Design and Analysis of Arduino Based Solar-driven Rocker Bogie Robot

Balaramanujala rao Marrey, vamsi Kurmasala, Chandu Saketi and Dr.V.S.V.Satyanarayana
Department of Mechanical Engineering
Vignan's Institute of Information Technology, Visakhapatnam, India
marreybalaji@gmail.com, Vk5550302@gmail.com, Chandusaketi8@gmail.com, svajrapu18@gmail.com

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 CATIA V5R20 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
Rocker-bogie, Stair climbing Rover, Wheel type mobile robot,HC-05 and Arduino.

1. Introduction
Rocker bogie is a six wheeled vehicle which runs on motor, this rover is capable to move on terrain surfaces and to overcome obstacles. It is provided with six wheels which are supported by each other while overcoming obstacles. The 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 centre of gravity. Systems using springs tend to tip more easily as the loaded side yields. This rocker bogie system reduces the motion of the main Mars Exploration Rover (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. 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. Based on the centre 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 centimetres per second (3.9 in/s) so as to minimize dynamic shocks and consequential damage to the vehicle when surmounting sizable obstacles. In order to go over a vertical obstacle face, the front wheels are forced against the obstacle by the centre 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.

© IEOM Society International

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 prescribed, although the various table text styles are provided. The formatter will need to create these components, incorporating the applicable criteria that follow.

1.1 Objectives

As we clearly identified the problem and solution methods through the various literatures, now the objective of the research is as follows

- To construct rocker bogie with proper design.
- To study and measure the reaction force produced by terrain surfaces on wheel and on suspension system.
- One of the shortcoming of current rocker bogie are slow, overcoming this problem by dynamically balancing of rocker bogie.
- To compare the experimental results with the theoretical results.

2. Literature Review

Yoshida. et.al, (2002) In this paper the author has investigated kinetic behavior of a planetary rover with attention to tire-soil traction mechanics and articulated body dynamics, and thereby study the control when the rover travels over natural rough terrain. The relationship of load-traction factor versus the slip ratio is modeled theoretically then verified by experiments. Simulations are carried out to be compared with the corresponding experimental data and verified to represent the physical behavior of a rover.

Bokade. et.al, (2016) In this paper proposed a method for controlling a wireless robot for surveillance using an application built on Android platform. The Android has a video screen for surveillance and buttons to control robot and camera. Android Smartphone and Raspberry pi board is connected to Wi-Fi. An Android Smartphone sends a wireless command which is received by Raspberry pi board and accordingly robot move. The Raspberry pi programming is done in python language. Güleçi and Orhun, (2017): Android based WI-FI controlled robot using Raspberry Pi.Banerjee et al, (2002) Rover: scalable location-aware computing. All the components necessary for realizing location-aware computing are available in the marketplace today. What has hindered the widespread deployment of location-based systems is the lack of an integration architecture that scales with user populations. The authors have completed the initial implementation of Rover, a system designed to achieve this sort of integration and to automatically tailor information and services to a mobile user's location. Their studies have validated Rover's underlying software architecture and other.

Toha and Zainol (2015) researched on a amphibious vehicle during the massive floods in Malaysia in December 2014. This paper contains study of the amphibious vehicle based on rocker bogie mechanism which can be operated in both water and land (terrain surface), that can be used by task force for carrying aids to the needy. Hari et al. 2017) The proposed modification increases in the stability margin and proved with valuable and profitable contrasting the static stability factor (SSF) metric with the 3D model simulations done in solid work. In future, if the system installed in heavy vehicles, it will surely decreases the complexity as well as power requirements to retain bumping within it. This is a wide field of study and is very less explored. Yang. et.al, (2014) Dr. Yang specializes in the study of stochastic simulation optimization problems, mobile robotic vehicles and job shop scheduling problems.

