

FABRICATION AND ANALYSIS OF QUARTUR-CAR SUSPENSION MODEL USING MATLAB

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Engineering degree in Automobile Engineering

By

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INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with Grade “A” by NAAC

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May 2022



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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of KISHORE K (38860009) , SHARAN RAJ (38860015) who carried out the project "**FABRICATION AND ANALYSIS OF QUARTUR-CAR SUSPENSION MODEL USING MATLAB**" under my supervision from November 2021 to April 2022.

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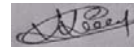
DECLARATION

We KISHORE K (38860009), SHARAN RAJ (38860015) here declare that the Project Report entitled “**FABRICATION AND ANALYSIS OF QUARTUR-CAR SUSPENSION MODEL USING MATLAB**” done by us under the guidance of **Mr. Arockia Suthan, ME.,(Ph.D)** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Automobile.

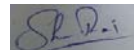
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ABSTRACT

The dynamics of a vehicle's suspension are studied using quarter-car suspension models. MATLAB will be used to investigate the variation in damping coefficient and stiffness in the damper and spring. The modelling method utilized is lumped parameters, which implies a quarter of the vehicle's body and wheel are concentrated in single mass parameters. The suspension and wheel stiffness and damping are also concentrated in lumped parameters. The purpose of a car's suspension system is to provide a more comfortable ride and better handling with the road profile. The goal of the research is to look at how the system reacts to a step and sinusoidal road profile input, which may be thought of as the wheel passing over a stiff item on the road.

In order to ensure comfort, vehicle position, and quality in ride, every automobile has a suspension system. In four-wheelers, commercial vehicles now use air-type suspension systems. This type of suspension setup gives the chassis and the ground little comfort. In a four-wheeler, replacing air suspension with a smart system will improve comfort while maintaining ride height and quality. When it comes to suspension, air suspension is far superior to coil-type suspension. So, in our project for autos, we'll employ an air suspension system powered by a pneumatic system to provide the vehicle more comfort. We will also construct the suspension model.

KEY WORDS:

Quarter Car Model, Suspension System, Vertical Dynamics, Pneumatic Actuator, MATLAB.

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CHAPTER 1

INTRODUCTION

Automobiles are becoming a popular mode of transportation for people who need to get from one place to another quickly. 2-wheelers are becoming the most demanding vehicles among automobiles. So there have been numerous innovations in two-wheelers from the past to the present. However, the suspension system is now the only thing holding back such innovation.

The suspension system is a critical component of an automobile's quality of rides and comfortless. The suspension mechanism used nowadays is helical coil spring-type suspension, which does not provide passengers with a high ride quality or comfort. The suspension system of a car is crucial for maintaining quality rides and comfort. Currently, the suspension system is helical coil spring-type suspension, which does not provide passengers with a high ride quality or comfort.

As a result, air suspension will deliver a better ride quality, comfort, and peace of mind than earlier suspension systems. The air suspension system makes use of a rubber tube that is completely closed and filled with compressed air from the compressor to a high-pressure rubber tube. This compressed air can handle the weight of people and other loads while still providing a comfortable ride.

It is well-designed and constructed, with no air leakage. When compared to conventional systems, this suspension system will give greater quality in ride, comfort full, and suspension.

