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Modified Rocker Bogie Rover

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Abstract: A rover is a vehicle for driving over rough terrain, especially one driven by remote control over extra-terrestrial terrain. Robotic rovers are used extensively for exploratory and military purposes in the fields of scientific exploration and defense. This paper focuses on the design and development of a rover with autonomous driving and environmental sensing capability. It can be used as an exploratory rover, providing information about the terrain and surrounding atmosphere. It can also be used as a surveillance robot to alert people in areas with security threats like national borders, terrorist occupied territories etc., where it is difficult for humans to work. The rover will be having a 'Rocker Bogie Suspension' system with six wheels for greater stability in crossing over obstacles. It can avoid un-mountable obstacles and can traverse over mountable obstacles. The rover is controlled by using a remote controller. The rover is equipped to send a live video feed to the computer display. We have modified the link design. Thereby we are expecting this design to be an improved one while comparing with the existing one.

Keywords: Autonomous, Terrain, Rocker, Bogie.

I. Introduction:

Mankind has sought improved method of land transport over the centuries these land locomotion methods have included on foot riding on the backs of horses or other animals using carts and wagons drawn by both humans and animals and using a variety of vehicles powered by steam internal combustion or other engines. With the advent of automation and robots in 20th century a new level of sophistication has been added to these methods namely the development of automated vehicles or mobile robots which can be sent to perform these tasks with little or no human intervention. In recent years practical mobile robots have been successfully used in controlled environments such as factories offices and hospitals as well as outdoors on prepared surfaces and terrain
with minor irregularities. However, the operation of mobile robots in extremely rough uneven terrain has been impossible or unreliable at best. Nevertheless many benefits would result if robotics mobility "in the field" were made practical. Hence the study of "field robotics" has become an active area of research.

Technological challenges abound in almost all aspects of mobile robot research. However the most critical factor that impedes creating legged vehicles that can safely operates on rough uneven terrain has been the need for the robot to reliably detect and reach enough secure footholds. If the legs of the walking vehicle are unstable, it will fall over possibly damaging itself. Exacerbating the problem are foothold areas that appear safe to the sensors of the robots yet because of hidden holes loose rocks or soft soil fail to support the weight of the vehicle when it places a leg in those locations .this problem a symptomatic of the underlying inadequacies in Terrain sensing and controls and the lack of a safety factor in the form of redundant supporting legs. State-of-art sensing and controls technology still cannot duplicate the abilities of most arthropods. Higher life forms this research seeking to solve the all-terrain mobility problem. Specifically the biological counterpart for the vehicle concept described in this research is the caterpillar the larva of moth. Caterpillars have flexible and longitudinal segmented bodies. They move via waves of muscular contraction that start at the posterior and progress forward to the anterior. Caterpillar are nearly blind and presumably have very little intelligence, yet they exhibit superb all terrain mobility relative to their size.

Therefore the approach taken in this research was to advance the development of a new category of vehicle that would be able to crawl over difficult, uneven terrain in a manner similar to caterpillar. To achieve this aim, the design choices for the crawling vehicle were guided by the hypothesis that the robot would achieve caterpillar like mobility, if its body structure and methods of locomotion could be made to emulate those of the caterpillar as will be known layer in this work this hypothesis is true.

II. Rocker bogie rover:

The rocker-bogie rover works on rocker bogie suspension system. The intelligently designed wheel suspension allows the vehicle to traverse over very uneven or rough terrain and even climb over obstacles. The Rocker-Bogie system has been the suspension arrangement used in the Mars rovers. 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. Robots using rocker bogie mechanism makes use of a suspension mechanism as shown in Figure.1, that consists of several rigid elements connected through joints of a certain number of degrees of freedom (DOF) resulting in a structure that has one system DOF. This enables them to move along uneven terrain without losing contact with the ground. The suspension has 6 wheels with symmetric structure for both sides. Each side has 3 wheels which are connected to each other two with links. The main linkage called rocker has 2 joints while first joint is connected to front wheel, the other joint is assembled to another linkage called bogie.

