Proceedings of the 10th Mechatronics Systems Design
ME 405/505, University of Hartford
Spring 2020, West Hartford, CT, USA

Group - 4

QUARTER CAR MODEL WITH PASSIVE AND ACTIVE SUSPENSION MODEL SIMULATION AND ANALYSIS

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ABSTRACT

The main objective of this project is to find an ideal setup based on the driver comfort of a vehicle which is the displacement of the top mass. It involves the study of passive and active suspension systems on a quarter car model by using a mathematical approach and simulation using a software to compare and analyze the results. This project also collaborates solid work modelling, LabVIEW Soft Motion and modelling of a simple mass-spring system. Suspension systems are generally rated based on their ability to provide good road handling effect and ride quality. Passive suspensions use a fixed - type components namely spring and dampers whereas an Active type uses components that can be variably modified based on the driver's need. Implementation of PID control techniques applied to different types of road profiles. The output from the PID controller can give concrete comparisons on which type of suspension works great for required road conditions. The soft motion stimulation gives us a good visualization on how the mass-spring damper system works.

KEYWORDS: Active Suspension system and Passive suspension system, PID controller, quarter car model, SolidWorks and LABVIEW Soft Motion Module.

INTRODUCTION

A car suspension system is a 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. It is a vibrating system with multiple degrees of freedom involved and particularly two major purposes to be solved.

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- Contributing to the vehicle's road handling and braking for active safety.
- Keeping the passengers comfortable and isolated from bumps, and vibrations.

In a Passive suspension, the parameters are fixed, and energy cannot be introduced newly. It has the ability to store energy in spring and dissipate it through dampers. It is an open loop control system. The active suspension system is a closed loop control system where the inputs can be adjusted. It has the ability to store, dissipate and introduce new energy forms. Hence these parameters can be varied whenever needed accordingly to the passenger's need. A force actuator and sensors are installed along with this type of suspension to produce the desired effect as needed. Therefore, the performance of the active suspension must be greater than the passive one.

NOMENCLATURE

m: Mass of the Body in (kg)
b: Damping Constant in (Ns/m)
k: Spring constant in (N/m) (for wheel and spring)
v: Velocity of car in (m/s)
t: Time in (s)
r: Road conditions
F: Force in (N)
g: Acceleration due to gravity in (m/s/s)

PASSIVE SUSPENSION MODEL

Passive suspension system is a conventional way of suspension system used in vehicles where the parametric values of spring and damper are fixed. The setup in the below image has the ability to retain the potential energy in the spring and release it through damper to one quarter of the vehicle [5].

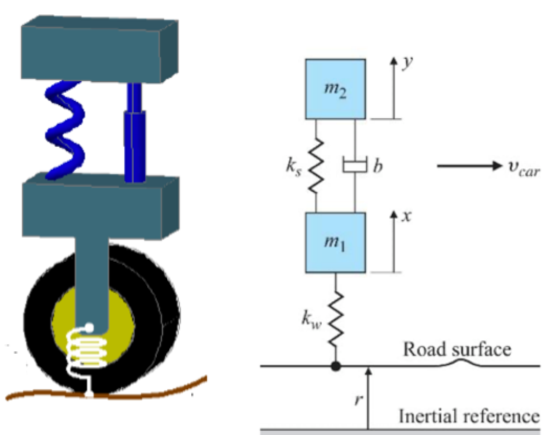

Fig.1 Passive Suspension Model

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FREE BODY DIAGRAM

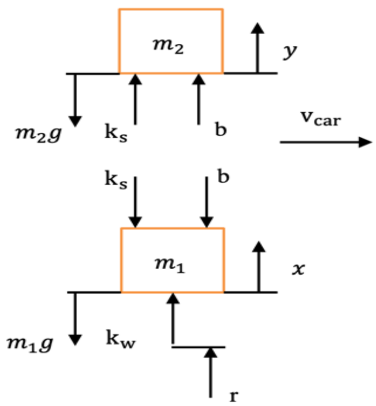

Fig.2 Passive-Free Body Diagram

Where,

$k_s = k(x - y)$
$k_w = k(r - x)$
b = b $(\dot{x} - \dot{y})$
m_1g and m_2g = Gravitational Force on mass m_1 and m_2

GOVERNING EQUATION

$$\sum_{M_1} F_{M_1} = \ddot{X}\, M_1$$
$$\ddot{X} = \frac{F_{M_1}}{M_1}$$

$$\sum_{M_2} F_{M_2} = \ddot{X}\, M_2$$
$$\ddot{Y} = \frac{F_{M_2}}{M_2}$$

$$\sum_{M_1} F_{M_1} = \ddot{X}\, M_1 = F_{kw} - k_s - F_B - m_1 g$$
$$= k_w(r - x) - k_s(x - y) - B(\dot{x} - \dot{y}) - m_1 g$$

$$\sum_{M_2} F_{M_2} = \ddot{Y}\, M_2 = F_{ks} + F_B - m_1 g$$
$$= k_s(x - y) + B(\dot{x} - \dot{y}) - m_2 g$$

