PROJECT REPORT

DESIGN AND ANALYSIS OF HARVESTER ROBOT

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Abstract—The theme for NERC (National Engineering Robotics Contest) is INDIGENOUS CATEGORY. This project focuses mainly on this theme in which harvester robot base is being developed for fruit plucking via Line and Wall Following. In this module the CAD MODEL and its ANALYSIS is required. Our team has developed CAD MODEL on SolidWorks 2020 according to the design requirements. The analysis is done on ANSYS WORKBENCH while keeping in view material selection and safety.

I. INTRODUCTION

In this AUTONOMOUS ROBOT CATEGORY robots are developed from scratch i.e., their mechanical structure, and controls etc. This is done by making cad model including parts like bolts, chains, sprockets, bearing, frame etc. And its analysis is done theoretically as well as on Ansys to optimize the design requirements.

II. DESIGN REQUIRMENTS

The base plate must not be greater than 10x10 inch in dimensions. The weight must be 12 to 14 kg. Keeping in view these values, the material should be selected.

III. MATERIAL SELECTION

In our scenario the main aim is that the robot structure should not exceed required weight and neither it should bend otherwise the working specially the alignment of the robot will be disturbed. Hence, we did complete material selection for optimized result for given constraints.
The function of the part is as follows:

Function: To support load without bending

Objective is as follows:

Objective: Minimize mass of robot

Constraints are as follows:

W (width), L (Length), S (bending stiffness)

Free Variables in our case are:

Thickness & Material Choice

Now, as our objective is to reduce the mass, we can use equation for mass;

$$m = \rho \times A \times L = \rho bdL = \rho wdL$$

We have equation for bending stiffness as well:

$$S = \frac{CEI}{L^3}$$

Where C is constant depending only on distribution of load, E is Young's Modulus, I is second moment of inertia and L is length. Where I is given as:

$$I = \frac{bd^3}{12}$$

Substituting value, we get.

$$S = \frac{CEbd^3}{12L^3}$$

Solving for d, we get.

$$d = \left(\frac{12S}{cb}\right)^{\frac{1}{3}} \times \frac{L}{E^{\frac{1}{3}}}$$

Substituting in mass formula.

$$m = \rho bdl = \left(\frac{12S}{cb}\right)^{\frac{1}{3}} (bL^2)\left(\frac{\rho}{E^{\frac{1}{3}}}\right)$$

Comparing the above result with Performance.

$$P = f\ (F, G, M)$$

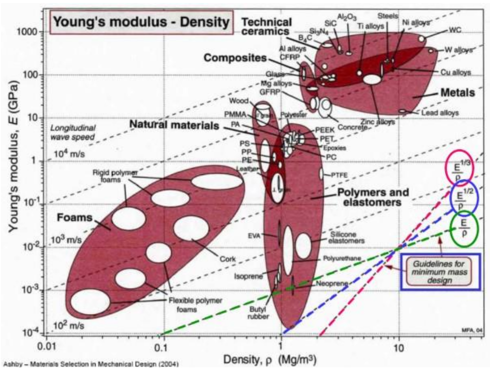
Hence, we have:

$$F = \left(\frac{12S}{cb}\right)^{\frac{1}{3}},\ G = (bL^2),\ M = \left(\frac{\rho}{E^{\frac{1}{3}}}\right)$$

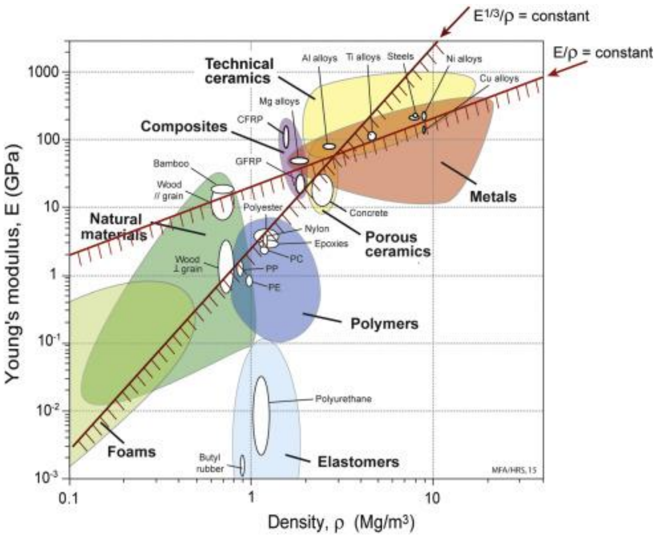
For minimizing weight, we need to minimize M or maximize p which is performance index and is inverse of M:

$$\boldsymbol{p} = \frac{\boldsymbol{E^{\frac{1}{3}}}}{\boldsymbol{\rho}}$$

Now plotting this performance index on material charts and finding the optimized material choices for the given conditions.