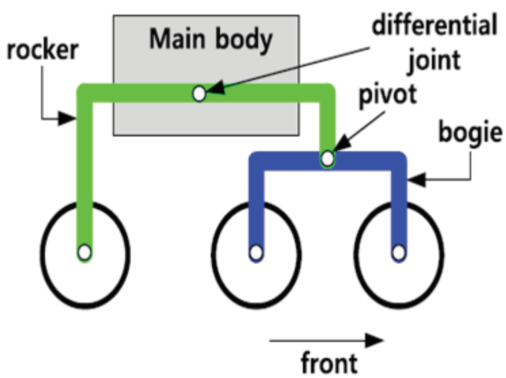

Figure 1: Rocker bogie mechanism.

Design of Links

For designing rocker bogie mechanism the dimensions of rocker and bogie linkages and angles between them have to be determined. The distance between wheel centers of the rocker bogie is 150 mm. The following figures provide the details regarding the dimensions of the links including rocker and bogie along with angles between links.

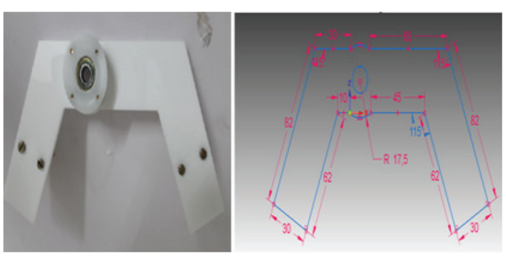

Figure 2: Bogie.

Figure.2 is the fabricated image of the bogie link along with CAD drawing. A ball bearing is attached to the link with a covering. This link has been designed on the basis of the CAD drawing given. These are the dimensions we have fixed and plotted using CAD software by using the trial and error method.

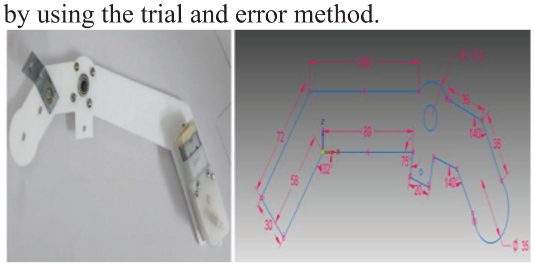

Figure 3: Rocker.

Figure.3 shows the fabricated image of the Rocker link. It has a ball bearing as well as DC gear motor attached to it. The dimensions of the Rocker link were designed using CAD software by using trial and error method.

II. Design calculations:

Rolling resistance

The kinetic friction between the wheel and the ground is given by: $F=W\times\mu = 14.7\times.25=3.675N$

Where, μ is coefficient of kinetic friction.
W is weight in Newton.

The condition for a rolling motion is $P_{max} \leq W\times\mu$

Maximum torque transferred to the ground by the wheel.
$T_{max}= rW\mu$
$T_{max}= (35\times14.7\times.25)/10^3$
$=.1286Nm$
Opposing to the rolling progression of a wheel is the rolling resistance. When a rigid wheel moves over the ground, the ground will be deformed and at the pressure centre a normal force N will act. This force consists of a vertical component opposing the weight of the wheel and a horizontal component, representing the rolling resistance, as in Figure.4.

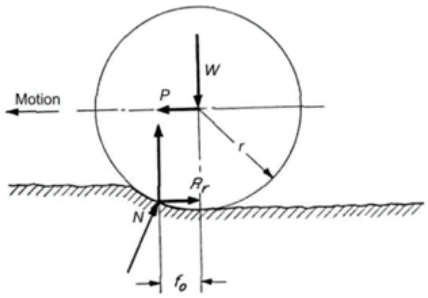

Figure 4: Forces acting on wheel.

The equilibrium of these forces can be stated as follows:
$P = R_r = Wf_o/r = W\mu$
Where, f_o is the coefficient of rolling resistance.

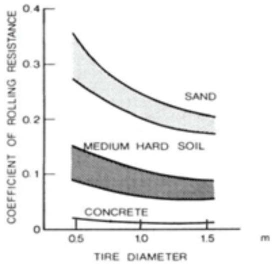

Figure 5: Coefficient of rolling resistance as function of wheel diameter.
In Figure 5 it is shown that f_o lies, for a wheel with a diameter of 70mm, between 0.1 (medium hard soil) and 0.4 (heavy sand).

