the inner piston and modifies the clearance volume between the piston seal and the bottom.

4.8 Top Seal

It seals the bottom part and creates an enclosed surface to maintain a 12bar pressure. Small grove is placed in the seal to lock the compressed air.

4.9 Valve Tighter

The valve which is placed on the outer piston is made with two holes and this valve is adjusted until correct preload is set in the valve spring. Thus the valve tighter is used for the purpose of applying preload to the suspension valve.

4.10 Fork Cap

The spring, spacer and the inner piston are maintained in compression with the help of fork cap. It is used for the purpose of closing the hollow forks.

4.11 Working Principle

The variable damping pneumatic shock absorber function is on the basic principle of changing. The diameter of the valve corresponding to the pressure generate inside the shock absorber. As the suspension is compressed the air flows through the valve holes, the velocity of the piston decides the pressure created in the suspension. If the pressure produced is enough to compress the valve spring the valve adjuster opens and the diameter increases. The inner piston moves along with the outer piston with the clearance volume. Which compresses the atmospheric air to a pressure of 12 bar and feed into the outer bottom. As the compression is happens on every cycle of the suspension movement. So the pressure remains same for longer period until idling of vehicle occurs. The valve tighter adjusts the preload of the valve depending on the vehicle specification on which it is implemented.

Fig1: Fabricated parts

V. SHOCK ABSORBER TESTING

The universal shock absorber testing rig plays a vital role in producing better suspensions by calculating basic parameters such as damping force, stiffness, natural frequency and velocity of the fluid in the component. The apparatus having the capacity to withstand a maximum load of 2500 kg, so it is easy to identify the dynamic characteristics of the shock absorber at different velocities. The parameters which are responsible for the damping force generated in the system are diameter of the valve, viscosity of the fluid and velocity of the piston.

Fig 2: Shock absorber testing machine

5.1 About the Experiment

The observation is carried out using Minitab 14 software and the main objective is to optimize the damping force of the front suspension of a two wheeler by considering various parameters involved in it.

Table1: Specifications of the testing rig

Terms	Values
Actuator rated force capacity	25 KN
Piston stroke	250 mm
Piston rod diameter	80 mm
Bearing	Hydrostatic bearing
Frame stiffness	500 KN/mm
Mass	Integral seismic mass
System pressure	280 bar
Velocity	7.4 m/sec
Velocity	4.1 m/sec

5.2 Experimental Setup

Number of experiments is carried out to identify the influence of damping force on a front suspension system. The testing is done using a servo hydraulic testing apparatus which has a multi bar linkages to hold the shock absorber. Most of the suspensions are of telescopic type so the linkages will suit for all of them. The experiment was conducted by keeping the oil level, clearance between the fork and the bottom and other assembly settings of the fork as constant.

5.3 Working Method

The following experiment is carried out in a way to compare the already available suspension and the new design which we made. The oil viscosity in case of old suspension is fixed and trails of experiment is carried out with the old suspension. Damping force vs velocity characteristics of both the suspensions are to be founded and compared to find the advantage of the new design.

5.4 Old Suspension

Inputs Required

Diameter of the valve = 10 mm

Viscosity of the fluid = 32 cSt (at 40^{o} C)

Density of oil = 857 kg/m^3

Mass subjected = 300 Kg

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Table2: Old suspension input values

Ex.no	Valve dia (mm)	Viscosity (cSt)	Velocity (m/s)
1.	10	32	0.3
2.	10	32	0.5
3.	10	32	1.0
4.	10	32	1.5
5.	10	32	2.0

5.5 Observation

By conducting the above five experiments the damping force for each set is obtained and this value helps to identify the damping coefficient of the suspension.

Table3: Observation for old suspension

Ex.no	Trail 1	Trail 2	Damping force (N)
1.	1228	1312	1270
2.	1525	1519	1522
3.	1592	1628	1610
4.	1774	1783	1779
5.	2163	2174	2169

From the observation it is clear that as the velocity of the fork increases the damping force also increases correspondingly.

