Shock Absorber Test Rig Design and Transmissibility Analysis

Rohit Londhe[1] Shantanu Swami[2] Ajay Pale[3] Abhijit Divekar[4] Prof. Siddhesh Bandekar[5]
[1,2,3,4,5]Department of Mechanical Engineering
[1,2,3,4,5]JSCOE Hadpsar, Pune, India

Abstract — Shock absorbers are crucial parts of cars that provide comfort and safety when driving. The performance traits of shock absorbers under actual use conditions are studied in this essay. Through computer modelling, testing, and experimental analysis, the dynamic behaviour of shock absorbers was investigated. MATLAB was used to validate the findings. Speed brakes were applied to a rotating drum in the model to imitate road disturbances. The research also examines and illustrates the dynamic characteristics curve of a single degree of freedom spring-mass-damper system (Hero Splendour rear shock absorber) for various spring stiffness values and various lubricants.

Keywords: Shock Absorber, MINITAB, MATLAB, Optimizing Fuzzy Logic

I. Introduction

A suspension system called a shock absorber is one that was mechanically created to control shock impulse and dissipate kinetic energy. It lowers the intensity of disruptions, increasing comfort and enhancing ride quality. Shock absorbers lessen the impact of driving through uneven terrain. Now-a-days Modern cars are equipped with powerful shock absorbers that can withstand any bumpy circumstances. Stiffer springs will be used to control excessive suspension movement if a shock absorber is not used. An automobile's suspension system is what keeps the wheel assembly from colliding with the body.

The main purpose of the suspension system is to protect the car's structure from shocks and vibrations brought on by the unevenness of the road. Weight support, road shock absorption and dampening, tyre contact maintenance and optimum wheel to chassis relationship are all accomplished by the suspension system. There is more to a moving vehicle than just its wheels. The suspension system rotates in a dynamic state of balance as the wheel spins, continuously compensating and adjusting for shifting driving circumstances in accordance with the road profile. Before construction, the vehicle's suspension needs to be studied. This is done to ensure that the shock absorber system's components stay in good shape. The shock absorber system must assess the impact to determine how it will respond in the worst-case scenario. A safe vehicle needs to be able to stop and man oeuvre on a variety of different types of roads. The ability to stop and manoeuvre rapidly depends on the tyres' ability to make good contact with the road.

The system of springs, shock absorbers, and connections that attaches a car to its wheels is known as the suspension. The shock absorber, as a whole assembly, is a crucial component of the car suspension system that affects ride quality. In order to lessen the tendency of a tyre to lift off the ground, shock absorbers are also essential for tyre to road contact. This has an impact on the vehicle's braking, steering, cornering, and overall stability. The vehicle may bob up and down if the shock absorber is removed from the suspension. The vehicle can still be driven, but if the suspension drops as a result of driving over a big bump, the rear spring may come loose.

In essence, the shock absorbers need to be replaced after a specific amount of driving. But if there were no flaws, this really shouldn't have been done.

II. Problem Specification

The aim of the project is to study and analyze single degree of freedom springmass-damper system and plot its dynamic characteristics curve for different values of spring stiffness for various speed condition FFT Analyzer.

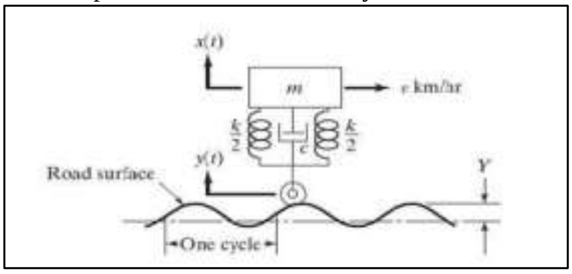

Fig. 1: Problem Specification

III. Objectives

1) To test suspension on various oil kinds and stiffnesses in order to determine the best motion transmissibility utilising DOE.
2) To figure out the dynamic properties of the shock absorber.
3) Different loads, speeds, and oils will be utilised for evaluating the suspension's stiffness at various stages.
4) A suspension testing setup for testing various suspensions using a motion transmissibility development.