The rolling resistance FR is proportional to the tire normal force.
$FN=mg/6 = 2.45N$

Rolling resistance of medium hard soil: FR= f_o×FN
= 0.1 x 2.45
= 0.245N
(f_o=.1)
Rolling resistance heavy sand: FR= f_o×FN
= 0.4 x 2.45
= 0.98N
(f_o=.4)

Assuming that the rover always drives on six wheels, and only walks on less than six, the normal force of one wheel is calculated. The normal force of one wheel is equal to FN = 1/6 mg = 1/6 ×1.5×9.81= 2.45N. This gives a rolling resistance that varies between FR = .245 N and .98 N.

Grade resistance

Grade resistance Rg is the component of the vehicle weight acting downhill. It is given by
Rg= Wsinθ
=14.715× sin$f_0$30
=7.3575
The maximum slope the rover should be capable to climb 30 degrees (in soft soil). This gives a maximum grade resistance for one wheel of 7.3575N. Compared to the rolling resistance this is quite big, however the rover will only climb steep slopes when in easy terrain.

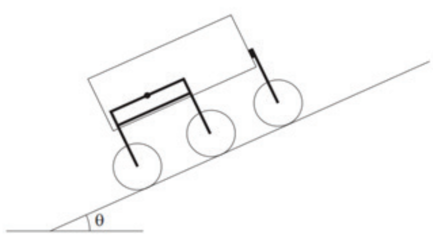

Figure 6: Grade resistance

Air resistance
The air resistance on Earth .The drag force FD can be calculated as follows:
FD = CD Aref (0.5ρU2∞)
With
Aref ≈ 2 m2
CD ≈0.5
ρ=1.225 Kg/m3
U2∞=.07 m/s
This gives an air resistance of approximately 3×10-3N. This is very low compared to the rolling resistance and grade resistance and can therefore be neglected.

Torque on the basis of weight
Gross vehicle weight (GVW) =14.7N
Radius of wheel = 70 mm
Desired top speed = 70 mm/s
Desired acceleration time (ta) = 1sec
Maximum incline angle (α) = 30º
Coefficient of friction (μ) = .25
Total tractive effort requirement for the vehicle:
TTE=RR(N)+GR(N)+FA (N)
Where, RR = Force necessary to overcome rolling resistance

FA = Force required to accelerate to final velocity
GR = Force required to climb grade

Rolling resistance:

The force resisting the motion when a body (such as a ball, tire, or wheel) rolls on a surface.
RR=GVW (N)+rr (-)
GVW = Gross vehicle weight
rr = Coefficient of friction
RR=14.7×.25
=3.675N
Rolling resistance = 3.675N
Grade resistance:
The amount of force necessary to move a vehicle up a slope or grade.
GR=GVW+sinα
GR = Grade resistance
α = Angle inclination
GR=14.75×sin30
GR=7.35N

Acceleration force:
It is force necessary to accelerate from a stop to maximum speed in a desired time.
FA=(GVW×Vmax)/(g×ta)
Vmax = Maximum velocity
g = Acceleration due to gravity

=(14.7×.07)/(9.81×1) = 0.105N

Total tractive effort:
It is the sum of the force.
TTE=RR+GR+FA
TTE=3.675+7.35+.105
=11.13 N
To determine wheel motor torque to verify the vehicle will perform as designed in regards to tractive effort and acceleration.
Required wheel torque based on the tractive force.
TW=TTE+RW+RF

Where, RW = Radius of wheel
RF = Resistance factor

Resistance factor typically range from 1.1 to 1.15

$TW=11.13\times70\times10^{3}\times1.1$
=.85701 Nm

Maximum tractive torque (MTT) = WW + μ + RW
Ww = Weight on drive wheel = 14.7 N

RW = 70×10-3

$MMT=(14.7\times.25\times70)/10^{3}=.25725$ Nm

Diameter and speed of the wheels
$V=\pi DN/60$

$70=\pi DN/60$ ie, $DN = 1336.9$

Where V, Speed of rover in mm/s
N, Speed of the wheel in rpm
D, Diameter of the wheel in mm