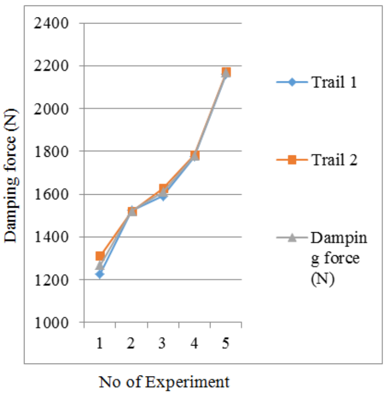

Fig 3: Damping force variation for old suspension

5.6 New Suspension

Inputs Required

Diameter of the valve = 1 mm

$\rho_{Dry\ air}$ = **P/ (RT)**

Air pressure = 12 Bar

ρ = density of air (Kg/m^3)

P = Air pressure ($1.2*10^6$ Pa)

R = Gas constant (287.05 J/KgK)

T = Temperature (40^o C)

$\rho_{Dry\ air} = (1.2*10^6)/(287.05*313)$

$\rho_{Dry\ air} = 13.36\ Kg/m^3$

Viscosity of air = $1.94*10^{-5}\ Ns/m^2$

Mass subjected = 300 Kg

Table4: New suspension input value

Ex.no	Valve dia (mm)	Viscosity (cSt)	Velocity (m/s)
1.	1	1.5	0.3
2.	1	1.5	0.5
3.	1	1.5	1.0
4.	1	1.5	1.5
5.	1	1.5	2.0

5.7 Observation

Table5: Observation of new suspension

EX.NO	TRAIL 1	TRAIL 2	DAMPING FORCE (N)
1.	4786	4739	4763
2.	3163	3228	3196
3.	1573	1623	1598
4.	996	972	984
5.	782	791	787

In the new design the damping force decreases with the increase in velocity and this change is due to the adjuster valve present in the piston.

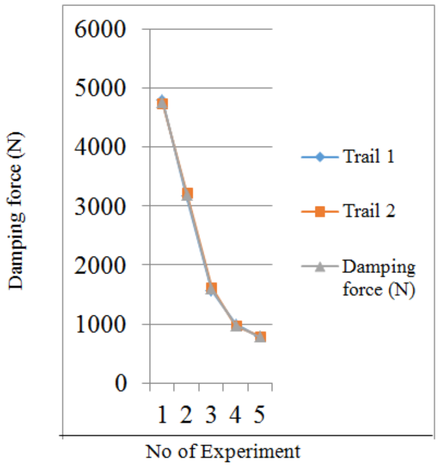

Fig4.Damping force variation for new suspension

VI. RESULTS AND DISCUSSIONS

The damping force values for both old and new suspension is founded using the shock absorber test rig. We know that

$$C = F_d/V$$

C – Viscous damping coefficient

F_d – damping force (N)

V – Velocity of the piston (m/s)

Table 6: Calculation of Coefficient of New and Old Suspension

Velocity Of The Piston (M/S)	Damping Force For Old Suspension (N)	Damping Force For New Suspension (N)	Damping Coefficient For Old Suspension	Damping Coefficient For New Suspension
0.3	1270	4763	381	1429
0.5	1522	3196	761	1598
1.0	1610	1598	1610	1598
1.5	1779	984	2669	1476
2.0	2169	787	4338	1574

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Calculation of Damping Ratio

$$\zeta = c/c_c$$

ζ< 1 (Under Damped)
ζ= 1 (Critically Damped)
ζ> 1 (Over Damped)

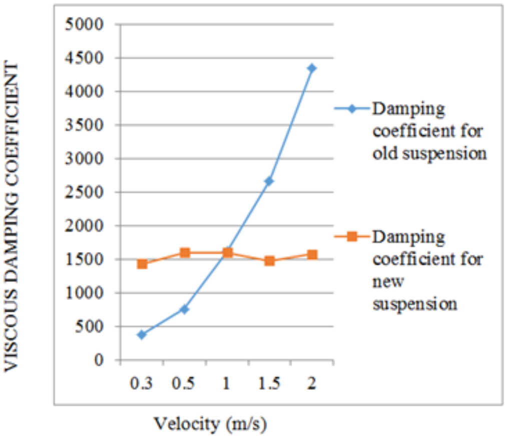

Fig 5.Comparison of viscous damping coefficient

Table 7: Damping ratio values

S.NO	OLD SUSPENSION			NEW SUSPENSION		
	C	Cc	Z	C	Cc	Z
1	381	836	0.455	1429	1752	0.815
2	761	836	0.910	1598	1752	0.912
3	1610	836	1.925	1598	1752	0.912
4	2669	836	3.192	1476	1752	0.842
5	4338	836	5.189	1574	1752	0.898

The damping ratio values obtained for the old suspension shows that the system is under damped for low speed and as the speed increases it is over damped which results in the sudden locking of the fork movement at higher speed ranges.

