Investigation on Influence of Elements and Parameters of the Suspension System in the Vibration and Isolation

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Abstract - **The article is about to study the influence of the suspension elements and its parameter in vibration isolation. The main elements and parameters of suspension systems are spring, damper, ride comfort, ride height and road holding ability of the vehicle. The modelling and simulation of a mono car model in MATLAB/Simulink are studied; the damped and undamped system characteristics and the influence of various damping conditions are simulated and analysed.**

Keywords - jerk, mono-suspension model, ride comfort, road holding .

1. INTRODUCTION

In olden days, when the mobility depends on the chariot which is a slow motion vehicle, the suspension system is not up to its important and potential but when there is advancement in propulsion and increment in speed of vehicle, the manufactures were pushed to concentrate on the suspension system. As the industrial revolution began, the use of motors and machines increases as so the vibration problem [1]. The suspension system comprises of two main elements spring and damper. The function of the spring is to observe the shock generated by the vehicle, in detail the spring converts the kinetic energy due to the upward movement of the axle into its potential energy and again it releases the potential energy into the kinetic energy. Thus if even the shock is absorbed the oscillation continues if only springs are used. This arises to the development of damper which dissipates the energy in proportion to that of the velocity. The function of the damper is to dissipate the energy stored by the spring. In easy words, the springs are meant to reduce the amplitude of the mass/vehicle and the damper is to reduce the frequency of the vibration i.e. oscillation. Some of the technical terms related to the suspension are amplitude, frequency, ride comfort, rattle space or ride height and road holding ability of the vehicle. The main functions of the suspension system are to isolate the passenger from the vibration, to bear the entire weight of the vehicle, to maintain the rattle space of the vehicle, to minimize the wheel deflection of the vehicle [2].
The parameters involved in the design of suspension system are ride comfort, suspension deflection, road holding ability, sprung mass, unsprung mass, rattle space and tyre displacement [3]. The ride comfort is a measure of comfort level of passenger in vehicle in case of vertical movement; the rattle space is a sensing parameter to describe the functionality of the suspension system, the wheel deflection is a measure of road holding ability of the vehicle [4].

Generally the research papers on the automotive suspension system based on high end system, this makes the learners difficult in understanding the basis of modeling and analyses of suspension system, this papers is about to explain such a thing. For simplicity, passive mono car two degree of freedom model is modeled and analyzed by varying the stiffness of the spring and damping value of the damper alternatively, to study its effect on ride comfort, suspension deflection and wheel displacement.

2. INFLUENCE OF SPRING AND DAMPER

In order to analyze the passive mono suspension model, the influence of spring and damper should be known and thus single degree of freedom model is used. Analyzes of the system are based on two cases they are damped system and un-damped system.

As there is no damper in the undamped system the transfer of potential and kinetic energy occurs, which leads to the continuous oscillation of the system, thus increases the frequency and arises the discomfort, but the amplitude of the mass is much reduced due to the stiffness of spring [Fig.1]. Considering the comfort both the amplitude and frequency are important parameters thus it should be optimized. In case of damped system, both the amplitude and frequency are much reduced comparing to the un-damped system, as the damper dissipates the energy [Fig.2].

