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Design and Simulation of Automotive Suspension System for Different Values of Damping

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Abstract: **The main aim of this paper is to simulate and analyze the passive suspension system for quarter car model with variable damping values. The main purpose is to provide background for mathematical model of a quarter-car model. Ride Comfort (RC) are important concern related to vehicle suspension system. The disturbances are mostly in the form of various road profiles that the unsprung mass comes in direct contact with and are transmitted to the sprung mass causing undesirable vibration that may cause discomfort to passenger. The purpose of mathematical modeling is to obtain state space representation of the quarter car model. In this project, analysis of vehicle suspension using Quarter-car model developed in MATLAB SIMULINK. The initial mathematical model is developed and the analytical results are taken on Matlab as an analytical solver. In later stages the experimental setup is developed and the actual readings are taken for various inputs (damping values); finally both experimental and analytical results are compared for ride comfort and reliability of experimental setup.**

Key words: **Quarter Car model, Passive Suspension system, Road Profile, Ride Comfort, Test Rig, SIMULINK, Variable Damping Coefficient.**

I. INTRODUCTION

A suspension system is the mechanism that physically separates the car body from the wheels of the car. The main focus of suspension system is to provide support, stability and control to the vehicle. There are three types of suspension system; passive suspension system, semi-active suspension system and active suspension system.

The different methods of measurement of vibrations in cars are studying the dynamics of motions, preparing the state space equations, conversion of acceleration inputs in velocity and displacement and analyze the frequency response in graphical form and also simulating the system using the matlab software. Measurement of tyre dynamics, degrees of freedom of the suspension components such as Mcpherson strut, control rods, lower arm, upright, car body frame. Quarter-car models are extensively used in automobiles due to their simplicity and it provides qualitatively correct information, at least in the initial design stages of vehicle dynamics. The model motions equation are found by adding vertical forces on the sprung and unsprung masses. Many of the quarter-car model suspension will represent the M as the sprung mass, while tyre and axles are illustrated by the unsparing mass m. The spring, shock absorber and a variable force-generating element placed between the sprung and unsparing masses constitutes suspension. The quarter-car model is used in suspension system analysis. Sprung mass is assumed to be one fourth part of total vehicle mass. In automotive industry, single- degree-of-freedom or two-degrees-of-freedom quarter-car models of suspension systems are commonly employed in many areas like the calculate of dynamic response, identification, optimization and control of ground vehicles. As quarter car models are simple and comparatively accurate their applicability area is large.

Suspension systems are classified as passive suspension systems, semi active suspension system and active suspension system.

1. Passive Suspension Systems

   A passive suspension is a mechanical system of springs and shock absorbers a conventional system composed of the noncontrolled spring and the shock- absorbing damper. Both components work parallel and are fixed between the wheel supporting structure (unsprung mass) and the vehicle body (sprung mass). The spring constant and damping coefficient values are fixed; spring stores vibration energy in form of strain energy and damper dissipates energy due to compressive action over fluid.

2. Semi Active Suspension System

   A semi-active suspension is similar to passive suspension system with only varying damping coefficient and constant spring constant one without active force sources. Thus, the mechanical layout of a semi-active suspension is similar to a passive one.

3. Active Suspension System

   An active suspension includes an actuator that can supply active force, which is regulated by a control algorithm using data from sensors attached to the vehicle. This suspension is composed of an actuator and a mechanical spring, or an actuator a mechanical spring and a damper. Spring supports the static load of sprung mass and force actuator

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gives the required reactive force to minimize or absorb deflection caused by road irregularities. The actuator can be hydraulic, pneumatic or electromagnetic.

II. LITERATURE SURVEY

Pankaj Sharma, Nittin Saluja, Dimple Saini and Parveen Saini et. al. [1] They designed a quarter car model with 2 DOF. The effect of speed bump as step function is analyzed for overshoot and settling time of sprung and unsprung mass. Using state space model matlab program was develope and analysis is performed. Program developed can be used for quarter-car model with 2 DOF for analysis.

S. Prabhakar, Dr. K. Arunachalam et. al. [2] They simulated passive suspension system for quarter-car model with variable damping and stiffness parameters. Using variable damping and stiffness parameters the suspension can provide optimal performance. Comparison between conventional passive suspension system and passive suspension with variable damping and stiffness parameters is done with the help of different road profiles simulations. Finally with the help of graphs, results are compared.

Abdolvahab Agharkakli, Ghobad Shafiei Sabet, Armin Barouz et. al. [3] They performed comparison between passive and active suspensions system by using different types of road profiles.

Guido Koch, Enrico Pellegrini, Sebastian Spirk and Boris Lohmann et.al.[4] They introduced the test rig concept including the actuator and sensor configuration. The test rigs' dynamic behaviour is presented and a nonlinear as well as a linear test rig model are derived and validated.