Poudel et al, (2018) stated that design and development of multi Terrain Vehicle. The design under consideration shows it was practically able to climb twice the wheel diameter because of the limitations explained above. On the other hand the single existing rocker bogie rover has its limitation to climb a maximum of twice the diameter of wheel. Changing the design has resulted in increase of height climbed but has reduced its stability because of more height of vehicle from ground level that increases the distance of cg. The power consumption is found to be minimum on sand hill and maximum when climbing the steps but since the modified rover uses more number of wheels and motor the power consumption is high. Pit test and sand hill test shows that the vehicle can climb a maximum elevation of about 50 (degrees). Miller and Lee, (2001) High-Speed Traversal of Rough Terrain Using a Rocker-Bogie Mobility System This paper describes a method of driving a rocker-bogie vehicle so that it can effectively step over most obstacles rather than impacting and climbing over them. Most of the benefits of this method can be achieved without any mechanical modification to existing designs – only a change in control strategy. Some mechanical changes are suggested to gather the maximum benefit and to greatly increase the effective operational speed of future rovers.

3. Methodology

Process of the work:

- In this section, the working procedure of the proposed prototype has been elaborated with the necessary illustration. As per Fig, batteries were used to power up all modules of the rover. It powers up drive motor subsystem and main controller powered up from drive subsystem.
- 3D modelling is done on the components in ANSYS , and then the parts are joined to finish the assembly.
- The rocker bogie analysis is simulated using Ansys software, and the results are observed (Figure 1).

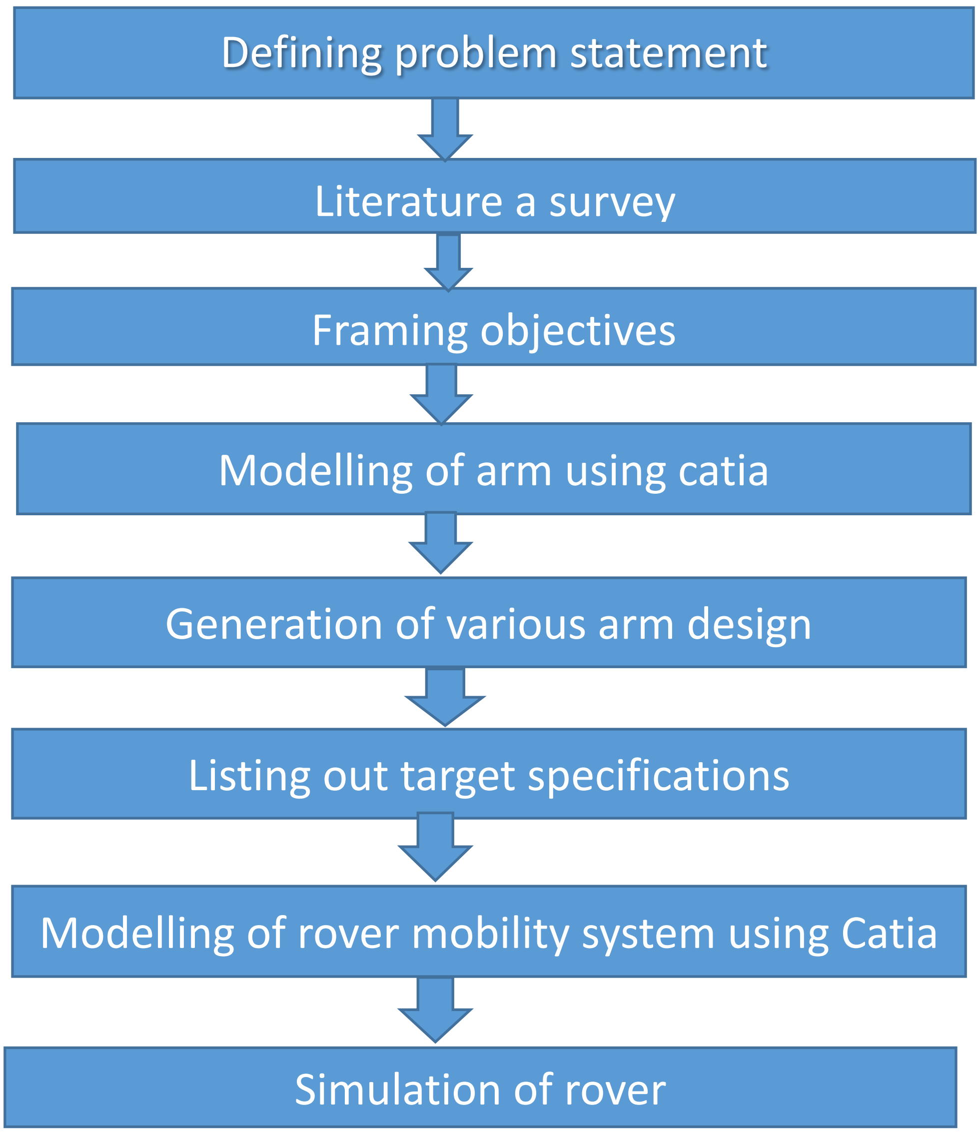

Figure 1. The flow chart of the Proposed methodology

- 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°.

