SIMULINK MODEL OF PASSIVE SUSPENSION AND IT'S VALIDATION

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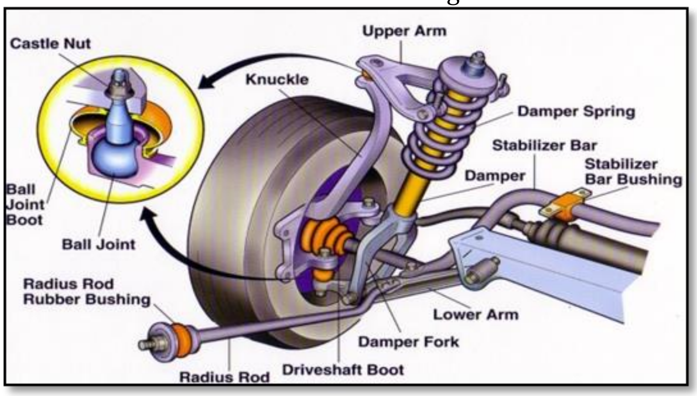
Abstract: This paper focuses on the effect of suspension parameters vertical acceleration. The vertical force transferred by the tire of wheel is directly depending on the vertical force. To measure this vertical acceleration and its maximum value for the different road input is carried out in the MATLAB Simulink toolbar. For analysis purpose quarter car model is considered.
Keywords: Simulink model, mathematical modeling, quarter car model

Introduction

Comfort in vehicle ride plays a vital role in the vehicle design. This becomes one of the important design considerations. The performance of driver is directly related to the ride comfort. There are adverse effects of low frequency vibration on human being. The mathematical models are able to convert the system into mathematical equations so the equations will be solved and some rigid conclusions can be drawn for proper and optimised performance.[3]

Figure 1 shows quarter car model considers only one wheel of car showing all its important parts. For vibration and vertical acceleration analysis its two degree of freedom model is used as shown in fig 2.



I. Ease of Use

Two Degrees of Freedom (DOF) Quarter-Vehicle Model:

Figure 2 shows a simplified 2 degrees of freedom (DOF) quarter-vehicle model. It consists of a sprung mass (m_2) supported by a primary suspension, which in turn is connected to the unsprung mass (m_1). The tire is represented as a simple spring, although a damper is often included to represent the small amount of damping inherent to the visco-elastic nature of the tire The road irregularity is represented by q, while m_1, m_2, K_t,K and C are the un-sprung mass, sprung mass, suspension stiffness, suspension damping coefficient and tire stiffness, respectively. This is very common model that can be considered while analysing the different parameters of suspension. In this model single suspension is considered for analysis purpose, which is shown in the fig 1.2.The tire has been replaced with its equivalent stiffness and tire damping is neglected. The suspension, tire, passenger seat are modelled by linear springs with dampers.

q=road input (m),K_t = stiffness of tire (N/m),m_1= mass of unsprung elements(kg),m_2=sprung mass (kg),K= stiffness of sprung mass (N/m),C=Damping coefficient (N/m/s),z_1=displacement of unsprung mass (m),z_2=displacement of sprung mass (m)[1]

The two degree of freedom is due to excitation of sprung and unsprung masses.

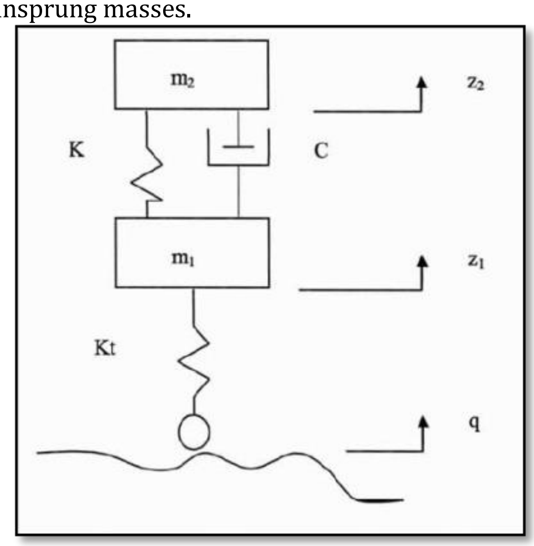


Fig 2Two-DOF or Quarter Car Model

EQUATIONS OF MOTION FOR 2 DOF SYSTEM AND SIMULINK MODEL

For Fig 2 equations of motions can be derived.[2]

$$m_2\ddot{z}_2 + C(\dot{z}_2 - \dot{z}_1) + K(z_2 - z_1) = 0$$
$$m_1\ddot{z}_1 + C(\dot{z}_1 - \dot{z}_2) + K(z_1 - z_2) + K_t(z_1 - q) = 0$$