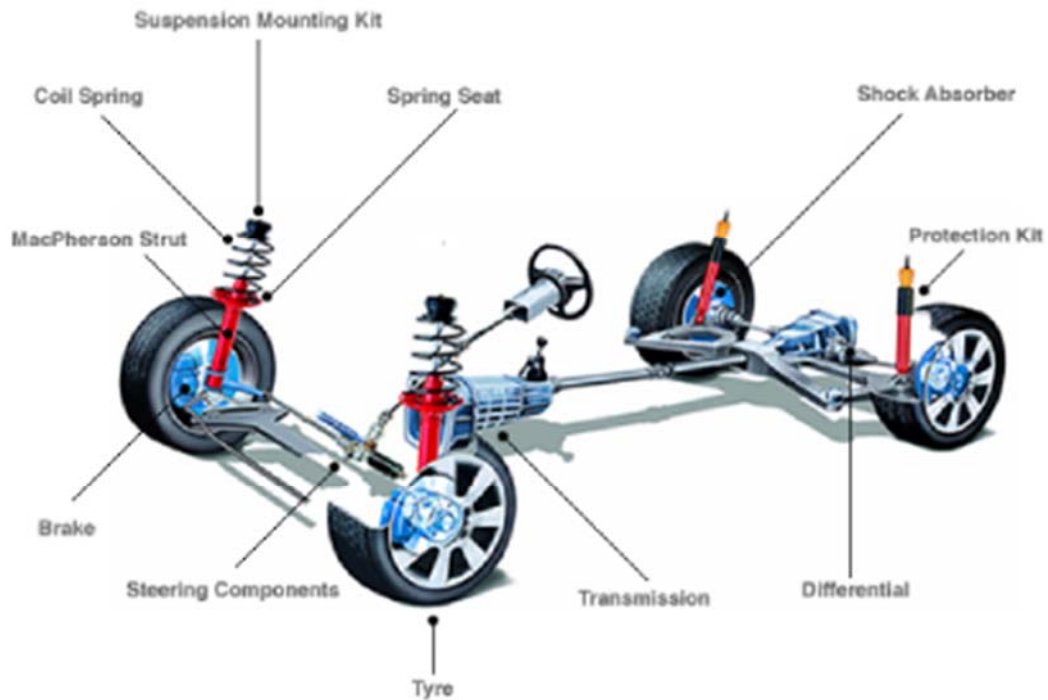


Fig: 1.1: Suspension system

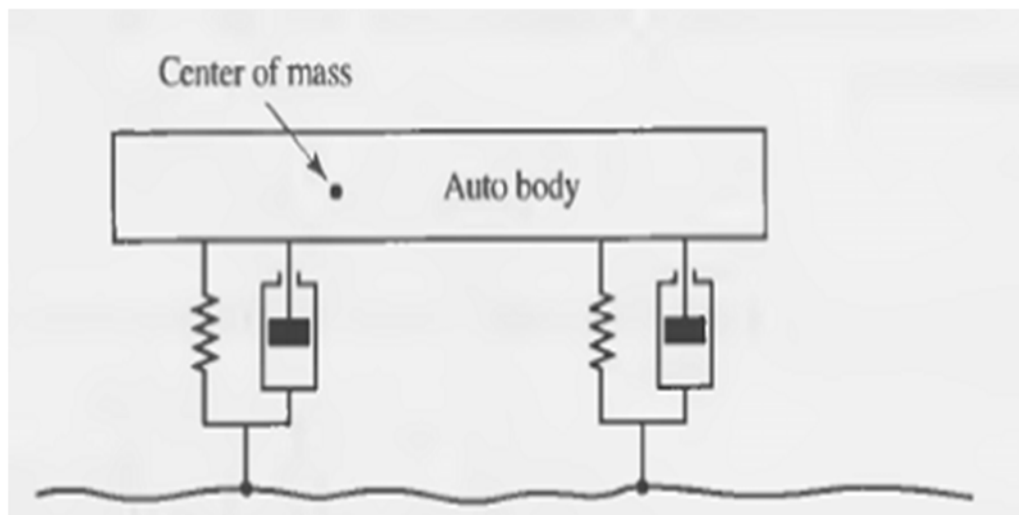


Fig: 1.2 Suspension with damper

- Compressed air is a gas (or a combination of gases) that has been compressed to a higher pressure than ambient air.

Compressed air is currently used in a wide range of applications, that includes jack hammers, tire pumps, air rifles, and aerosol cheese.

- Compressed air, offers enormous potential as a clean, economical, and many renewable energy source. It is now being researched as a possible replacement for fossil fuels. Pneumatic energy is inexpensive and widely available. Compressed air is a gas that has been compressed to a higher pressure than ambient air. Compressed air is currently used in many applications, that includes jack hammers, tire pumps, air rifles, and aerosol cheese.
- Non-conventional energy systems are critical to the planet at this time. As a result, compressed air was produced in this project using car suspension. The vehicle is then operated using this compressed air. The creation of compressed air utilizing vehicle suspension does not necessitate any input power.

1.1 THE SUSPENSION SYSTEM:

- The suspension elements connect the wheel suspension and the bodywork as "supporting" components of the suspension system. The spring action of the tyres and car seats adds to this mechanism.
- Steel springs, gas/air, rubber/elastomers, or combinations of these are among the suspension elements. Steel spring suspensions have become commonplace in passenger cars.
- Steel springs exist in a number of shapes and sizes, with the coil spring being the most popular. Due to its system-related advantages, air suspension, which has been utilised in heavy freight vehicles for many years, is finding growing use in passenger vehicles.
- We can distinguish between sprung masses (the body with the drive system and sections of the running gear) and unsprung masses (the rest of the vehicle) (the wheels, brakes, and parts of the running gear and the axle shafts).
- The car becomes an oscillatory unit as a result of the suspension system, with the inherent frequency of the bodywork

dictated by the sprung masses and the suspension system's matching.

- In theory, the goal is to reduce the volume of unsprung masses and their impact on vibration characteristics (natural frequency of the bodywork). Furthermore, low mass inertia minimizes the impact load on the unsprung components and enhances the suspension's reaction characteristics greatly. Driver comfort is significantly improved as a result of these factors.

1.2 VIBRATION:

- When a force deflects a mass on a spring from its rest position, the spring creates a restoring force that permits the mass to rebound. A further restoring force is exerted when the mass oscillates beyond its rest position.
- This process is repeated until the vibration stops due to air resistance and internal friction in the spring.
- The bodywork's natural frequency, the degree of amplitude and frequency of the vibrations define them. During suspension matching, the natural frequency of the bodywork is especially significant.
- For a medium-sized vehicle, the inherent frequency of unsprung parts is between 10 and 16 Hz. The natural frequency of the bodywork (sprung mass) is reduced to between 1 and 1.5 Hz when the suspension system is properly matched.
- The tyre air, shock absorbers, and linkages that connect a vehicle to its wheels and allow relative motion between them make up the suspension system.
- By providing comfort and ride quality to the vehicle's occupants, this system contributes to the vehicle's profile handling and braking for good active safety and driving pleasure. By providing the vehicle's occupants with comfort and a high level of ride quality, this system contributes to the vehicle's profile handling and braking for good active safety and driving pleasure.
- Shock absorbers connect the vehicle to its wheels and are an important part of the suspension system. Dampers are another name for these. Dampers are required to compensate for the roll

and pitches associated with vehicle motion, as well as the roughness of roadways.

