

Design and Development of a Mobile Platform for Unstructured Terrain

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Abstract: *Mobile robots are the need of the hour. There are different designs of platforms for different mobile robot. In most of the mobile robots four wheeled platforms are used with simple designs. But in mobile robots the design of the platform is the most important part. The design of the platform will dictate the working conditions of the robot. The objectives of this paper are to Design, develop and test a robo cart on rocker bogie mechanism to serve as a mobility platform, suitable for testing planetary surface exploration technologies in harsh earth environments. The design will focus on incorporating features that are believed to be essential for most planetary exploration missions based on research of past and current rovers. The rover will aim to recognize the size and weight constraints that all space bound vehicles face. This paper discusses about a six wheeled robotic platform. The design is done in solid works software to the exact dimensions and analyzed in ANSYS for load taking capacity. This platform is powered with a battery of 12V and each wheel is powered with DC servo motors.*

Keywords: *Mobile robot,*

Introduction

It is a complex task to design a mobile robot because there are several issues which affect its design. The first step in design of a robot is to evaluate the environment in which the robot has to work and the function of mobile robot in those conditions. In early stage of development of robots, the robotic arms were there which were fixed on a fixed platform so as to work in a very small area and were designed for some specific work such as pic and place. Then the mobile robot came into existence and with that arrives the concern of designing the platform for various working environment as the robot has to move from one place to another. Also, the weight carrying capacity was a concern. It is also important to note that the walking structure face more difficulties than wheeled robots in terrains with more gaps [1]. The robots with legs are generally inspired by nature but wheeled mobile robots are more successful and easy to design. There are more linkages in legged robots and can be source of consumption of high energy. This will require more energy and hence larger batteries. This whole makes the structure heavy and robust and fails the very reason of design of the mobile robot.

The wheeled type robots are more common in design and use for indoor environment. For indoor environment the design is kept simple. Because of simplicity of design of wheeled robot compared to legged robot, the wheeled robot are designed for outside environment also. The wheeled robots have to work in various environments outside, these are designed accordingly. As the interest is continuously increasing to explore other planets, the latest MER robot is the Curiosity rover launched in 2011, Arvidson (2016) the need is also increasing for mobile robots which can work in different environments. The design requires the mobile robots to traverse through terrains containing boulders, crates and desserts, Siegwart et al. (2002). The mobile robots which can work in such conditions can also work in hazardous conditions. This type of robots can save human lives by turning them in autonomous or semi-autonomous robots. Till now maximum research is done for the rover design keeping in mind the difficult terrain of the planets. Tao et al. (2006) designed, developed and tested a prototype of a six wheeled rover to be able to work in a difficult terrain. A four wheeled lightweight structure with high mobility and maneuverability was designed by Wen et al. (2013) for a novel lunar robotic. Lionel et al. (2014) proposed the reconfigurable rover concept design which can perform rolling and roving according to the condition..

However, very less research is done in the area of mobile robotic platforms which can take a sufficient amount of load and can carry it through different terrains and can be reconfigured according to the need of the conditions. In this paper we have tried to find a solution for this problem. The platform which we have designed and developed will be able to perform the task of taking a load around 10kg through unstructured terrains. The design of this mobile platform is such that it could be used to perform various other tasks other than roving on planetary surfaces. By making little changes in the configuration and sensors this robotic platform can perform the duty of a landmine detector. It can be very useful in material handling in industries from one place to other place without much human assistance. The design of legs of the boggy allows the robotic platform to reach the places where the reach of human is difficult and hazardous for mankind.

The platform will be controlled with the help of radio wave remote control which will make the access of human to difficult conditions without actually going there in physical. For that we can take the example of chemical leakage which can be health hazardous other sources can not detect the gravity of the situation. By reconfiguring the sensors, this platform will be able to detect the problem without any damage to any life. There will be a controller which will control the supply of voltage to all the motors and the motion of the complete body. This controller will control the navigation of the boggy.

