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Design and Fabrication of Rough Terrain Traversal Rocker Bogie Mechanism

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ABSTRACT

This paper details the design and implementation of a terrain traversal system leveraging the rocker-bogie mechanism, specifically tailored for agricultural applications where uneven terrain presents significant challenges. The rocker-bogie suspension system, renowned for its application in planetary rovers, is innovatively adapted to navigate the complexities of agricultural fields. The primary objective of this research is to create a prototype that minimizes soil disturbance while effectively maneuvering over obstacles such as rocks, furrows, and varying soil conditions. Through this approach, the prototype aims to enhance operational efficiency in critical agricultural tasks, including planting, monitoring, and maintaining crops. The system's design incorporates advanced navigation capabilities, potentially integrating sensors for obstacle detection and GPS for precise positioning. This research addresses the pressing need for low-cost, scalable solutions in the realm of agricultural mechanization, ultimately contributing to improved productivity and reduced labor costs in farming operations. The findings from this study are anticipated to provide significant insights into the future of agricultural technology, paving the way for further innovations in automated systems that can adapt to the dynamic challenges of modern agriculture. The successful deployment of this prototype not only underscores the feasibility of the rocker-bogie mechanism in agricultural settings but also highlights its potential to revolutionize practices in the industry.

1.INTRODUCTION

The Rocker-Bogie mechanism is widely used in planetary rovers for its ability to traverse rough terrain while maintaining stability. This mechanism consists of a set of wheels connected through a system of rockers and bogies, which distribute the load and allow the system to overcome obstacles smoothly. In this setup, we integrate six motors and bevel gears to drive and stabilize a mounted plate. The primary goal of the system is to maintain stability while navigating uneven surfaces, making it suitable for applications likeagriculture terrain traversal, robotic exploration, inspection systems, and autonomous vehicles.

1.1 Need Of An Attachment

To effectively travel on a rough terrain with maneuverability and providing traction control.Capable of climbing obstacles upto twice the wheel diameter. Fewer moving parts compared to active suspension systems. These advantages make the Rocker-Bogie mechanism a preferred choice for robots and vehicles operating in unpredictable and rough terrains.

1.2 Problem Statement

Design and optimize a Rocker-Bogie mechanism to enable stable, energy-efficient traversal of rough and unpredictable terrains (e.g., rocky surfaces, slopes, loose soil) for applications in planetary exploration, search-and-rescue robots, and off-road autonomous vehicles. The system should passively adapt to obstacles without complex control, ensuring durability, traction, and minimal power consumption.

2.LITERATURE REVIEW

This study focuses on simulating off-road robots by analyzing the mechanical behavior of their locomotion systems and their interaction with different terrains. It examines various wheel-soil contact behaviors, considering factors such as slippage, soil compaction, shear deformation, and wheel elasticity. Analytical models are developed to express the relationship between contact force components (radial, longitudinal, and lateral) and relative displacements (radial, slip ratio, and side slip angle). These models are integrated into the system's dynamic equations to describe overall behavior. A visual simulation system is used to implement these models, aiding in mechanical design, path planning, and control system development.[1].

The rocker-bogie design, known as Ro, features a free rocking bogie in front of a master bogie. It has a single rigid body, high ground clearance, all-wheel steering, and a differential connection between the left and right sides. With no springs or elastic members except in the tires, its linkage system distributes weight across wheels, enhancing obstacle-climbing ability and bump performance [2].

This study presents an analytical approach for enabling a rocker-bogie mechanism to climb stairs. Kinematic analysis determines whether the system can ascend based on link lengths and wheel radii. Three-wheel contact with the stair is analyzed using the center of mass trace, leading to the development of a Stair Climb ability Graph (SCG), which defines climbable stair groups based on length and height. Two prototypes with different linkage sizes were tested: the smaller linkage climbed a 450mm x 150mm stair but failed on 300mm x 175mm, while the larger linkage successfully ascended both. [3]

As planetary rover missions expand, greater autonomy is needed for navigating challenging terrain. This study presents a planning approach based on a physics-based model, considering power, actuators, wheel slip, and stability constraints. The method enables rovers to execute tasks efficiently, with results demonstrated through detailed simulations.[4].

3.CONSTRUCTION CONCEPT

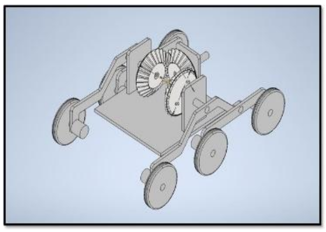

FIG 3.1 Inventor Model

The chassis supports all components and serves as the main structure. The rocker arms are pivoted to the chassis and connected to the bogies, ensuring balanced movement. Wheel Configuration and Motor DriveSix independent motors (one per wheel) provide traction control and maneuverability. Each motor is placed on a wheel hub and directly drives the wheels. Bevel Gear Mechanism for Plate Stabilization. A system of bevel gears is used to transfer rotational motion to stabilize the top plate. The bevel gears allow for torque transmission at 90-degree angles, ensuring smooth rotation. The stabilization system compensates for any tilting caused by uneven terrain. Suspension and Balancing Mechanism. The Rocker-Bogie design inherently adjusts to obstacles without additional suspension. The top plate remains stable due to passive balancing or an active servo-based stabilization system. Control System A microcontroller or embedded system regulates motor speeds based on sensor feedback. IMU (Inertial Measurement Unit) sensors can be added to adjust the plate's position dynamically.

