DESIGN, FABRICATION AND ANALYSIS OF ROCKER BOGIE MECHANISM

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Abstract

The present work is carried out on modelling robotics and analysis of rocker bogie mechanisms used in the mars rovers the main purpose of this project is to overcome the rough terrains while maintaining stability. This enables to have a suspension-based mechanism that distributes the vehicle load as evenly as possible even on bumps and irregular surfaces. The modelling of rocker bogie mechanisms is carried out by **SOLIDWORKS 2019** and analysis it with **ANSYS 19.2**. A Rocker Bogie Mechanism is made completely from PVC pipe to increase its capability to withstand shock Vibration and mechanical failures. An android application is developed in order to communicate with the Arduino on the rover and can control the rover with mobile application. The important factor in manufacturing of rocker bogie mechanism is to determine the dimensions of rocker bogie linkages and angle between them. The lengths and angles of this mechanism can be changed as per requirement.

Keywords: Arduino, Rocker Bogie, Rover design, MIT App Inventor-II, robotics, HC-05**.**

1. Introduction

On July 4, 1997, an orange colored big ball softly bounced on the surface of Mars with an unusual robotic vehicle inside. This was the first planetary mission which has been widely public interest after the first man on the moon. Small rover "Sojourner" conducted scientific experiments for 83 Sols (Mars Days) and took hundreds of photographs. Roving on another planet came from dream to real by the help of science and patient ambitious research. This successful mission encouraged the scientists and NASA to continue the Mars exploration with new rovers. Many rovers developed after Sojourner with different features and scientific objectives. In the early days of January 2004, second and third rovers landed different locations on Mars named Spirit (MER1) and Opportunity (MER2). Scientific results of these powerful vehicles are bigger than their physical dimensions. All of the three rover's success and scientific results show that space agencies will continue robotic geologists frequently in future.

2. Literature Review

VILCOX, T.NGUYEN [1], the authors describe about the existing rovers, their features, significance, constructional details and required advancements. The requirements of a rover required to overcome in order to withstand the environmental conditions are described.
RICHARD VOLPE AND STEPHEN [2], This paper provides an overview of the rover technology development, integration, validation, and mission infusion process now being used by the NASA Mars Technology Program. Described are the relevant mission scenarios of long range traverse and science instrument placement, along with the enabling algorithmic components for them. These are being integrated into the robotics research software

environment for demonstration and component validation, and then infused into the MDS spacecraft flight software environment for system level validation. Dongmok kim [3], the author first presents an optimal design of a wheel-type mobile robot in order to ensure high mobile stability as well as excellent adaptability while climbing stairs. As an optimization tool, the Taguchi method is adopted due to its simplicity and cost effectiveness both in formulating an objective function and in satisfying multiple constraints simultaneously. The sensitivity analysis with respect to design parameters is carried out to provide an insight to their effects on the performance criterion under kinematic constraints which are imposed to avoid undesired interferences between a mobile robot and stairs. To evaluate the climbing capability of the optimized rocker-bogie mechanism, the friction requirement metric is chosen, which is defined as a minimum friction coefficient required for a mobile robot to climb a stair without slip. Xiaolin Xie,Feng Gao,Chuan Huang[4], the author proposed a new design of transformable wheels for use in an amphibious all-terrain vehicle. The wheel has two extreme working statuses: unfolded walking-wheel and folded rigid wheel. When the wheel is unfolded at walking-wheel status, the displacement, velocity and acceleration of the wheel with different slip rates were analyzed. The stress condition is studied by using a classic soil mechanics method when the transformable wheel is driven on soft terrain. The relationship among wheel traction, wheel parameters and soil deformation under the stress were obtained. The results show that both the wheel traction and trafficability can be improved by using the proposed transformable wheel. Finally, a finite element model is established based on the vehicle terramechanics, and the interaction result between the transformable wheel and elastic–plastic.

3. Wheeled locomotion and suspension

This suspension has 6 wheels with symmetric structure for both sides. Each side has 3 wheels which are connected to each other with two links. Main linkage called rocker has two joints. While first joint connected to front wheel, other joint assembled to another linkage called bogie, which is similar to train wagon suspension members. In later design of articulated suspension system, called rocker-bogie with small changes.

