Investigation Study on Fluid Flow Modelling and Damping Response of Automobile Hydraulic Damper

Kautkar Nitin Uttamrao, S.T Satpute, L.M Jugulkar

I. INTRODUCTION

Isolation from forces transmitted by external excitation is the fundamental task of any suspension system. In case of a vehicle a classical car suspension aim to achieve isolation from the road by means of spring-type element and viscous damper (shock absorber) dampers are also called shock absorbers, shocks or spring energy dissipaters and contemporarily to improve road holding and handling. Dampers are an integral part of any suspension system. The main function of the dampers is to control the transient behaviour of the sprung and unsprung masses of the vehicle. This is accomplished by damping the energy stored in the springs from suspension movement. The elastic element of suspension is constituted by spring (coil spring but also air spring and leaf spring), where as the damping element is typically of the viscous type. Shock absorbers are compact, light weight suspension struts which reduce the suspension play and they can be used in very heavy load applications such as heavy military vehicles, landing gear suspension in aircrafts and space shuttles. The liquid flow through orifices produces larger damping where as the cushioning effect comes from the fluid’s compressibility. The liquid spring design is subject to constant high pressure necessary to achieve required forces, which drastically increases during dynamic operation. These peak dynamic pressures which may propagate fluid leakage the shock transmissibility and the suspension play are the critical design parameters. Unlike automobile suspension design where the trade OFF between the driving comfort and manoeuvrability is the principal design concern robustness and reliability are key design aspects in defence systems. Theoretical studies have long back shown that liquid springs are very effective in isolating large shocks high-rate input loading [3]. The basic schematic of a liquid spring is shown in Fig.1 where variables H, ht, Ap, Ar, M, W, g and V(t), respectively, represent the overall internal height of the device, thickness of the piston, piston cross-section area, piston-rod cross-section area, supported mass its weight, gravity and the velocity excitation from the ground.

Primary suspension is the term used to designate those suspension components connecting the axle and wheel assemblies of a vehicle to the frame of the vehicle. This is in contrast to the suspension components connecting the frame and body of the vehicle, or those components located directly at the vehicle’s seat, commonly called the secondary suspension. There are two basic types of elements in conventional suspension systems. These elements are springs and dampers. The role of the spring in a vehicle’s suspension system is to support the static weight of the vehicle. The role of the damper is to control the input from the road that is transmitted to the vehicle. The basic function and form of a suspension is the same regardless of the type of vehicle or suspension. Primary suspensions will be divided into passive, active adjustable and semiactive systems, as will be discussed next, within the context of this study.

Abstract -Automobile shock absorber consists of a dissipative element connected in parallel with an elastic element. Fluid damper are most reliable to be used as a dissipative elements in the vehicle shock absorber. Damping action in fluid shock absorbers is obtained by throttling viscous fluid through an orifice. Fluid shock absorbers offer sufficient damping force with compact size, also the damping force is linear in nature. Damping force of the fluid damper depends on orifice properties and on the physical properties of oil used.

This case study carry out on fluid flow modelling and damping response of hydraulic damper also Computational Fluid Dynamics (CFD) trial study method is used to investigation 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.

Keywords –Shock absorber, Hydraulic damper, Hydraulic valve, CFD simulation
II. ANALYSIS OF DAMPING:

Rebound valve consists of rebound slice which locates piston underside and piston under-surface, the basic components include piston orifice, throttle slice, throttle holes and down-check ring. Schematic diagram is shown in Figure 2. In Figure 2, dh is diameter of piston orifice, nh is the number; p is pressure on throttle slice; frk0 is pre-deformation of throttle slice which is decided by the fixing size to ensure right valve-opening velocity; rh is outer radius of slice, rk is valve mouth radius, ra is inner radius of slice (taking the fixing size into account); $k$ is the opening size of rebound slice, and it is equal to difference between total deformation frk and pre-deformation frk0 of slice. For the design of throttle holes area, it should take the piston orifice, the piston slot and local throttle loss with suddenly expansion, and shrinkage and direction change into account. [4]

The damping force of shock absorber is determined by the forces acting on the both sides of the piston. And the friction forces are another factor that determines damping force. Nevertheless, in this study, the friction forces are ignored to simplify the analysis. Fig.1.3 shows free body diagram of the piston considering the damping force [10]

By considering the forces acting on the piston, the damping force can be obtained as follows:

\[ F_{\text{damping}} = p, A_r - p, A_c \pm F_{\text{friction}} \] .... 1 [10]

A_r = A_p - A_{rod}

Where,

F_{\text{damping}} is a damping force. F_{\text{friction}} is the friction force, that is acting on piston rod. [10]

2.1Piston orifice:

