DESIGN OF A MOBILE MECHANICAL STRUCTURE FOR AGRICULTURAL ROBOTS

BY

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FINAL YEAR PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF MECHANICAL ENGINEERING FACULTY OF ENGINEERING, TECHNOLOGY, APPLIED DESIGN AND FINE ART OF KABALE UNIVERSITY IN PARTIAL FULLFILLMENT OF THE AWARD OF BACHELOR'S DEGREE IN MECHANICAL ENGINEERING

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For the Degree of

Bachelor of Mechanical Engineering

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SUMMARY

This report covers the design of a mobile mechanical structure for agricultural robots that will fit in the current crop spacing using the extendable link mechanism based on a four bar link mechanism linear actuator. This covers the analysis of the steering, suspension spring, singularity with its maximum and minimum angles, wheel arrangement, selection and design. The structural analysis using ANSYS is included to evaluate the strength of the mechanical structure used when in its worst working conditions and the results were presented and included in this report. The problem of farmers buying a mechanical platform for different crop spacing will be solved by this mechanical structure hence reducing the costs involved in agricultural activities and this will be the motivation factor for farmers to practice agricultural activities using one mobile mechanical structure which will solve the problem of unreliable human labour and encourage farmers to practice modernized and precision agriculture. The related work from the related projects is included with n this report since such technology is not new but it needed modification to fit in the current agricultural activities to reduce on the costs involved in carrying out agricultural works. Since there is no economical alternative for food agriculture sector needs serious attention to cater for the increasing global population.

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ACKNOWLEDGMENT

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ABSTRACT

The project of design of mobile mechanical structure for agriculture robots is undertaken to solve the problem of farmers buying different mechanical platforms for different crop spacing. This includes the study of the existing mechanical platforms, analyzing the row spacing for different crops, developed the conceptual design, sizing and analyzing the mechanical structure, sizing and wheel arrangement selection, analyzing steering mechanism, analyzing screw and nut. All the components are produced in solid works, assembled and finite element analysis done using ANSYS.

Keywords

Link mechanism, wheel arrangement selection, crop spacing, steering mechanism and finite element analysis

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NOMENCLATURE

a	Contact Radius
c	Spring Index
D	Diameter
da	Depth of cut
d	Core Diameter
d	Outside Diameter
<l00	Collar Diameter
d,	Inner Diameter
E	Young's Modulus
F	Load on the Tyre
G	Modulus of Rigidity
H	Height
1	Length
1,	Solid Length
lr	Free Length
M	Moment Force
Il	Factor of Safety
Ile	Number of Coils
n	Number of Threads
p	Pitch
P	Bearing Pressure

13.

R	Radius
S	Ultimate Stress
Sy	Yield Stress
T	Torque
v	Poisons Ratio
w	Width
W	Load
Xn	Linear Distance
6	Deflection
cr	Stress
t	Shear Stress

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ABBREVIATIONS

GDP	Gross Domestic Product Free
FBD	Body Diagram Unmanned
UGV	Ground Vehicle Global
GPS	Positioning System

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

The republic of Uganda is located in east Africa. It lies between 10 29' South and 40 12 'North latitude, 290 34' East and 350 0' East longitude. It is a landlocked country covering an area of 241,55lkm^2. Uganda shares a border with Kenya, South Sudan, Democratic Republic of Congo, Rwanda and Tanzania to the east, north, west, southwest and south respectively. Wetlands and inland water bodies occupy 18% of its total area while 3 7 .8 % is arable land [1]. The land area covers 200,523 km^2 [2] .

Uganda's gross domestic product (GDP) annual growth rate was 5.2%, 4.8%, 3.9%, 6.2% and 6.9% during the 2014/15, 2015/16, 2016/17, 2017/18 and 2018/19 financial years respectively [3].The agricultural sector contributed 23.3%, 22.4%, 23.5%, 22.8% and 21.9% during 2014/15, 2015/16, 2016/17, 2017/18 and 2018/19 financial years respectively [3]. According to [1], the agricultural sector contributed 23.6%, 25.1 %, 24.7% and 24.5% to the national gross domestic product (GDP) in 2007, 2009, 2011 and 2013 respectively. The contribution of cash crops to the nation's GDP was 2.0%, 2.1%, 2.4%, 2.2% and 2.1 % during 2014/15, 2015/16/, 2016/17, 2017/18 and 2018/19 respectively while the contribution of food crops to the nation's GDP was 12.0%, 11.2% 12.3%, 12.0% and 10.5% during 2014/15, 2015/16, 2016/17, 2017/18 and 2018/19 respectively [3] .However, the percentage growth rate in the GDP of the agricultural sector was 2.3%, 2.8%, 2.8%, 3.8% and 5.0% during 2014/15, 2015/16, 2016/17, 2017/18 and 2018/19 respectively [3]. The agricultural, fisheries and forestry sector is the backbone of Uganda's economy [3] .This is due to the fact that it contributes the largest percentage to the country's GDP as portrayed by the above statistics. Furthermore, the agricultural sector is the main sector of employment in the country.

Agriculture is humankinds oldest and still its most important economic activity, providing the food, feed, fiber and fuel necessary for our survival. With global population expected to reach 9 billion by 2050 [4]. Agricultural production must double if it is to meet the increasing demands for food and bioenergy. Given limited land, water and labor resources, it is estimated that the

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1.3Justification of the problem

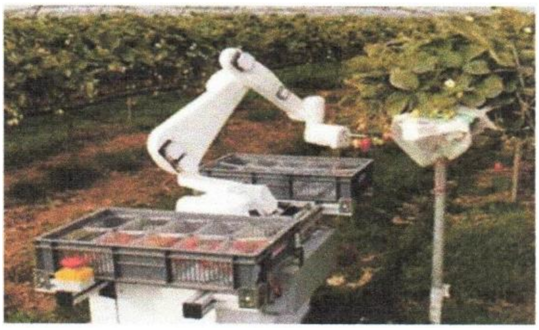

Figure.1 Fruit Picking Manipulator

16.