J B Ashtekar , A G Thakur et. al. [5] They focus the effect of suspension parameters i.e. sprung mass, unsprung mass, damping value, spring stiffness and tyre stiffness on vertical acceleration. Nagendra Iranna Jamadar and K K Dhande et. al.

[6] The presented analysis sets a benchmark for evaluation of performance characteristics of active suspension system.

G. Verros, S. Natsiavas ,C. Papadimitriou et. al. [7] They introduced a technique for optimizing the suspension damping and stiffness parameters of nonlinear quarter-car models subjected to random road excitation. A comparison is carried out between the results obtained for vehicles with passive suspension dampers and semi-active shock absorbers.

Anirban. C. Mitra, Nilotpal Benerje et al.[8] The main aim is to develop and apply a systematic methodology leading to optimum combinations of the suspension damping and stiffness parameters of as a quarter-car setup. The McPherson strut independent suspension system was used, a ground vehicle subjected to road excitation Yogesh Sanjay Pathare, Nimbalkar Sachin R. et. al. as nowadays it is most popular suspension system in passenger cars. The procedure for development was analytical as well as experimental. Hence the initial mathematical model was developed in matlab and the analytical results were taken on Matlab 10, as an analytical solver.

III. Objectives

The main functions of a quarter-car test rig include the ability to mount different designs of actual car suspensions, having the ability to perform a wide range of tests.

The objective is to study and develop a quarter car suspension test rig model and to perform its simulation. A new quarter-car test rig has been designed and built. The data obtained by the analytical simulation carried out in Matlab SIMULINK is compared with the actual test results. The analytical and experimental results are compared for the ride comfort i.e. displacement of sprung mass for three different values of damping.

IV. Linear State Space Equations

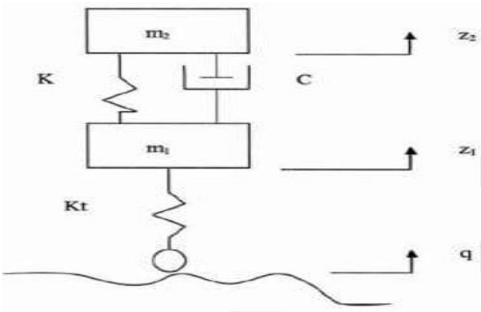

Figure 1: Quarter Car Model

Parameters used for mathematical modeling are as follows:
m_2= Sprung Mass
m_1= Un-sprung Mass
K= Suspension spring stiffness
K_t = Tyre stiffness
C = Damping coefficient of absorber
z_2= Sprung mass vertical movement
z_1 = Unsprung mass vertical movement
q= Road input (height of road bump)

The equation of motion for 2DOF system is given as:

$$m_2\ddot{z}_2 = -K(z_2 - z_1) - C(\dot{z}_2 - \dot{z}_1)$$

$$\ddot{z}_2 = \frac{1}{m_2}[-K(z_2 - z_1) - C(\dot{z}_2 - \dot{z}_1) \quad ....(1)$$

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

$$\ddot{z}_1 = \frac{1}{m_1}[K(z_2 - z_1) + C(\dot{z}_2 - \dot{z}_1) - K_t(z_1 - q)] \quad .....(2)$$

By using equations (1) and (2) mathematical model is made in MATLAB SIMULINK as shown in Fig.