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BLOCK DIAGRAM

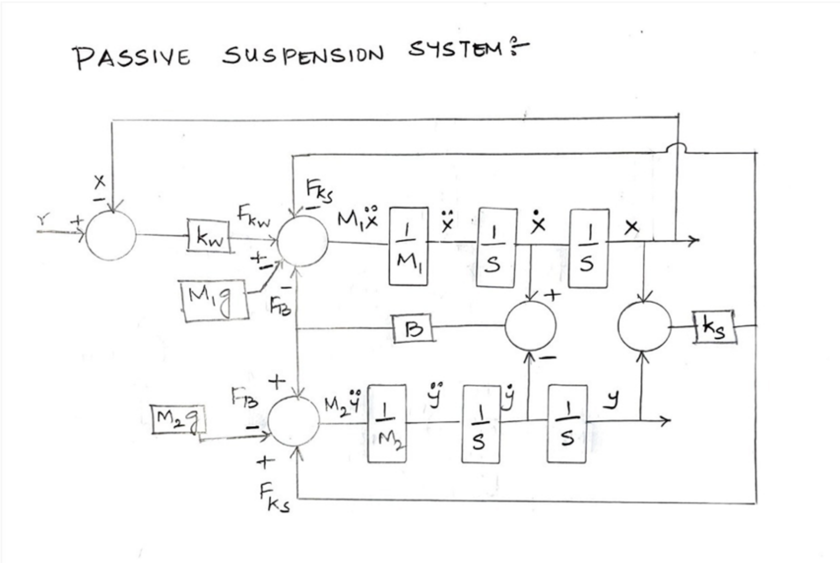

Fig.3 Passive- Block Diagram

ACTIVE SUSPENSION MODEL

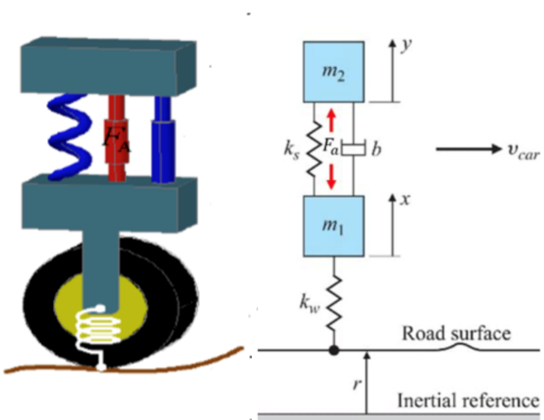

Fig.4 Active Suspension Model

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FREE BODY DIAGRAM

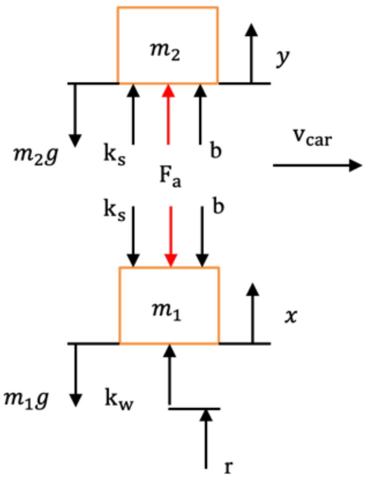

Fig.5 Active-Free Body Diagram

Where,

$k_s = k(x - y)$

$k_w = k(r - x)$

b = b $(\dot{x} - \dot{y})$

$F_a =$ limits the control of motion m_2

GOVERNING EQUATION

$$\sum_{M_1} F_{M_1} = \ddot{X} M_1$$

$$\ddot{X} = \frac{F_{M_1}}{M_1}$$

$$\sum_{M_2} F_{M_2} = \ddot{Y} M_2$$

$$\ddot{Y} = \frac{F_{M_2}}{M_2}$$

$$\sum_{M_1} F_{M_1} = \ddot{X} M_1 = F_{kw} - k_s - F_B - F_a - m_1 g$$
$$= k_w(r - x) - k_s(x - y) - B(\dot{x} - \dot{y}) - m_1 g$$

$$\sum_{M_2} F_{M_2} = \ddot{Y} M_2 = F_{ks} + F_B + F_a - m_1 g$$
$$= k_s(x - y) + B(\dot{x} - \dot{y}) + F_a - m_2 g$$

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BLOCK DIAGRAM

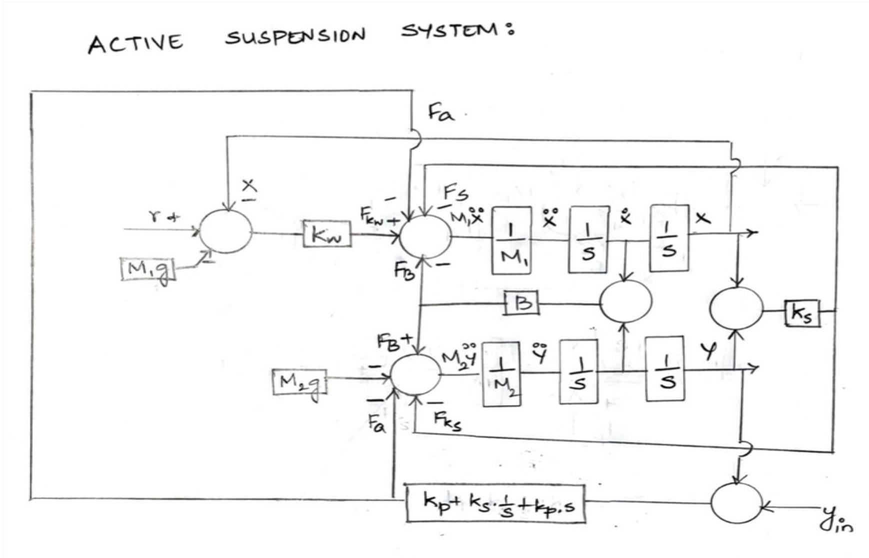

Fig.6 Active-Block Diagram

LABVIEW

PASSIVE SUSPENSION SYSTEM
QUARTER CAR SUSPENION PARAMETERS

SUV

$m_1 = 600\ kg$

$m_2 = 100\ kg$

$k_s = 30000\frac{N}{m}$

$k_1 = 160000\frac{N}{m}$

b = 250 N.s/m

ROAD CONDITIONS

t = 0-2 seconds: r=0 m
At t=2, r= 0.05m [impulse function]
t = 2-17 seconds, r=0 m.
At t = 17, r=0.1 m [impulse function] t = 17-30 seconds, r=0m