Figure.1 Agro Chemical Spraying

Figure.2 Crop Mapping Manipulator

1. To carry robotic maniplators for crop health monitoring, crop mapping, fertilizer application, planting, seeding, weeding, and fruit picking.
2. To carry farm payloads

1.4 Objectives

1.4.1 General Objective

To design a mobile mechanical structure for field agricultural robots.

1.4.2 Specific Objectives

17. To conceptualize the design
18. To design a mobile mechanical structure
19. To perform a finite element analysis by ANSYS

20.

CHAPTER TWO

2.1 LITERATURE REVIEW

Research on the development of mechanical structure for agricultural robots is not new. Related works in this research point is as follows:

Researchers in [5] , developed a four HV-100 mobile robot as shown in Fig.4. The robot is to distribute and collect container grown plants in greenhouse and on large nursery farms using Unmanned Ground Vehicle (UGV) with a fixed platfonn for sensing. It consists of four wheels, four actuators, microcontroller, and internal sensors (Inertial Measurement Unit, Global Navigation Satellite System, Linear Laser Scanners, and Pan-tilt -zoom Camera) with a maximum speed of 3m/s and an autonomy between 5h (continuous 'motion) and 20h (standard laboratory use)

Figure.3 Four HV-100 Robot

In [8] researchers designed a novel mobile platfonn as in fig.5 below based on four legs and four wheels for light weight manipulator with a rectangular base, one real time high performance embedded controller, four linear actuators, and two motor drives. Four legs have been added to the platfonn in order to increase the polygon support of the system and increase considerably the physical stability of the system with each leg having a four-bar mechanism of 1 DOF actuated by a linear actuator fitted between the four bar mechanism to keep changing the length of the leg with ground contact. The platfonn is based on two configuration that is when the legs are up and

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when they are in contact with the ground while helping in modifying the height and the posture of the base system.

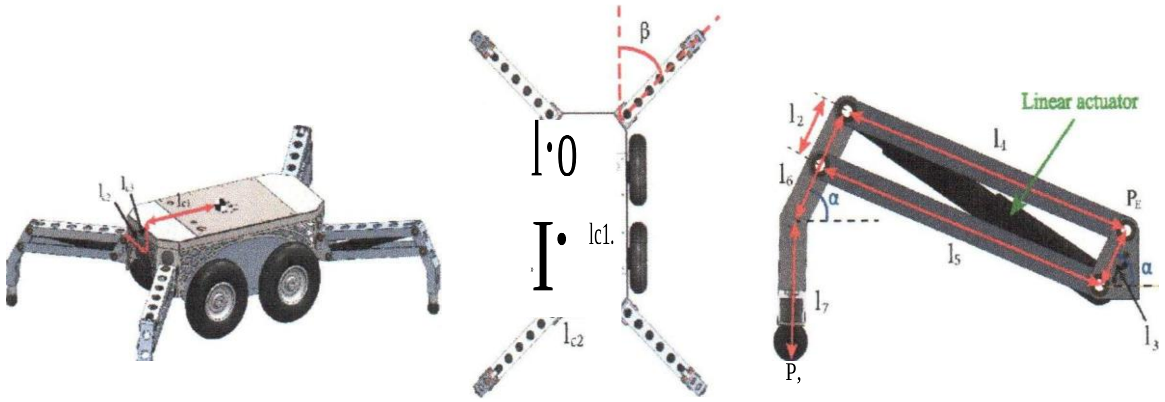

Figure.4 Novel Mobile Robot

In paper [9],a four wheel independent driven structure was designed based on the advantage of mecanum wheels [10]. For expansibility and versatility, a mult-layer mechanical modules and a modular wheel structure were used for its body that is divided into three layers (the chassis layer, the control system and application layer) as in fig.6 below connected with screw bolts for easily assembling and disassembling. The chassis layer contains the movement mechanism and the power source, four modular wheels are arranged symmetrically along the longitudinal center axis of the chassis (a 48V 40Ah lithium battery is used as power supply of the platform and can last for three hours). The control layer consists the control system (the controller, motor drives, an internet router and a touch screen), the on-board sensory suit and the power converters [11] [12] , the built in PID control with PID parameters can be regulated manually from the touch screen to obtain ideal dynamic responses. The application layer can be modified to meet different needs like a light weight robot manipulator and a fork arm. RedwallBot-1 is oriented to convey materials for an intelligent manufacturing system. For vibration effects elastic wheel hubs and suspension mechanisms were designed for all four wheels. The linear velocity of 0.3m/s and angular velocity of 0.6 rad/s were obtained while the robot tracing a square with side length of 4M.

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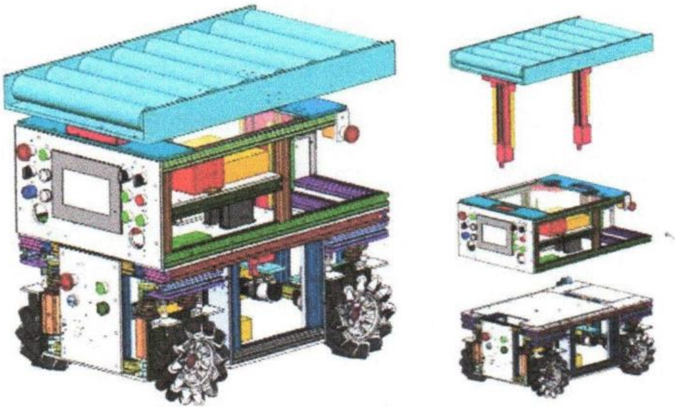

Figure.5 RedwallBot-1

Researchers in [11] designed a multipurpose agricultural robot for harvesting orange fruits with two main parts that is the mechanical part and electrical part based on a four wheeled platform structure as in fig.7 below (two rear wheels-8inch diameter and two front wheels - 10inch wheel diameter) from aluminium profile material because of its strength, durability, corrosion resistance, flexibility and lightness. The tested results it was found out that it can perform basic tasks like moving forward, backward, turning left and right using two rear wheel for driving system and two front wheels for turning.