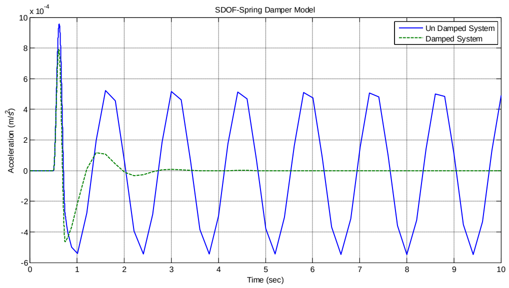

Figure 1: Body Acceleration -SDOF

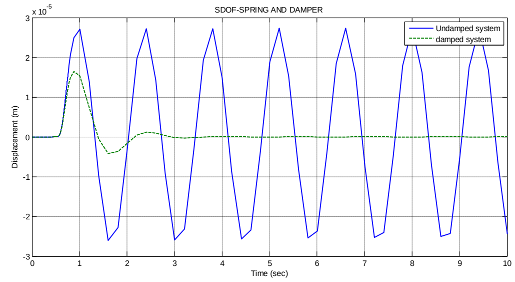

Figure 2: Body Displacement-SDOF

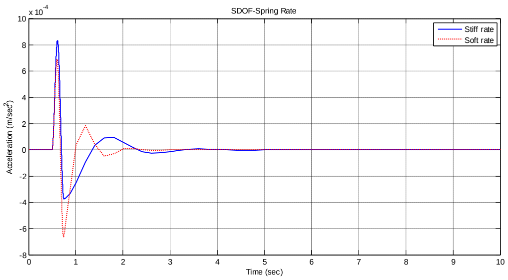

Figure 3: Acceleration- spring rate

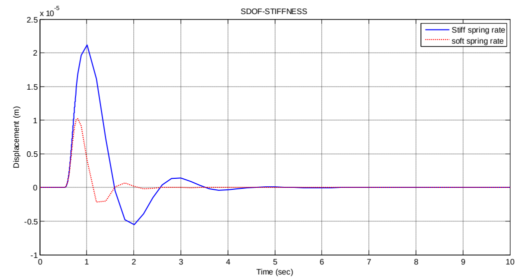

Figure 4: Displacement- spring rate

The effect of spring rate can be analyzed using the figure 3 & 4. The acceleration of the stiff spring is high than that the soft spring rate as the stiff spring passes the vibration, in case of displacement the stiff spring produces the maximum displacement as the deflection of the spring is reduced. At the same time the stiff spring is required to bear the load.

3. MODELING OF PASSIVE QUARTER CAR MODEL

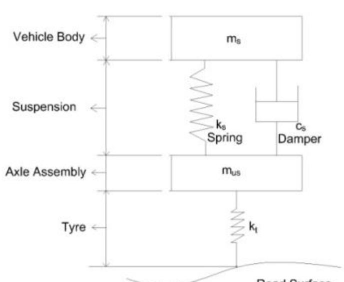

Figure 5: Mono suspension model

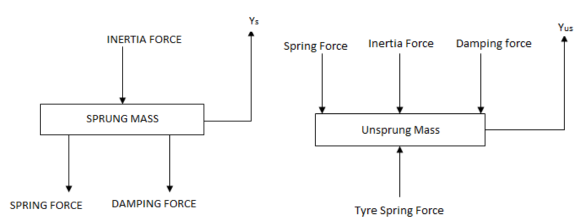

Figure 6: FBD sprung mass and unsprung mass system

The mono suspension model [Fig.5] is a model represents the motion occur at the single wheel of a vehicle. The dynamic motion of a mono-suspension model is derived using the D'Alemberts principle, i.e the inertia force of a body is equal to the summation of the force acting on the body. Certain assumptions are to be made for modeling the quarter car model of the system they are as follows: only the vertical motion is considered for the modeling and the tyre is modeled as a spring with stiffness equivalent to the stiffness of the tyre and as the dampness of the damper is negligible it is neglected. The mass above the suspension system is considered as sprung mass system m_s and the mass below the suspension system such as suspension elements and axle are considered as unsprung mass m_{us}.

$$\ddot{y}_s = \frac{1}{m_s}[-c_s(\dot{y}_s - \dot{y}_{us}) - k_s(y_s - y_{us})] \quad (1)$$

$$\ddot{y}_{us} = \frac{1}{m_s}[c_s(\dot{y}_s - \dot{y}_{us}) + k_s(y_s - y_{us}) + k_t(y_{us} - y_r)] \quad (2)$$

The modeling deals with the representation of the dynamic motion of suspension system in mathematical equation which is also called as dynamic model. By the help of the free body diagram [Fig-6] the mathematical equation is derived for the passive system and these equations used to model the suspension system. The sum of forces acting on the body will be equal to inertia force of the moving body. The forces acting on the body are spring force, damping force. The spring force is the product of stiffness of the spring and displacement of the spring, the damping force will be equal to product of damping co-efficient and velocity of the damper rod. The model is considered as two degree of freedom of quarter car in which there will be two masses representing the sprung and un-sprung mass.
In order to verify the system modeled it is simulate under certain assumption and the parameter used to simulate the model are M_s=290 Kg; M_{us}=50 Kg; K_s=16816 N/m; K_t=190000 N/m; C=1000 Ns/m. These are the values used by researches for quarter car modeling and in this article the value of K_s and C are going to be varied to analyze its influence in the suspension system.