IV. Methodology

With the help of the information from the literature review, we can determine how the CAD model should be created. The technical publications cited provide a brief overview of the conditions necessary for imposing certain limitations and how the loads are applied.

A. *Generation of CAD Model*

Gathering input data for the shock absorber test rig's dimensions.

B. *Determining the loads*

By reviewing several reference papers and other relevant resources, it is possible to determine the various loads and boundary conditions that are acting on the component.

C. *Analysis and Testing*

Testing is done by using FFT analyzer & Matlab software

D. *Analysis the Results and Regeneration*

– Modifying the model for optimum performance.

- Examine this brand-new model.
- Use MINITAB to check the transmissibility ratio.

E. *Fabrication and Experimental validation*

- Prototype fabrication.
- Appropriate experimental and model comparison.
- Validation of result by comparing with software results.

V. THE ANALYTICAL CALCULATIONS

A. *Spring Stiffness, Calculation*

Fig. 2: Spring Stiffness Measurement

For the two suspensions that are being used for the experiments, we do not originally have a value for the spring stiffness. To determine the stiffness for this, one brief experiment is conducted. Scale is used to measure the spring's initial length. Then, the spring of one of the shock absorbers is loaded with 60 kg. As a result, the spring is compressed, and its length is now measured.

Using the spring stiffness calculation formula,

$$K= (F/X) \times 9.81 \text{ N/mm}$$

Where,

K-Stiffness of the spring in N/mm

F- Force (kg)

X-Displacement because of loading (mm.)

Calculations,

For the Splendor,

$K= (60.00\times9.81)/ (230.00-205.00)$

$K= 23.541$ N/mm

Sr. No	Shock Absorber of	Load on the Spring in Kg	Length in (mm)		Stiffness of Spring in (K) N/mm
			Free body Length	Compressed Length	
1	Splendor	60.00	230.00	205.00	23.540
2	Honda Shine	60.00	240.00	206 .00	17.310

Table 1: Spring Stiffness of Shock Absorber

B. *Shaft material and Calculation*

Shaft made of EN 19 Alloy steel. It is a high-quality, high-tensile steel that can typically be easily machined in any temperature condition. It also has good wear resistance along with good ductility and shock resistance.

1) *Applications:*

When EN19T initially came into being, it was intended to be used for gears, pinions, shafts, spindles, and other components in the machine tool and motor industries. Later, as its uses expanded greatly, it is now extensively used in sectors like the oil and gas industries. A high tensile steel grade of good quality is appropriate for a wide range of applications, including gears, bolts, and studs.

2) *Calculation*

Perimeter of Drum

$P=2\pi r$

$P=2\pi \times 0.305$

$P=1.91637$ m

volume of drum

$V=2\pi r^2 h$

$V=2\times3.14\times0.305\times0.305\times0.005$

$V=0.00292246$ m3

Mass of Drum

$M=V\times\rho$

$M=0.00292246\times7860$

$M=22.98$ kg

WEIGHT OF DRUM

$W=m\times g$

$W=22.98\times9.81$

$W=225.48$ N

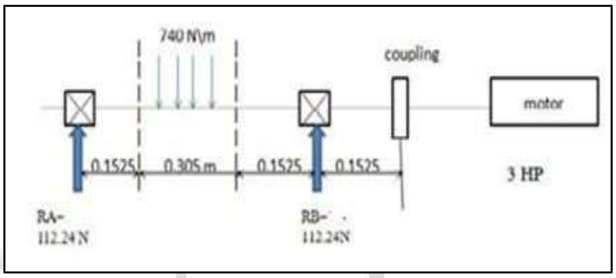

Fig. 3: Force Diagram

By maximum shear stress theory

Support reaction (RA, RB)

$\sum MA=0$

$[(-RB\times0.6096) + (740\times0.305\times0.15252)]=0$

$RB=112.74N$

$RA= -RB+ (740\times0.305)$

$RA=112.74$ N

Bending Moment (M)