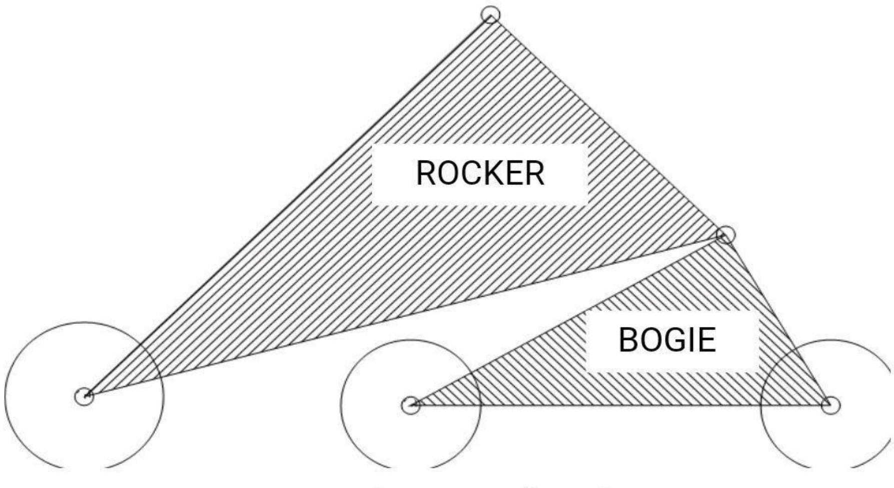

Figure-1: Kinematic diagram of Rocker-Bogie suspension

Wheeled locomotion’s main component is its suspension mechanism which connects the wheels to the main body or platform. This connection can be in several ways like springs, elastic rods or rigid mechanisms. Most of the heavy vehicles like trucks and train wagons use leaf springs. For comfortable driving, cars use a complex spring, damping and mechanism combination. Generally, exploration robots are driven on the rough surface which consists of different sized stones and soft sand. For this reason, car suspensions are not applicable for rovers. The requirements of a rover suspension are:

• As simple and lightweight as possible
• Connections should be without spring to maintain equal traction force on wheels
• Distribute load equally to each wheel for most of the orientation possibilities to prevent from slipping

3.1 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 wheels then lift the front of the vehicle up and over the obstacle. The middle wheel is then pressed against the rear wheel by the obstacle until it is lifted up and over. Finally, the rear wheels are pulled over the obstacle by the front two wheels, during each wheel 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.

3.2 Wheel Motion

When the rover is moving on a flat surface, if there is no slip, wheel center will move on a line parallel to the surface with a constant velocity. Although, obstacles can be different in concern of geometry, most difficult geometry which be can climbed by wheel is stair type rectangular obstacle.

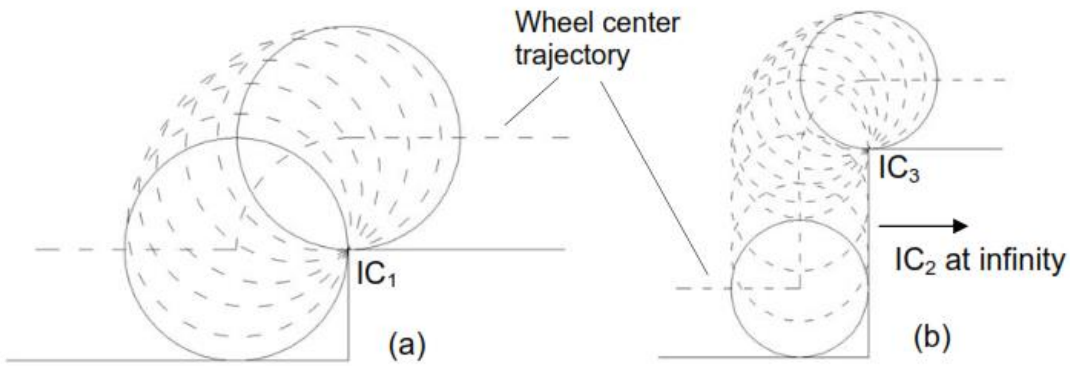

Figure-2: Wheel passing over an obstacle having (a)equal height having the radius of wheel
(b)height more than the radius of wheel

In figure 3-2(a), height of the obstacle is same or less than the half diameter of the wheel. For this condition, the wheel's instant center of rotation (IC1) is located at the contact point of the obstacle and wheel. Trajectory of the wheel centers' during motion generates a soft curve, thus, horizontal motion of the wheel center does not break. Since in figure 3-2(b), height of the obstacle is more than the half diameter of wheel, this condition can be classified as climbing. Climbing motion consist of two sub motions. First one is a vertical motion, which causes a horizontal reaction force on wheel center . This vertical motion's instant center (IC2) is at infinity. Second one is a soft rotation similar to figure 3-2(a) with instant center of rotation (IC3) at the corner.

3.2 Design of Rocker Bogie mechanism

Principle:

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. The important factor in designing of rocker bogie mechanism is to determine the dimensions of rocker bogie linkages and angle between them. The lengths and angles of this mechanism can be changed as per requirement. In this the work is to design the rocker bogie mechanism of length 367mm and can overcome the obstacles of 260 mm height (like stones, wooden blocks) and can climb over stairs of height 260 mm and also to climb any surface at an angle of 35°. To achieve the above targets we had designed the rocker-bogie model by assuming stair height 260mm and length 260mm. Using Pythagoras theorem, we had find the dimensions of the model. It will have both angles of linkages 90˚. To achieve proper stair climbing the dimensions of linkages should be proper. Assume the stair height as 260mm and length as 367mm.

