ISSN No:-2456-2165

Design and Implementation of Miniature of Rocker Bogie Suspension System

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Abstract:-Rocker Bogie Suspension has the specialty of being able to climb over obstacles twice the diameter of the wheel, that too without compromising the stability of the rover as a whole. The mechanism allows to climb over high obstacles, while keeping all the six or eight wheels in contact with the ground. This project aims to study the various mechanisms and the various components of rocker bogie suspension system.

I. INTRODUCTION

A. History

The rocker-bogie was first used for the Mars Rover and introduced for the Mars Pathfinder and also used on the Mars Exploration Rover (MER) and Mars Science Laboratory (MSL) missions and is currently NASA's favoured design for rover wheel suspension. It was specifically designed for space exploration vehicles have deep history embedded in its development and This system can be traced to the development of Planetary rover which are mobile robots, especially designed to move on a planet surface. The ancient FIDO rover and the Sojourner contain 6 independently steered and driven wheels suspended from a rocker-bogie mechanism for maximum suspension and ground clearance. Rocky Seven Rover has a similar suspension system just differ in front wheels. The Nano rover & Nomad Rovers have four steered wheels suspended from two bogies & CRAB Rover utilizes two parallel bogie mechanisms on each side to overcome obstacles and large holes. As far as the initial research is concerned, the software optimization seeks for an optimum in the constrained solution space given an initial solution and Dr. Lietal derive a mathematical model to generalize rover suspension parameters which define the geometry of the rocker-bogie system. The objective behind evolution of rocker bogie suspension system is to develop a system which minimizes the energy consumption, the vertical displacement of the rover's centre of mass and its pitch angle.

B. About Rocker Bogie System

The rocker-bogie suspension design has become a proven mobility application known for its superior vehicle stability and obstacle-climbing capability Following several technology and research rover implementations, system was successfully flown as part of Mars Pathfinder's Sojourner rover. When the Mars Exploration Rover (MER) Project was first proposed, the use of a rocker-bogie suspension was the obvious choice due to its extensive heritage. The challenge posed by MER was to design a lightweight rocker-bogie suspension that would permit the mobility to stow within the limited space available and deploy into a configuration that the rover could then safely use to egress from the lander and explore the Martian surface .

When building a robot you'd like it to be as simple as possible. In most cases you'd never need a suspension system, but there were several instances when a suspension system cannot be avoided.

It is currently NASA's favored design:

The term "rocker" comes from the rocking aspect of the larger links on each side of the suspension system. These rockers are connected to each other and the vehicle chassis through a differential**.** Relative to the chassis, when one rocker goes up, the other goes down. The chassis maintains the average pitch angle of both rockers. One end of a rocker is fitted with a drive wheel and the other end is pivoted to a bogie.

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. Both applications now prefer trailing arm suspensions.

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. Both applications now prefer trailing arm suspensions. The rocker-bogie design has no springs or stub axles for each wheel, allowing the rover to climb over obstacles, such as rocks, that are up to twice the wheel's diameter in size while keeping all six wheels on the ground. As with any suspension system, the tilt stability is limited by the height of the center of gravity.

