Study on Dynamic Characteristics of Automotive Shock Absorber System

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Abstract Shock absorber is one of important component in a vehicle suspension system. The shock control spring motion by damping energy from the spring. This paper was focused on the dynamic characteristics of an automotive shock absorber. The design of interchangeable shock absorber test rig was developed and fabricated for the dynamics measurement system. This test rig integrated with the computer systems to record the signal. An experiment was conducted to identify the stiffness and damping parameter for 850 cc and 1600 cc shock absorber. Simulation study was performed utilizing the COSMOS Motion software. It can be seen from the results that there is a good agreement between the experimental and simulated results in terms of stiffness and damping value except few discrepancy. The acquired results show that the range of discrepancy within 10%. The good range of stiffness of the passenger vehicle shock absorber is 20 N/mm to 60 N/mm while the damping of passenger vehicle shock absorber is 1 Ns/mm to 6 Ns/mm.

Keywords Suspension system, shock absorber, damping, stiffness and dynamic characteristics

INTRODUCTION

Suspension system is an assembly used to support weight, absorb and dampen road shock, and help maintain tire contact as well as proper wheel to chassis relationship. A vehicle in motion is more than wheels turning. As the wheel revolves, the suspension system is in a dynamic state of balance, continuously compensating and adjusting for changing driving conditions. Suspension of vehicle need to analyze before be manufacturing. This is because to make sure components in shock absorber system remain in good conditions. In the other hand, shock absorber system need to analyze how shock to see how they going to perform in worst-case scenario.

A safe vehicle must be able to stop and maneuvre over a wide range of road conditions. Good contact between the tires and the road will able to stop and maneuver quickly [1]. Suspension is the term given to the system of springs, shock absorbers and linkages that connects a vehicle to its wheels. Shock absorber is an important part of automotive suspension system which has an effect on ride characteristics. Shock absorbers are also critical for tire to road contact which to reduce the tendency of a tire to lift off the road [2]. This affects braking, steering, cornering and overall stability [3]. The removal of the shock absorber from suspension can cause the vehicle bounce up and down. It is possible for the vehicle to be driven, but if the suspension drops from the driving over a severe bump, the rear spring can fall out [4].

Basically, the shock absorbers must be replaced after driving exceeds certain distance. But this actually not should have been followed if there are no defective. To ensure there are no defective, the consideration to check the condition of the shock absorber is the best way. There are several methods to test the condition of the shock absorber. One of the tests is endurance test use frequency response

method which applied to the suspension and tire. But this test is very complicated and costly because the machine is very expensive. The other method to check the shock absorber without removing from the vehicle is by using the bounce test [5]. In the workshop, some mechanics will perform bounce test which is push down each corner of the car several times to check the condition of shock absorber. However, the result of this test is not very accurate to indicate the condition of shock absorbers. The objectives of this paper are to determine the dynamic characteristics of automotive shock absorber systems.

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.

In order to collect signals generated from the test rig components, there are the sensors positioned on the test rig. The unit of accelerometer is secured on the middle plate to record signal from the vibration caused from the cylinder when activated to compress the shock absorber. The accelerometer is low impedance, voltage mode designed for vibration measurement.
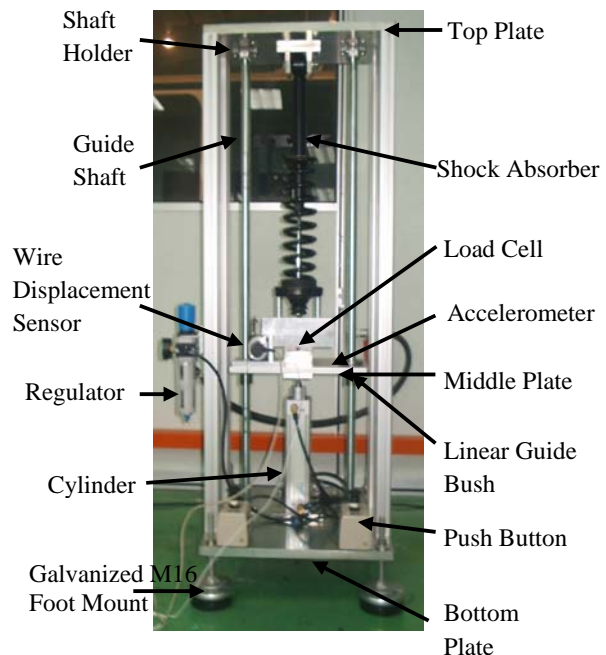

Figure 1: Design of shock absorber test rig

The sensing element (accelerometer) actually is in contact with the process and gives an output which depends in some way on the variable to be measured. Than the element that take the output of accelerometer and convert it into more suitable for further processing is a signal conditioning elements. Therefore, it is suitably processed and modified in the signal conditioning element so as to obtain the output in desired form [6]. Figure 2 shows the picture of accelerometer.