With Simulink, one can move beyond idealized linear models to explore more realistic nonlinear models, factoring in friction, air resistance, gear slippage, hard stops, and the other things that describe real-world phenomena. Simulink turns your computer into a laboratory for modeling and analyzing systems that would not be possible or practical otherwise. Above equation is the governing equation of the quarter car model. This equation can be easily solved in Simulink. Simulink also includes a comprehensive block library of sinks, sources, linear and nonlinear components, and connectors. If these blocks do not meet your needs, however, you can also create your own blocks. The interactive graphical environment simplifies the modeling process, eliminating the need to formulate differential and difference equations in a language or program. This model is like the laboratory.

We can change one parameter and can see the effect on displacement, acceleration and velocity.
The simulation results can be put in the MATLAB workspace for post processing and visualization.[4]

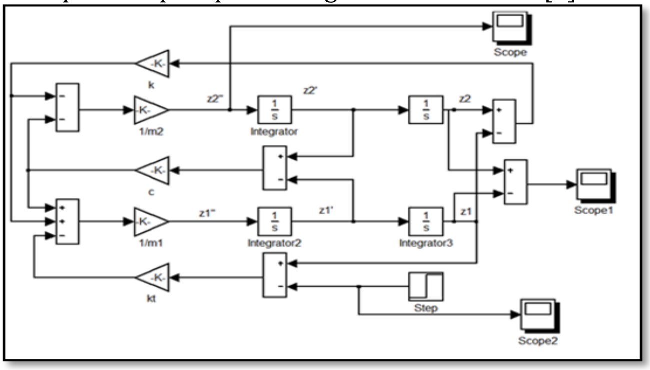


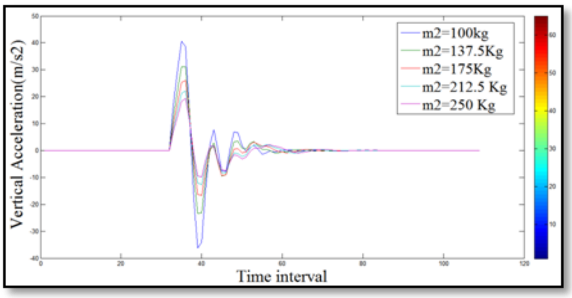
Fig.4.Simulink block diagram of the suspension system

ANALYSIS: Plots for the Simulink: In Simulink results are obtained by varying suspension parameters as follows:
1. Sprung mass from 100 to 250 kg with equal intervals
2. Change in suspension spring stiffness
3. Change in damping coefficient
4. Change in unsprung mass
5. Effect of change in tire stiffness
Plots and respective acceleration and body travels are as follows:

1. Change in sprung mass

Table1.2Acceleration values at different sprung mass

Mass Kg	Vertical Acceleration (m/s2)		Body Travel (m)	
	Max	Min	max	min
100.00	40.6414	-36.2788	0.0714	-0.0958
137.50	31.1445	-23.3874	0.0576	-0.1060
175.00	25.9298	-16.7602	0.0531	-0.1125
212.50	22.1732	-12.6394	0.0580	-0.1169
250.00	19.3520	-9.8861	0.0587	-0.1201



Change in suspension spring stiffness:[

Table 2Acceleration values at different spring stiffness

stiffness N/m	Jerk in Z m/s2		Body Travel m	
	max	min	Max	Min
10000	16.8320	-10.3773	0.0411	-0.1262
12291	17.4679	-10.0866	0.0472	-0.1247
14583	18.0963	-9.8423	0.0521	-0.1232
16874	18.7175	-9.7336	0.0559	-0.1217
19165	19.3314	-9.8396	0.0587	-0.1202