3.3 Design calculations:

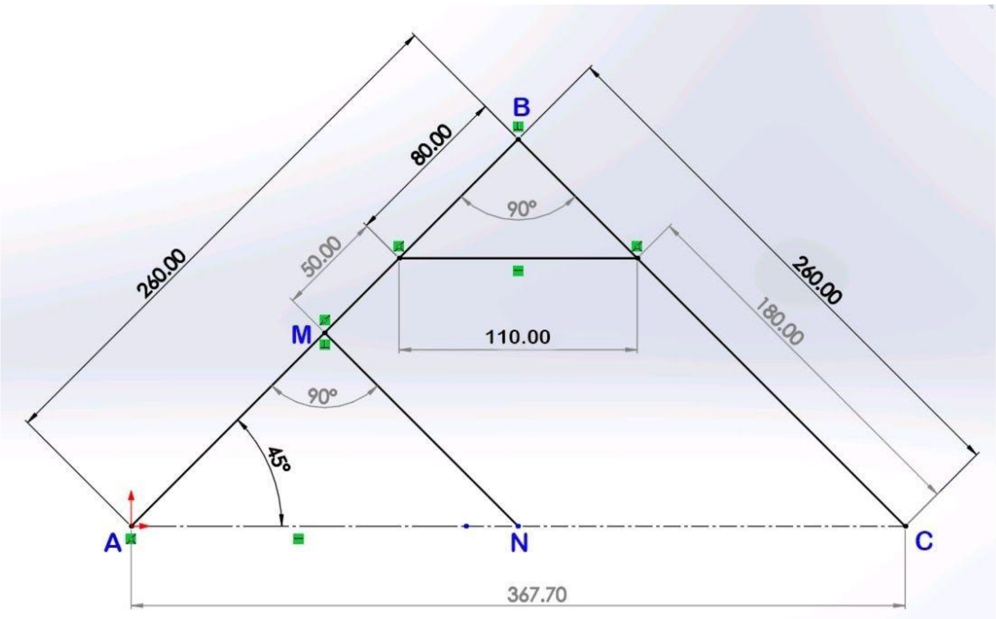

Figure-3: Design dimensions of the mechanism

From the triangle AMN,

$AN^2=AM^2+MN^2$

$=2(AM^2)$ (AM=MN)

$=2(130^2)$

AN=183.8mm

From the triangle BNC,

$BC^2 = BN^2+NC^2$

=2(NC2) (BN=NC)

$=2(183^2)$ (NC=AN)

BC =260mm.

Velocity of rocker bogie robot

V = rω

= (65*2*π*60)/60

= 408.2mm/s

= 0.408m/s

Maximum height rover can climb,

Tan(x)=(stair height /wheel base)

=260/367

=0.7

x =35°

The wheels are desired to be wider for increasing the traction to traverse upon the obstacles. And their diameter depends upon the availability and amount of speed required. The actual rover uses billet wheels, and machines the wheel and tread from one piece of round aluminum stock. The main problem during the selection of the wheels is lightweight consideration and the distribution of load on the wheels. The Design of the wheel is to do such that it can run at a velocity up to 0.408 m/s. Speed 60 rpm of motor.Therefore, we select the wheel of 130 mm diameter. For the light weight and cost effectiveness of the rover, we will choose plastic wheels with rubber treads available in the market depending upon the calculations. The plastic wheels offer a low-cost solution and are durable enough for a combat robot which is still light enough to be practical. Here six wheels are used for the robot. Wheel Diameter: 130 mm, Wheel Width: 40 mm. It's desired to take an acceleration of about half of the maximum velocity for a typical robot to run on flat terrain. The maximum velocity of the robot is 0.4 m/s therefore; the acceleration of the robot will be 0.4/2 means 0.2 m per second square. If the robot is moving up inclines or through rough terrain, we need a higher acceleration due to the center of gravity we can climb the angle of up to 35˚.

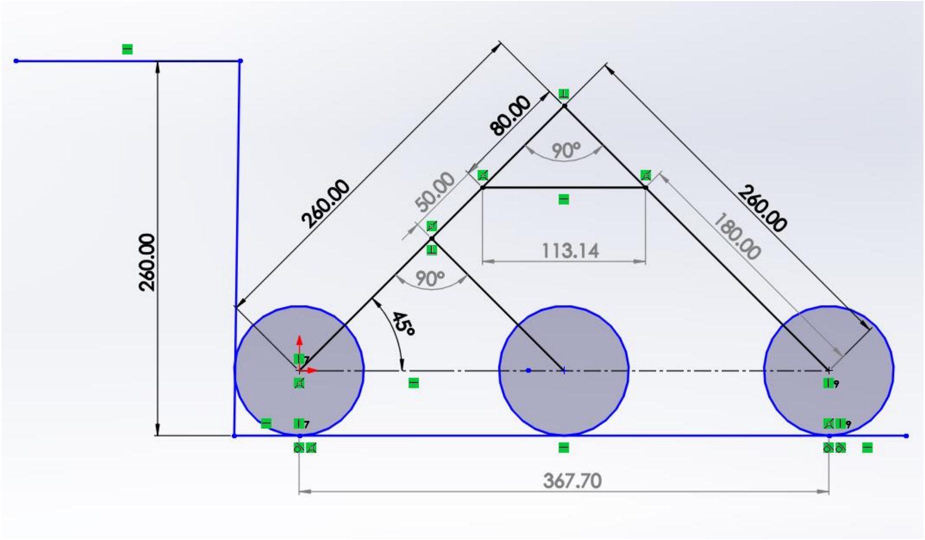

Figure-4: Design dimensions of the mechanism on a stair

4. MODELLING AND ANALYSIS

Introduction to Ansys

ANSYS is a general-purpose finite element modelling package for numerically solving a wide variety of mechanical problems. ANSYS simulation software enables organizations to confidently predict how their products will operate in the real world. It expands the use of physics. It gains access to any form of engineering field someone may account in. The ANSYS program has many finite element analysis capabilities, ranging from a simple, linear, static analysis to a complex, nonlinear, transient dynamic analysis.