Figure. 6 Four Wheeled Platform

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In [11] researchers developed BoniRob as fig.8 below to replace the use of tractors, the UG vehicle developed of flexible platform using multi sensor fusion (spectral imaging and 3D time cameras and RTK-DGPS system) with 4 wheels each steered separately based on four wheel hub motors and hydraulic components, therefore offering a high flexibility with respect to navigation and changing height positions to adapt its track. The vehicle comprises 16 DOF implemented by a mix of electro and hydraulic actuation with a number of dedicated control units of 4 motor controllers, motor and hydraulic interface, navigation control unit connected by ethemet while communicate using TCP/IP (except for the motor controllers that are connected by a CAN bus) [12] [13]. The navigation concept of BoniRob is developed including options for data and software exchange between the simulator and the real robot. This however was designed for weeding.

Figure.7 BoniRob

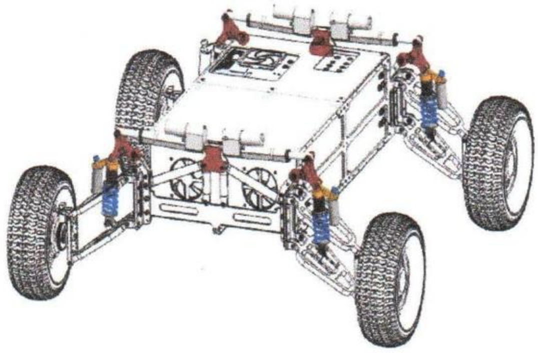

Figure.8 3D Model of Tiger

researchers in [15] Tiger fig.9 above of reconfigurable four wheeled with 16DOF was developed with electrically actuated suspension system to increase wheel base along the rough terrain while adapting to the working conditions and payload. The main mechanical structure is built from a strong and light weight of aluminium alloy sheets, and carbon fiber tubes while critical components are built using stanless steel [15] [16]. Brushless in wheel DC motors are used for driving the robot with the high speed and hgh torque in codination with high level control architecture using robot operatng system framework. Suspension and robot mobility controllers are used with different sensors(speed, position, current sensors and IMU) [17] [18]. AIthhoug there was an acheivement of width expansion and mobility in rough trrain [19] [20], its widith expansion cannot be modified to suit for diffirent crop spacing.

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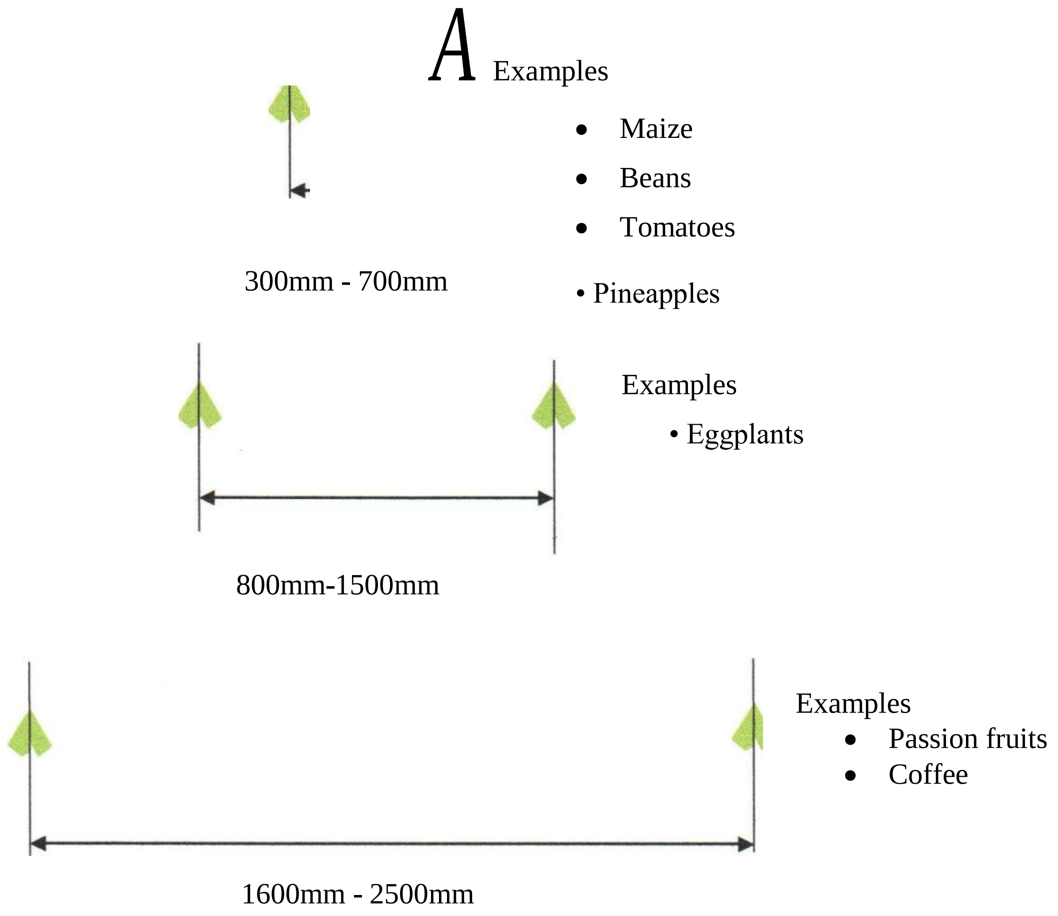
CHAPTER THREE

3.0 METHODOLOGY

3.1 Spacing for different crop

Although increasing crop spacing doesn't add anything on crop production, the standard crop spacing must be used to improve crop production, easy crop monitoring, weeding, and fertilizer application. Crop spacing is the number of crops planted in a unit area. Agriculturalists have advice about spacing with regard to particular crops, and this is based on research findings with a view to maximizing crop yields. Farmers aim to fully exploit their land by getting the best yields and at the same time sustain the productivity of the soil in their gardens. The following is the spacing range for some of the crops [21]



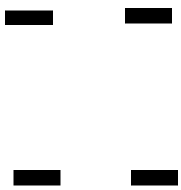
3.2 Wheel arrangement

Wheel configurations for autonomous underground vehicles

Differential drive (Two wheeled)

Differential drive (Two wheeled), One steered

The idea of smaller, energy efficient vehicles for transportation seems to naturally introduce the here wheel platform. Opinions normally run either strongly against or strongly in favor of the three wheel arrangement. Advocates point to a mechanically simplified chassis, lower cost of manufacturing and superior handling characteristics. Negatively the three wheels propensity to overturn, and when poorly designed is a less forging layout.