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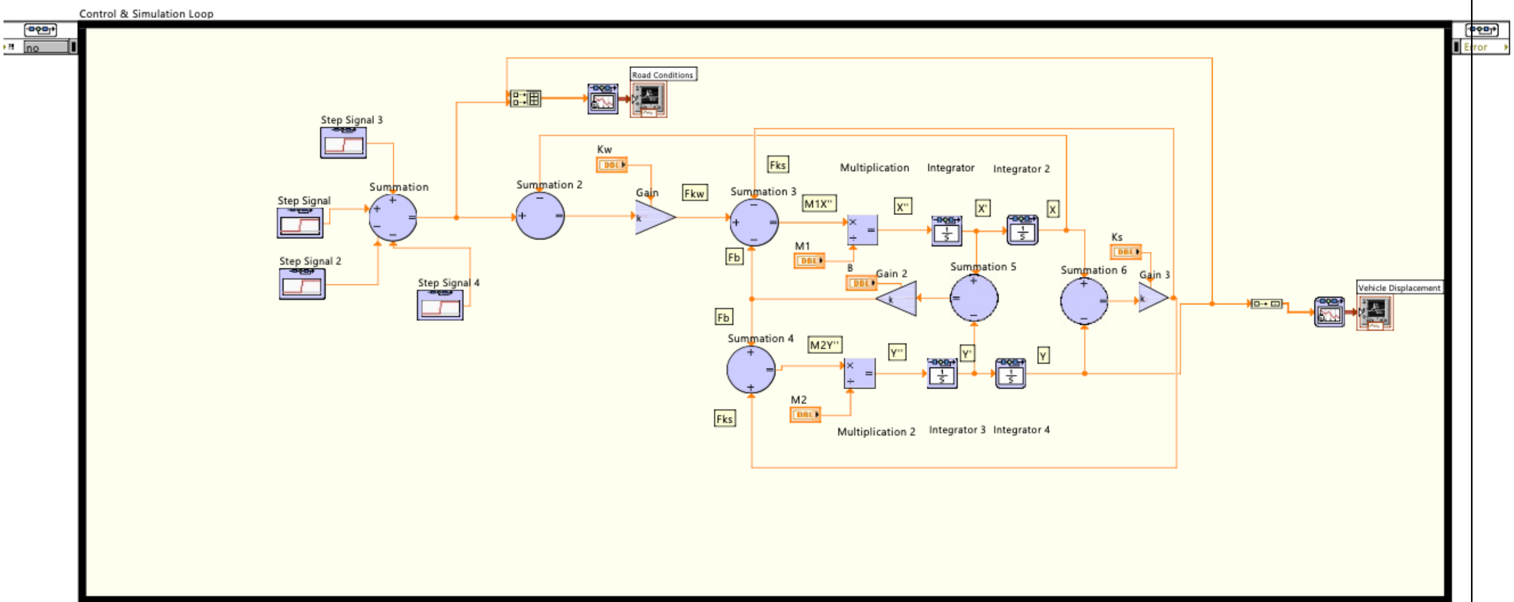

Fig 7

EXPERIMENTAL RESULTS
PLOTS

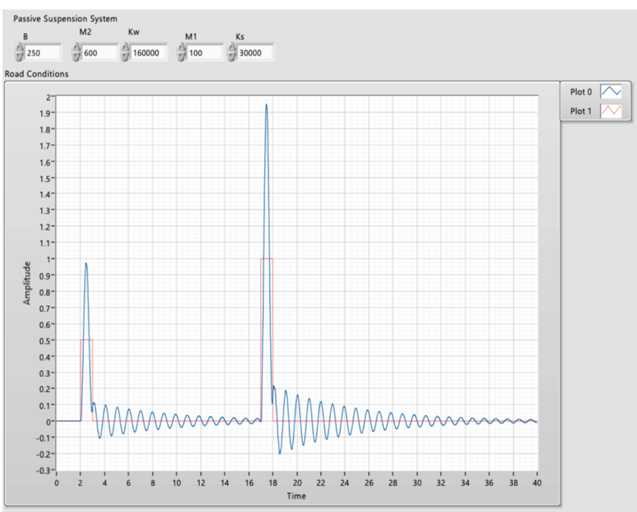

Fig.8 Passive Suspension response for two-unit step road condition

From the above graph, it describes how there is vehicle displacement based on the two-unit step function used as a road condition. Passive suspension being a conventional suspension and being an open loop system, it does not have a control over the input. So having a fixed value of inputs results in high displacement of the vehicle along the road in this passive system.

