Study and Charecterization of Non-Linear Damper

Vrushal Kamble[1], Shantilal Bahiram[2], Shubham Patil[3], Viraj Borge[4], Prof. V.M. Chavan[5]

[1]Department of Mechanical Engineering, Smt. KashibaiNavale College of Engineering,
kvrushal@gmail.com
[2]Department of Mechanical Engineering, Smt. KashibaiNavale College of Engineering,
lalitbahiram1994@gmail.com
[3]Department of Mechanical Engineering, Smt. KashibaiNavale College of Engineering,
patilshubham112@gmail.com
[4]Department of Mechanical Engineering, Smt. KashibaiNavale College of Engineering,
virajborgepatil@gmail.com
[5]Department of Mechanical Engineering, Smt. KashibaiNavale College of Engineering,
vmchavan@gmail.com

ABSTRACT

For this modern fast pace world transportation being the backbone of society, the fact of luxury and comfort has also become of utmost interest for many people. The competition in automobile industries put the standards on higher level concerned about vehicle suspension as it is directly related to human health and comfort. As the vehicle suspension is concerned, it varies from one vehicle to another and from one application to another. These various suspension systems are designed accordingly with the desired effects and performances. The testing and calibrating facilities for these suspension systems are available at their manufacturers and some purposefully established organizations only. The setup is made as a quarter car setup, the reduced model from a full car, to reduce the cost of development and the complications in its design and manufacturing. The work involved was from selection of suspension system to final readings and analysis. The passive suspension was selected due its low cost and it is . The procedure for development was analytical as well as experimental. The results were tallied on MatLab 10, as an analytical solver. In later stages the experimental setup is selected and the actual readings were taken for various inputs; finally both experimental and analytical results are compared.

Keywords*: Passive Suspension, Damping Coefficient, Characterization, etc.*

---

1. INTRODUCTION AND AIM

The main functions of an automotive suspension system are to provide vehicle support, stability and directional control during handling maneuvers and to provide effective isolation from road disturbance. These different tasks result in conflicting design requirements. Directional control and stability requires a suspension that is neither very stiff nor very soft. Insensitivity to external loads requires a stiff suspension, whereas good ride comfort demands a soft suspension. In a conventional passive suspension system, the designer is faced with the problem of choosing the suspension stiffness and damping parameters, which inevitably involves a difficult compromise in view of the wide range of conditions over which a vehicle operates.

Suspension system is one of the important part of the vehicle. Therefore, it is quite necessary to design finer suspension system in order to improve the quality of vehicles. Since the disturbances from the road may include uncomfortable shake and noise in the vehicle body, it is important to study the vibrations of the vehicle. An automobile is a nonlinear system in practical terms because it consists of suspensions, tires and other components having nonlinear properties. Therefore, the chaotic response may appear as the vehicle moves over a road . Suspension is subjected to various road conditions like a single step road profile, brake and release maneuver, sinusoidal road profile with pitching, heaving and mixed model excitation, broad band road profile etc. at constant or variable speed. The objective for this work is to study and analyze the suspension system on various parameters both analytically and experimentally.

This work will be useful in improvement in design and performance of suspension system. It will help in the problem of choosing the suspension stiffness and damping parameters, which inevitably involves a difficult compromise in view of the wide range of conditions over which a vehicle operates.

1.2 Methodology

To achieve these tasks the following approach is taken. With known data the analytical simulation is carried out on Matlab and the results were recorded. Then comparison is to be done with the actual test results. In the proposed work, a 2-DOF linear quarter car is modeled to carry out computer simulations. During simulations, a vehicle is assumed to run at certain speed while it hits a step or a pothole or a bump or a random road profile. Vehicle response corresponding to above mentioned road disturbances is obtained for ride quality and comfort. Quarter Car suspension system is modeled and simulated for above mentioned road disturbances to analyze performance.

The work involves -

- Study of suspension systems.
- Modeling of a vehicle suspension system – A linear quarter car model.
- Deriving the equations for the quarter car model and formulation of Transfer Function and State Space equations for vehicle suspension system.
- Simulation of suspension system using road surface disturbances as input at the tire to analyze the vehicle performance.
- Simulation of suspension system using Matlab software.
- Experimental analysis of suspension system.
- Comparison of both results.

