NUMERICAL MODELLING FOR SHOCK ABSORBER HEALTH MONITORING OF PASSENGER CARS UNDER HARSH DRIVING CONDITION

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ABSTRACT

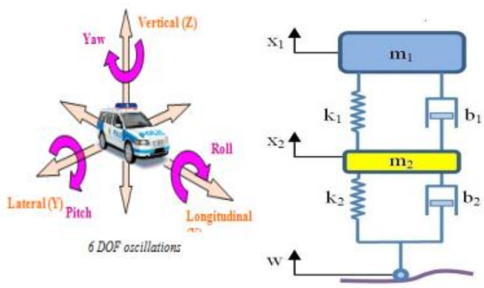
Shock absorber is a critical component of the vehicle suspension system designed to absorb shock loads. It is of great interest and importance to be able to observe the condition of them to make sure proper functioning. This system could be used to check the behavior (condition) of the shock absorbers or dampers while it is fixed on the vehicle. It is provides a reliable, convenient, economical, and compact method and device for monitoring health of suspension system without dismantling from the vehicle and without fixing to any machine. However some kind of latest models are having such systems to observe the condition of it's suspension system controlled by electronically. But no method is available in vehicles which are having conventional suspension systems. This paper present the overview of propose suspension health monitoring system for conventional automobiles.

Keywords: *Automobile, Damper, Shock absorber, Suspension.*

1. INTRODUCTION

The primary requirement of springing in a vehicle suspension system is to permit the vertical oscillation of the vehicle body relative to other parts of the vehicle while supporting the static weight of the vehicle body. The body of a vehicle has six degrees of freedom (6 DOF) as shown in the figure 1.a [1] and can perform six different oscillations. Due to the complexity of investigating a system with 6 DOF and in order to simplify the calculations of the suspension system, the body of the vehicle is simplified to a system with 2 DOF considering only the vertical oscillation and the pitch oscillation. Vertical oscillations of the body occur mainly when the wheels go over the road irregularities.

The vehicle suspension system is help to isolate the vehicle body from the road surface and hence do isolate tyre irregularities and wheel out-of balance forces so that the passengers, goods and the vehicle body do not suffer undue disturbances. Further, they keep the wheels in close contact with the road surface to ensure adequate adhesion for accelerating, braking and cornering. The spring supports the static weight of the mass of the body and the shock absorber (damper) dissipates the energy from the road disturbances.



(a) (b)

Figure 1a. Degree of oscillations of an automobile suspension system, 1b. Quarter car model [2]

The main purpose of shock absorbers is to limit overall vehicle body movement Depending on road conditions or driving style, a vehicle can go from smooth and controlled to bumpy and erratic in a short time period. Shock absorbers stabilize the overall vehicle ride, preventing an excess of vehicle body lean or roll in any one direction, especially when cornering or navigating sharp turns. This stabilization [3] allows for greater vehicle control and stability

2. METHODOLOGY

2.1. Procedure for Analysis

The method use to modify the system is the quarter car system and described as follows.

Using the above figure 1.b, the below calculation has been used to design the system. By the equations taken through the calculations the maximum and minimum movement points could be found and using a suitable sensor [5] it can be used in the cars practically.

2.2. Calculation

As per the figure 3 using F=ma, upwards

$$m_1\ddot{x}_1 = k_1 (x_2 - x_1) + c_1 (\dot{x}_2 - \dot{x}_1)$$

$$m_1\ddot{x}_1 + k_1 (x_1 - x_2) + c_1 (\dot{x}_1 - \dot{x}_2) = 0 \quad (1)$$

Considering the motion of m_2 mass by applying same

$$m_2\ddot{x}_2 = k_2 (x_3 - x_2) + c_2 (\dot{x}_3 - \dot{x}_2) - k_1 (x_2 - x_1) - c_1 (\dot{x}_2 - \dot{x}_1)$$

$$m_2\ddot{x}_2 + k_2 (x_2 - x_3) + c_2 (\dot{x}_2 - \dot{x}_3) + k_1 (x_2 - x_1) + c_1 (\dot{x}_2 - \dot{x}_1) = 0 \quad (2)$$

Now

$$\ddot{x}_1 + \frac{k1}{m1} (x_1 - x_2) + \frac{c1}{m1} (\dot{x}_1 - \dot{x}_2) = 0$$

$$\ddot{x}_2 + \frac{k2}{m2} (x_2 - x_3) + \frac{c1}{m2} (\dot{x}_2 - \dot{x}_1) + \frac{k1}{m2} (x_2 - x_1) = 0$$