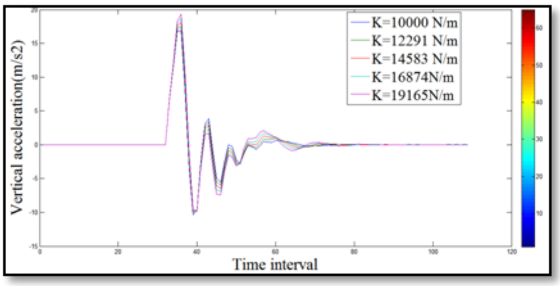


Fig.5 Effect of change in suspension stiffness

3. Change in damping coefficient

Table 3Acceleration values at different damping coefficient

damping coefficient N/m/s	Vertical Acceleration m/s2		Body travel(m)	
	Max	Min	Max	Min
800	15.9339	-9.0880	0.0807	-0.1355
925	16.4648	-8.7326	0.0742	-0.1312
1050	17.5510	-8.9557	0.0685	-0.1271
1175	18.5702	-9.7732	0.0634	-0.1233
1300	19.5265	-10.5107	0.0589	-0.1197

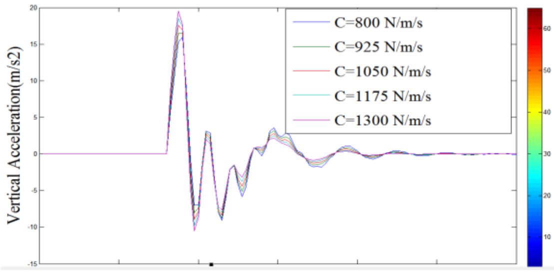


Fig. 6 Effect of change in damping coefficient

4. Change in unsprung mass:

Table 4.Acceleration values at different unsprung mass

unsprung Mass	Vertical Acceleration		Body Travel	
	Max	Min	Min	Max
50	24.3433	-9.1475	0.0483	-0.1196
62.5	22.0938	-9.3245	0.0483	-0.1189
75	21.6044	-10.0099	0.0485	-0.1192
87.5	20.7262	-10.2262	0.0539	-0.1209
100	19.7185	-10.7132	0.0590	-0.1202

5. Effect of change in k_t

Table 5.Table Acceleration values at different stiffness values

Kt	Vertical Accln m/s2		Body Travel M	
n/m	Max	Min	Max	Min
100000	14.4766	-7.5293	0.0543	-0.1027
117500	16.0433	-7.9088	0.0557	-0.1064
135000	17.3594	-9.1366	0.0581	-0.1092
152500	18.4383	-9.8698	0.0577	-0.1154
170000	19.2931	-9.7895	0.0587	-0.1203

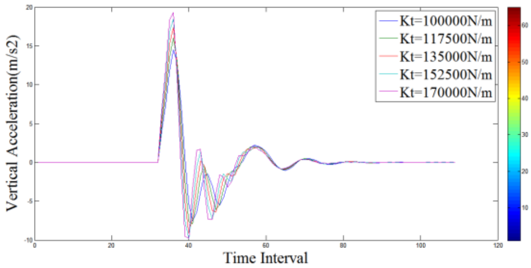


Fig7.Effect of change in tire stiffness

RESULTS AND VALIDATION

The results obtained were analytical and experimental in nature and were to be compared simultaneously for accuracy. The results are given in subsequent topics.

Result comparison:

After simulating the McPherson strut in MATLAB, the results were obtained in graphical format. The results obtained were readable and self explanatory in nature.

As shown in below figures, the results on Matlab simulation are given for various vehicle suspension parameters, which are self explanatory in nature.

The input data for suspension for two strut as follows as follows,

m_2 = 250 kg
m_1 = 100kg
C = 1300
K = 16195 n/m
K_t = 170000 N/m

Table 6 Suspension Properties

Property	Strut1	Strut2
C (N/m/s)	1050	1300
K (N/m)	12283	19165

Where,

m_2 = sprung mass or body mass;
m_1 = unsprung mass;
C = suspension damper damping coefficient;
K = suspension spring stiffness;
And K_t = Tire stiffness.

The simulation was carried at different values by changing the different parameters of the suspensions. The results of the same are shown in the previous section.