2. EXPERIMENTAL SETUP

2.1 Hydraulic Testers

Where high power inputs and flexible control is required, hydraulically driven testers are used. The hydraulic ram is double acting, typically operating at a pressure around 1 MPa with a force capability of 10 kN. Very-high-quality valves are required for the ram, to regulate the oil supply accurately with a sophisticated control system and a large pump, making for an expensive system. The ram position is controlled by a voltage input. There will be provision for an adjustable constant voltage which will set a steady position anywhere in the range of the ram. In addition, there is a signal input allowing variation of the position relative to the mean. This variable signal may take any form required. In practice the system control unit will provide some or all of the following:

(1) Sinusoidal wave
(2) Triangular wave
(3) Square wave
(4) Random motion
(5) External input

For the cyclical motions, the frequency and amplitude can be set as required. The random signal is white noise over a limited frequency range. The upper frequency limit of response is effectively set by the frequency response of the valves and ram. Because of the flow rate limitations of the valves, the frequency response will depend upon the amplitude.

Hydraulic testers can have their own problems, of course, including signal processing limitations and Imperfect motion control. Such a system can be used for testing dampers or for testing the complete suspension for a quarter car including wheel and tyre, with the ram acting as the road profile, determined by a known road profile or by random generation with an appropriate frequency distribution.

Four such systems can be used to support a complete car through the four tyres, and give a complete ride stimulus with the semi-random motions of the four rams given values correctly related to each other, requiring appropriate frequency-dependent correlation between left and right tracks and the rear stimulus being the same as the front, but with a time delay given by the vehicle wheelbase divided by the notional vehicle speed.

The ram may alternatively be controlled to give a specified force rather than position, and again this has constant and variable elements. In practice, the sinusoidal activation is the one mainly used for damper testing. It is also possible to use a hydraulic tester to perform transient tests or single-cycle tests instead, to reduce damper heating.

2.2 MaKron Servo-Hydraulic Testing Machines

UT-02-0025 Makron Test System is a single foot print assembly with an enclosure housing controller and hydraulic power pack. The Load frame with a T-slot bed and provision to mount actuator on top may be located on the top of enclosure. These systems are easy to install and usually do not require any additional utilities such as cooling. Just plug i to the closest 15A mains socket and the system is ready for use.

2.2.1 Standard Features

- Up to 100Hz cycling frequency
- Flexible operation
- 25 kN force rating actuators
- 50 to 100 mm actuator stroke
- Adaptable to wide range of fixtures & grips
- Energy efficient pumps
- User friendly MTL software
- Single foot print assembly
- Frame stiffness: 600kN/mm

2.2.2 Applications

- Tension/Compression/3-point bend
- Fatigue crack propagation
- Fracture mechanics
- Room temperature tests
- Low/High temperature tests
- Low/High cycle fatigue(LCF/HCF)
- Damping force measurements
- Elastomer testing
- Ductile/brittle fracture
- Threshold stress intensity.

2.2.3 Specifications

Model	MaKron 25
Model No.	UT-02-0025
Capacity, KN	25
Column clearance, mm	400
Maximum daylight, mm	700
Total frame height, mm	1500
No of columns	2
Weight, kg	400

Table- 1: Specifications of Testing Setup

Fig- 1: Testing Setup

2.3 Shock Absorber Test Rig

The design of shock absorber test rig has been developed for vibration measurement system. This product actually developed to test and indicates the condition of shock absorber in automotive vehicle. As it functioning, this product can be used as a tool to verify the capability of shock absorber. Figure 1 shows the complete of the design of shock absorber test rig. This shock absorber test rig is a rigid structure with two main components connected vertical. The upper vertical is the shock absorber while the lower connection to the base structure is the pneumatic cylinder. The upper and lower component is divided by the middle plate. This middle plate is supported with two units of guide shaft for smooth movement. The shaft holder is placed at each end of the guide shaft for protecting and secures the guide shaft joints. The complete shock absorber test rig is system consist of a few important parts which are: shock absorber, guide shaft, linear guide bushes, air cylinder, air regulator and air pilot valve. This test rig is design for interchangeable shock absorber testing. Therefore, it can be used to test the shock absorber according to: vehicle 850cc and 1600cc capacity.

secured to the top plate. So, the compression of shock absorber from the activation of cylinder will show the displacement.

