

Designing and Modelling Vehicle Suspension Systems to Improve Performance

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Abstract

This paper proposes the investigation of active suspension systems in automobiles with the goal of enhancing ride comfort for passengers while also improving the stability of the vehicle by decreasing vibration impacts on the suspension system, as described in the literature. It has been determined that the physical model of the car suspension system is generated from the laws of motion, and Simulink building blocks are formed by splitting a set of equations for the various parts. Simulation of the vehicle has been completed, and the resulting reactions have been plotted. In response to the rising need for fine control of parameters, the mechatronic controller is being created for the purpose of boosting the comfort of the vehicle through the application of the controller to the vehicle's suspension system. The inclusion controller and the Jerk measure in the active suspension system should be taken into consideration at this point in the system's design.

Keywords: *Automotive suspension system, Traffic, Simulink, Systemdesign*

INTRODUCTION

In traffic deaths and road accidents, more than one million (approximately) people lose their lives every year in the world and around 50 million (approximately) people suffer non-fatal injuries. The suspension

system of a car, which transmits the force between the vehicle and the road, plays a significant role in determining the handling capabilities and ride safety of the vehicle. The suspension system should not only allow the driver to maintain control of

the vehicle in crucial situations, but it should also give a high degree of ride comfort to protect the driver from becoming physically exhausted throughout the journey.

Because the suspension system has a substantial impact on the subjective perception of a vehicle, the demands of customers for modern vehicles in terms of safety and ride comfort are continually growing. These considerations create a significant difficulty for the designers of automotive suspension systems.

The wheels with the tyres, the wheel carrying systems, the spring and damper elements, the steering, and the brakes are the major components of a passive (traditional) suspension system.

The choice of the damper (dc damper coefficient) and spring in a passive automotive suspension system is the most important factor influencing the dynamic behavior of the system (cc stiffness). Different considerations are taken into account while determining the damper (dc) and spring (cc) settings, respectively. Suspension should, on the one hand, provide exceptional ride comfort through the use of a soft damper and spring

arrangement that isolates the chassis from road-induced vibration.

On the other hand, in order to maintain ride safety, the vehicle must be controllable by the driver, which necessitates a firm, well-damped coupling between the vehicle and the road, particularly while performing non-stationary drive movements, such as driving on a bumpy road or cornering. As a result, the demands for comfort and safety are at odds with one another.

There are three fundamental techniques to controlling the suspension system: passive suspension, semi-active suspension, and active suspension. Passive suspension is the most basic approach, followed by semi-active suspension and active suspension. Some aspects, such as suspension design, rapid response to a jolt, intelligence, and the capacity to function in real-time operating circumstances, among others, play a critical role in delivering good ride comfort, enhancing road holding, and increasing the overall stability of the vehicle [3, 4].

An external actuator, in addition to this, can be used to impart a controlled action of force on the suspension travel during travel. Control of these extra forces is

accomplished by a variety of control algorithms that are in turn regulated by data from a sensor affixed to the vehicle body.

When using an active suspension system, passive components are supplemented by actuators that supply extra forces while pulling down or pushing up the body masses in order to achieve the required degree of comfort and to minimize vibrations caused by road imperfections. System characteristics with active control can be improved by incorporating an

active shock absorber, which creates instantaneous forces that allow for the support of loads as well as the provision of safety and comfort in the face of limits. The primary disadvantage of active suspension is that the actuation energy is supplied to the system from an external source, increasing the overall cost of the system. Different control approaches for active control in suspension system applications, such as back stepping control, have been introduced thus far.