$M=RA\times x- w \times (0.15252)/2$

$M=112.74\times0.305-740\times (0.1525)\ 2/2$

$M=25.78$ N-m Torque

$T=F\times r$

$T= (149\times9.81) \times0.405$

$T= 592$ N-m

Equivalent Torque

$Te = \sqrt{(M2+T2)}$

$Te = \sqrt{(25.782 + 5922)}$

$Te = 593$ N-m

Diameter of Shaft

$d= \sqrt[3]{(16\times Te/\ \pi\ \tau)}$ $d = \sqrt[3]{[(16\times593\times1000)/\ (\pi\times45)]}$

$d=40.69$ mm~50 mm

By maximum principal stress theory

Equivalent Moment

Me= [M +√ (M2+T2)] /2

Me= [25.78+√ (25.782+5922)] /2

Me=309.17 N-m

Diameter of Shaft d=

∛ (32×Me/πσ)

d=∛((32×309.17)/(π×75)

) d=41 mm

Selecting maximum diameter & after select the roller bearing

Find Te < T

T= (60×1000×P/2πN)

T= (60×1000×2.238/2 π×240)

T=89.047 N-m

Velocity

V= πDN/60

V=π×0.05×240/60

V= 628.31 m/s

V=2.2611 Kmph

3) *Bearing*

A bearing is a mechanical component that places two machine parts in relation to one another and allows them to move with one another. It has two or more contacting surfaces that make touch with one another and transfer load. For the shaft, UCP210 bearing is used.

Plummer block bearings are chosen with an internal diameter of 50 mm and a necessary torque of 89 Nm.

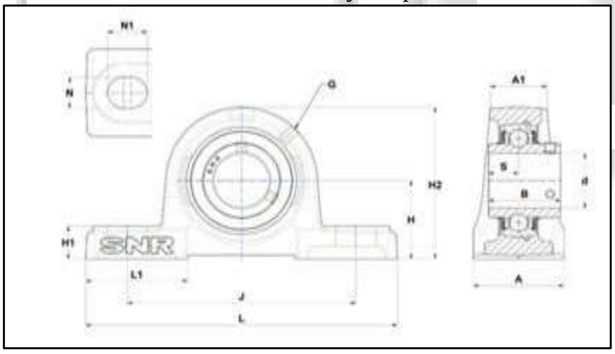

Fig. 4: Bearing UCP210

4) *Key*

A mechanical component known as a key is used on shafts to lock down spinning components such as gears, pulleys, or sprockets and stop relative motion between them. The key transfers torque from the shafts to the element that is supported by the shaft, or vice versa. It is always inserted with the shaft's axis parallel.

In carbon steels, carbon is the main alloying component. They also contain 0.4% silicon and up to 1.2% manganese. Additionally, these steels still have trace amounts of copper, molybdenum, aluminum, chromium, and nickel..

VI. EXPERIMENTAL SETUP

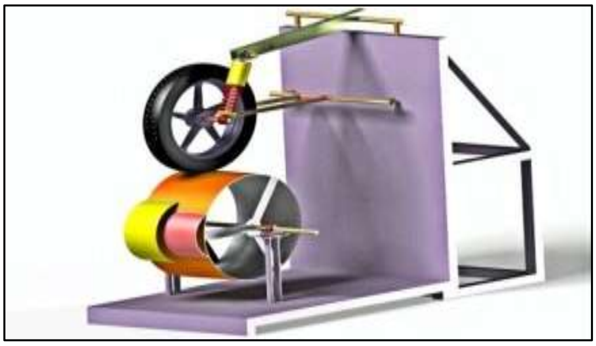

Fig. 5: Experimental Setup (CAD Model)

A. *ABOUT SETUP*

1) *FRAME*

It serves as the setup's foundation. The C-Section is formed of MS bars. 35 feet of material was used in total. All assembly components are supported by the frame.

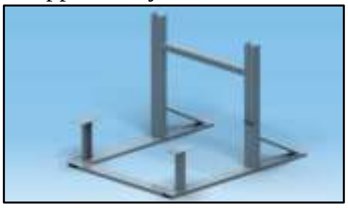

Fig. 6: Frame

2) *DRUM*

Fig. 7: Drum

It is constructed from 4mm thick MS sheet. It is produced through the rolling of sheet metal. Sheet metal is used to create the standard speed breaker profiles, and the drum is then welded to the sheet metal. Three spokes support the drum.