Fig- 2: Accelerometer

Fig- 3: Wire Displacement Sensor

Furthermore, one unit of force sensor is mounted to the cylinder shaft at middle plate. This is to measure the force generated from the cylinder when activated to push up the shock absorber. The data acquisition system used is the digital type using a digital computer and has multiple channels for measurement of various physical variables. The computer controls the addressing, data input and processes the signals as desired for display and storage. The computer, control the addressing and data input and processes the signal as desired for display and storage [6]. Data acquisition system consists of the components which are:

a) Personal Computer
b) 8 channels signal analyzer
c) Analog to digital acquisition card
d) Software (DEWESoft 6.3)
e) Amplifiers

Figure 4 shows the 8 channel rack signal analyzer. The sensors that are secured on the shock absorber test rig are connected to the computer using this 8 channel rack. This 8 channel rack is a signal conditioning element. The output from the sensors is converted into more suitable output for further processing. It is because the output of the transducers or sensors element is usually too small to operate an indicator or a recorder. Therefore, it is suitably processed and modified in signal conditioning element to obtain the output in desired form.

This shock absorber test rig is designed for vibration measurement to analyze the capability of shock absorber. Before the analysis on the shock absorber is done, this test rig must be tested. In order to perform testing on shock absorber test rig, the shock absorber was mounted on the test rig. For activation of the cylinder, the minimum of air supply from 2 to 7 bars is required. This air is directly supplied to air regulator then to solenoid valve. The right button is pressed to activate the pneumatic cylinder to compress the shock absorber. The other button was pressed to bring back the pneumatic cylinder to home position. When the test rig is at home position, the cylinder piston is retracted.

The input signal of all sensors is recorded by the Data Acquisition System after generated from the test rig. The force generated from the cylinder is measured by the load cell. The displacement of the shock absorber is measured by wire displacement sensor while the vibration of the middle plate is measured by accelerometer. All the input signal from the sensor than were processed to get the output data.

3. ANALYSIS AND DISCUSSION OF EXPERIMENTAL RESULTS

Analytical Study of Simple Equivalent Model of Practical Damper (Kelvin -Voigt model) has been done, Sinusoidal Excitation is generally used in Characterization of Damper.

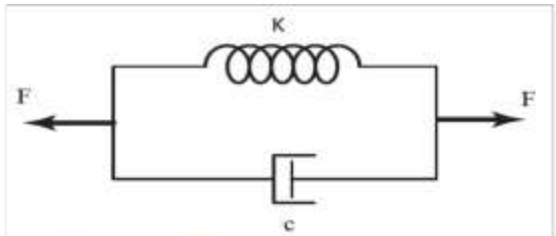


Figure. 2 Kelvin -Voigt model

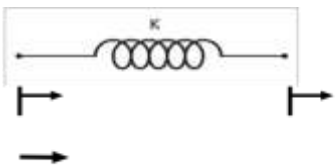


Figure 3 Spring

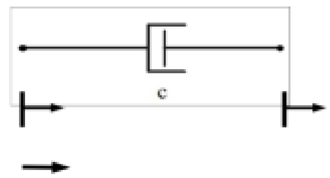


Figure 4 Damper

3.1Analytical calculations

Calculations for sinusoidal Excitation is given as Follows;

1. $z(t) = Z_a. \sin(\omega t)$
2. $\dot{z}(t) = Z_a * \omega \cos(\omega t)$
3. T=1/f
4. Spring Force (F_s) = K * z
5. Damping Force (F_d) = C * $\dot{z}$
6. Total Force (F) = $F_s + F_s$

3.1.1 For frequency:

1. 1)f = 0.1
2. T=1/f =1/0.01=100cycle/sec, time interval=T/10=100/10=10 sec
3. No. of cycles=10 (assumed)
4. Total time=100*10=1000sec/cycles

ISSN: 2321-8169
1691 – 1699

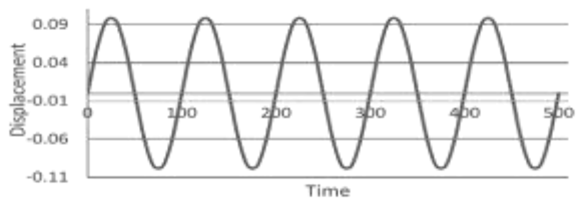


Fig. 5.4 (a) Time vs Displacement (*f*= 0.01 Hz)

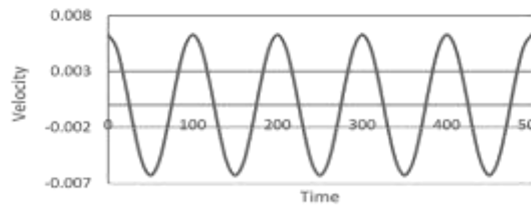
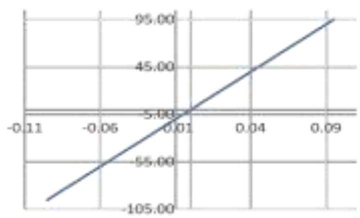