Differential drive (Two wheeled), Two steered [selected]

Most agricultural mechanical structures reported use wheels or legs but legs are advantageous for flexible movement in the agricultural field with high inclusion of stems and branches, and wheels provide faster and more convenient navigation in the field. The two wheeled one is very expensive and it is no easy to achieve the balance, the two wheeled one steered the middle wheel affects crop rows and also the balancing can't be well achieved. So the two wheeled and two

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steered is selected because it is easy to achieve balancing and even wheel arrangement doesn't interrupt the crop rows.

3.2 3D Model of the mobile structure

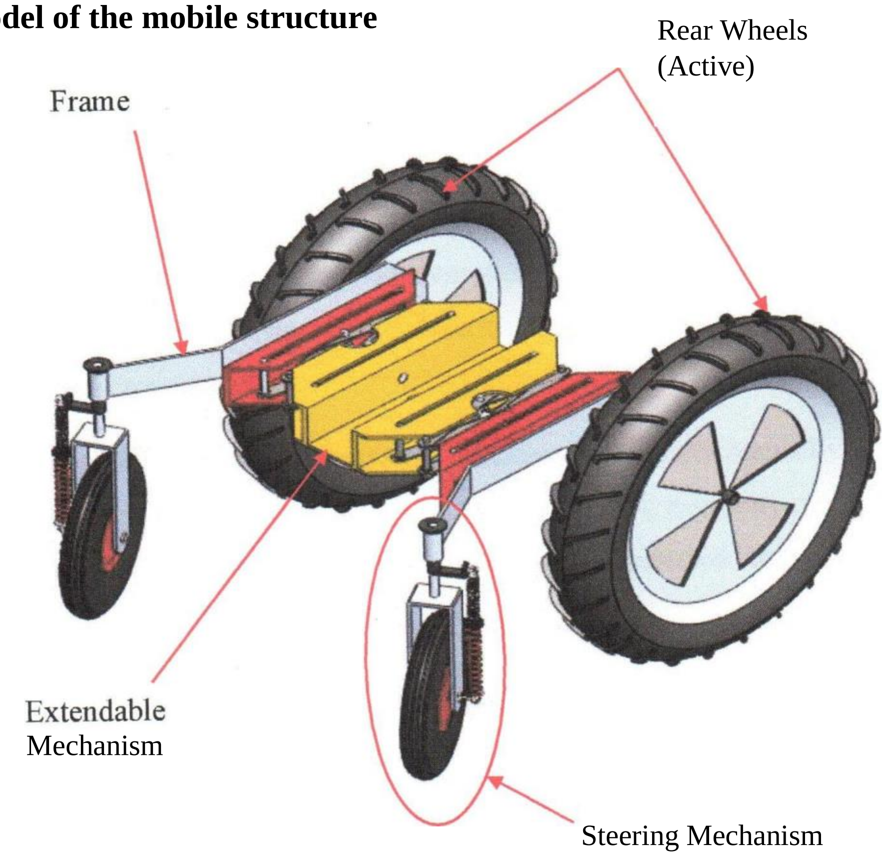

Figure.9 Fully Compressed

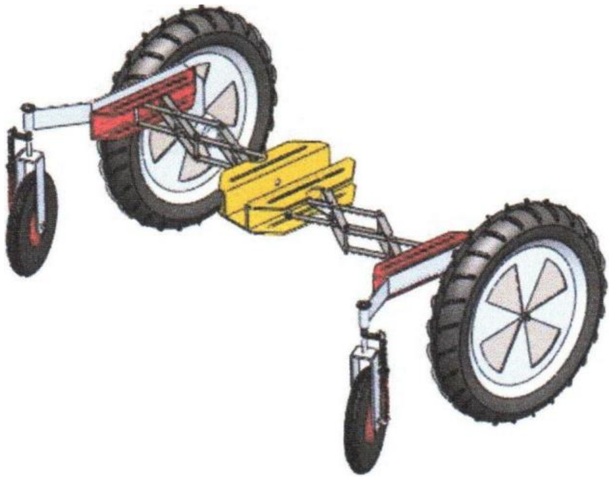

Figure.10 fully extended

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3.4 Link design

The link design mechanism that brings in linear movement. The linear actuator develops force and provides motion through a straight line. There are different designs and concepts for linear actuator '[technology to attain high performance in terms of speed, acceleration, precision. Based on the working principles, these designs and concepts are broadly categorized as mechanical, electrical, hydraulic, pneumatic, magnetic and many others. However very few of these can actually obtain rapid acceleration with modest repeatability for industrial and practical applications. This design, development and control of the linear actuator can be modified to fit in any spacing of the crops and its actuation is done through the nut and the screw to increase or reduce the working crop spacing.

The major requirement of the link design should be compact and mechanically rigid with a double arrangement so that it can work in standalone condition, extremity positions will be having a minimum offset, and the actuator position has to be selected the closest to the base that is nonmoving joints.

