International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 1, January - 2014

Design of Shock Absorber Test Rig for Measurement and Analysis of Transmissibility

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Abstract

Shock absorber, an example of under damped vibration system is the key element in the suspension system of any automobile vehicles which aim to absorb a maximum amount of kinetic energy and sometimes potential energy. This paper mainly focuses on the measurement of transmissibility of shock absorber and its analysis at various loads and speeds. Transmissibility is a measure of effectiveness of the vibration isolating material. For the measurement of the transmissibility of the shock absorber a test rig is designed and developed. An experiment on the test rig is carried out at different speeds and loads which lead to the output in terms of sinusoidal waveform on strip chart recorder. The waveform is used to find out the transmissibility at different load-speed combination. The results obtained are used to find out the behaviour of transmissibility at different speed and loads.

1. Introduction

Driving comfort and manoeuvrability are the primary design objectives in development of an automobile's shock-isolation system which transmits fewer amounts of vibrations to the person sitting on the vehicle. Shock absorber subjected to the vibratory forces is a necessary component in the vehicle suspension system. It is an example of under damped vibration system; creating the vibrations under the external loading on it. It absorbs some amount of force, motion and transmits remaining amount of force and motion to the person sitting on the vehicle.

Attempts have been made previously to find out the various shock absorber properties by various approaches.Rao and Greenberg carried experiment for measurement of equivalent stiffness and damping properties of shock absorber.[1] Y. Ping studied dynamic behaviour of an oil-air coupling shock absorber.[2] A K Samantray developed preloading mechanism for liquid spring /damper shock absorber and studied the shock isolation properties.[3] For nonlinear viscous damping device force transmissibility of multidegree of freedom is also studied by Peng and others.[4] Also simulation and experimental validation of vehicle dynamic characteristic for displacement sensitive shock absorber with fluid flow modelling.[5,6]

An extensive work has been done on transmissibility of vibration isolator like SALIM vibration isolator [7],Pneumatic Vibration Isolator[8] which is used in various stationary applications. Yang Ping and other researched on dynamic transmissibility of complex non linear coupling isolator.[9]

From the above literature review it is found that very limited work has been done on the force transmissibility of the shock absorber so far as the loading condition is concerned. This experimental research work presents a model to calculate the force transmissibility of shock absorber at various loading conditions. The principle mechanism for the basis of this test rig designed to measure the force transmissibility is scotch yoke mechanism(ref net). This mechanism converts rotary motion of the circulating disc into the linear motion of the shock absorber. At various loads and speeds combinations the readings on the test rig is taken with the help of bar graph recorder and by using the data available from the graphs in terms of amplitude the transmissibility at various load-speed combinations is calculated.

2.Transmissibility

The transmission of the vibration can be specified by the term force transmissibility.

In order to reduce as much as possible the amount of force transmitted to the seat of the vehicle due to the vibration of the vehicle because of interaction with the roads, vehicles are usually isolated from the roads by means of wheels and suspension system which involves the shock absorber and the spring damper system in it. As a result the force transmitted to the seat of vehicle is the sum of the spring & the damper force of the shock absorber. i.e. $F_t = kx + cx$

Force transmissibility is defined as the amplitude ratio of the transmitted force to the impressed force. The formula for the force transmissibility is given as per equation 1

$$T_r = \frac{\sqrt{1+(2\xi\omega/\omega n)^2}}{\sqrt{[1-(2\xi\omega/\omega n)^2]^2+[2\xi\omega/\omega n]^2}} \quad (1)$$

Where, $r = (\omega / \omega_n)$= frequency ratio,
ξ = damping factor.

3. Design of Test Rig

3.1 Conceptual Design

The conceptual design involves the selection of the standard parts required for the test rig as follows

3.1.1 DC motor

Specification: power = 0.5 HP =0.37 KW (1HP=746 Watt) Speed = 1500 rpm

3.1.2 Strip Chart recorder

It is used to record the motion of the shock absorber under different loading and speed conditions. Readings can be taken on the strip chart recorder with the help of the pen arrangement.

