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Design and Development of an Autonomous Rover Application using A Rocker-Bogie Mechanism In Agriculture

Rutvik Sandbhor, Sanket Kachale, Aditya Bhosale, Adhiraj Gaikwad,
Prof. Kundlik Kshirsagar, Prof. Pravin Sharma
Department of Mechanical Engineering
Dr. D Y Patil Institute of Technology, Pimpri, Pune, India
rutviksandbhor19@gmail.com, skachale43@gmail.com, adityachandanbhosale@gmail.com
20511460.dypit@dypvp.edu.in, kundlik.kshirsagar@dypvp.edu.in, pravin.sharma@dypvp.edu.in

Abstract: *The crucial topic of upgrading the rover over its earlier designs is covered in the project work "STUDY ON ROCKER ROVER AND ITS IMPLEMENTATION IN THE FIELD OF AGRICULTURE." The ROCKER rover was intended for use on similar excursions that require it to function in challenging conditions, such as the Moon's surface. However, the use of the rocker rover can be expanded even further in fields of employment where the land has to be used for operations, such as agricultural farming. Our research focuses on how the rocker rover can be modified for use in farming, greatly increasing the automation of the agricultural sector. The rover's body is entirely composed of PVC to boost.*

With the introduction of cutting-edge technologies, agricultural practices are changing with the goal of enhancing sustainability, accuracy, and efficiency. The design and construction of an autonomous rover with a rocker-bogie suspension system specifically intended for agricultural applications is the main goal of this study.

When doing in-situ scientific investigation of goals that are separated by several metres to tens of km, rocker bogie are crucial. The complicated mobility designs of today use numerous wheels or legs. They are vulnerable to mechanical failure brought on by Mars' hostile atmosphere. a four-wheeled rover with a high degree of mobility suspension system that is effective in navigating uneven terrain. The main mechanical characteristic of the rocker bogie design is how simple its drive train is—it only requires two motors to move. Because both motors are housed inside the body, where heat variance is minimised, dependability and efficiency are raised. Because there aren't many barriers on natural terrain that call for the rover to use all of its front wheels, four wheels are used.

Keywords: Rocker-Bogien Mechanism-Precision Agriculture-Crop Monitoring-Autonomous Farming

I. INTRODUCTION

The term "bogie" refers to the links that have a drive wheel at each end. Bogies were commonly used as load wheels in the tracks of army tanks as idlers distributing the load over the terrain. Bogies were also quite commonly used on the trailers of semi-trailer trucks. A rover, or occasionally a planetary rover, is a space exploration vehicle designed to move across the surface of a planet or other celestial body. The rocker-bogie suspension design has become a proven mobility application known for its superior vehicle stability and obstacle-climbing capability.

Trailing arm suspensions are now preferred in both applications. The links with a drive wheel at either end are referred to as "bogies." on order to evenly distribute the load over the terrain, army tanks frequently used bogies as load wheels on their tracks. Additionally, bogies were frequently utilised on semi-trailer vehicle trailers. Trailing arm suspensions are now preferred in both applications. Because the rocker-bogie design does not have stub axles or springs for each wheel, the rover may climb over objects up to twice as big as the wheel's diameter while maintaining all six wheels on the ground, such as boulders. The centre of gravity's height determines the tilt stability, just like it does for any suspension system.

Two rocker arms enable the simple drive train, which is the main mechanical characteristic of the Rocker Bogie design. The rear wheels press the obstruction against the front wheels so that they can pass it. Because of its improved vehicle stability and capacity to climb obstacles, the rocker-bogie suspension design has gained popularity over the last ten years as a reliable mobility application.

The system was successfully flown as a component of Mars Pathfinder's Sojourner rover after multiple technological and research rover installations. Because of its long history, the utilisation of a rocker-bogie suspension was the natural choice when the Mars Exploration Rover (MER) Project was first proposed. The MER presented a challenge to build a lightweight rocker-bogie suspension that would allow the mobility to deploy into a configuration that would allow the rover to safely exit the lander and explore the Martian surface while also stowing inside the restricted area available.

You want the construction of a robot to be as straightforward as feasible. Although most of the time you wouldn't need one, there are a few situations in which one can't be avoided. The links with a drive wheel at either end are referred to as "bogies."