2. Methodology

2.1 Project overview

In this project, we make a robust and ruggedized platform Rover that will be suitable for testing in harsh earth environments, on terrain similar to that of our moon and Mars. Given sufficient mobility in planetary environments, the rover must also be able to accommodate payloads, if

possible. Transporting sensitive scientific instruments across rough terrain is the main goal for nearly all exploration rovers, and thus one of our central requirements.

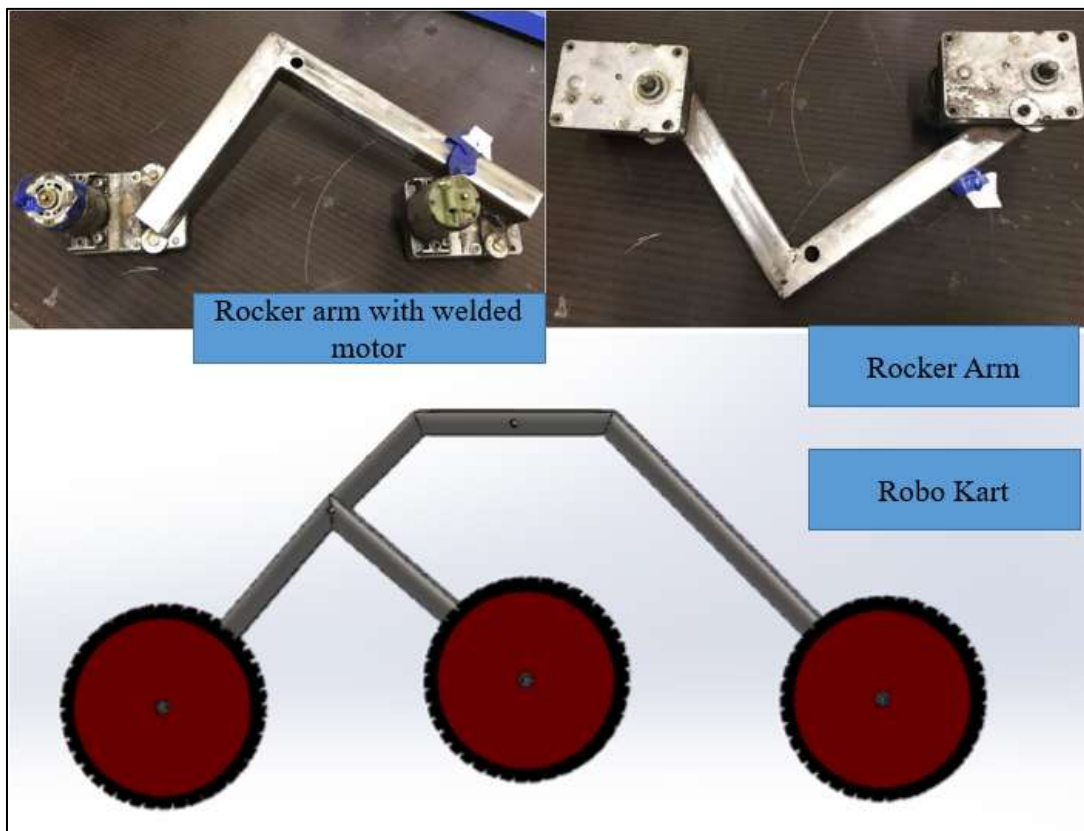


Fig.1: Project overview of Roboca

2.2 System architecture

Table 1 shows the project specification for this Robo cart. The main purpose of producing this specification is to clarify some important aspects of the project and to make sure that the project is feasible as well as appropriate to use in the market.

Table 1: Specification of Robo cart

Module	Specification
Interface	Arduino Mega
Controller	
Programming language	
actuator	Sevo motor

2.3 Mechanical design

Fig.2 illustrate the designing of the Robo cart with (a) main structure Robo cart with wheel (b) base structure of Robo cart.