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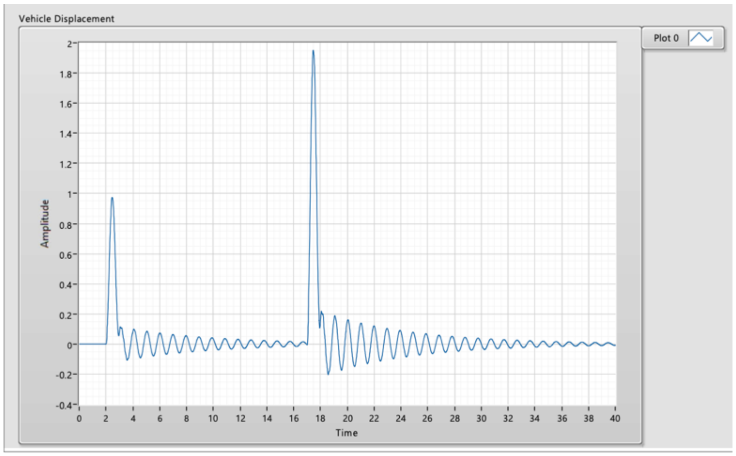

Fig.9 vehicles response in passive condition

ACTIVE SUSPENSION

Parameters used are same as that of passive suspension.

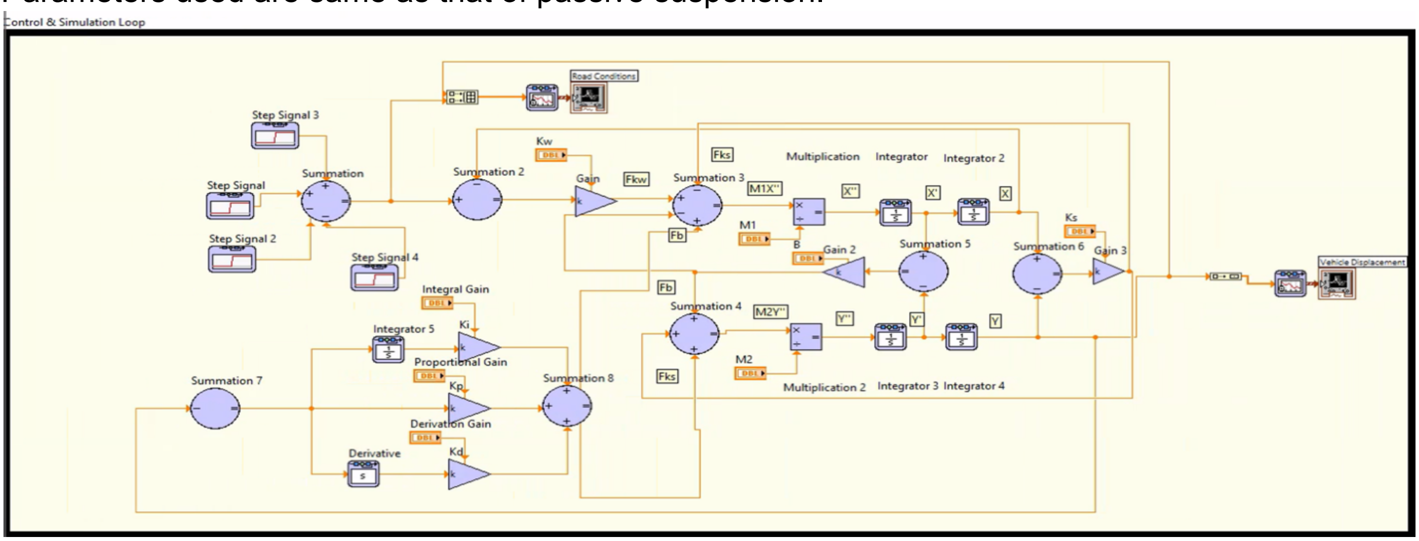

Fig10

In the active suspension system, as we see in LabVIEW block diagram, the system is made a closed loop feedback system by having a PID (Proportional-Integral-Derivative) which makes the variables constant by getting feedback from the input maintaining the required amount for the input by directly controlling the forces of the suspension based on the varying road conditions in order to make the driver to have a comfortable ride [1].

In this active suspension system, a force actuator is used to limit the displacement of the vehicle with respect to the road conditions.

PID (Proportional-Integral-Derivative)

The basic concept of a PID controller is to get a feedback from a sensor, and then to compute the desired actuator (in our case is the force actuator) output by calculating proportional, integral, and derivative responses and summing those three components to calculate the output value.

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Proportional, Integral and Derivative values are varied to get an optimal response.

EXPERIMENTAL RESULTS

PLOTS

The plots below are compared with different PID values in order to find an optimal solution in order to reduce the displacement of the vehicle.

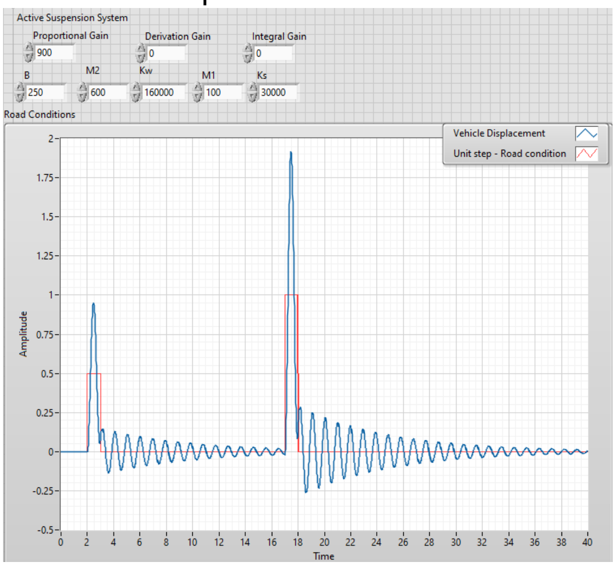

Fig 11

Keeping the Derivative and integral gain 0, adding value for the proportional gain, but there is no change in the graph.