- Power output from I.C engines is vastly growing. This, along with the technical ability of car and component designers, as well as a general commercial atmosphere that encouraged development and change, created an environment conducive to shock absorber creation and innovation.
- Shock absorbers are devices that smooth out a vehicle's impulse and correctly dissipate or absorb kinetic energy.
- Even though shock absorbers have become such an important thing in automobile, there has never been a specific way for testing them using the FEA technique, and most testing is done through tests.

1.3 COIL SPRING ABSORBER:

- Most commercial two-wheelers today use coil spring shock absorbers. This type of shock absorber is made up of a steel coil and a hydraulic piston. It is commonly equipped with an open coil spring for compression. As a result, it is known as compression coil spring suspension.
- Gas spring shock absorbers are most commonly found on four-wheelers and large trucks. There are only three types of air suspension available. Bellows coils, and taper tubes are examples of these. A conical sleeve is employed as an air spring at the two wheels in this project.

The air pressure inside the rubber material is strong enough to support the weight of the two-wheeler and the driver. The pressure inside the air spring's rubber tube gives superior suspension than coil springs.



Fig: 1.3 Coil spring absorber

1.4 PNEUMATIC CYLINDER:

- They are used to transform the energy of air pressure into mechanical work. They use mechanical actuation to substitute human effort. A single-acting cylinder was employed in this experiment.
- Because air is the driving medium, it must be connected to the actuation using polyurethane pipes to maintain the needed pressure. The brake wire is pulled by one single-acting cylinder, while the bumper is extended horizontally by the other. The piston of the cylinder, as well as the actuators, are driven by a quick burst of air.

1.5 SOLENOID VALVE:

- Electromechanical switches that may be operated by an electronic circuit are known as solenoid valves. They are used to control the flow of fluid, and when the current runs through their circuit, the gadget changes state.
- When an electric circuit is completed, a solenoid valve activates pneumatic actuation. It holds the compressed air pressure from the tank and only allows the fluid to flow in pre-crash situations. The device is made up of two solenoid valves that are triggered at the same time.
- One is in charge of the brake cylinder, while the other is connected to the extensible bumper cylinder.

CHAPTER 2

LITERATURE SURVEY

1. Hydro Pneumatic Suspension System, S. Bauer W ,2007: Defines the enhanced velocity obtained in narrow cross sections. The minimal value for this cross section must be met. The lower the cross section damping value, the greater the property loss of the utilized suspension oil, which is undesirable.

2. Design and Analysis Of Machine Elements, Bhandari V B, 2010: Explains that suspension is meant to handle the vehicle's turning and braking as well as absorb disturbances. The primary goal of any shock absorber is to insulate passengers from driving conditions. In most vehicles, the front wheel has a pair of telescopic forks while the back wheel has one or two. The general principle employed in shock absorber manufacturing could be mechanical, hydraulic, or pneumatic.

3. Suspension In Bikes Considering Preload, Damping Parameters And Employment Of Mono Suspension In Recent Bikes, Chavan D K, 2013: Suspension is meant to handle the vehicle's turning and braking as well as absorb disturbances. Any shock absorber's primary function is to isolate passengers from road conditions. In most vehicles, the front wheel has a pair of telescopic forks while the rear wheel has one or two. The shock absorber's general principle of construction could be mechanical, hydraulic, or pneumatic.

4. Pneumatic suspension system with independent control of damping, stiffness and ride height, Hrishikesh Deoet, 2006: Establishes that, unlike hydraulic shock absorbers, the stiffness value of pneumatic suspensions can be modified. This is accomplished by altering the content of air held in suspension. Variable stiffness is used in advanced technologies for various speed and road applications. A high-pressure compressor does the job.

5. Design evaluation of a two-wheeler suspension system for variable load conditions, Kommalapatiet, 2013: According to

the manufacturer, the primary function of a shock absorber is to absorb and dissipate energy. According to him, one thing to keep in mind is that design considerations must include the time it takes to disperse energy into heat. The dashpots are constructed in such a way that the energy is transferred to the viscous fluid. Some electromagnetic shock absorbers store the energy for later use. It is in charge of providing comfort on various rough routes.

6. Formula sae shock absorber design, Maxwell J C , 2004: It is evident that the liquid's viscosity get down's as the temperature rises, the viscosity of air goes up as the temperature rises. The viscosity values are directly related to the air pressure. This allows the two fluids to be channeled in opposite directions and to distinct purposes.

7. Automatic air suspension in cars ,Prof. D. A. More, 2017: In a car, an air-suspension system is employed instead of a helical spring, which is normally used to absorb stress and provide comfort. The air springs are made of heavy-duty rubber. On-board compressors, air bags, solenoids valves, and lines are among the components of this air suspension system, which help to balance heavy preload and improve the vehicle's ride.

8. Mono air suspension fabrication in two wheelers Pranav Badole, 2015: Both motorcyclists and passengers benefit from the improved ride comfort provided by bellow tube air suspension. Both the on-board and off-board compressors are fitted to the rear wheel's mudguard. The off-board compressor aids in the bellow tube inflation. During compression, a pressure release valve is also utilized to adjust pressure.

CHAPTER 3

AIM AND OBJECTIVE

3.1 AIM:

The aim of the project is to analyse Quarter-car suspension model's acceleration, velocity and displacement for Sprung and unsprung masses using Simulink MATLAB.

