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Analysis of effect of change in operational/constructional parameters on the performance of twin tube hydraulic shock absorber

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ABSTRACT

Suspension system plays an important role in any automobile's control and comfort. It controls the various motions such as dive, squat, roll, yaw etc. to maintain the standard ride and the comfort conditions to the passenger travelling in a vehicle. The commonly available shock absorbers in any passive suspension system for two wheelers are mono-tube and twin-tube shock absorber. In two wheelers, mostly the twin tube suspension system is employed because of some of its inherent advantages such as more comfortable ride and accommodates the large stroke in comparison with the mono-tube suspension system. The damping force is one of the commonly used parameter to evaluate the damper's performance. The performance of the damper largely depends on the operational and the constructional variables such as no. of holes on the valves, viscosity of the damper oil, suspension velocity etc. The following study is dedicated to the evaluation of the damping forces generated in the twin tube hydraulic shock absorbers employed in the rear suspension system of the two wheeler automobile when one of its constructional or operating variables are changed.

Keywords— **Twin-tube shock absorber, Damping Force, Constructional Variables, Operational Variables.**

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I. INTRODUCTION

Automobiles have many inputs that contribute to their performance and the comfort of the passengers. The first automobiles had merely a rigid frame which, coupled with the poor roads at the time, provided for a very rough ride. As the decades passed the linkages between the tires and the chassis became more and more complex. Today, every vehicle incorporates components to smooth out the ride, and to improve handling at higher speeds. The main components of a suspension that improve handling, noise, vibrations and harshness (NVH), and passenger comfort are the tires, springs, and the damper. The function of the tires is to maintain a frictional force at the road to prevent sliding and improving acceleration. The dampers and springs are utilized to further help the tire maintain contact with the ground. The springs can be used to control where the sprung mass resonance falls in the frequency spectrum. So the main task of any suspension system is providing steering stability with good handling and ensuring passengers comfort. Suspension system absorbs the vertical accelerated wheel allowing frame and body i.e. the sprung mass to remain undisturbed while the wheel follows bump and ditches.

Springs in the suspension system simply oscillate when a vehicle encounters a ditch or a bump. It does not absorb the energy. This work is done mainly by the damper. The damper in any suspension system works by dissipating the kinetic energy between the sprung and unsprung masses. This energy is converted to heat by the internal pressurized oil passing through the valves and orifices which creates fluid shear and thus friction. There are three types of the the suspension system commonly used in any kind of the automobile system depending on the power supply needed to control i.e. Active, Semi Active and Passive. Active system needs power to be supplied to control damping; Semi-active on the other hand maintains the reliability of passive control methods and also includes the advantage of the adjustable parameter characteristics of active systems. However, because of the low cost of the passive system which does not need external power to be supplied to control damping, it is most widely used in the automobiles specially two wheelers. The main types of the passive dampers that are used in two wheelers are twin tube dampers and mono-tube damper. It is easier to secure sufficient stroke in twin tube damper because the oil and gas chambers are separated and not positioned serially. Also, the use of base valve enables to keep gas pressure low, allowing for a more comfortable ride in a twin tube damper. So majority of the two wheelers still prefer using twin tube dampers over mono-tube dampers.

The performance of the shock absorber depends on the performance of individual components inside it. Damper plays an important role in this. Damper consists of the internal mechanism through which the viscous fluid flows causing the resistance to the movements of the mechanism. This resistance offered to the movement of the damper piston assembly by the complex valving structure and the viscosity of the oil is called as the damping force generated inside the damper. Further, this mechanism helps to maintain the ride and the comfort of the vehicle. So the ways in which different values of the damping forces is can be obtained must be studied as it will help in obtaining the various conditions of the damper for which the passenger comfort and the safety conditions can be evaluated. These variables that mainly affect the damping force can be classified primarily into two types namely constructional and the operational parameters. This study highlights the outcome of the performance of damper when the constructional parameter of the damper is changed.