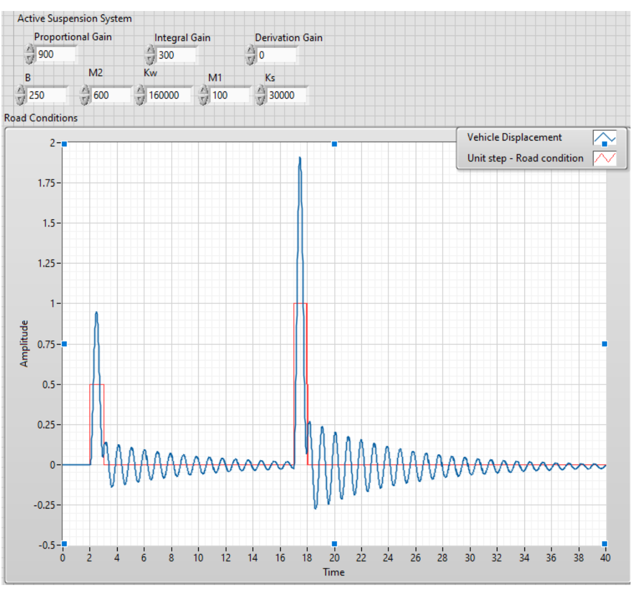

Fig 12

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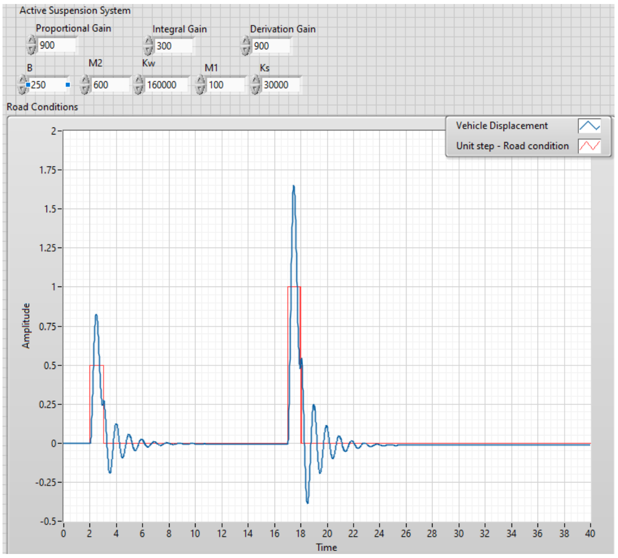

Fig 13

After adding values to the Proportional gain and derivative gain, there is a control over the displacement of the vehicle as the vibration in the graph decreases to certain extent.

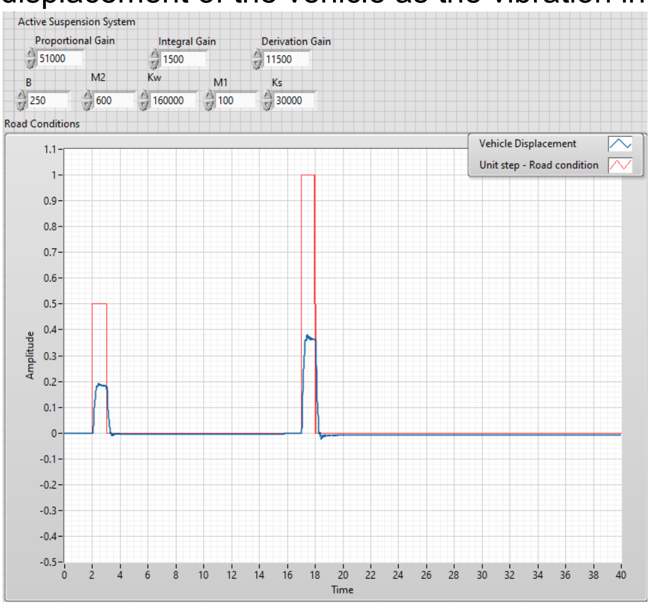

Fig 14

As the in the above graph, where after increasing the values, it can be noticed that vehicle displacement is under control and the turbulence in the vehicle is much reduced.

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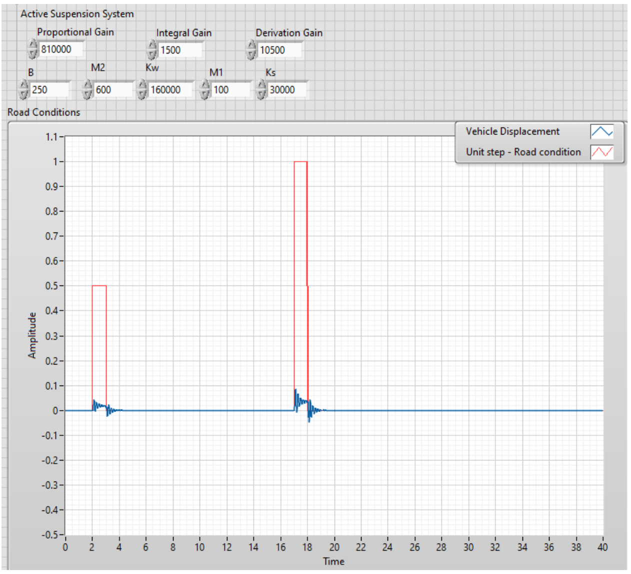

Fig15

In order to get an optimal solution, the values are further increased (as shown in above graph) where, the displacement of the vehicle is much lower, hence a very small turbulence in the vehicle is noticed. Thus, using PID, the turbulence in the vehicle is controlled.