Following plots shows the response to the step input of 0.1m and speed of 30 kmph for two Struts are available with us

For Change in sprung mass

Table 7 Comparison of Simulink and Experimental result for change in Sprung mass

Sr.No.	Mass in Kg	Simulink Acceleration(m/s^2)		Experimental Acceleration(m/s^2)	
		Max.	Min.	Max.	Min.
1.	100	40.64	-36.27	**30.25**	**-29.3782**
2.	137.5	31.14	-23.38	**27.38**	**-20.1872**
3.	175	25.92	-16.76	**21.54**	**-12.5684**

Change in spring stiffness

Table 8 Comparison of Simulink and Experimental result for change in Spring stiffness

Sr.No.	Spring stiffness N/m	Simulink Acceleration(m/s^2)		Experimental Acceleration(m/s^2)	
		Max.	Min.	Max.	Min.
1.	12283	17.46	-10.08	15.83	-11.23
2.	19165	19.33	-9.83	17.85	-8.32

Change in Damping

Table 9 Comparison of Simulink and Experimental result for change in damping

Sr. No.	Damping coeff. N/m/s	Simulink Accel(m/s^2)		Experimental Accel(m/s^2)	
		Max.	Min.	Max.	Min.
1.	1050	17.55	-8.95	13.78	-7.4523
2.	1300	19.52	-10.51	17.45	-8.2317

4. Experimental Results

Out of the four parameters viz. road distance, body travel, body acceleration and suspension deflection the body acceleration is the most important and considerable parameter to be observed and kept within the permissible limits.

Hence in the present experimental tests as per the availability of instrumentation and the economy of project is concerned the concern has been given to body acceleration.

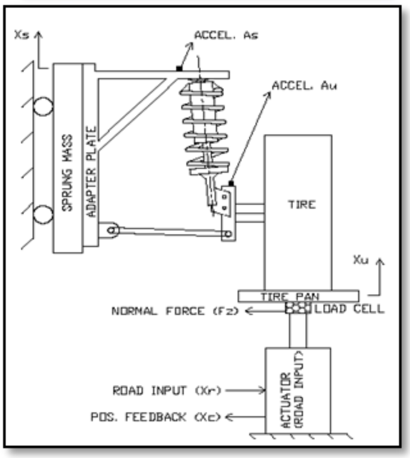


Fig.8 Test rig

The experimental setup **(Fig.8 and Fig.9)** was capable of measuring only the body acceleration. The body acceleration was given in the form of tabulated data on HMI as an .xls file reading the acceleration values at particular time interval. The acceleration values were recorded at regular interval of 10 second of simulation time. The tabulated data in the excel file was taken on the portable memory drive as the HMI facilitates the port for

USB pen drive for data interaction. The Simulink results and actual results are varying by 15%-20% due to following conditions.

- The analytical analysis uses the standard equations, methods which may or may not consider the actual working conditions.
- The analysis occurs on the basis of many assumptions and considerations, such as there is no material defect in the specimens that practically may have e.g. voids, nonlinear material properties, anisotropic nature, manufacturing defects, defects induced while handling.
- The simulation method also assumes that the specimen for which the model is developed has the perfect geometry and lacks no errors in their alignments, positioning and working.
- There is no human error involved while the results are being recorded unlike in experimental tests.

CONCLUSION

1. Effect of change in sprung mass:

From the result of simulation it is clear that initially the less amount of sprung mass causes the large vertical acceleration. But as sprung mass goes on increasing then vertical acceleration sharply decreases. But sprung mass can't be increased beyond 175 Kg otherwise the high dynamic forces strikes the shaker.

Thus high sprung mass gives comfort but striking of sprung and unsprung mass should not takes place. The simulation result shows that we have extended the mass up to the 250 kg .But actually we take it up to 175 kg for safety purpose.

2. Change in suspension spring stiffness:

Simulation shows that as suspension spring stiffness increases the vertical acceleration increases. From results it can be proved that 18.63% change in the stiffness changes vertical acceleration only by 3.64%.It does not mean that we should use less stiffness spring. That causes increase in flexibility. Thus it should be such that it will reduce vertical acceleration as well as should give the stability.

In suspension spring we take five different values but we are having the two struts thus experimental and simulation values are compared for those two values only.

3. Change in the damping coefficient:

The damping coefficient damps the amplitude suddenly and brings system to the mean position. The vertical acceleration increases by 3.2% while an increase in the damping coefficient is increased by 13.5%.

4. Change in the unsprung mass:

The unsprung mass of quarter car model is the ¼ th of the total car. This mass is not being changed practically. But still we can get its effect on the vertical acceleration in Simulink.

As unsprung mass increases the vertical acceleration goes on decreasing.

5. Tire stiffness:

Tire stiffness is dependent of the pressure in the tire. The minimum pressure in the tire should be maintained. At that air pressure the particular stiffness should be considered. As tire air pressure increases the rigidity of tire and transfers the vibrations. Thus, tire pressure increases the stiffness increases and vertical acceleration also goes on increasing.

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