SYSTEM MODELING

Modeling of Half Car Model Suspension System

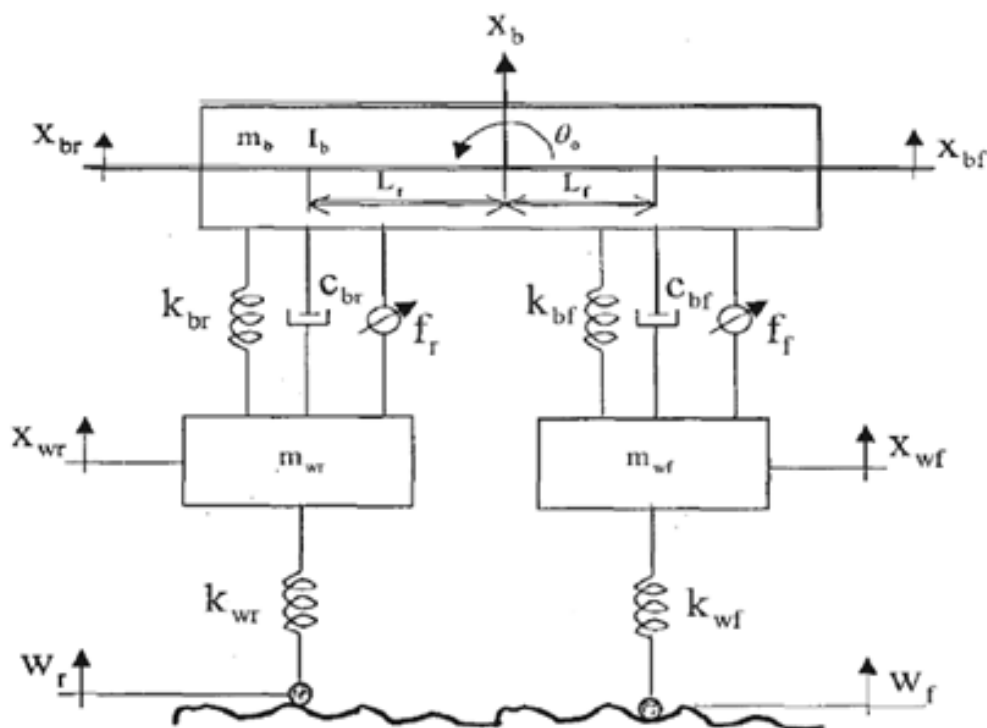


Fig.1: The Half Car Model of Suspension System

A comprehensive mathematical model of the passive suspension for a half-car model, as seen in Figure 1, is presented in this section. Based on the technique described in Yoshimura, the following results were obtained: In the half-car model, the passive suspension is made up of the front and rear wheels and axles, which are coupled to the half-portion of the vehicle's body by means of a passive springs-dampers combination, while each tyre is modeled as a basic spring without a damper.

For this suggested system, equations of motion are constructed by taking into account a variety of various characteristics. It is possible to generate these differential equations by the application of physical principles (Newton's laws of motion), and they will be linear time invariant for the linear system under consideration. Table 1 contains a list of the criteria that were taken into consideration.

Table 1 Parameters Used In the System Simulation

S.N.	Parameter	Symbol	Unit
1.	Mass of vehicle's body	m_s	Kg
2.	Total Length of the body	L	m
3.	Length of the body front from centre of gravity	L_f	m
4.	Length of the body rear part from centre of gravity	L_r	m
5.	Stiffness of the Tyre material	k_{br}, k_{bf}	N/m
6.	Coefficient of springs	k_{wr}, k_{wf}	N/m
7.	Damping coefficients of the dampers	c_{br}, c_{bf}	N-s/m
8.	Moment of inertia for the car body	I_b	kgm ²
9.	Rotary angle of the car body at the center of gravity	θ_b	rad
10.	Un-sprung masses of the suspension	m_{wr}, m_{wf}	kg
11.	Body vertical Displacements (Sprung mass)	x_{br}, x_{bf}	m
12.	Suspension Travel (un-sprung mass vertical displacement)	x_{wr}, x_{wf}	m
13.	Tyre vertical travel due to road disturbance (Jerk Height)	w_r, w_f	m

The motion equation for the passive suspension for the half car model may be derived as follows-

- **Top section:** Initially by considering only top section of the suspension systems following two mathematical equations are derived.

$$m_b \ddot{x}_b + c_b(\dot{x}_b - \dot{x}_w) + k_b(x_b - x_w) + c_r(\dot{x}_r - \dot{x}_w) + k_r(x_r - x_w) = 0 \quad \dots 1$$

$$I_b \ddot{\theta} + L_f[c_h(\dot{x}_h - \dot{x}_w) + k_h(x_h - x_w)] + L_r[c_r(\dot{x}_r - \dot{x}_w) + k_r(x_r - x_w)] = 0 \quad 2$$