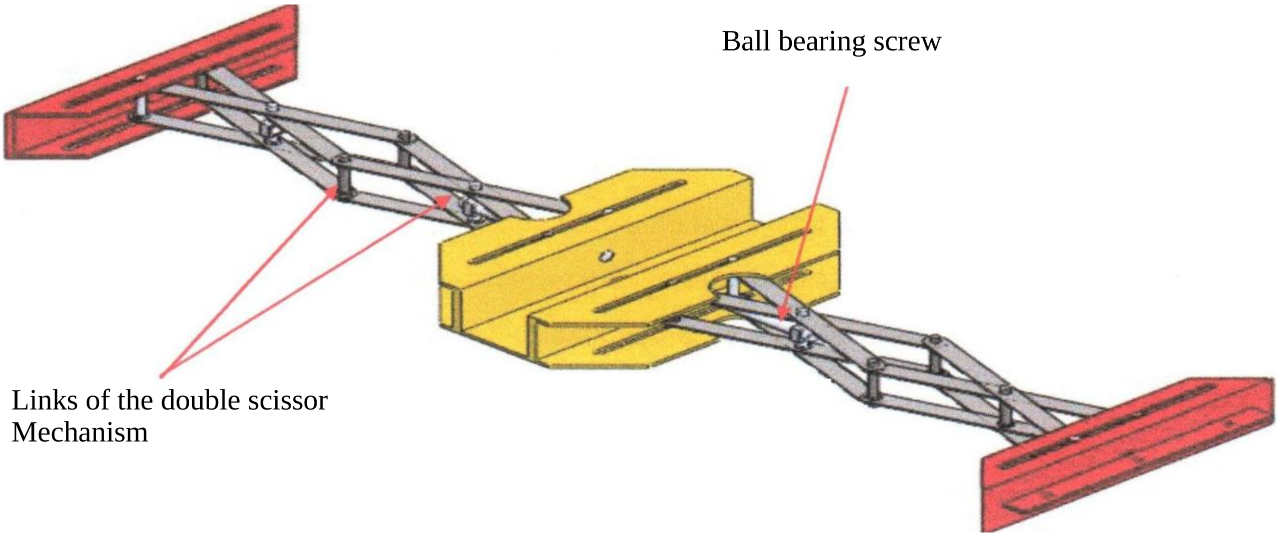

Figure.11 Link mechanism

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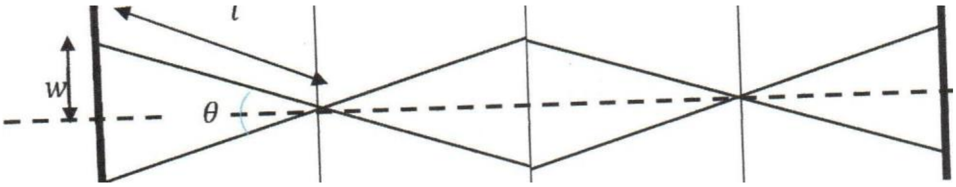
'/, *segment* 1 *segment* '/, *segment*

J *I y*]

n= 2



The width of the structure

***2x,* + 600 mm,**

Xn is selected as **1000mm** Link

length, **2l**

x, = nlcos8

Where ***n*** - Number of Segments ***l***-Link

length.

8 - The angle between the links

Singularity is a point at which a function takes a finite value. It is either addition or loss of DOF; meaning a point where the torque becomes infinite and mechanism locks its self or a point where the mechanism is moving whatever the motor torque. In actuator design this points are very important as we need to identify those points to avoid them during the movement of the actuator. Geometrically links have no material existence and they can occupy the same position in space. In reality, the mass doesn't allow such cases. Here singularity is calculated in terms of input angle and extremity positions. First the singularity is calculated in terms of input angle **0**

$$\sin\left(\frac{\theta}{2}\right) = 0$$

So singularity at ***8*** **O**and its counterpart is ***8*** **= 360,** so during construction of the actuator such points must carefully be avoided.

In terms of the extremity position ***(a)***

$$\sqrt{4-\left(\frac{x^2}{l^2}\right)} = \mathbf{0}$$

By solving the above equation $x = 2l$ corresponds to the same in tenns of input angle as ***8*** **= 0°** To avoid singularity in the mechanism at full expansion ***8*** is selected as **10°** [8]

$$\mathbf{1000 = 2}\boldsymbol{l}\ \mathbf{cos10}$$

Link thickness, ***t***

−o»(#)

The vehicle steering system has experienced several stages, such as manual steering, hydraulic steering, electro-hydraulic steering, and electric power steering and by wire steering. However in order to achieve the letter two, the structure becomes more complicated because one or more motors are required [23]. The appearance of four wheel independent drive electric vehicles opens up the possibility of differential steering system by coupled control of left and right in wheel motors which eliminates the restriction of a traditional steering system completely. Further improvements have been made to improve on the system and reduction in power consumed during operation, here comes a two wheel drive and two wheel steered independently platform. Steering is important for the vehicle to be able to steer very precisely in the crop rows and also to make as little damage as possible to the crop.

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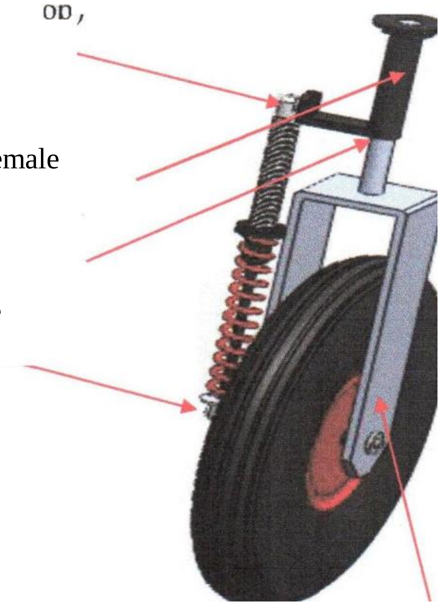

Figure.12 3D Model of Steering system

Description , Symbol	Value, Unit
Young's Modulus of the Tyre rubber (E_1)	l0MPa
Poisson's Ratio of the Tyre Rubber (v_1)	0.79
Young's Modulus of the soil (E)	5 GPa
Poisson's Ratio of the Tyre Rubber (v)	0.33
Load on Tyre *(F)*	450N
Static Friction (u_1)	0.89

Table - 1 Dynamic data for contact mechanics

3.5 Steering torque

Steering wheel torque is the influence of loads on the steering while driving. This is due to a variance of traction between the two drive wheels normally experienced in front wheels.