II. LITERATURE REVIEW

The literature on the suspension system related to the two wheeler and some of the passenger cars that were available were reviewed. Most of the literature that was available on the topic of interest was related to passenger cars. The change in the operational and the constructional parameters was studied but significant literature hadn't been reported relative to the qualitative and quantitative analysis of the effect of the different type of the suspension oil on the damping characteristics of the shock absorber. Computer aided designed model was prepared and tested for finite element analysis and also computational fluid dynamic analysis was performed on the same by some of the researchers.

Choon-Tae Lee et. al **s**tudied a mathematical dynamic model of shock absorber proposed to predict the dynamic characteristics of an automotive system. The performance of shock absorber is directly related to the car behaviours and performance, both for handling and ride comfort. Damping characteristics of automotive can be analysed by considering the performance of displacement-sensitive shock absorber (DSSA) for the ride comfort. The proposed model of the DSSA is considered as two modes of damping force (i.e. soft and hard) according to the position of piston inside the inner cylinder. For the simulation validation of vehicle-dynamic characteristics, the DSSA is mathematically modeled by considering the fluid-flow in chamber and valve in accordance with the hard, transient and soft zone [1]. Urszula Fredeck et. al studied the physical and mathematical modeling of the Displacement Sensitive Shock Absorber (DSSA) using oil as a working medium for a twin tube shock absorber has been done. The effect of the amplitude and frequency of the excitation and the parameters describing the flow rate of oil through the valves were examined to obtain the basic characteristics of the damping force. The largest impact on the characteristics of the damping force depends on the geometrical parameters such as the top and the bottom valve design. The asymmetry of the force characterization specifically for the comfort of the ride can be achieved by lowering the mass flow rate through the base valve in rebound rather that in compression [2].

Janusz Goldasz studied the results of the amplitude selective damping (ASD) valve by inducing the changes in the geometry and the performance characteristics of the piston valve and bottom valve. Author further examined the influence of key characteristics of the ASD valve on the performance of a conventional automotive hydraulic twin-tube shock absorber as well as outlined a fairly complete model of the ASD valve. The result of the simulation model indicates that the application of an ASD valve may be a powerful method for shaping the basic damper characteristics in a twin tube shock absorber. The biggest impact on the damper force generated inside the damper is because of the restriction level at the valve's inlet and the exit [3]. Yuming Hou et. al studied the mathematical model of the shock absorber containing rebound chamber, compression chamber, piston valve assembly, base valve assembly is and then simulated the same model using Modelica software to simulate the damping force on the shock absorber. Modelica is a freely available, object-oriented language for modeling of large, complex, and heterogeneous physical systems. Models in Modelica are mathematically described by differential, algebraic and discrete equations [4].

M. Shams et. al analyzed the CFD and FEA model of an automotive shock absorber to find the relationship of the force, deflection and the velocity along with the effects change in the temperature of the oil. CFD analysis is carried out for different intake valve deflections and piston velocities. The force exerted on the valve in each valve deflection is obtained. The valve deflection and force relationship is investigated by the FEA method. The force exerted on the valve in each piston velocity is obtained with a combination of CFD and FEA results. It was observed that the net force decreases by increasing valve deflection due to an increasing pressure drop across the. Also increasing piston velocity increases the force. Increasing the piston velocity increases the valve deflection [5]. Kautkar Nitin Uttamrao et. al carried out fluid flow modeling and damping response of hydraulic damper and also Computational Fluid Dynamics (CFD) trial study method to investigate fluid flow pressure in moped (Luna) hydraulic damper. Averaged Navier-Stokes equations are solved by the SIMPLE method and the RNG k- ε is used to model turbulence. It was concluded that fluid while passing through one chamber to another orifice region is the region of influence from where pressure losses initiate and the damping response depends on pressure difference [6].