A typical ANSYS analysis has three distinct steps

- Build the model
- Apply loads and obtain the solution
- Review the results

➢ **Building a model**

Building a finite element model requires more of an ANSYS user's time than any other part of the analysis. First, the job name and analysis title is specified . Then the PREP7 pre-processor is used to define the element types, element real constants, material properties, and the model geometry.

➢ **Apply loads and obtain the solution**

In this step,by using the SOLUTION processor to define the analysis type and analysis options, apply loads, specify load step options, and initiate the finite element solution. It can also apply loads using the PREP7 pre-processor.

➢ **Review the results**

Once the solution has been calculated, the ANSYS post processors is used to review the results.There are two post processors they are available –POST1 and POST26.

4.1 Loading overview:

The main goal of a finite element analysis is to examine how a structure or component responds to certain loading conditions. Specifying the proper loading conditions is, therefore, a key step in the analysis. The loads can be applied on the model in a variety of ways in the ANSYS program. Also, with the help of load step options, one can control how the loads are actually used during solution.

4.2 Solution:

In the solution phase of the analysis, the computer takes over and solves the simultaneous equations that the finite element method generates. The results of the solution are

• Nodal degree-of-freedom values, which form the primary solution.

4.3 Model generation:

The ultimate purpose of a finite element analysis is to re-create mathematically the behaviour of an actual engineering system. In other words, the analysis must be an accurate mathematical model of a physical prototype. In the broadest sense, this model comprises all the nodes, elements, material properties, real constants, boundary conditions, and other features that are used to represent the physical system.

In ANSYS terminology, the term model generation usually takes on the narrower meaning of generating the nodes and elements that represent the spatial volume and connectivity of the actual system. Thus, model generation in this discussion will mean the process of defining the geometric configuration of the model's nodes and elements. The ANSYS program offers the following approaches to model generation:

• Creating a solid model within ANSYS.
• Using direct generation.
• Importing a model created in a computer-aided design (CAD) system.

4.4 The SolidWorks Software

The SolidWorks CAD software is a mechanical design automation application that lets designers quickly sketch out ideas, experiment with features and dimensions, and produce models and detailed drawings.

Assemblies

An assembly design consists of two or more components assembled together at their respective work positions using parametric relations. In SolidWorks, these relations are called mates.

➢ Assembling Components Using the Mate Property Manager

In SolidWorks, mates can be applied using the Mate Property Manager.
Choose the Mate button in the Assemble Command Manager or
choose Insert > Mate from the Menu Bar menus; the Mate Property Manager will
be invoked, as shown.

4.5 Structural Analysis

Structural analysis is probably the most common application of the finite element method. The term structural (or structure) implies not only civil engineering structures such as bridges and buildings, but also naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools.

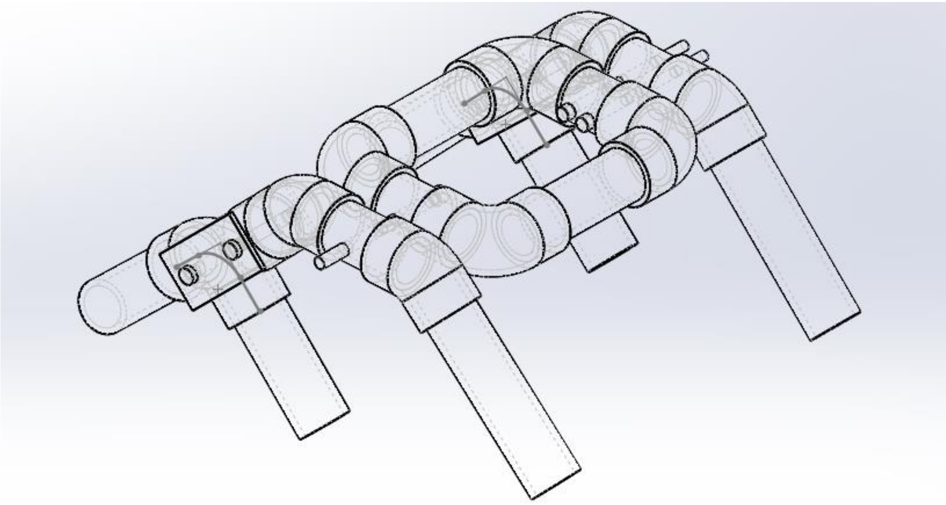

Figure-5: 3D-Model of Rocker Bogie Mechanism (Isometric)

4.6 Meshing of the model

The significant factor that will affect the possibilities to obtain acceptable results from the analysis is how the mesh is defined. A finer mesh will generate more accurate results, at the price of longer calculation time. Triangular meshing is done. The numbers of elements are 26213 and the numbers of nodes are 75462. It is necessary to mesh manually in subsequent simulations where the model is more detailed, and the geometry is more complex.