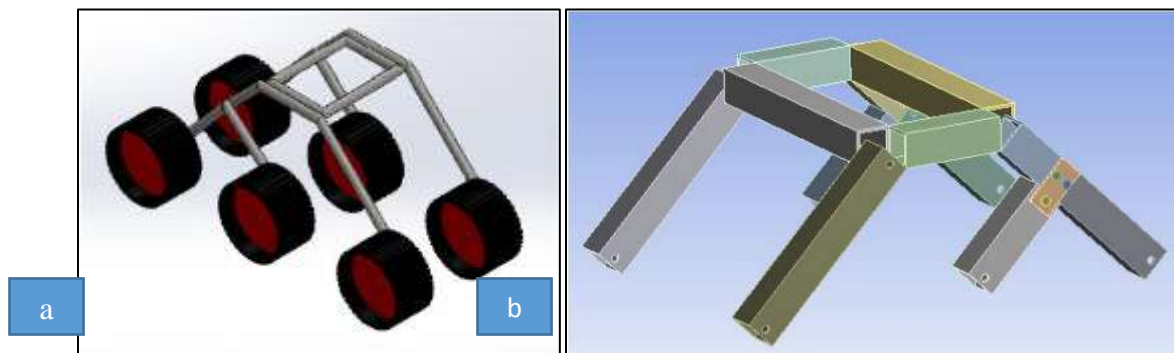


Fig.2: (a) main structure Robo cart with wheel (b) base structure of Robo cart.

2.4 Electrical design:

Fig.3 shows the electrical designing using Proteus simulation for Robo cart, each electrical component has been arranged specifically to create space for Arduino Mega.

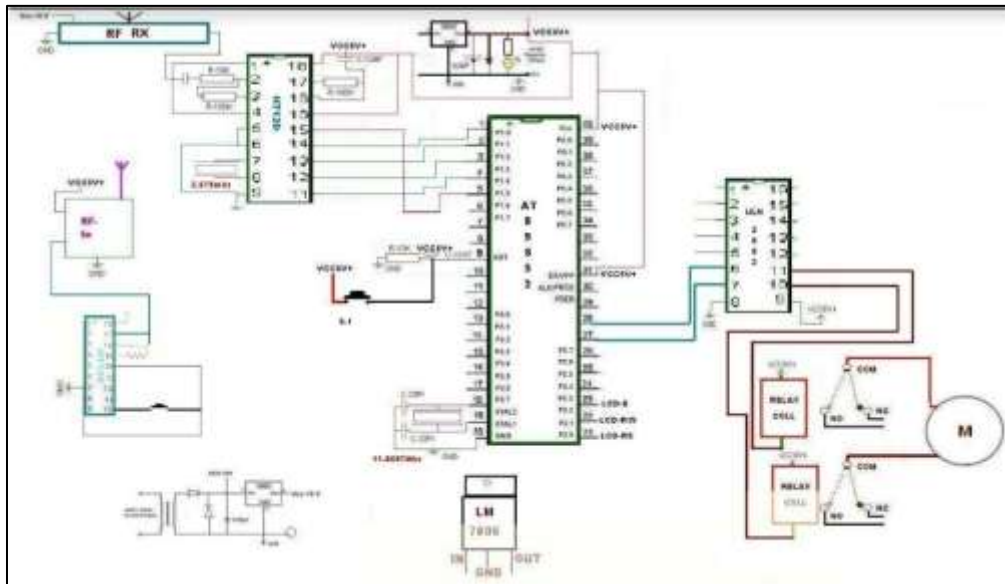


Fig.3: complete circuit for Robo cart.

2.5 Software development:

Software is a set of programs, procedures, algorithms and its documentation concerned with the operation of a data processing system. In this case, we use C++ software to complete task for the project.