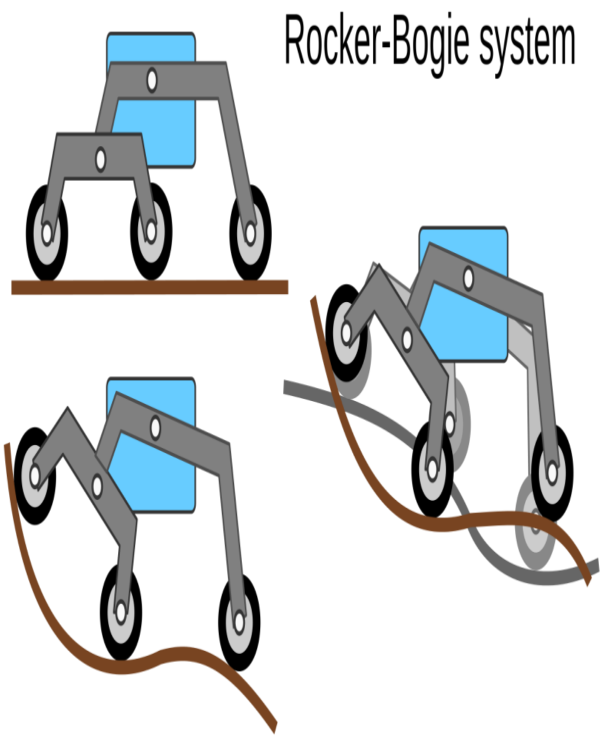

Fig.1:- 2D Diagram of Rocker-Bogie system

C. Objective

To reduces the main body motion by half, compared to any other suspension. The jerk experienced by any of the wheel is transferred to the body as a rotation via the differential connecting the two rockers, not as translation and in order to remove discomfort and complexities present in conventional suspension system in general and suspension system of heavy vehicles.

II. EXISTING METHODS

A. Convention Suspension System

The retrofit table kit consists of a clamp, which restricts engagement of gears when the side-stand is not pushed back.

The gear lock clamp consists of an angular rod welded to the base washer, which achieves locking of the gears. Currently this kit has been configured for some models of Hero, Honda bikes.

B. Air Suspension System

Air suspension is a type of vehicle suspension powered by an electric or engine-driven air pump or compressor. This compressor pumps the air into a flexible bellows, usually made from textile-reinforced rubber. The air pressure inflates the bellows, and raises the chassis from the axle

C. Hydrostatic Suspension:

The arrangement of this kind of suspension is like an individual suspension system only. A displacer unit is fitted at each of the four wheels where rubber is used as a spring and the fluid, under pressure, is used as a damping medium. The stem is connected to the wheel through suitable linkage so that its movement is proportional to the up and down movement of the wheel. A two way valve assembly controls the up and down flow of the fluid. The upper valve opens up when the fluid pressure rises sufficiently.

Similarly, the lower valve allows the fluid to pass in the downward direction under pressure. When, the piston moves updue to the movement of the wheel, the diaphragm pushes the fluid up through the opening, by pushing the damper valve. The fluid under pressure above the valves compresses the rubber which acts as a spring. Different attributes and operations take place in different road conditions, as in case of bouncing, rolling and pitching. This is the basic working of the Hydrostatic suspension system.

D. Drawbacks

- These systems does not work on the place where the gravitational force is zero
- Force is transferred to the body

III. DESIGN OF ROCKER BOGIE SUSPENSION SYSTEM

The rocker-bogie design has no springs or stub axles for each wheel, allowing the rover to climb over obstacles, such as rocks, that are up to twice the wheel's diameter in size while keeping all six wheels on the ground. As with any suspension system, the tilt stability is limited by the height of the center of gravity. Systems using springs tend to tip more easily as the loaded side yields. Based on the center of mass, the Curiosity rover of the Mars Science Laboratory mission can withstand a tilt of at least 45 degrees in any direction without overturning, but automatic sensors limit the rover from exceeding 30-degree tilts. The system is designed to be used at slow speed of around 10 centimeters per second (3.9 in/s) so as to minimize dynamic shocks and

ISSN No:-2456-2165

consequential damage to the vehicle when surmounting sizable obstacles.

NASA Jet Propulsion laboratory states that rocker bogie system reduces the motion of the main MER vehicle body by half compared to other suspension systems. Each of the rover's six wheels has an independent motor. The two front and two rear wheels have individual steering motors which allow the vehicle to turn in place. Each wheel also has cleats, providing grip for climbing in soft sand and scrambling over rocks. The maximum speed of the robots operated in this way is limited to eliminate as many dynamic effects as possible so that the motors can be geared down, thus enabling each wheel to individually lift a large portion of the entire vehicle's mass.

In order to go over a vertical obstacle face, the front wheels are forced against the obstacle by the center and rear wheels. The rotation of the front wheel then lifts the front of the vehicle up and over the obstacle.

