Proceedings of the
International Conference on Mechanical Engineering and Renewable Energy 2019
(ICMERE2019) 11- 13 December 2019, Chittagong, Bangladesh

ICMERE2019-PI-003

HALF CAR SUSPENSION SYSTEM ANALYSIS BY USING MATLAB SIMULINK

Md. Niamul Quader, Syed Mohammad Ikram, and Md. Arafat Rahman*

Department of Mechanical Engineering, Chittagong University of Engineering & Technology,
Chittagong, 4349, Bangladesh
quaderniamul@gmail.com; ikramctg007@gmail.com; and arafat@cuet.ac.bd*

Abstract*-Car suspension systems are used to create road comfort in various roads profiles. An independent front and rear vertical passive suspension are 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. 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, road handling, and suspension deflection. In this model, the vehicle body pitch is represented by pitch angular displacement and pitch angular velocity and bounce degrees of freedom is represented by vertical displacement and vertical velocity.*

Keywords: Half car suspension, mass, spring, damper, Simulink

1. INTRODUCTION

For vehicle suspension design, it is always challenging to maintain simultaneously a high standard of ride, handling, and body attitude control under all driving conditions. The problems stem from the wide range of operating conditions created by varying road conditions, vehicle speed, and load. In general, during cornering, braking, and bumping, a high stiffness and damping is needed to provide good handling properties, and to satisfy workspace limitations of the suspension Model. However, when a vehicle runs on a low roughness road, a suspension Model with low stiffness and damping is needed for good ride comfort. A good suspension Model should provide good vibration isolation, i.e. small acceleration of the body mass, and a small "rattle space", which is the maximal allowable relative displacement between the vehicle body and various suspension components [1]. The goal is to maintain the suspension travel within the rattle space and to minimize car-body rate-of-change of acceleration. Ride comfort is one of the most critical factors to evaluate the automobile performance and has been an interesting topic for researchers for many years [2]. Automobile designers give an abundant attention to the isolation of vibrations in the car, in order to provide a comfortable ride for the passengers.

2. LITERATURE REVIEW

It is seen that, over many years, automotive designers are working on the development of a state-of-the-art car with a view to provide better ride comfort and handling characteristics and reliable operation. The focus of their work seems to be on changing the passive suspension principle to innovative active suspension. As such, in this chapter, a brief review of the literature on dynamics of vehicle systems has been carried out. A number of theoretical and experimental investigations on the dynamic response of passive, active and semi-active suspension systems for ground vehicles have been reported. In these investigations various aspects of suspension system design such as, ride comfort, road holding, vehicle handling, road safety and reliability have been studied [3]. Therefore, a literature survey has been carried out on the above mentioned and other related topics connected with design of passive, active and semi-active suspension systems by referring various International Journals: Vehicle System Dynamics, Transactions of the ASME: Journal of Mechanical Design , Journal of Dynamic Systems, Measurement and Control , Journal of Vibration and Acoustics, JSME InternationalJournal C , IEEE / ASME Transactions on Mechatronics, Journal of Sound and Vibration, Computing and Control Journal , Proceedings of Institution of Mechanical Engineering (London) , SAE Technical Papers etc. and Proceedings of International Conferences such as, American Control Conference ,IFToMM World Congress, Biennial ASME Conferences on Engineering Systems Design and Analysis , IEEE Conferences on 26 Control Applications etc. From this literature survey, some selected research papers have been reviewed, taking into consideration, the following aspects.

3. MATHEMATICAL MODEL

For vehicle suspension design, it is always challenging to maintain simultaneously a high standard of ride, handling, and body attitude control under all driving conditions. The problems stem from the wide range of operating conditions created by varying road conditions, vehicle speed, and load. In general, during cornering, braking, and bumping, a high stiffness and damping is needed to provide good handling properties, and to satisfy workspace limitations of the suspension Model. However, when a vehicle runs on a low roughness road, a suspension Model with low stiffness and damping is needed for good ride comfort [4]. A good suspension Model should provide good vibration isolation, i.e. small acceleration of the body mass, and a small “rattle space”, which is the maximal allowable relative displacement between the vehicle body and various suspension components [5]. The goal is to maintain the suspension travel within the rattle space and to minimize car-body rate-of-change of acceleration.