Material Chart (Young's Modulus vs Density)



Plot

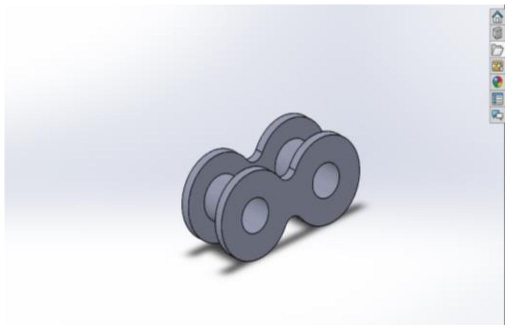
As we can see we have multiple choices including but not limited to "Aluminum", "Polycarbonate", "Nylon", "Acrylic" and many more.

Now considering cost and few more factors we decided to go with "Polycarbonate".

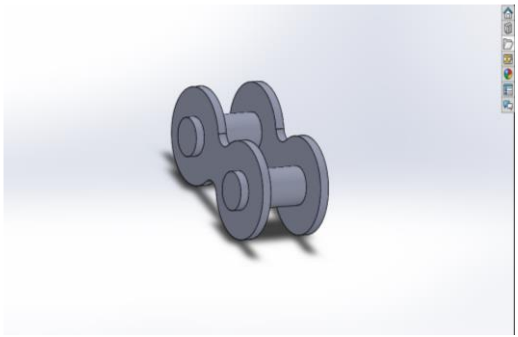
IV. PARTS

A. Chains

Two types of chains are being designed here inner and outer. The first one is outer while the other one is the inner chain. The chain is important so that it can be attached with the sprocket.

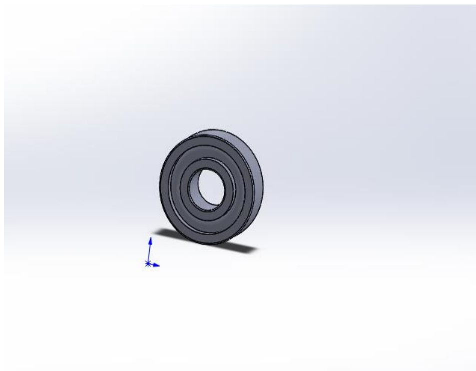


Chain 1



Chain 2

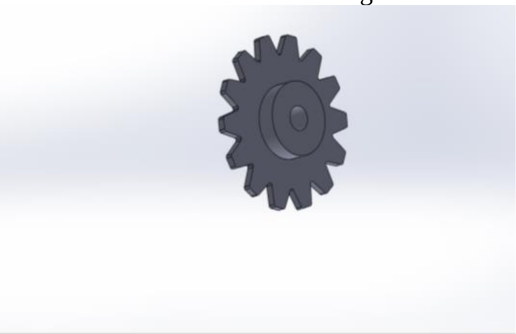
B. BEARING



Bearing

C. SPROCKET

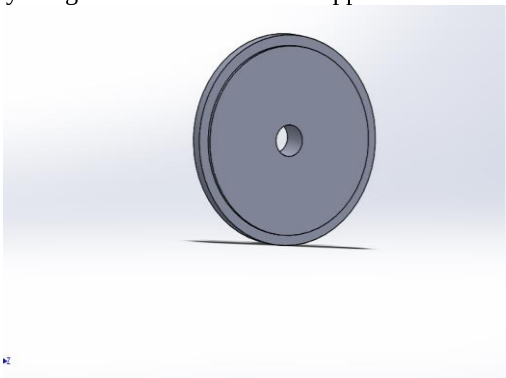
Sprocket will be attached with bearing as shown above.



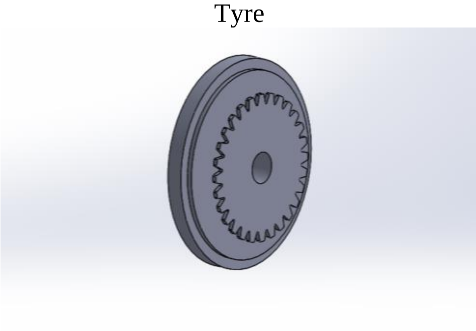
Sprocket

D. Tyre

In tyre a gear is attached which supports chain.