Yanqing Liu et. al studied the multi-body system dynamics; the virtual prototype of the hydraulic shock absorber for the bench test developed in the ADAMS environment. Dynamic behaviors of the absorber were studied by both computer simulation and real test. Numerical predictions of dynamic responses were produced by the established virtual prototype of the absorber and compared with experimental results. It has been shown from the comparison that the vibration behaviors of the prototype with hysteretic damping characteristics are considered to be more identical with the bench test results than those of the same prototype with piecewise linear damping properties are same. The current virtual prototype of the shock absorber is correct and can be a developing terrace for the optimizing design of the absorber and matching capability of the whole car [7]. M. A. Jadhav et. al analyzed a new twin tube DSSA model. The function of all components like piston valve, compression and rebound chamber and the flow analysis of the fluid through these valves are studied in detail. It also showed that the damping force can be calculated according to the excitation. The authors also studied the effects of the combined change in the spring stiffness and the damping coefficient on the ride comfort [8].

Hashmi Ayas et. al investigated that automotive suspension plays important role in vehicle safety and driving comfort. One of the most important components in vehicle suspension is the damper. The detailed structure include in the model are three parameter such as damping diameter of holes, suspension velocity, oil viscosity etc related to the front fork suspension system of a two wheeler. In this investigation, an effective approach based on Taguchi method, analysis of variance, multivariable linear regression, has been developed to determine the optimum conditions leading to higher damping force. The experiments were conducted by varying damping hole, suspension velocity and using L9 orthogonal array of Taguchi method for the front fork suspension of a two wheeler [9]. Sandip K. Kadu et. al observed the changes that take place in the suspension system when the constructional parameters such as no of holes, damping diameter and the suspension velocity on the effective damping force in the rear suspension of the two wheeler are changed. The same was then verified by using statistical tools ANOVA and OVAT and the contribution of the individual parameters was studied. Taguchi method was used for the purpose of designing the experimentation [10].

Jignesh Rana et. al performed experiments of changing the fluid gap inside the reservoir chamber by use of the liquids instead of gas such as ethylene glycol, propylene glycol and glycerol to increase the heat transfer rate. Glycerol was found to be the most effective for the considered case. With increased heat transfer rate from inside absorber to surrounding, the problem of overheating of damper fluid decreases and maintains shock absorber performance for a long time [11].

III. CONSTRUCTION AND WORKING OF TWIN TUBE SHOCK ABSORBER

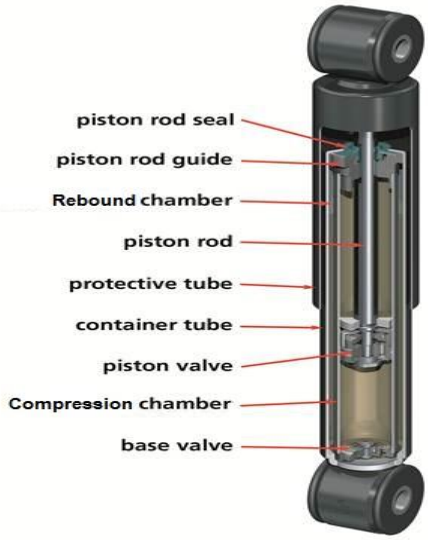

Fig.1 Twin Tube Shock Absorber

Twin-tube shock absorber has a coaxial tube arrangement such that when bike encounters ditch or a bump, two separate compartments for the suspension oil are created in a single tube alone causing the fluid to flow from inner container tube to the outer tube enclosing the reservoir chamber. The cylinder is fastened to the axle or wheel suspension, and the piston is connected via the piston rod to the frame of the vehicle. Fluid flows from the various chambers through the arrangement of the complex valves and orifices. There is a piston valve and base valve. Piston rod is attached to the piston which is guided by the rod guide during its reciprocating motion and the base valve is stationary, fixed at the lower end of the inner tube. As the piston is forced to move with respect to the cylinder, a pressure differential is developed across the piston causing the fluid to flow through orifices and valves in the piston. The portion of the cylinder above the piston is known as the rebound chamber, and the portion of the cylinder below the piston is known as the compression chamber. The volume which surrounds the inner cylinder is known as the reservoir chamber. The fluid flow between the compression and reservoir chambers passes through the body valve assembly at the bottom of the compression chamber and that between the rebound chamber and compression chamber takes place through the piston valve assembly [12].