3.2 OBJECTIVE:

- i. Supports the weight of the vehicle.
- ii. Provide a smooth ride.
- iii. Enables quick cornering without excessive roll.
- iv. Maintains tyre contact with the road.
- v. Allows steering by turning the front wheels left (or) right.
- vi. Isolate the body from road shocks and vibrations.

CHAPTER 4

MATHEMATICAL MODEL, SIMULINK AND FABRICATION

4.1 QUARTER-CAR MODEL:

- Demonstrating of suspension framework is done in the vertical plane.
- A linear two degree of freedom system is utilized as a model for the street vehicle.
- The two masses M_s and M_u of the vehicle model represent the wheel and the vehicle body often called as sprung and unsprung masses.
- These masses representing a quarter of a real car. The spring stiffness are K_t , K_s and the damper stiffness are C_s .

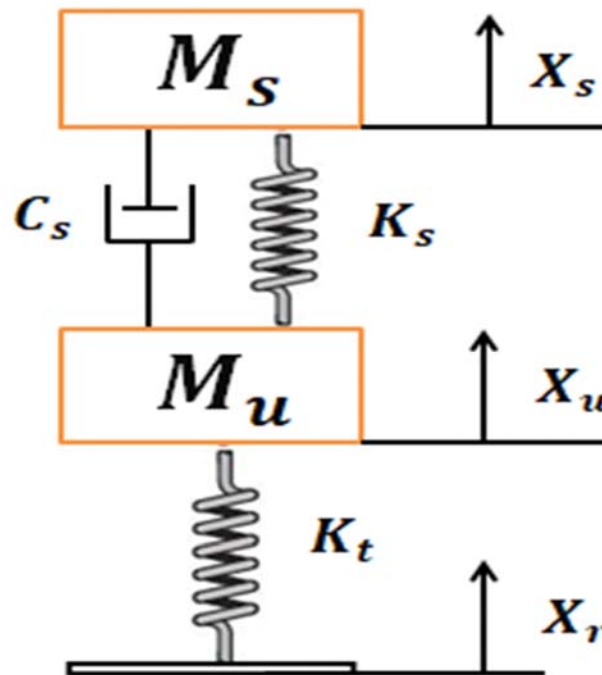


Fig: 4.1 Quarter-car

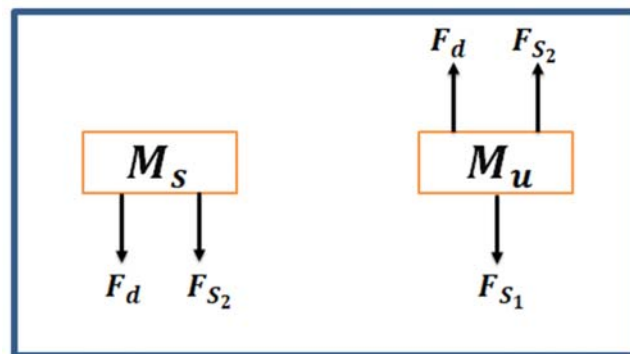
4.2 EQUATION OF MOTION:

- A basic two-degree of freedom system representing the quarter-car model.
- In this model the sprung mass is represented by M_s , the unsprung mass is represented by M_u , spring stiffness is represented as K_s , type stiffness is represented as K_t , Damping coefficient is represented as C_s

$$F_d = C_s [\dot{X}_s - \dot{X}_u]$$

$$F_{S_1} = K_t [X_u - X_r]$$

$$F_{S_2} = K_s [X_s - X_u]$$



force applied on two masses

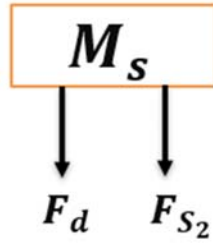
4.3 MASS M_s :

$$F = -F_d - F_{S_2}$$

$$M_s \ddot{X}_s = -C_s [\dot{X}_s - \dot{X}_u] - K_s [X_s - X_u]$$

$$M_s \ddot{X}_s = C_s [\dot{X}_u - \dot{X}_s] + K_s [X_u - X_s]$$

$$\ddot{X}_s = \frac{1}{M_s} [C_s (\dot{X}_u - \dot{X}_s) + K_s (X_u - X_s)]$$



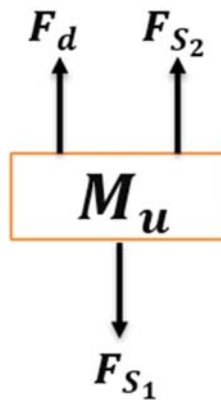
4.4 MASS M_u :

$$F = F_d + F_{S_2} - F_{S_1}$$

$$M_u \ddot{X}_u = C_s [\dot{X}_s - \dot{X}_u] + K_s [X_s - X_u] - K_t [X_u - X_r]$$

$$M_u \ddot{X}_u = C_s [\dot{X}_s - \dot{X}_u] + K_s [X_s - X_u] + K_t [X_r - X_u]$$

$$\ddot{X}_u = \frac{1}{M_u} [C_s (\dot{X}_s - \dot{X}_u) + K_s (X_s - X_u) + K_t (X_r - X_u)]$$