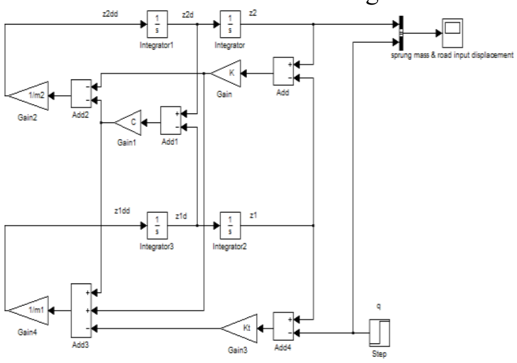

Figure 2: Quarter Car Passive Suspension System SIMULINK Model

V. DEVELOPMENT OF QUARTER CAR TEST RIG

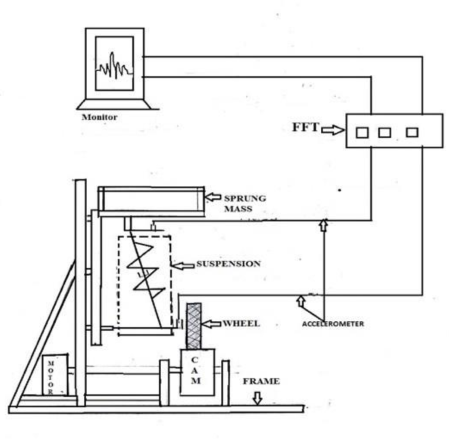

Figure: 3 Schematic Diagram of Proposed Test Rig

Current quarter-car test rigs are first evaluated. With known data the analytical simulation is carried out on Matlab and the results were recorded. Then comparison is to be done with the actual test results. In the experimental set-up, a PMDC motor with controller is connected to a cam and follower mechanism to provide harmonic base excitation. It is mounted on a base frame. Necessary instrumentation for obtaining time-based data for sprung mass displacement and base excitation and converting the same in graphical form, using FFT interfacing system has been developed. The suspension of a two-degree-of-freedom (2-DOF) vehicle traveling on a road surface is studied and is simulated with respect to test rig design. In the proposed work, a 2-DOF quarter car is modeled to carry out computer simulations. During simulations, a vehicle is assumed to run at a certain speed while it hits a step defined by cam. Vehicle response corresponding to above mentioned road disturbances is obtained for ride quality and comfort. Quarter Car suspension system is modeled and simulated for a range of road disturbances to analyze performance.

The work involves

1. Modeling of a vehicle suspension system as a linear quarter car model.
2. Deriving the equations for the quarter car model and create a Simulink model in Matlab
3. Simulation of suspension system using step input at the tyre to analyze the vehicle performance.
4. Repeating the simulations over range of road surfaces and vehicle speeds and analyzing the performance of the vehicle in terms of sprung mass displacement, unsprung mass displacement etc
5. Mechanical Design and Development of a Quarter Car Test Rig.
6. Simulation of a Quarter Car Test Rig.
7. Design, Implementation and Simulation of Suspension System on a Quarter Car Test Rig.
8. Validation of simulation and Quarter Car Test Rig results.

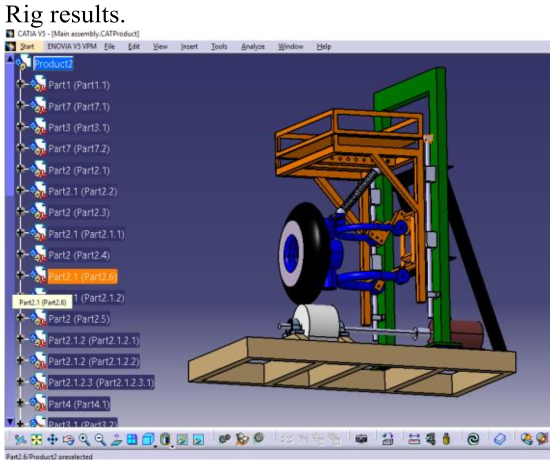

Figure 4: CATIA Model

VI. SIMULATION

1) For simulation the following parameters are used:

Sprung Mass (Ms)	290 kg
Unsprung mass (Mu)	59 kg
Spring Stiffness (K)	16182 Ns/m
Tyre Stiffness (Kt)	190000 N/m

Table 1: Input Values for SIMULINK Analysis [9]

2) For following values of Damping:

Sr. No.	Damping (C) N/m/s
1	1000
2	1300
3	2000

Table 2: Different Damping Values for Simulation [9]

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The purple coloured line shows the road input (q) which is a step input. The green coloured line shows the displacement of sprung mass (z_2) and the cyan coloured line shows unsprung mass displacement (z_1).

VII. GRAPHICAL REPRESENTATION OF THE SIMULATION

The above values are given as the input to the simulation. Following three cases of quarter car model are analyzed in MATLAB SIMULINK: Case I] C= 1000 N/m/s.
Figure 5 shows the effect of variation of input parameters graphically.
Case II] C= 1300 N/m/s.
Figure 6 shows the effect of variation of input parameters graphically.
Case III] C= 2000 N/m/s.
Figure 7 shows the effect of variation of input parameters graphically.

The obtained results from simulation are as below:

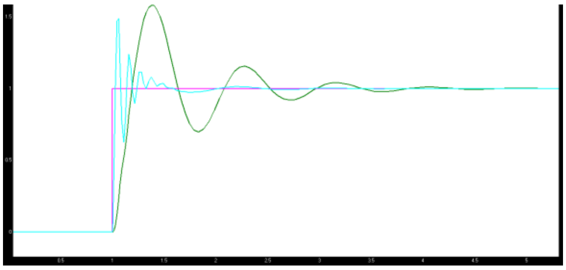

Figure 5: Sprung Mass Displacement (m), Unsprung Mass Displacement (m) and Road Input (m) Vs. Time (sec) (Case I: C= 1000 N/m/s)

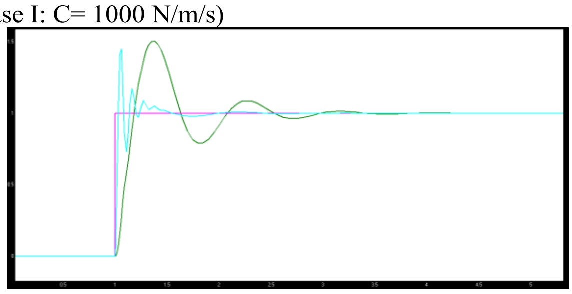

Figure 6: Sprung Mass Displacement (m), Unsprung Mass Displacement (m) and Road Input (m) Vs. Time (sec) (Case II: C= 1300N/m/s)