The coding is:

```
#include<reg51.h>
sbit s1=P1^0;
sbit s2=P1^1;
sbit s3=P1^2;
sbit s4=P1^3;
sbit relay1=P2^0;
sbit relay2=P2^1;
sbit relay3=P2^2;
sbit relay4=P2^3;
sbit relay5=P2^4;
sbit relay6=P2^5;
sbit relay7=P2^6;
sbit relay8=P2^7;
void main()
{
P1=0xFF;
P2=0x00;
while(1)
{
if(P1==0XFE)
{
relay1=1;
relay2=0;
relay3=1;
relay4=0;
relay5=0;
relay6=0;
relay7=0;
relay8=0;
}
if(P1==0xFD
```

3. Result and discussion

3.1 Complete designing robot



Fig.4: Completed Robo cart

Fig.4 shows a completed mechanical structure of Robo cart. The dimension of the robot are

Total carriage height	5.5 inches
Total length of carriage	12 inches
Total width of carriage	6 inches
Rocker Arm	10 inches, 5.5 inches
Boggie	7 inches, 9 inches
50rpm motor size	4 inches

3.2 Loading and Constrain:
Maximum Stress: 10.975 MPa

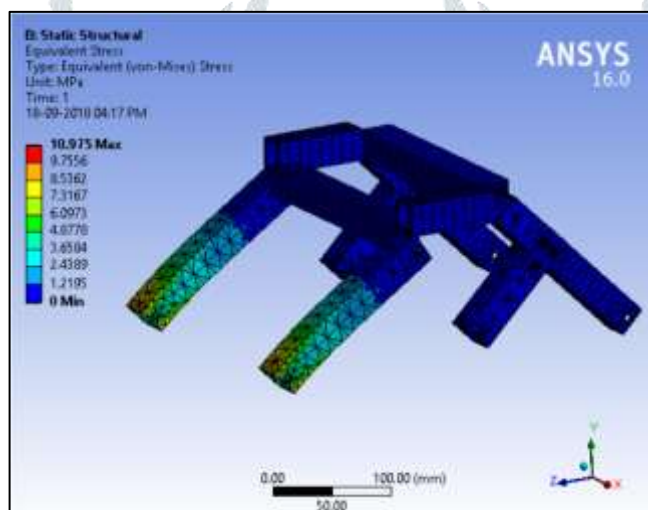


Fig.5: Stress Analysis

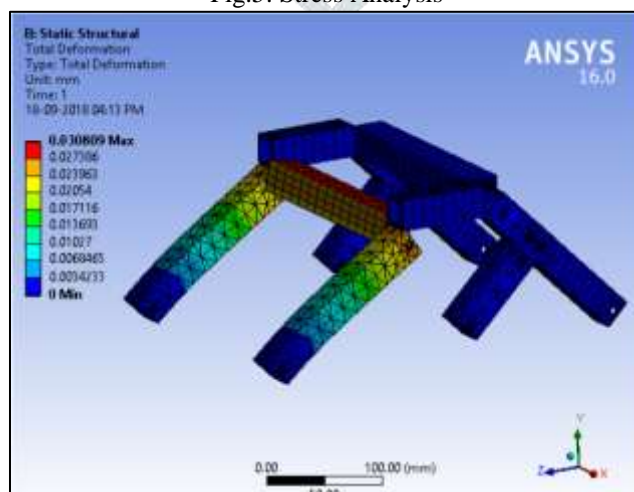


Fig.6. Displacement Analysis

Maximum deformation: 1.97 mm

3.3 Diameter of wheel:

As per availability in market we are using tyres of diameter 85mm that is enough to climb on stairs upto double of its diameter.