As vibration can be express as a function of displacement, a unit of wire displacement sensor is installed at the middle plate. This wire is pulled and

secured to the top plate. So, the compression of shock absorber from the activation of cylinder will show the displacement. The picture of wire displacement sensor is show in Figure 3.

Figure 2: Accelerometer

Figure 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.

Figure 4: Signal Conditioning 8 Channel

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.

RESULTS AND DISCUSSION

Figure 5 shows the experimental force profiles with time for 1600 cc shock absorber. The maximum force 1800 n was applied to 1600cc shock absorber with spring and the maximum amplitude of shock absorber is obtained 305 mm. By using harmonic motion calculation, the stiffness of spring that had calculated is 29.56 N/mm and the damping of shock absorber is 5.75 Ns/mm.

$$\text{Displacement}, x = A \sin \omega t$$
$$= 305 \sin(1.047)(11) = 60.9 \text{ mm}$$

$$\text{Velocity}, v = \omega A \cos \omega t$$
$$= (1.047)(305)\cos(1.047)(11) = 312.91 \text{ mm/s}$$

$$\text{Stiffness}, k = F / x$$
$$= 1800 / 60.9 \text{ mm} = 29.56 \text{ N/mm}$$

$$\text{Damping}, c = F / v$$
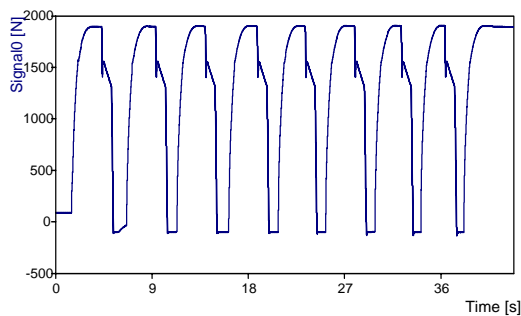$$= 1800 / 312.91 = 5.75 \text{ Ns/mm}$$

Figure 5: Experimental force versus time profiles for 1600cc shock absorber

Figure 6 shows the simulated force profiles with time for 1600 cc new shock absorber with damper using COSMOS motion. From displayed the load that given is 2000 N for simulation but the force that attach to shock absorber to make a compression is 1708 N. Then, the spring displacement for 2000 N load a given is 98 mm. From simulation the stiffness of the spring and damping values are 28.5 N/mm and 5.26 Ns/mm respectively. Figure 7 shows the design of shock absorber using solidworks and analysis by
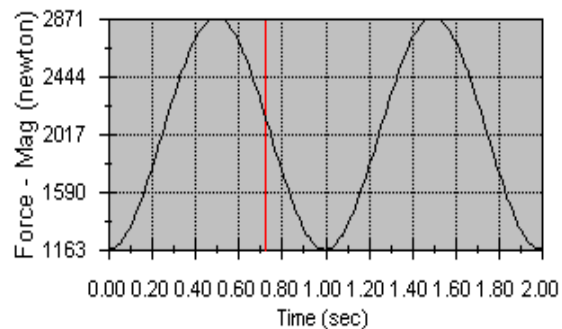
cosmos motion.