3.1 Data Collection

The required data is collected from Data sheets in table 1.

Table 1. Design data sheet for Rocker bogie

Serial No.	Criteria	Value
1	Weight	40kg
2	Width	34inch
3	Length	44inch
4	Control	Wireless
5	Lifting capacity	Maximum 10kg
6	Reaching capability	Maximum 40cm below the surface
10	Frequency bands	5GHz
11	Sensors	Weight, Moisture, pH, Sonar
12	Wheel width	7inch
13	Wheel diameter	8Inch
14	Controlling range	Maximum 1000m
15	Temperature range	-30^0C to 50^0C

3.2 Construction and working of model

Rocker and bogie link

The term rocker comes from the rocking issue of the bigger hyperlinks on every aspect of the suspension system. These rockers are linked to every different and the car chassis via a differential. Relative to the chassis, whilst one rocker is going up, the opposite is going down. The chassis keeps the common pitch perspective of each rockers. One give up of a rocker is outfitted with a pressure wheel and the opposite give up is pivoted to a bogie.

The term bogie refers back to the hyperlinks which have a pressure wheel at every give up. Bogies had been typically used as load wheels withinside the tracks of military tanks as idlers dispensing the weight over the terrain. Bogies had been additionally pretty typically used at the trailers of semi-trailer trucks. Both programs now select trailing arm suspensions (Figure 2).

Figure 2. Rocker and bogie link

Wheels and Batteries
A 12volt battery is a rechargeable battery that supplies electrical current to a motor vehicle. Its main purpose is to feed the starter, which starts the engine. Once the engine is running, power for the car's electrical systems is supplied by the alternator. Typically, the starting discharges less than three percent of the battery capacity. For this reason, automotive batteries are designed to deliver maximum current for a short period of time. They are sometimes referred to as SLI batteries for this reason, for Starting, Lighting and Ignition (Figure 3).

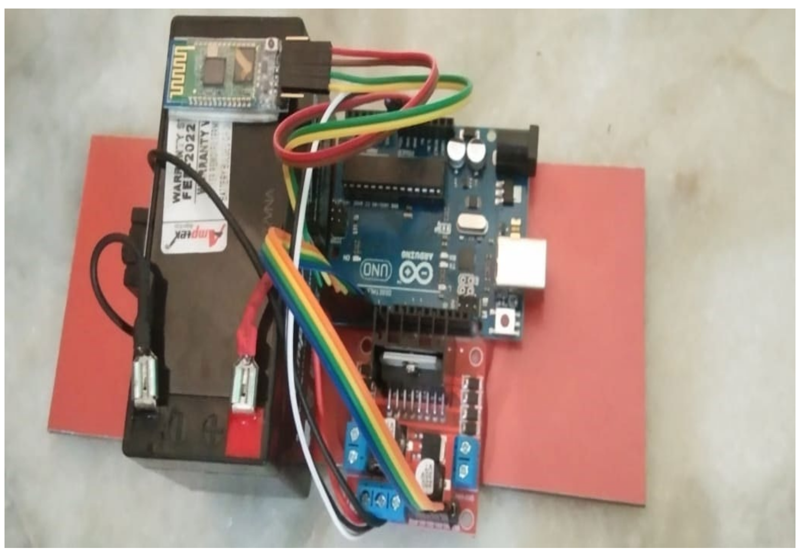

Figure 3. Battery

Solar panel and Arduino

A solar panel employs solar energy to supply electricity to devices or charge batteries. They are generally portable. Solar chargers can charge lead acid or Ni-Cd battery banks up to 48 V and hundreds of ampere-hours (up to 4000 Ah) capacity. Such type of solar chargers setups are generally used as an intelligent charge controller. A series of solar cells are installed in a stationary location and can be connected to a battery bank to store energy for off-peak usage. They can also be used in addition to mainssupply chargers for energy saving during the daytime.Most portable chargers can obtain energy from the sun only. Some, including the Kinesis K3, and GeNNex Solar Cell 2 can work either way (recharged by the sun or plugged into a wall plug to charge up.