3) *Wheel Assembly*

Fig. 8: Wheel assembly

It is the Hero Splendour Bike's wheel assembly. Swing arm is equipped with a wheel. Swing arms are attached with the lowest point of shock absorbers. Swing arms are put together for the frame.

4) *MOTOR*

3 HP single phase motor is coupled to Shaft runs on 1440 RPM. It rotates the shaft and ultimately drum.

5) *DIMMERSTAT*

The voltage of a dimmestat, an automatic transformer, is continually changeable. Its construction is straightforward, and the output voltage variation is smooth, constant, and breakless. It is quite effective and has a great short-term overload capacity. The motor speed is regulated by a 20 amp dimmerstat.

6) FFT Analyzer

Fast Fourier Transform, or FFT. It is a tool for measuring vibration and noise. Data is transformed from time domain to frequency domain.We will use an accelerometer to take readings. The outcomes are shown using DEWEsoft Software.

Fig. 9: FFT Analyzer

SPECIFICATION

- Smaller USB- based system
- 8 analogue input channels (strain, voltage; with MSI adapters any input)
- 200 kS /s aliasing-free 24bit-ADC
- 8 counters which are precisely real time
- 2 isolated CAN bus ports

7) Accelerometer

The accelerometer, a Piezo-electric accelerometer, is regarded as the industry-standard vibration transducer for measuring machine vibration. The piezoelectric crystal that forms the basis of the accelerometers has a mass fastened to one of its surfaces. When a vibration signal is applied to a mass, the mass accelerates the vibration, which is then transformed to a force, which is then converted to an electrical signal. The foundation of the "accelerometer" is this.

8) The DEWsoft Software

With the DEWESoft Software, the analysis is done. The software includes a number of dynamic signal analysis approaches, covering sound level, torsional vibration, and human vibration.

B. *Working*

- A shaft is mounted in a bearing. This allows the shaft to rotate freely while supporting its weight.
- A drum is mounted on the shaft. The drum is the part that will rotate when the motor is turned on.
- Speed breaker profiles are welded to the drum. These profiles help to slow down the drum when it rotates.
- A wheel assembly is mounted on the drum. The wheel assembly includes the wheel itself, as well as the axle and bearings that allow the wheel to rotate freely.
- The shaft is coupled to a motor. This allows the motor to turn the shaft, which in turn turns the drum.
- The motor speed is controlled using a dimmerstat. The dimmerstat allows you to adjust the speed of the motor, which in turn adjusts the speed of the drum.
- As the wheel and drum rotate, the speed-beaker profile of the wheel causes a bump on the shock absorber.

Fig. 10: Actual Experimental Setup

- Shock absorber will get saturates or compressed.
- FFT analyzers one sensor will attached to higher and another is one at lower point of shock absorbers then the readings printed on computers screen.

VII. RESULTS AND DISCUSSION

A. *Experimental Results*

Table 2. SPLENDOR SUSPENSION (OIL 1)

S.N	Spring Stiffness (K)	Load (Kg)	Peak(RMS) m/s2		Transmissibility T_R=(A/B)
			Top (A)	Bottom (B)	
1	(N/m) 23540	27	17.085	23.347	0.7317
2	23540	32	14.420	24.23	0.6073
3	23540	37	11.71	22.955	0.4932
4	23540	42	10.59	23.544	0.4147

Table 3. HONDA SHINE SUSPENSION (OIL 1)

S. N	Spring Stiffness (K)	Load (Kg)	Peak(RMS) m/s2		Transmissibility T_R=(A/B)
			Top (A)	Bottom (B)	
1	(N/m) 17310	27	13.34	24.32	0.5485
2	17310	32	11.54	25.66	0.45
3	17310	37	10.73	26.19	0.41
4	17310	42	10.30	28.61	0.36

Table 4. SPLENDOR SUSPENSION (OIL 2)