Figure 6: Simulated force profiles with
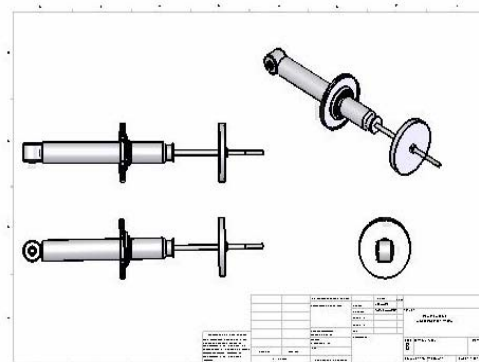
time for 1600 cc shock absorber

Figure 7: The Design of Shock Absorber by Using Solidworks and Analysis Using Cosmos Motion

Table 1 gives the experimental and computational results for 1600 cc shock absorber. It can be seen from the results that there is a good agreement between the experimental and simulated results in terms of stiffness and damping value with small discrepancy. The acquired results show that the range of discrepancy within 10%. The good range of stiffness of the passenger vehicle shock absorber is 20 N/mm to 60 N/mm while the damping of passenger vehicle shock absorber is 1 Ns/mm to 6 Ns/mm. The result valid that shock absorber test rig on experimental method capable to test dynamic measurement.

Table 1: Comparison results of stiffness and damping value for 1600cc shock absorber

	Stiffness, k (N/mm)	Damping, c (Ns/mm)
Experimental	29.56	5.75
Simulation	28.5	5.26
Error (%)	3.59	8.52

The result for new shock absorber without spring of 800cc vehicle is shows in Figure 8. The load that applied to shock absorber is 180 N while the force that attach to shock absorber to move a piston of shock absorber is 160 N. The displacement measured was 160 mm. The damping is calculated by determine the velocity of shock absorber and the result that obtained was divided with the force that applied to shock absorber. The damping value of shock absorber 850cc vehicle without spring is 0.9713 Ns/mm.
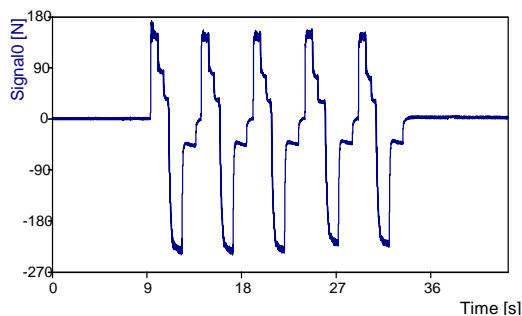

Figure 8: Experimental force profiles with time for 850cc shock absorber without spring

Figure 9 shows the force profiles with time for 850cc new shock absorber without spring. The maximum load applied to the damper is 122 N to make a movement. The small load was given due to the small design of shock absorber. The design and dimension of shock absorber can effect the load a given. Then, the displacement of a damper is 40 mm due to a load given. The damping value of new shock absorber without spring 800cc by using COSMOS motion is 1.0391 N-s/mm. The percentage of damper difference of new shock absorber 850cc between simulation by using COSMOS motion and experimental is 6.98%. The difference of percentage due to the small shock absorber design can give small effect to reading of force and displacement that can affect a result of damping.
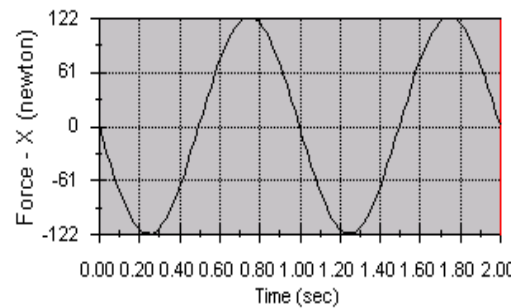

Figure 9: Simulated force profiles versus time for 850cc shock absorber without spring

The stiffness is refer to a how a spring compress when a load a given and the damping is measure while a shock absorber has a displacement when load attach to shock absorber. In measure a stiffness and damping of shock absorber system there are many non linear parameters should be known. This is because the parameter can give effect to a

data that be collected. Besides that, from previous data there are a few elements that be recognize can contributed to make a shock absorber damages. The material that use to shock absorber also can contribute to a result of an experimental that has done. The value of stiffness of spring will increase a lot with a small increase of wire diameter.

CONCLUSIONS

The purpose of this project is to study and analysis stiffness and damping of shock absorber system. The stiffness and damping value for shock absorber are strongly related to the capacity of the shock absorber. The results show that good matching with small discrepancy between the experimental and simulation results. As conclusion, the shock absorber test rig capable to identify dynamic characteristics of shock absorber.

ACKNOWLEDGEMENT

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THE DESIGN OF SHOCK ABSORBER BY USING
ANALYSIS USING COSMOS MOT