- **Bottom section:** The second approach involved bottom section of the system-
 $m_w \ddot{x}_w - c_b(\dot{x}_b - \dot{x}_w) - k_b(x_b - x_w) + k_w(x_w - w) = 0 \dots \dots \dots 3$

$$m_w \ddot{x}_w - c_r(\dot{x}_r - \dot{x}_w) - k_r(x_r - x_w) + h_w(x_w - w) = 0 \dots \dots \dots 4$$

in order to consider the vertical displacement of the front and rear car body, x_b and x_r respectively,

$$x_b = (L_f x_{bf} + L_r x_{br}) / L \dots \dots \dots 5$$

$$\theta_b = (x_{bf} - x_{br}) / L \dots \dots \dots 6$$

Therefore equations (1) and (2) can be rewritten as,

$$m_b/L(L_f \ddot{x}_{bf} + L_r \ddot{x}_{br}) + c_b(\dot{x}_{bf} - \dot{x}_w) + k_b(x_{bf} - x_w) + c_r(\dot{x}_{br} - \dot{x}_w) + k_r(x_{br} - x_w) = 0 \quad 7$$

$$I_b/L(\ddot{x}_{bf} - \ddot{x}_{br}) + L_f[c_b(\dot{x}_{bf} - \dot{x}_w) + k_b(x_{bf} - x_w)] - L_r[c_r(\dot{x}_{br} - \dot{x}_w) + k_r(x_{br} - x_w)] = 0 \quad 8$$

So far the mathematical modeling for the proposed passive suspension system is done as in above equations (1), (2), (3), (4), (5), (6), (7) & (8).

Modeling of Active System

The capacity to store, disperse, and infuse energy into the system is a feature of active suspension technology. Parallel connections are made between the hydraulic actuator and a spring and an absorber.

In contrast, sensors for the body are placed at various spots throughout the vehicle in order to measure the motions of the body. It may change the parameters of its operation based on the operational conditions. Figure 2 depicts the active suspension system for a vehicle.

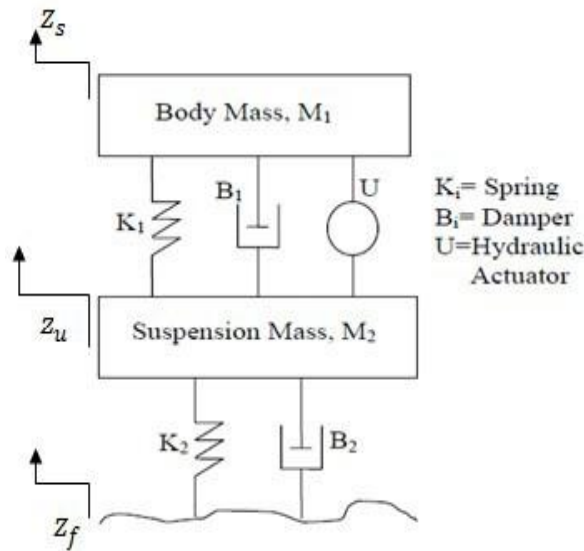


Fig.2: The active car suspension system

It is used to analyse the ride performance of the physical active automobile suspension system depicted in fig.2. The spring mass (M1) and un-spring mass (M2) are both expressed as kilogram's (kg). Because the current study is concerned with an active suspension system, the stiffness of the suspension spring, K1, (N/m), and the damping coefficient, B1, (N-s/m), are treated as constants that are not affected by time. The tyre stiffness K2 is measured in Newton's per meter of tyre length, while the tyre damping coefficient B2 is measured in Newton's per meter of tyre length. In this equation, Zs denotes displacement of the spring mass, Zu, and Zf denotes unspring displacement and road input correspondingly. Figure 2 shows the ordinary differential equation (ODE),

which is denoted by Eqs. 1 and 2, which correspond to the spring and unspring masses, respectively.

$$M_1 (\ddot{Z}_s) + B_1 ((\dot{Z}_s) - (\dot{Z}_u)) + K_1(Z_S - Z_u) + M_1g + U = 0 \dots\dots\dots 1$$

$$M_2 (\ddot{Z}_u) - B_1 ((\dot{Z}_s) - (\dot{Z}_u)) - K_1(Z_S - Z_u) + B_2 ((\dot{Z}_u) - (\dot{Z}_f)) + K_2(Z_u - Z_f) + M_2g = 0 \dots\dots\dots 2$$

Equation 1 & 2 are solved by a SIMULATION tool box of MATLAB.

Simulation in Matlab

The MATLAB software is used to design controllers in simulation, and the results of the simulation are used to evaluate the suspension system's performance.

