Mathematical Modeling and Experimental Validation of Modification of Mono-Tube Shock Absorber

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Abstract— Function of the suspension system is reducing the deviation of the vehicle body from the mean line of travel to a minimum, and the same time, thereby giving the passengers the best possible ride and making best use of contact with ground via tires to provide good adhesion during cornering, acceleration and braking. The work presented in this dissertation is concerned with mathematical modeling and experimental validation of mono-tube shock absorber, goal of this research is to create damper model to predict accurately damping force, experimental analysis done by varying the various parameters, such as flow area in bleed(Ab), mass (M) and operating frequency(ω). Here in this, input is given in the form of sinusoidal excitation and the output is received as a numerical data of the displacement transmissibility. This data is then processed to get the values of transmissibility and magnification factor for various frequency ratios.

Key words: Suspension, Damping, Damper, Shock Absorber

I. INTRODUCTION

If motor-vehicle wheels were attached directly to the chassis frame it would become immediately obvious that every shock a form tyre impact on road surface fault would be transmitted, unchecked, to the whole of the body structure. The resultant loss in riding comfort, operating efficiency and serviceable life of all components would be very considerable. An automotive suspension system is meant to provide both safety and comfort for the occupants. It is a well known fact that the characteristics of the suspension system are of importance in determine the handling properties and ride comfort characteristics of a minimal nuisance to the passengers. When a vehicle encounters a road surface irregularity, the tire deforms and the suspension displaces. Some of the energy caused by the disturbance is dissipated in the tire, some of the energy is dissipated in damper and remainder of the energy is stored in the spring. The spring then release this energy as a damped oscillation. If the behavior of the whole vehicle is simulated, the shock absorber sub-system is usually modeled as a simple linear spring-damper unit. If a vehicle suspension system is to improve passenger ride comfort and increase vehicle control, the design of an automotive damper requires two damping value, one setting for ride comfort and another harder setting for vehicle control. Influence on handling performance and riding comfort. Shock absorber plays an important role not only for comfort of the riders of the vehicle but also in the performance and life of the vehicle. However, no further reduction of vehicle vibration can be expected for using the optimum values of damping coefficient and spring stiffness for the shock absorber. Thus it is necessary to make modification to improve the functions of shock absorber.

II. NATURE OF WORK

The work presented in this paper is concerned with Mathematical modeling and experimental validation of mono-tube shock absorber, goal of this research is to create damper model to predict accurately damping force and offers greater variation in damping.

III. DAMPER MODEL

Mono-tube racing dampers were the basis for the damper model. In this case external oil flow adjustment system was attached (shown in figure) to the mono-tube shock absorber (Apache) for changing the oil flow through orifice to adjust the damping to get good ride comfort.
In that external flow adjustment system there were two circular plates with circular slots as shown in figure. Lower circular plate was fixed and upper circular plate was rotated by rod to get variable damping. By rotating the upper circular plate opening and closing area for oil flow increases and decreases depending upon position of upper circular plate we got different damping values.

Fig. 1: External adjustable shock absorber

Testing of shock absorber may be categorized under two main headings:
1) Rig testing of part or whole of the shock absorber;
2) Road testing of the shock absorber on the vehicle;
   Rig testing of complete shock absorbers or their separate parts may be placed under three further headings:
   1) To measure performance;
   2) To check durability;
   3) To test theoretical models.

Testing of theory is required to validate methods of analysis and to give confidence in theory for design work. This is likely to involve testing of individual parts or testing of complete shock absorber to relate damping characteristics, to investigate piston or rod seal friction effects, etc.

Performance testing is required to check that prototypes or samples of production dampers meet their specifications within tolerance, and are adequately consistent one to another. In competition, performance testing is required to check that a given valve set-up gives the expected behavior and, again, that dampers are consistent and in matched pairs. Consistency tests and matching tests are frequently disappointing because of the sensitivity of the dampers to small dimensional discrepancies in the valves and to small leakage paths. Adjustable are frequently inconsistent one to another in their response to the adjustment setting. Testing may therefore be used to select matched pairs or to refine manufacture and assembly to the necessary level.

Durability testing is sometimes performed by rig testing, and this can be useful for initial testing of new materials or production methods, but the primary durability testing is by road testing.

Road testing may be divided into four main categories
1) Long-distance testing of durability on public roads;
2) Short-distance durability testing on severe test roads;
3) Ride and handling testing on public roads;
4) Ride and handling testing on special test roads.

Long-distance road testing of dampers alone would generally be uneconomic, but is undertaken in conjunction with reliability testing of all the other parts of complete vehicles. Short-distance severe testing of complete vehicles is sometimes used, driving over pave’d type surfaces or similar.

Testing of handling is mainly undertaken on special circuits; for safety reasons, public roads are not generally suitable for extreme cornering testing. Ride testing is of course viable on public roads, but special roads with particular surface conditions obviously offer some advantages. Testing of the complete vehicle may be intended to assess the suitability of proposed dampers for a particular vehicle, or to relate actual vehicle behavior in ride and handling to theoretical predictions in order to validate vehicle dynamics theory for design purposes.

The experimental setup involves following steps:
- The shaft is driven through a single-phase AC motor.
- From AC motor, drive is brought to a gear reducer whose gear reduction ratio is 12:1.
- From these the shaft is driven at constant rpm.
- As the scotch yoke mechanism is connected to the shaft, mechanism rotates from which the rotary motion is converted into reciprocating motion by means of follower.
- The follower is guided by a bush and in order to overcome any distortion, side frames are welded to that.
- This follower is connected to the dead weight and from there to shock absorber.
- The shock absorber, which is subjected to both compressive and tensile force.
- FFT analyzer is used to get output displacement, velocity and acceleration.
IV. PROCEDURE

The experimental involves following steps:

- For conducting the experimental analysis on motorcycle shock absorber a mechanical exciter is used.
- A heavy structure c-channel is used so as to provide firm support for the exciter mechanism.
- Cylindrical guide bars are used to guide the upper and lower bush plate assembly, between which a shock absorber is fitted.
- Guide bars are aligned properly with alignment plate.
- An arrangement is made over the upper bush plate assembly for placing the mass.
- Motorcycle shock absorber is fitted between upper and lower bush plate assembly.
- AC motor with different diameter of pulleys is used to input the different speeds.
- A scotch yoke mechanism is used to convert the rotary motion into reciprocator one.
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From the value, the performance testing of the shock absorber is inferred.

A. Testing Photos

Fig. 3:

Fig. 4:

Fig. 5:
V. RESULT

A. Result Table for Experimental Analysis

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<th>SR. NO.</th>
<th>Spring stiffness (K/N/m)</th>
<th>Mass (M) kg</th>
<th>$x_{0}$ (m)</th>
<th>$\omega_{0}$ (rad/sec)</th>
<th>$\omega$ (rad/sec)</th>
<th>Frequency ratio($r$)</th>
<th>$A_{0}$ (m$^2$)</th>
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<th>Transmissibility (TR)</th>
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Table 1: Experimental result

Mean Transmissibility (TR): 1.1033

VI. CONCLUSION

The reason for conducting this study is that semi-active suspension systems with modification of Mono-tube shock absorber are currently the only means of further improving the ride comfort and handling of heavy off-road vehicles, cost effectively. From various testing and experimental results it is proved that with Modification in mono-tube shock absorber we get varying damping and improving ride comfort and hence increasing the life of vehicles.

REFERENCES