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MODELLING OF ACTIVE SUSPENSION SYSTEM FOR QUARTER CAR (PID CONTROL, MATLAB)

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***Abstract*—We are discussing active suspension in this research. It also includes an actuator or controller (ECU), wheels and body. The rider feels comfort in travelling due to the use of these types of suspension. Because it controls vertical moments or moves of the wheels and stable rider or passenger. It is most important in the automobile industries. There are many types of controllers used for fine control to vibration caused by wheels. E.g., PID controllers, it stands for Proportional Integral Derivative. PID controller provides better simultaneous vibration of the output of the control loop. It also used for improving the performance of the suspension system. We can do modelling and simulation carried out in MATLAB software for active suspension.**

Keywords – proportional integral derivative, ECU.

I. INTRODUCTION

With the help of an active suspension system, the framework is to isolate the vehicle body from road disorders for smooth comfort. Also too as well performs the most important function of connecting the car body and tires. Also, there are many some components included like springs, dampers, linkages. Due to the use of the damper, it absorbs energy and also reduces the damp vibrancy.

Researchers have been trying for a long time to balance the car with the help of suspensions. Some factors attract the researcher such or like as stagnation, path holding and comfortable ride in various conditions. Nowadays, A Special type of spring or coil used in the automobile. But in 1920, Leyland Motors Utilized a torsion bar for a suspension system. In the 18th era beginning, a steel spring had been connected to the wagon by French.

There are three types of suspension systems used to control the Quarter-Car modal.

- Passive suspension system
- Active suspension system
- Semi-active suspension system

- **Passive suspension system:**
  - In the passive suspension system, some component is fixed such as spring, damper etc.
  - The passive suspension system is also used for better comfort riding.

- **Active suspension system:**
- In active suspension system, spring and damper are replaced by control force.

- **Semi-active suspension system:**
- The semi-active suspension is also used in an automobile which controls damping force.
- We can also customize the damping coefficient.

II. PURPOSE

My purpose is to make a batter active suspension system with the help of which we can control my system. My target is also to achieve setting time less than 7 second and overshoot have to reduce less than 5% in my suspension system.

III. MODELLING OF ACTIVE SUSPENSION SYSTEM

The active suspension system consists of sprung and unsprang mass. Sprung mass displays car

body. And unsprang mass (suspension mass) including tire or wheel. The wheel is also represented parallel spring in the active suspension system.
In the figure shows, **"x"** represents the vertical position of a car body, **"y"** represents the upward position of the suspension system and **"R"** represents the upward position of the road.

S.N.	Symbols	Unit and data	parameters
1	Mc	2065 kg	Mass of car body
2	Ms	305 kg	Suspension mass
3	Z1	70000 N/m	spring for suspension system
4	Z2	500000 N/m	Spring for wheel
5	D1	450 N-s/m	Damper for suspension system
6	D2	16500 N-s/m	Damper for wheel
7	F	N	Control forces

Table - 1 Data used for modelling for an active suspension system

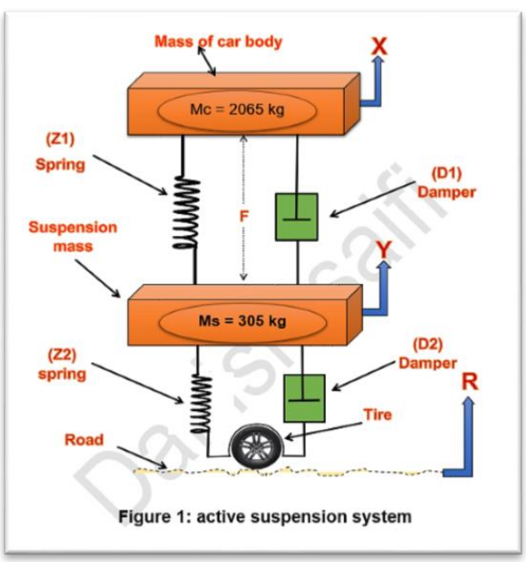


Figure 1: active suspension system

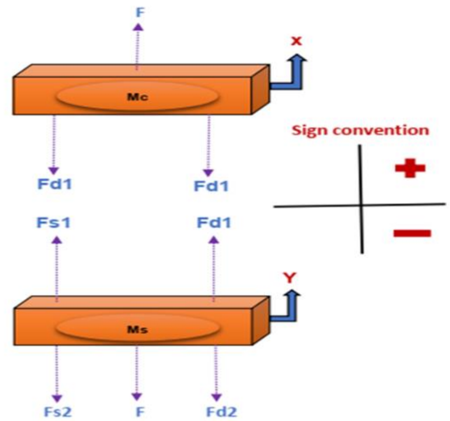


Fig. 2. Free body diagram

Assumptions:

- (x, y) is coordinate
- Let x = 0, y = 0 when system is in static equilibrium.

