# DESIGN AND FABRICATION OF SIX WHEELS ROCKER BOGIE MECHANISMS

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Engineering in Mechatronics

by

SRINATH S (39090052)
NEVYA K ABRAHAM (39090032)

**DEPARTMENT OF MECHATRONICS**

**SCHOOL OF MECHANICAL ENGINEERING**

# SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY**
**(DEEMED TO BE UNIVERSITY)**
**Accredited with Grade "A" by NAAC I 12B Status by UGC I Approved by AICTE**
**JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119**

**MAY - 2023**

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Jeppiaar Nagar, Rajiv Gandhi Salai, Chennai - 600119
**www.sathyabama.ac.in**

## DEPARTMENT OF MECHATRONICS

## BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **SRINATH S (39090052), NEVYA K ABRAHAM (39090032)** who carried out the project entitled **"DESIGN AND FABRICATION OF SIX WHEELS ROCKER BOGIE MECHANISMS"** under our supervision from Jul 2022 to May 2023.

**Internal Guide**
**Dr. B KANIMOZHI, M.E., Ph.D.,**

**Head of the Department**
**Dr. S. PRAKASH, M.E., Ph.D.,**

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**Submitted for Viva Voce Examination held on**

**Internal** **External**

# DECLARATION

We **SRINATH S (39090052) and NEVYA K ABRAHAM (39090032),** hereby declare that the Project Report entitled **"DESIGN AND FABRICATION OF SIX WHEELS ROCKER BOGIE MECHANISMS"** done by us under the guidance of **Dr. B KANIMOZHI, M.E., Ph.D.,** at **SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY,** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Mechatronics.

1)

2)

**DATE:**

**PLACE:** Chennai

**SIGNATURE OF THE CANDIDATE**

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## ABSTRACT

To navigate simple terrain while keeping balance, Mars rovers often employ the Rocker bogie system. It is NASA's preferred method for rovers and spacecraft. It has two arms that each have 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. The present Rocker-Bogie rovers have a lot of problems, including being sluggish. In our project, we have concentrated on designing a six-wheeled rocker-bogie suspension system, which benefits from linear bogie motion to prevent rollovers of the entire system during high-speed operations. As a result, the structure is now much more reliable on uneven terrain and can travel at higher speeds while still being able to clear obstacles of the same height. A wheel that is twice as wide as the others are connected to a DC Gear Motor powered by a DC Battery and the operation of this mechanism is controlled by a wire-free remote control with a circuit board. At Catia Software, this rocker bogie mechanism was created. The project intends to enhance several fundamental operations to function more effectively.

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# LIST OF ABBREVIATION

| S.NO. | ABBREVIATION | MEANING |
|---|---|---|
| 1 | NASA | National Aeronautics and Space Administration |
| 2 | DC | Direct Current |
| 3 | MSL | Mars Science Laboratory |
| 4 | MER | Mars Exploration Rover |
| 5 | FIDO | Field Integrated Design and Operations |
| 6 | JPL | Jet Propulsion Laboratory |
| 7 | UK | United Kingdom |
| 8 | UB | Universal Beams |
| 9 | UC | Universal Columns |
| 10 | IPE | Inter-professional Education |
| 11 | HE | Heavy Equipment |
| 12 | HL | Hydrodynamic Lubrication |
| 13 | HP | High Power |
| 14 | US | United States |
| 15 | WF | Wide Flange |
| 16 | HSS | Hollow Structural Section |
| 17 | SHS | Structural Hollow Section |
| 18 | RPM | Revolution per minute |
| 19 | ASK | Amplitude-shift Keying |
| 20 | RV | Recreational Vehicle |
| 21 | AC | Alternating Current |
| 22 | IEC | International Electrotechnical Commission |
| 23 | CD | Compact Disk |
| 24 | CAD | Computer-Aided Design |
| 25 | CAM | Computer-Aided Manufacturing |
| 26 | CAE | Computer-Aided Engineering |
| 27 | PLM | Product Lifecycle Management |

| | | |
|---|---|---|
| 28 | CAx | Computer-Aided Technologies |
| 29 | XML | Extensible Markup Language |
| 30 | NC | Nonconformity |
| 31 | CADAM | Computer-aided stability analysis of gravity dams |
| 32 | CATI | Conception Assistee Tridimensionelle Interactive |
| 33 | CEO | Chief Executive Officer |
| 34 | FEA | Finite Element Analysis |
| 35 | CFD | Computational Fluid Dynamics |
| 36 | MBD | Multibody Dynamics |
| 37 | NASDAQ | National Association of Securities Dealers Automated Quotations |

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# 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 and 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 either side, 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. Presently, both programmes favour.

The Rocker Bogie design, which uses stub axles instead of springs for each wheel, allows the rover to climb over objects like boulders that are up to twice as big as the wheel's diameter while still keeping all six wheels in contact with the ground. As with any suspension system, the tilt stability is determined by the height of the centre of gravity.

Systems using spring-based suspensions are more likely to topple as the loaded side yields. Based on its centre of gravity, the mission's rover, Curiosity, can endure a tilt of at least 50 degrees in any direction without suffering any harm from overturning, while automated sensors prohibit it from tilting beyond 30 degrees. The technology is designed to be used at a slow pace of roughly 10 cm/s to minimise dynamic shocks and resultant damage to the vehicle when navigating major obstacles. The rover has six wheels, and each wheel has its own motor. The two front and two rear wheels each have a separate steering motor that allows the vehicle to turn in place. Additionally, each tyre has studs that provide traction for climbing on rocks and in soft sand.

For each wheel to be able to independently lift a sizable portion of the vehicle's mass when the motors are geared down, the maximum speed of the robots operated in this fashion is limited to avoid as many dynamic effects as feasible. The centre and rear wheels push the front wheels up against an impediment to going over a vertical obstacle face. The front wheel then rotates, raising the front of the vehicle and allowing it to pass over the obstacle. The centre wheel is then lifted up and over while the front wheel pulls against the obstruction and the back tyre presses against it.

The rear wheel is eventually lifted over the obstacle by the front two wheels. Each time a wheel crosses an obstruction, the car advances at a slowed or stopped rate. This is not a problem at the operating speeds at which these vehicles have been operated thus far.

***Fig: 1.1: Vehicle Climbing Steps***

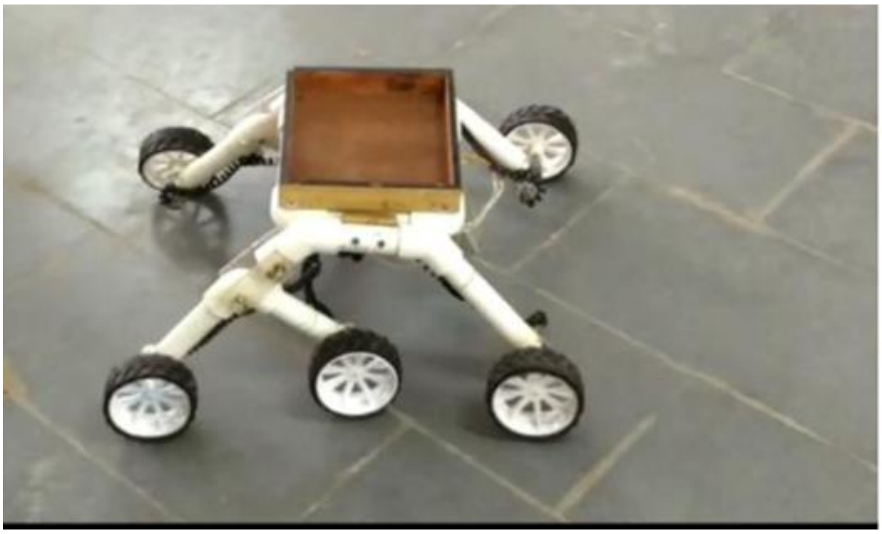

***Fig: 1.2: Vehicle at Stable Surface***

# CHAPTER 2

# LITERATURE SURVEY

This study simulates off-road robots while considering the mechanical behaviour of the locomotion system and how it interacts with its surroundings. For various wheel soil contact behaviours, this interaction is investigated and explained. The study takes into account the slippage, soil compaction, soil shear deformation, and wheel elastic deformation phenomena. Analytical relationships that relate each of the contact force components radial, longitudinal, and lateral forces to relative displacements radial displacement, longitudinal slip ratio, and side slip angle express models of wheel-soil contact. The behaviour of the entire system is then described by coupling these rules to the mechanical system's dynamic equations. These models are put into practise using a visual simulation system that offers a fundamental tool for mechanical system design, path planning, and the construction of control systems [1].