The middle wheel is then pressed against the obstacle by the rear wheels and pulled against the obstacle by the front until it is lifted up and over. Finally, the rear wheel is pulled over the obstacle by the front two wheels. During each wheel's traversal of the obstacle, forward progress of the vehicle is slowed or completely halted. This is not an issue for the operational speeds at which these vehicles have been operated to date.

One of the future applications of rovers will be to assist astronauts during surface operations. To be a useful assistant, the rover will need to be able to move much faster than human walking speed or at least equivalent. Other missions which have been proposed, such as the Sun-Synchronous Lunar Rover, require even greater speeds (4–10 km/h).

IV. VARIOUS PARTS

- Push switch - A Electrical switch.
- Battery- Powers the motor.
- Shaft- connects the wheels
- Torque DC motor-drives the wheel.
- Nut & Bolts- Joints the links

A. Switches

Fig.2:- 1&3 Way Switches

An electrical switch is any device used to interrupt the flow of electrons in a circuit. Switches are essentially binary devices they are either completely on (“closed”) or completely off (“open”).

B. Battery

Fig.3:- Battery

An electric battery is a device consisting of one or more electrochemical cell with external connections provided to power electrical devices. A battery has a positive terminal, or cathode, and a negative terminal, or anode. The terminal marked positive is at a higher electrical potential energy than is the terminal marked negative. The terminal marked negative is the source of electrons that when connected to an external circuit will flow and deliver energy to an external device. When a battery is connected to an external circuit, electrolytes are able to move as ions within, allowing the chemical reactions to be completed at the separate terminals and so deliver energy to the external circuit. It is the movement of those ions within the battery which allows current to flow out of the battery to perform work. Historically the term "battery" specifically referred to a device composed of multiple cells, however the usage has evolved to additionally include devices composed of a single cell.

Batteries are classified into primary and secondary forms

- Primary batteries irreversibly transform chemical energy to electrical energy. When the supply of reactants is exhausted, energy cannot be readily restored to the battery.
- Secondary batteries can be recharged; that is, they can have their chemical reactions reversed by supplying electrical energy to the cell, approximately restoring their original composition.

C. Motor

An electric motor is an electrical machine that converts electrical energy into mechanical energy. The reverse of this would be the conversion of mechanical energy into electrical energy and is done by an electric generator.

In normal motoring mode, most electric motors operate through the interaction between an electric motor's magnetic field and winding currents to generate force within the motor. In certain applications, such as in the transportation industry with traction motors, electric motors can operate in both motoring and generating or braking modes to also produce electrical energy from mechanical energy.

DC motor is designed for two speed operation. It consists of three brushes namely common, low speed, high speed. Two of the brushes will be supplied for different made of operation.

The DC motor does not oscillate back and forth, it rotates continuously in one direction like most others motors. The rotational motion is converted to the back and forth wiper motion by a series of mechanical linkage.

This type of motor is called a gear head or motor end has advantage of having lots of torque. The dc motor works on 12volt D.C. battery.

Fig. 4:- Dc Motor

D. Shaft

A Shaft is a rotating machine element ,usually circular in cross section, which is used to transmit power from one part to another , or from a machine which absorbs power.

The material used for ordinary shafts is mild steel. When high strength is required, an alloy steel such as nickel, nickel-chromium or chromium-vanadium steel is used.

Shafts are generally formed by hot rolling and finished to size by cold drawing or turning and grinding.

Fig. 5:- Shaft

E. Nuts And Bolts

In physics, in the theory of general relativity, space times with at a 1-parameter group of isometrics can be classified according to the fixed point set of the action. Isolated fixed point is called NUTS. A nut is a type of fastener with a threaded hole. Nuts are almost always used in conjunction with a mating bolt to fasten two or more parts together. The two partners are kept together by a combination of their threads' friction (with slight elastic, deformation), a slight stretching of the bolt, and compression of the parts to be held together. The most common shape today is hexagonal, for similar reasons as the bolt head: six sides give a good granularity of angles for a tool to approach from (good in tight spots), but more (and smaller) corners would be vulnerable to being rounded off. It takes only one sixth of a rotation to obtain the next side of the hexagon and grip is optimal. The other possibility is that the fixed point is a metric 2-sphere , called BOLT The number of nuts and bolts can be related to topological invariants, such as the Euler characteristic.