Ride comfort is one of the most critical factors to evaluate the automobile performance and has been an interesting topic for researchers for many years. Automobile designers give an abundant attention to the isolation of vibrations in the car, in order to provide a comfortable ride for the passengers [6].

A half car model with multi degrees of freedom system considered for analysis. It is consisting of sprung mass referring to the part of the car that is supported on springs and unsprung mass which refers to the mass of wheel assembly. The tire has been replaced with its equivalent stiffness and tire damping is neglected as it’s a negligible compare to tire stiffness. If stiffness is constant then, the value of stored potential energy in the spring is equal to the work done by the spring force F_s during the spring deflection. The spring potential energy is then a function of displacement. If the stiffness of a spring is not a function of displacements, it is called linear spring. Force exerted by the spring of the front suspension due to the bounce of the car [7].

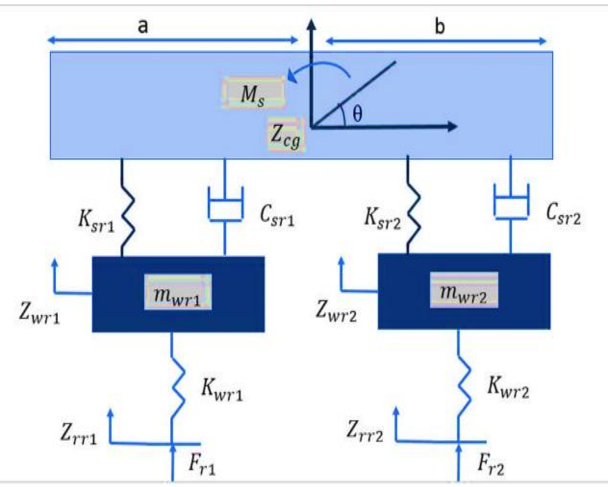

Fig. 1: Schematic model of a half car suspension system

After mathematical calculation we get four important equations, using the Newton’s second law of motion and free-body diagram concept, the following 4 equations [Eq.1- Eq.4] of motion are derived.

$M_s\ddot{Z}_{cg}$ = - $K_{sr1}(Z_{cg} - \theta a - Z_{wr1})$ - $K_{sr2}(Z_{cg} + \theta b - Z_{wr2})$ - $C_{sr1}(\ddot{Z}_{cg} - \dot{\theta}a - \dot{Z}_{wr1})$ - $C_{sr2}(\ddot{Z}_{cg} + \dot{\theta}b - \dot{Z}_{wr2})$ ----------[1]

$I_{xx}\ddot{\theta}$ = $K_{sr1}(Z_{cg} - \theta a - Z_{wr1})a$ - $K_{sr2}(Z_{cg} + \theta b - Z_{wr2})b$ - $C_{sr1}(\ddot{Z}_{cg} - \dot{\theta}a - \dot{Z}_{wr1})$ - $C_{sr2}(\ddot{Z}_{cg} + \dot{\theta}b - \dot{Z}_{wr2})$ ------------[2]

$m_{wr1}\ddot{Z}_{wr1}$ = $K_{sr1}(Z_{cg} - \theta a - Z_{wr1})$ - $K_{wr1}(Z_{wr1} - Z_{rr1})$ - $C_{sr1}(\ddot{Z}_{cg} - \dot{\theta}a - \dot{Z}_{wr1})$------------------------------------[3]

$m_{wr2}\ddot{Z}_{wr2}$ = $K_{sr2}(Z_{cg} + \theta b - Z_{wr2})$ - $K_{wr2}(Z_{wr2} - Z_{rr2})$ - $C_{sr2}(\ddot{Z}_{cg} + \dot{\theta}b - \dot{Z}_{wr2})$ -----------------------------------[4]

In order to analyze the behavior of the half car suspension, model is simulated in MATLAB SIMULINK.

