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DESIGN, ANALYSIS AND FABRICATION OF ROCKER BOGIE MECHANISM

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ABSTRACT

The Rocker Bogie system is crucial for exploring distant locations, like Mars, and conducting scientific analysis. Unlike other complex designs with many wheels or legs that can break down in harsh environments, the Rocker Bogie system is simpler and more reliable. It uses just six motors for movement, making it less likely to fail. This system is designed to move slowly but can still handle obstacles the size of its wheels.

It is NASA's preferred method for rovers and spacecraft. It has two arms that each has a steering wheel. There is a movable joint connecting each component to the others. This makes it feasible to employ a suspension-based system to distribute the vehicle's tonnage evenly over protrusions and irregular surfaces.

To make it even more durable, we are planning to make this vehicle entirely of Structural steel to withstand shocks, vibrations, and mechanical failures in harsh environments. We have used computer software to perfect the vehicle's design and test the prototype in real-life situations to ensure it works effectively.

Keywords: Rocker Bogie System, Mars Rover Design, Space Exploration, Robotic Mobility, Suspension Systems, Structural Steel, Vehicle Durability, Obstacle Navigation, NASA Rover Technology, Prototype Testing.

CHAPTER-1

INTRODUCTION

The rocker-bogie suspension system was developed in 1988 for NASA's Mars rover Sojourner and has since evolved into the organization's preferred rover design. The rovers from the Mars Science Laboratory (MSL) mission in 2012 Spirit and Opportunity were part of the Mars Exploration Rover project in 2003.

As a result of the larger, body-mounted linkages on each side of the rover, the suspension system includes a "rocker" component. These rockers are connected to the car's chassis and to one another via a differential. The rockers will rotate in opposition to one another with respect to the chassis to provide equal wheel contact. The chassis keeps both rockers' average pitch angles constant. A rocker has a bogie attached to one end and a drive wheel attached to the other.

The "bogie" component of the suspension is the smaller linkage with a drive wheel at each end and a pivot to the rocker in the middle. In order to evenly disperse the load across the terrain, bogies were widely used in the trailers of semi-trailer vehicles and as load wheels on the tracks of army tanks. Both tanks and semi- trailers prefer trailing arm suspensions today.

The front wheels of the Sojourner rover attach to the bogies, whereas the front wheels of the MER and MSL rovers attach to the rockers.

The Rocker-Bogie suspension system is used in the mechanical robots called Mars rovers that were developed for the Mars Pathfinder mission as well as the Mars Exploration Rover (MER) and Mars Science Laboratory (MSL) missions. NASA now prefers this design. The suspension system rocks because of the larger links on both sides, hence the word "rocker."

These rockers are connected to the car's chassis and to one another via a differential. When one rocker moves up concerning the chassis, the other moves down. The average pitch angle of both rockers is maintained by the chassis. A driving wheel is attached to one end of a rocker, and a bogie is attached to the other end.

"Bogies" are the linkages that have a driving wheel at either end. Bogies were widely used as load wheels on army tank tracks to spread the burden out over the terrain. Bogies were frequently used on the trailers of semi-trucks.

The place, where the value of gravity remains lower than earth's own gravitational coefficient, at that place the existing suspension system fails to fulfill desired results as the amount and mode of shock absorbing changes.

To counter anti-gravity impact, NASA and jet propulsion Laboratory have jointly developed a suspension system called the "Rocker-Bogie suspension system".

So, now the same mechanism is used in our environment with rough roads, agriculture land, inclined stairs and obstacles filled surfaces. There is an increasing need for mobile robots which can operate in unstructured environments with highly uneven terrain. These robots are mainly used for tasks which humans cannot do and which are not safe.

The rocker-bogie suspension is a mechanism that enables a six-wheeled vehicle to passively keep all six wheels in contact with a surface even when driving on severely uneven terrain.

There are two key advantages to this feature. The first is that the wheel pressure on the ground will be equilibrated. This is extremely important in soft terrain where excessive ground pressure can result in vehicle sinking into driving surface. The second is that while climbing over hard, uneven terrain all six wheels will nominally remain in contact with the surface and under load, helping to propel the vehicle over the terrain.

FIG 1.1 ROCKER BOGIE

1.1 HISTORY OF ROVERS

1.1.1 LUNAKHOD:

The first planetary exploration rover was "Lunakhod" which has been sent Moon2 times with USSR – Luna missions to gather information around landing site and send pictures of terrain.

Lunakhod has guided in real-time by a five-person team at the Deep Space Center near Moscow, USSR. Lunakhod-2 toured the lunar Mare Imbrium for 11 months in one of the greatest successes travelled 37 km on Moon surface.

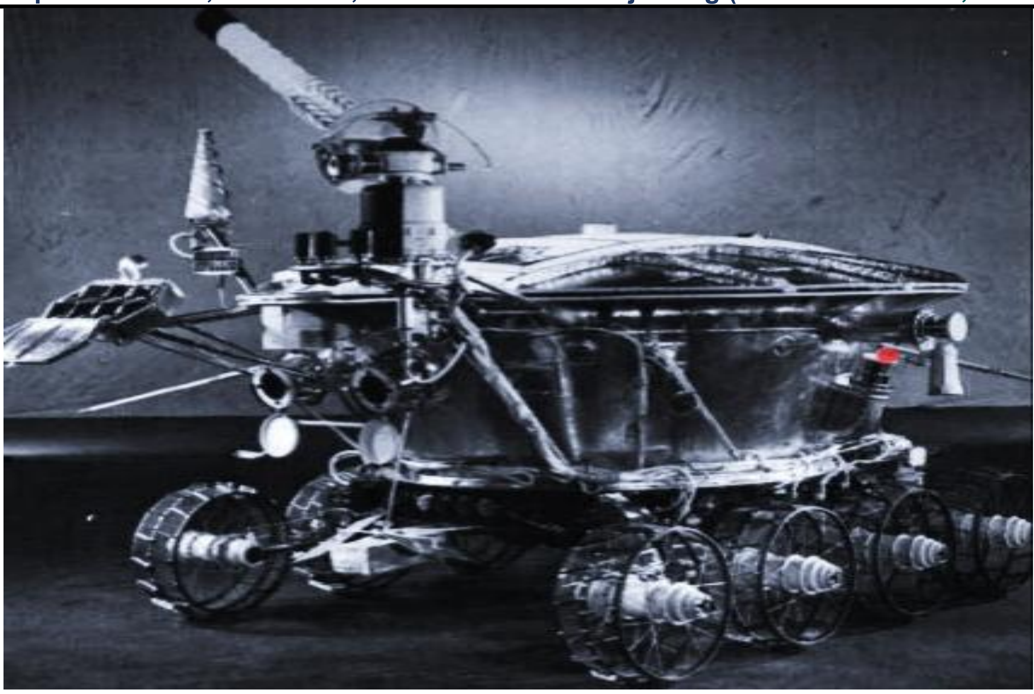


FIG 1.2 First Planetary Exploration Rover "Lunokhod"

1.1.2 SOJOURNER:

In 1996, NASA – Jet Propulsion Laboratory and California Institute of Technology have designed new rovers with identical structure named Sojourner and Marie-Curie. These small rovers were only 10.5 kilograms and microwave were oversized Rover Sojourner launched with Pathfinder landing module in December 1996.

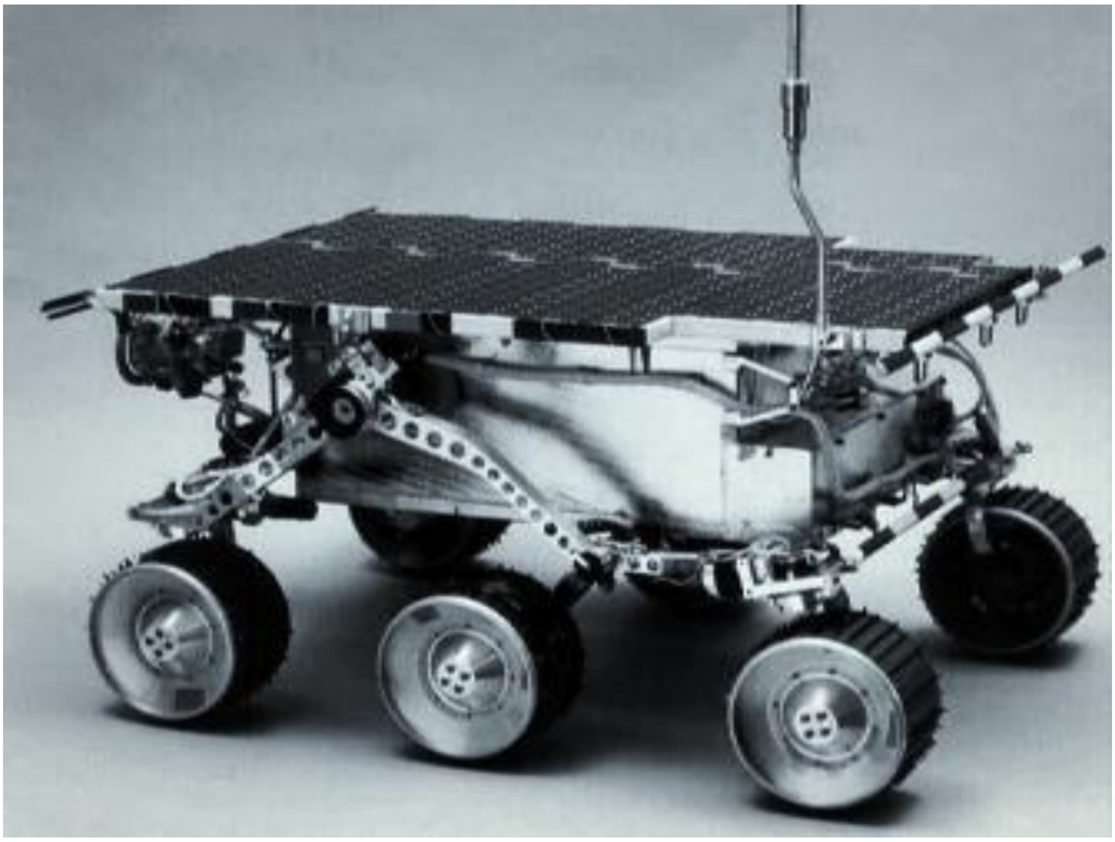


Fig 1.3 NASA - JPL Sojourner Rover

1.2 ADVANTAGES:

- The design incorporates independent motors for each wheel, eliminating the need for springs or axles, which simplifies the design and enhances reliability.
- The Rocker Bogie Suspension can withstand a tilt of at least 50 degrees in any direction without overturning, a significant advantage for heavily loaded vehicles.
- It is capable of operating in harsh environments.
- The mechanism can function in areas that are beyond human reach.
- The Rocker Bogie design, with no springs and stub axles on each wheel, allows the chassis to climb over obstacles such as rocks, ditches, and sand that are up to twice the diameter of the wheels, while keeping all wheels in contact with the ground as much as possible.