Fig. 6: -Nuts and Bolts

F. Aluminium

Aluminium is remarkable for the metal's low density and its ability to resist corrosion through the phenomenon of passivation. Aluminium is a relatively soft, durable, lightweight, ductile, and malleable metal with appearance ranging from silvery to dull gray, depending on the surface roughness.

It is nonmagnetic and does not easily ignite. A fresh film of aluminium serves as a good reflector(approximately 92%) of visible light and an excellent reflector (as much as 98%) of medium and far infrared radiation. Aluminium is theoretically 100% recyclable without any loss of its natural qualities.

After iron, aluminium is now the second most widely used metal in the world. The properties of aluminium include: low density and therefore low weight, high strength, superior malleability, easy machining, excellent corrosion resistance and good thermal and electrical conductivity are amongst aluminium's most important properties. Aluminium is also very easy to recycle.

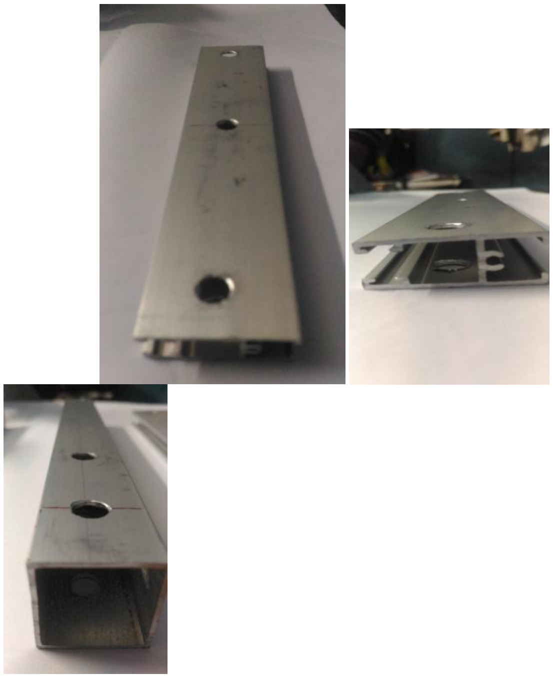

Fig. 7:- Aluminium

V. DESIGN CALCULATIONS:

A. Power Required For the motor

$$P=VI(\text{watts})$$
$$=12\times1.3$$
$$=15.6W$$

B. Torque Required For the motor

$$p=2\pi\ NT/60$$
$$T=60\times P/(2\pi\ N)$$
$$=(60\times15.6)/(2\ \pi\times300)$$
$$=0.4968N\text{-}m$$
$$T=496.8N\text{-}mm$$