4. SIMULATION AND RESULT

For simulation purpose, the values of masses, damping coefficients and spring constants of sprung and unsprung masses for both front and rear wheels are considered. It is assumed that the tire act as a absorber having only spring in action with no damper for simplicity

4.1 3D MODEL CAR

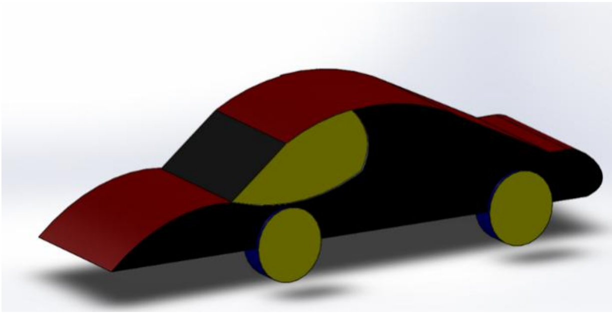

Fig. 2: Half Car

4.1 Parameter for simulation of half car

The fixed parameters mentioned in various research papers are taken for the simulation study. Suspension spring stiffness are considering 55000 N/m, 25000 N/m and damping coefficient 4000 N-s/m, 1000 N-s/m respectively. The fixed parameters of half car model are shown in Table 1.

Table 1: Values of various parameters.

Mass of vehicle body in Kg	M_s	1200kg
Mass of Front right wheel	m_{wr1}	60kg
Mass of rear right wheel	m_{wr2}	60kg
M.I @ X-X axis	I_{xx}	4000kg-m^2
Spring stiffness of Front right	K_{sr1}	55000N/m
Spring stiffness of rear right	K_{sr2}	25000N/m
Damping coefficient of Front right	C_{sr1}	4000Kg-m^2
Damping coefficient of rear right	C_{sr2}	1000Kg-m^2
Spring stiffness of Front right	K_{wr1}	30000N/m
Spring stiffness of rear right	K_{wr2}	30000N/m
Distance from CG to Front Wheel	a	1.5m
Distance from CG to rear Wheel	b	1.5m

4.2 Analysis of Simulink Model

For the proper road holding relative displacement between wheel and road must be in the range of 0.0508 m (Gillespie, 2003). In this paper, analysis of validated half car simulation model is conducted to study the effect of suspension spring and damping coefficient on ride comfort and road holding.

First we calculate for quarter car suspension for fornt and rear portion of the car than we calculate half car suspension. The plot of variation of displacement of Z_{CG} with time obtained by simulation of SIMULINK model. The simulation result is in good agreement with analytical solution.