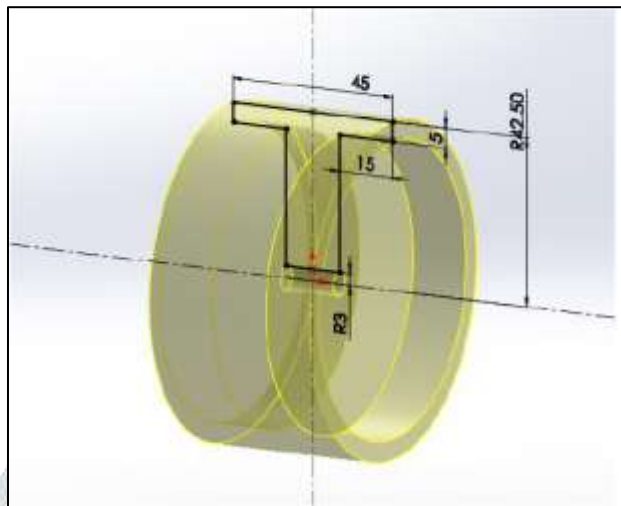


Fig.7: wheel cross section(all dimensions are in mm)

3.4 Speed

As $V = \pi * D * N / 60$

According to standards, 85 million tyre is available.

If we will take $N=60$ rpm then $V = \pi * 85 * 60 / 60$
 $= 267.035$ mm/sec
 $= 26.70$ cm/sec

At $N = 30$ rpm
 $V = 133$ mm/sec
 $= 13.3$ cm/sec

3.5 Calculation of Wheel Base:

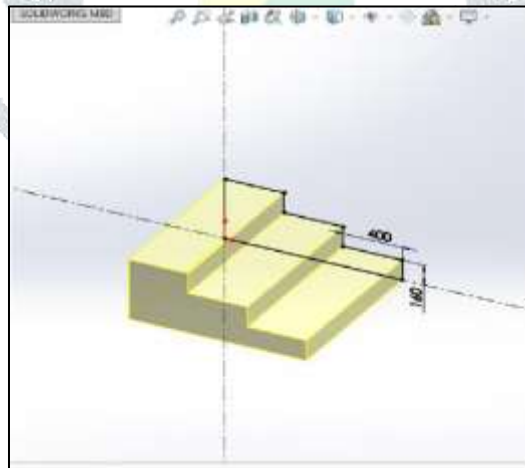


Fig.8: wheel base climb (all dimensions are in mm)

$\theta = \tan^{-1} (y/x)$
 $\theta = \tan^{-1}(160/400)$
 $\theta = 21.80^\circ$

Now width of stairs = 400 mm.

So maximum length of robot with tyres can be 400mm.

To deduce wheel base:

$= \text{Total length} - (\text{radius of front wheel} - \text{radius of rear wheel})$
 $= 400 - (42.5 + 42.5)$
 $= 400 - 85 = 315$ mm

So, the maximum length of chassis without tyres can be 315 mm.