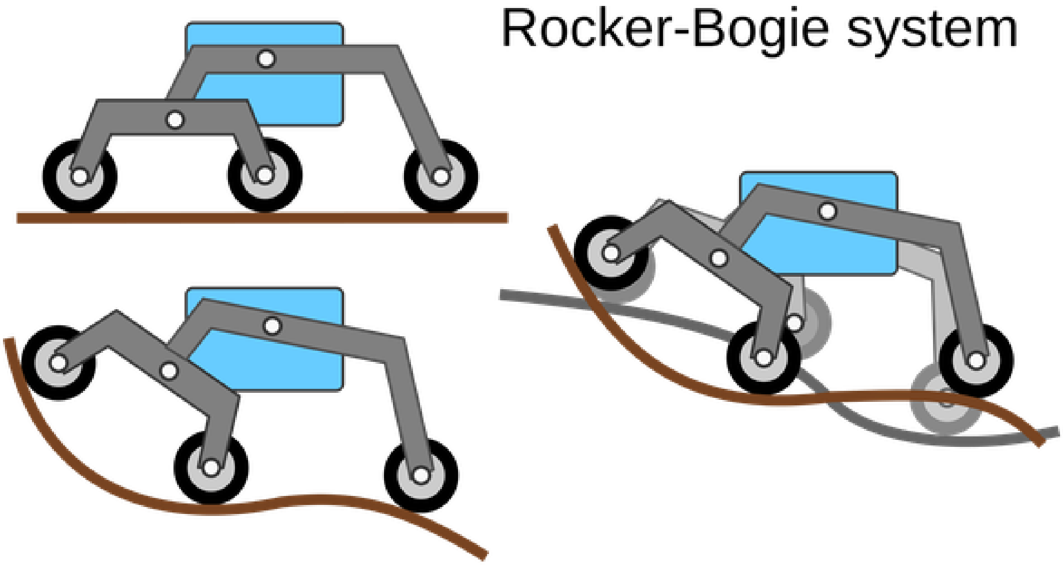


FIG 1.4 ROCKER BOGIE IN DIFFERENT ENVIRONMENT

CHAPTER 2

LITERATURE REVIEW

Nitin Yadav et.al. (2015) [1].

"Design analysis of Rocker Bogie Suspension System and Access the possibility to implement in Front Loading Vehicles".

The paper introduces a new design to improve the way heavy vehicles move over rough terrain at high speeds. This design has two modes: one where the vehicle uses a traditional rocker-bogie system to navigate obstacles, and another where it spreads out its support by rotating the bogies on each side. This change makes the vehicle more stable and capable of handling rough terrain better. The researchers tested their design using computer simulations and found that it performed well. If this design is used in heavy vehicles and off-road vehicles in the future, it could make them simpler, more efficient, and better at dealing with bumps in the road.

Chitravelan et.al.(2015) [2].

"Analysis and simulation of a rocker-bogie exploration rover engine".

Their research shows that the design works well for exploring rough terrain. They found that the rocker-bogie system helps the rover move smoothly over obstacles, and their simulations confirmed its effectiveness. Overall, their work suggests that this type of rover engine is a good choice for exploring challenging environments.

M. D. Manik et.al [3].

"Experimental Analysis of climbing stairs with the rocker-bogie mechanism".

The rocker-bogie mechanism shows promise for climbing stairs effectively. Through their experiments, they found that this mechanism enables smooth and stable traversal of stairs, showcasing its potential for use in various applications where stair climbing is necessary. Overall, their study demonstrates the effectiveness of the rocker-bogie mechanism in handling this particular task.

B. D. Harrington and C. Voorhees[4].

"The Challenges of Designing the Rocker-Bogie Suspension for the Mars Exploration Rover".

In this Study, Over the last ten years, engineers have found that the rocker-bogie suspension system works really well for moving vehicles because it keeps them stable and helps them climb over obstacles easily. They've used this system in different experimental rovers, and it worked so well that they even sent it to Mars on the Sojourner rover.

When they were planning the Mars Exploration Rover (MER) Project, they knew they wanted to use the rocker-bogie suspension because it had a good track record. But they had a problem: they needed to make it light enough to fit on the rover and still be strong and sturdy enough to work on Mars. This paper explains how they managed to solve this problem by designing a lightweight rocker-bogie suspension that could fold up to fit in a small space and then unfold safely when the rover landed on Mars. It also talks about all the different ways they made sure the suspension would work properly when it unfolded on the Martian surface.

Y. L. Maske et.al [5].

"Modelling and MBD simulation of stair climbing robot with rocker bogie Mechanism".

Their proposed design performs well in navigating stairs. Through their simulations, they demonstrated that the robot equipped with the rocker bogie mechanism can effectively climb stairs with stability and efficiency. This suggests that the design is a promising solution for applications requiring stair climbing capabilities. Overall, their study highlights the potential effectiveness of the rocker bogie mechanism in stair climbing robots.

L. Bruzzone and G. Quaglia, [7].

"Locomotion systems for ground mobile robots in unstructured environments".

In their review article they discussed various methods for designing robot movement systems that can handle rough terrain effectively. They discussed different approaches and technologies used in designing such systems. Overall, their review provides valuable insights into the options available for developing robots capable of navigating challenging environments successfully.

CHAPTER-3

PROBLEM DEFINATION AND TOOLS USED

3.1 PROBLEM DEFINATION:

- The project eenables a six- wheeled vehicle to passively keep all six wheels in contact with a surface even when driving on severely uneven terrain.
- Also aim is to climbing over obstacles, climbing stairs and move in harsh environment, to do work in places which are beyond human reach.
- To deliver specified payload from one location to another where there is risk for human beings to deliver.

3.1 TOOLS USED:

3.2.1 SOLIDWORKS

Solid Works is a popular computer-aided design (CAD) software used by engineers, designers, and architects to create 3D models and drawings.

Solid Works is powerful and versatile CAD software that streamlines the design process, from initial concept development to detailed modeling, analysis, and documentation. Its intuitive interface, robust feature set, and extensive capabilities make it a preferred choice for professionals across various industries.

3.2.2 ANSYS WORKBENCH

Ansys Workbench is the integration and workflow platform that connects Ansys products. The project schematic enables users to configure their simulation processes, optimize exploration through parametric management, and submit jobs to solver both locally and remote, and adds APIs that allow for third-party software.

Workbench is a simulation management tool that connects Ansys products, enabling users to configure their simulation processes and optimize exploration through parametric management and more—all on a user's local workstation. For a SPDM (simulation process and data management) solution, Ansys Minerva, (powered by Aras) supports both on-premises and cloud deployment ecosystems, connecting team members regardless of geography and functional silos.

CHAPTER-4

AIM AND SCOPE OF SIX WHEELER ROCKER BOGIE MECHANISM

4.1 AIM:

A six-wheeled rocker bogie mechanism aims to provide a stable and robust suspension system for a vehicle operating in rough or uneven terrain. The mechanism allows the vehicle to traverse obstacles such as rocks, crevices, and uneven surfaces while maintaining high stability and mobility.

The six-wheeled rocker bogie mechanism includes a central support with two shafts, one in each wheel well. The shafts are connected to toothed discs on the axle, which rotate in unison with the wheels. On each side of the central support, there is an identical rocker arm and wheel hub. The rocker's arm connects the central support to a link arm that pivots on a ball joint. The link arms connect at their free ends to short bars that cross over one another under and between each set of three wheels respectively; these bars are also connected through links to moveable.

4.2 SCOPE:

The mechanism used in the exploration rovers, military vehicles, and off-road vehicles allows them to navigate difficult terrain with less risk of damage or getting stuck. It has a wide range of applications that make it a popular choice.

The six-wheeled rocker bogie mechanism consists of a suspension system that utilizes a combination of rigid and flexible links to maintain constant contact between the wheels and the ground, even on uneven surfaces. The mechanism also includes a rocker arm that allows the vehicle to maintain a stable stance, regardless of the angle of the surface. The six-wheeled bogie is an articulated bogie, which means it is hinged at two pivotal points. The front of the vehicle is hinged at the center of the leading truck, while the rear is hinged inboard to one of each truck's clevis pins.

Finally, scope of the six-wheeled rocker bogie mechanism is to provide a reliable and versatile suspension system that can handle the challenges of rough terrain and maintain stability for the vehicle.

CHAPTER-5

MATERIALS AND HARDWARE COMPONENTS

5.1 MATERIALS USED

5.1.1 STRUCTURAL STEEL:

Construction components come in a variety of shapes and sizes, thanks to the use of structural steel. Structural steel is a type of steel specifically designed for use in construction. One common form of structural steel is an extended beam with a specific cross-sectional profile, such as an I-beam.

Most industrialized countries have regulations that govern the shapes, dimensions, chemical composition, and mechanical properties of structural steel, including its strength and storage practices.

Structural steel designs, such as I-beams, have significant second moments of area, which makes them extremely stiff relative to their cross-sectional area. This characteristic allows them to support heavy loads with minimal deflection.

International standards detail the various shapes available for structural steel, and there are also specialized and exclusive cross-sections designed for specific applications.

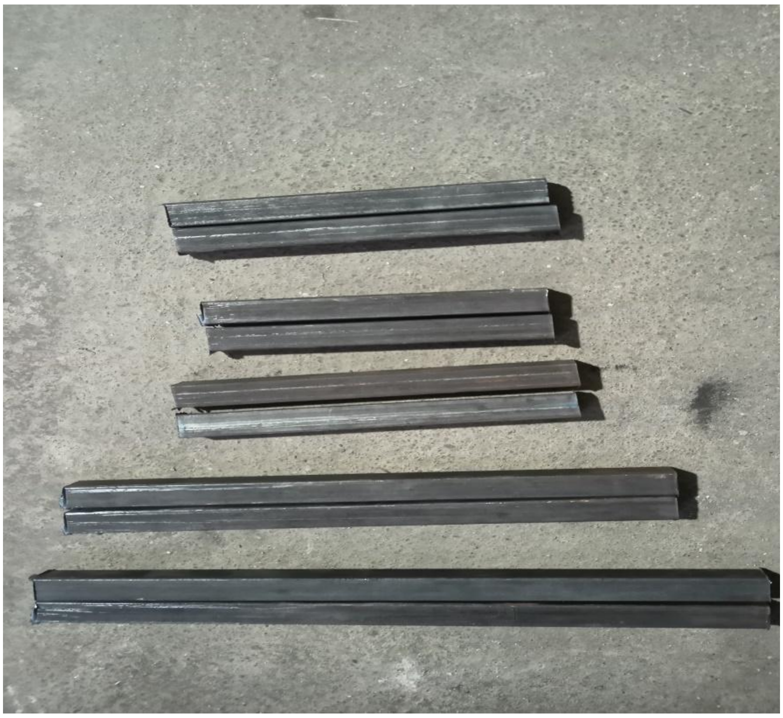


Fig 5.1 Structural Steel used for a rocker bogie mechanisms

5.1.2 MATERIAL ANALYSIS:

TABLE- 5.1: PROPERTIES OF STRUCTURAL STEEL

S.NO	PARAMETERS	VALUE
1	DENSITY	7.8x10^(-6) Kg/mm^3
2	YOUNGS MODULUS	2x10^5 N/mm^2
3	POISSON RATIO	0.3
4	YIELD STRENGTH	260 MPa

5.2 HARDWARE COMPONENTS

5.2.1 GEAR MOTORS:

A basic DC motor with a gearbox is a common component in geared motors. This setup, which includes a 12V DC motor with a 30 RPM gear ratio, is widely used in various robotic applications, including all-terrain robots.

The motor typically features a 3 mm threaded drill hole at the center of the shaft, which facilitates easy attachment to wheels or other mechanical assemblies.

The 30 RPM, 12V DC geared motors are popular in robotics due to their user-friendly nature and availability in standard sizes. Moreover, controlling these motors with an Arduino or similar microcontroller is cost-effective and straightforward.

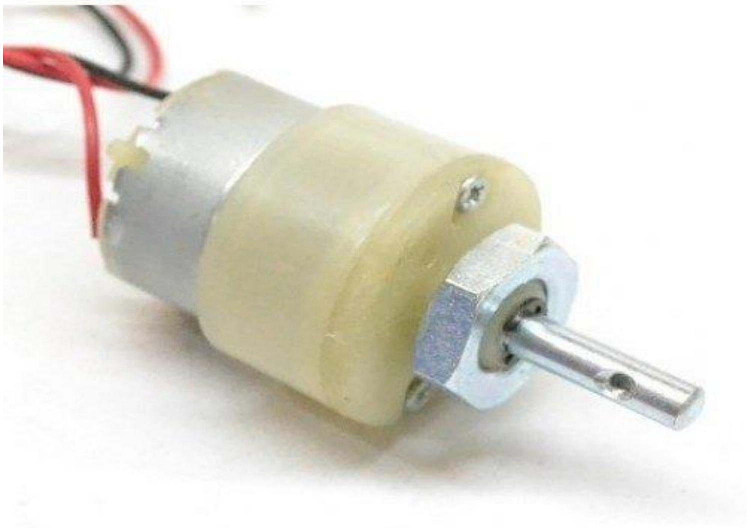


FIG-5.2: DC MOTOR

TABLE-5.2: Specifications and Features of Gear Motor

S.NO	**SPECIFICATIONS**	**FEATURES**
1	RPM	30
2	OPERATING VOLTAGE	12VDC
3	GEARBOX	ATTACHED PLASTIC GEARBOX

4	SHAFT DIAMETER	6mm WITH INTERNAL HOLE
5	TORQUE	2 kg-cm
6	NO LOAD CURRENT	60mA (Max)
7	LOAD CURRENT	300 mA (Max)

5.2.2 ARDUINO NANO:

The Arduino Nano is a compact and versatile microcontroller board based on the ATmega328P chip. It is similar to the Arduino Uno but comes in a smaller form factor, making it ideal for projects with limited space or weight constraints.