In order to distribute the load throughout the terrain, army tank tracks frequently employed bogies as load wheels. Semi-trailer truck bogies were also frequently utilised on their trailers. Trailing arm suspensions are now preferred in both applications. Because the rocker-bogie design eliminates the need for springs or stub axles on each wheel, the rover can climb over objects up to twice as large as the diameter of the wheel while maintaining all six wheels.

NASA has started a mission to explore Mars. Pathfinder is the first rover explorer in this program. In the future, rovers will need to travel several km over several months, handling samples of rock and soil. They'll also need to be somewhat self-sufficient. The ideal rovers for these missions are most likely those having a rocker-bogie base . The Mars Exploration Rover (MER) Project selected a rocker-bogie suspension due to its effective obstacle climbing capability .A six-wheeled vehicle's rocker-bogies suspension system and differential allow it to passively keep all six wheels in contact with the ground when driving over highly uneven terrain . The first advantage is that the whales' ground pressure will be equal.

This is crucial in soft terrain since too much ground pressure might cause the car to sink into the pavement. The second benefit is that all six wheels will stay in contact with the ground and bear weight while ascending over difficult, uneven terrain, aiding in the vehicle's progress. The suspension mechanism of a rocker bogie consists of six independently powered wheels fixed to a frame . The main body of the frame is joined to two rocker arms. The system's longest link is the rockerarm. Every rocker has a secondary rocker, known as a bogie, attached to one end and a rearwheel attached to the other.

A free pivoting joint connects the bogie to the rocker, and it has drive wheels at each end. The body's pitch angle is determined by averaging the pitch angles of the rockers, which are attached to the main body through a differential. Additionally, it must absorb the impact loads when moving across uneven terrain.

II. LITERATURE REVIEW

Our research project's idea is to develop a rocker bogie drive system that is modelled after NASA's. The suspension system known as rocker-bogie, which NASA designed and installed in the Mars Pathfinder and Sojourner rovers, is credited to IARJSET. Even on uneven conditions, the robot's rocker-bogie suspension system passively maintains all six of its wheels in touch with the ground. Strong traction and manoeuvrability result from this (Harrington & Voorhees).

Currently NASA's authorised design for wheeled mobile robots is the rocker-bogie suspension system, mostly because of its robust or resilient qualities to deal with impediments and because it evenly distributes the cargo over its six wheels at all times.

It can also be used for other things, such operating on uneven terrain and climbing stairs. Although it had several benefits, one of the main drawbacks is that the mechanism must rotate when and where it is needed. Individual motors for each wheel makes rotation feasible, but this adds to the expense and complexity of the design. Here, an effort was made to alter the current design by adding a gear-type steering mechanism that will be powered by a single motor, which simplifies the design and lowers the system's overall and operating costs.

This task involved designing the suggested steering mechanism, modelling it in CATIA (V-5), and using ANSYS to analyse the static analysis for the suggested torque state of the motor. Every analysis result was examined for static

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analysis .

The idea and parameter design of a robust, overhang-capable modular robot that complies with stair climbing regulations are discussed by the researchers.

Overhangs can be avoided by altering the shape of our robot's wheel periphery. Robust design parameters were defined in addition to creating a concept design in order to reduce performance fluctuation.

The Taguchi Method, which is based on grey, was utilised to determine the ideal configuration for the robot's design parameters. The robot prototype was demonstrated to be able to climb steps with overhang and of different sizes, supporting the analysis that was done.

In the work, an analysis technique was developed to enable the rocker bogie mechanism to ascend a staircase. Heavy rainfall created a major flood that severely damaged property and caused irreversible loss of life along Malaysia's east coast. The debris, soil, and trees that the flood carries with it damage the building's structure and the road itself, making it uneven.

Task forces providing assistance face challenges in managing the aftermath of a disaster.

The study article suggested using intelligent inclination motion control to move an amphibious vehicle over uneven ground .

Homeland security, demining, surveillance, hazardous terrain reconnaissance, and agriculture are important application domains.