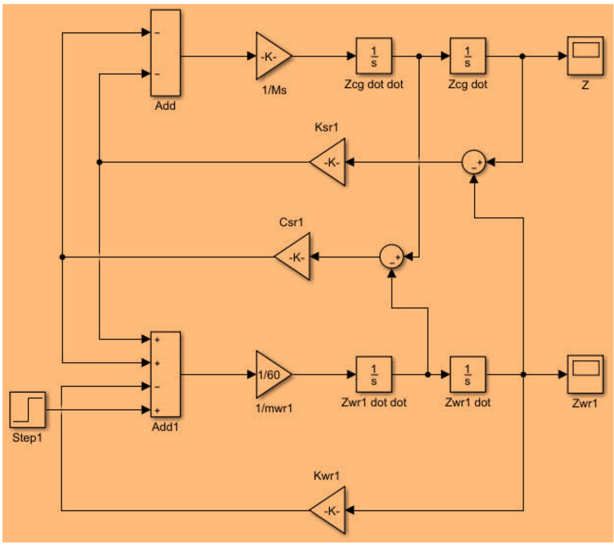

Fig. 3: Quatre car suspension for front wheel

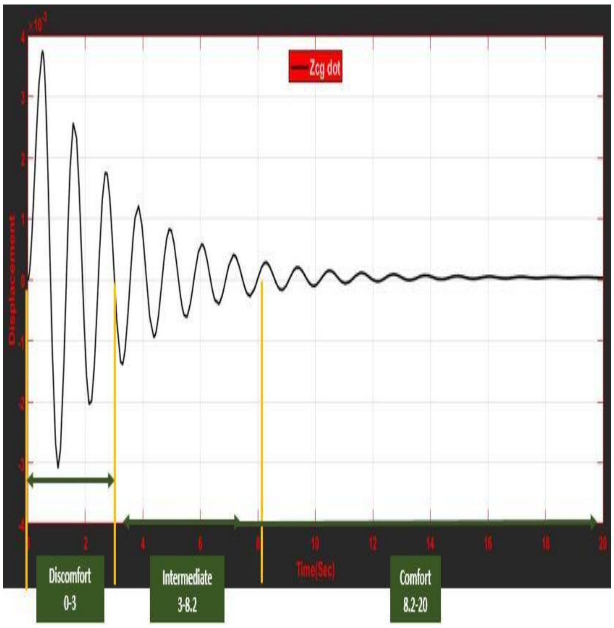

Fig. 4: Passenger compartment displacement

In this front wheel quarter car suspension system when 60N force applied front suspension vibrate or massive discomfort occurred for 3 seconds then intermediate stage stayed for 3 to 8.2 seconds and less comfort zone happened for 8.2 to 14 second.

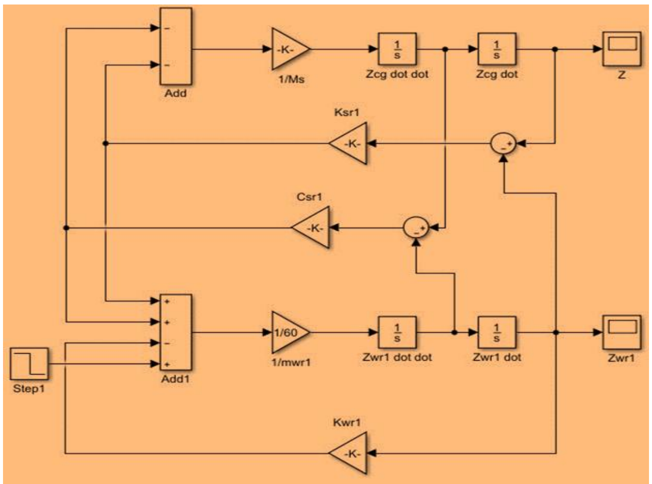

Fig. 5: Quarter car suspension for rear wheel

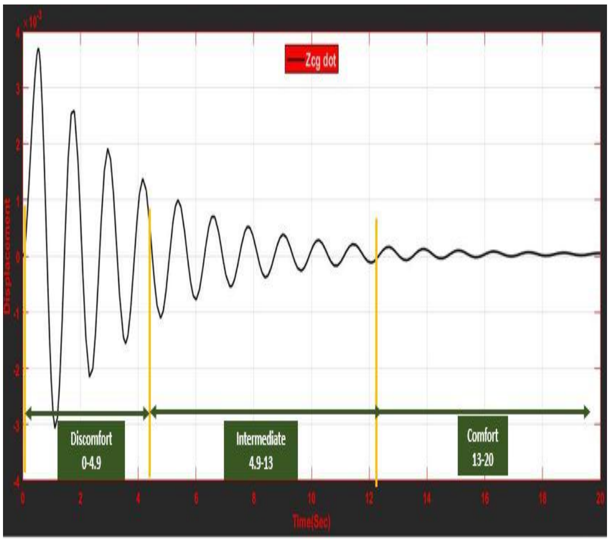

Fig. 6: Passenger compartment displacement

In this rear wheel quarter car suspension system when 60N force applied front suspension vibrate or massive discomfort occurred for 4.9 seconds then intermediate stage stayed for 4.9 to 13 seconds and less comfort zone happened for 13 to 20 second.