3.6 Length of Links:

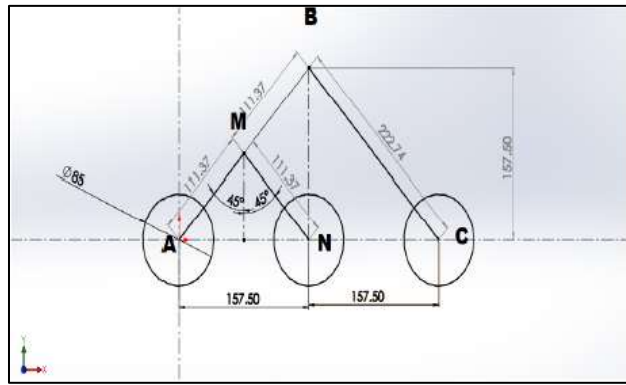
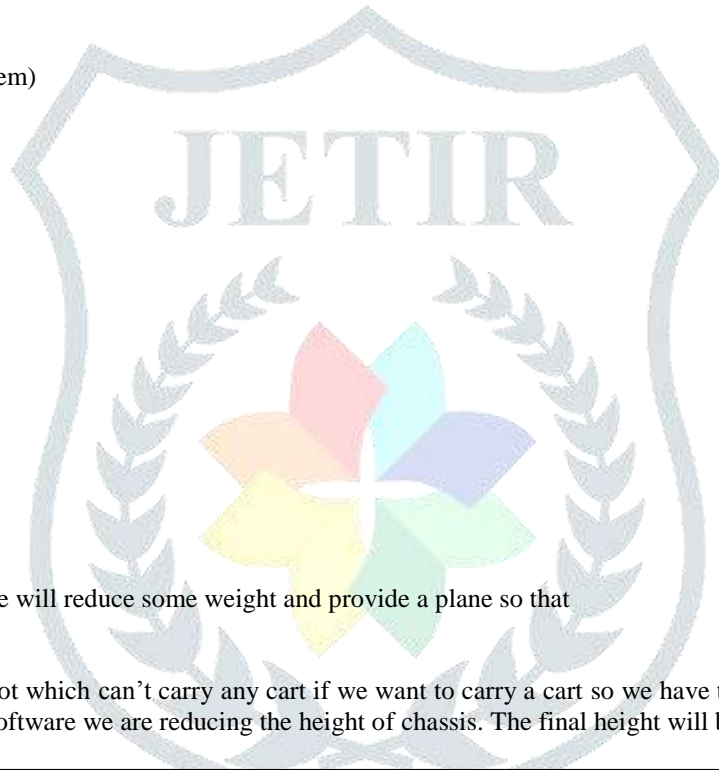


Fig.9.links of robo cart (all dimensions are in mm)

Total Wheel Base = 315 mm
 Let us assume, $\theta = 45$ degree
 In triangle BNC, $\angle BNC = 90^\circ$
 $\angle NBC = \angle NCB = 45^\circ$
 So, $NC = NB$
 $BC^2 = NC^2 + NB^2$ (By Pythagoras theorem)
 $BC^2 = 2 * (NC)^2$
 $= 2(157.5)^2$
 $BC^2 = 49612.5 \text{ mm}^2$
 $BC = 222.73 \text{ mm}$
 In triangle AMN
 $\angle AMN = 90^\circ$
 $AM^2 + MN^2 = AN^2$
 $2 * AM^2 = AN^2$
 $2 * AM^2 = (157.5)^2$
 $AM = \sqrt{12403.125} \text{ mm}$
 $AM = 111.36 \text{ mm}$
 Now due to gravity,
 $AM = MN = 111.36 \text{ mm}$
 $BM = AB - AM$
 $= 222.73 - 111.36$
 $BM = 111.37 \text{ mm}$



Now by using SolidWorks Software we will reduce some weight and provide a plane so that we can provide a cart on this robot.

3.7 Height of chassis:

The above data is just for a simple robot which can't carry any cart if we want to carry a cart so we have to provide a plane surface to fix cart on rocker arm. So, by using solid works software we are reducing the height of chassis. The final height will be as:

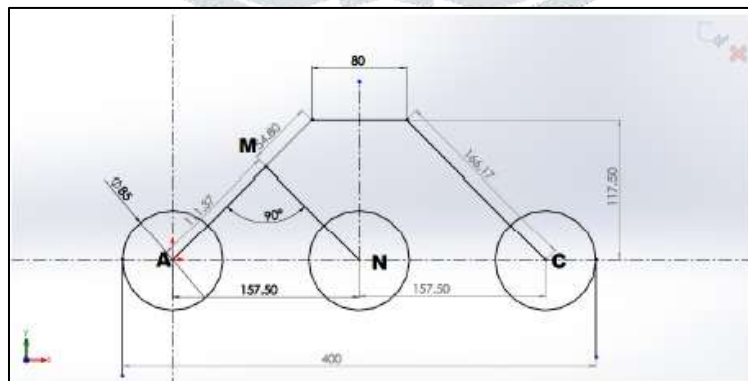


Fig.10: height measurement of robo cart (all dimensions are in mm)