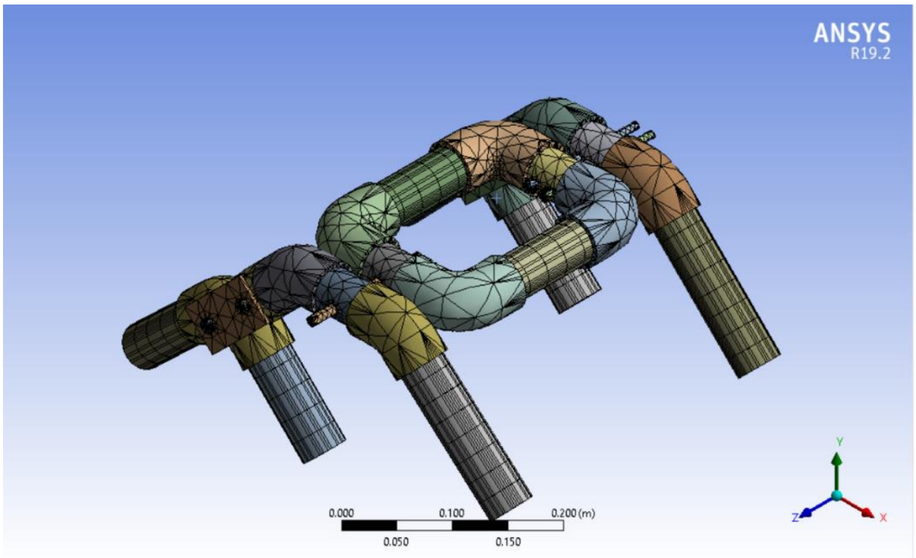

Fig-6: Image showing the meshing details of the model

4.7 Von Mises stress

When a body in an initial state of equilibrium or undeformed state is subjected to a body force or a surface force, the body deforms correspondingly until it reaches a new state of mechanical equilibrium or deformed state. The inner body forces are the result of a force field, such as gravity, and the surface forces are forces applied on the body through contact with other bodies. The relations between external forces which characterize what is called the stress and the deformation of the body, which characterizes strain, are called Stress-Strain relations.

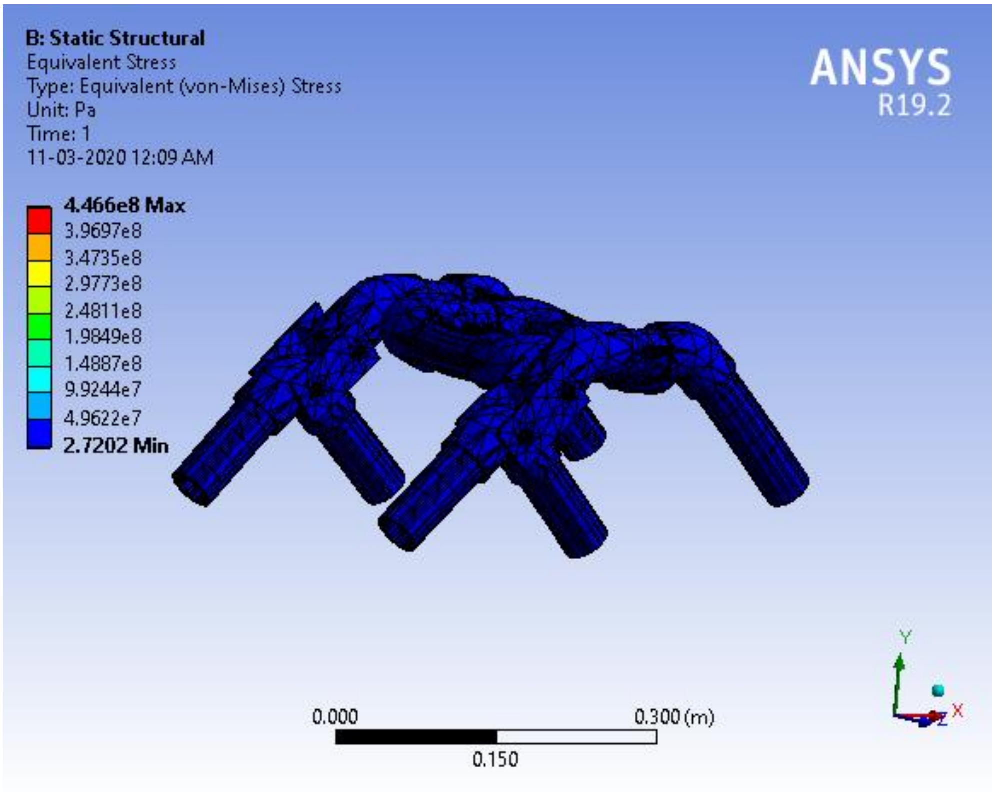

Figure -7: Equivalent von Mises stress

4.8 Total deformation

Deformation refers to any changes in the shape or size of an object due to an applied force or change in the temperature Total Deformation or directional deformation both are used to obtain displacement from stresses directional deformation are used to calculate the deformation in X, Y, and Z planes for a given systems. Total deformation gives a square root of the summation of the square of X-Direction, Y-direction and Z-directions.