C. Wheel torque

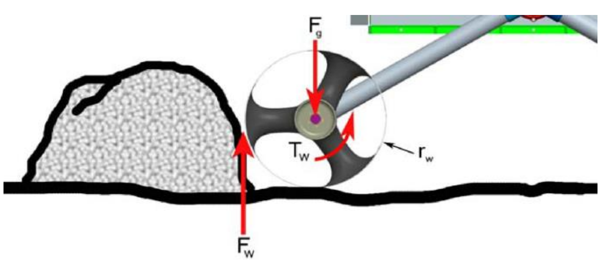

Fig. 8:- Wheel Torque

wheel torque free body diagram

$$Fg = mr \cdot g/4$$
$$= 2\times9.81/4$$
$$=4.905\ N$$
$$Tw = Fg\times rw$$

where rw is the radius=35mm

$$=4.905*0.035$$
$$=0.171675N\text{-}m$$
$$Tw=171.675N\text{-}mm$$

Each wheel required 171.675N-mm of torque

D. Calculation of stair climbing

Using Pythagoras in ΔABC 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

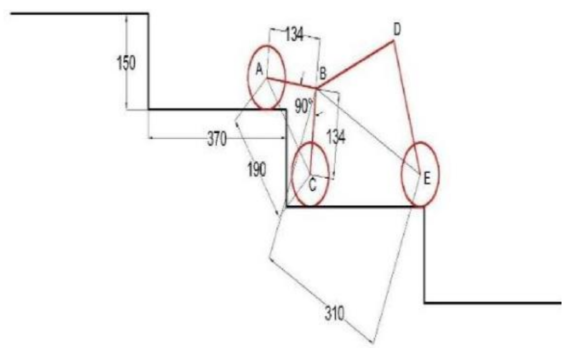

Fig. 9:- Stair climbing

For a typical robot on flat terrain, it's needed to take acceleration about half of maximum velocity. Maximum velocity of robot is 0.5 m/s. Hence the acceleration of robot will be 0.5/2 means 0.25 m/s^2. This means it would take 2 seconds to reach maximum speed. If robot is going up inclines or through rough terrain, you will need a higher acceleration due to countering gravity. We needed to climb the angle up to 45˚. Hence,