The twin tube shock absorber has two working strokes to provide damping effect namely compression and rebound damping. Compression damping is incorporated when the wheel moves down in a ditch. Because of this movement of the piston, pressure difference is incorporated in the compression chamber and rebound chamber causing fluid to flow from compression chamber to rebound chamber through the piston valve assembly. Also some of the fluid enters from compression chamber into the reserve chamber through the base valve assembly. The base valve assembly consists of circlip (1), plain disc valves (2 & 5), leaf spring

(3), orifice plate (4) and valve body (6) are as shown in the below fig.

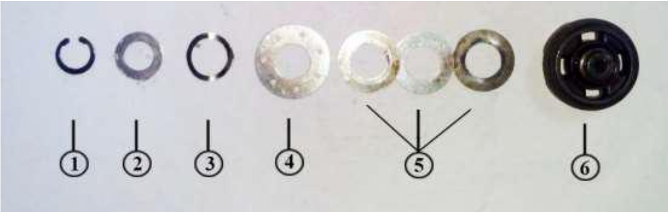

Fig.2 Details of the base valve assembly

IV. METHODOLOGY & EXPERIMENTATION

A. Methodology

For the purpose of the experimentation three dampers manufactured by Munjal Showa corporation ltd, were used which are fitted in almost all the Hero Honda and Hero Motor Corporation bikes. As the constructional feature of the damper under consideration was base valve, the orifice plate was constructed and manufactured having the quantity of the holes greater than that used in the actual damper. The original orifice plate had a thickness of 0.4mm, made of the hardened spring steel En 47 and having no. of holes on it as 4. So the new orifice plate keeping the other dimensions as it is, were manufactured having the no. of holes 5 and 6. The orifice plates were then assembled on the base valve at their respective position. These base valves were then installed on three dampers having the viscosity grade of the oil as ISO VG 68 and the stroke length of 85 mm. Other parameters of the dampers were kept constant.

TABLE I
DAMPER SPECIFICATION FOR THE EXPERIMENTATION

Damper Specification	No. of Holes on the orifice plate
Damper D1	4
Damper D2	5
Damper D3	6

B. Experimentation

The damping force measurement measuring equipment is available in two different types of the machines, they are MTS made in USA and BISS affordable Indian option. So the testing was done on the BISS machine. As the stroke of the selected damper was 85mm, the amplitude for experimentation was taken about 40mm. The excitation was given by a servo hydraulic exciter at different velocities 0.05, 0.1, 0.2, 0.3, 0.5, 0.6, 0.8 and 1.0 m/s. The process of warm up of the exciter and the purging of the damper were carried out at different velocities such as 0.3 m/s, 0.6 m/s and 0.9 m/s. Purging removes the additional air that has been developed inside the rebound chamber when damper is left standing. The damper is initially mounted on the upper and the lower mounts of the performance testing machine perfectly vertical ensuring that no thrust or side forces acts on the inner tube, piston and the piston rod causing eccentric wear of the components.

V. RESULTS

Results are obtained for the compression and the rebound stroke at different velocities. It is observed from graphs that as the suspension velocity increases the damping force obtained also increases for compression as well as the rebound stroke.

Fig.3 BISS Performance Testing Machine Setup

TABLE III
COMPRESSION DAMPING FORCE VS SUSPENSION VELOCITY FOR ALL DAMPERS

Sr No.	Suspension Velocity (m/s)	Damping Force (N)		
		D1	D2	D3
1	0.05	63.4	43.9	149.2
2	0.1	74.7	44.5	149.7
3	0.2	148.3	53.5	167.6
4	0.3	164.2	56.5	169.7
5	0.5	224.5	93.3	185.6
6	0.6	244.5	110.8	209.7
7	0.8	289	157.4	259.8
8	1.0	317.6	198.1	297.7

TABLE IIIII
REBOUND DAMPING FORCE VS SUSPENSION VELOCITY FOR ALL DAMPERS

Sr No.	Suspension Velocity (m/s)	Damping Force (N)		
		D1	D2	D3
1	0.05	50.1	75	78.7
2	0.1	147	249.3	196.9
3	0.2	543.4	1275.9	1163.8
4	0.3	605.8	1491.5	1733.4
5	0.5	899.5	2791.4	2435.6
6	0.6	1373.4	3241.4	2844
7	0.8	1401	4548.8	3390
8	1.0	1608.4	5290	3685.8

The graph of the damping force against the suspension velocities is plotted. As the suspension velocity increases the damping force also increases in almost a linear manner and this also true for other dampers D2 and D3.