Selected D-N combination is
V=70 mm/s
D=66.84 mm
N=20 rpm

Table.1: Calculation of diameter and RPM

N	D
10	133.69
20	66.84
30	44.56
40	33.42
50	26.73
60	22.28
70	19.09
80	16.71

Calculation of wheel base

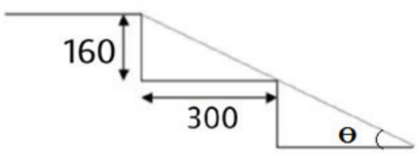

Figure 7: Stair dimensions

Tilt angle, $\Theta=\tan^{-1} y/x$
$\Theta=\tan^{-1} 160/300$
$\Theta=28.08°$
Now width of stairs is 300 mm so the maximum length of the rover can be 300 mm.
To deduce the wheel base,
Total Wheel base =Total length – (Radius of front wheel+ Radius of rear wheel)
= 300-(35+35)
= 230mm
Performance
Various tests were done to check for the efficiency of the rover. It was tested on different rough terrains and was able to overcome it with stability. The rover could climb the height of 120mm and that is equal to the height of bricks. An inclined plane was made to measure its capability of ascending and descending in different angles, in order to increase friction over the inclined plane the surface was roughened. It came to a conclusion that the robot could climb up to an inclination of 40° without overturn. The rover was moved over flat surface without any obstacles to check for its speed and it was noted that the maximum speed of the rover is 4.13 m/min. Table.2 shows the reading of speed test.

No.	Distance(m)	Time (S)	Speed(m/min)
1.	1	14.14	4.25
2.	1	14.80	4.06
3.	1	14.90	4.03
4.	1	14.16	4.20

Average : 4.13

Table.2: Rover speed test

3D Modeling

3D modeling is done using the software Solid Edge ST5.

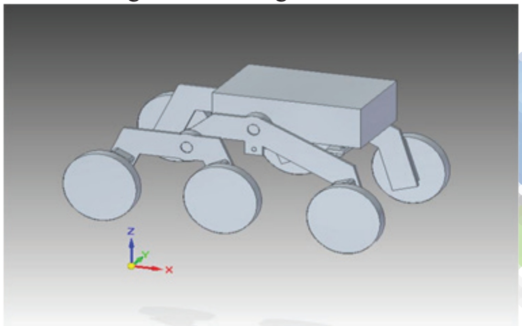

Figure 8: ISO view of total assembly.

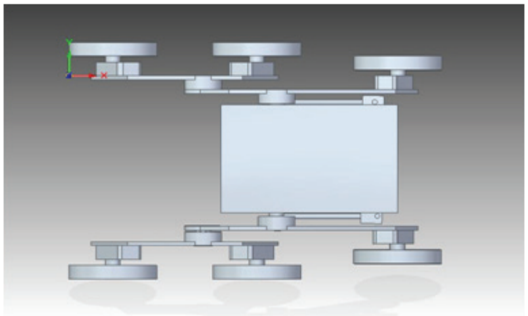

Figure 9: Top view.

Figure 10: Testing of robot.

III. Conclusion :

The unmanned terrain rover with rocker bogie suspension is completed successfully. All the components operation is tested and found to be correct. Tests in real life, field testing conditions have done to show the success. The designed and manufactured Robotic rover can climb up to 40° inclination and climb height up to 120mm. The objective of the project, which was to show that rovers that are deployed to explore the planets and rough terrain completed successfully also, the rovers can be made at a lower cost.
With the further advancement in technology it can further pushed into greater depths of Robotics. As modular research platform the rover developed by this project is designed specifically to facilitate future work. With same developments like attaching arm to the rover it can be made useful for the Bomb Diffusing Squad such that it can be able to cut the wires for diffusing the bomb. By the development of a bigger model it can be used for transporting man and material through a rough terrain or obstacle containing regions like stairs. We could develop it into a wheel chair too. It can be send to valleys, jungles or such places where humans may face some danger. It can also be developed into low cost exploration rover that could be send for collecting information about the environment of some celestial bodies.

This work has provided us an excellent opportunity and experience, to use our limited knowledge. We gained a lot of practical knowledge regarding, planning, purchasing, assembling and machining while doing this work. We are proud that we have completed the work with the limited time successfully. The robot was tested over various terrains and its operation is found to be satisfactory.

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