The 'rocker-bogie,' often known as Rocky, is a novel form of vehicle design with a free rocking bogie in front of a master bogie. All vehicles of the Rocky design share the following characteristics: they have a single rigid body, very high ground clearance, all wheels can be turned, and the body is differentially connected between the left and right sides on a transverse axis. There are also no springs or elastic members other than those used with the tyres. It detailed how the design's foundation a linkage system that distributes weight across the wheels over a wide range of individual wheel elevations leads to greater capability for scaling obstacles and superior bump performance [2].

This work achieves an analytical approach to enable the rocker bogie mechanism to ascend a stair. Kinematic analysis and the rocker bogie's posture are established in order to assess whether or not the rocker-bogie might climb up the target stair at a certain length of the links and radii of the wheels. Three wheels coming into contact with the front of the stairway are analysed in the context of the rocker bogie's centre of mass trace. The stair climbs ability graph (SCG), which was determined by a stair's length and height, was produced using these two studies. For a rocker-bogie with a specific size, the SCG displays the climbable stair group. Two rocker bogie prototypes with various connection lengths were created and put to the test on two different staircases. The first prototype rocker bogie with a tiny rocker linkage achieves the same result as the SCG in that it can climb up one stair (length 450 mm, height 150 mm), but not the other (length 300 mm, height 175 mm). Both steps may be climbed using the second prototype rocker bogie with a massive rocker linkage [3].

A planetary rover has returned from Mars with crucial scientific data. Missions with greater scope are anticipated. We need new planning techniques that provide rovers with a high degree of autonomy while they investigate difficult terrain. The planning approach presented in this study is based on a physics-based model of the rover and its surroundings. Plans are created that let a rover carry out a task while expressly taking limitations like power, actuator, wheel slip, and vehicle stability restrictions into account. Results from thorough rover simulations are displayed [4].

One of the initial Discovery-class missions, Mars Pathfinder, would deploy a single spacecraft equipped with a micro rover and a number of experiments on the surface of Mars in 1997. In order to characterise the rocks and soils in a landing area on Mars covering hundreds of square metres, Pathfinder will be the first mission to utilise a rover carrying chemical analysis equipment. This will serve as a calibration point or "ground truth" for orbital remote sensing studies. Pathfinder includes three science instruments in addition to the rover, which also conducts many technological experiments: an alpha proton X-ray spectrometer, an atmospheric structure instrument, and a meteorology package. The stereoscopic image with spectrum filters on an extensible mast. The instruments, rover technology tests, and telemetry system will enable investigations of the surface morphology and geology at submeter to hundred metre scale, the petrology and geochemistry of rocks and soils, the magnetic properties of dust, the mechanics and properties of soil, a variety of atmospheric investigations, and the rotational and orbital dynamics of Mars. The possibility of identifying and analysing a wide range of crustal materials, from the ancient heavily cratered terrain, intermediate-aged ridged plains, and reworked channel deposits, is offered by landing downstream from the mouth of a massive catastrophic outflow channel in Ares Vallis at 19.5°N, 32.8°W. This will allow first order scientific investigations of the early differentiation and evolution of the crust, the development of weathering products, and the early environments [5].

For upcoming Mars missions that call for lengthy traverses and rover-based science investigations, a miniature rover was designed and put into operation at the Jet Propulsion Laboratory, as described in this study. Rocky 7, a tiny rover prototype, has lengthy traverse capabilities, autonomous navigation, and instrument control. Three pieces of scientific equipment are carried by this rover, which can be controlled through the World Wide Web from any computer platform and location. The mobility system, sampling system, sensor suite, navigation and control, onboard science equipment, and the ground command and control system are all described in this study [7].

It is taken into consideration to model and simulate wheeled rovers over unforgiving natural terrains using computer-based methodologies. Testing the consistency of the simulations in scaled testing may be done using physical representations of a prototype vehicle. One of the computer-based methods uses a quasi-static planar or two-dimensional analysis and design tool based on the amount of traction required for the vehicle to move quickly. The Rocker Bogie, an original kinematic design six by six-wheel drive vehicle, was modelled by the computer programme. Prior to the creation of a prototype, the articulation parameters of the Rocker Bogie were optimised using quasi-static software. In a different method, the Rocker Bogie vehicle's dynamics in 3-D space were modelled using commercial software on an engineering desktop. The complicated and nonlinear interaction between the terrain and the tyre was incorporated into the model. The investigation's findings revealed numerical and visual evidence of the rover navigating difficult terrain on Mars, the moon, and the earth. Furthermore, animations of the rover trips were produced. Then, several field and testbed studies were conducted using a prototype vehicle. Then, a connection was made between the physical model and the computer models. The outcomes showed the value of the quasi-static tool for configurational design as well as the 3-D simulation's propensity to accurately forecast the dynamic behaviour of the vehicle over brief travels [8].

Presenting a brand-new laser-based optical sensor system for planetary rovers that detects hazards. Large (1 m) rovers may safely travel at rates of up to 12 cm/second when on Earth or Mars in direct sunshine. Compared to the sensor on NASA's Mars Pathfinder rover, this is at least a five-fold gain. The approach gets over the prior design's restrictions, which required picture differencing to find a laser stripe in direct sunlight. The new technique guarantees that the projected laser light is discernible in a single image, doing away with the need for numerous distinct images. The improvement is noteworthy because any decrease in the time required for picture acquisition or processing enables quicker rover movements. Since power and radiation-hardening requirements result in extremely restricted computing resources, the savings are much more significant in the case of a Mars rover. The research presents a comprehensive analysis of design features and trade-offs for optical danger sensing, which will aid future work in this field [9].

For usage at modest speeds, the Rocker-Bogie Mobility system was created. It can go past obstructions that are roughly the size of a wheel. However, when overcoming a significant obstruction, the vehicle's momentum essentially comes to a complete halt when the front wheel ascends the obstruction. Dynamic shocks are reduced when working at low speeds (more than 10cm/second). Future planetary missions will need rovers to travel at speeds comparable to those of humans (around 1 m/s). The payload or the vehicle might sustain damage from shocks brought on by the front wheel colliding with an obstruction. In contrast to hitting and climbing over most obstacles, the rocker-bogie vehicle is driven in this article such that it may successfully step over them. Only a change in control technology is required to reap the majority of the benefits of this approach without requiring mechanical changes to existing systems. To reap the most benefits and significantly boost the effective operational speed of future rovers, several mechanical adjustments are recommended [10].