This system can be said as the brain of the vehicle. The controlling system will control all the activities going on the vehicle. The main components of the controlling system are Arduino and Zigbee, boards. The Arduino board is a type of microprocessor which can be used to give commands to the movement of the vehicle. This board is a programmable

© IEOM Society International

one and can able to change the instructions according to the user need. The commands needed for the movement and other activities are stored inside the Arduino in form of computer program. The power needed for the working of the Arduino is taken from the external power source and using a regulator to change the current to its need the Arduino will operate the vehicle according to the commands user gives through the laptop. A pair of Zigbee transmitter is also used in the controlling system. These boards are similar to the wi-fi in functioning which helps in transmitting commands from the receiver side to the vehicle (Figure 4-7).

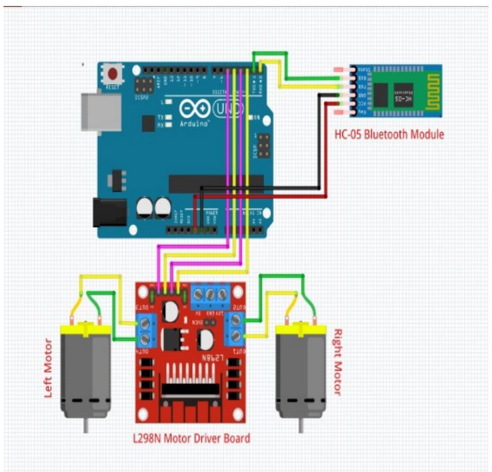

Figure 4. Arduino

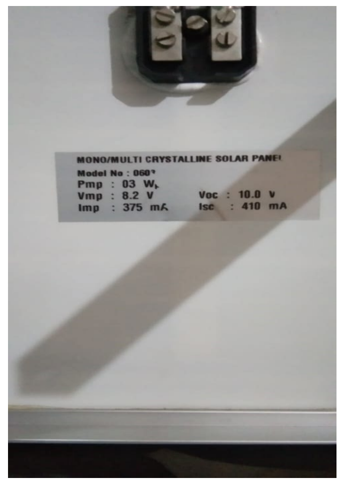