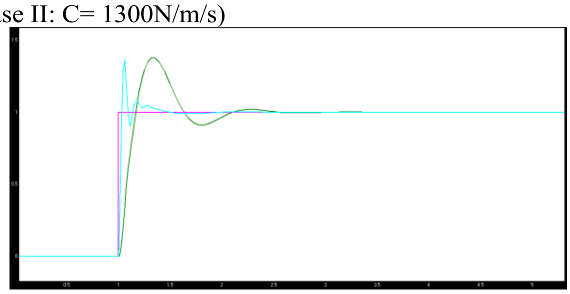

Figure 7: Sprung Mass Displacement (m), Unsprung Mass Displacement (m) and Road Input (m) Vs. Time (sec) (Case III: C= 2000 N/m/s)

VIII. RESULT AND DISCUSSION

Sr. No.	Damping Value (C) N/m/s	Sprung Mass Displacement (m)	Time required for Vibration reduces to Neutral Position (sec)
1	1000	1.6	5
2	1300	1.5	4.2
3	2000	1.4	3.6

Table 3: MATLAB Simulation Result

The simulation is done for three different values of damping keeping the other parameters constant. The graphs obtained by SIMULINK shows that for the case I i.e. C= 1000 N/m/s the sprung mass displacement (green line) value is more compared to case II i.e. C= 1300 N/m/s. and case III i.e. C= 2000 N/m/s i.e. when the damping value increase the vibration reduces in sprung mass. Body comes to neutral position faster compared to case I & II showing that ride comfort in case III is more than that in case I and case II.

IX. CONCLUSION AND FUTURE WORK

Simulation based on the mathematical model for quarter car is performed by SIMULINK (Matlab software). Performances of the suspension system in term of displacement of sprung and unsprung mass will be observed where speed bump as a step input is assumed as the input for the system.

The quarter car test rig will be simulated and tested for three different value of damping by changing the suspension. The graphical representation (time-based graph) is obtained by using sensors and FFT analyzer and later these experimental results are compared with the analytical results obtained by Matlab (SIMULINK).

X. REFERENCES

[1] Pankaj Sharma, Nittin Saluja, Dimple Saini And Parveen Saini (2013), “Analysis of Automotive Passive Suspension System with Matlab Program Generation”, International Journal of Advancements in Technology, Volume 4, Issue 2, ISSN: 0976-4860
[2] S. Prabhakar, Dr. K. Arunachalam (2015), “Simulation and Analysis of Passive Suspension System for Different Road Profiles with Variable Damping and Stiffness Parameters”, National Conference on Recent Trends and Developments in Sustainable Green Technologies, ISSN: 0974-2115
[3] Abdolvahab Agharkakli, Ghobad Shafiei Sabet, Armin Barouz (2012), “Simulation and Analysis of Passive and Active Suspension System using Quarter Car Model for Different Road Profile”, International Journal of Engineering Trends and Technology, Volume 3 ,ISSN: 2231-5381

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 03 , March - 2026

[4] Guido Koch, Enrico Pellegrini, Sebastian Spirk And Boris Lohmann (2010), "Design and Modeling of A Quarter-Vehicle Test Rig for Active Suspension Control", Technical Reports On Automatic Control, Vol. TRAC-5

[5] J B Ashtekar, A G Thakur (2014), "Simulink Model of Suspension System& Its Validation on Suspension Test Rig", International Journal of Mechanical Engineering & Robotics Research,
Volume 3, Issue 3, ISSN:2278 – 0149

[6] Nagendra Iranna Jamadar And K K Dhande, "Transient Analysis of Vehicle Passive Suspension System", International Journal of Mechanical Engineering & Robotics Research, Volume 3, Issue 3, ISSN:2278 – 0149

[7] G. Verros, S. Natsiavas ,C. Papadimitriou (2005),"Design Optimization of Quarter-Car Models with Passive and Semi-Active Suspensions Under Random Road Excitation", Journal Of Vibration and Control, Volume 11

[8] Anirban. C. Mitra, Nilotpal Benerje (2013),"Ride Comfort and Vehicle Handling of Quarter Car Model using SIMULINK and Bond Graph", 1st International and 16th National Conference on Machines and Mechanisms

[9] Yogesh Sanjay Pathare, Nimbalkar Sachin R. et. al.(2014), "Design and Development of Quarter Car Suspension Test Rig Model and It's Simulation", International Journal of Engineering Science & Advanced Technology ,Volume-3, Issue-3, 157-170 , ISSN: 2250-3676