Like the Arduino Uno, the Nano is powered by the ATmega328P microcontroller. It features 14 digital input/output pins (6 of which can be used as PWM outputs), 8 analog input pins, and supports UART, SPI, and I2C communication interfaces.

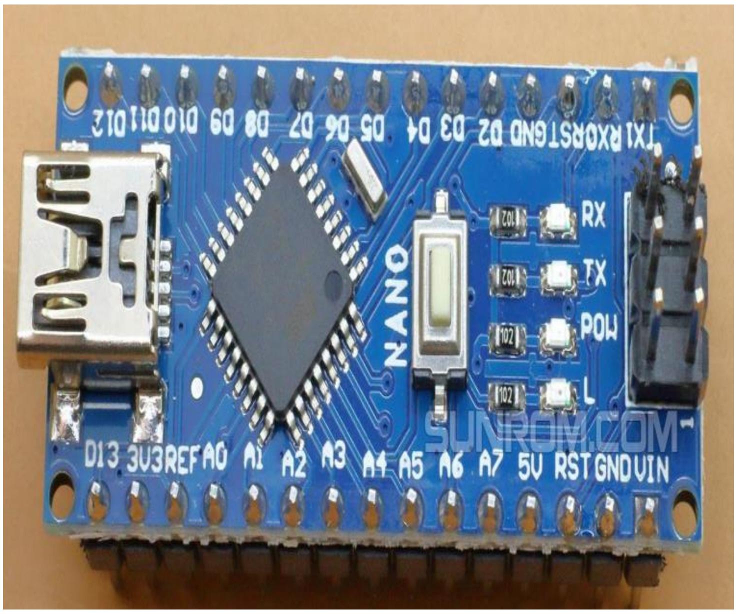


FIG-5.3 ARDUINO NANO

5.2.3 VOLTAGE REGULATOR:

A voltage regulator is an electronic component or circuit designed to maintain a stable output voltage despite variations in input voltage, load current, or temperature. Its primary function is to provide a consistent and reliable power supply to electronic devices, protecting them from voltage fluctuations and potential damage. By ensuring that the voltage remains constant, voltage regulators help prevent issues related to power instability and improve the overall reliability and performance of electronic systems.

FIG-5.4 VOLTAGE REGULATOR

5.2.4 MOTOR DRIVER L293 :

The L293 is a widely used integrated circuit (IC) designed for motor driving in various robotic and mechatronic applications. It features two H-bridges, which are transistor arrangements that enable bidirectional control of current flow to a load, such as a motor. Each H-bridge can independently control one motor, allowing for forward, reverse, and braking operations.

The L293 IC is capable of handling relatively high currents, making it suitable for driving a range of DC motors, stepper motors, and other inductive loads. Its robustness and versatility make it a popular choice in motor control applications.

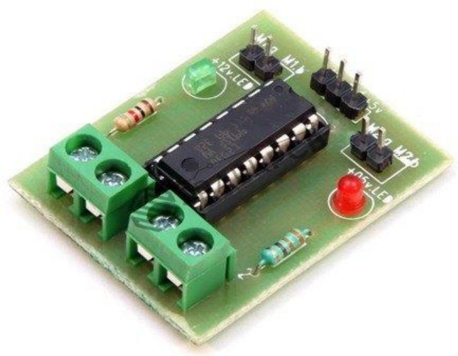


FIG-5.5 MOTOR DRIVER L293

5.2.5 BLUETOOTH MODULE HC05:

The HC-05 is a popular Bluetooth module that facilitates wireless communication between electronic devices over short distances. It is widely used by hobbyists, makers, and developers due to its ease of use, affordability, and versatility.

The HC-05 module provides a convenient and cost-effective solution for integrating wireless communication into electronic projects. It enables data exchange and control between devices without the need for physical connections, making it an ideal choice for various applications that require wireless connectivity.

FIG-5.6 BLUETOOTH MODULE HC05

5.2.6 LEAD ACID BATTERY:

Lead-acid batteries are a fundamental type of 12V battery, commonly used in various applications. They consist of lead plates immersed in an electrolyte solution of sulfuric acid, which facilitates a chemical reaction to store and release energy.

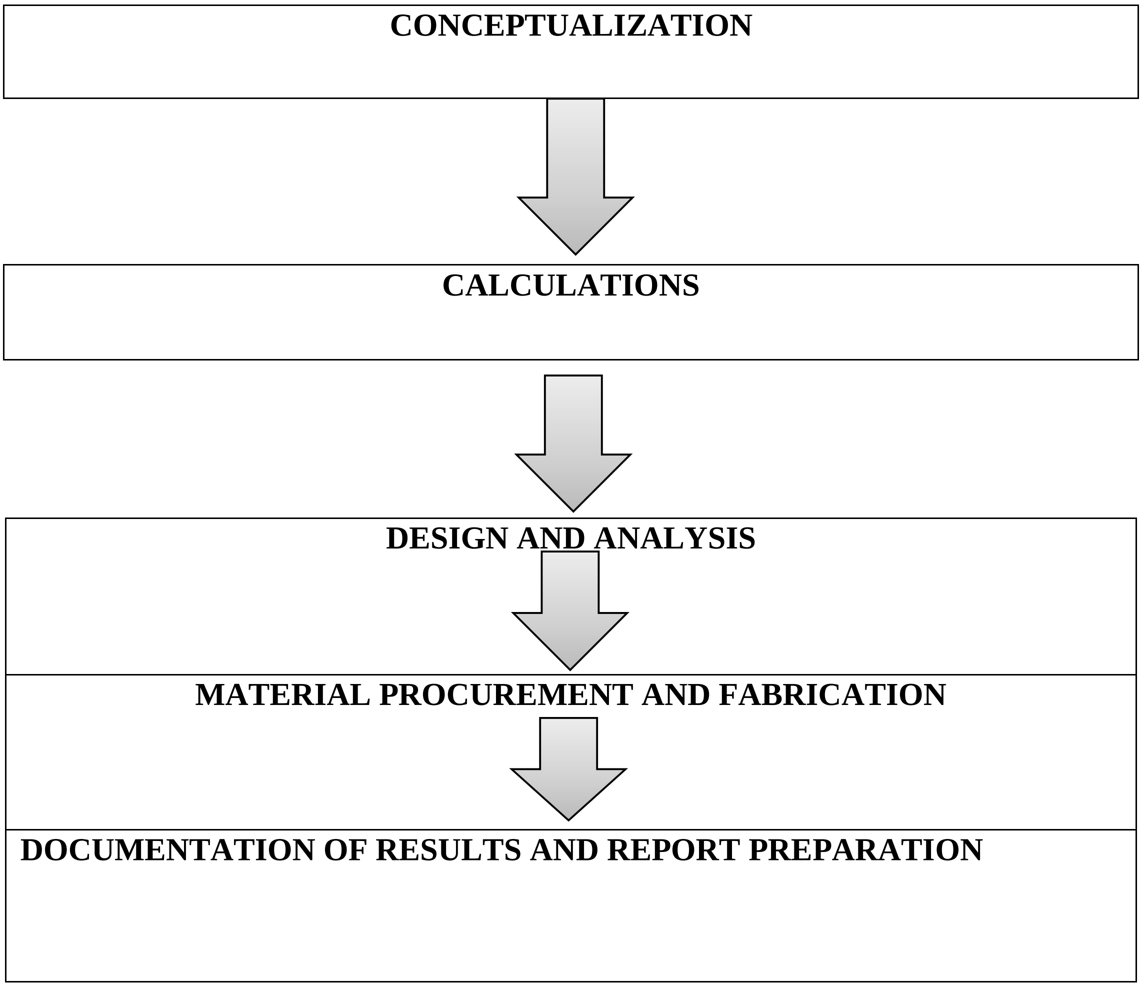
The most common type of lead-acid battery is the flooded battery. This type requires regular maintenance to ensure optimal performance, including checking and maintaining the proper level of water in the electrolyte. Flooded lead-acid batteries typically have a lifespan of two to five years, depending on usage, maintenance, and environmental conditions.

FIG-5.7 LEAD ACID BATTERY

CHAPTER-6

METHODOLOGY

6.1 FLOW CHART



6.1 CALCULATION:

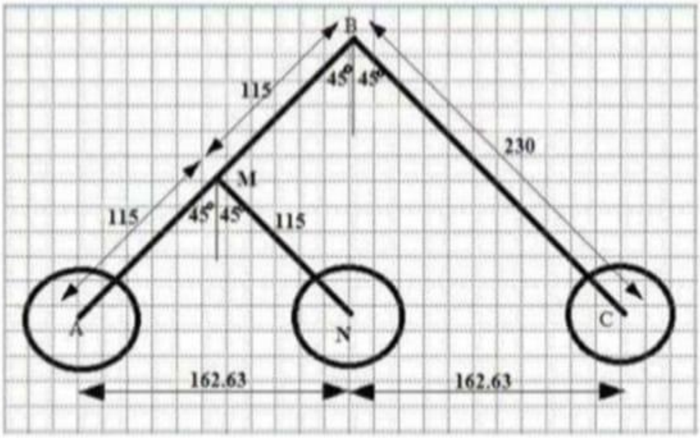


FIG 6.1 DESIGN OF ROCKER BOGIE

If horizontal length of stairs is 400 mm

Then wheel base = horizontal length of stairs – (Rf + Rr) Rf = radius of front wheel

Rr = radius of rear wheel

So wheel base = 400 – (35+35) Wheel base = 330 mm

Let $\theta = 45^0$

In Triangle BNC, Angle BNC = 90^0 Angle NBC = Angle NCB =

45^0 Therefore, NC = NB

$NC^2 + NB^2 = BC^2$ (from Pythagoras theorem) $BC^2 = 2(NC^2)$ .... (1)

$= 2(165^2)$

BC = 233.33 mm

Rounding off to 230 mm BC = 230 mm

Substituting in eqn (1) we get, $230^2 = 2(NC^2)$

NC = 162.63 mm

NC = AN = 162.6 mm

In Triangle AMN, angle AMN = 90^0 $AM^2 + MN^2 = AN^2$

$2(AM^2) = AN^2$ AM = 114.99 AM = 115 mm

Now due to symmetry, AM = MN =115 mm BM =

AB – AM

= 230-115

BM = 115 mm

Height of RBM $Height^2 = BC^2 - NC^2$

$Height^2 = 230^2 - 162.63^2$

Height = 162.4 mm

Net Height = Height + radius of wheel

= 162.4 + 35

= 197.64 mm

6.2 DESIGN

SOLID WORKS:

Solid Works is a popular computer-aided design (CAD) software used by engineers, designers, and architects to create 3D models and drawings.

Solid Works is powerful and versatile CAD software that streamlines the design process, from initial concept development to detailed modeling, analysis, and documentation. Its intuitive interface, robust feature set, and extensive capabilities make it a preferred choice for professionals across various industries.