Accelerationofinclines=9.81 × sin angle of inclination ×π/180

= 0.121 m/s^2

Total Acceleration = 0.25+0.121 = 0.371 m/s^2

VI. MODELLING OF ROCKER BOGIE SUSPENSION

ISSN No:-2456-2165

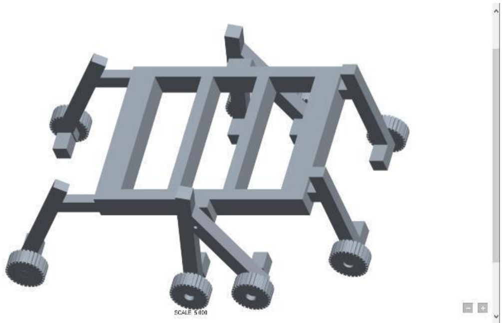

Fig. 10: -Modeling With Dimension

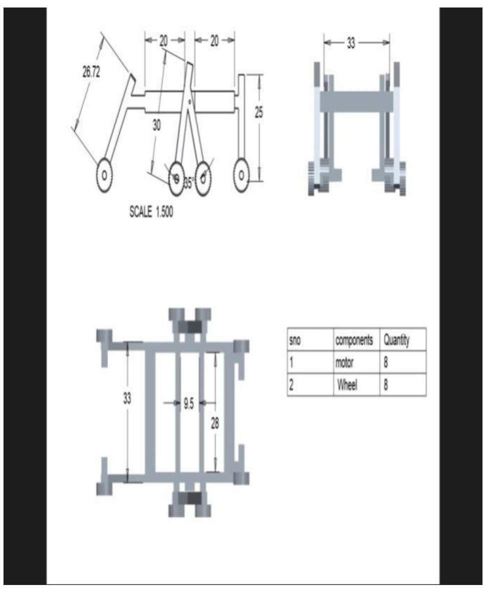

Fig. 11: - Solid work 3D Model

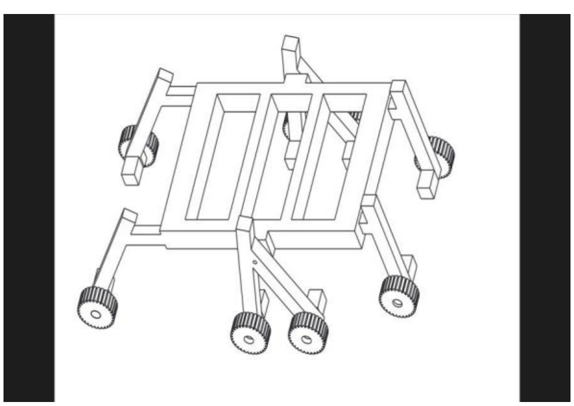

Fig. 12:- Wire frame Isometric view

VII. WORKING OF ROCKER BOGIE SUSPENSION SYSTEM

The Rocker Bogie system reduces the motion by half compared to other suspension systems because each of the bogie's Eight wheels has an independent mechanism for motion and in which the two front and two rear wheels have individual steering systems which allow the vehicle to turn in place as 0 degree turning ratio. Every wheel also has thick cleats which provides grip for climbing in soft sand and scrambling over rocks with ease. In order to overcome vertical obstacle faces, the front wheels are forced against the obstacle by the centre and rear wheels which generate maximum required torque. The rotation of the front wheel then lifts the front of the vehicle up and over the obstacle and obstacle overtaken. Those wheels which remain in the middle, is then pressed against the obstacle by the rear wheels and pulled against the obstacle by the front till the time it is lifted up and over. At last, the rear wheel is pulled over the obstacle by the front two wheels due to applying pull force. During each wheel's traversal of the obstacle, forward progress of the vehicle is slowed or completely halted which finally maintain vehicles centre of gravity

The main problem associated with current suspension systems installed in heavy loading vehicles rovers (including those with active and semi active suspension systems) is their slow speed of motion which derail the rythem to absorb the shocks generated by wheels which remain the result of two factors.

First, in order to pass over obstacles the vehicle must be geared down significantly to allow for enough torque to raise the mass of the vehicle. Consequently, this reduces overall speed which cannot be tolerated in the case of heavy loading vehicles.

Second, if the vehicle is travelling at a high speed and encounters an obstacle (height greater than 10 percent of wheel radius), there will be a large shock transmitted through the chassis which could damage the suspension or tapple down the entire vehicle. That is why current heavy loading vehicles travel at a velocity of 10cm/s through uneven terrain.

Load equalization over all wheels ensures equal work conditions for all wheels. Geometric traffic ability ensures that the suspension structure does not interfere with the ground. The analysis of geometric traffic ability is only done for the bogie, as the swinging scope for the bogie is much bigger than that of the rocker.

The rover is said to be stable when it is in a quasi-static state in which it does not tilt over. The simplest approach to find the static stability is using the geometric model, which is commonly referred to as stability margin. As the asymmetric suspension system of the passively articulated rover has a great influence on the vehicle's effective stability, a more advanced approach is using a static model

VIII. ADVANTAGES:

- Load on each wheel is nearly identical.
- Has no axles or springs which helps to maintain equal traction force on all the wheels.
- Can climb over blocks twice the height of the wheel while keeping all 8 wheels on the ground.
- Each wheel can individually lift almost the entire mass.
- Distributing the weight and drive torque to Eight wheels instead of three, gives the rover greater traction and stability.
- As with any suspension system, the tilt stability is limited by the height of the center of gravity.

IX. APPLICATIONS

The project focuses on developing a platform which can be used for many applications. The rover can travel in uneven terrain autonomously with the help of the rocker bogie suspension system and the sensor values obtained from the rover help in evaluating the atmospheric conditions present around the rover.

It can be used for exploration in places which require continuous environmental and video surveillance. Reconnaissance is one of the major applications of such rovers. It can also be used for geological mapping of unknown terrain as it can even provide live video feed and images of the terrain being explored. Information about the terrain and the climate around it can be studied and recorded for mapping.

X. FUTURE SCOPE

One of the main problems of this rover is the limitation offered by the battery power and the communication range. When these limitations are answered by using solar panels to charge the battery and mobile data cards for internet connectivity, the rover can be made operational in real time and can be left in a remote terrain for continuous operation. With higher computing electronics, a higher level of autonomy can be given to the rover in navigation by using GPS modules and path planning algorithms. Devices and subsystems like autonomous robotic arm, stereo camera and various useful sensors can also be attached to the rover to further enhance its functionality.

XI. CONCLUSION

This work describes the Design of a rocker-bogie suspension system, followed by the identification of several performance metrics which are to be optimized if the rover is to execute its tasks and reach its goals in the best possible way. The design is pursued due to increase the rocker-bogie stability while at higher speeds traversal motion is required. The expanded support polygon achieved by rotating the bogies of each side of the vehicle. In future, if the system installed in heavy vehicles and conventional off road vehicles, it will definitely decreases the complexity as well as power requirements to retain bumping within it.

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