Net height = height of chassis + radius of tyre
 $= 117.50 + (85/2)$
 $= 117.50 + 42.5$
 $= 160 \text{ mm}$

3.8 Track Width:

$$SSF = Tw / 2h$$

$$1.3 = Tw / (2 \times 160)$$

$$T_w = 416 \text{ mm}$$

3.9 Gross Weight Calculation:

Mass = volume x density

Density of mild steel: 0.00785 g/mrn³

Weight of rocker arms = 2[(320*225*3*0.00785) + (200*25*3*0.00785)] = 612.3gm

Weight of bogies = 2[2*(180*25*3*0.00785)] = 423.9gm

Weight of shaft = [(22/7/4)*9*9*230*0.00785] = 114.8grn

Weight of pin = 2*[2(22/7/4)*8*8*7*0.00785) + ((22/7/4)*9*9*7*0.00785)] = 18.02gm

Weight of bearings = 4*10 = 40gm

Weight of bush = 4*28.7 = 114.8gm

Total weight: 612.3+423.9+114.8+18.02+40+114.8 =1323.82gm

Gross weight of the mechanism is 1.323kg

3.10 Force by motors

We are using 12 V Dc motor with provided torque 5 to 7 Kg cm and the tyres we are using is of 85 mm diameter.If we divide torque by radius of tyre we will get the load which a motor can bear.

Let take at 5 Kg cm,

Force will be 5/4.25 = 1.176 Kg (By one motor)

6*1.176= 7.05 Kg (By six motors)

At 6 Kg cm,

Force by six motors = 8.47 Kg

3.11 Turning Mechanism

Here, we will use two channel remote controlled with 3 motors of left side on single and other 3 on second channel. If we want to turn it in left side then we will slow down or make reverse direction of motor and other side motor will in forward. Same for right.

3.12 Traction and Slip:

The rover must maintain good wheel traction in challenging rough terrains. If traction is too high, the vehicle consumes a lot of power in order to overcome the force and move. If traction is too low, the rover is not able to climb over obstacles or inclined surfaces.Slip occurs when the traction force at a wheel-terrain contact point is larger than the product of the normal force at the same wheel and the friction coefficient. Hence, no slip occurs ifthe condition $T_i \leq \mu N_i$ is satisfied. In reality it is very challenging to determine the precise friction coefficient μ for the interaction of two surfaces

3.13 Lateral Stability:

The rover is said to be stable when it is in a quasi-static state in which it does not tilt over.

The lateral stability of the rover ensures that the rover does not tip sideways. As the rover has two symmetric sides, the geometric model is used to find the lateral stability of the vehicle.

Lateral stability is computed by finding the minimum allowed angle on the slope before the rover tips over.Lateral stability of the rover is ensured if the overall stability angle

$$\theta_{stab} \geq \alpha \therefore \min(\theta_r, \theta_l) \geq \alpha$$

For Lateral Stability, let N_1 be the reaction on right wheel and N_2 be reaction on the left wheel. Let ‘a’ be the slope of the inclination, θ_r & θ_l the angle that the point of contact makes with the Centre of Gravity on the left and right wheels respectively. Z be the height of the centre of gravity and y_l and y_r be the perpendicular between the point of contact and the Centre of Gravity.

In this condition to ensure the stability the rover should not tip off the inclined. And hence the normal reaction on any of the wheel should not be 0.