Figure 5. Solar panel

Working of model

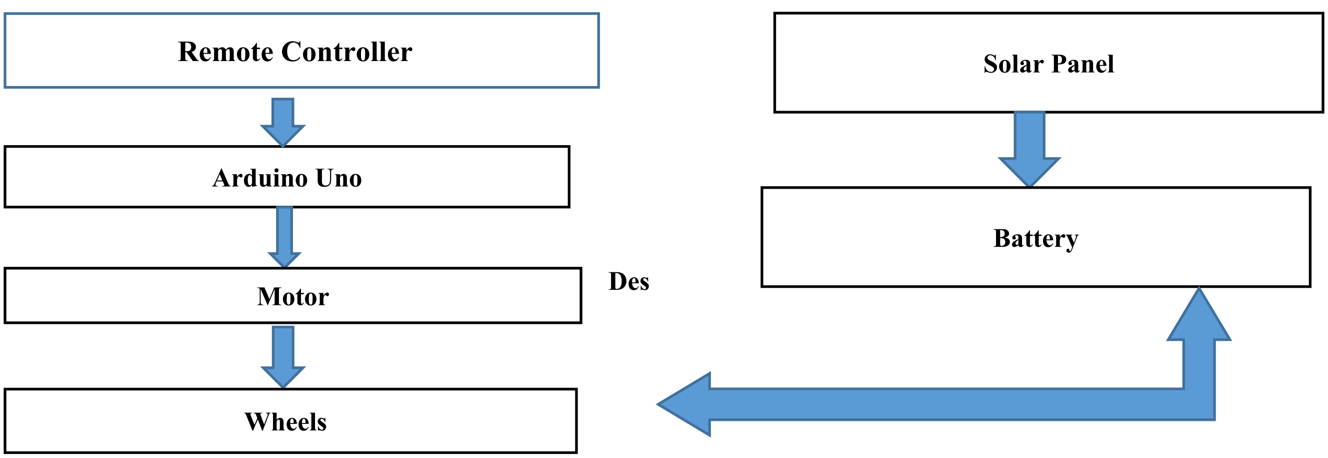

Figure 6. Working of the model

3.2 Design of Rocker bogie suspension system

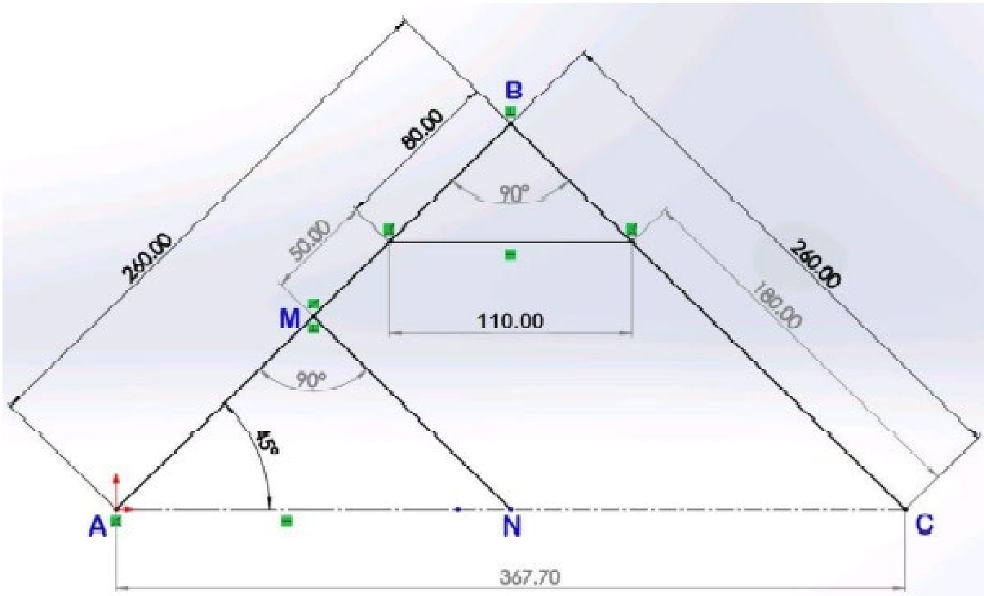

Figure 7. Design dimensions of mechanism

3.2.1. Design calculations

Wheel

Wheel: - Wheel torque free body diagram
Fg =mr.g/4 [5]
=(6×9.814)/4
=4.905 N
Where rw is the radius of wheel=35 mm
Tw=Fg×rw [5] =4.905×0.035
=0.1712 N-m
Each wheel required 0.1712N.m of torque

Inputs parameters to design

From the triangle AMN,

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

=2(1302)

AN=183.8mm

From the triangle BNC,

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

$=2(NC^2)$ (BN=NC)

=2(1832) (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°.

4. Results and Discussion

The main aim of this work is to Design, and Analysis of Solar driven remotely controlled rocker bogie robot. 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

4.1 Analysis of Rocker bogie suspension system

4.1.1. Structural analysis using ansys

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 8).