On uneven ground, mobile manipulators operating in field contexts will be needed to complete duties, which might push the system dangerously close to or over the edge of a tip-over instability. It is required to specify a measure of stability margin in order to prevent tip-over in an autonomous system or to give a human operator an indicator of approaching tip-over. This study introduces a novel tip-over stability metric that is sensitive to top heaviness and simple to compute: the force-angle stability measure. Systems operating on even or uneven terrain that is susceptible to inertial and external influences can use the suggested metric. A forestry vehicle simulation is used to show how well the measure works [11].

# CHAPTER 3

# AIM AND SCOPE OF SIX WHEELER ROCKER BOGIE MECHANISM

## 3.1 AIM OF SIX WHEELER ROCKER BOGIE MECHANISM

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

## 3.2 SCOPE OF SIX WHEELER ROCKER BOGIE MECHANISM

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. The suspension system utilizes a combination of rigid and flexible linkages designed to maintain constant contact with a hard surface on all wheels regardless of their position or inclination relative to the ground.

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

# CHAPTER 4

# EXPERIMENTAL SETUP, MATERIALS, AND METHODOLOGY OF SIX WHEELER ROCKER BOGIE MECHANISM

## 4.1 MATERIALS USED FOR SIX WHEELER ROCKER BOGIE MECHANISM

### *4.1.1 Structural Steel*

Construction components come in a range of shapes and sizes thanks to the usage of structural steel, a type of steel. An extended beam with a specific cross-section profile is a typical shape for structural steel. The majority of industrialised countries have regulations governing the shapes, dimensions, chemical makeup, and mechanical characteristics of structural steel, such as strengths, storage practises, etc.

Most structural steel designs, such as I-beams, have significant second moments of area, making them extremely stiff in relation to their cross-sectional area and capable of bearing heavy loads without excessive drooping.

The forms that are offered are detailed in several international standards that have been made public, and a variety of specialized and exclusive cross-sections are also offered.

***Fig: 4.1: Steel used for a six wheels rocker bogie mechanisms***

***Fig: 4.2: load-bearing structure of a six wheels rocker bogie mechanism***

In this instance, a steel I-beam was employed to support wood joists within a home.

I. I-beams (I-shaped cross-sections; referred to as Universal Beams (UB) and Universal Columns (UC) in the UK; IPE, HE, HL, HD, and other sections in Europe; Wide Flange (WF or W-Shape) and H sections in the US).

II. Z-shape (one-half flange facing in two different directions)
III. Structural Hollow Section (SHS), also known as HSS-Shape, which has square, rectangular, circular (pipe), and elliptical cross sections.
IV. (L-shaped cross-section) Angle
V. C cross-section (T-shaped cross-section), structural channel, or C beam
VI. Asymmetrical I-beam rail size

(i) Flanged T rail
(ii) Vignoles rail
(iii) Railway rail
(iv) Oblique rail

VII. A bar is a long, rectangular shape that is just barely too narrow to be referred to as a sheet.
VIII. A rod is a round or square piece that is longer than it is wide; words like rebar and dowel are related.
IX. Plate, which are metal sheets 6 mm (or 14 in) or thicker.
X. Open-web joists made of steel

Some parts are manufactured by combining flat or curved plates, while others are made by hot or cold rolling several sections (for instance, the largest circular hollow sections are made from flat plates twisted into a circle and seam-welded).

The terms angle iron, channel iron, and sheet iron were frequently used until wrought iron was replaced by steel for commercial application. Despite being erroneous, they have persisted since the end of the commercial wrought iron era and are still occasionally used informally today to refer to steel sheet, channel stock, and angle stock (compare "tin foil," which is still occasionally used informally for aluminium foil). For situations involving metalworking, precise terminology like angle stock, channel stock, and sheet are used in formal writing.

#### *4.1.2 Wood*

The stems and roots of trees and other woody plants contain the structural tissue known as wood. It is an organic substance made of cellulose fibers, which are strong under tension, contained in a lignin matrix, which is resistant to compression. Some people describe wood as merely the secondary xylem in tree stems, while others define it more widely to encompass the same type of tissue elsewhere, such in a tree's or a shrub's roots. It serves as a structural component of a live tree, allowing woody plants to expand or stand upright on their own. Moreover, it transfers nutrients and water between the roots, other developing tissues, and leaves. Other plant materials with similar qualities can also be referred to as wood, as can products made from wood, woodchips, or wood fiber.

For thousands of years, people have utilized wood as fuel, a building material, to make tools and weapons, furniture, and paper. It has more recently become a feedstock used to make cellophane and other derivatives of cellulose, such as cellulose acetate. As of 2020, the total stock of forests worldwide increased to approximately 557 billion cubic metres.

Given their abundance and lack of carbon emissions, woody materials have received a lot of interest as a source of renewable energy. In 2008, it was estimated that 3.97 billion cubic metres of wood were cut. Construction of furniture and buildings were the two principal uses.

The earliest known plants that have developed wood were found in New Brunswick, Canada, in 2011, between 395 and 400 million years ago.

To ascertain the date an object made of wood was formed, carbon dating and, in some species, dendrochronology can be used.

For thousands of years, people have used wood for a variety of things, such as fuel or as a building material to create things like houses, tools, weapons, furniture, packaging, artwork, and paper. Ten thousand years ago, wood was first used to build structures. The main material used to construct structures like the European Neolithic long house was wood.

Steel and bronze have recently been used to build, enhancing the utilization of wood.

Tree-ring widths and isotopic abundances vary from year to year, providing hints about the environment that prevailed when a tree was chopped down.

***Fig: 4.3: Wood***

### *4.1.3 Natural Rubber*

Here's where "rubber" and "India rubber" redirect. To learn more, go to Rubber (disambiguation). This article is about synthetic rubber substances. See Synthetic rubber for man-made rubber products.

***Fig: 4.4: Rubber***

When first created, rubber, also known as latex, caoutchouc, caucho, or rubber from the Amazon, is made of polymers of the chemical compound isoprene with trace amounts of other organic compounds. One of the top three countries for producing rubber in Thailand. Elastomers are a category for several types of polyisoprene that are utilized as natural rubbers. At the moment, rubber is mostly obtained from the rubber tree (Hevea brasiliensis) or other sources such as latex. The method of "tapping" involves cutting incisions in the bark and drawing out the latex, a sticky, milky, and white colloid. After further processing, Rubber that is appropriate for industrial application is created from latex. In the collecting cup, latex is permitted to clump together in significant areas. The coagulated lumps are collected and converted into dry forms for sale. Natural rubber is frequently used, either alone or in combination with other materials, in a wide range of products and applications. Towards the end of the 19th century, the industrial demand for rubber-like materials started to outpace natural rubber resources, which led to the chemical production of synthetic rubber in 1909.

### *4.1.4 Material Analysis:*

***Table: 4.1: Analysis of Major materials used in Six Wheeler Rocker Bogie Mechanism***

| S.No | Parameters | Structural Steel | Wood | Natural Rubber |
|---|---|---|---|---|
| 1 | Density | 7.8x10^(-6) $Kg/mm^3$ | $400Kg/m^3$ | $1.34g/cm^3$ |
| 2 | Youngs Modulus | 2x10^5 $N/mm^2$ | $8000N/mm^2$ | $104N/m^2$ |
| 3 | Poisson Ratio | 0.3 | 0.3 | 0.5 |
| 4 | Yield Strength | 260 MPA | 15.58MPA | 10-30MPA |

### *4.1.5 Gear Motor*

DC Motor, 12 volts, 60 RPM A basic DC motor and a gearbox are the typical components of geared motors. This has a wide range of robotic applications, including all-terrain robots. The center of the shaft of these motors has a 3 mm threaded drill hole, making it simple to attach them to wheels or other mechanical assemblies.