S. N	Spring Stiffness (K) (N/m)	Load (Kg)	Peak(RMS) m/s2		Transmissibility T_R=(A/B)
			Top (A)	Bottom (B)	
1	23540	27	18.774	25.407	0.7371
2	23540	32	14.469	24.525	0.6045
3	23540	37	11.375	21.876	0.52
4	23540	42	9.809	21.876	0.4484

Table 5. HONDA SHINE SUSPENSION (OIL 2)

S. N	Spring Stiffness (K) (N/m)	Load (Kg)	Peak(RMS) m/s2		Transmissibility T_R=(A/B)
			Top (A)	Bottom (B)	
1	17310	27	13.791	25.898	0.5325
2	17310	32	12.24	27.664	0.4427
3	17310	37	9.4176	24.721	0.3809
4	17310	42	7.651	23.093	0.33134

B. *FFT RESULTS*

1) *Splendor Suspension Bottom (32Kg for Oil 1)*

2) *Splendor Suspension Top for weight 32Kg for Oil 1*

Figure 12.Graph 2

3) *Splendor Suspension Bottom for weight 32 Kg for Oil 2*

Figure 13.Graph 3

4) *Splendor Suspension Top of weight 32Kg for Oil 2*

Figure 14.Graph 4

VIII. RESULTS AND DISCUSSION

A. *Transmissibility comparison*

The transmissibility as calculated using experimental readings and the MATLAB solution can now be compared. The following table displays the transmissibility error percentage.

1) *Splendor Suspension (K=23540N/m and Oil 1)*

Table 6. Transmissibility comparison of Splendor suspension with Oil 1

Load (Kg)	ω/ ωn	Transmissibility		% Error
		Experimental	MATLAB	
27	1.524	0.7317	0.7859	6.896
32	1.659	0.5951	0.6073	2.009
37	1.784	0.51	0.4932	3.406
42	1.901	0.45	0.4147	8.512

2. Honda Shine Suspension (K=17310N/m and Oil 1)

Table 7. Transmissibility comparison of Honda Shine suspension with Oil 1

Load (Kg)	ω/ ωn	Transmissibility		% Error
		Experimental	MATLAB	
27	1.777	0.5485	0.5203	5.419
32	1.9348	0.45	0.4149	8.459
37	2.08	0.41	0.3445	19.013
42	2.21	0.36	0.2943	22.324

2. Splendor Suspension (K=23540N/m and Oil 2)

Table 8. Transmissibility comparison of Splendor suspension with Oil 2

Load (Kg)	ω/ ωn	Transmissibility		% Error
		Experimental	MATLAB	
27	1.524	0.7371	0.7837	5.946
32	1.659	0.59	0.6045	2.398
37	1.784	0.52	0.4906	5.993
42	1.901	0.4484	0.4123	8.756

3. Honda Shine Suspension (K=17310N/m and Oil 2)

Table 8. Transmissibility comparison of Honda Shine suspension with Oil 2

Load (Kg)	ω/ ωn	Transmissibility		% Error
		Experimental	MATLAB	
27	1.777	0.5325	0.5159	3.218
32	1.9348	0.4427	0.411	7.713
37	2.08	0.3809	0.3411	11.67
42	2.21	0.33134	0.2913	13.745

B. *Result of MATLAB*

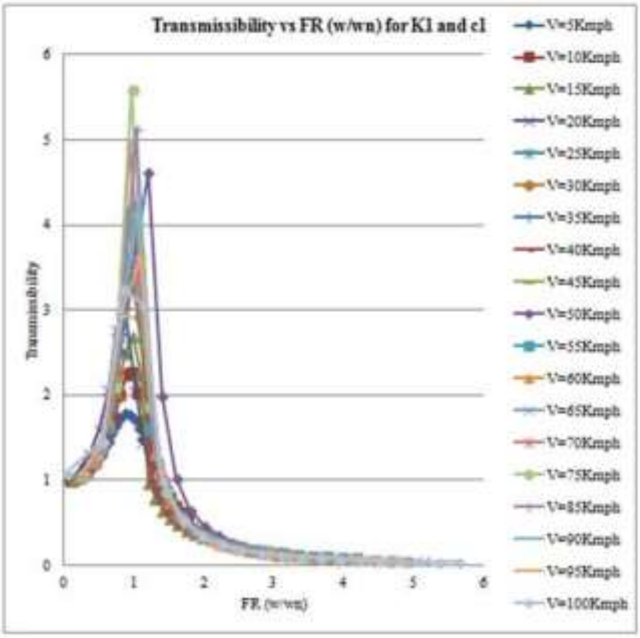

Fig. 15. Transmissibility Vs FR (ω/ ωn) for K1 and c1

IX. Conclusion

We can test numerous suspensions using this suspension testing system at various speeds and loads. Suspension systems of various heights are another option.