4. RESULTS AND DISCUSSION

In the results and discussion, the acceleration, Jerk, Tyre displacement and the suspension deflection of the model is alone considered for the study of the influence of the suspension parameters on its performance.

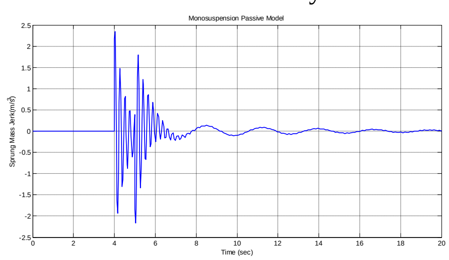

Figure 7: Jerk

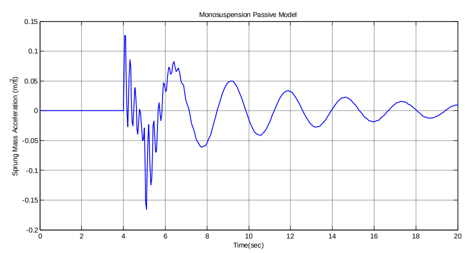

Figure 8: Acceleration

Both the jerk [Fig.7] and acceleration [Fig.8] results describes the comfrot level of the passenger The Jerk can be defined as the rate of change of acceleration and it stresses the improtance of the amplitude and frequency over the comfort of the passenger. In acceleration the highest value recorded is about $0.15 m/s^2$ and the peak value of the jerk is around $2.5 m/s^3$. This two results are used to to study about the discomfort arised with respect to the time. The suspension deflection [Fig-9] is a parameter which protrays about the working condition of the suspension systems and the ride hieght of the system.the suspension deflection should be limited to the 8cm travel of up and down. The trough in the figure indicates the compressible state of the suspension system and crest indicates the expansion of the system. from this figure we can easily able to understand the conversion of potential energy to kinetic energy and vice versa.

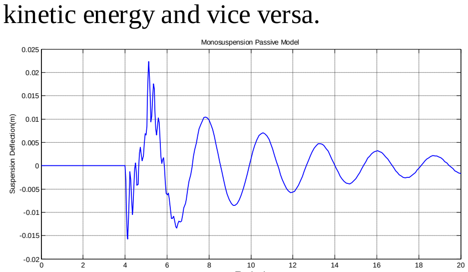

Figure 9: Suspension Deflection

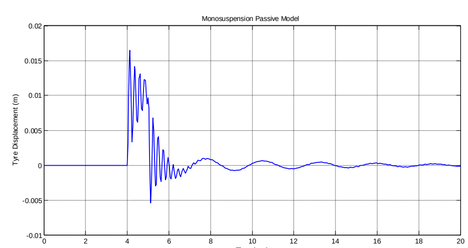

Figure 10: Tyre Displacement

The suspension displacement is recorded by the minus of displacement of sprung mass and un sprung mass. If the diffence is made as zero while ensuring deflection of suspension elements, i.e maintaing the position of the sprungmass as were it is, the comfort can be increased further.

The tyre displacement [Fig-10] refers to the road holding ability of the vehicle, it is sugessted that the line in graph should follow the base line as possible as to ensure the maximum contact of the wheel to the road surface.the maximum displacement will be in upward movement because the base line indicates the surface of the road, so the possibilty to move up is more and the little deflection on the negative side is occurred because of the assumption that tyre is considered as a linear spring with its equivalent stiffness.
The above parameter values are standard for the quarter car model investigation, now these values are changed on the basis of damper and stiffness. The damper values are changed to analyze the behavior of the system in critical damping, over damping and under damping based on ς values 0.5,1 and 1.5.