60 RPM 12V DC geared motors are commonly used in robotics. Very user-friendly and available in standard sizes. Additionally, controlling motors with an Arduino or another similar board doesn't have to be expensive. The most popular L298N H-

bridge module with an onboard voltage regulator can drive this motor, which runs between 5 and 35V DC. Alternatively, you can choose the most precise motor diver module from the wide selection available in our Motor divers category based on your specific needs.

Simple connection is made possible by an internally threaded shaft and nut, and the shaft has threads on both sides. DC Robotics and industrial applications are the perfect fit for geared motors with sturdy metal gearboxes for heavy-duty applications. Extremely user-friendly and offered in regular sizes. The shaft is threaded on both sides and has an internally threaded nut for easy connection.

***Table: 4.2: Specifications and Features of Gear Motor***

| S.NO | SPECIFICATIONS | FEATURES |
|---|---|---|
| 1 | RPM | 60 |
| 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) |

### *4.1.6 Remote Controller*

#### *4.1.6.1 Remote Control Parameters*

Working voltage: 1pc L1028 12V & 9V 23A battery

Working current: ≤15mA

Quiescent current: 0mA

Operating frequency: 315MHz

Chip Type: Fixed Code (2260) Learning Code Ev1527

Oscillation resistance: according to customer requirements (commonly used 4.7)

Modulation method: ASK amplitude modulation

Size: 56.36 x 31.58 x 11.03mm

Button: 4 button

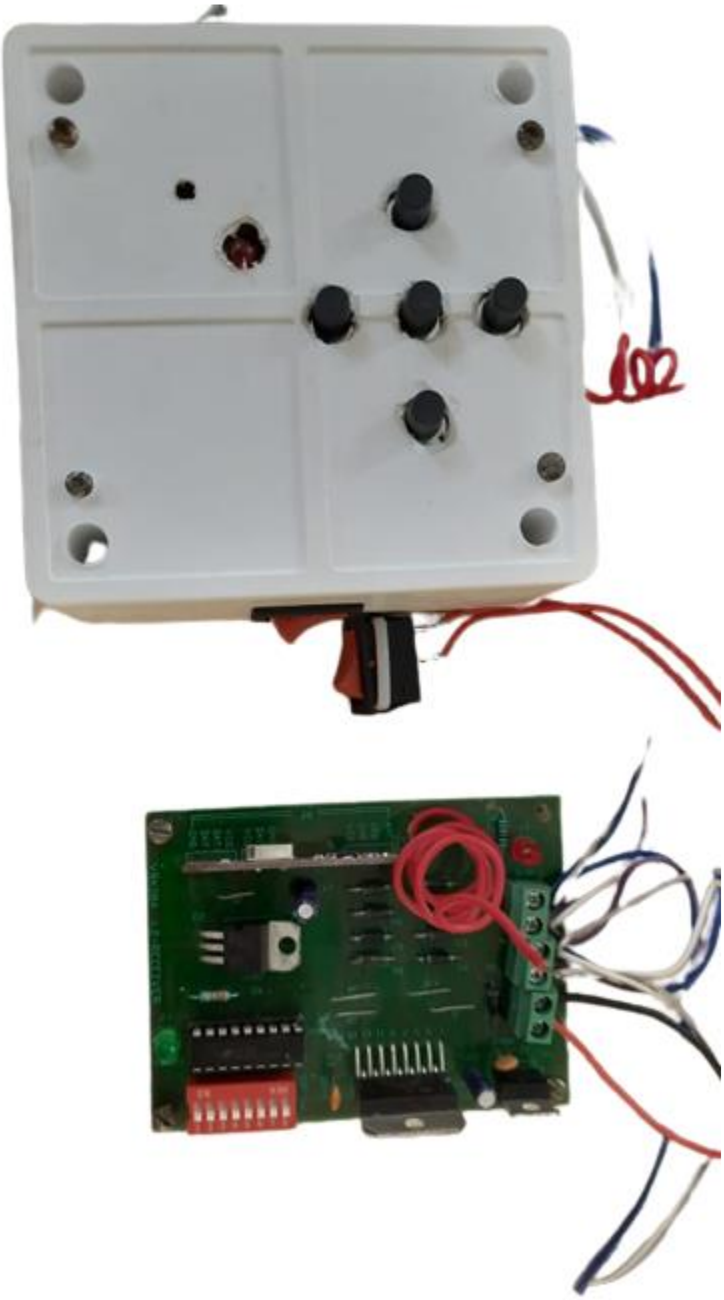

***Fig: 4.5: Remote Controller***

100 m for remote control distance (in an open environment) (The distance is shortened in the presence of an obstruction or interference; please refer to the real distance.)

### *4.1.7 12V Lead Acid Battery*

For individuals who are not familiar with battery science, the selection of 12-volt battery types might be a little overwhelming. The commonality across all 12-volt battery types is that they all supply electricity to your 12V electrical system. Yet, there are major disparities in their capacities, maintenance requirements, and purchase and installation costs.

#### *4.1.7.1 12V Battery*

RV, boat, and other vehicle applications typically employ batteries with a voltage of 12 volts. A battery is a device that employs one or more cells to facilitate a chemical reaction that causes the flow of electrons in a circuit. Batteries are unable to generate power or energy on their own. The only energy that batteries can store is usable energy.

Direct current (DC) electricity, as opposed to the alternating current (AC) power that comes from your home's wall outlets, is what you get from a battery. If required, a power inverter can convert DC electricity to AC power.

You can connect numerous 12-volt batteries either in series or parallel to boost power or storage capacity. For instance, your system will have 24 volts if two 12-volt batteries are connected in series. If you connect these identical 12-volt batteries in parallel, the 12-volt system will still function, but it will be able to power the same device for twice as long as a single 12-volt battery.

Your 12V battery system powers the bulk of your RV's essential features, such as your lights and some appliances. You will utilise this battery system while you are travelling or boondocking, and it will be charged while you are connected to shore power.

#### *4.1.7.2 Lead Acid Batteries*

Lead-acid batteries are the most fundamental kind of 12V battery. They are made of lead plates that are dissolved in acid to form the structure. This results in a chemical reaction that makes it possible to store energy.

A flooded battery is the most common variety of lead-acid battery. You must keep the appropriate amount of water in these batteries for effective operation. This shows that regular maintenance is required for this battery. Flooded lead-acid batteries typically last between two and five years, depending on usage and maintenance.


***Fig: 4.6: Lead Acid Battery***

*4.1.7.3 Alkaline Battery (9V)*

A type of primary battery known as an alkaline battery (IEC code: L) contains an electrolyte with a pH value that is typically potassium hydroxide. These batteries often get energy from reactions between nickel and cadmium, nickel and hydrogen, or both manganese dioxide and zinc metal.

Alkaline batteries provide the same voltage as zinc-carbon batteries of the Leclanché cell or zinc chloride types, but they have a superior energy density and a longer shelf life. The alkaline potassium hydroxide (KOH) electrolyte of the zinc-carbon batteries is in contrast to the acidic ammonium chloride (NH4Cl) or zinc chloride (ZnCl2) electrolyte of the zinc-carbon batteries. Other battery systems also use alkaline electrolytes, but the electrodes in those systems are built of different active materials.