6.2.1 ROCKER:

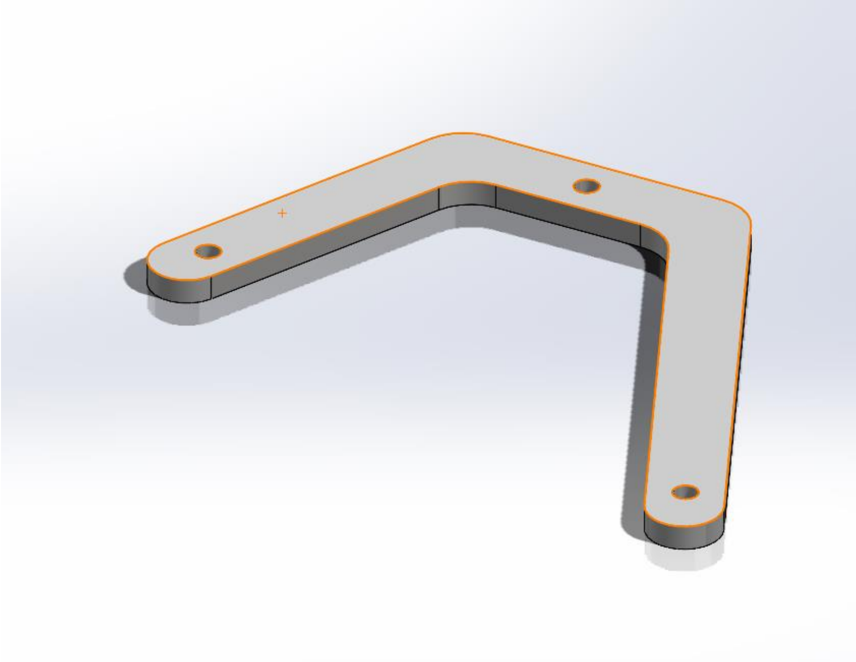


FIG 6.2 DESIGN OF ROCKER IN SOLID WORKS

6.2.2 BOGIE:

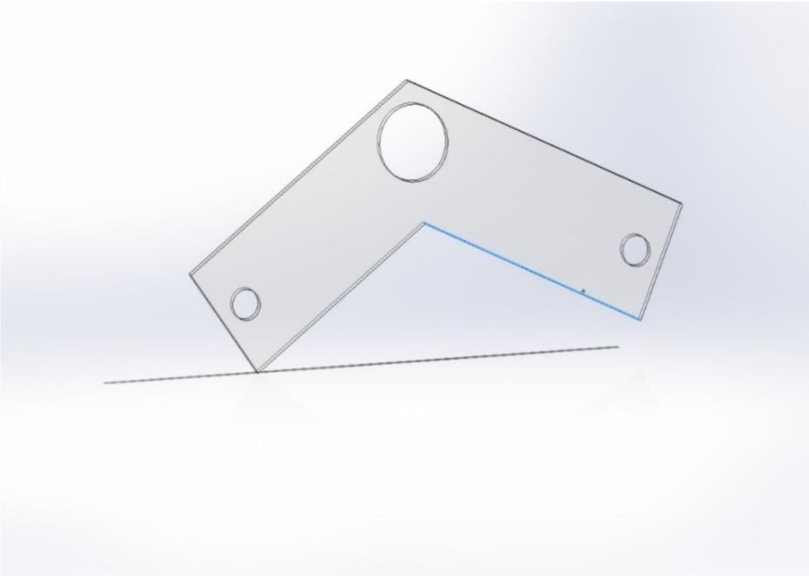


FIG 6.3 DESIGN OF BOGIE IN SOLID WORKS

6.2.3 DC MOTOR:

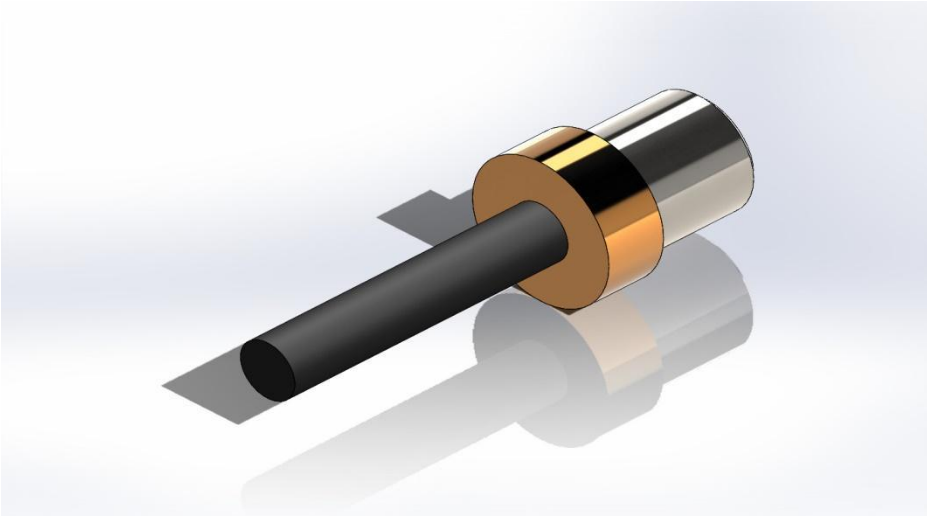


FIG 6.4 DESIGN OF MOTOR IN SOLID WORKS

6.2.4 WHEEL:

WHEEL DESIGN:

Velocity, V =(πDN)/60

VELOCITY 80mm/s		VELOCITY 100mm/s		VELOCITY 120mm/s	
SPEED(N) rpm	DIA(D) mm	SPEED(N) rpm	DIA (D) mm	SPEED(N) rpm	DIA (D) mm
10	152.77	10	190.96	10	229.15
20	76.38	20	95.48	20	114.58
30	50.92	30	63.65	30	76.38
40	38.19	40	47.74	40	57.29
50	30.55	50	38.19	50	45.83
60	25.46	60	31.83	60	38.19
70	21.82	70	27.28	70	32.74
80	19.10	80	23.87	80	28.64