Orifices are distributed on the piston uniformity. The diameter dh and number nh are both serialization, and dh is in series, such as 1.5 mm, 1.75 mm, 2.0 mm, nh is in series too, such as 2, 4, 6, 8. For single piston orifice with diameter dh and length Lh, its type can be selected by the ratio Lh/dh > 4, according to the definition of orifice sort, piston orifice can be regarded as slim orifice. So the throttle pressure of piston orifice as follows

\[ P_{ho} = \frac{128\pi \mu L}{\pi d h^2} \] ................. 2 [4]

Where, pho is the pressure of piston orifice; L is the equivalent Length the value is equal to sum of the physical length and the local loss calibrated length, that is L = L_h + L_e; \( \mu \) is the dynamic viscosity of fluid. [4]

III. THE 3D ANSYS:

3.1Fluent Simulations:

Fluent Simulations In order to capture the fluid flow pressure behaviour in CFD analysis have been performed. The ANSYS Fluent solver has been used to run a set of steady-state simulations for the parametric design moped (Luna) geometries. The hydraulic damper have been analysed in two separate chamber which is rebound and compression chamber. Mass flow inlets/pressure outlets boundaries are chosen in order to cover the known operating range main settings for the performed steady-state CFD analysis. This model is used in many practical engineering flow calculations, thanks to its robustness, economy and accuracy for a wide range of turbulent flows. Additionally, the realizalbe version, compared to...
standard k-ε models, improves the mathematical formulations around the definition of the critical Reynolds stresses, leading to a better prediction over flows characterized by strong streamline curvature, vortices and rotations.

Fig 3.1: Fluid domain in ANSYSE FLUENT

3.2 MASS FLOW CALCULATIONS:

Density of Fluid *Area * Velocity of Fluid

Where, Density of fluid (ρ) = 860 kg/m³

TABLE 3.2.1 - PARAMETRIC DIMENSION FOR MOPED (LUNA)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinder Diameter</td>
<td>18.9</td>
<td>mm</td>
</tr>
<tr>
<td>Piston Diameter</td>
<td>18.6</td>
<td>Mm</td>
</tr>
<tr>
<td>Rod diameter</td>
<td>8.8</td>
<td>mm</td>
</tr>
<tr>
<td>Rod length</td>
<td>142</td>
<td>mm</td>
</tr>
<tr>
<td>Piston height</td>
<td>8</td>
<td>Mm</td>
</tr>
<tr>
<td>Cylinder height</td>
<td>118</td>
<td>Mm</td>
</tr>
</tbody>
</table>

Area Consideration for Rebound stroke while Mass Flow Calculation for 2 Orifice = Area of Piston – Area of Rod

\[ = \pi r^2 - \pi r'^2 \]

\[ = \pi*9.3^2 - \pi*4.4^2 \]

\[ = 210.895 \text{ mm}^2 \]

Area Consideration for Compression stroke while Mass Flow Calculation Orifice for 2 Orifice = Area of Piston

\[ = \pi r'^2 \]

\[ = \pi*9.3^2 \]

\[ = 271.176 \text{ mm}^2 \]

Velocity of fluid which is basic mineral oil as given below (calculate Mass flow for each Velocity for given Velocity range by considering Area and Density constant) 0.1, 0.2

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Velocity of fluid</th>
<th>Mass flow for Rebound stroke (kg/s)</th>
<th>Mass flow for Compression stroke (kg/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.1</td>
<td>0.018130</td>
<td>0.023367576</td>
</tr>
<tr>
<td>2</td>
<td>0.2</td>
<td>0.03627</td>
<td>0.046735152</td>
</tr>
</tbody>
</table>

Typical CFD analysis results from simulation are shown by Figure where the complexity of the fluid flow and its influence on the hydraulic pressure build up can be noticed.

Fig 3.2: ANSYSE FLUENT result for fluid pressure pattern at 0.01813 kg/s mass flow in rebound stroke

Fig 3.3: ANSYSE FLUENT result for fluid pressure pattern at 0.023367576 kg/s mass flow in compression stroke

VI. CONCLUSIONS

Fluid flow modelling of the shock absorber/hydraulic damper which contains rebound chamber, compression chamber, orifice, assembly is given in this paper, then a trial CFD simulation model is established using ANSYS software, whole study describe that damping force or response is the distributed parameter modelling/design is not only necessary to understand the impact of key design features, but also to extract physical variables associated with the fluid flow. In particular, flow pattern and static pressure distributions on the piston are studied.

Finally, based on a investigation study evaluation of the information obtained from all the cases examined, it was concluded that while fluid passes through one chamber...
to another orifice region is the influence region from where pressure losses are going to start, however pressure difference is the function of damping force moreover damping response depend on pressure difference.

REFERENCES