In general, mobile robot locomotion systems for unstructured environments were designed to be complicated, especially when the robots had to climb barriers or move over uneven or soft terrain. The three primary locomotion system categories—wheeled, or W; tracked, or T; and legged, or L—as well as the four hybrid categories that result from combining these primary locomotion system categories—were examined in relation to the following: maximum speed; obstacle-crossing; step/stair climbing; slope climbing; walking on soft terrains; walking on uneven terrains; energy efficiency; mechanical complexity; control complexity; and technological readiness. There was discussion of the developments in mobile robotics, both present and future .

In this research work, a stair climbing robot is designed and modelled using Ansys rigid body dynamics module's well-known rocker-bogie mechanism.

When climbing steps and stairs, robots frequently experience the undesirable phenomena of slipping, sticking, and floating, which can lead to mobile robot instability. In order to optimise the centre of mass's trajectory and maintain all wheels in contact with the ground while climbing stairs, the Taguchi method was selected.

The Taguchi approach was chosen because it was easy to use and reasonably priced, and it was able to meet several constraints at once in addition to helping to formulate the goal function. Seven kinematic parameters of the rocker bogie mechanism—three wheel radiuses (R1, R2, and R3) and four link lengths (l1, l2, and l3)—were optimised in the optimisation process. The suggested mechanism's kinematic model was constructed, and ANSYS Rigid body dynamics was used to simulate it. To find a reliable best solution, three common staircase shapes were chosen as user criteria.The outcome demonstrates how the centre of mass position changes over time, how a joint's velocity changes over time, and how force changes over time.

It functioned essentially as a suspension system for mechanical robotic vehicles designed for space travel. For the Mars Pathfinder, Mars Exploration Rover (MER), and Mars Science Laboratory (MSL) missions carried out by top space exploration organisations worldwide, the rocker-bogie suspension-based rovers have been effectively implemented. Presently, every space exploration organisation involved in space research has a preference for the proposed suspension system design. The goal of the research was to comprehend the advantages of the Rocker-Bogie suspension system's mechanical design and determine whether it could be used in conventional loading vehicles to increase efficiency and reduce maintenance costs associated with those systems.

Over the next 20 years, it was anticipated that the global market for mobile robots will grow significantly and overtake the industrial robotics market in terms of units and sales.

The improvement of a specific suspension system for our Mars Rover called the "rocker-bogie." The majority of Mars rovers have utilised this kind of mechanism, which has shown to be an elegant and straightforward design.The rover's wheel suspension system's shape and kinematics were optimised using a Genetic Algorithm in accordance with predetermined performance metrics.

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This article demonstrates how well a rocker-bogie suspension system can be optimised using a genetic algorithm. It also shows that the final system satisfies all requirements and greatly lowers the inaccuracy of both the system as a whole and each individual performance parameter.It was demonstrated that after 100 iterations, the rover suspension system's overall fitness could be improved by an average of 28% over the initial estimate. Throughout the optimisation process, every performance metric that was specified saw a significant improvement.The technique can be used to optimise the geometry of the wheel-suspension system on various rover types.

III. DESIGN OF ROCKER BOGIE

Determining the dimensions and angles of the rocker and bogie links is a crucial step in the construction of the rocker bogie system. This mechanism's lengths and angles can be adjusted to suit the needs. The goal of the work is to create a rocker bogie mechanism that can climb over 150 mm-tall steps and overcome obstacles up to 150 mm in height, such as stones and wooden blocks. Another goal is to climb any surface at a 45-degree angle. We had to create the rocker-bogie type with the stair height of 150 mm and the length of 370 mm in mind in order to meet the aforementioned goals. Determine the model's dimensions using the Pythagorean theorem. Both of the connection angles are 90˚.

A. Design calculation

Stair climbing is the research project's goal. Adequate stair climbing necessitates appropriate linkage dimensions. Assume that the steps are 150 mm in height and 370 mm in length. Only one set of wheels must be in the rising position at a time in order to climb stairs with greater steadiness. Therefore, as indicated in Fig. 1, the first pair of wheels should be positioned horizontally, that is, at the end of the rising, in order to determine the dimensions of the bogie connections. And the second pair have to be positioned right before the rising motion begins. Between the second pair of wheels and the stair's vertical edge, there should be some space before the wheels strike.