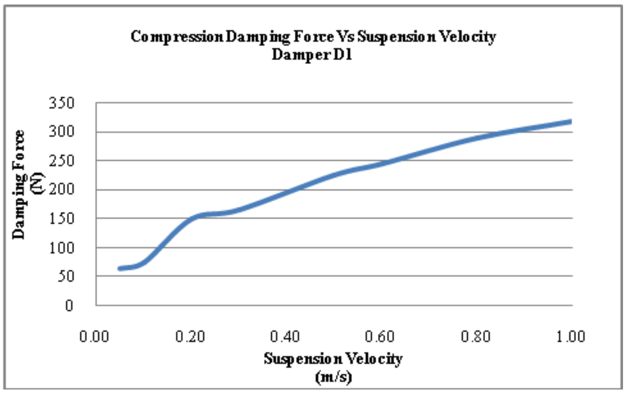

Fig.4 Compression Damping Force Vs Suspension Velocity

The same trend is observed when the damping forces in rebound are plotted against suspension velocity. However, there are some irregularities in the nature of the plot in case of the rebound conditions.

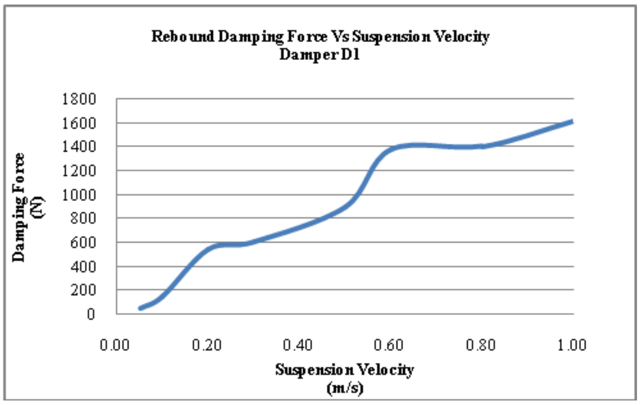

Fig.5 Rebound Damping Force Vs Suspension Velocity

The comparison of all the dampers in compression and rebound stroking conditions is also done.