We can obtain equation of motion by Newton's law of motions

For Mc (mass of the car body):

$Z1\,(x-y) = Fs1$ …………………………… (1)

$D1\,(\dot{x} - \dot{y}) = Fd1$ ……………………………. (2)

For Mc (suspension mass):

$Z2\,(y-r) = Fs2$ ……………………………. (3)

$D2(\dot{y} - \dot{r}) = Fd2$ ...……………………………. (4)

We know that

$\sum F = ma$

Mass 1:

$\sum F = -Fs1 – Fd1 + F$ …. …………………………… (5)

Putting the value of Fs1 and Fd1 in equation of (5), we get

$Mc\,\ddot{x} = -Z1(x-y) – D1(\dot{x} - \dot{y}) + F$ ………………….....…………. (6)

Mass 2:

∑F = Fs1 + Fd1 – Fs2 – Fd2 – F ……………………….……… (7)

Putting the value of Fs1, Fd1, Fs2 and Fd2 in equation of (7), we get

Ms $\ddot{y}$ = Z1(x-y) + D1($\dot{x}$-$\dot{y}$) – Z2(y-r) – D2($\dot{y}$-$\dot{r}$) - F …………………… (8)

And hence equation of motion

$$Mc\,\ddot{x} = -Z1(x-y) - D1(\dot{x}-\dot{y}) + F$$

$$Ms\,\ddot{y} = Z1(x-y) + D1(\dot{x}-\dot{y}) - Z2(y-r) - D2(\dot{y}-\dot{r}) - F$$

All initial conditions are zero

Taking Laplace in equation (6) and (8) on both sides

From equation (6), we get

Mc L⟦(d^2 x(t))/〖dt〗^2 ⟧ = -Z1 L⟦x(t)⟧ + Z1 L⟦y(t)⟧ -D1 L⟦(dx(t))/dt⟧ + D1 L⟦(dy(t))/dt⟧ + L⟦F(t)⟧

Then

Mc ⟦s^2.X(s)-s.x(0)-(dx(t))/dt⟧ =

-Z1.X(s) + Z1.Y(s) – D1⟦s.X(s)-x(0)⟧ + D1⟦s.X(s)-x(0)⟧ + F(s)

Therefore,

X(s) ⟦Mc.s^2+Z1+D1.s⟧ = Y(s) ⟦Z1+D1.S⟧ + F(s) …………………………... (9)

And from equation (8), we get

MsL⟦(d^2 y(t))/〖dt〗^2 ⟧ = Z1L⟦x(t)⟧ – Z1L⟦y(t)⟧ + D1L⟦(dx(t))/dt⟧ – D1L⟦(dy(t))/dt⟧ – Z2L⟦y(t)⟧ + Z2L⟦r(t)⟧ – D2L⟦(dy(t))/dt⟧ + D2L⟦(dr(t))/dt⟧ – L⟦F(t)⟧

And therefore

Y(s) ⟦Ms.s^2+(Z1+Z2)+s(D1+D2)⟧ = X(s)⟦Z1+D1.S⟧ + R⟦Z2+D2.s⟧ – F(s)

……………………. (10)

Mathematical modelling has been completed. In which two forces act vertically to balance the entire system.

The two equations explained here.

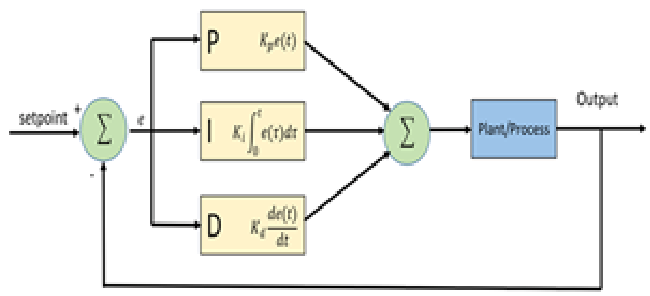
$$X(s)\,[\![Mc.s^2 + Z1 + D1.s]\!] = Y(s)\,[\![Z1 + D1.S]\!] + F(s)$$

$$Y(s)\,[\![Ms.s^2 + (Z1+Z2) + s(D1+D2)]\!] = X(s)[\![Z1 + D1.S]\!] + R[\![Z2 + D2.s]\!] - F(s)$$

IV. PROCESS AND RUNNING BY PID CONTROLLER

PID control is a type of feedback control system which control the dynamic system and it is connected between sprung and unsprung mass. It uses three types of parameters proportional, integral and derivative. With the help of these parameters, we can get better stability. Get better stability we can tune the parameters.

Fig. 3. PID controller with feedback



Control response	Kp	Ki	Kd
Rise time	decrease	decrease	Small change
overshoot	increase	increase	decrease
Steady state error	decrease	eliminate	No change
Setting time	Small change	increase	decrease

Table -2 PID controller activity

For better tuning we considered value like

Kd = 208025; Kp = 832100; Ki = 624075.