The contact stiffness at the wheel contact is caused by local elastic deformation which creates a contact area, the size of which increases as the nonnal load increases. Hertz is the stiffness between contacting bodies described by their radii of curvature at the contact; in easiest form between the sphere and plane.

Hertzian Contact Equivalent Young's Modulus

$$E' = \left(\frac{1-v_1^2}{E_1} + \frac{1-v_2^2}{E_2}\right)^{-1}$$

Force equation according to Hertzian Contact

$$F = \frac{4}{3} E' R a^{3/2}$$

Contact radius here for simplicity, the contact area is considered as a circle

$$a = \sqrt{Ra}$$

Torque, T=Torque to overcome inertia+ Torque to overcome friction

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3.6 Steering shaft

Steering shaft is a component of the steering system that controls wheel movement thus keeping the system connected together for effective motion transfer.

Fatigue Equation **- ANSI/ASME B106.1M-1985** Standard For constant torque loadings

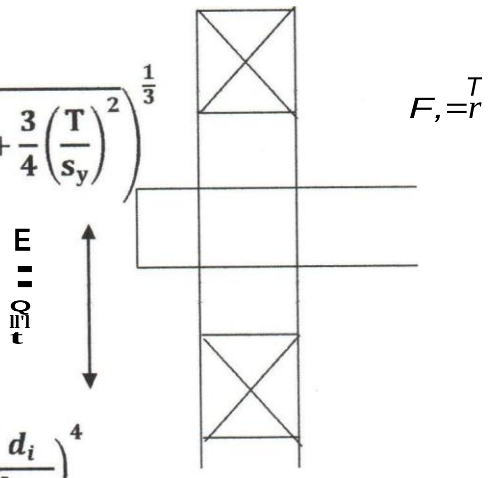
32lJs s– T ($d > \sqrt{\left(\frac{K_tM}{s_n}\right)^2 + \frac{3}{4}\left(\frac{T}{s_y}\right)^2}\Bigg)^{\frac{1}{3}}$

Assume,n = 1.0, Kt = 2.5, and M = 2 N - m

For Steel s, = S, = 300 MPa,T = 12.76N - m

Torsional Equation and keeping the outer stress constant

$$\left(\frac{d_s}{d_{new}}\right)^3 = 1 - \left(\frac{d_i}{d_{new}}\right)^4$$



FBD of Shaft Arrangement

3. 7 Spring /shock absorber design

To improve on stability of the platform the spring is designed. The springs allow the wheels to move up to absorb bumps in the roads and reduce jolting, while the dampers prevent bouncing up and down. The spring is to compensate for any irregularities in the surface of the road. They also keep the suspension system at a calculated height and support the additional weight without extreme sagging.

33.

Modulus of rigidity E

$$G = \frac{E}{2(1+\mu)}$$

Deflection

$$\delta = \frac{8WnD^3}{Gd^4}$$

Solid length $l_s = n \times d$

Free solid length

$$l_f = (n \times d) + \delta + (0.15\delta)$$

Pitch

$$p = \frac{l_f}{n-1}$$

Load,

$W = 450N$ **Number of coils,** $n = 12$ **Diameter of the wire,** $d = 10mm$ **Diameter of the spring,** $D = 100mm$

3.8 Screw and nut

In order to achieve the best actuation results the link mechanism, a screw and a nut is designed to transfer power from the driving motor through the screw and to achieve the best results with plain carbon 30C8 material is selected due to sufficient strength, high wear resistance, and good machinability.

Plain carbon steel **30C8** for the screw

Factor of safety ***n* 4**

Ultimate stress, **S1ooN/mm**

Young's modulus **E = 207GPa**

Load is assumed as *W* = **1000kg**

W rking s ress, CJ= **ultimatebstress** / **factor of safety**

$$a = \frac{4W}{rd_c}$$

Mean diamete, $d_{mean} = \frac{d_1 + d}{}$

Where L - lead=pitch **4W**

$$\sigma_c = \frac{}{\pi d_c^2}$$

Principle stresses

Maximum principal stress, o =- F%/o? + 4r

Maximum shearing stress, 1:max = i .J CJc ² + 41:²

34.

In order to reduce the friction resistance between the screw and nut a softer material is selected for the nut. Phosphor bronze is a proper material for nut construction because it acts very well against wear resistance and reduces torque to overcome friction

o, = 190MPa, 0,,= 100MPa, O = 90MPa

Bearing pressure, $P = \frac{p}{\pi n(d^2 - d^2)}$

Transverse shear stress in the screw and nut

$$\tau_s = \frac{W}{\pi d_c t n}$$

$$T_n \quad \frac{W}{Tdtn}$$

Nominal/major diameter (d)mm	**Minor/ core diameter (d)mm**	**Pitch (p) mm**	**Area of core (Ac)mm^2**
10	6.5	3	33
12	8.5	3	57
14	9.5	4	71
16	11.5	4	105
18	13.5	4	143
20	15.5	4	189
22	16.5	5	214

Table- 2 Basic Dimensions for Acme Threads

35.