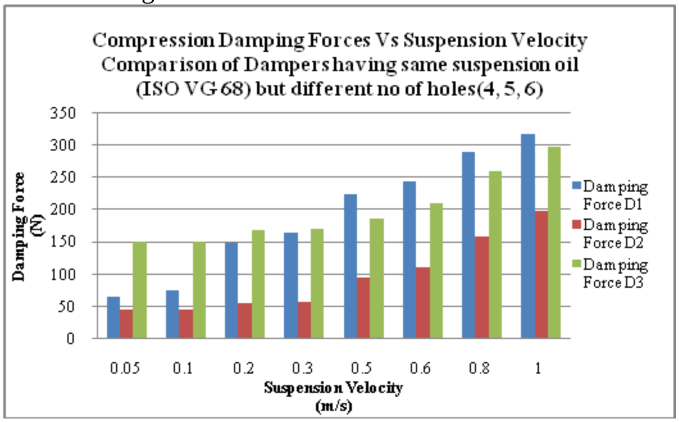

Fig.6 Comparison of all the dampers for Damping Forces in
Compression stroke

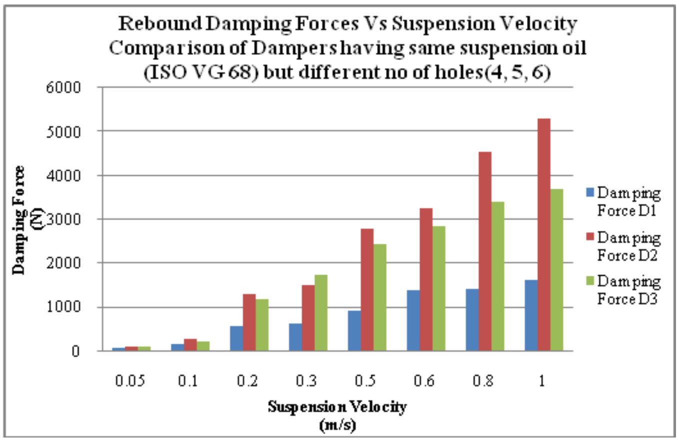

Fig.6 Comparison of all the dampers for Damping Forces in Rebound stroke

VI. CONCLUSIONS

The general observation concludes to the fact that as the suspension velocity increases the amount of the damping forces that are generated also increases irrespective of the change in the parameter such as the viscosity grade of the oil. But when the comparison of the increase in the damping force is analyzed separately for compression and the rebound strokes, the effect of the increase in the damping forces in rebound is significant in comparison with that in compression stroke.

From comparison of the dampers based on the utilization of the various orifice plates having four, five and six no. of holes in the base valve of the damper, it is found that the experimental results for the compression stroke as well as for rebound stroke that as the no of holes on the orifice plate increases, the damping force in a damper increases. However the results are not in a good agreement with the actuality that as the damper D3 should have generated the maximum damping force as compared to other dampers. The possible reasons for this redundancy in results are the contamination of the damper oil, air compressibility effects and improper flow of the damper fluid from the valve structures and the manufacturing difficulties.

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REFERENCES

[1] Choon-Tae Lee and Byung-Young Moon, Simulation and experimental validation of vehicle dynamic characteristics for displacement-sensitive shock absorber using fluid-flow modeling, Mechanical Systems and Signal Processing, 373–388, 2006.

[2] Urszula Fredeck and Jan Luczko, Modeling and Analysis of Twin-Tube Hydraulic Shock Absorber, Journal of Theoretical and Applied Mechanics, 627-638, 2012.

[3] Janusz Goldasz, Modeling of Amplitude Selective Damping Valves, Mechanics and control, Vol. 30, 60-64, 2011.

[4] Yuminghou, lingyang li, et al, Shock Absorber Modeling and Simulations Based on Modelica,

proceedings of the 8th Modelica conference, 843-846, 2011.

[5] M. Shams, R. Ebrahimi1 et al, CFD-FEA Analysis of Hydraulic Shock Absorber Valve Behavior, International Journal of Automotive Technology, Vol. 8, 615−622, 2007.

[6] Kautkar Nitin Uttamrao, S.T Satpute et al, Investigation Study on Fluid Flow Modeling and Damping Response of Automobile Hydraulic Damper, International Journal on Mechanical Engineering and Robotics, vol. 2, 12-15, 2014.

[7] Yanqing Liu and Jianwu Zhang, Non Linear Dynamic Response of Twin Tube Hydraulic Shock Absorber, Mechanics Research Communication, 359-365, 2001.

[8] M. A. Jadhav, S. B. Belkar, et al, Analysis of displacement Sensitive Twin tube Shock Absorber, International Journal of Engineering Research and Development, Vol. 5, 31-41,2012.

[9] Hashmi Ayas Jameel and Ahmed, Rathi M.G, Effect of Damping parameter on Damping force of two wheeler front suspension ,International Journal of Engineering Research & Technology, vol. 2, 229-237, 2013.

[10] Sandip K. Kadu, M. S. Mhaske, Experimental investigation of damping force of twin tube shock absorber, International Journal of Engineering Research and Applications, Vol. 4, 59-64, 2013.

[11] JigneshRana, SwastikGajjar, et al, Experimental Analysis And The Heat Transfer of The Damping Fluid In The Shock Absorber Operation, International Journal of Engineering Research and Development, Vol. 2, 2939-2947, 2014.

[12] John C. Dixon, The Shock Absorber Handbook, 2nd Edition, Wiley-Publishing series, 2007.