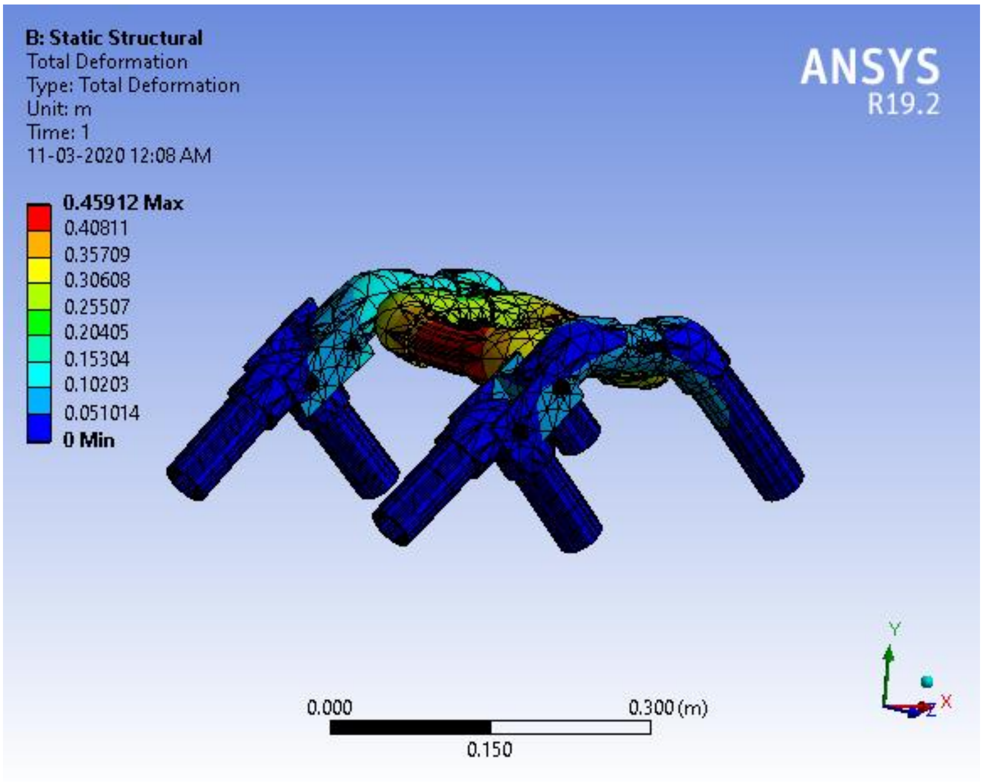

Figure-8: Total Deformation

5. Robotics and App Management

The mechanism is fabricated using PVC pipes and electronic components are included in order to make the model move. The components used are Arduino UNO R3, L298N motor driver, HC-05 Bluetooth module, Jumper cables, 12V 60RPM DC Motor, 12V 7AH lead acid battery. An application is made with the help of MIT App Inventor-II. It is an application that can be installed on an android based phone. The app inventor environment contains 2 workplaces where we can create an outer view of the app and can write a block code of the app. The Bluetooth module in the robotic circuit is made to connect with the phone's Bluetooth and exchange commands to operate the rover. Initially a set of code is fed into the Arduino using Arduino IDE by connecting the Arduino board to the computer. The code is written on the basis of the circuit diagram. The buttons in the app are build in such a way that they pass a certain command to the Arduino and the Arduino decodes the received data and sends pulses to the L298N motor driver and makes the motors rotate.