We can determine the best motion transmissibility by experimenting with various suspensions and oils. With the ultimate goal of analyzing and displaying the dynamic properties of the suspensions of the Honda Shine and the Hero Splendor utilizing a single wheel model of suspension analysis, several data were produced. The project work is nevertheless concluded with the following remarks:

1) A suspension system that is purposefully under-damped performs at its best.
2) Based on experimental findings and graphs, we can deduce that transmissibility should be as low as possible for a decent ride, and that this can be done by employing a low damping constant and a high spring stiffness. Honda Shine suspension performs better than Splendor suspension, and both offer comparable results.

References

[1] Javad Marzbanrad, Masoud Mohammadi and Saeed Mostaani "Optimization of a passive vehicle suspension system for ride comfort enhancement with different speeds based on design of experiment method (DOE) method " Vol. 5(3), pp. 50-59, March 2013 DOI 10.5897/JMER10.061 , ISSN 2141-2383 © 2013 Academic Journals http://www.academicjournals.org/JMER

[2] Prof.Amol P.Kokare,AkshayKamane,VardhanPatil, Vikrant Pakhide, of "Performance Evaluation of Shock Absorber Acting as a Single Degree of Freedom SpringMass-Damper System using MATLAB", Dept. of Mech, JSCOE Engg., Pune, India, International Journal of Engineering Research & Technology (IJERT) IJERTV4IS090621(This work is licensed under a Creative Commons Attribution 4.0 International License.)Vol. 4 Issue 09, September-2015, pp[730-734]

[3] Chaudhari Arati G., Shilawat Pooja S., Butte Vinod Y., Dhage Pradip U.,Prof.Londhe B.C " A Review of Design of Shock Absorber Test Rig International Research Journal of Engineering and Technology (IRJET)" Volume: 04 Issue: 03 | Mar -2017 www.irjet.net

[4] Nikhil S. Kothawade, Amol D. Halwa,Ajay I. Chaudhari,Bhushan R. Mahajan, of "Design of Shock Absorber Test Rig for Measurement and Analysis of Transmissibility", Department of Mechanical Engineering,Amrutvahini COE, Sangamner, Maharashtra, India. International Journal of Engineering Research & Technology (IJERT), Vol. 3 Issue 1, January – 2014 ISSN: 2278-0181.pp [2827-2832].

[5] K. S. Patil, Vaibhav Jagtap, Shrikant Jadhav, Amit Bhosale, Bhagwat Kedar Performance Evaluation of Active Suspension for Passenger Cars Using MATLAB 1(Department of Mechanical Engineering, Sree Chatrapati Shivaji College of Engineering, Pune, India) IOSR Journal of Mechanical and Civil Engineering (IOSRJMCE) ISSN(e) : 2278-1684, ISSN(p) : 2320–334X, PP : 06-14

[6] Arokiasamy Mariajayaprakash1, Thiyagarajan Senthilvelan and Krishnapillai Ponnambal Vivekananthan" Optimisation of shock absorber processparameters using failure mode and effect analysisand genetic algorithm", Mariajayaprakash et al.

Journal of Industrial Engineering International 2013, 9:18http://www.jiei-tsb.com/content/9/1/18

[7] M.S.M.Sani, M.M.Rahman, M.M.Noor, K.kadirgama and M.R.M.rejabof"Study on Dynamics Characteristics of Automotive Shock AbsorberSystem",Faculty of Mechanical Engineering, University Malaysia Pahang, TunAbdulRazak Highway,26300 Gambang, Kuantan, Pahang Malaysia, Malaysian Science and Technology Congress, MSTC08, 16-17 Dec, KLCC, Malaysia, 2008.