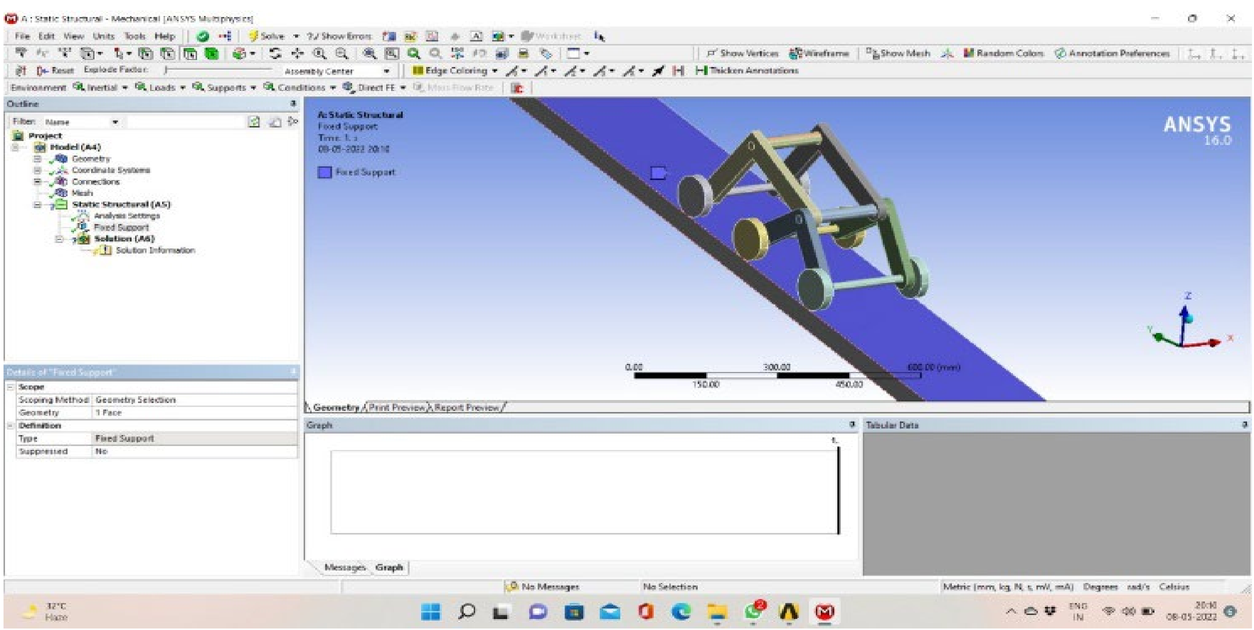

Figure 8. Structural analysis using Ansys

4.1.2. Meshing of the model

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 (Figure 9).

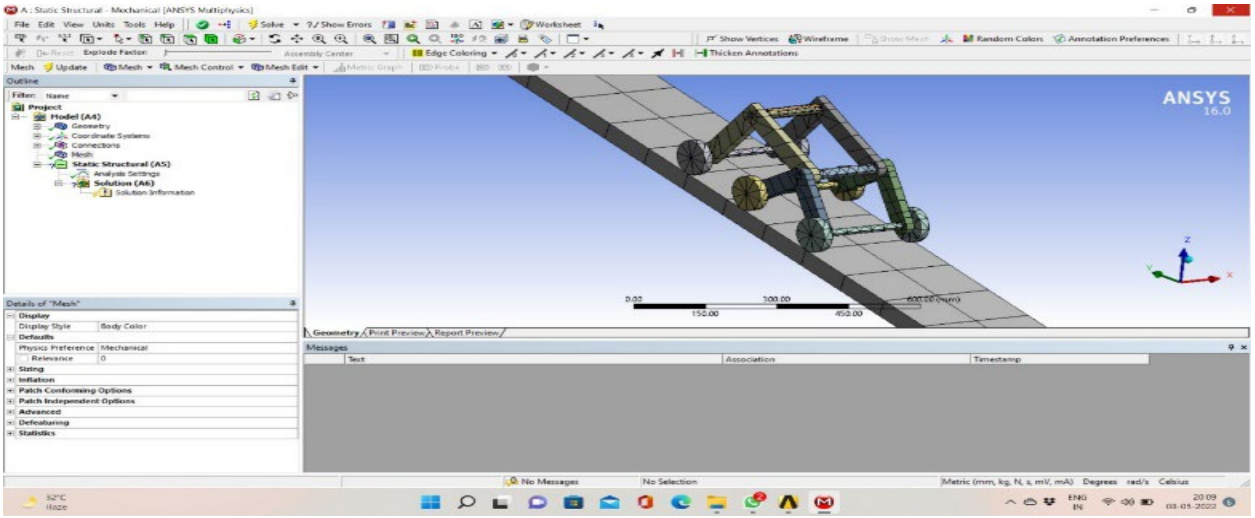

Figure 9. Meshing of the model

4.1.3. 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 10 and Figure 11).