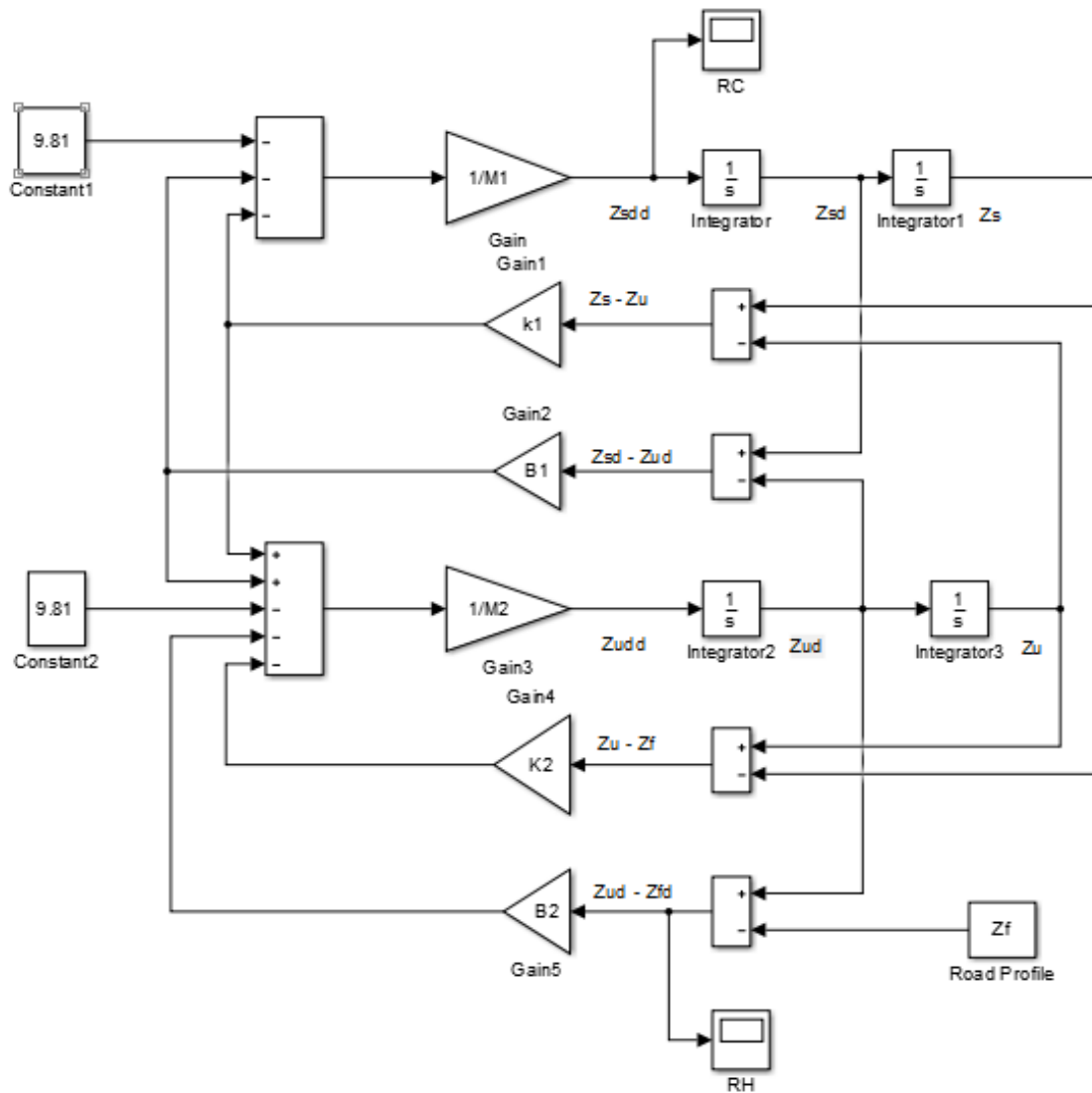


Fig.3: Block diagram active car suspension system SIMULATION in MATLAB

Table 4.1 numerical values for the model parameters.

S.N.	Parameter	Value	Unit
1.	M1	430	Kg
2.	M2	30	Kg
3.	B1	150	N-s/m
4.	B2	6666.67	N-s/m
5.	K1	500	N/m
6.	K2	1000	N/m
7.	Zf	2	N/m