COMPARISON BETWEEN PASSIVE AND ACTIVE SUSPENSION SYSTEM

PASSIVE SUSPENSION SYSTEM.

ACTIVE SUSPENSION SYSTEM

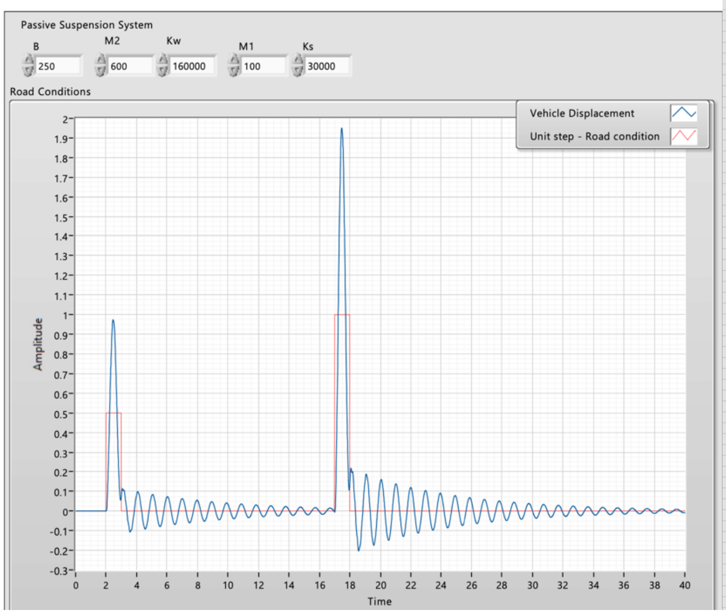

Fig 16

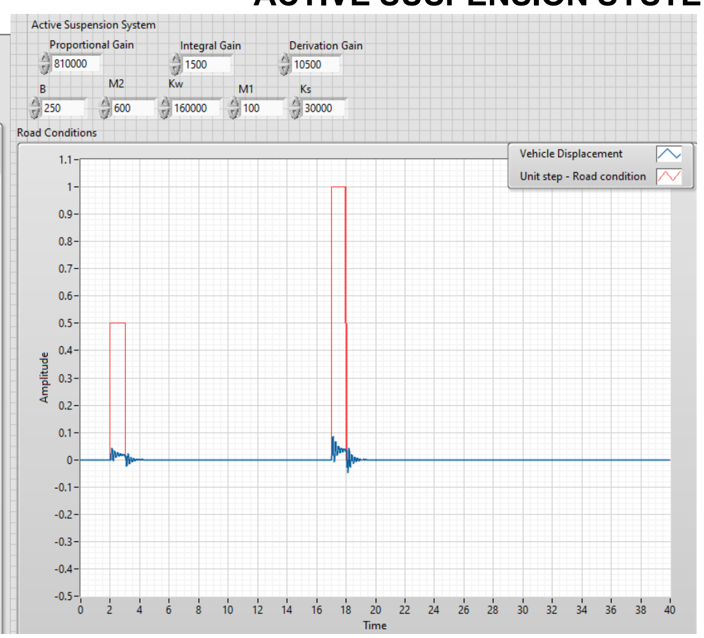

fig 17

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OBSERVATION

From the graphs, we can observe that the displacement of the vehicle which has an active suspension system that undergoes through an uneven road condition is controlled to an optimal level by implementing the proper PID values, whereas a vehicle with passive suspension having no control on the input variables have a large displacement of the vehicle as shown in the graph when it passes through a bump.

SOLIDWORKS

By Using the Solidworks software we designed a simple mass spring system based on quarter suspension model. The assembly consists of a Mass (m), a base and a spring. First the individual parts are modelled in Solidworks as part files and then assembled. The spring itself is not animated and doesn't move. So, we had to use the inbuilt spring effect feature that is available in Solidworks. To add this feature, we needed to first choose the surfaces where the spring action would act. In this case, it is between the pate and the mass. The we used the following constraints to design our spring.

Spring constant (k)= 50N/mm
Free length = 20mm

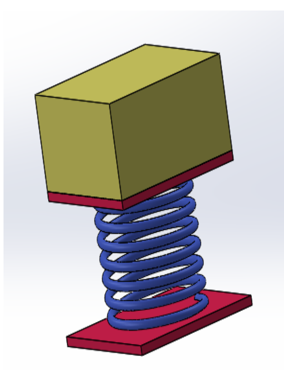

Fig 18 Solid works model

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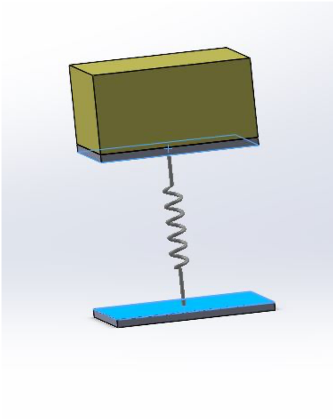