V. RESULTS AND DISCUSSION

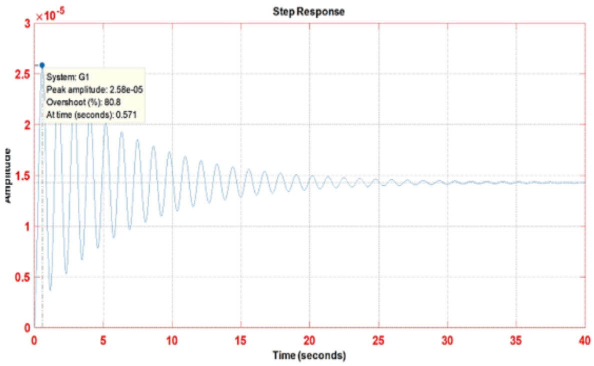


Fig. 4. This graph represents car body mass (Mc) response

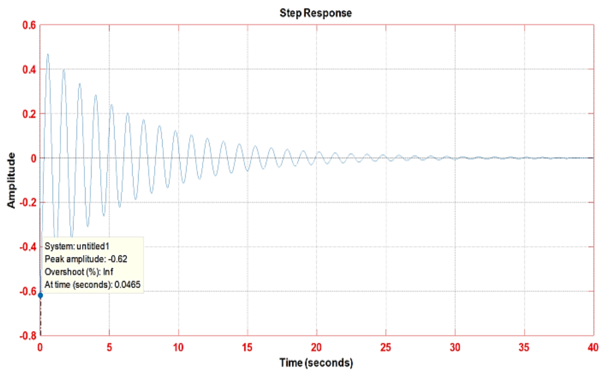


Fig. 5. This graph represents suspension system (Ms) response

In Fig 4. When we give a small amount of actuating force in the absence of feedback control. The figure shows that the open-loop system is an underdamped condition. Due to this response passenger feels a small amount of vibration. which lasts a long time.

In Fig5. The response of 10 cm steps disturbance, in the open-loop graph. when Quarter-Car moves over the 10 cm road bump. we can see that the quarter car oscillates for a long time of about 40 seconds. when we give initial amplitude of 8.5 cm. Due to these conditions' passenger feel bizarre motion.

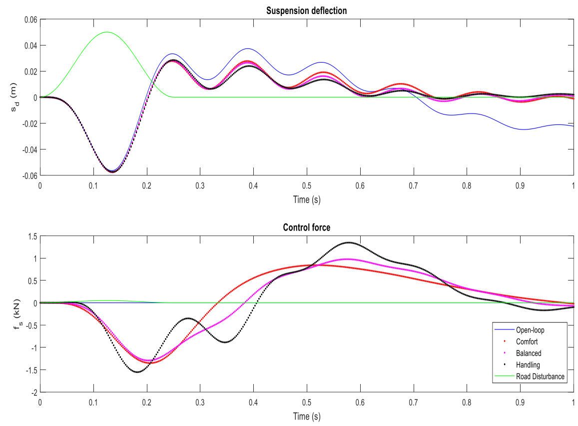


Fig. 6. Suspension deflection and control force

In Fig 6. We can see in the graph body acceleration is less than controller emphasizing. And a large controller indicates suspension deflection.

From the balanced system, we get a better understanding between the body increasing speed and suspension deflection

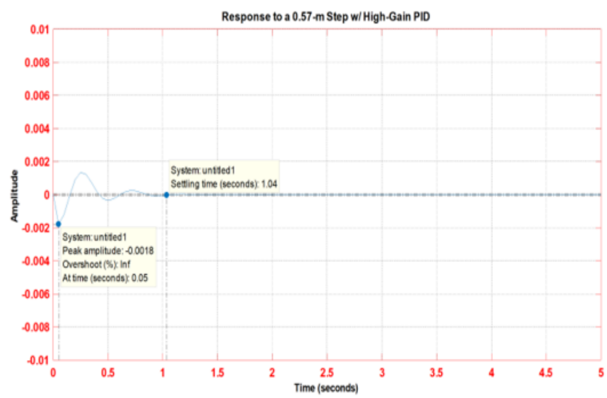


Fig. 7. Response to a 0.57m step w/ high gain PID

In Fig 7. We can see in the above figure the setting time is 1.04 second is less than 7 second and overshoot also less than 5%.

Characteristics	Results	Final results
Peak response (overshoot)	**80.8%**	**5% < 80.8%**
Settling time	**26 seconds**	**1.04 < 7 seconds**
Rise time	**0.226 seconds**	**0 seconds**
Steady state	**1.43e-05**	**0 seconds**

Table -3. Final result of active suspension system

VI. CONCLUSION

- The above data is correct. If we make an active suspension system with the data, we get better stability.
- we can see that in the above graph overshoot is less than 5% and the settling time is 1.04.

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