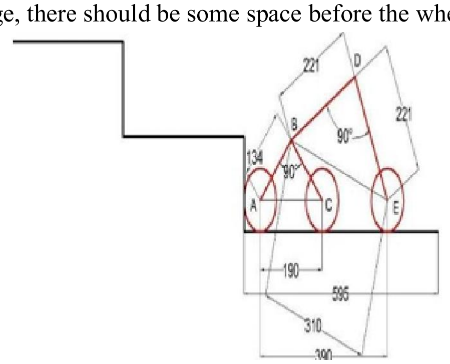

Fig. 1. Cad drawing for first triangle

It is now necessary to use CAD software to determine the distance (190 mm) between the first and second wheels. Taking into account the ABC right-angled triangle

Using Pythagoras in ΔABC (Fig. 2.)

assume lengths AB and BC is x.

$AC^2 = AB^2 + BC^2$

$190^2 = x^2 + x^2$

$190^2 = 2x^2$

x = 134 mm

Hence, AB = BC =134 mm (Fig. 2.)

Similar to this, the first two wheel pairs should be positioned horizontally in order to determine the measurements for the rocker linkages. Before the first pair of wheels begin to rise, the third pair of wheels should almost entirely rise. The dimension of link BC (311mm) was acquired by positioning the wheel in this way.

Now consider ΔBDE (Fig. 3.),

$BE^2 = BD^2 + DE^2$

$311^2 = 2y^2$

y = 221 mm

Hence, BD = DE = 221 mm (Fig. 3.)

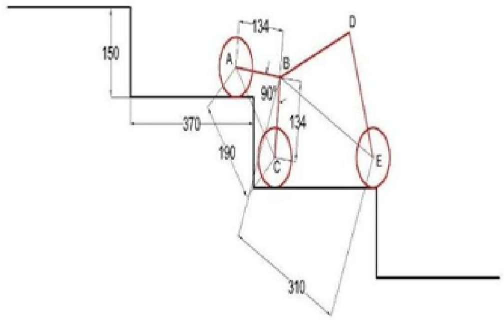

Fig. 2. Cad drawing for second triangle

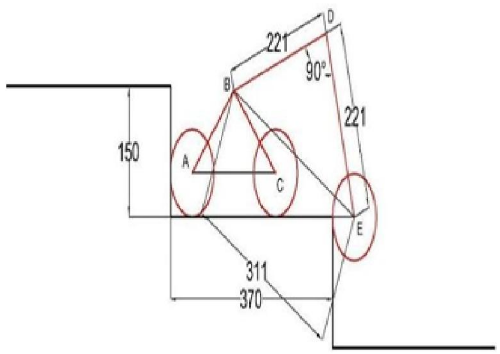

Fig. 3. CAD drawing of both triangles

With all of these lengths and angles in mind, we have drawn the entire system. The robot's dimensions are displayed above in Figure 3. We use 40 mm wide acrylic, which is appropriate for drilling holes with a 15 mm diameter.

B. Drawing

Following the triangle's dimensions are calculated using CAD software, a 2D drawing is created according to the results, and the identical drawing perspectives are displayed in Fig. 4.

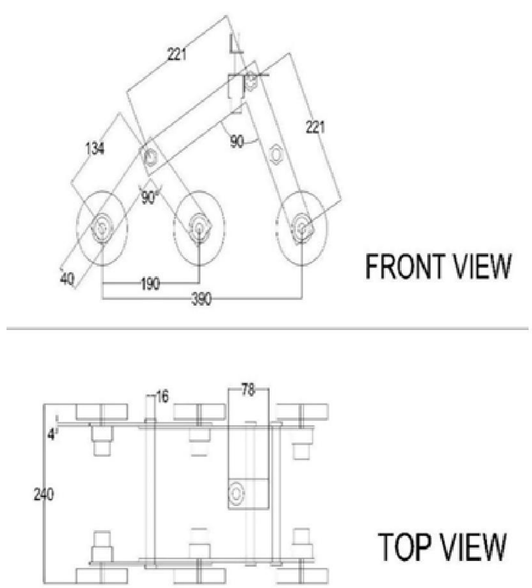

Fig. 4. 2D Drawing of Rocker Bogie Mechanism

C. Design & Selection of Wheel

Wheel design is necessary at velocities up to 0.5 m/s.