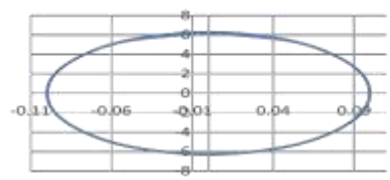
Fig. 5.4 (b) Time vs Velocity (*f*= 0.01Hz)

3.2Analytical Results

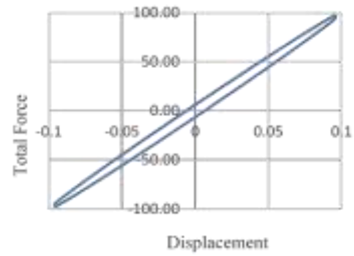
f=0.1



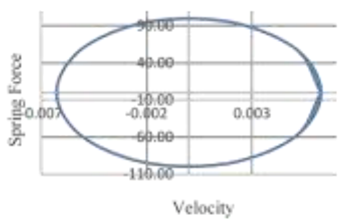
(a) Displacement vs Spring Force



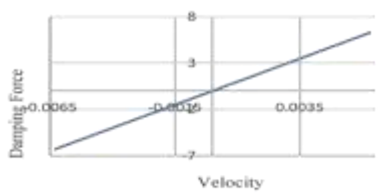
(c) Displacement vs Damping Force



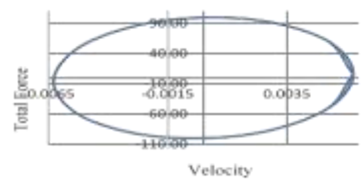
(e) Displacement vs Total Force



(b) velocity vs Spring Force

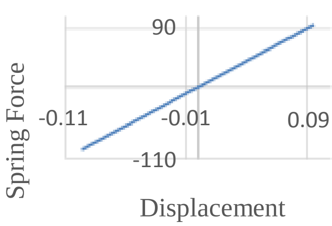


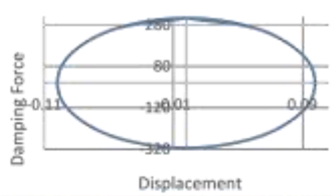
(d) Velocity vs Damping Force



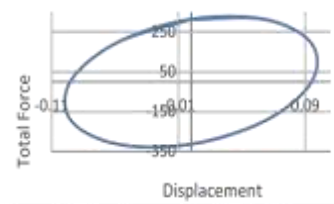
(f) Velocity vs Total Force

F=1.5

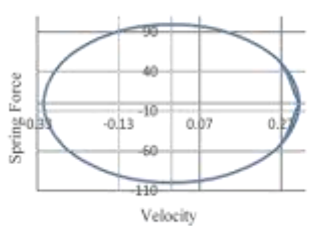




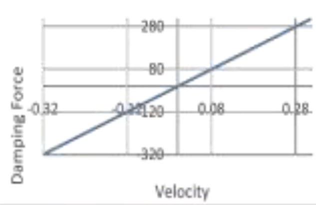
(c): Displacement vs Damping Force



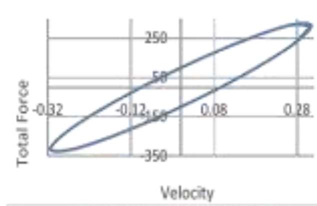
(e) Displacement vs Total Force



(b): Velocity vs Spring Force

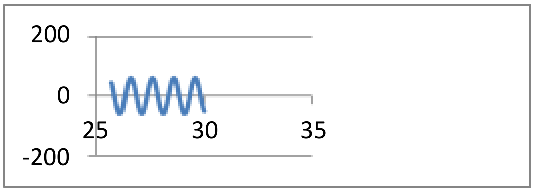


(d): velocity vs Damping Force

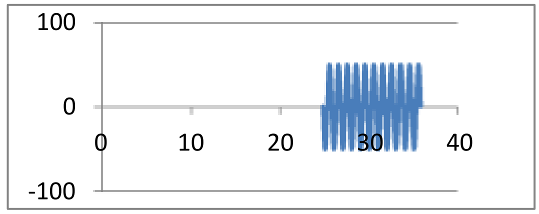


(f) Velocity vs Total Force

3.3 EXPERIMENTAL RESULTS

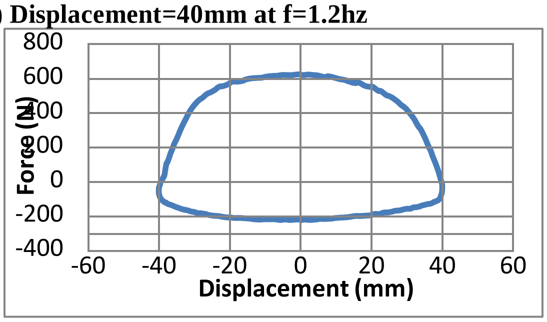


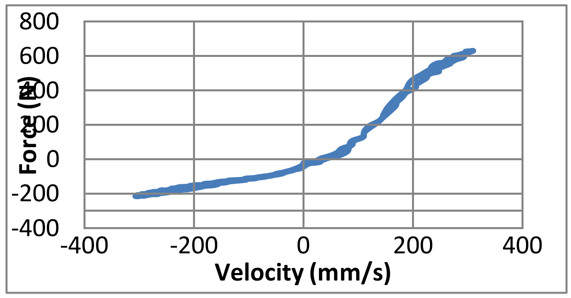
Sinusoidal

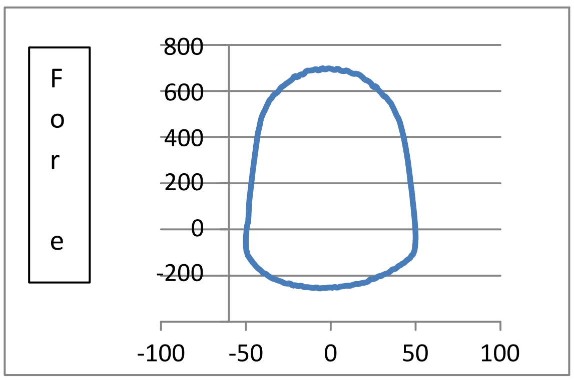


Constant velocity

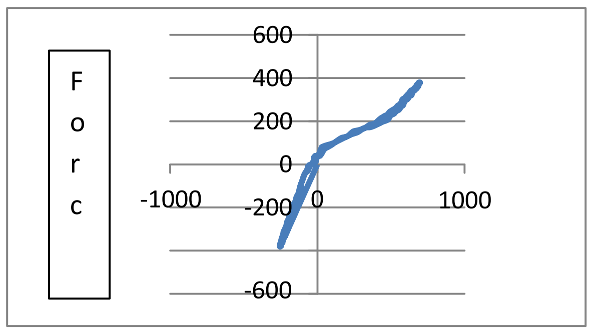
1) Displacement=40mm at f=1.2hz







Displacement (mm)



Velocity(mm/s)

4.0 CONCLUSION

- Comparison of the characteristics diagram show that the force model is capable of predicting nonlinear behaviour which is a better replacement for the linear model for accurate predictions of damper characteristics