From eq (1)

$$m_1\ddot{x}_1 + k_1x_1 - k_1x_2 + c_1\dot{x}_1 - c_1\dot{x}_2 = 0$$

$$m_1\ddot{x}_1 + c_1\dot{x}_1 + k_1x_1 - k_1x_2 - c_1\dot{x}_2 = 0$$

$$m_1 (\ddot{x}_1 + \frac{c1}{m1} \dot{x}_1 + \frac{k1}{m1} x_1) - c_1 (\dot{x}_2 + \frac{k1}{c1} x_2) = 0 \quad (3)$$

By neglecting tire damping from the tyre from equation (2)

$$m_2\ddot{x}_2 + k_2 (x_2 - x_3) + c_2 (\dot{x}_2 - \dot{x}_3) + k_1 (x_2 - x_1) + c_1 (\dot{x}_2 - \dot{x}_1) = 0$$

$$c_2 (\dot{x}_2 - \dot{x}_3) = 0 \text{ because } c_2 = 0,$$

$$m_2\ddot{x}_2 + k_2 (x_2 - x_3) + k_1 (x_2 - x_1) + c_1 (\dot{x}_2 - \dot{x}_1) = 0$$

$$m_2\ddot{x}_2 + c_1\dot{x}_2 + (k_1 + k_2) x_2 - c_1\dot{x}_1 - k_1x_1 - k_2x_3 = 0$$

$$m_2 [\ddot{x}_2 + \frac{c1}{m2} \dot{x}_2 + (\frac{k1+k2}{m2}) x_2] - c_1 (\dot{x}_1 + \frac{k1}{c1} x_1) - k_2x_3 = 0 \quad (4)$$

From equation (3), substituting the numerical values

m_1 = 250 kg, m_2 = 40 kg, k_1 = 28000 N/m, k_2 = 125000 N/m, c_1 = 2000 N s/m, c_2 = 0.(Reference)

Substituting them on equation,

$$250 (\ddot{x}_1 + \dot{x}_1 + \frac{28000}{250} x_1) - 2000 (\dot{x}_2 + \frac{28000}{2000} x_2) = 0$$

$$250 (\ddot{x}_1 + 8 \dot{x}_1 + 112 x_1) - 2000 (\dot{x}_2 + 14 x_2) = 0 \quad (5)$$

From equation (4), substituting the numerical values

$$40 [\ddot{x}_2 + \frac{2000}{40} \dot{x}_2 + (\frac{125000+28000}{40}) x_2] - (\dot{x}_1 + \frac{28000}{2000} x_1) - 125000 x_3 = 0$$

$$40 (\ddot{x}_2 + 50\dot{x}_2 + 3825 x_2) - 2000 (\dot{x}_1 + 14 x_1) - 125000 x_3 = 0 \quad (6)$$

By equation (5)

$$250 (\ddot{x}_1 + 8 \dot{x}_1 + 112 x_1) - 2000 (\dot{x}_2 + 14 x_2) = 0$$

$$\ddot{x}_1 (t) = 8 \dot{x}_2 (t) + 112 x_2 (t) - 8 \dot{x}_1 (t) - 112 x_1 (t)$$

By equation [6],

$$40 [\ddot{x}_2 (t) + 50\dot{x}_2 (t) + 3825 x_2 (t)] - 2000 [\dot{x}_1 (t) + 14 x_1 (t)] - 125000 x_3 (t) = 0$$

By taking Laplas transformation of Equation (5)

$$250 (s^2 + 8 s + 112) x_1 (s) - 2000 (s + 14) x_2 (s) = 0$$

By taking the Laplas transformation of equation (6)

$$40 (s^2 + 50 s + 3825) x_2 (s) - 2000 (s +14) x_1 (s) - 125000 x_3 (s) = 0 \quad (8)$$

$$250 \ddot{x} (t) + 2000 \dot{x}_1 (t) + 28000 x_1 (t) - 2000 \dot{x}_2 (t) - 28000 x_2 (t) = 0$$

$$250 \ddot{x} (t) = 2000 \dot{x}_2 (t) + 28000 x_2 (t) - 2000 \dot{x}_1 (t) - 28000 x_1 (t)$$

$$\ddot{x}_1 (t) = 8 \dot{x}_2 (t) + 14 x_2 (t) - 8 \dot{x}_1 (t) - 14 \dot{x}_1 (t)$$

See the graph 1 according to the results.

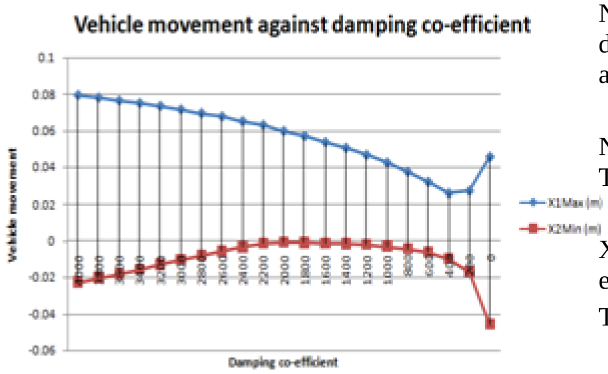


Figure 2: Vehicle movement against damping co-efficient.