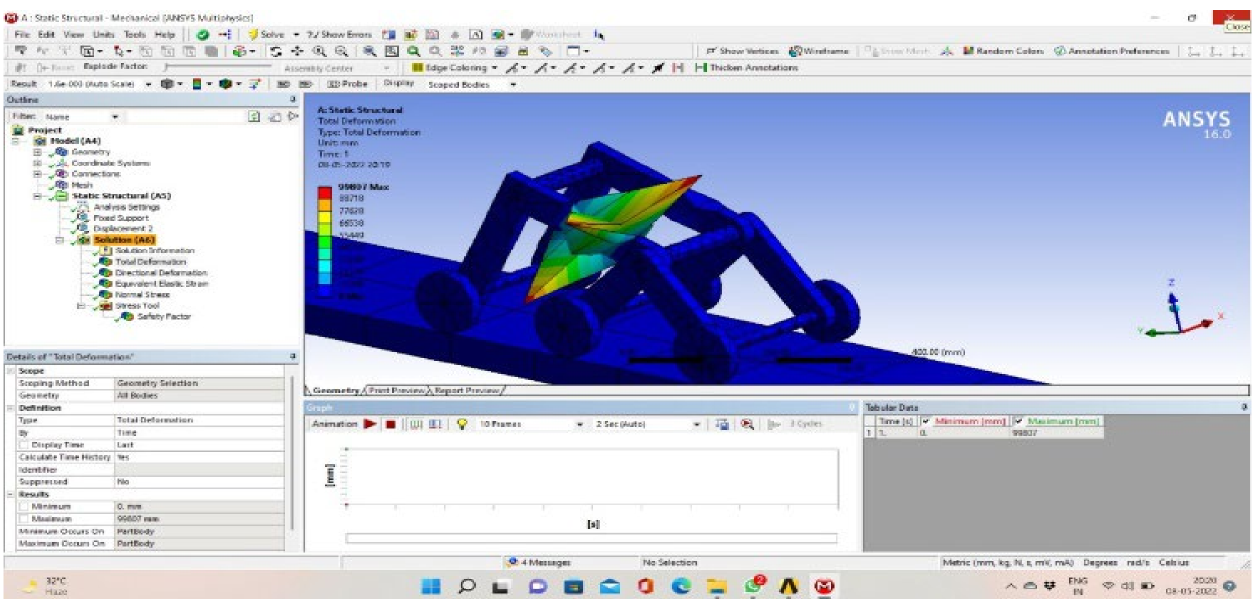

Figure 10. Total deformation

4.1.4. Blue tooth electronics app interface

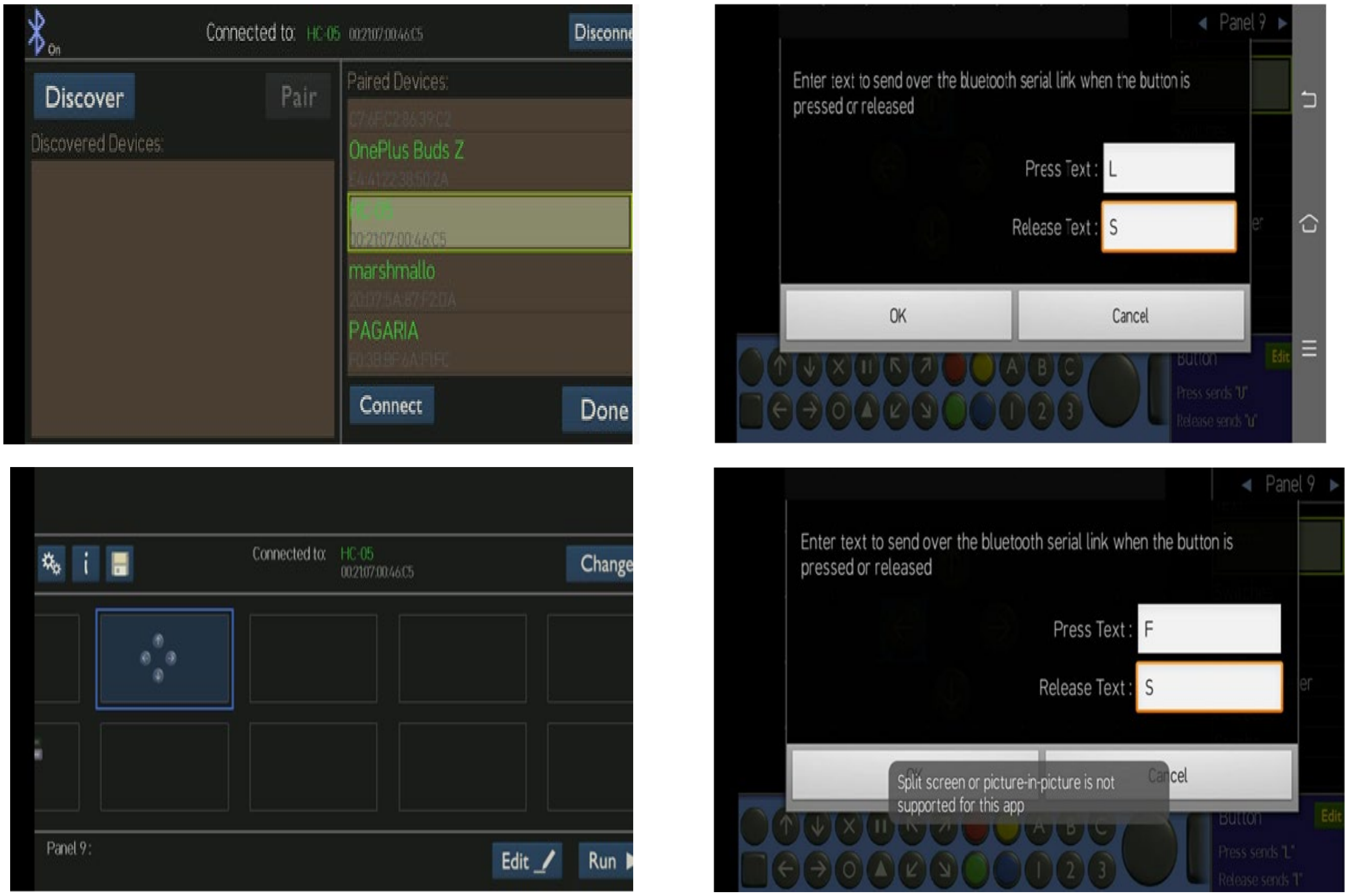

Figure 11. Blue tooth electronics app interface

5. Conclusions and future research

In this thesis work we have analyzed the six wheeled rocker-bogie rover. The Kinematics of the rover is presented in detail and quasi-static force analysis is also done for the rover for planar case. The rover is simulated over various uneven terrains and the performance of the rover is analyzed over flat, slope, step and ditch profile of surface. The results of simulation show that rover crosses flat and slope profiles.In case of step profile only front wheel crosses the step, when middle wheel hit the step the velocity becomes zero and it is not able to climb. In case of ditch profile also only front wheel crosses the ditch, when middle wheel hit the up of ditch the velocity goes to zero and it is not able to climb.

● 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.

References

Ashish U. Bokade, V. R. Ratnaparkhe, Video surveillance robot control using smartphone and Raspberry pi, Published *in International Conference on Communication and Signal Processing (ICCSP)*, 6-8, 2016.

Aayush Poudel, Yashaswi Khandelwal, et al, Design and Development of Multi Terrain Vehicle, *International Journal of Trend in Scientific Research and Development, Bangalore*, Karnataka, India, 2018.

