Vibration and Suspension Deflection Controlling of Half Car Model using ANSYS and MATLAB

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Abstract - *An independent front and rear vertical passive suspension is implemented on a half car model to simulate and analysis the reaction force exerted by the front and rear wheel due to pitch and bounce degrees of freedom of the car. MATLAB Simulink environment is used for numerical simulation of this model. This simulation provides a description about the ride characteristics of the model. A conventional passive suspension is used between the car body and wheel assembly which is made of a spring and a damper. The spring-damper characteristics are pre-selected to emphasize one of several conflicting objectives such as passenger comfort and suspension deflection. Vibration analysis is performed with and without tune mass damper.*

***Key Words*: MAT LAB, SIMULINK, ANSYS** etc...

1. INTRODUCTION

A car suspension system is the mechanism that physically separates the car body from the wheels of the car. The performance of the suspension system has been greatly increased due to increasing vehicle capabilities. In order to achieve a good suspension system, several performance characteristics have to be considered. These characteristics deal with the regulation of body movement, the regulation of suspension movement and the force distribution. Ideally the suspension should isolate the body from road disturbances and inertial disturbances associated with cornering and braking or acceleration. The suspension must also be able to minimize the vertical force transmitted to the passengers for their comfort. This objective can be achieved by minimizing the vertical car body acceleration. An excessive wheel travel will result in non-optimum attitude of tire relative to the road that will cause poor handling and adhesion. Furthermore, to maintain good handling characteristic, the optimum tire-to-road contact must be maintained on four wheels. In conventional suspension system, these characteristics are conflicting and do not meet all conditions. Automotive researchers have studied the suspension on the system extensively through both analysis and experiments. The main goal of the study is to improve the traditional design trade-off between ride and road handling by directly controlling the suspension forces to suit with the performance characteristics.

Suspension systems can be categorized as passive, semi-active, and full-active suspensions system. Passive system consists of conventional components with spring and damping (shock absorber) properties which are time-invariant. Passive element can only store energy for some portion of a suspension cycle (springs) or dissipate energy (shock absorbers). No external energy is directly supplied to this type of suspension. Semi-active suspensions contain spring and damping elements, the properties of which can be changed by an external control. A signal or external power is supplied to these systems for purpose of changing the properties. Full-active suspensions incorporate actuators to generate the desired forces in the suspension. The actuators are normally hydraulic cylinders. External power is required to operate the system.

Design and development of automotive suspension systems has a great interest for nearly 100 years. Early systems were derived directly from horseless carriage practice. Complicated vibration problems have arisen as a result of the increase in vehicle speeds which directly affect both the ride comfort and the ride safety. The solution of these problems in general may be achieved either by the reduction of the excitation level which mainly comes from the road surface irregularities or by the design of good suspension systems capable of maintain an acceptable level of comfort and ensuring the vehicle safety on existing tracks . The latter has been considered an important area of study and has been extensively investigated. The application of science to the problem has been increasing as time has passed.

The primary purpose of the suspension system is to provide a high level of ride quality and protect the vehicle structure from harmful stressed by performing good isolation from the road surface irregularities. This requires a soft suspension. It should also assure the lateral stability ad controllability at various running conditions (road qualities, speeds, accelerating, braking, and maneuvering), besides supporting the variable static loads. This requires a stiff suspension.

Although considerable theoretical and practical studies have been carried out in order to improve real suspension systems, most current road vehicles suffer this fundamental conflict and their suspension parameters still compromise between the requirements. Moreover, further improvement seems to be very difficult to achieve using only convention elements. However, active and semi-active suspension systems offer new possibilities for improvement in vehicle behavior, but the road vehicle industry is still cautious about their introduction, except in some racing and experimental cars, because of the cost and complexity implied. Development in computer facilities, as well as advances in mathematical analysis, offer good opportunity for theoretical analysis to be used as an aid to good practical system design. It is advantageous to use a simple model containing few parameters, if it is possible to reasonably represent a real system with this restriction, in order to obtain economical and fast guidelines to the system design.

1.1 Problem Statement

The suspension system that commonly applied on the vehicle is a passive suspension system in which its spring stiffness and dumping value is constant. In the passive suspension system it dumping system has not yet gives a high performance where its vibration amplitude still high and the time required terminating the vibration is quite longer. To overcome this condition, it is then introduced a semi-active suspension and active suspension system. Unfortunately the active suspension system requires larger energy and less economical, so then the semi-active suspension become a better choice to keep the quality of the car comfortable on any road condition.

1.2 Objectives of Study

The objectives of this research are as follows:

- To design the passive system of half car model.
- To design an active suspension for a half car model
- To find out the natural frequency of vehicle
- To find out the harmonic response of half car model
- To reduce the vibration due to tune mass dampers.

1.3 Scope of Work

The scopes of work for this study are as follows:

- Study on semi-active suspension system for a half car model and the LQR controller used in the system.
- Design the system by using MATLAB/SIMULINK.
- Simulate the system using MATLAB/SIMULINK.