Suppose the motor runs at 60 to 100 rpm. For an assumed speed, velocity is computed using the velocity relation. The estimated velocity value must be used to determine that the wheel's diameter is 95.35 mm. As a result, we choose the standard wheel, which has a diameter of 100 mm.

The rubber thread that is attached to the wheel gives it exceptional traction and friction while still being lightweight and long-lasting. These inexpensive plastic wheels (as seen in Fig. 5) provide a practical yet robust option that is yet lightweight for use in a battle robot. Six wheels are employed by the robot.

Wheel Diameter: 100 mm

Wheel Width : 20 mm

Shaft Diameter : 6mm

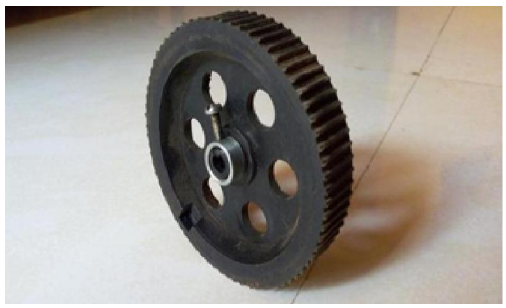

Fig. 5. Photo Image of Rubber Wheel

D. Selection of acceleration for robot

On level ground, a typical robot has to accelerate at a rate that is around half of its maximum velocity. The robot's maximum speed is 0.5 m/s. Therefore, the robot's acceleration will be 0.5/2, or 0.25 m/s2. Accordingly, it would take two seconds to accelerate to its fastest point. Robots must accelerate more quickly to overcome gravity when moving through uneven terrain or up inclines (Equation No. 1). We had to climb to a 45-degree angle.

$$\text{Acceleration of inclines} = \frac{9.81 * \sin(\text{angle of inclination}) * \pi}{180}$$

$$= 0.121 \text{ m/s}^2$$

Total Acceleration = 0.25+0.121 = 0.371 m/s2

IV. PERFORMANCE AT DIFFERENT CONDITIONS

Based on ground-level experiments conducted by Rocker Bogie, Inc., it was found that the performance was sufficient on various obstacles and surfaces. The results are displayed in Figure 6-10.

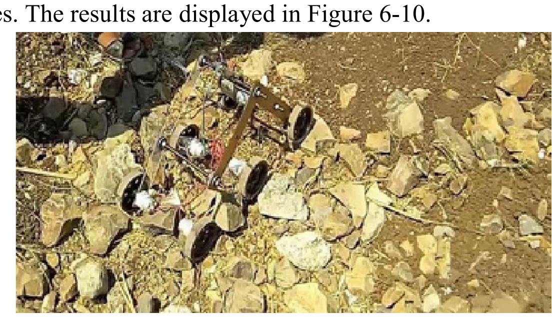

Fig. 6. Photo image of on rough surface

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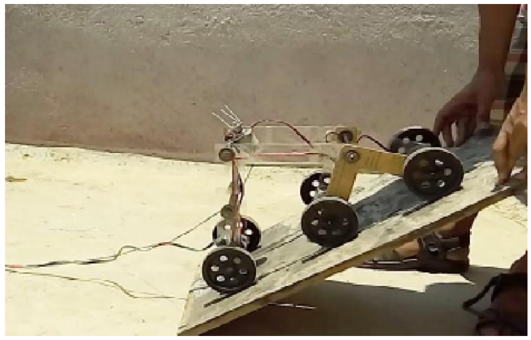