***Fig: 4.7: Alkaline Batteries***

80% of batteries are created in the US and more than 10 billion individual batteries produced worldwide are alkaline. Alkaline batteries represent 46% of total primary battery sales in Japan. Alkaline batteries make up 68% of total battery sales in Switzerland, 60% in the UK, and 47% in the EU, including sales of secondary types of batteries. Zinc (Zn) and manganese dioxide (MnO2), which are both cumulative neurotoxins and can be hazardous at greater doses, are components in alkaline batteries (Health Codes 1). Alkaline batteries have a moderate level of toxicity compared to other battery types.

Several home gadgets, including MP3 players, CD players, digital cameras, toys, torches, and radios, require alkaline batteries.

Waldemar Jungner created the first alkaline batteries in 1899, while Thomas Edison, working separately, created the first batteries with an acid-free electrolyte in 1901. Building on earlier work by Edison, Canadian engineer Lewis Urry created the modern alkaline dry battery in the 1950s utilizing the zinc/manganese dioxide chemistry before beginning work for Union Carbide's Eveready Battery business in Cleveland, Ohio.

When alkaline batteries were first launched in the late 1960s, they shared a surface mercury amalgam layer with the widely used carbon-zinc cells of the time. Its goal was to prevent the undesirable electrolytic action on zinc impurities that would shorten the metal's shelf life and encourage leaking. It was important to significantly increase the purity and uniformity of zinc when reductions in mercury concentration were required by several legislative bodies.

4.1.7.3.1 Chemistry

In an alkaline battery, manganese dioxide (MnO2) acts as the positive electrode while zinc acts as the negative electrode. During discharge, only zinc and MnO2 are utilised; the alkaline potassium hydroxide (KOH) electrolyte is replenished rather than being destroyed. The amount of potassium hydroxide in the alkaline electrolyte doesn't change since the two half-reactions at the electrodes consume and produce an equal quantity of OH anions.

These are the two half-reactions:

The electrode used in an oxidation reaction is known as an anode, which accepts electrons from the cell's reductant:

$Zn_{(s)} + 2\ OH^-_{(aq)} \rightarrow ZnO_{(s)} + H_2O_{(l)} + 2\ e^-$ ($E°_{ox} = +1.28$ V) ---- (1)

Providing e to the cell's oxidizer via the positively charged electrode cathode (reduction process):

$2\ MnO_{2(s)} + H_2O_{(l)} + 2\ e^- \rightarrow Mn_2O_{3(s)} + 2\ OH^-_{(aq)}$ ($E°_{red} = +0.15$ V) ---- (2)

The total reaction (a combination of the cathodic and anodic reactions) is:

$Zn_{(s)} + 2\ MnO_{2(s)} \rightleftharpoons ZnO_{(s)} + Mn_2O_{3(s)}$ ($E°_{cell} = E°_{ox} + E°_{red} = +1.43$ V)

### *4.1.8 Robotic Wheel*

10 cm in diameter and 2 cm in width Your robot's wheels are inexpensive, quick to install, and sturdy. These wheels are very simple to place on motors since they have a 6mm shaft hole with a screw for fitting.

***Fig: 4.8: Robotic Wheel***

*4.1.8.1 Features of Robotic Wheel*

(i) High-Quality Material
(ii) Light-Weight and Durable
(iii) Smooth Surface

***Table 4.3 : Specifications and features of Robotic Wheel***

| S NO | SPECIFICATIONS | FEATURES |
|---|---|---|
| 1 | Loading Capacity (Kg) | 3 |
| 2 | Dhole for BO Motor (mm) | 6 |
| 3 | Weight (gm) | 28 |
| 4 | Wheel Diameter (mm) | 100 |
| 5 | Wheel Width (mm) | 20 |
| 6 | Body Material | Plastic |
| 7 | Grip Material | Rubber |
| 8 | Weight (gm) | 83 |

## 4.2 METHODOLOGY OF SIX WHEELER ROCKER BOGIE MECHANISM

We employ wireless circuits to prevent this issue since traditional robots need more wires or complex circuits, which leads to short circuits and increases the risk of robot damage. As a robot only needs one person to control it, fewer people are needed to run it, reducing the need for additional labour. In general, robots demand more electricity to function, therefore their power consumption rises quickly. It can effortlessly climb any thrust and step with the assistance of its six wheels. This chapter will begin by covering a few prior space exploration rovers and rovers presently in development, as well as the design components and characteristics that made these rovers successful in accomplishing their missions on the lunar surface. The six-wheeler rocker bogie mechanism is a type of suspension system used in vehicles to improve their ability to traverse uneven terrain. The mechanism is commonly used in planetary rovers and other off-road vehicles. Here's an overview of the methodology used in designing and implementing the six-wheeler rocker bogie mechanism:

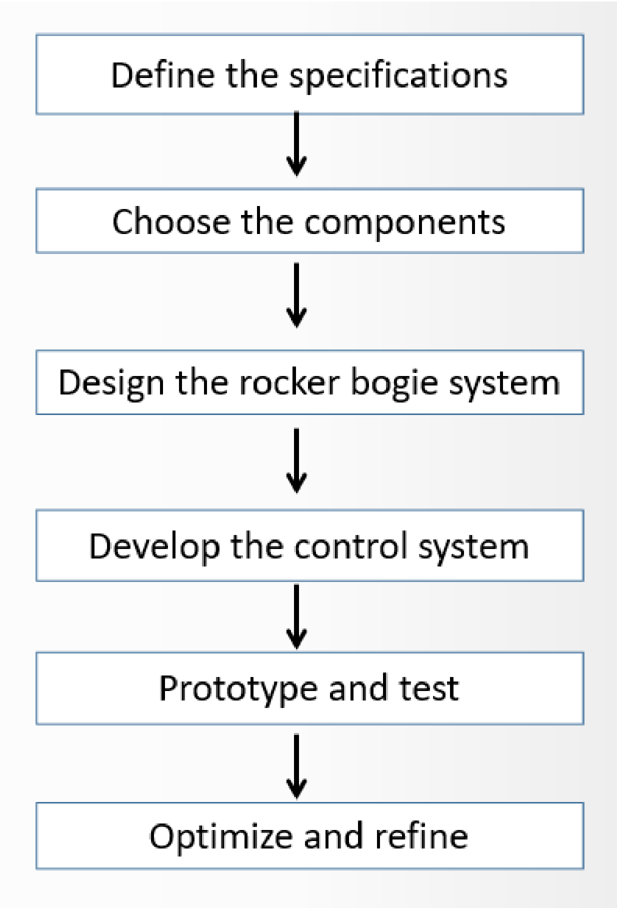


***Fig: 4.9: Methodology of Six Wheeler Rocker Bogie Mechanism***

### *4.2.1 CAD Design Software*

*4.2.1.1 CAD*

Computer-aided design, or CAD, is the use of computer-based software to facilitate design processes. Various categories of engineers and designers frequently use CAD software. CAD software can be used to create both three-dimensional (3-D) models and two-dimensional (2-D) drawings.

*4.2.1.2 CAD V5*

CATIA, short for computer-aided three-dimensional interactive application, is a multi-platform software suite for Computer-Aided Design (CAD), Computer-Aided Manufacturing (CAM), Computer-Aided Engineering (CAE), 3D modelling, and Product Lifecycle Management (PLM). It was developed by the French company Dassault Systèmes.

It is categorised as CAx software and occasionally referred to as a 3D Product Lifecycle Management software package because it includes conceptualization, design, engineering, and production stages as well as other phases of product development. It encourages collaborative engineering using an integrated cloud service, just like the bulk of its competitors, and supports application across disciplines, including surface and form design, electrical, hydraulic, and electronic systems design, mechanical engineering, and systems engineering.