FIG 6.5 WHEEL DESIGN

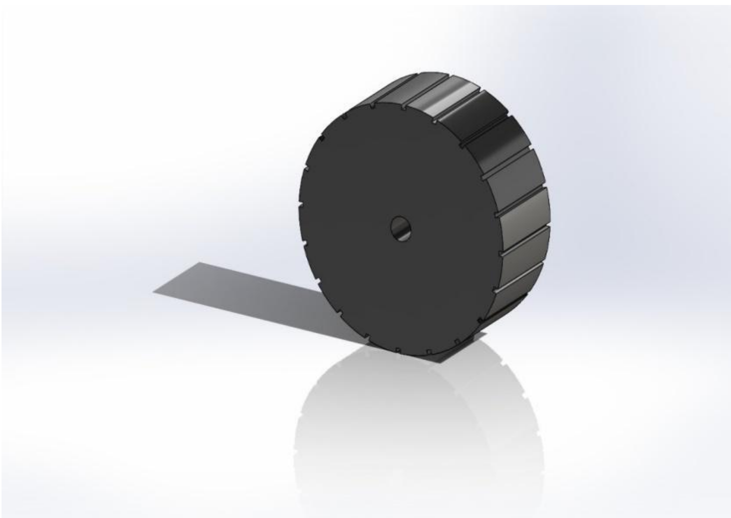


FIG 6.6 DESIGN OF WHEEL IN SOLID WORKS

6.2.5 ASSEMBLY:

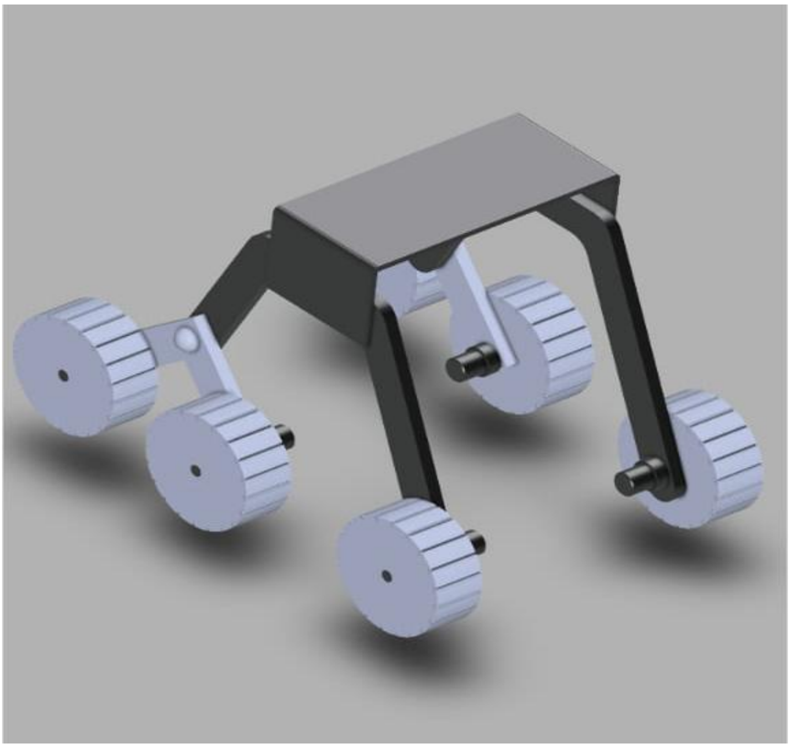


FIG 6.7 ROCKER BOGIE ISOMETRIC VIEW

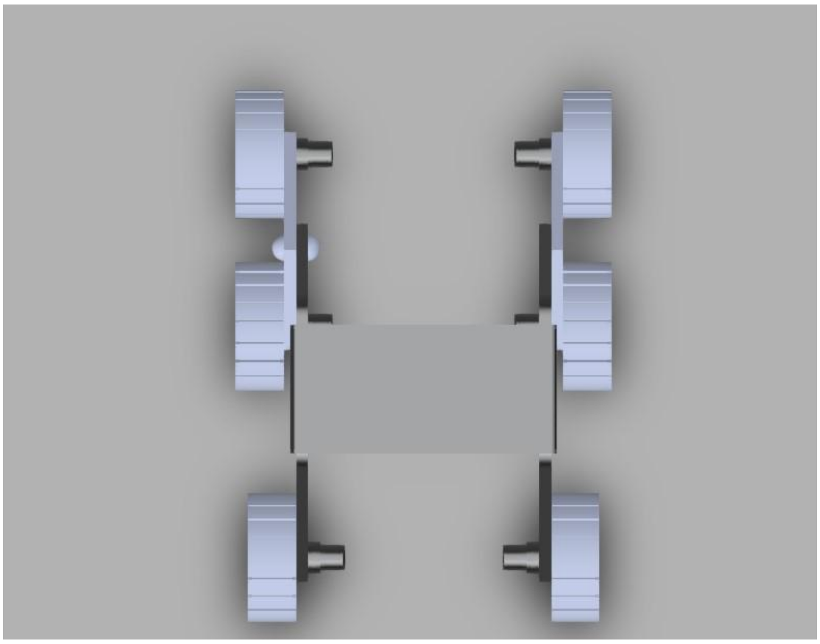


FIG 6.8 ROCKER BOGIE TOP VIEW

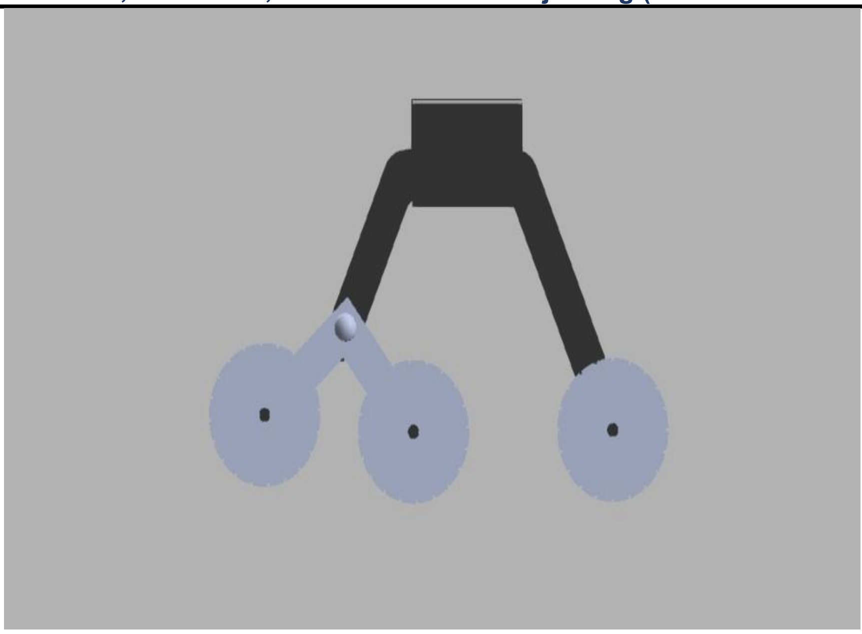


FIG 6.9 ROCKER BOGIE SIDE VIEW

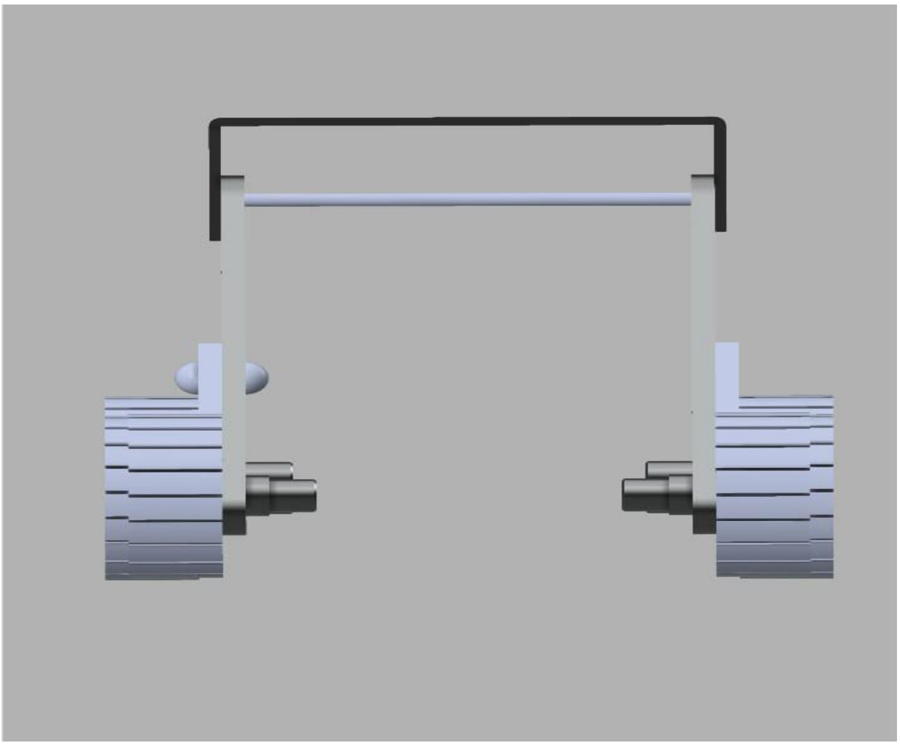


FIG 6.10 ROCKER BOGIE FRONT VIEW

6.3 ANALYSIS

6.3.1 ANSYS WORKBENCH:

Ansys Workbench is the integration and workflow platform that connects Ansys products. The project schematic enables users to configure their simulation processes, optimize exploration through parametric management, and submit jobs to solver both locally and remote, and adds APIs that allow for third-party software.

The six-wheeled rocker bogie mechanism consists of six wheels arranged in a triangular pattern, with two rocker arms connecting each set of two wheels to a central chassis. The rocker arms allow the wheels to move independently over uneven terrain while keeping the chassis level. The entire mechanism is designed to be highly adaptable and capable of traversing difficult terrain without tipping over.