3.1.3 Circular disc

The disc used is to convert the rotary motion of the motor shaft into the linear motion of the shock absorber. To achieve this purpose the appropriate eccentricity is provided to the disc. The disc presently used is having an eccentricity of 2.5 cm. figure 1 shows the disc and its different views.

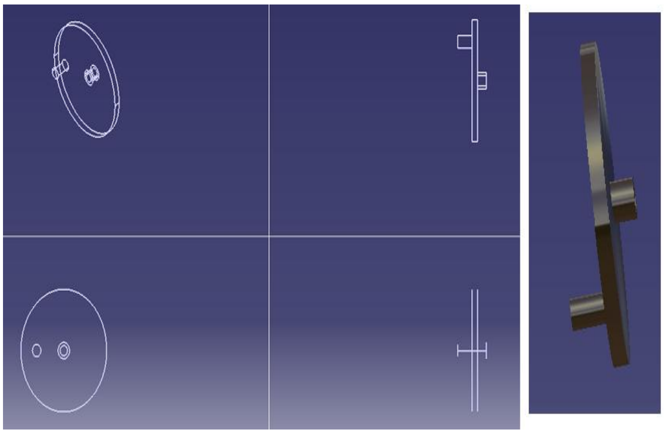

Fig.1 Circular Disc

3.2Mathematical Design

3.2.1Maximum force acting on the roller:

Motor Power = P = 0.5 HP= 0.37 KW

Motor is run at 1500 rpm so that it can lift the shock absorber and also produces maximum torque.

$$P=(2\pi NT) / (60) \quad (2)$$

Where, P = Motor Power , N= r.p.m., T = Torque

Therefore, $(0.37\times10^{3}) = (2\pi\times1500\times T) / (60)$

T= 70.66 Nm

Torque is given as, T= F×R (3)

Where, F= Force acting on roller

R= Distance between the centre of eccentricity to the motor output shaft.

= (0.04+0.012) m

Therefore,

70.66= F × (0.04+0.012)

F=1358.84 Newton

F=1360 Newton

As total force acting downwards (Weight of the bushes +Max dead weight can be added) = 5+4 = 9 kg= 90 Newton is less than the force acting upwards (1360 Newton). So that shock absorber is easily lifted upwards by the disc.

3.2.2Selection of Bearing

The deep groove ball bearing is selected to convert the rotary motion of the disc into the linear motion of the shock absorber. The protruded rod of the disc is fitted into the inner race of the bearing and outer race rotates and converts the rotary motion of the disc into linear motion of the shock absorber simultaneously.

Now from equation 3,

Radial load (F_r) = 1360 N, Axial load (f_a) = 0 N

Assuming static load carrying capacity C_o = 3550

$$F_a / F_r = 0 \ \& \ F_a / C_o = 0$$

X= Radial factor Y = Axial factor

So taking X = 1 & Y= 0

$P = X F_r + Y F_a$

Effective load = P =1360 N

Assuming bearing life L_h = 8000 Hrs

Life $L = 60\, n\, L_h / 10^6$

$L = 60 \times 150 \times 8000 / 10^6 = 72$

$L = (C / P)^3$ For ball bearing

Therefore, $C= (1360 \times 72^{1/3)} \times 1.2$

$$C= 6789.39 \text{ N} < 7800 \text{ N}$$

So design is safe.

So we selected the bearing no. SKF-6202.

Fig.2 SKF 6202 bearing connected with disc protrusion

4. Specifications of the test rig

The Detailed specifications of the various standard and manufactured components is given in the Table 1

Table 1. Specifications of Test Rig

Sr. No:	Component	Quantity	Specification
1.	DC Motor	1	P=0.5HP, 1500 RPM
2.	Circular disc	1	d= 195 mm, t= 12 mm
3.	Bearing	1	SKF 6202
4.	Shock Absorber	1	Bajaj M80(Moped), k=17000 N/m
5.	Bushes	2	I.D.= 37mm, O.D.= 42mm, h= 76mm
6.	Pillar	2	d= 37 mm, h=960mm
7.	Connecting Plates	2	l=410 mm, h=76 mm
8.	C-Channel (base)	1	L= 920mm, b= 600mm, h= 78mm
9.	Solid bar(For back bush)	1	d= 43mm, h=450mm
10.	Rectangular slot	1	L= 160mm, h= 50mm, t= 6mm
11.	Eccentricity	-	e=40mm
12.	Disc protrusion	-	d =13mm, l=40 mm