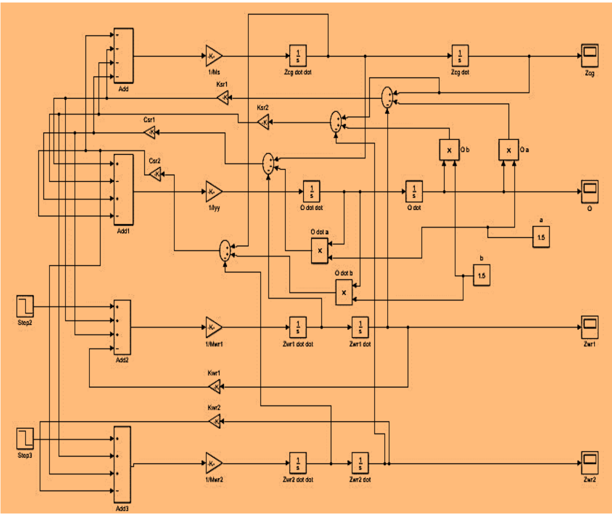

Fig. 7: Half car suspension Simulink model

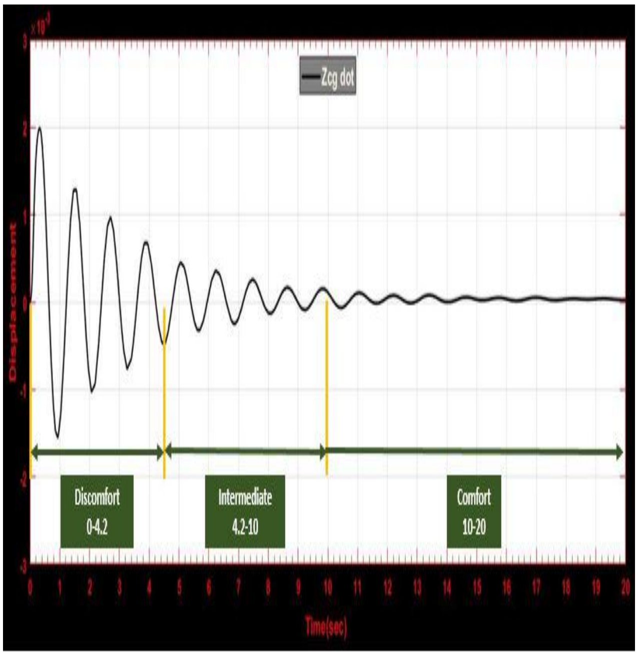

Fig.8: Passenger compartment displacement

In this Half car suspension system when 120N force applied in front and rear suspension create discomfort occurred for 4.2 seconds then intermediate stage stayed for 4.2 to 10 seconds and less comfort zone happened for 10 to 17 second.

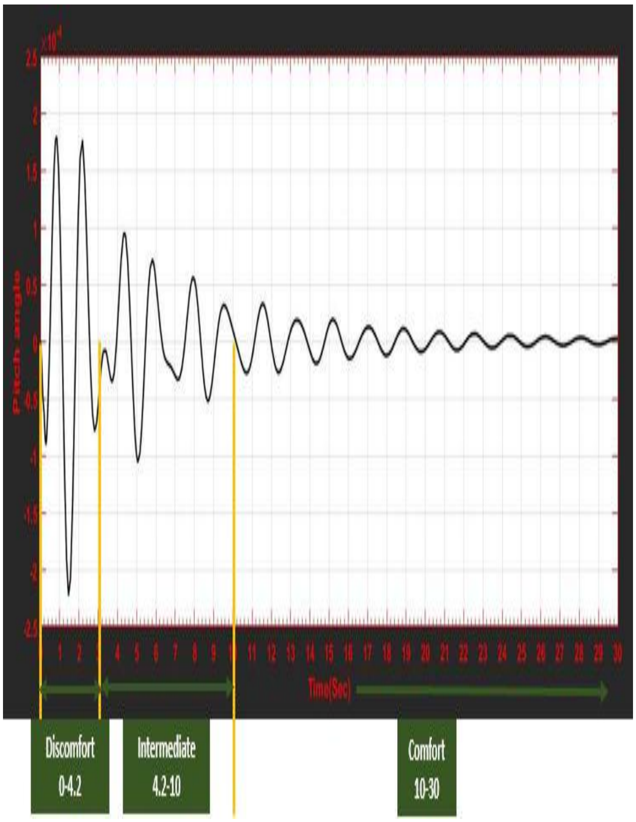

Fig. 9: Pitch angle of the body displacement

Suspension vibrate or massive discomfort occurred for 3 seconds then intermediate stage stayed for 3 to 10 seconds and less comfort zone happened for 10 to 17 second. Here this graph is not simultaneous cause two spring have different stiffness, so for this reason in intermediate reason another pitch angle occurred.