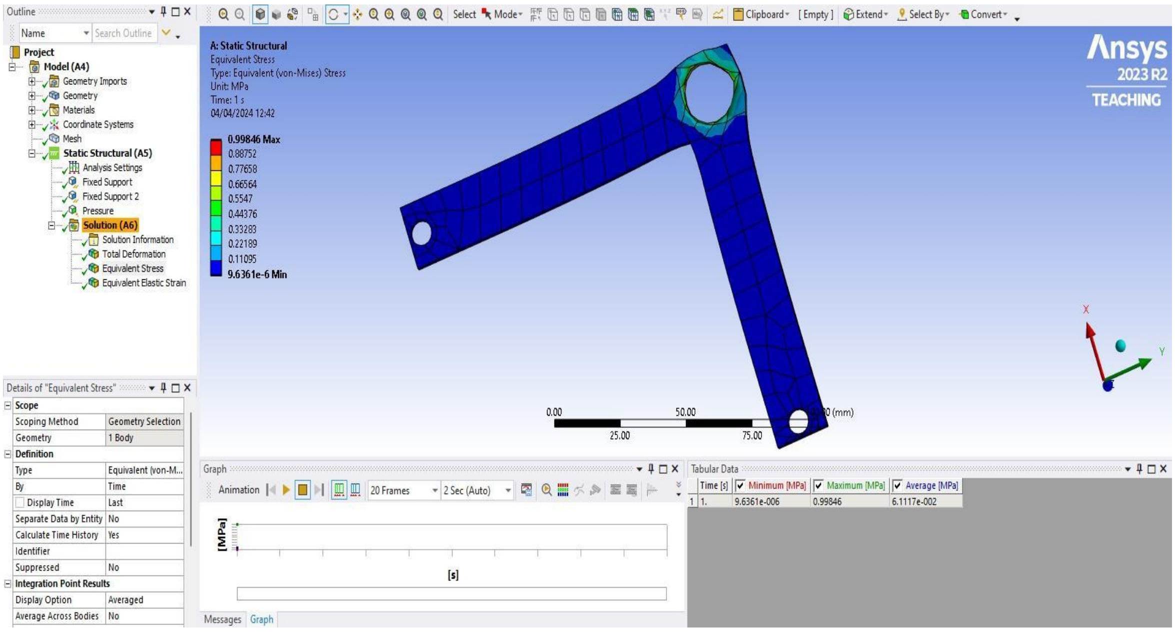


FIG 6.11 EQUIVALENT STRESS OF BOGIE LINK

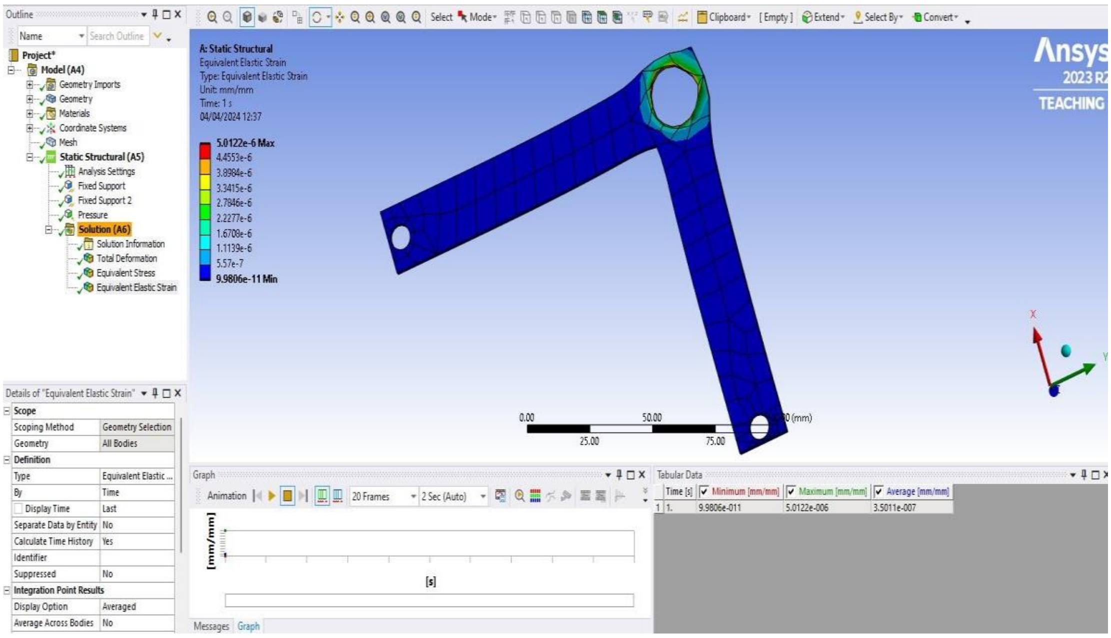


FIG 6.12 EQUIVALENT STRAIN OF BOGIE LINK

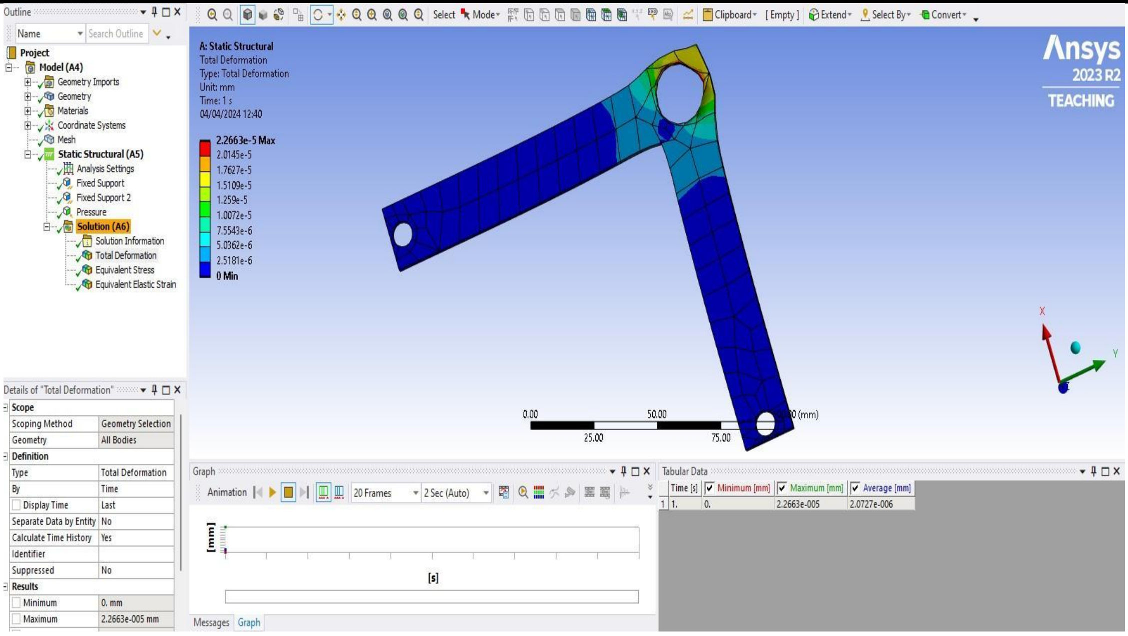


FIG 6.13 TOTAL DEFORMATION OF BOGIE LINK

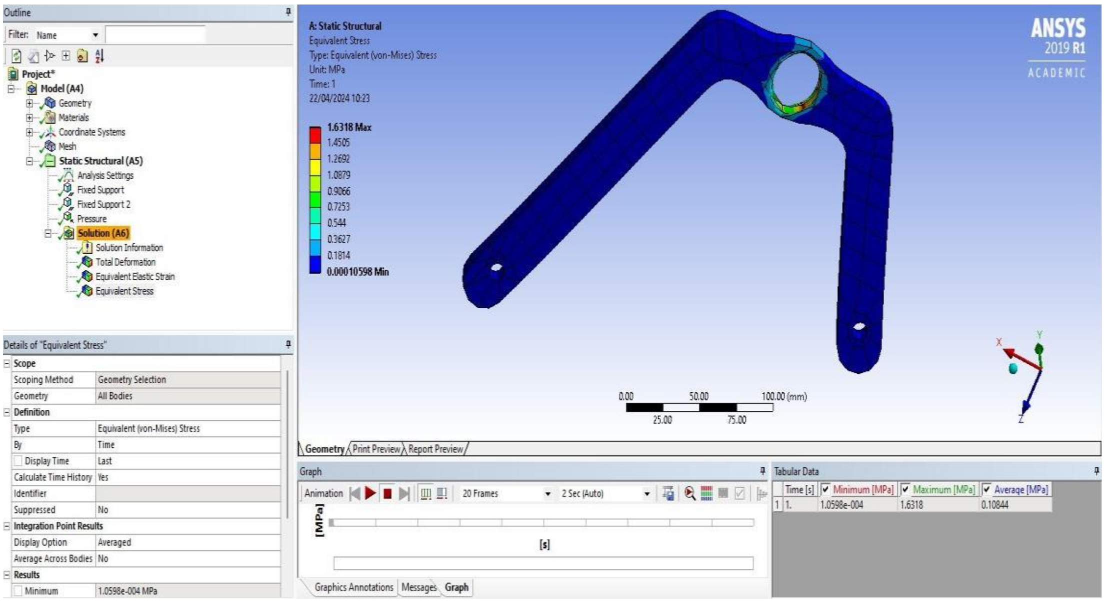


FIG 6.14 EQUIVALENT STRESS OF ROCKER LINK

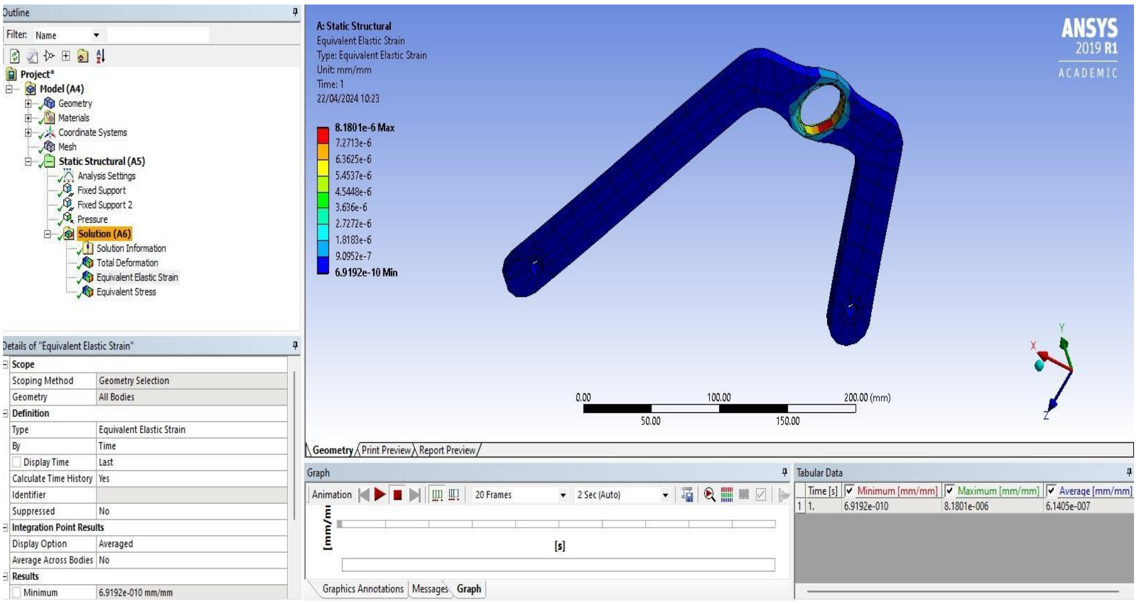


FIG 6.15 EQUIVALENT STRAIN OF ROCKER LINK

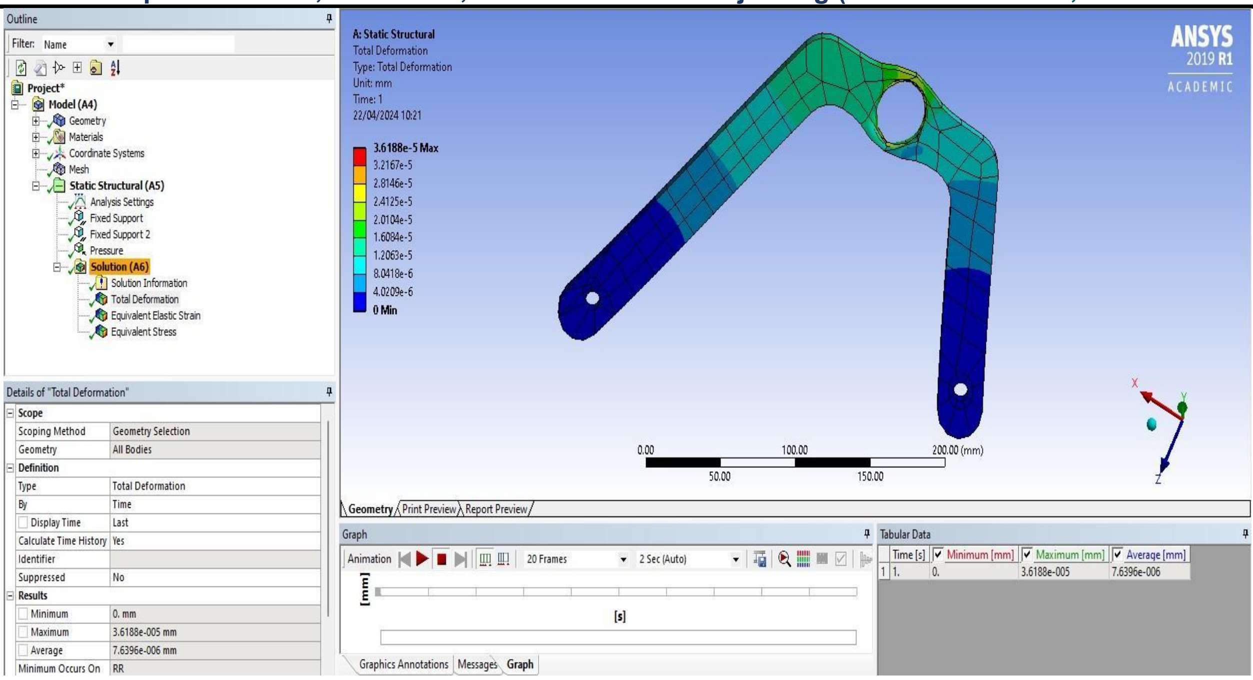


FIG 6.16 TOTAL DEFORMATION OF ROCKER LINK

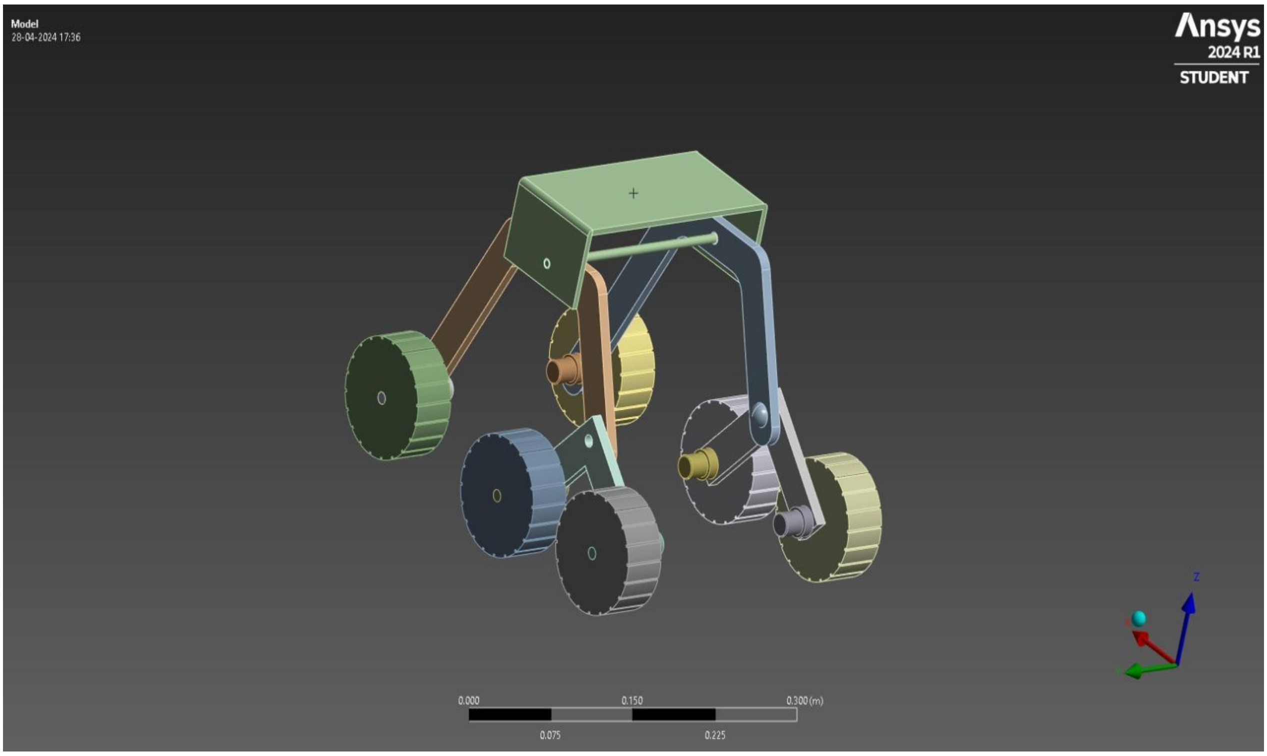


FIG 6.17 ANSYS MODEL OF ROCKER BOGIE

6.3.1.1 MESHING:

The mesh of a six-wheeled rocker bogie mechanism refers to the finite element mesh used in numerical simulations of the mechanism, often conducted with tools like Ansys. The finite element mesh is a discretization of the 3D geometry of the mechanism, where the complex geometry is divided into small, interconnected elements.

The mesh is crucial because it enables the solution of complex mathematical equations that describe the behavior of the mechanism under various operating conditions. By breaking down the geometry into smaller elements, these equations can be solved for each element individually. The results are then combined to provide an overall solution, offering insights into how the entire mechanism will perform in real-world scenarios.