Fig.3 Test Rig and its ProE Solid model

5. Experimental Procedure

Following steps are followed while conducting an experiment

1. Connect all the set up equipment.
2. Connect the motor to dimmer stat and the strip chart

recorder to voltage eliminator.
3. Assure the proper connection and check it once again.
4. Now take the weights(in kg) and place it on the top of the bush on weight stand.
5. Start the motor with the help of power supply through dimmer stat and measure the speed of the motor in RPM using the tachometer.
6. Start the strip chart recorder and maintain the constant speed of it.
7. obtain the readings (Sinusoidal wave) on the recorder and record the speed and the load at which it is obtained.
8. Repeat the same procedure for various speed and load combinations and obtain the readings.

6.Calculation

The readings on the strip chart recorder for various load-speed combinations are obtained. The reading for the 49.05 N load and 120 rpm speed is shown below in figure 4

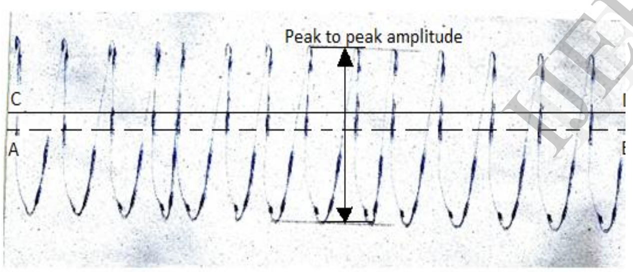

Fig.4 Reading for load 49.5N & 120 RPM

Similar readings are obtained for different loading and speed conditions with different peak to peak amplitude.

A)Theoretical approach to transmissibility caWe know the following standard values for the Bajaj M80 shock absorber as follows:

K=17000 N/m Cc=320 N/ms

Deflection of the spring(x) can be recorded on the graph at various load-speed combinations.

Now,

Sample calculation for load(W)= 49.05N and speed(n)= 120 RPM is given as below.

F_{dw}= Dead Weight(Bush+ Shock absorber weight) = (3.5+1.5)*9.81
= 49.05 N

$F_1 = K*X_1$
= 17000*0.00294
= 49.98 N

$F_2 = F_1+F_{dw}$
= 49.98+49.05
= 99.03

$\omega = 2*(\pi)*n/60$
= 12.57 RPS

$K' = [K^2 + (c\ \omega)^2]^{(1/2)}$
$= [17000^2 + (31.94*12.57)^2]^{(1/2)}$
= 17004.74 N/m

$F_{tr} = K' * X_2$ = 49.82 N

$(T_r)_{Therotical} = F_{tr} / F_2$ = 0.5031

Where-
F_1= Dynamic force due to spring
F_2= Total dynamic force = $F_1 + F_{dw}$
F_{dw}= Dead weight(Weight of shock absorber=1.5 kg and weight of bush=3.5 kg is added while calculating the dead weight as it also contributes in the to the total weight.)
F_{tr}= Transmitted force
X_1=Deflection of spring without dashpot.
X_2=Deflection of spring with dashpot.

B)Practical approach to transmissibility calculation:
Readings on the strip chart recorder in the form of sinusoidal waveform are taken. These readings are nothing but the representation of the force transmission. Line AB is supposed to be the centre line of the waveform but dut to the application of load and speed the centre transfers to the upwards and the new centre line will be the CD. Hence from the readings obtained we can calculate the transmissibility practically using equation

$$(T_r)_{Practical} = \frac{Distance\ from\ the\ upper\ peak\ to\ the\ centre\ of\ the\ waveform\ (Line\ CD)}{peak\ to\ peak\ amplitude\ /2}$$

For W= 49.01N and n= 120 rpm

$$(T_r)_{Peactical} = \frac{18}{48/2} = 0.75$$

7.Results and Discussions

The results for the loads 49.05N(0 kg) ,68.67N(2 Kg), 88.29N(4 Kg) and speeds 120 RPM, 150RPM,and 180 RPM with their combinations is take. Results for practical and theoretical transmissibility are obtained. Table 2 shows the values of the inputs given to the test rig and table 3 shows the results obtained.