- The model replicates the behaviour of the damper quite good. However, at some frequencies error is seen and this error is encountered due to hysteresis effect
- The hysteresis Zeffect is recorded in experimental results mainly due to oil compressibility and any type of the damper compliance.

REFERENCES

[1] M.S.M. Sani, M.M. Rahman, M.M. Noor, K. Kadirgama and M.R.M. Rejab, "**Study on Dynamic Characteristics of Automotive Shock Absorber System**", Malaysian Science and Technology Congress, Malaysia, (2008), 623-628.

[2] A. M. Salem, W. Galal, "**Identification of Characteristics of Hydraulic Shock Absorbers Used in Light Weight Tracked Vehicles**", 13th International Conference on AEROSPACE SCIENCES & AVIATION TECHNOLOGY, (2009), 1-13.

[3] Yongjie Lu, Shaohua Li and Na Chen "**Research on Damping Characteristics of Shock Absorber for Heavy Vehicle**", Research Journal of Applied Sciences, Engineering and Technology, (2013), Vol: 5(3),842-847.

[4] Branislav Titurus, Jonathan du Bois, Nick Lieven, Robert Hansford, "**A method for the identification of hydraulic damper characteristics from steady velocity inputs**", Mechanical Systems and Signal Processing Vol. 24, (2010) 2868–2887.

[5] Roberto Basso, "**Experimental Characterization of Damping Force in Shock Absorbers with Constant Velocity Excitation**", Vehicle System Dynamics, Vol. 30, (1998), 431- 442.

[6] S Cafferty, K Worden and G Tomlinson, "**Characterization of automotive shock absorbers using random excitation**", Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering, (1995), 209-239.