Frank Gehry utilized CATIA to design some of his iconic curvilinear buildings and his business Gehry Technologies was creating their Digital Project software based on CATIA. CATIA is used in a broad range of sectors, from packaging design to aerospace and defense. The program has been coupled with the other software package from the business, 3D XML Player, to create Solidworks Composer Player.

In order to add 3D surface modelling and NC functionality to the CADAM software they were using at the time to develop the Mirage fighter plane, the French aviation company Avions Marcel Dassault originally developed CATIA internally in 1977. CATI (Conception Assistée Tridimensionnelle Interactive) was the division's initial name when Dassault created it in 1981 to develop and market the programme; Francis Bernard, the company's first CEO, modified it to CATIA. Dassault Systèmes and IBM, which had been supplying CADAM to Lockheed since 1978, negotiated a non-exclusive distribution agreement. In 1982, Version 1 became an add-on for CADAM.

In the 1980s, CATIA was more widely used in the aviation and defense sectors by companies like General Dynamics Electric Boat Corp. and Boeing.

Dassault Systèmes purchased CADAM from IBM in 1992, and CATIA CADAM was released in 1993. CATIA was initially ported from one to four Unix operating systems in 1996, then for version 5 in 1998, it underwent a thorough redesign to include Windows NT. Prior to 2000, this caused problems with version incompatibility that caused delays in the production of the Airbus A380, which added an extra $6.1B in costs.

When the Dassault Systèmes 3D EXPERIENCE Platform debuted in 2014, CATIA was made accessible in the cloud.

### *4.2.2 CATIA Design*

***Fig: 4.10: Side view of Six-Wheel Rocker***

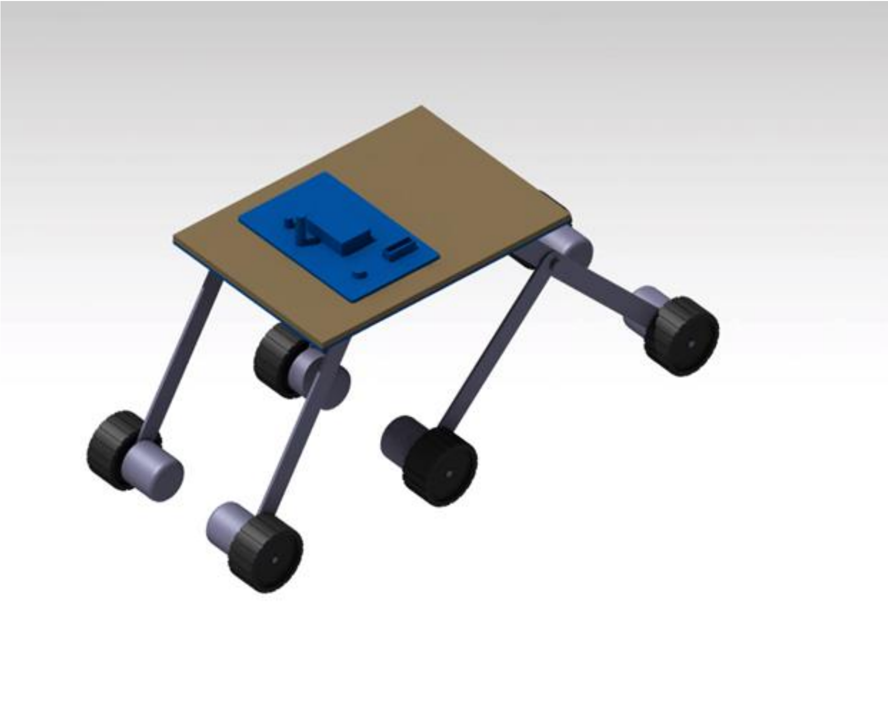

***Fig: 4.11: Isometric view of Six-Wheel Rocker***

### *4.2.3 Analysis Model*

*4.2.3.1 CAE*

The primary tool used in computer-aided engineering is computer-aided design (CAD) software, also referred to as CAE tools. CAE tools are used to assess the effectiveness and robustness of components and assemblies. CAE tools can simulate, validate, and optimise products and manufacturing equipment. CAE systems aim to be important information sources that assist design teams in making decisions. The shipbuilding, aerospace, and automotive industries are just a few that use computer-aided engineering.

Businesses can benefit from CAE systems' assistance. By utilizing reference architectures and their capacity to integrate information perspectives into the business process, this is accomplished. Information is modeled using reference architecture, particularly for product and industrial models.

The application of computer technology in engineering has been referred to as CAE in a manner that goes beyond engineering analysis. Jason Lemon, the company's creator in the late 1970s first used the phrase with this meaning. Nonetheless, the words CAx and PLM are more often used nowadays to refer to this concept.

CAE applications include:

i. Finite Element Analysis stress analysis on parts and assemblies (FEA)
ii. Computational Fluid Dynamics for thermal and fluid flow analysis (CFD)
iii. Kinematics and Multibody Dynamics (MBD)
iv. Process simulation analysis tools for casting, molding, and die press forming activities
v. Product or process improvement.
vi. Every endeavor requiring computer-aided engineering typically includes three phases:
vii. Pre-processing is the process of establishing the model and the environmental parameters that will be applied to it (usually a finite element model, though facet, voxel, and thin sheet approaches are also employed);
viii. An analysis solver (often used by powerful computers);
ix. Results post-processing (using visualization tools).

Iterations of this cycle are performed manually or with the aid of commercial optimization tools, frequently repeatedly.

#### *4.2.4 Ansys*

The corporate headquarters of the American company Ansys, Inc. are in Canonsburg, Pennsylvania. The company produces and markets CAE/multiphysics engineering simulation software and offers its products and services to customers all over the world.

In 1970, John Swanson founded Ansys. He gave venture capitalists his ownership stake in 1993. Ansys went public on the NASDAQ in 1996. In the 2000s, the company acquired a number of additional engineering design firms, expanding its access to fluid dynamics, electronics design, and physics analysis capabilities. Ansys joined the NASDAQ-100 index as a component on December 23, 2019.

When employed for Westinghouse Astronuclear Laboratory in the 1960s, John Swanson originally had the idea for Ansys. Engineers at the time manually carried out finite element analysis (FEA). Because Westinghouse disapproved of Swanson's plan to automate FEA by creating general-purpose engineering software, Swanson left the organization in 1969 to work independently on the project. The next year, he established Ansys under the name Swanson Analysis Systems Inc. (SASI), operating from his Pittsburgh farmhouse.

Swanson utilized punch cards and an hourly-rented mainframe computer to create the first version of the Ansys software. Swanson worked as a consultant for Westinghouse under the agreement that whatever code he created for Westinghouse may also be used in the Ansys product line. Westinghouse also used Ansys for the first time.

*4.2.4.1 Analysis*

The Ansys model of a six-wheeled rocker bogie mechanism is a virtual representation of a complex mechanical system used in space exploration vehicles such as NASA's Mars rovers. The model is used to simulate the behavior and performance of the mechanism under various operating conditions.

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.