Application of screw	Material		Safe bearing pressure in N/mm²	Rubbing speed at thread pitch diameter
	screw	Nut		
Hand press	Steel	Bronze	17.5-24.5	Low speed, well lubricated
Screw jack	Steel	Cast iron	12.6-17.5	Low speed< 2.4m/min
	Steel	Bronze	11.2-17.5	Low speed <3m/min
Hoisting screw	Steel	Cast iron	4.2-7.0	Medium speed 6 12m/min
	Steel	Bronze	5.6-9.8	
Lead screw	Steel	Bronze	1.05-1.7	High speed> 15m/min

Table - 3 Limiting Values of Bearing Pressure

3.9 Finite element analysis by ANSYS

For any design to be judged as a good design, it must be proven that it is useful for the purpose it is made for. In this case, we have analyzed our model by creating the simulation environment which is mostly close to the actual working conditions and we have obtained some results. Now to check whether these results are satisfactory, we must take the Factor of Safety concept. Factor of safety is generally the ratio of Yield Stress of the design to the allowable stress. A yield strength or yield point is the material property defined as the stress at which a material begins to defonn plastically. Prior to the yield point the material will deform elastically and will return to its original shape when the applied stress is removed. Ultimate tensile strength is the capacity of a material or structure to withstand loads tending to elongate, as opposed to compressive strength, which withstands loads tending to reduce size. In other words, tensile strength resists tension (being pulled apart), whereas compressive strength resists compression (being pushed together). Ultimate tensile strength is measured by the maximum stress that a material can

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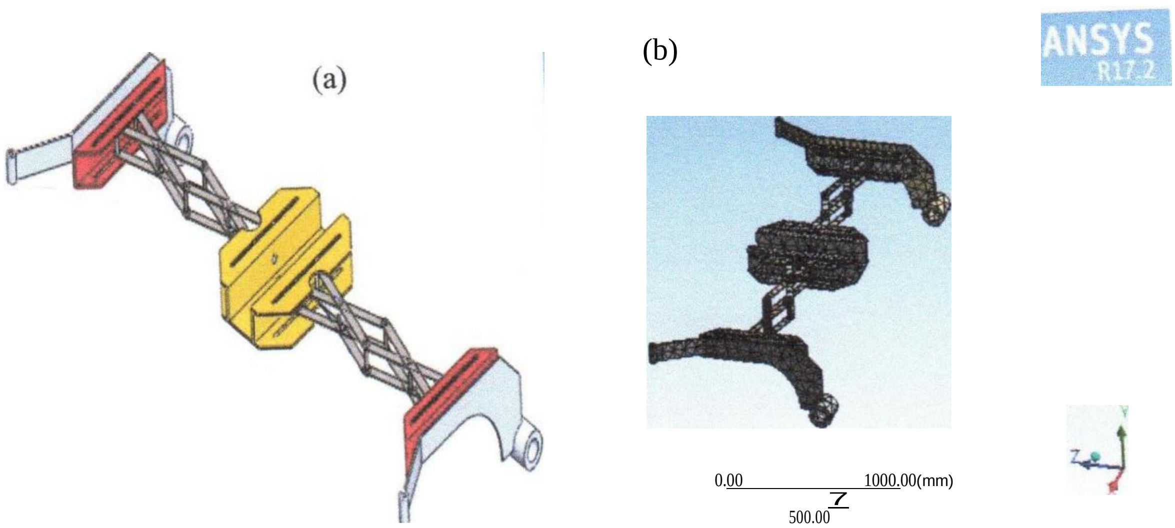
withstand while being stretched or pulled before breaking. If we observe the Stress-Strain curve, we can see that the Ultimate tensile strength always comes after the yield point. This point serves

a very important observation.

FEA is the process of simulating the behavior of a part or an assembly under given conditions so that it can be assessed using the finite element method. The method of analysis the structure under its worst working conditions, that is when it is fully extended and having a payload

The following are Steps for performing structural analysis in ANSYS of the proposed structure;

1. Define the geometry. This is the drawing of the structure in solid works and saved in a file which can be read by ANSYS
2. Material selecting and assigning. This happens in ANSYS where the part is assigned to a required material and mild steel material is assigned.
3. Meshing. This is process of dividing the structure into smaller units called mesh for easy and better accurate results here a 10mm mesh is used.
4. Applying boundary conditions and loads, here the boundary is fixed and loads applied.



37.

A: Static Structural
Static Structural
lime: 1, s
13-De-20 312 **PM**

{!] **Force 2: 100. N**
{!] **Force: 100. N** ~
Displacement []
uptacement ? []
Fixed Support [] **Fixed**
Support 2
Force3: 400 N

0.00 1000.00 (mm)
500.00

(a) Unconstrained SolidWorks model of the proposed mechanical structure without applied boundary conditions and loads.

(b) Meshed look in the virtual prototype in ANSYS environment.

(c) The constrained virtual prototype

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CHAPTER FOUR

4.1 RESULTS AND DISCUSSIONS *l* =

507.7 = **510mm**

Link length **=1020mm**

This is one side of the link length, bringing them together gives total of the length covered by the whole unit to **2640mm** since it is made up of two which is enough covered space at fully expanded and it can cover a wide range of crops within that range