Fig. 7. Photo image of on angle surface about 45˚ inclination

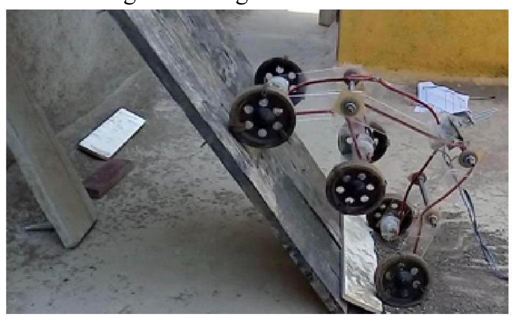

Fig. 8. Photo image of on angle surface about 75˚ inclination

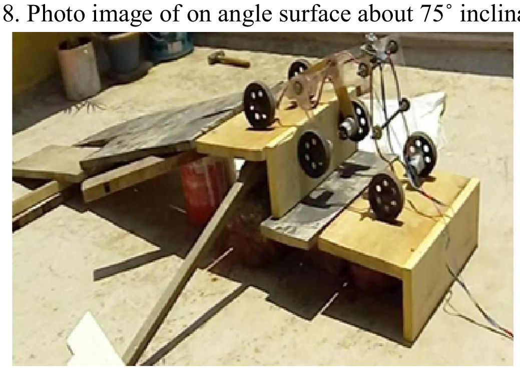

Fig. 9. Photo image stair Climbing

Fig. 10. Photo image in Farm with AV recording through IP web cam

V. ROCKER ROVER AND AGRICULTURE:

In India, cultivating may be one of the most stressful jobs. Lack of jobs, unstable power supplies, and water shortages have consistently resulted in low yield, which has a cascading effect on a larger problem that lasts for a considerable amount of time year after year. This vicious cycle of poverty is exacerbated by the burden of borrowing placed on farmers. India is the world's top producer of agricultural goods, and a large portion of this ranking may be attributed to

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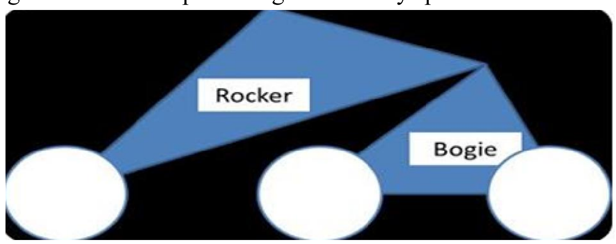
the country's extensive crop cultivation practises. Nevertheless, automation is not very prevalent in the agriculture industry. Particularly in the agricultural industry, farmers are required to perform the majority of the labour by hand.

With the advent of automation, farmers may now produce a higher annual harvest while working in the fields. One of the greatest engineering feats ever devised is the idea of the rocket-rover, an autonomous all-terrain mobile device whose applications in other domains will almost certainly benefit humanity.

When the Rocker Rover is used in agriculture, labor-intensive tasks like distributing seeds may be completed quickly and easily with fewer workers needed only to operate the rovers in the fields. The seeds needed for distribution and seeding can be carried by the Rocker Rover's "bogie." The seeds planted on the rover will be evenly dispersed around the field, significantly reducing seed waste and producing a uniformly spread result.



The rocker-rover concept can be applied in this area of agriculture because it is quite economical compared to tractors and has good efficiency in crop fields due to its ability to navigate rough terrain without the need for suspensions. Rocker Rover is a good fit for the business because of its features, which perfectly match the requirements and wants of both farmers and the agricultural sector.

- Reduced Jerks without the use of suspensions.
- Less maintenance required
- Cost-efficient.
- Works on alternate sources of energy.
- Fewer movable components.
- Rocker bogie system can bear a tilt of 50 degrees in any direction.
- The design is simple and reliable.
- The front and back wheel shave individual drives for climbing, enabling the Rover to traverse obstacle without slip.

VI. FUTURE SCOPE OF ROCKER ROVER IN THE FIELD OF AGRICULTURE

In the near future, there is a lot of promise for using rocker rovers in agriculture. Due to the existing and projected economic structures, the cost of equipment in the agricultural sector is at its peak and will only rise. As a result, the agricultural industry might benefit from a gadget that promotes economy, automation, and lower energy usage.

The application of rocker rovers in agriculture appears to hold great potential in the near future. The cost of equipment in the agriculture sector is at an all-time high and is only going to get higher due to the current and anticipated economic structures. Therefore, a device that encourages economy, automation, and reduced energy consumption could be advantageous to the agriculture sector.

In addition, the rocker rover has solar panels and rechargeable batteries instead of using conventional fuels like diesel, which comes from fossil fuels and produces large-scale carbon footprints that are seen in the case of tractors and other powered equipment used in agricultural fields.