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5.1 CIRCUIT DIAGRAM

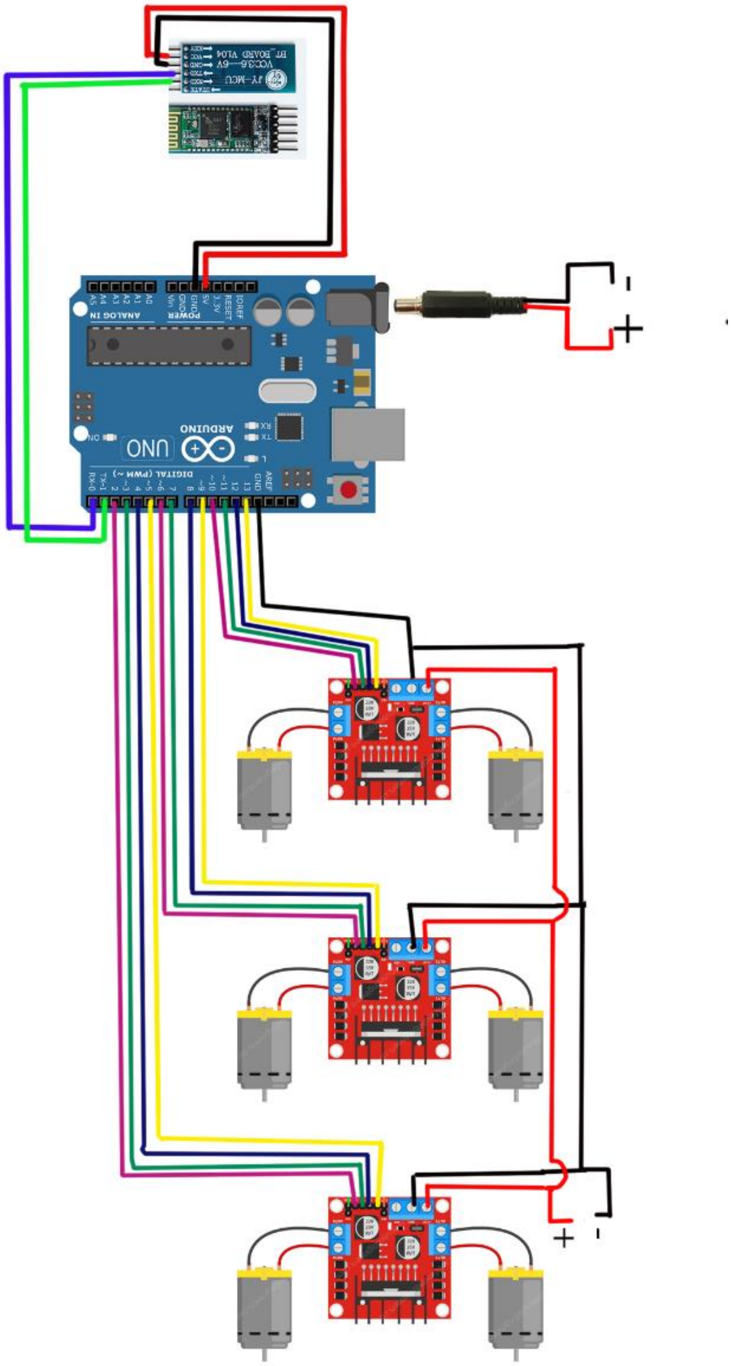

Figure-9: Circuit Diagram

5.2 ARDUINO UNO R3 CODE

```
void setup()
 {
  Serial.begin(9600);
  pinMode(2,OUTPUT);
  pinMode(3,OUTPUT);
  pinMode(4,OUTPUT);
  pinMode(5,OUTPUT);
  pinMode(6,OUTPUT);
  pinMode(7,OUTPUT);
  pinMode(8,OUTPUT);
  pinMode(9,OUTPUT);
  pinMode(10,OUTPUT);
  pinMode(11,OUTPUT);
  pinMode(12,OUTPUT);
  pinMode(13,OUTPUT);
}

void loop()
 {
  if(Serial.available()>0)
  {
    char data = Serial.read();
    if (data == 'w')
    {
      digitalWrite(2,HIGH);
      digitalWrite(4,HIGH);
      digitalWrite(6,HIGH);
      digitalWrite(8,HIGH);
      digitalWrite(10,HIGH);
      digitalWrite(12,HIGH);
      digitalWrite(3,LOW);
      digitalWrite(5,LOW);
      digitalWrite(7,LOW);
      digitalWrite(9,LOW);
      digitalWrite(11,LOW);
      digitalWrite(13,LOW);
    }
```

```
else if(data == 's')
{
  digitalWrite(2,LOW);
  digitalWrite(4,LOW);
  digitalWrite(6,LOW);
  digitalWrite(8,LOW);
  digitalWrite(10,LOW);
  digitalWrite(12,LOW);
  digitalWrite(3,HIGH);
  digitalWrite(5,HIGH);
  digitalWrite(7,HIGH);
  digitalWrite(9,HIGH);
  digitalWrite(11,HIGH);
  digitalWrite(13,HIGH);
      }
 else if(data == 'd')
{
  digitalWrite(2,HIGH);
  digitalWrite(4,LOW);
  digitalWrite(6,HIGH);
  digitalWrite(8,LOW);
  digitalWrite(10,HIGH);
  digitalWrite(12,LOW);
  digitalWrite(3,LOW);
  digitalWrite(5,HIGH);
  digitalWrite(7,LOW);
  digitalWrite(9,HIGH);
  digitalWrite(11,LOW);
  digitalWrite(13,HIGH);
      }
else if(data == 'a')
{
  digitalWrite(2,LOW);
  digitalWrite(4,HIGH);
  digitalWrite(6,LOW);
  digitalWrite(8,HIGH);
  digitalWrite(10,LOW);
  digitalWrite(12,HIGH);
  digitalWrite(3,HIGH);
  digitalWrite(5,LOW);
  digitalWrite(7,HIGH);
  digitalWrite(9,LOW);
  digitalWrite(11,HIGH);
  digitalWrite(13,LOW);
      }
```

```
      else if(data == 'f')
      {
        digitalWrite(2,LOW);
        digitalWrite(4,LOW);
        digitalWrite(6,LOW);
        digitalWrite(8,LOW);
        digitalWrite(10,LOW);
        digitalWrite(12,LOW);
        digitalWrite(3,LOW);
        digitalWrite(5,LOW);
        digitalWrite(7,LOW);
        digitalWrite(9,LOW);
        digitalWrite(11,LOW);
        digitalWrite(13,LOW);
          }
    }
  }
```

5.3 MIT App Inventor-II interface

It is a web application integrated development environment provided originally by Google and now developed and maintained by Massachusetts Institute of Technology(MIT). It is a free ware and can be used to create and develop android and iOS application by anyone.