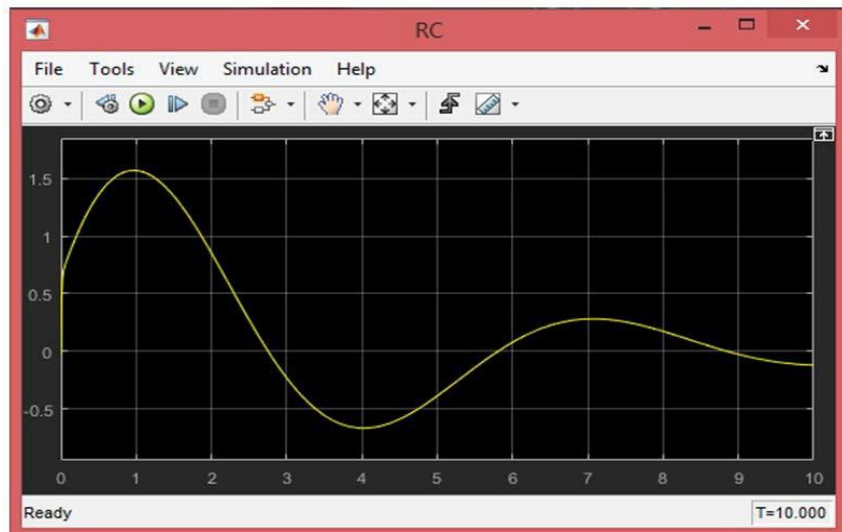
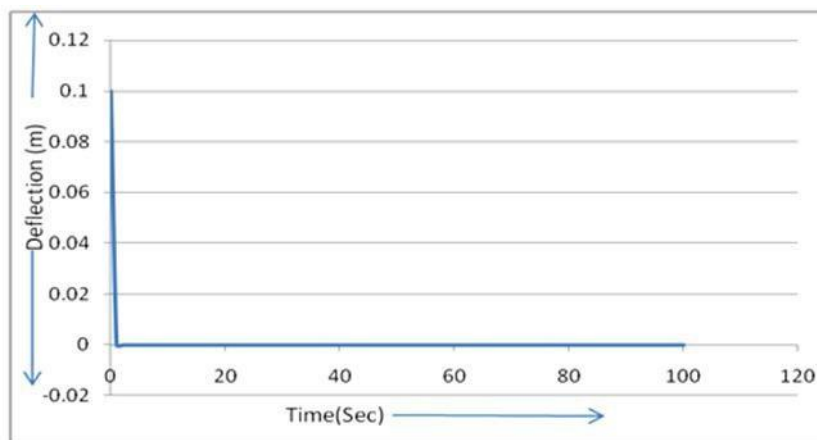


Fig.4 Result of Road Profile in jerk measure RC & RH.



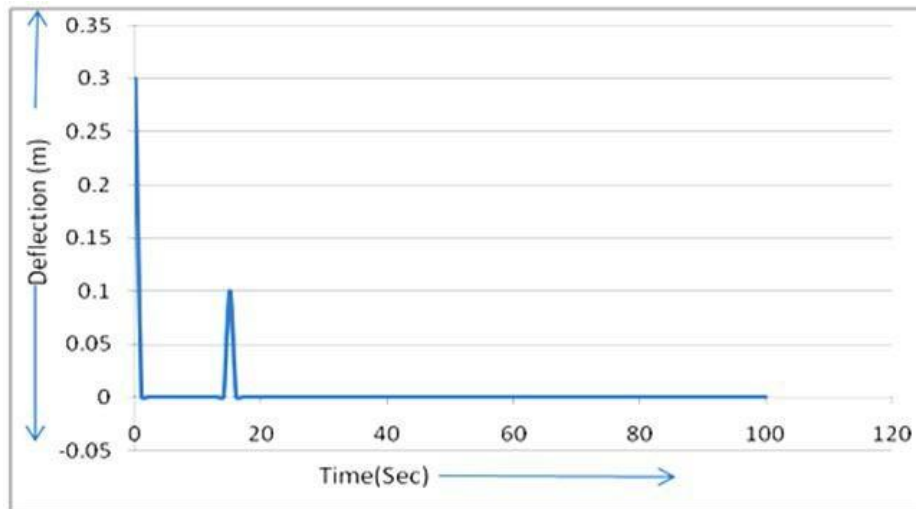


Fig.5

The wheel deflection responses for single step input of 0.1m, the wheel deflection responses for double step inputs of 0.3 m & 0.1 m

CONCLUSION

The simulated model is studied after it has been run for a predetermined amount of time, and various observations are made in relation to the performance and behavior of the suspension system.

- The graphs RH and RC depict the results of the jerk measurement from top to bottom. In order to conduct the practical simulation, software must be used to draw conclusions from the analysis. MATLAB software may be used to support the practical simulation.
- Using a single jerk as a road input, a bump with an average height of 0.1m

is considered. In this case, the road input is represented by two jerks, each with a 15-second time delay between them, and the bumps have heights of three and one millimeters.

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