t = 44.2 = **45 mm**

E' = **13.13 x10°Nm ?**

Cut depth d, = **7.9x10m**

a= **0.015 m**

T = **12.76N - m**

d, > 0.00743m = **8 mm** The Shaft is hollow, **di = 10mm**

dnew = 23.8 = **24mm**

Shaft diameter of hollow section = **24.0 mm**

Modulus of rigidity, **G = 81. 395kN/mm²**

Spring index, **c = 10** Deflection, **6 = 82. 6mm**

Solid length, ***ls*** = **120mm**

Pitch, **p = 19.5mm**

o,= **100MPa**

d.= **11.3mm**

The nearest minor or core diameter from the table is de= **11. 5mm**

Nominal diameter, **d = 16mm**

Pitchp = **4mm**

Area of core Ac = **105mm²**

T = **75.8NM**

O = 96. 28MPa

t= 2. 919MPa

CT max = **96. 408MPa** Tension, **0. 048MPa** compression

1:max = **48. 228MPa** *n,*= **6.6=7** t,= **20.96MPa** 1:n=

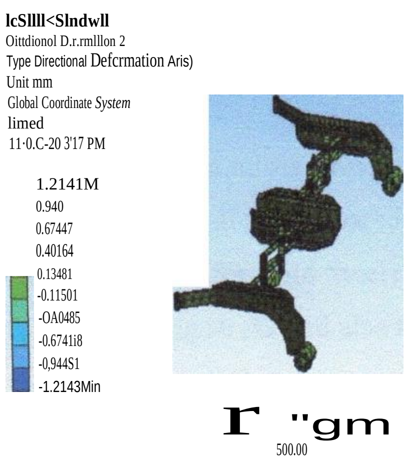
15.07MPa

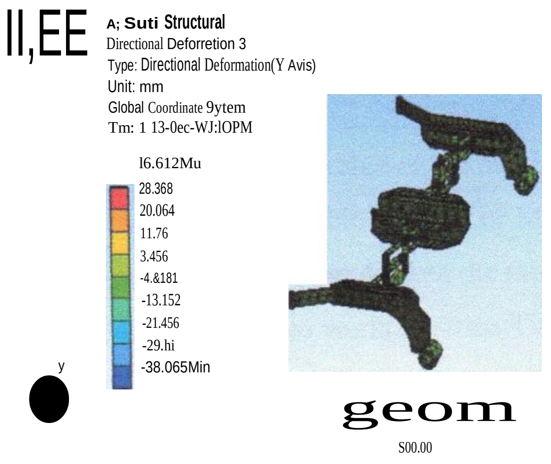
Height of the nut **H = 26. 4mm** Outside

diameter **D = 23. 2mm** Thickness of

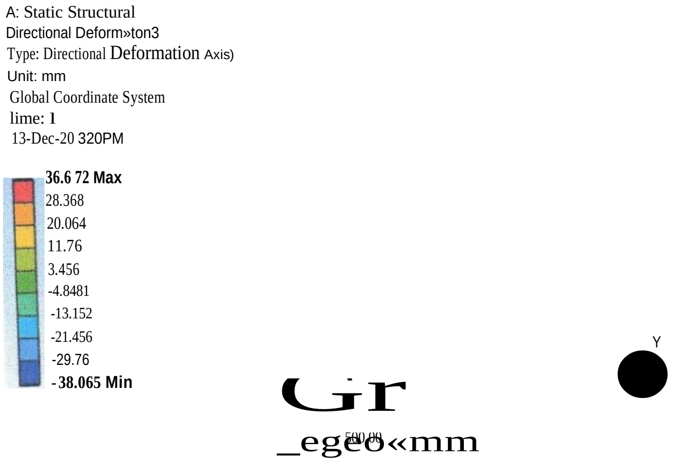
the collar **t = 8. 3mm**

Collar diameter, **D = 26. 1mm**

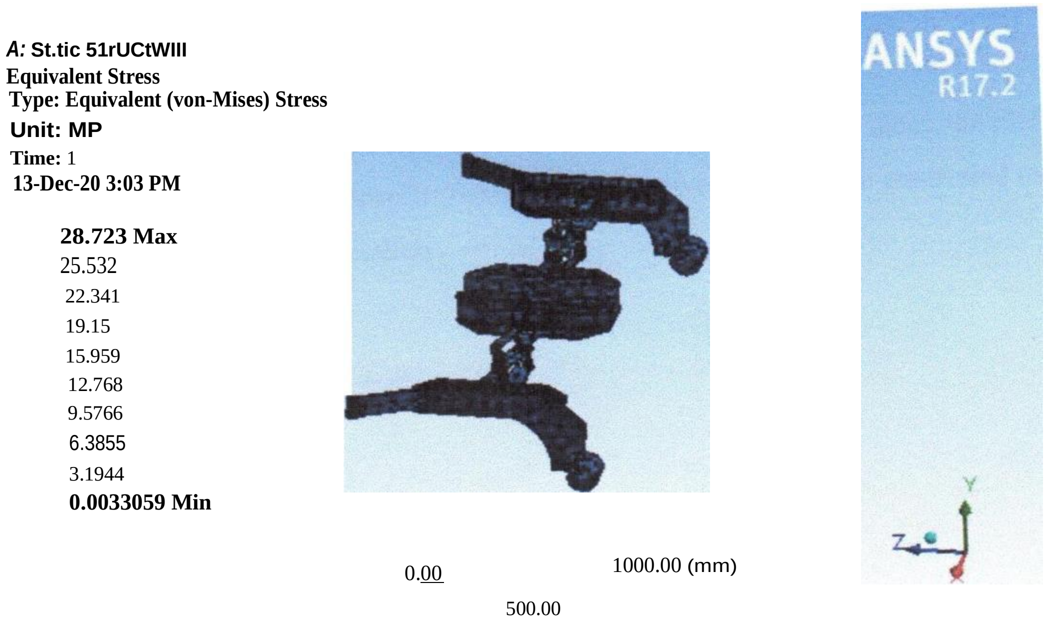




41.



The maximum deformations in X, Y and Z are 1.2mm, 3.1mm and 38. 065 mm respectively and are quite small (Acceptable)



The maximum von mises stress is recorded as 28.723 MPa. The value of the maximum von mises stress is small as compared to that of the maximum allowable strength of Mild Steel (around 300 MPa for Mild Steel). The factor of safety is more than 4 when the ratio is yield stress to working stress and also the same for ultimate tensile to working stress Thus the proposed mechanical structure is safe and far from failure, can withstand the applied loads at worst case loading configuration due its large factor of safety and strong enough to work for a long time without failure.

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CHAPTER FIVE

5.0 CONCLUSIONS

5.1 Conclusion

The design of the mobile mechanical structure for agricultural robots is carried out and presented which is to reduce the cost involved in agricultural activities. The platform will cover a width distance of 2640mm while monitoring or covering the crops at a height of 1340mm with a maximum load capacity of 640N while in its operation. All important features for the proposed structure has been defined for further developments to implementation level.

Finite element analysis is carried out to validate the capability of the structure, and results found satisfactory.

5.2 Future or prospective works

Dynamic and kinematic analysis to investigate the motion and forces along the platform. Electrical, electronic and controller designs for the power supply with controlled movement of

the structure while in its operation

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CHAPTER SIX

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