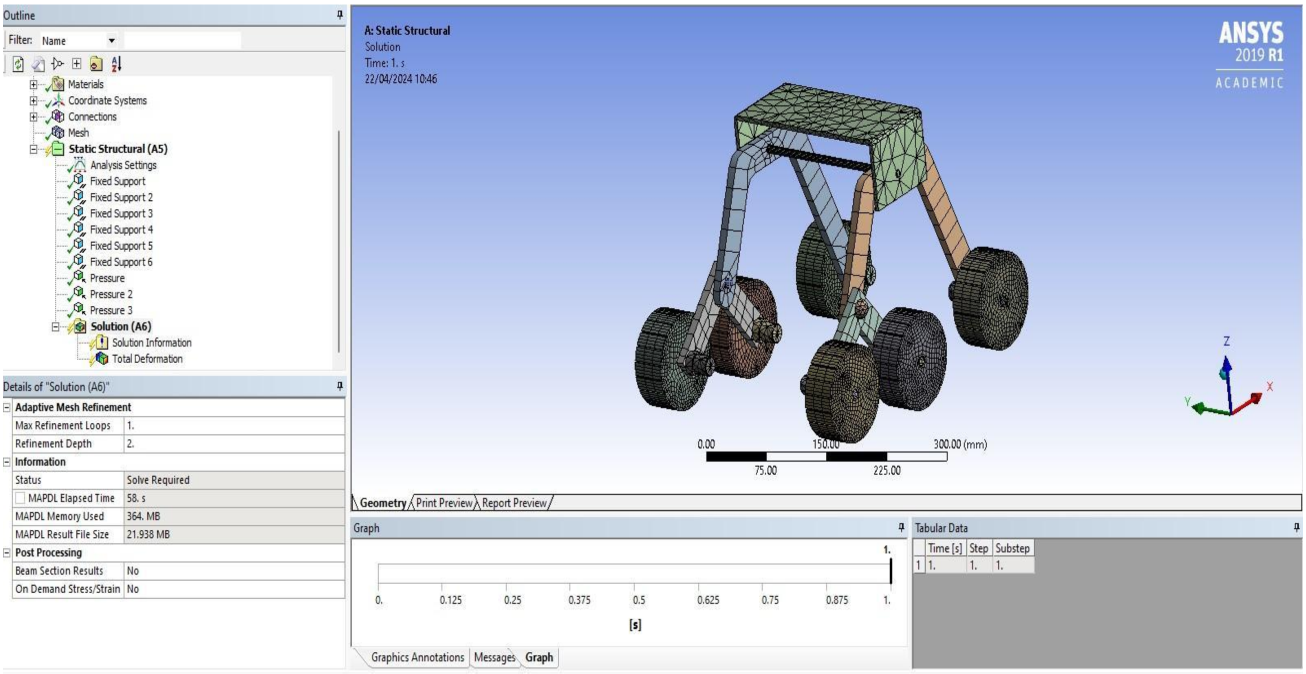


FIG 6.18 MESH OF ROCKER BOGIE

6.3.1.2 TOTAL DEFORMATION OF ROCKER BOGIE:

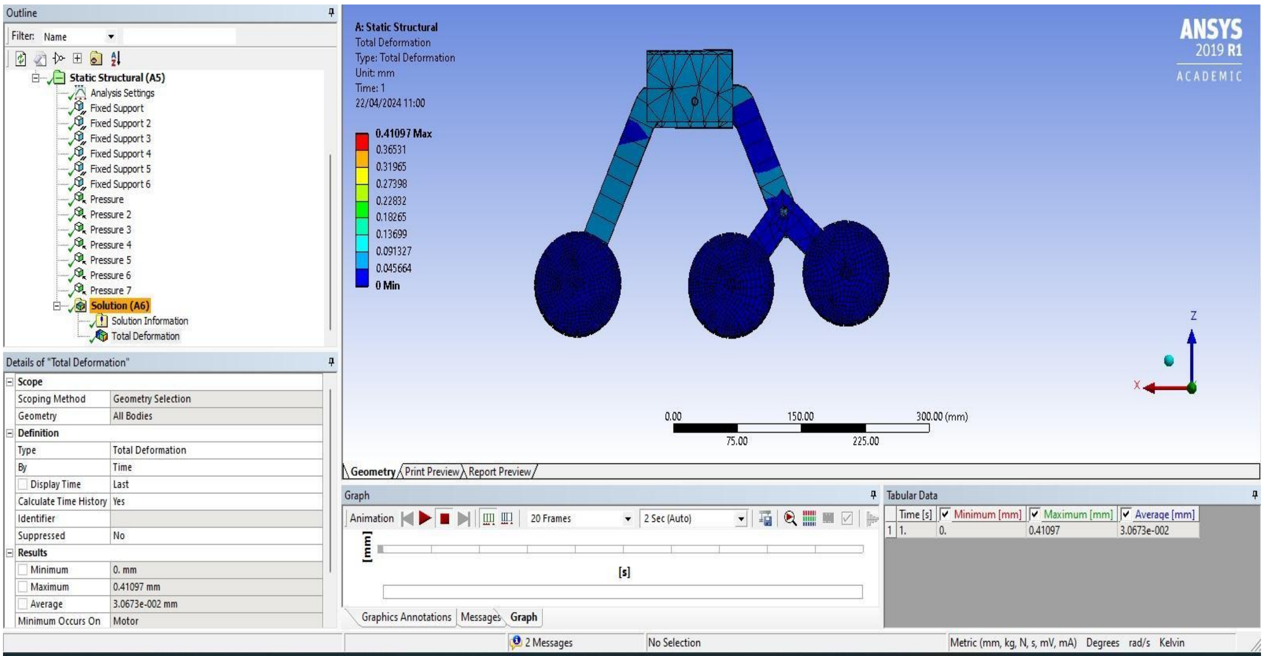


FIG 6.19 TOTAL DEFORMATION OF ROCKER BOGIE SIDE VIEW

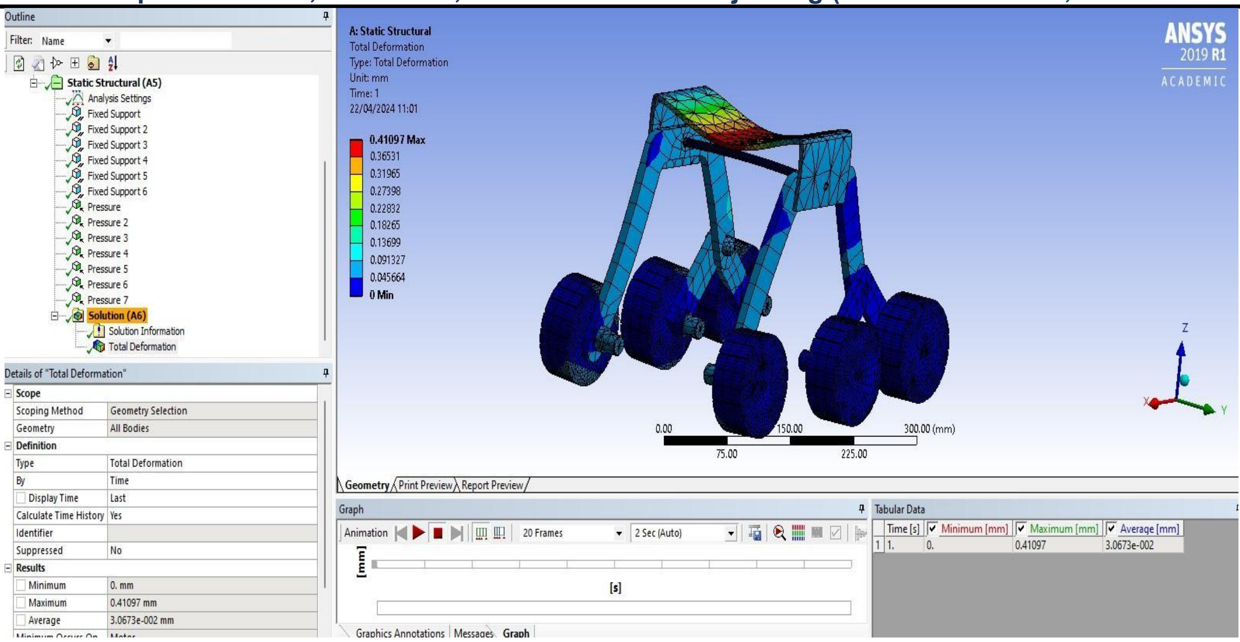


FIG 6.20 TOTAL DEFORMATION OF ROCKER BOGIE ISOMETRIC VIEW

6.4 FABRICATION:

6.4.1 CUTTING

As per the design parameters we have cut the structural steel rod with the help of cutting machine and dimensions of rods is as follows.

6 inches □2 pieces

10 inches□4 pieces

12 inches□2 pieces

14 inches□2 pieces

Fig 6.21 ROD CUTTING

6.4.2 WELDING

Welding is a fabrication process used to join materials, typically metals or thermoplastics, by melting them together and allowing them to cool, forming a strong bond. It is widely employed across various industries, including construction, manufacturing, automotive, aerospace, and shipbuilding.

For our project, we utilized "Arc Welding" to fabricate the vehicle. Arc welding involves creating an electric arc between an electrode and the workpiece, which melts the materials to form a strong, durable weld.

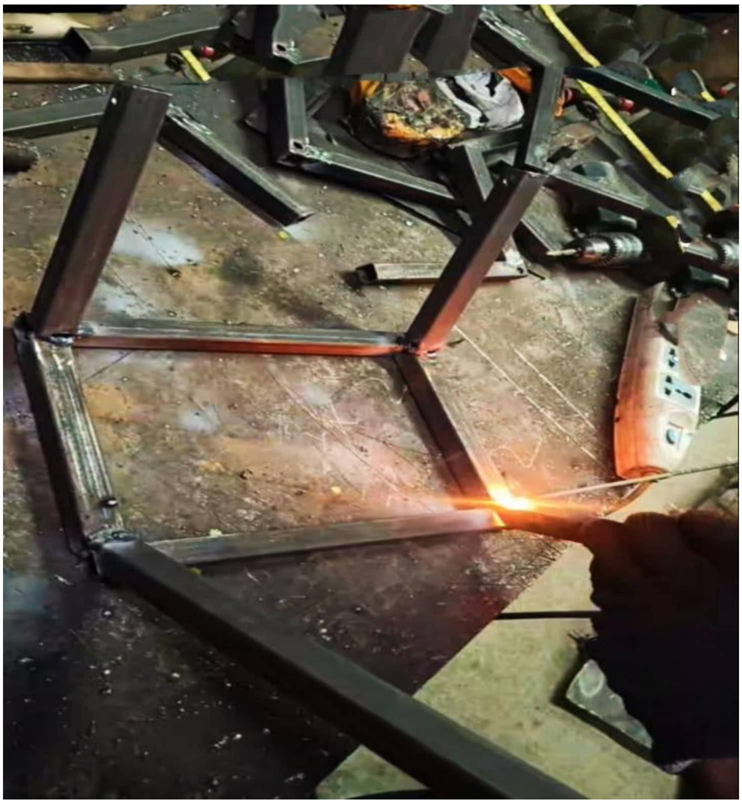


Fig 6.22 WELDING

Fig 6.23 CHASIS FABRICATION

FIG 6.24 TOTAL VEHICLE FABRICATION

CHAPTER-7

CIRCUIT AND CONNECTIONS, WORKING PRINCIPLE

7.1 CIRCUIT:

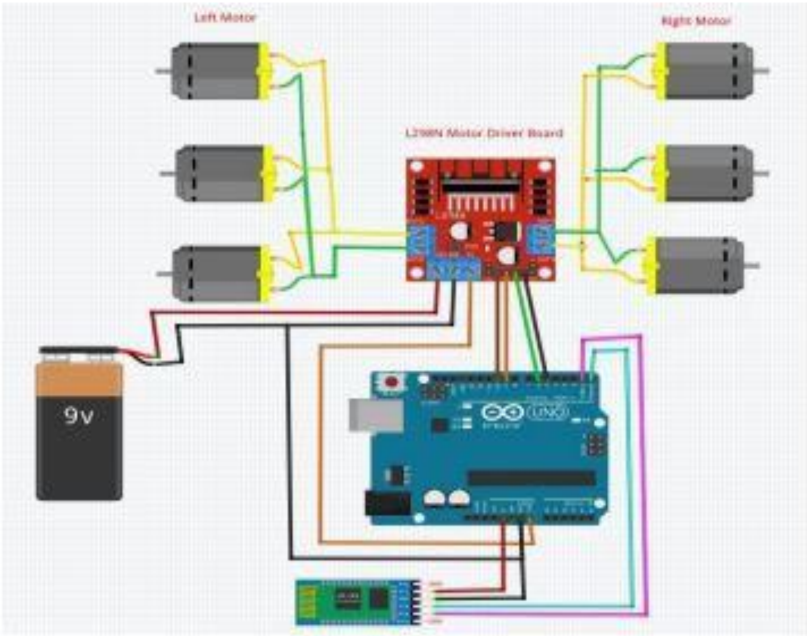


FIG 7.1 CIRCUIT

7.2 CONNECTIONS:

 Power Supply:

- The positive terminal of the battery is connected to the 12V input terminal on the L298N motor driver module.
- The negative terminal of the battery is connected to the GND connection on the L298N.

 Arduino UNO Connection:

- A 5V supply is provided to the Arduino UNO through the VIN port.

- The GND connection is also linked to the Arduino UNO.

 Motor Connections:

- Motors are connected in parallel to the Out1 and Out2 ports of the L298N motor driver.
- An additional set of motors is connected to the Out3 and Out4 ports on the L298N.