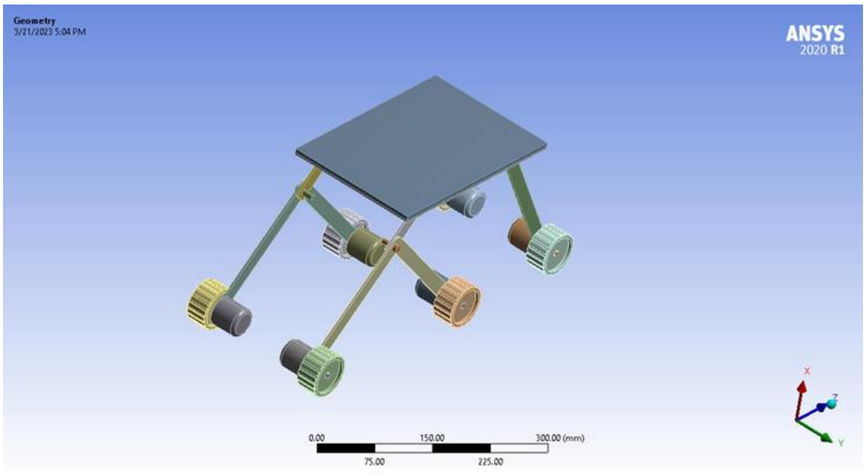


***Fig: 4.12: Ansys Model of Six-WheelRocker***

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

The mesh is important because it allows for the solution of complex mathematical equations that describe the behavior of the mechanism under various operating conditions. By dividing the geometry into small elements, the equations can be solved for each element individually and then combined to provide an overall solution for the entire mechanism.

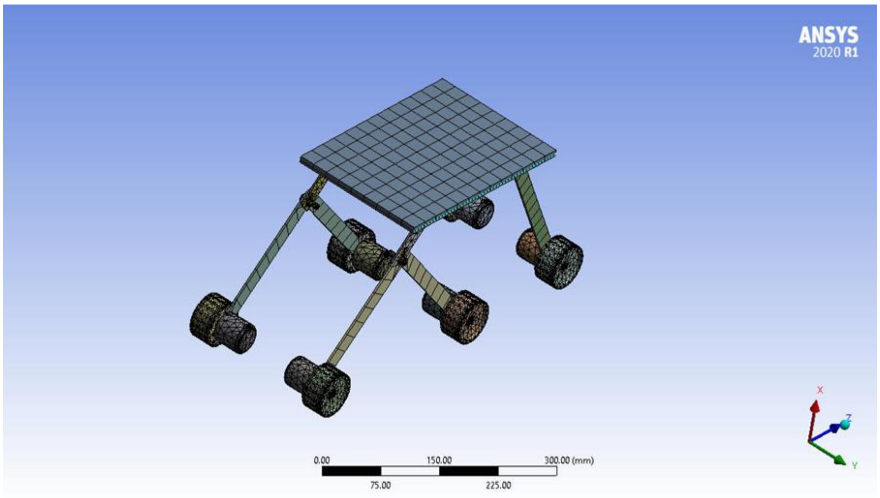


***Fig: 4.13: Mesh of Six-Wheel Rocker***

In the case of the six-wheeled rocker bogie mechanism, the fixed support would typically be applied to the main chassis of the mechanism. This would prevent the chassis from moving or rotating relative to the larger rover structure, while still allowing the wheels and rocker arms to move freely over uneven terrain.

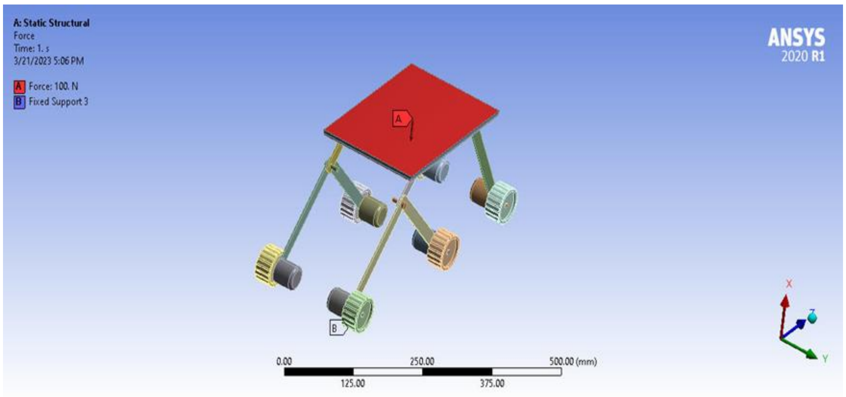


***Fig: 4.14: Fixed Support of Six-Wheel Rocker***

Total deformation is an important parameter in the design and analysis of mechanical systems like the six-wheeled rocker bogie mechanism, as it can help to identify areas of the mechanism that may be prone to excessive stress or failure. By analyzing the total deformation, engineers can identify areas of the mechanism that are experiencing large amounts of strain and take steps to mitigate these issues before they lead to failure.

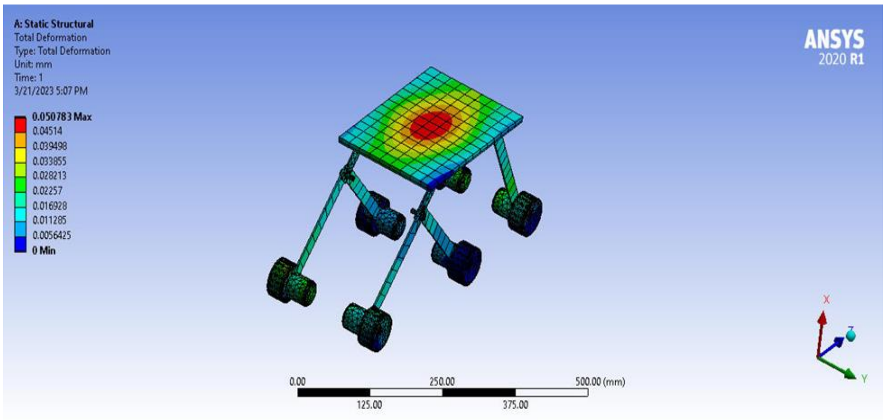


***Fig: 4.15: Total Deformation of Six-Wheel Rocker***

The equivalent strain is a useful parameter for assessing the performance and durability of the six-wheeled rocker bogie mechanism, as it can provide valuable insights into the behavior of the mechanism under different operating conditions. Engineers can use the equivalent strain to identify areas of the mechanism that may need to be reinforced or redesigned to improve its performance and longevity.

In numerical simulations, the equivalent strain is typically visualized using color maps or contour plots that show the magnitude and distribution of the strain across the mechanism's geometry.

This information can be used to identify areas of the mechanism that are experiencing high levels of stress or strain, and to optimize the design to improve its performance and durability.

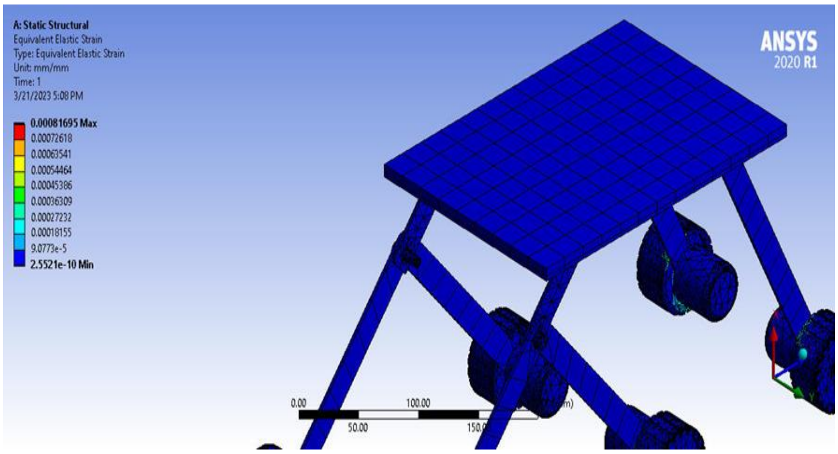


*Fig: 4.16: Equivalent Strain of Six-Wheel Rocker*

The equivalent stress is an important parameter to consider in the design and analysis of the six-wheeled rocker bogie mechanism, as it can help to ensure that the mechanism is safe, reliable, and performs as intended under a wide range of operating conditions. By analyzing the equivalent stress, engineers can identify areas of the mechanism that may need to be reinforced or redesigned to improve its performance and longevity.