2.3. Measuring the movement

The most important part of this exercise is to measure the movement of the vehicle with respect to the floor and transferring those data to the meter panel. For this purpose it can be used low cost laser sensors. [4]

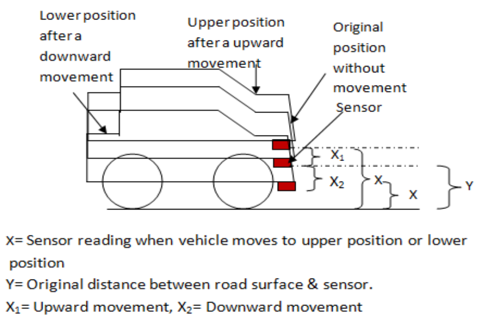


Figure 3: Minimum / maximum movement

Now, the minimum sensor reading when the damper is just about to fail (X) can be calculated as follows.

$$X = Y - X_2$$

Now if we consider the 2012 Toyota Camry [6]

$$Y = 180 \text{ mm}$$

X_1 = 0.009819 m = 9.819 mm at damping co-efficient 400 Nm/s.

Therefore;

$$X = (180 - 9.819) \text{ mm}$$
$$= 170.181 \text{ mm}$$

Therefore the minimum sensor reading should be 170.181 mm for this particular vehicle and if the reading goes lower than this value it should be illuminated the dash board indicator showing that the shock absorber is defective.

Now, the maximum sensor reading when the damper is just about to fail (X) can be calculated as follows.

$$X = Y + X_1$$

Now if we consider the same vehicle, 2012 Toyota Camry,

$$Y = 180 \text{ mm}$$

X_1 = 0.0625 m = 62.5 mm at damping co-efficient below 200 Nm/s.

Therefore;

$$X = (180 + 62.5) \text{ mm}$$
$$= 242.5 \text{ mm}$$

Therefore the maximum sensor reading should be 242.5 mm for this particular vehicle and if the reading goes more than this value it should be illuminated the dash board indicator showing that the shock absorber is defective. The shock absorbers cannot be checked at each and every road condition by using this system. Therefore a test track has to be designed. The test track is designed as per the values used for the MATLAB simulation.

3. RESULTS

The readings taken after simulating in MATLAB are as per the below table.

Table 1: Min & Max values for different damping co-efficient

c_1 (Ns/m)	Max (m)	Min (m)
4000	0.07962	-0.022750
3800	0.07820	-0.020370
3600	0.07660	-0.018080
3400	0.07517	-0.015850
3200	0.07360	-0.013140
3000	0.07168	-0.010610
2800	0.06961	-0.008218
2600	0.06785	-0.005915
2400	0.06521	-0.003535
2200	0.06317	-0.001544
2000	0.05983	-0.000986
1800	0.05707	-0.001142
1600	0.05368	-0.001393
1400	0.05053	-0.001788
1200	0.04670	-0.002263
1000	0.04247	-0.003078
800	0.03746	-0.00431
600	0.03182	-0.00624
400	0.02576	-0.00976
200	0.02695	-0.01695
0	0.04564	-0.04563

4. CONCLUSION

The goal of this project was to design & manufacture a Shock absorber condition warning indicating system for automobiles while the vehicle is being driven. Before taking the actual car details it was assumed some data and those data were simulated by using MATLAB simulation and plotted a graph. According to the graph it was identified the variation of the graph according to the condition of the shock absorber. Then those data were taken as a base and the actual data of vehicles were fed in to the MATLAB simulating system and plotted the graph. According to the graph the minimum and maximum condition of the shock absorber was found.

However this system is not matching for each and every road condition and therefore a special test track had to be designed and did the tests. According to the test it will be possible to find whether the shock absorber is in good condition or whether it has to be replaced.

Observing above graph, it can be decided that the general shape of the graph is as above and it does not vary for a decided vehicle with mass and the other spring constants etc. Further it can be said that if the damping ability of the shock absorber is in good condition the values of the maximum & minimum movement of the vehicle body is limited to certain value and if the damper is defective the said value will be varied. Therefore this particular value could be taken as maximum and minimum movement can be observed in the particular vehicle and if the movement is more than these two values it can be decided that the damper is defective and the warning lamp will be illuminated in the vehicle meter panel. Generally for a good shock absorber, the co-efficient of damper is about 2000 Ns/m. As per the graph if the co-efficient of damper is “0”, the movement of minimum and maximum is very much higher than other stages. Even the damping co-efficient is higher then also the movement of the vehicle body is comparatively higher. Therefore the best value for the damper is about 2000 Nm/s.

5. REFERENCES

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