fig 19 model with spring effect feature

NI SOFTMOTION

The LabVIEW SoftMotion Module helps you integrate motion control with your labview program NI SoftMotion provides VIs and functions that allow you to use the NI SoftMotion function block API to communicate with hardware devices as well as to perform path planning, trajectory generation, output control, PID control, and synchronization. This module even allows you to control the axis of the model with labview. In this project, we have used softmotion to stimulate the position change of the mass with the presence of spring and damper.
First, we had to import the designed solidworks into the Labview Vi. After that we had to select the axis where the control was required. In this case, it was the Y axis as it is the place where the mass moves. Now, the axis is chosen, the next step was to create a block diagram for the stimulation. For this we used a straight-line motion module Inside a synchronized time loop. This module requires the input control for the position. So, we had used a control knob that controls the position of the mass. The velocity in this case was chosen to be constant. After modelling this, a knob would appear in the front panel to control the position of the mass.
The knob would have the divisions based on the overall compression of the spring,0 denoting the rest position and 100 for fully compressed.

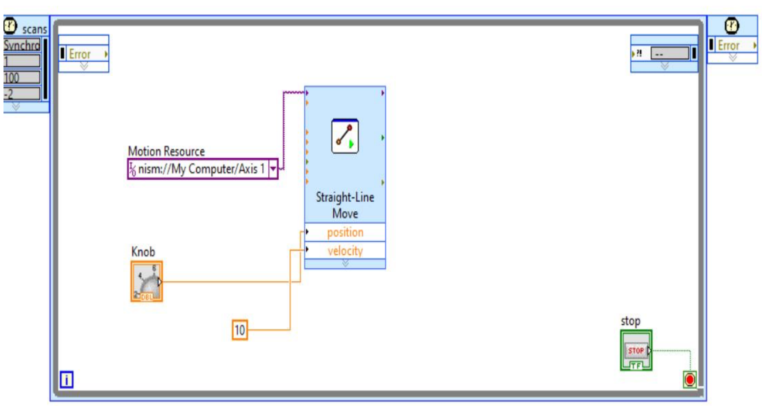

Fig 20

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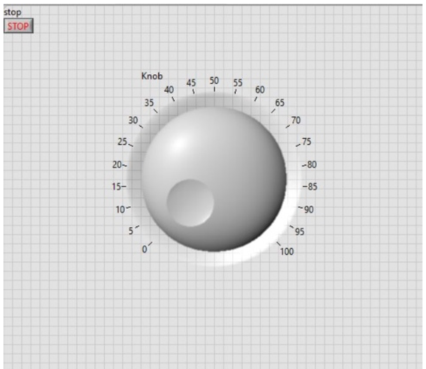

Fig 21

Based on the Block diagram, the software is deployed, and the stimulation is started. On running the motion analysis with just the spring, we found when the spring is compressed or loaded, it returns to its original position but causes an up and down oscillation.

In order to reduce this unwanted up and down motion we added a damper with various damping constants. It was found that the damper reduces to up and down motion to a significant level. This study shows why the damper is used in the suspension systems. In real life scenarios, these dampers are filled with fluids and the compression is dissipated as heat energy. This is a non- realistic model, so it only depends on the spring constant. Thus, the damper increases driver comfort by decreasing vibrations.

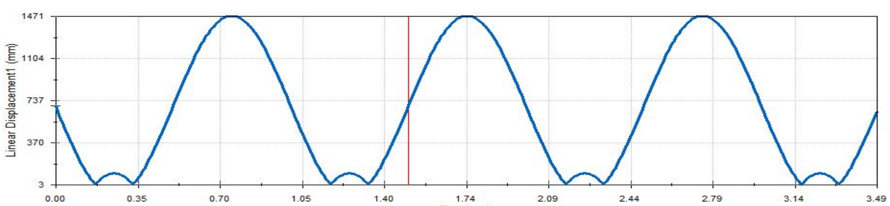

FIG 22

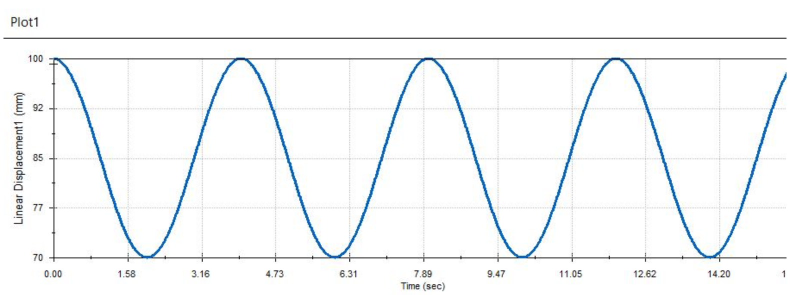

Fig 23.

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Literature review

Suspension systems in car perform mainly three functions those are ride comfort, reduction of dynamic road-tire forces, and reduction of relative motions between vehicle bodies. Based
on the control input there are two types of suspension system they are passive and active suspension systems. Further active suspension systems are classified into fully active and semi-active suspension system. An active adaptive suspension system is in which the controlling parameters are continuously adjusted by adapting the time varying characteristics of the system.