VII. ADVANTAGES OF AUTONOMUS ROVER ROCKER BOGIE IN AGRICULTURE FIELD

The following are some benefits of employing an autonomous rover equipped with a rocker-bogie mechanism in agriculture:

1. Enhanced Terrain Adaptability: By enabling the rover to traverse uneven and rugged terrains frequently encountered in agricultural areas, the rocker-bogie system ensures smooth operation and lowers the chance of getting stuck.

2. Enhanced Precision: High precision operations, such planting seeds, dousing crops with fertiliser, and crop monitoring, can be put into autonomous rovers, resulting in more productive and efficient agricultural methods.
3.24/7 Operation: Regardless of the weather or time of day, autonomous rovers can work nonstop for extended periods of time without becoming fatigued, which boosts production.
4.Labour Cost Reduction: By eliminating the need for physical labour, autonomous rovers can help alleviate labour shortages in the agriculture sector and cut labour expenses.
5. Constant Monitoring: Sensor-equipped rovers are able to keep an eye on crop development, soil health, and environmental factors all the time, giving decision-makers access to real-time information.
6. Precision agriculture: minimises waste and lessens its negative effects on the environment by allowing the farmer to accurately apply fertiliser, herbicides, and water exactly where necessary.
7. Preservation of Soil Health: The rocker-bogie mechanism's design disperses weight more evenly, which lessens soil compaction and protects soil health.

VIII. DISADVANTAGES OF AUTONOMUS ROVER ROCKER BOGIE IN AGRICULTURE FIELD

Although autonomous rovers with a rocker-bogie mechanism have numerous benefits for agriculture, there are a few drawbacks to take into account as well:
1. High Initial Cost: Developing and deploying autonomous rovers can be costly, requiring farmers to make large initial investments, especially in small-scale enterprises.
2. Upkeep and Repairs: Due to their intricacy, autonomous rovers need frequent, expensive, and specialised maintenance and repairs.
3. Technical Difficulties: It might be difficult to design and programme an autonomous system that can work well in a variety of uncertain agricultural conditions and navigate and complete tasks.
4. Power source: It might be challenging to provide autonomous rovers with a dependable and long-lasting power source, particularly for prolonged activities across vast fields.
5. Weather Dependency: Adverse weather can interfere with autonomous rovers' ability to operate, sometimes leading to delays or damage. Examples of these situations are intense heat, snow, or rain.
6. Problems with connectivity: GPS and wireless connection are frequently used by autonomous rovers to transmit data and navigate. Their performance may be affected by connectivity problems in isolated or rural locations.
7. Data management: It can be difficult to handle the massive amounts of data that autonomous rovers collect; this calls for strong data processing, storage, and analysis capabilities.
8. Integration with Current Systems: Farmers may encounter challenges when attempting to integrate autonomous rovers with current agricultural machinery and systems, which could result in inefficiencies.

IX. CONCLUSION

An autonomous rover fitted with a rocker-bogey suspension system in agriculture represents a major development in contemporary farming methods. This experiment shows that a rover of that kind is capable of manoeuvring and carrying out activities in the difficult and uneven terrain that is typical of agricultural fields. Important conclusions consist of:
1. Improved Mobility and Stability: The rover can travel over uneven ground and around obstacles with greater mobility and stability thanks to the rocker-bogey suspension, all without sacrificing performance or balance.
2. Precision and Efficiency: Precision tasks like planting, weeding, and crop monitoring are made possible by rovers' autonomy, which boosts productivity and lowers labour costs.
3. Real-time Data Collection: The rover's sensors and cameras allow it to gather and send data in real-time on crop growth, soil health, and environmental conditions. This helps farmers make well-informed decisions.
4. Sustainability and Scalability: By reducing soil compaction and facilitating focused treatments that can be scaled to different farm sizes and crop varieties, the rover supports sustainable farming methods.
To sum up, the autonomous rover equipped with a rocker-bogey system is a promising technical advancement that has the potential to completely transform agricultural operations, resulting in higher yields, cheaper operating expenses, and more environmentally friendly farming methods. Subsequent research endeavours ought to concentrate on refining its

self-governing skills, including sophisticated artificial intelligence to enhance cognitive processes, and investigating its potential in various farming contexts.

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