But in the new suspension the system is under damped in all the speed ranges. So no locking problem occurs. Thus this suspension serves the best for all sorts of speed ranges.

Note: The new suspension is under damped at all speed ranges; allow the suspension to rebound as it is under damped close to the critical damping value.

The testing result of variable damping pneumatic shock absorber show the certain advantages like,

The system is very compact and sensitive. The cost of this method is very less compared to other automatic methods. It is completely mechanical hence can be adjusted by a mechanic itself. Better Handling and Cornering at any types of roads. Better Stability and Steering in continuously changing speed conditions. More Ride Comfort as the damping changes corresponding to speed. Lower Weight than other mechanical methods for altering suspension properties. Certain disadvantages of variable damping pneumatic shock absorber are as follows, Leakage of air may occur. The service need to be done at regular interval of time Dust particle may settle in the suspension during intake of atmosphere air.

VII. CONCLUSION

The project was successfully fabricated and tested using the shock absorber machine. The result from the shock absorber machine is satisfied and this suspension will be suitable for two wheelers. The Variable damping pneumatic shock absorber is the best economical, compared to the existing suspension. Variable damping pneumatic shock absorber is able to fill the air automatically. There is no need to fill the air manually. This pneumatic suspension will provide more comfort for rider. So that the variable damping pneumatic shock absorber can be used for all kind of two wheelers with more economical advantage and within comfort zone.

VIII. FUTURE SCOPE OF THE PROJECT

The result from this suspension testing machine satisfied so that we are planning to implement this variable damping pneumatic shock absorber for both front and rear wheel. We also plan to implement this variable damping pneumatic shock absorber for four wheelers so that we can provide the same economical advantage and also to provide comfort level for all vehicles in future. Calculations may be performed for every vehicle as per its weight and road it is being used. It can be modified as per the requirement of individual automobile to achieve its own advantage.

REFERENCE

1. Amit A. Hingane'Analysis Of Semi-Active Suspension System With Bingham Model Subjected To Random Road Excitation Using Matlab/Simulink', Iosr Journal Of Mechanical And Civil Engineering (Iosr-Jmce) Issn: 2278-1684, Pp: 01-06.
2. Bauer W (May 22, 2007) 'Hydro Pneumatic Suspension System' United States Patent No.: Us 7,219,779 B2.
3. Bhandari V. B., (2010) 'Design And Analysis Of Machine Elements' Text Book.
4. Chavan D.K., (2013) 'Suspension In Bikes Considering Preload, Damping Parameters And Employment Of Mono Suspension In Recent Bikes' International Journal Of Engineering Trends And Technology-Volume4 Issue2.
5. Chavhan, g.r. et. Al. (2014) 'analysis of shock absorber using different material of spring', internal journal of advanced engineering technology, vol. 5, pp. 19-21.
6. Ghosh a.k., (2000) 'evaluation of dynamic stiffness and damping factor of a hydraulic damper' government of india atomic energy commission barc/2000/e/006.
7. Hrishikeshdeo, (june 13-16, 2006) 'pneumatic suspension system with independent control of damping, stiffness and ride height' 4th international conference on axiomatic design firenze.
8. Kommalapati, (april 2013) 'design evaluation of a two wheeler suspension system for variable load conditions' international journal of computational engineering research vol, 03, issue: 4.
9. Meganathan b., (3, march 2017) 'design and fabrication of pneumatic suspension system in two wheeler' international journal of innovative research in science, engineering and technology vol. 6, issue 3.
10. Michael james atherder, (november 2004) 'formula sae shock absorber design' the university of queensland bachelor of engineering thesis.
11. more d.a., (2017) 'automatic air suspension in cars', journal of information, knowledge and research in mechanical engineering issn 0975 – 668x| nov 16 to oct 17 , volume –04, issue – 02.
12. Poona mohan, (dec-2012) 'design and analysis of a shock absorber' ijret: international journal of research in engineering and technology issn: 2319-1163 volume: 01 issue: 04.
13. Pranav badole, (march-2015) 'mono air suspension fabrication in two wheelers' international journal of management and applied science, issn: 2394-7926 volume-1, issue-2.

14. Shendevignesh,(october 2015 – march 2016) 'magnetic suspension system for two wheeler' international journal of recent research in civil and mechanical engineering (ijrrcme) vol. 2, issue 2, pp: (141-146).

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