4.METHODOLOGY

The Rocker Bogie Mechanism operates by distributing the vehicle's weight evenly across all six wheels, ensuring maximum traction and stability on uneven terrain. As the vehicle moves, the rocker arms pivot up and down, allowing the bogie arms to swing in a seesaw motion. This independent suspension system enables each wheel to move up and down without affecting the others. When a wheel encounters an obstacle, the rocker arm and bogie arm adjust to maintain traction and stability, redistributing the vehicle's weight as needed. This continuous adjustment enables the vehicle to navigate challenging terrain efficiently, clearing obstacles and maintaining contact with the ground. The Rocker Bogie Mechanism's unique design provides improved traction, stability, and obstacle clearance, making it ideal for agricultural vehicles operating in difficult-to-reach areas.

5.CALCULATION

Selection of DC motor:

FIG. 5.1 Actual Experimental Setup

Torque calculation without battery:

T_{total}=F×R [6]

Force calculation to move the mechanism:

By using setup:

M=1.7 Kg

F=16.677 N

R= Wheel Radius =0.035 m

T_{total}=16.677×0.035(This is for 6 motors)

=0.5836Nm

T =0.0972………………………… (this is for 1 motor)

Torque calculation with battery:

M=2.7 Kg

F= 26.487 N

T_{actal} =0.9270 Nm (This is for 6 motors)

T=0.1545………………………… (this is for 1 motor)

of 2 Kg.cm(0.1962Nm) with 150 rpm

Selection of Battery:

Theoretical Calculation for Battery:

Given Parameters:

Voltage(V): 12V

Load: 2.7Kg

Torque(τ): 2Kg.cm (=0. 196N.m)

Speed: 150 RPM

Efficiency: 85% (0.85)

1) Calculate mechanical power (P_{Mech}):

Angularspeed(ω)= $\frac{2\pi \times RPM}{60} = \frac{2\pi \times 150}{60}$=15.71rad/sec [7]

P_{Mech}=$\tau \times \omega$ =0.196×15.71=3.08Watts [8]

2) Calculation for electrical power input (P_{Elect})

By considering efficiency 85%

P_{Elect}= $\frac{PMech}{\eta}$=$\frac{3.08}{0.85}$=3.62Watts [9]

3) Calculation for Current Draw per motor (i)

I=$\frac{PElect}{V}$=$\frac{3.62}{12}$=0.30A (300mA) [10]

4) Total Current for 6 Motor:

I_{total}=6×0.30=1.8A

5) Battery Runtime Calculation:

We have 12V 12Ah Battery (typical lead-acid ,80%usable capacity)

Runtime = $\frac{\text{Battery Capacity (Ah)} \times \eta}{\text{Total Current(A)}}$=$\frac{12}{1.8}$=6 hours 39 min [11]

Actual Runtime of Battery=5-hour 54 min

6. CONCLUSION

The rocker-bogie mechanism is a smart, simple, and reliable solution for moving over rough terrain. Passive Obstacle Climbing Automatically adjusts to uneven terrain without sensors or active control

Can climb obstacles nearly twice thewheel height

Maintains all wheels in ground contact at all timesEven weight distribution prevents tipping on slopes.

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7] H.C. Verma – "Concepts of Physics" (Vol. 1 & 2) Vol. 1 – Chapter 10: Rotational Mechanics (Derives relations between angular velocity, frequency, and RPM.) Example problems often use this conversion.

[8] H.C. Verma – "Concepts of Physics" (Vol. 1 & 2)Vol. 1: Chapter 10 – Rotational Mechanics Derives the relation $P=\tau\omega$ for rotating bodies. Vol. 2: Electromagnetism (AC Motors & Generators)Applies this formula in electrical machinery.

[9] H.C. Verma – Concepts of Physics (Vol. 2) Chapter on Electromagnetic Induction & AC Circuits Discusses power losses and efficiency in motors/generators

[10] H.C. Verma – Concepts of Physics (Vol. 2)Chapter on Current Electricity – Derives P=VIand rearranges it to P=VI.AC Power Section – Discusses RMS values for current and power.

[11] H.C. Verma – Concepts of Physics (Vol. 2) Chapter on Current Electricity Covers power dissipation and energy calculations.