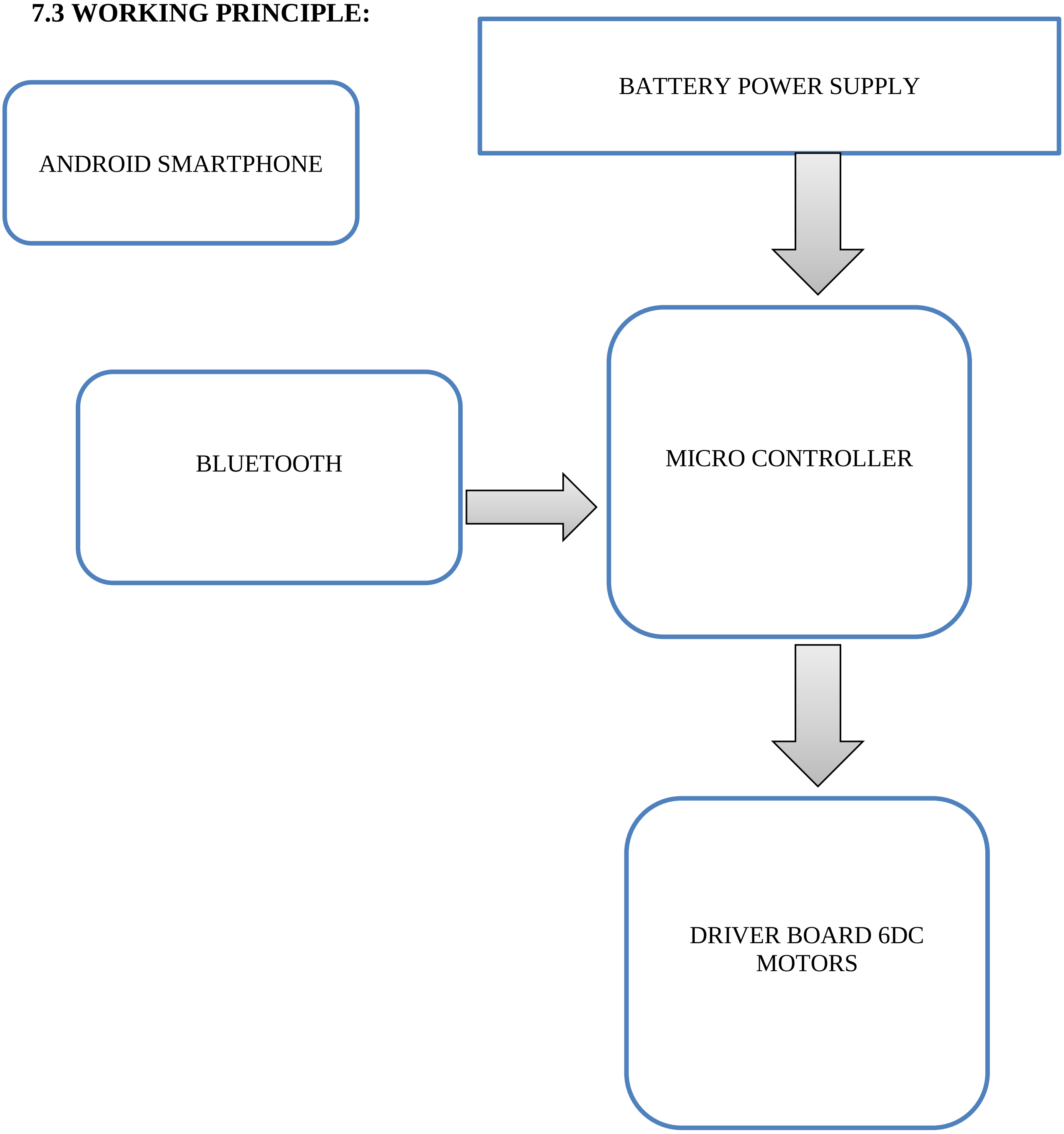
 Motor Control:

- Motor control signals are managed using four input terminals: In1, In2, In3, and In4.
- These terminals are connected to the 10, 9, 7, and 8 pins on the Arduino UNO, respectively.

 Bluetooth Module (HC-05) Connections:

- The HC-05 Bluetooth module is powered by a 5V supply from the Arduino UNO.
- The RXD terminal of the HC-05 is connected to the TXD terminal of the Arduino UNO.
- The TXD terminal of the HC-05 is connected to the RXD terminal of the Arduino UNO.

7.3 WORKING PRINCIPLE:



CHAPTER-8

8.1 CODE:

```
char a;
const int led =
13; void
Robot_Forwar
d()
 {
 digitalWrite(8,1);     //Forward digitalWrite(9,0); digitalWrite(10,1);
 digitalWrite(7,0);
 }

void Robot_Backward()
 {
 digitalWrite(8,0);     //Backward digitalWrite(9,1); digitalWrite(10,0);
 digitalWrite(7,1);
 }

void Robot_Right()
  {
  digitalWrite(8,1);     //Right digitalWrite(9,0); digitalWrite(10,0);
  digitalWrite(7,1);
  }

void Robot_Left()
  {
  digitalWrite(8,0);     //Left digitalWrite(9,1); digitalWrite(10,1);
  digitalWrite(7,0);
  }
void Robot_Stop()
  {
  digitalWrite(8,0);     //Stop digitalWrite(9,0); digitalWrite(10,0);
  digitalWrite(7,0);

  }

void setup()
{

 pinMode(led, OUTPUT);

 pinMode(8,OUTPUT);     //Robot pinMode(9,OUTPUT);
 pinMode(10,OUTPUT
 );
 pinMode(7,OUTPUT);


 Serial.begin(9600);
 digitalWrite(led,HI
 GH); delay(500);
 digitalWrite(led,LO
 W); delay(500);
```

```
 digitalWrite(led,HI
 GH); delay(500);
 digitalWrite(led,LO
 W); delay(500);
 Serial.println("Welcome to Android
 controlled robot"); delay(1000);
}

void loop()
{


 while(Serial.available())
   {
    a = Serial.read();
    delay(10);
   //digitalWrite(led,LOW);
   //Serial.println(c);

    if(a=='f')       //FORWARD
     {
       Serial.println("For
       ward");
       digitalWrite(led,L
       OW);
       Robot_Forward();
       delay(50);
       digitalWrite(led,L
       OW);
     }
    else if(a=='b')       //BACKWARD
     {
      Serial.println("Bac
      kward");
      digitalWrite(led,L
      OW);
      Robot_Backward()
      ; delay(50);
      digitalWrite(led,L
      OW);
     }
    else if(a=='l')       //LEFT
```

```
    {
     Serial.println("L
     eft");
     digitalWrite(led
     ,LOW);
     Robot_Left();
     delay(50);
     digitalWrite(led
     ,LOW);
    }

   else if(a=='r')      //RIGHT
    {
     Serial.println("R
     ight");
     digitalWrite(led,
     LOW);
     Robot_Right();
     delay(50);
     digitalWrite(led,
     LOW);
    }



   else if(a=='s')
    {
      Serial.println("Stop");
      digitalWrite(led
      ,LOW);
      Robot_Stop();
      delay(50);
      digitalWrite(led
      ,LOW);
    }
  }
}
```

CHAPTER-9

EXPERIMENTAL SET UP OF ROCKER BOGIE

FIG 9.1 ROCKER BOGIE WHEN CIRCUIT IS OFF

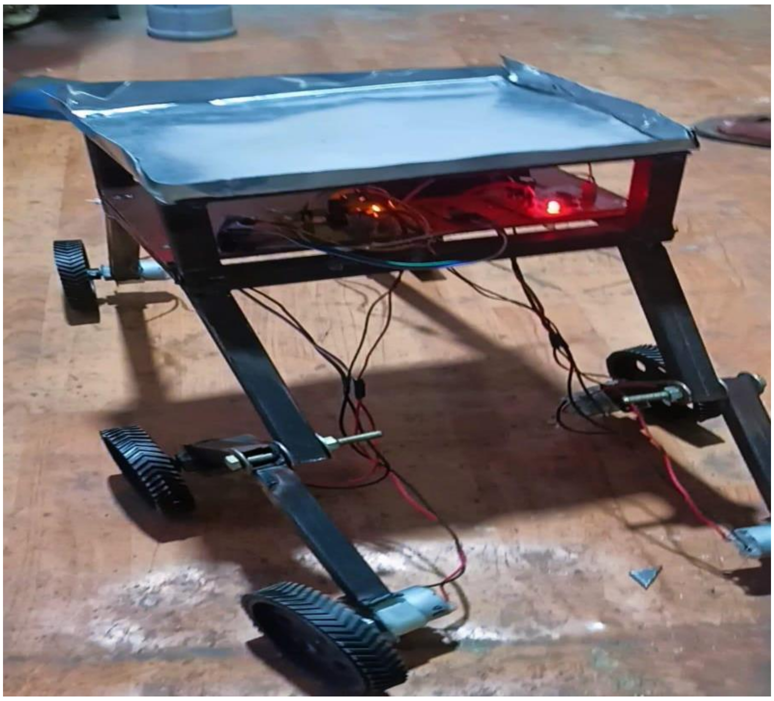


FIG 9.2 ROCKER BOGIE WHEN CIRCUIT IS SWITCH ON

CHAPTER-10

RESULTS AND DISCUSSION OF ROCKER BOGIE MECHANISM

The six-wheeled rocker bogie mechanism is a type of suspension system commonly used in off-road vehicles, particularly in rovers and exploration vehicles designed for extraterrestrial environments like Mars. This mechanism allows the vehicle to traverse rough terrain and overcome obstacles with greater ease, stability, and control compared to other suspension types.

The rocker-bogie mechanism consists of two "rocker" arms, each with two wheels at one end and a pivot point at the other. These rockers are connected to a central chassis by "bogies," which help maintain stability while crossing uneven terrain. Each pair of wheels on the ends of the arms is connected by a differential, ensuring that all six wheels maintain traction and move at the same speed.

One of the key advantages of the six-wheeled rocker bogie mechanism is its ability to traverse rough terrain without getting stuck or tipping over. This is because the mechanism allows the wheels to remain in contact with the ground even when the vehicle encounters steep slopes or large obstacles.

Another advantage of the six-wheeled rocker bogie mechanism is its simplicity and durability. The mechanism is relatively easy to build and maintain, and it can withstand the harsh conditions of off-road environments. This makes it an ideal choice for exploration vehicles, such as Mars rovers.

However, the six-wheeled rocker bogie mechanism has limitations. Its size and weight can make it difficult to transport and maneuver in tight spaces. Additionally, the mechanism can be prone to oscillations at high speeds due to the lack of active damping, which can affect the vehicle's stability and control.

Overall, the six-wheeled rocker bogie mechanism is an effective and reliable suspension system for off-road vehicles. Its ability to traverse rough terrain, maintain stability, and withstand harsh conditions makes it ideal for exploration vehicles and other off-road applications. However, its size, weight limitations, and potential for oscillations at high speeds should be considered during design and implementation.

CHAPTER-11

SUMMARY AND CONCLUSION OF ROCKER BOGIE MECHANISM

11.1 SUMMARY OF ROCKER BOGIE MECHANISM

The six-wheel rocker bogie mechanism is a type of suspension system used in vehicles, particularly in rovers for space exploration. It features six wheels: the middle wheels are mounted on a pivoting rocker arm, while the front and rear wheels are supported by bogies. This design allows the rover to traverse rough terrain without getting stuck or tipping over.

A significant advantage of the rocker bogie mechanism is its ability to keep all six wheels in contact with the ground, even when navigating large obstacles or uneven surfaces. This ensures excellent stability and traction, which is crucial for rovers exploring planets with challenging terrain.

11.2 CONCLUSION OF ROCKER BOGIE MECHANISM

In conclusion, the six-wheel rocker bogie mechanism is an innovative and effective suspension system that has been successfully utilized in various space exploration missions, as well as in military and agricultural vehicles. Its design enables it to handle rough terrain and maintain stability, making it an ideal choice for rovers exploring the demanding environments of other planets. The mechanism's proven performance in diverse applications underscores its versatility and reliability in challenging conditions

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