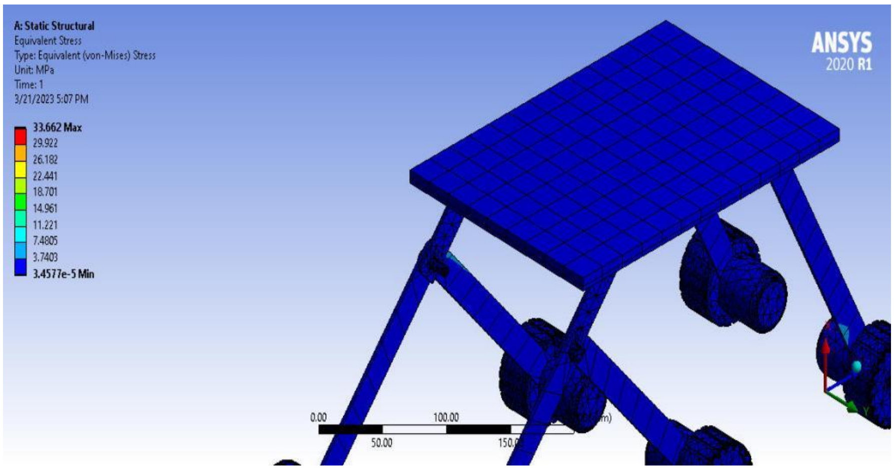


*Fig: 4.17: Equivalent Stress of Six-Wheel Rocker*

4.3 EXPERIMENTAL SETUP OF SIX-WHEELER ROCKER BOGIE MECHANISM

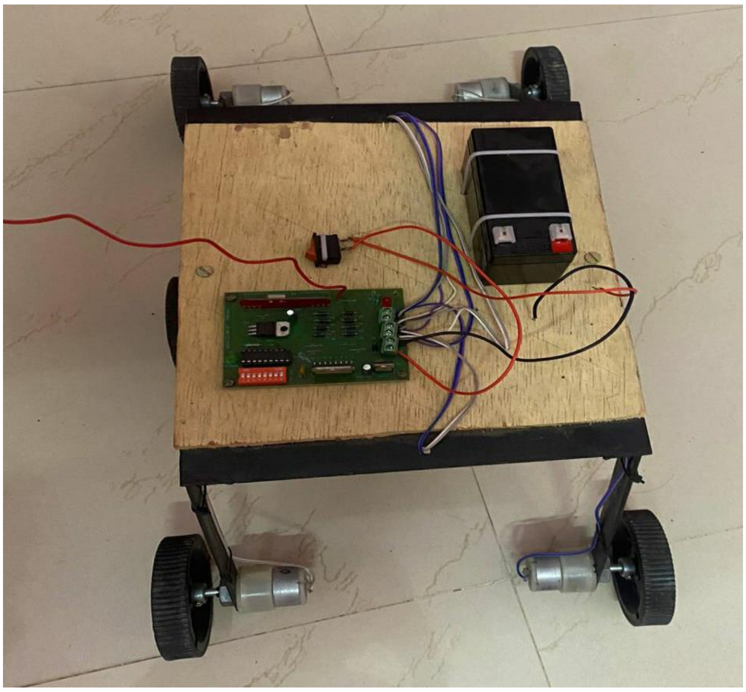

***Fig: 4.18: Top View of Six Wheeler Rocker Bogie Mechanism***

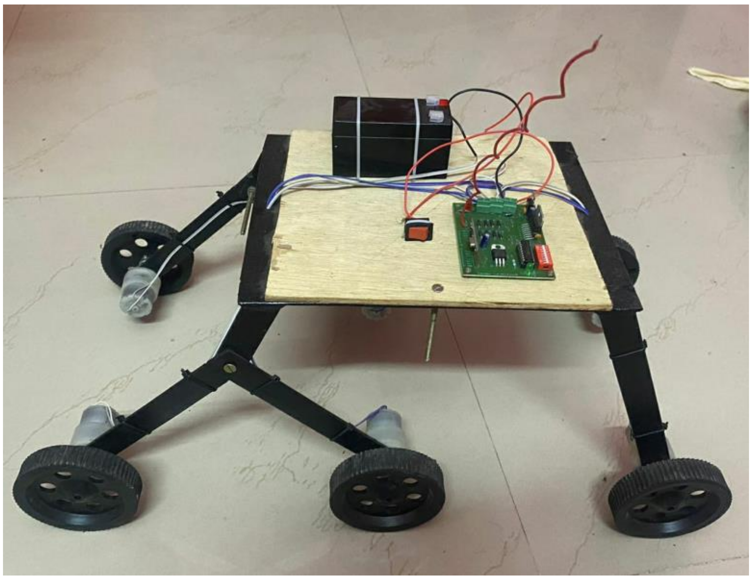

***Fig: 4.19: Side View of Six Wheeler Rocker Bogie Mechanism***

# CHAPTER 5

# RESULTS AND DISCUSSION OF SIX-WHEELER 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 extra-terrestrial environments like Mars. This mechanism allows the vehicle to traverse rough terrain and overcome obstacles with greater ease, stability, and control than other types of suspensions.

The rocker-bogie mechanism consists of two arms, each with two wheels at one end and a pivot point at the other end. The arms are connected to a central chassis by two rockers, which allow the vehicle to maintain stability while crossing uneven terrain. The wheels on the end of each arm are also connected by a differential, which ensures 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 if the vehicle encounters steep slopes or large obstacles. Additionally, the differential ensures that all six wheels maintain traction, which helps to prevent slipping and sliding.

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 vehicles designed for exploration, such as the Mars rovers.

However, the six-wheeled rocker bogie mechanism is not without its limitations. One major drawback is its size and weight, which can make it difficult to transport and maneuver in tight spaces. Additionally, the mechanism can be prone to oscillations at high speeds, 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 an ideal choice for exploration vehicles and other types of off-road vehicles. However, its size and weight limitations and potential for oscillations at high speeds should be considered when designing and implementing this mechanism in vehicles.

# CHAPTER 6

# SUMMARY AND CONCLUSION OF SIX WHEELER ROCKER BOGIE MECHANISM

## 6.1 SUMMARY OF SIX WHEELER ROCKER BOGIE MECHANISM

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

One of the key advantages of the rocker-bogie mechanism is its ability to keep all six wheels on the ground, even when driving over large obstacles or uneven terrain. This provides excellent stability and traction, which is critical for a rover exploring a planet with little or no atmosphere.

## 6.2 CONCLUSION OF SIX WHEELER ROCKER BOGIE MECHANISM

In conclusion, the six-wheel rocker bogie mechanism is an innovative and effective suspension system that has been successfully used in multiple space exploration missions, military vehicles, and agriculture. Its ability to traverse rough terrain and maintain stability makes it an ideal choice for rovers exploring the challenging terrain of other planets. The six-wheel rocker bogie mechanism is an innovative and effective suspension system that has been successfully used in multiple space exploration missions, military vehicles, and agriculture. Its ability to traverse rough terrain and maintain stability makes it an ideal choice for rovers exploring the challenging terrain of other planets.

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