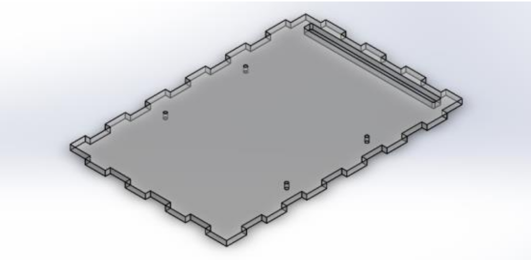


Tyre



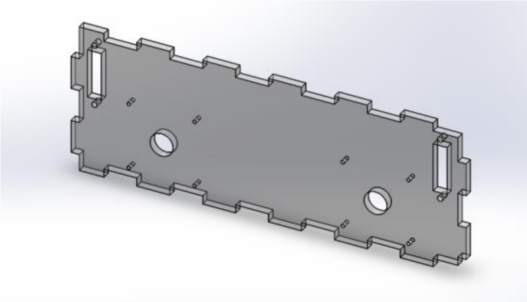
Tyre with Gear

E. Base Plate



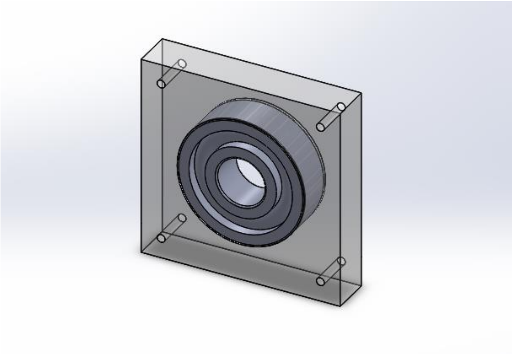
Base Plate

F. Side Plate



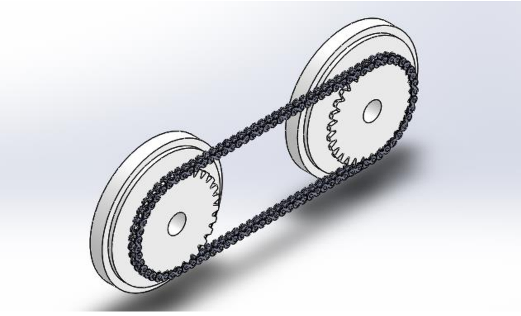
Side Plate

G. Bearing Assembly



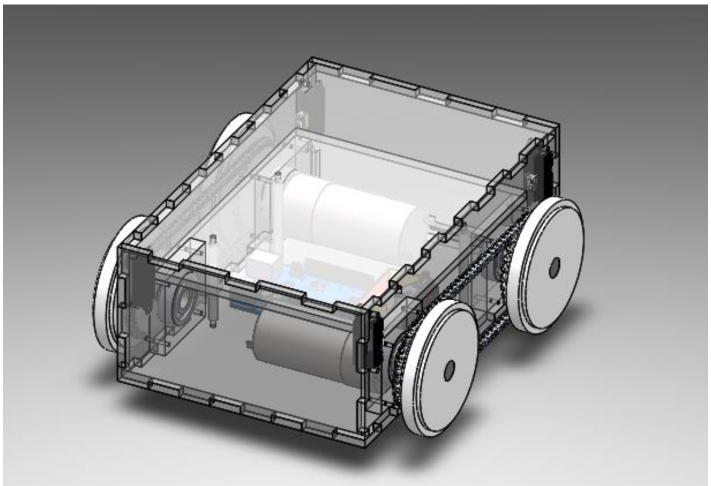
Bearing Assembly

H. Tyre Chain Assembly



Tyre Chian Assembly

I. Final Harvester Robot Assembly



Final Harvester Robot Assembly

IV. ANALYSIS(THEORETICAL)

There are many forces that can occur in the body like upward driving force, force by weight, drag force and driving force etc. but we are taking 3 forces upward and downward force. These values are calculated by estimation and can change when physical bot will be built.

Material used is Polycarbonate

$$Area = 0.161 \times 0.24 = 0.03864m^2$$

A. Equations and Values

Calculating Stress and Strain due to gravity

Upward force will be opposite to gravity.