4.5 SIMULINK:

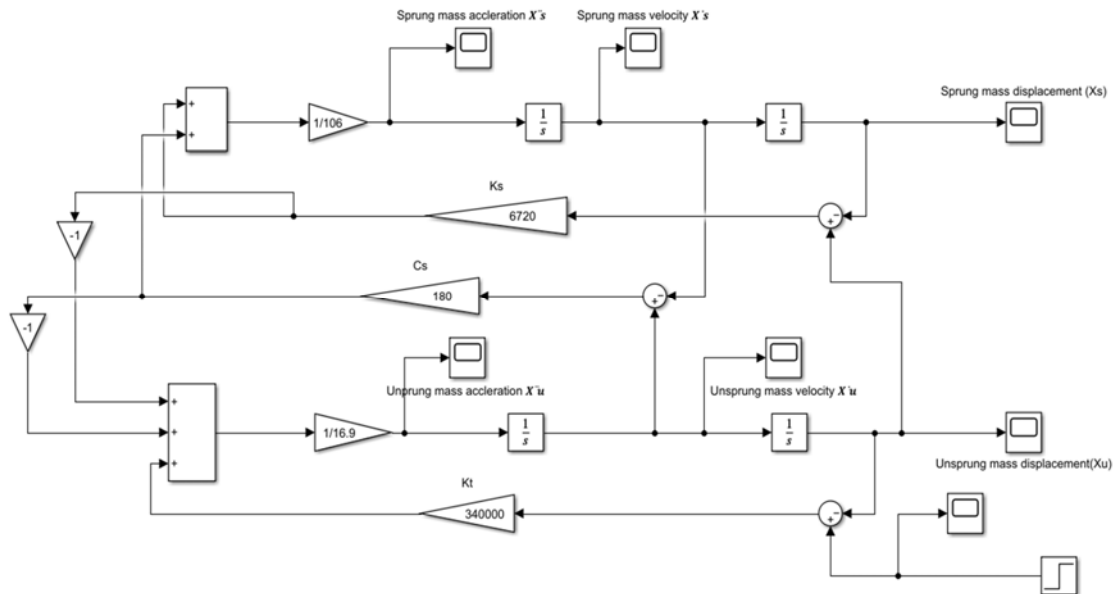


Fig: 4.2 Simulink in MATLAB

- As previously stated, a quarter automobile model is utilised to create a Suspension System. The figure below shows the complete Simulink model for an suspension system, and this model was built based on equations 1 and 2.
- A Quarter vehicle model (one of the four wheels) is used to improve the suspension framework when it is planned. The vertical displacement of the road, unsprung mass, and sprung mass are shown here.
- A automobile suspension system should be capable of maintaining road grip while also offering comfort when travelling over bumps and potholes.
- When the vehicle encounters a road disturbance (such as potholes or fissures), the car body should not be significantly affected, and the disturbance should be resolved fast.

4.6 QUARTER-CAR PARAMETER DETAILS:

Symbol	Symbol Name	Value's
Ms	Sprung mass	103 kg
Mu	Unsprung mass	16.9 kg
Ks	Spring stiffness	6720 N/m
Kt	Tyre stiffness	180 N/m
Cs	Damping coefficient	340000 N-s/m

Table 4.1 Quarter-car parameter detail's

- **Sprung mass (M_s)** : Mass above the suspension unit. For example: Chassis, Engine etc.,

Here we taken Honda Activa's Sprung mass that is **106 Kg**.

- **Unsprung mass (M_u)**: Mass below the suspension unit. For example: Wheels

Value = **16.9 Kg**

- **Spring stiffness (K_s)**: Spring stiffness is actually the ability of a spring to resist a force.

It means the stiffer the spring the larger the force will be to compress or extend the spring.

Value = 6720 N/m (Approx.)

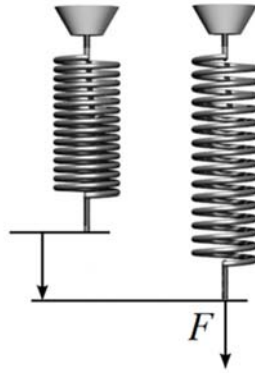


Fig: 4.3 Spring stiffness

- **Tyre stiffness (K_t)** : The ability of a tyre to withstand deformation in its shape when the vehicle corners is known as stiffness.
- Value = 180 N/m (Approx.)
Values taken from IJCER



Fig: 4.4 Tyre stiffness

- **Damping coefficient (C_s)**: Damping coefficient is measure of effectiveness of damper, it reflects ability of damper to which it can resist the motion.
If the unit has high damping coefficient which has good bounce back.
Value = 340000 N-s/m (Approx.)

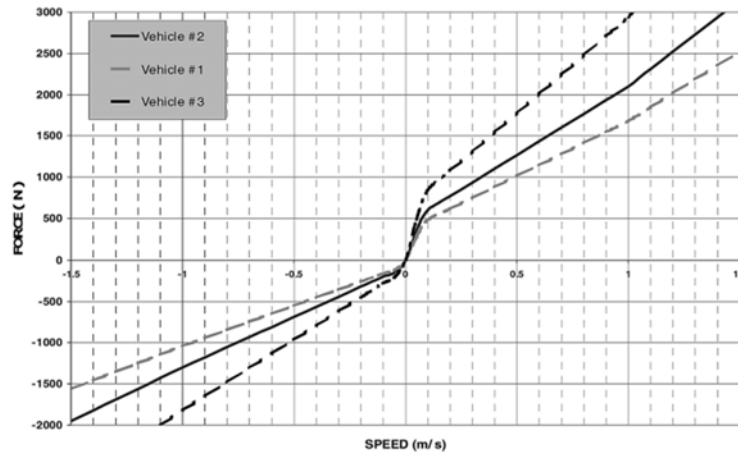


Fig: 4.5 Damping coefficient

4.7 COMPONENTS USED:

S.No.	Components
1.	Frame
2.	Pneumatic cylinder
3.	Solenoid valve
4.	Wheel
5.	Spring

Table 4.2 Components used

- **Frame:**

The frame is utilized to carry the entire arrangement setup. It must be capable of supporting the entire arrangement's weight. Arc welding would be used to create a permanent junction. As a result, the frame is crucial to our project.