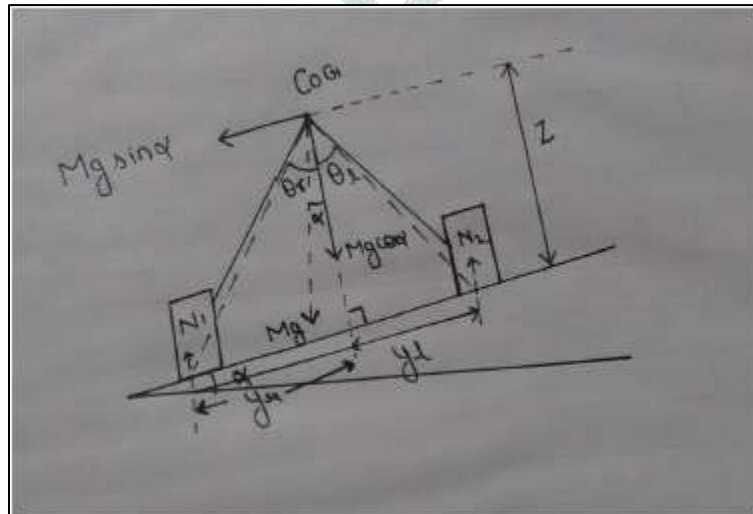


Fig.11: calculation for lateral stability of wheel

aking moment at left wheel.

$$Mg \cdot z \sin \alpha + Mg y_1 \cos \alpha = N_1 (y_1 + yr)$$

Dividing the equation by z

$$Mg \sin \alpha + Mg y_1/z \cos \alpha = N_1 (y_1 + yr)/z$$

From the figure above the $y_1/z = \tan \theta_1$ and $yr/z = \tan \theta_r$

$$Mg \sin \alpha + Mg \tan \theta_1 \cos \alpha = N_1 (\tan \theta_1 + \tan \theta_r)$$

Let θ_1 , θ_r and α be very small then

$$Mg \alpha + Mg \theta_1 = N_1 (\theta_1 + \theta_r)$$

$$Mg (\alpha + \theta_1) = N_1 (\theta_1 + \theta_r)$$

$$Mg > N_1$$

$$(\alpha + \theta_1) < (\theta_1 + \theta_r)$$

$$\alpha < \theta_r$$

3.14 Longitudinal Stability:

According to, longitudinal stability of the vehicle is given when all wheels have ground contact and the condition $N_i > 0$ is satisfied, where N_i is the normal force at wheel i . It should be noted that even though this condition is compulsory for the statical model to work, a physical rover does not necessarily tip if a wheel loses contact to the ground. However, it is less steerable.

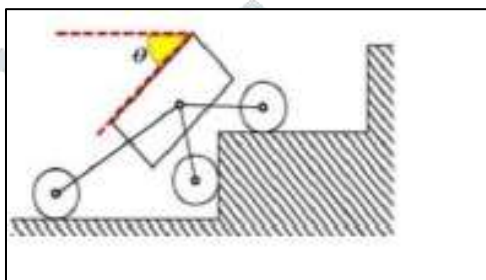


Fig.12: calculation for lateral stability of wheel

3.15 Static Stability Factor:

The Static Stability Factor (SSF) of a vehicle is one half the track width, TW, divided by h, the height of the centre of gravity above the road. A reduction in CoG height increases the lateral inertial force necessary to cause rollover by reducing its leverage, and the advantage is represented by an increase in the computed value of SSF.

A wider track width also increases the lateral force necessary to cause rollover by increasing the leverage of the vehicle's weight in resisting rollover, and that advantage also increases the computed value of SSF.

The inertial force which causes a vehicle to sway on its suspension (and roll over in extreme cases) in response to cornering, rapid steering reversals or striking a tripping mechanism, when sliding laterally may be thought of as a force acting at the CoG to pull the vehicle body laterally. $SSF = TW / (2 \cdot h)$.

3.16 Mobility:

In order to go over an obstacle, the front wheels are forced against the obstacle by the rear wheels. The rotation of the front wheel then lifts the front of the vehicle up and over the obstacle. The middle wheel is pressed against the obstacle by the rear wheel 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. These rovers move slowly and climb over the obstacles by having wheels lift each piece of the suspension over the obstacle one portion at a time.

CONCLUSION:

This project will try reaching nearly all of our design requirements, and in many respects exceeding original design goals. Furthermore all components, mechanical and electrical, will be thoroughly tested as a completed system in real-world field testing conditions to validate their success.

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