Suspension system usually have to compromise on one of the three that is road handling, load carrying capacity and passenger comfort. Now days vehicle suspensions use hydraulic dampers and springs that are charged with the tasks of absorbing bumps, minimizing the car's body motions while accelerating, braking and turning and keeping the tires in contact with the
road surface. The damper is the component that defines the suspensions placement on the compromise curve and the spring is chosen based solely on the weight of the vehicle.
Depending on the type of vehicle, a damper is chosen to make the vehicle perform best in its application. The suspension must be able to minimize the vertical force transmitted to the passengers for passengers' comfort. An active suspension is one in which the passive components are replaced by actuators that
supply additional forces.
These above research papers were studied to get in depth knowledge and understanding of on our topic.

Dowds, P., & O'Dwyer, A. (2005). Modelling and control of a suspension system for vehicle applications. In this research paper, the author has made an in-depth research on the active and passive suspension system in a car model and has conducted experiments based on quarter car model and a full car model. Dowds made a study on the passive suspension system, and he added a suitable feedback system in the active suspension in order to reduce the impact movement in car on the passengers. This research will be helpful to learn about how these two suspension systems are modelled for a quarter car and a full car model.

Changizi, N., & Rouhani, M. (2011). Comparing PID and fuzzy logic control a quarter car suspension system. *The journal of mathematics and computer science*, *2*(3), 559-564. The research paper discusses about the using a fuzzy logic technique and Proportional Integration Derivative (PID) in the MATLAB. Changizi made a
comparative study on fuzzy logic technique and the PID made a conclusion that fuzzy logic controller is performed very well than the PID operator and made a conclusion that it can be used in the manufacturing of future cars. This paper will be useful in getting knowledge about PID and how it can be employed into the quarter car suspension.

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GANTT CHART

QUARTER CAR SUSPENSION **MECHATRONICS SYSTEM** **4/14/2021** START DATE **5/12/2021** END DATE

Task Name	Start Week	End Week	Resources	WK01	WK02	WK03	WK04	WK05	WK06	WK07	WK08	WK09	WK10	WK11	WK12	WK13	WK14	WK15	WK16	WK17
SELETION OF TOPIC	WK01	WK02		1	1															
FREE BODY DIAGRAM	WK02	WK02			1															
DERIVING EQUATION	WK03	WK03				1														
VEHICLE TYPE SELECTION	WK03	WK03				1														
BLOCK DIAGRAM	WK02	WK04			1	1	1													
LABVIEW IMPLEMENTATION	WK02	WK04			1	1	1													
SOLIDWORKS	WK03	WK04				1	1													
NISOFTMOTION	WK05	WK05						1												
COMPARING RESULTS	WK05	WK05						1												
FINAL PRESENTAION	WK01	WK05		1	1	1	1	1												
FINAL REPORT	WK01	WK05		1	1	1	1	1												

CONCLUSION

The Quarter car suspension system was studied, based on the studies, FBD, governing equation and block diagram was drawn. From the block diagram, it was performed in the LabVIEW to compare the passive and active suspension system.For the active suspension system PID was employed to control the displacement of the vehicle. Plots were drawn from the LabVIEW and comparison between the plots was made. From the resulted plots, it showed that active suspension is better than passive suspension system. Second part of the project is to design a simple mass-spring system and implement in the LABVIEW Softmotion. The Motion analysis was done for the mass-spring system through the SolidWorks Motion. It was implemented into the LABVIEW Softmotion to control the motion of the spring.

ACKNOWLEDGMENT

We would like to express our deep gratitude to Professor Claudio Campana, our research supervisor, for his patient guidance, enthusiastic encouragement, and useful critiques of this research work.

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EXECUTIVE SUMMARY

#1 The project compresses of two main suspension system-active and passive. This is an attempt to know how the theories can be applied to practical situation. In the first part of the project report, the general information of the topic has been collected. Information is gathered through the primary and secondary source as well. In the second part of the report, contains the FBD and calculations. Objective of the project is to work on the types of suspension system and find which is the best one. My focus was on passive suspension system and show how it works and how is the comfort level while using this type of suspension model.
I have also done the analysis of active suspension model and its results with passive model shows good results and give a perfect ride to the driver and the passengers. I have also learnt to do the motion analysis of the suspension system with the model made in solidwork. Doing this project has made refreshing the old concepts of solidworks and learnt a new software.

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#2 This project has made me understand the concept of quarter car suspension. This project taught me the difference between the active and passive system, this project gave me the skills required to convert a real-life problem into a Block diagrams and solve the equation with various parameters. The project gave me the insights to solidworks modelling and stimulation. I have learnt a new software, NI softmotion. This project gave me the knowledge to learn about softmotion and how to implement it in Solidworks. With this project, I have learnt that active suspension is better than a passive one with the correct PID factors. Without correct PID factors the active suspension would become meaningless. Finally, the project has given me confidence to solve real life problems with the help of various software.

#3 My contribution to the project is studying about active suspension system and implementing into LABVIEW. PID was employed in block diagram in the LABVIEW and the PID values was varied in order to obtain an optimal solution. After running various runs in the LABVIEW, the displacement of the vehicle was well controlled even when the vehicle passes through the bump. A comparison of passive and active suspension system is done in order to find an which is an better option, based on the graphs obtained, active suspension system proved to be better than passive as we can adjust the input variables with the help of a feedback from a sensor.
It gave me a good experience in working with LABVIEW and helped to develop my skill in it. Also, It helped me to get awareness about the suspension system in vehicles. Therefore, by actively performing in this project, my problem solving skill was developed and how to coordinate with the team members.

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