Fig: 4.6 Frame

- **Pneumatic cylinder:**

Four-wheelers and large trucks are the most common vehicles that use air spring shock absorbers. There are only three types of air suspension. The three are the bellow tube, rolling lobe, and tapering sleeve. In this project, the tapered sleeve is used as an air spring in two-wheelers. The air pressure inside the rubber material can support the weight of the two-riders. The air spring's pressure inside the rubber tube gives a superior suspension to the coil spring. Pneumatic cylinders (sometimes called air cylinders) are mechanical devices that employ compressed gas to generate force in a reciprocating linear motion. Something compels a piston to move in the desired direction, similar to hydraulic cylinders. The piston is a disc or cylinder, and the piston rod transmits the force developed by the piston to the thing being moved. Pneumatics are sometimes preferred by engineers because they are quieter, cleaner, and require less room for fluid storage. Leakage from a pneumatic cylinder will not trickle out and contaminate the environment because the operating fluid is a gas, making pneumatics more suitable when cleanliness is required.



Fig: 4.7 Pneumatic cylinder

- **Solenoid valve:**

A solenoid valve is a reliable way to transform electrical signals into pneumatic operations. When power is applied to the solenoid, air is swiftly directed through the valve and into the circuit. For the usage of single or numerous valves, pneumatic solenoid valves are a cost-effective and space-saving solution. To make the selection and installation of your solenoid valves quick and straightforward, we offer a number of voltage, wattage, connector, and mounting options. Our pneumatic solenoid valves are appropriate for a wide range of applications due to their quick response times and high flow rates.



Fig: 4.8 Solenoid valve

4.8 CONSTRUCTION:

- One end of the suspension unit is connected with sprung mass (frame A) and other end is connected with unsprung mass (frame B).
- Wheel is fixed in frame B & C using coupling.
- The pneumatic press machine is connected below wheel and steel frame.
- For the sprung mass we are adding frame A.
- For the support we are adding frame B (wheel).

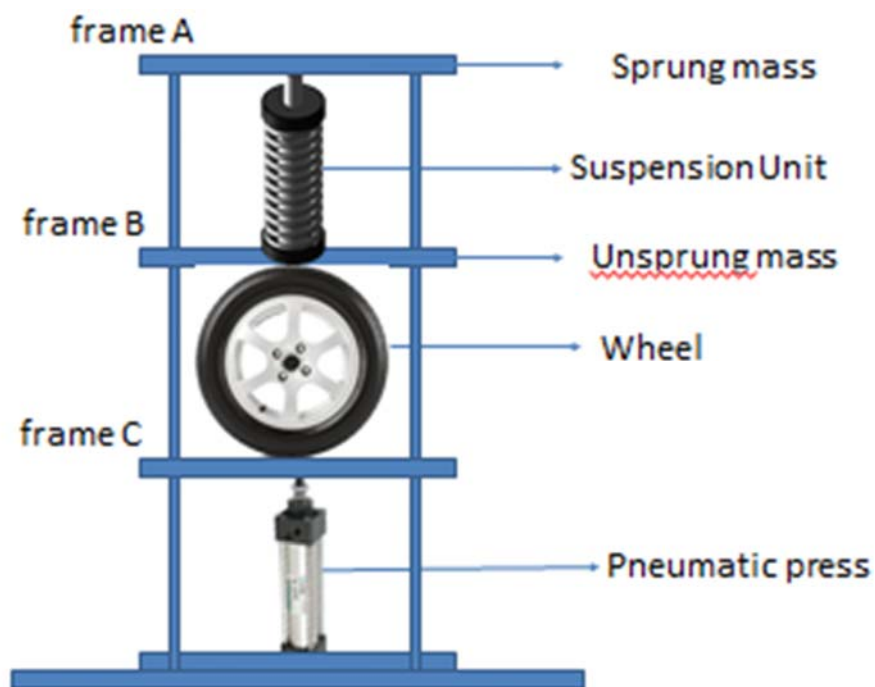


Fig: 4.9 Construction

4.9 WORKING PRINCIPLE:

- The pneumatic cylinder is connected to the air compressor. When the air compressor is in on condition, the air supply will be given to the pneumatic cylinder.

- Then the piston of the cylinder goes up and down position.
- When the piston in the cylinder was operated, it will press the tire as well as the spring.
- The spring will come to its own position, when the piston goes down. This cyclic process will make vehicle smooth riding.