Banerjee .et.al, Rover: scalable location-aware computing, Volume: 35, Issue: 10 , Oct 2002.

Hong-an Yang et al , Dynamic Rocker Bogie: A Stability Enhancement For High Speed Traversal, IRJT, 2014.

Jothees S., Hari Ragul K., Abhilash k., Govendam M., Design and Optimization of a Mars Rover's Rocker Bogie Mechanism, (IOSR-JMCE), 2017.

Mehmetcan Güleçi, Murat Orhun, Android based WI-FI controlled robot using Raspberry Pi, Published in *International Conference on Computer Science and Engineering (UBMK),* 5-8 Oct. 2017.

Miller T. Lee, High-Speed Traversal of Rough Terrain Using a Rocker-Bogie Mobility System. School of Aerospace & Mechanical Engineering, University of Oklahoma, USA 2001.

Toha and Zakariya Zainol, System modeling of Rocker Bogie Mechanism for Disaster Relief, *International Conference on Intelligent Robots and Systems* (IRIS 2015), Malaysia.

Yoshida and H. Hamano, Motion dynamics of a rover with slip-based traction model*, Proceedings IEEE International Conference on Robotics and Automation,*2002.

Biographies

Balaramanujala rao Marrey graduated from vignan's institute of information technology with bachelor of degree in mechanical engineering in 2022.

Vamsi Kurmasala graduated from vignan's institute of information technology with bachelor of degree in mechanical engineering in 2022.

Chandu Saketi graduated from vignan's institute of information technology with bachelor of degree in mechanical engineering in 2022.

© IEOM Society International