Table 2 Input data to test rig and displacements obtained at strip chart recorder

LOAD	SPEED (RPM)	F_{DW} (N)	X_1 (m)	X_2 (m)
0 KG	120	49.05	0.00294	0.00293
	150	49.05	0.00295	0.00295
	180	49.05	0.00298	0.00298
2 KG.	120	68.67	0.00409	0.00409
	150	68.67	0.00413	0.00412
	180	68.67	0.00417	0.00417
4 KG.	120	88.29	0.00526	0.00526
	150	88.29	0.00530	0.00531
	180	88.29	0.00535	0.00536

Table 3. Practical and theoretical Transmissibility

F_1 (N)	F_2 (N)	F_{TR} (N)	T_R (Pract.)	T_R (Theo,)
49.98	99.03	49.82	0.75	0.5031
50.15	99.2	50.17	0.76	0.5057
50.66	99.71	50.69	0.78	0.5084
69.53	138.2	69.55	0.68	0.5033
70.21	138.88	70.07	0.69	0.5045
70.89	139.59	70.93	0.71	0.5082
89.42	177.71	89.44	0.64	0.5033
90.1	178.39	90.31	0.66	0.5062
90.95	179.24	91.18	0.67	0.5087

From the data obtained in Table 2 and Table 3 graphs can be plotted for the speed verses Transmissibility and Load verses Transmissibility. The graphs are given in Figure 5 and Figure 6.

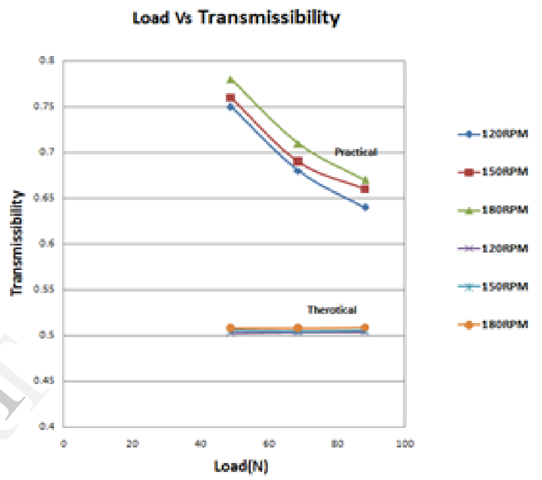

Fig 5. Graph of Load vs Transmissibility

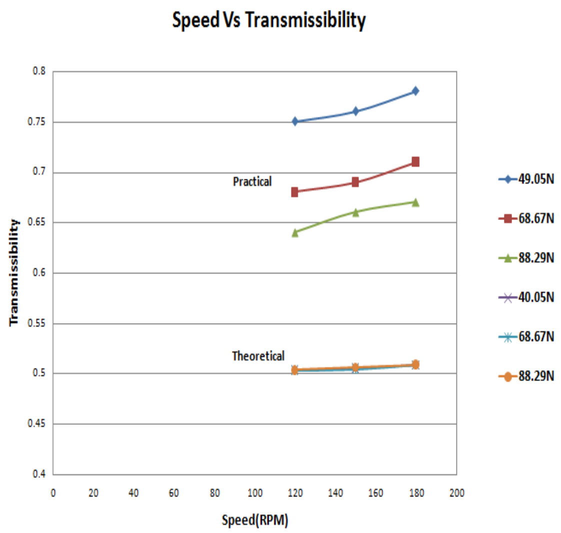

Fig 6. Graph of Speed vs transmissibility

8.Conclusion

1) From Fig.5 it is clear that as load increases at constant speed, the transmissibility of the system goes on decreasing practically. There is increase in transmissibility calculated by theory but it is nearly negligible.
2)From Fig.6 it can be concluded that when speed increases at constant load, the transmissibility of the system goes on increasing. Practically it shows the increase in distinct manner while theoretically it shows very small increase.

9.Acknowledgement

The authors would like to show their deep gratitude towards Prof. Sandeep Fargade for his valuable support and guidance throughout the project work and paper writing.

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