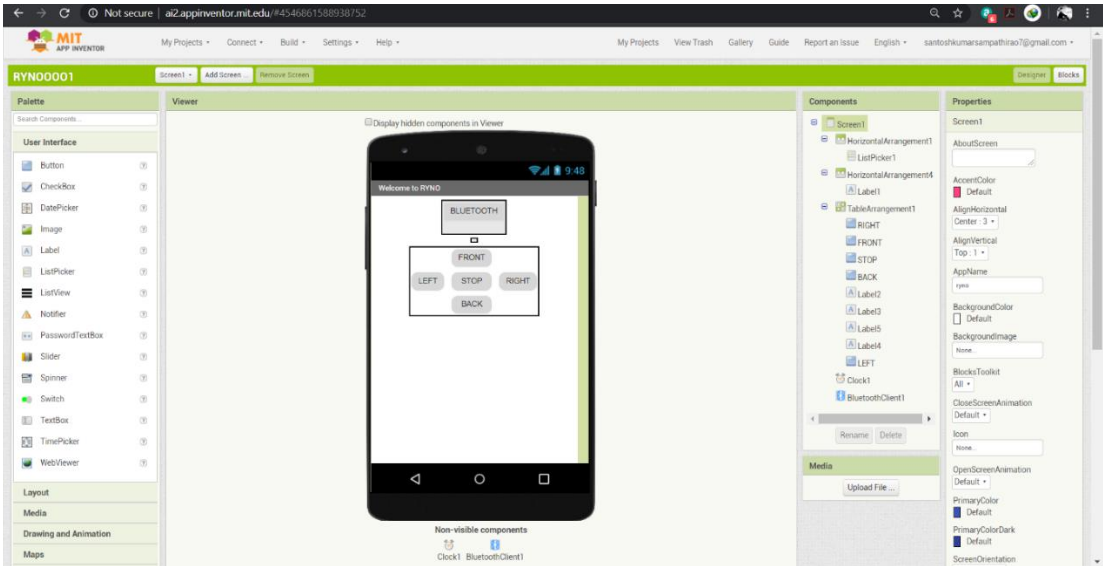

Figure-10: User interface of MIT App inventor2 design modular

Figure-11: Block code of the application created in app inventor

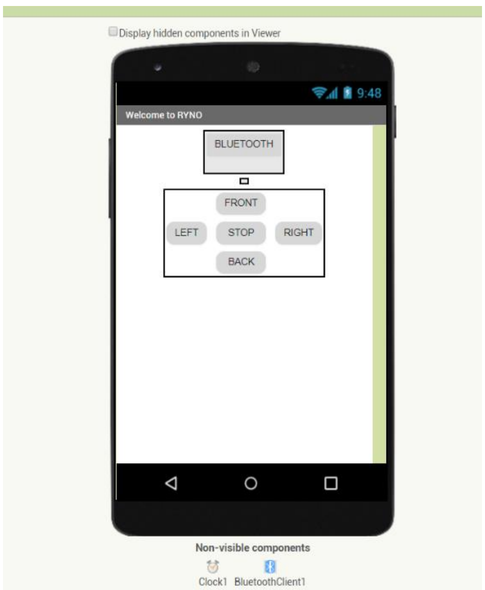

Figure-12: Interface of the app installed in phone

6. CONCLUSIONS

The various components of rocker bogie mechanisms are assembled. This is a wide field of study.

- The main function of this mechanisms is to overcome the rough terrains while maintaining stability.
- The most important thing in this mechanism is that the length and angles can be changed and can be used as per the requirements.
- This mechanism is studied under the design calculations, communicated with the A.P.I (Application Programming interface) and finally the design has done in SOLIDWORKS and for the structural analysis performed in ANSYS.
- Thus, we get to know the behavior of rocker bogie mechanisms under different conditions.

7. FUTURE SCOPE

- With the development in technology the rover can be used for reconnaissance purposes with the cameras installed on the rover and minimizing the size of rover.
- With some developments like attaching arms to the rover it can be made useful for the Bomb Defusing Squad such that it can be able to cut the wires for diffusing the bomb.
- By the development material through a rough terrain or obstacles containing regions like stairs.
- We could develop it into a Wheelchair too. It can be sent in valleys, jungles or such places where humans may face some danger.
- It can also be developed into Suspension System for the automobile vehicles through proper research.

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