Fig: 4.10 Fabrication

CHAPTER 5

RESULTS AND DISCUSSION

5.1 RESULT FOR SPRUNG MASS:

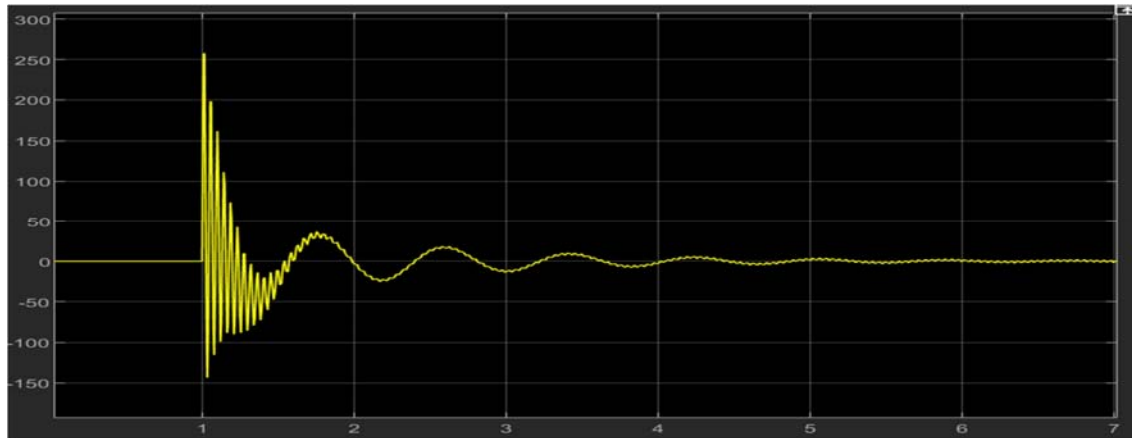


Fig: 5.1 Sprung mass acceleration

- The above graph represents acceleration for sprung mass. The X-axis denotes distance, while the Y-axis denotes time.

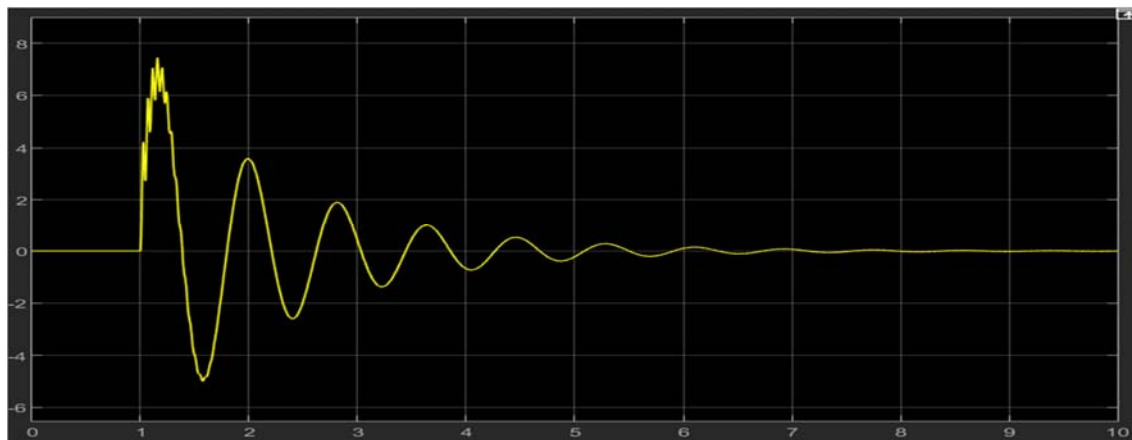


Fig: 5.2 Sprung mass velocity

- The above graph represents velocity for sprung mass. The X-axis denotes distance, while the Y-axis denotes time.

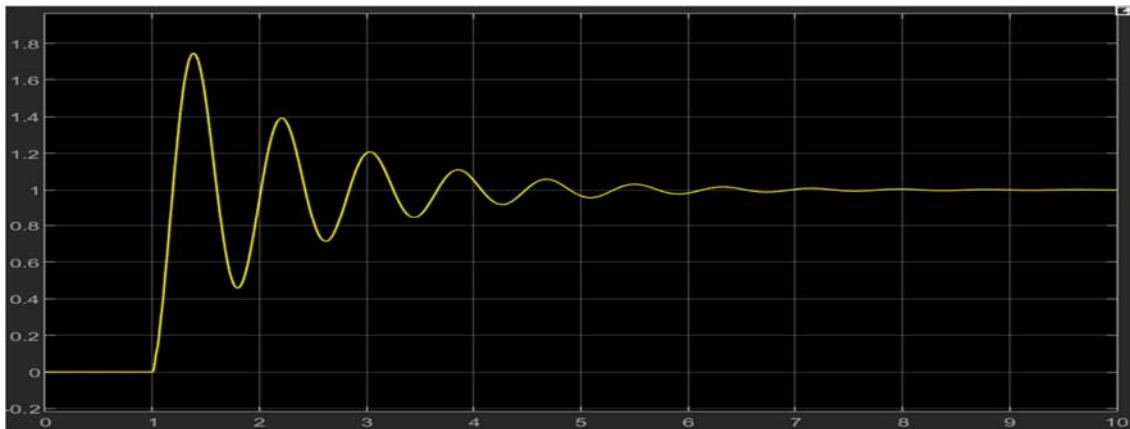


Fig: 5.3 Sprung mass displacement

- The above graph represents displacement for sprung mass. The X-axis denotes time.