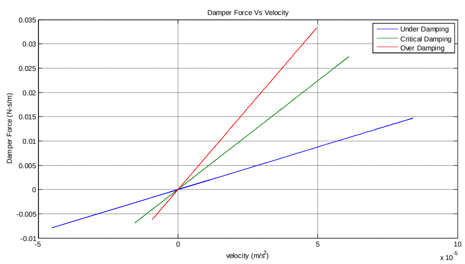

Figure 11: Damper characteristic

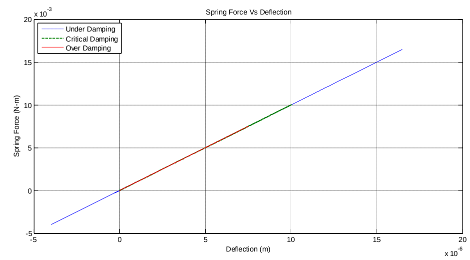

Figure 12: Spring characteristic

The above figures are plotted to study the behavior of the suspension elements spring and damper. The variation of the damper force and spring force with respect to the velocity and deflection are shown in above figure [11, 12]. In figure it can be seen that the highest amount of damped force are recorded in the order of over damping, critical damping, and under damping but the range of damping capability are high in reverse order of above. In case of spring the highest are recorded in the order of under damping, critical damping, and over damping, the same case is followed for the range.

The Figure 13 describes the behavior of damper and spring in a suspension system during the vibration reduction. In all the cases it can be noted that the damping force is increased at the beginning and attains the peak value before the spring does and gets decreases gradually till spring force attains maximum, because the damping force is directly proportional to the velocity, thus at nearest of peak value of spring force, velocity gets decreases this is due to the transformation of potential energy to kinetic energy and vice versa. Thus how the damper behaves towards the spring in a suspension system. This figure also shows the maximum range is presented by the under damping system.

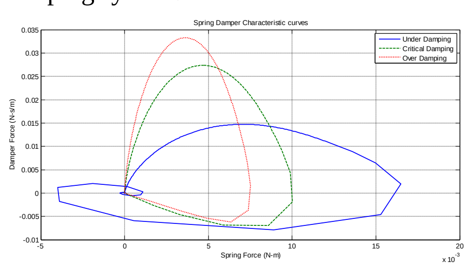

Figure 13: Spring-Damper Characteristic curves

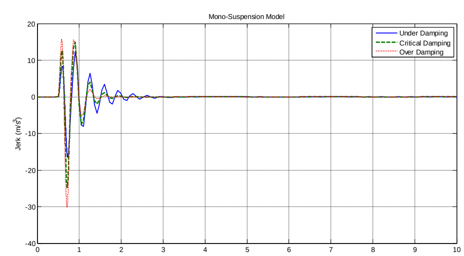

Figure 14: Jerk – UCO

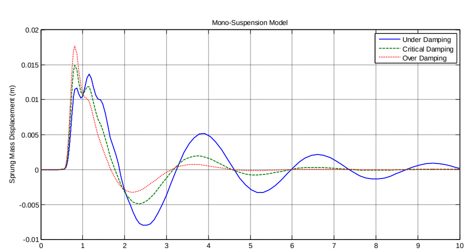

Figure 15: Displacement – UCO

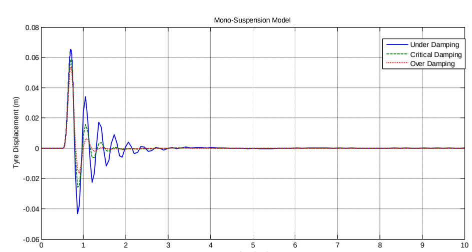

Figure 16: Tyre Displacement-UCO

From above fig [14,15,16] it is observed that the jerk is increased from under damping, critical damping and over damping. The rate of change of acceleration is known as jerk and it can able to decribe both the acceleration and frequency of the disturbance. The settling time or the steady state of the system quickly achieved by the system in the order of Over damping,Critical damping and then by Under damping. On comparing these two parameters, the over damping system and critical damping system has settled quickly as result the jerk in those system is increased. In case of displacement the critical and under damping produce similar values but the over damping has reduced the displacement of the system. from over all observance, the under damping system is suitable for the vibration isolation.

5. CONCLUSION

The mono suspension passive model and sdof is modelled and simulated to know the influence of the parameters in suspension systems performance. The ride comfort, rattle space and road holding ability are illustrated by the result of acceleration, jerk, suspension deflection, tyre displacement. From this analysis the importance of amplitude and frequency over the ride comfort is under stood and further the mono suspension is simulated for under damping ,over damping and critical damping and the results obtained clearly shows the under damping characteristic gives the optimum performance.

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