2. VEHICLE PARAMETERS

A vertical half car 4DOF model of active suspension, semi-active suspension and passive suspension systems are indicated in Fig from left to right respectively. The equations of motion for 4DOF half car model are obtained with Newton's second law of motion. It consists of sprung mass (M) free to heave and pitch connected to two un sprung masses represented as m_f and m_r are free to bounce vertically with respect to the sprung mass and pitch and roll angles are assumed to be small. The two tires are modelled as front tire with spring stiffness (K_{tf}) and rear tire with spring stiffness (K_{tr}).The suspension between sprung mass and unsprung mass are modeled as front suspension spring stiffness K_f and front dampers of damping coefficient (C_f) and rear suspension spring stiffness (K_r) and rear dampers of damping coefficient (C_r).Variable dampers inserted in the suspension for semi-active suspension system and the corresponding control forces are F_{dr} and F_{df} and acted on both sprung mass and unsprung masses as shown in Fig 3.2. Hydraulic actuators inserted in the suspension for active suspension system and corresponding control forces are Uf and Ur acted on both sprung mass and unsprung mass as shown in below Fig. The sprung mass (M) has 2DOF representing body bounce, pitch movement. The Y_c is vertical displacement of sprung mass at the center of gravity and θ is the pitch angle of sprung mass. The unsprung masses has 2DOF due to vertical motions Y_r and Y_f.The input to the wheels is the road excitation Y_r. Thus there are a total of four second order differential equations governing the motion of the sprung and unsprung masses.

Table -1: Parameters of 4-DOF vehicle model

Parameter Symbol	Description	Numerical Value
M	Sprung mass of the vehicle body	1570 kg
I	Mass moment of inertia of the vehicle body with respect to the center of gravity (C.G)	2730 Kgm²
m_f, m_r	Unsprung mass of the front and rear wheels	40 kg, 45kg
K_f ,K_r	Stiffness of the front and rear passive suspension	364000 N/m,27300N/m
K_{tf} ,K_{tr}	Stiffness of front and rear tires	200,000 N/m
C_f ,C_r	Front and rear passive suspension damping coefficients	3250 Ns/m,2600 Ns/m
A	Distance from C.G to the front wheel	1.23 m
B	Distance from C.G to the rear wheel	1.65 m

3. RESULTS & DISCUSSIONS

The specification of the vehicle is taken from the car Toyota Avalon XLE 2015. These specifications are introduced in the Simulink model by uploading the variables in workspace of MATLAB from M file editor. The results are viewed and plotted by using scope block.

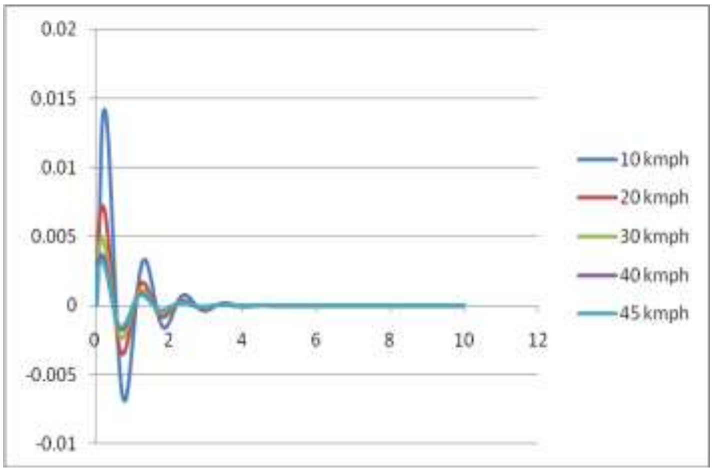

Chart -1: vehicle displacement at different velocities.

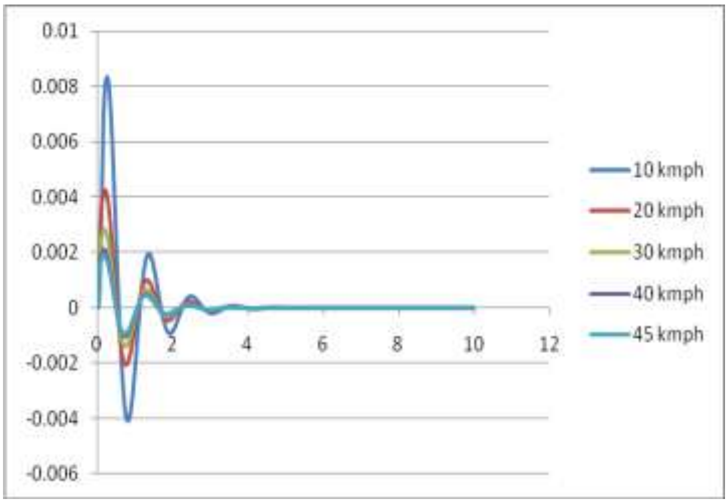

Chart-2: vehicle pitch at different velocities.

The above graph shows the pitch of vehicle with different velocity of vehicle. From the above graph, it was clearly observed as if vehicle moves with minimum speed, vehicle will get maximum displacement.

4. CONCLUSIONS

In this work, mainly concentrate on simulating and understanding the behaviors of the conventional mechanical spring and damper system. By using this model, the effects of changing the suspension damping and stiffness can be simulated, thereby investigating the tradeoff between comfort and performance. It is known to all of us that racing cars have very stiff springs with a high damping factor, whereas passenger vehicles have softer springs and a more oscillatory response. Different velocity parameters are considered in this work to find out the vehicle behavior. Vehicle getting maximum bounce at low speed travelling. It can be reduced by controlling force, in this work LQR controlling technique is used to give the comfort to the passenger. Vibration analysis also performed to the vehicle. Initially natural frequency has fond using MATLAB and ANASYS, both reading having good agreement. At 1.955 Hz resonance amplitude is observed. And it was reduced by 11% by using tune mass dampers. Finally it was concluded that external controlling force and tune mass dampers are useful for give the more comfortable to the passengers.

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