Since due to gravity $F_x = 0$

Deflection = $Tan^{-1}(\frac{Fy}{Fx})$ = 90 degrees theoretically

Stress on x axis will be zero here.

Max Shear stress = 1776.9/2 = 888.46 Pa at angle of 45 degrees

Young's modulus of Polycarbonate = 21.4 GPa

Ultimate Tensile Strength = 165 MPa

Since weight can be less than 12 Kg according to the theme.

Mass (Kg)	F = w = mg	Stress (Pa) F/A	Strain (mm/mm) (Stress/Y)	Total Deformation (mm)
4Kg	39.24N	1,015.5	4.7 E-8	0.188 E-6
6Kg	58.86N	1,523.2	7.11 E-8	0.377 E-6
8Kg	78.48N	2,031.0	9.4 E-8	0.503 E-6
10Kg	98.10N	2,538.8	1.1 E-7	0.630 E-6
AVG	**68.67N**	**1,776.9Pa**	**8.05 E-8**	**0.424 E-6**

Total Deformation = (original length x strain)

A. Steps to calculate:

i) Area
   Area = length x width
ii) Force = weight = mg
iii) Stress = F/A
iv) Strain = Stress/ Young's modulus of Al
v) Total deformation = change in length(mm)

The Results will be

We can also determine deformation stress and strain as ANSYS does like finite element analysis while changing the area. Like we have to focus on a certain area to find different values. The value in the above table is the complete area.

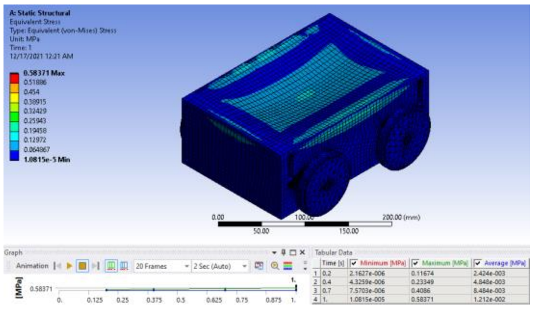
V. RESULTS(THEORETICAL)

Avg results are given below

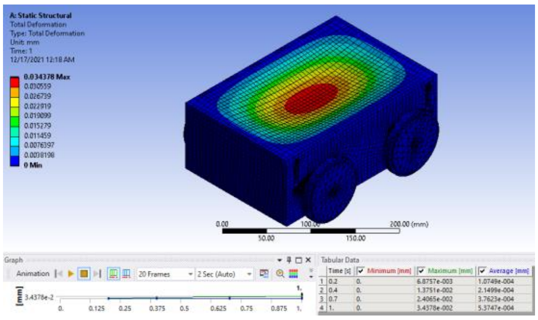
- **TOTAL DEFORMATION = 0.424 x 10^-6 mm**
- **STRESS = 1.776 KPa**
- **STRAIN = 8.05×10^{-8} (mm/mm)**

VI. ANSYS SIMULATION

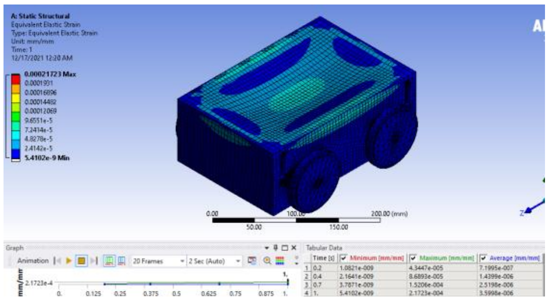
Stress



Total Deformation



Strain



Safety factor for this design will be:

$$n = \frac{S_y}{\sigma_c}$$

$$n = \frac{70\ MPa}{0.32\ MPa} \approx 218$$

VII. CONCLUSION

The stress analysis shows that the design is up to the mark and keeping in view the safety factor **(**Which came out to be 218**)** and performance of the robot, the material is chosen by proper material selection method. Finding Von Mises stress shows that the material will not fail according to Distortion energy theory or Von Mises theory.

ACKNOWLEDGEMENT

Thanks to Sir Mubashir Saleem for guiding as mentor and Research Assistant Waleed Ahmed and Fahad for guiding through the designing phase.

REFERENCES

[1] Ardiuno and Lipo Models were taken from GRABCAD

[2] Motor, Tyre and Bearing Models were taken from DE-40 & DE-39 Seniors

[3] Properties: Polycarbonate (PC) - Conductive Polycarbonate - Properties - Supplier Data by Goodfellow (azom.com)