5.2 RESULT FOR UNSPRUNG MASS:

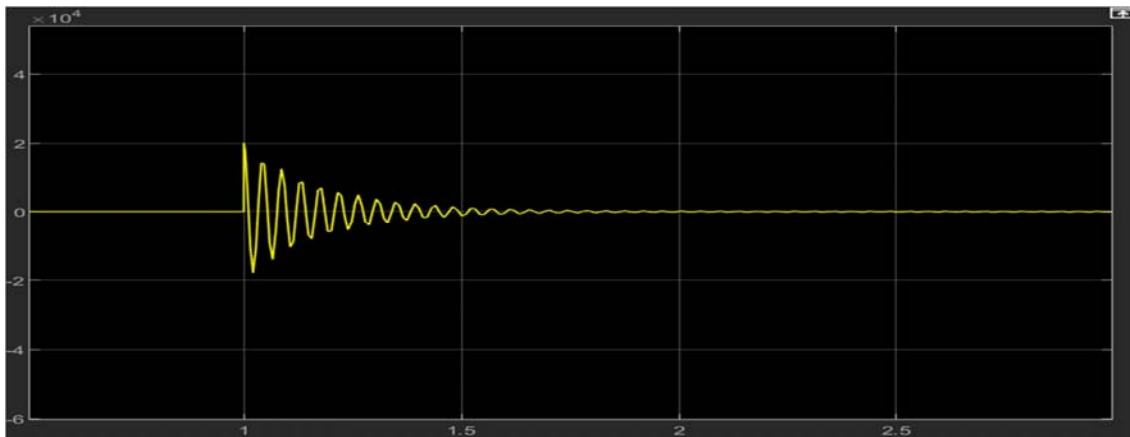


Fig: 5.4 Unsprung mass acceleration

- The above graph represents acceleration for Unsprung mass. The X-axis denotes distance, while the Y-axis denotes time.

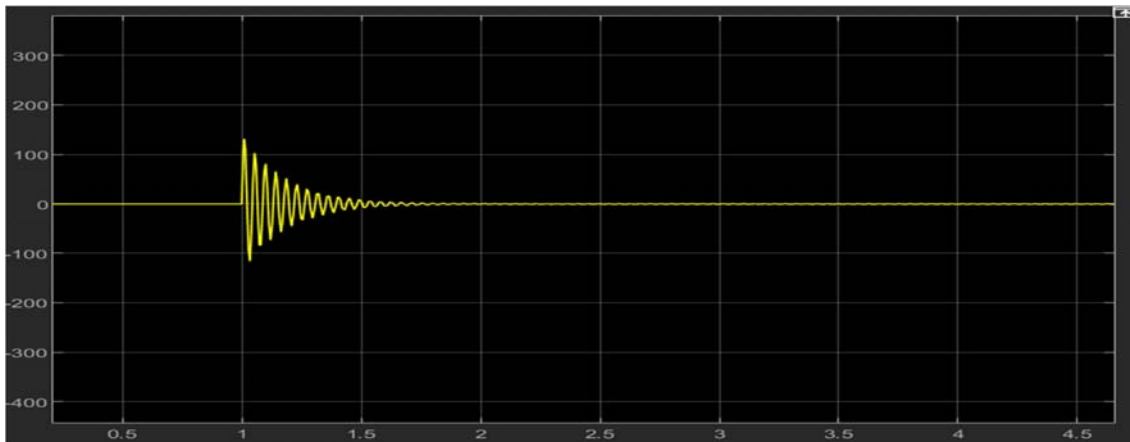


Fig: 5.5 Unsprung mass velocity

- The above graph represents velocity for Unsprung mass. The X-axis denotes distance, while the Y-axis denotes time.

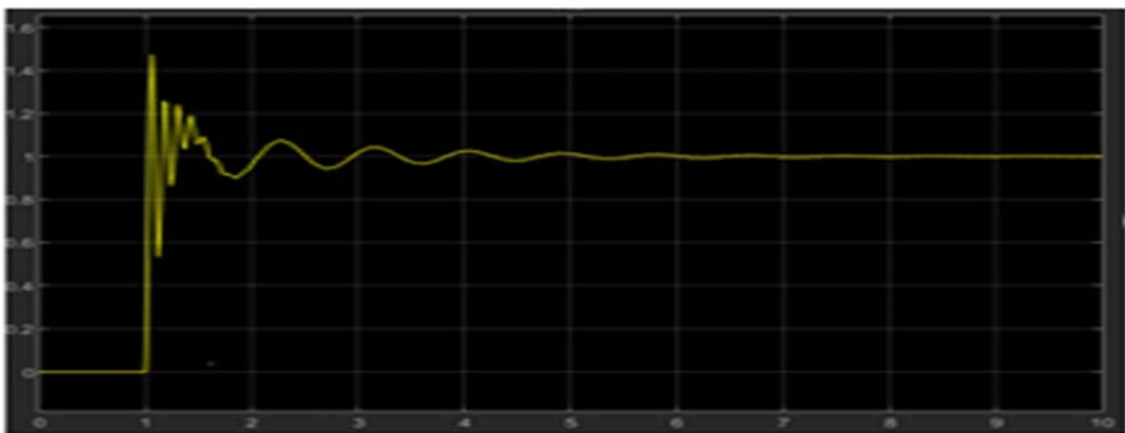


Fig: 5.6 Unsprung mass displacement

- The above graph represents displacement for Unsprung mass. The X-axis denotes distance, while the Y-axis denotes time.

CONCLUSION

- Analyzed quarter-car suspension model using MATLAB.
- We are going to analyzed variance in damping coefficient and stiffness in the damper and spring
- And fabricate basic suspension model.
- Outcome of the project is to get analyzed output of **acceleration, velocity and displacement**.

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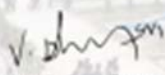
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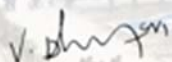
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