[8] A. M. Salem, W. Galal, of "Identification of Characteristics of Hydraulic Shock Absorbers Used in Light Weight Tracked Vehicles", Aerospace Sciences & Aviation Technology, ASAT- 13, May 26 – 28, 2009.

[9] N. B. Kate, T. A. Jadhav, of "Mathematical Modeling of an Automobile Damper",Dept. of Mechanical Engineering, Sinhgad College of Engineering, Pune, India International Journal of Engineering Research (ISSN : 2319-6890) Volume No.2, Issue No. 7, pp. : 467-471 01 Nov 2013.

[10] Mohan D. Raoa and Scott Gruenbergb "Measurement of Equivalent Stiffness and Damping of Shock Absorbers" Mechanical Engineering-Engineering Mechanics Department Keweenaw Research Center Michigan Technological University, Houghton, MI 49931, USA

[11] T. Yoshimura, A. Kume, M. Kurimoto and J. Hino, of "Constuction of an active suspention system of quarter car model using concept of sliding mode control" Department of Mechanical Engineering, Faculty of Engineering, The university of Tokushima,Minamijosanjima-cho 21,okushima 770-8506, Japan.

[12] Daniel Fischer, RolfIsermann, of, "Mechatronic semiactive and active vehicle suspensions", Institute of Automatic Control, Darmstadt University of Technology, Landgraf-Georg-Str. 4, D-64283 Darmstadt, Germany Received 14 February 2003; accepted 25 August 2003.pp [1353-1367]

[13] Semiha Turkay, Huseyin Akcay, of "A study of random vibration characteristics of the quarter-car model", Department of Electrical and Electronics Engineering, Anadolu University, 26470 Eskisehir, Turkey, Journal of sound and vibration, Received 7 July 2003; accepted 16 February 2004, pp[111-124].

[14] Huijun Gao, James Lam, Changhong Wang, of "Multiobjective control of vehicle active suspension systems via load-dependent controllers", Space Control and Inertial Technology Research Center, P.O. Box 1230, Harbin Institute of Technology, Xidazhi Street 92, Harbin, 150001, PR China Department of Mechanical Engineering, The University of Hong Kong, Pokfulam Road, Hong Kong Journal of Sound and Vibration 290 (2006) 654–675 24 August 2005.

[15] Lei Zuo, of "Effective and Robust Vibration Control Using Series Multiple Tuned-Mass Dampers", Department of Mechanical Engineering, State University of New York at Stony Brook, Journal of Vibration and Acoustics JUNE 2009, Vol. 131 / 031003-1

[16] Junghsen Lieh Professor, of "Tire Damping Effect on Ride Quality of Vehicles With Active Control Suspensions", Mechanical and Materials Engineering, Wright State University, Dayton. Journal of Vibration and Acoustics JUNE 2009, Vol. 131 / 031011-1.

[17] Marco Danti, DavideVige, Guido Vincent Nierop, of "Modal Methodology for the Simulation and Optimization of the Free-Layer Damping Treatment of a Car Body", Engineering and Design Virtual AnalysisNVH, Fiat Auto, Corso Settembrini 40,10135 Torino, Italy Journal of Vibration and Acoustics APRIL 2010, Vol. 132 / 021001-1.

[18] P. Polach, M. Hajzman, of "Design of the hydraulic shock absorbers characteristics using relative springs deflections at general excitationof the bus wheels", Section of Materials and Mechanical Engineering Research, SKODA V YZKUM s. r. o., Tylova 1/57, 316 00 Plzen, Czech Republic, Received 8 October 2010; received in revised form 13 December 2010.

[19] Shaohua Li, Yongjie Lu and Liyang Li, of "Dynamical Test and Modeling for Hydraulic Shock Absorber on Heavy Vehicle under Harmonic and Random Loadings" Mechanical Engineering School, Shijiazhuang Tiedao University, Shijiazhuang 050043, China, Research Journal of Applied Sciences, Engineering and Technology 4(13): 1903-1910, 2012, ISSN: 2040-7467 ,July 01, 2012.