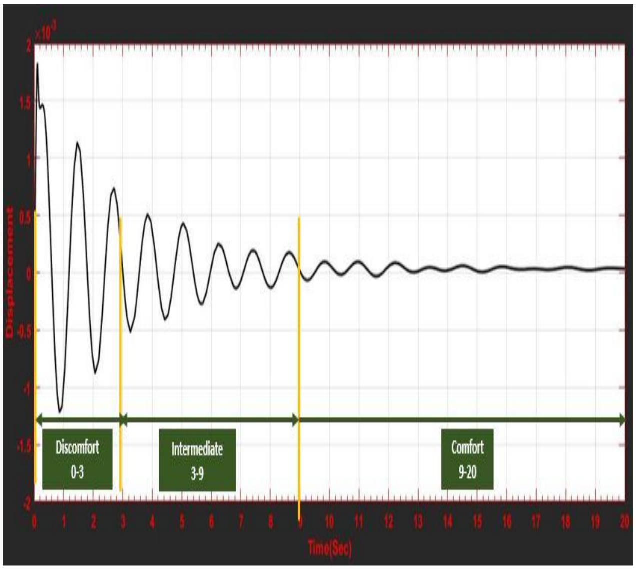

Fig. 10: Front wheel displacement

Front wheel displaces or vibrate for 3 second then 3 to 9 second for intermediate and less comfort for 9 to 16 second.

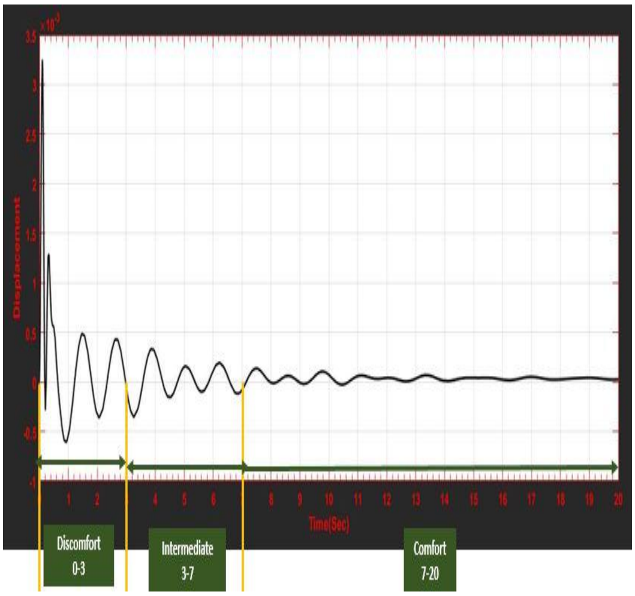

Fig. 11: Rear wheel displacement

Here rear wheel suspension first creates high displacement then it goes through comfort zone more quickly than front wheel suspension.

5. DISCUSSION

In this simulation two spring have different spring stiffness, rear spring have less stiffness than front spring stiffness, so rear wheel first displaces more than front wheel, but rear wheel stable more quickly than front wheel, so firstly in passenger compartment feels a sudden shock but after that it will stable more quickly than front portion of the car. This type of suspension we can use for hill side area, because their car speed is less important. This type of suspension is not for racing car because their traction is less in rear wheel, so car speed will decrease and will loss balance when it will go through an obstacle.

6. ACKOWLEDGEMENT

This research is financially supported through DRE project “Design and fabrication of low natural frequency driver seat suspension system”, Chittagong University of Engineering and Technology, Cittagong-4349.

7. REFERENCES

[1] Automotive engineering powertrain, chassis system and vehicle body edited by david a. Crolla.

[2] Reza n. Jazar (2008). Vehicle dynamics: theory and applications spring. P. 455. Retrieved 2012-06-24.

[3] "suspension basics 1 - why we need it" initial Dave. Archived from the original on 2015-01-29. Retrieved 2015-01-29.

[4] Ali mohammadzadeh, salimhaider, “analysis and design of vehicle suspension model using matlab and simulink”, American society for engineering education, 2006.

[5] Sun, l., on human perception and evaluation to road surfaces, journal of sound and vibration, 247, 547-560, 2001.

[6] Theoretical and numerical analysis of half car vehicle dynamic model subjected to different road profiles with wheel base delay and nonlinear parameters s.s.Patole† and dr. S.h. Sawant‡

[7] simulation and analysis of half-car passive suspension system a. Shahriar1, k. A. Rahman2* and s. Tanvir3