Claw Machine

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I. Introduction

In our project we designed a claw machine where you can play and earn prizes. To achieve this structure, statics analysis followed by stress analysis were done for the structure to withstand loads almost equal to 1 kg. We did normal stress, shearing stress, bearing stress, torsion in addition to bending stress analysis. In hardware implementation, we chose PLA to make the x, y and z forks, steel pins and nuts and we used cardboard for the columns.

II. Analytical and Mathematical Model

a) Stress analysis and calculations (Normal, Shear & Bearing Stresses)

We calculated the normal, shear and bearing stress for the Gripper, Z-fork links and columns to find the stresses acting upon the structure to make sure they do not exceed the ultimate stress, then for our design, we calculated the maximum load, which is 11.05 N (mass = 11.05/9.8 = 1.127 Kg). We used PLA for the links, and steel for the pins.

The main equation for calculating the stress: $\sigma = \frac{F}{A}$

Our dimensions for the whole structure are:

- **links:** thickness t = 5 mm, width w = 10 mm
- **Gripper:** diameter hole: d = 2 mm, thickness t = 5 mm
- Using safety factor = 2, **we calculated the following:**
- σ(ult), PLA = 33 MPa → σ(all) = 16.5 MPa
- τ(ult), PLA = 37.5 MPa → τ(all) = 18.7 MPa
- σ(ult), steel = 420 MPa → σ(all) = 210 MPa
- τ(ult), steel = 280 MPa → τ(all) = 140 MPa

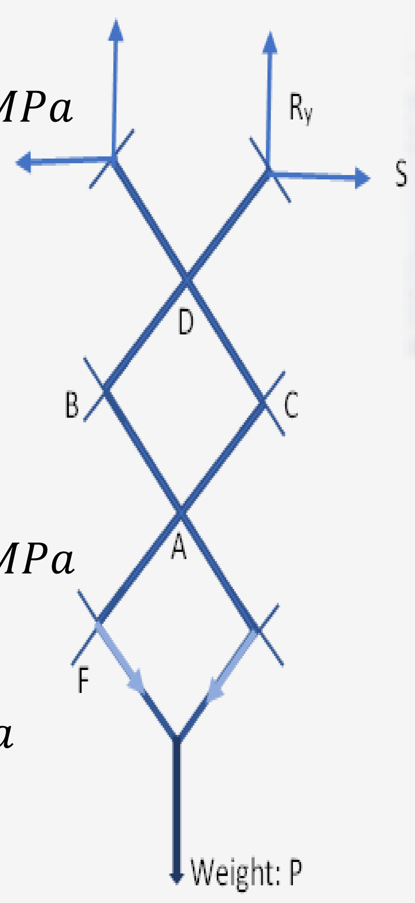
Gripper:

- Normal: σ(finger) = F/A → 16.5 MPa = $\frac{\frac{P}{3}}{5*(10-2)}$

  $\rightarrow P = 1980\ N$
- Shearing: τ(finger) = $\frac{\frac{P}{3}}{5*10} = 18.75\ MPa$

  $\rightarrow P = 2812.5\ N$
- Bearing: σ(b) = $\frac{P}{3*\cos 40*5*2} = 16.5\ MPa$

  $\rightarrow P = 379.17\ N$



Z- fork: Collapsed (θ = 15°)

- Normal: σ $= \frac{9.14\ P}{5*(10-2)} = 16.5\ MPa$

  $\rightarrow P = 72.2\ N$
- Shearing: τ(pin) G $= \frac{14.93\ P}{\pi*(1)^2} = 140\ MPa$

  $\rightarrow P = 29.5\ N$
- Bearing: σ (b, F) = $\frac{5.62\ P}{5*2} = 16.5\ MPa$

  $\rightarrow P = 29.36\ N$

Column:

Normal: σ $= \frac{-\frac{P}{4}}{20*10} = -0.74\ MPa$(Compression)

$\rightarrow P = 592\ N$

b) (Torsion and Bending Stresses)

For torsion, we used rack and pinion mechanism to transfer the rotary motion of the servo motor into linear motion, so we assumed a solid steel shaft connected to the gear of the motor to calculate the torsion. Torque T of the motor is 3.2 kg.cm = 313.6 N.mm and the required force is F = 46.65 N

$T = r \times F \qquad r = \frac{T}{F} = \frac{981}{46.65} \approx 21.028\ mm$

- **L shaft** = 10 mm , c shaft = 1.647mm
- **G steel** = 79.3 GPa, Using a factor of safety of 2

τ(ult), steel = 280 MPa → τ(all) = 140 MPa

Using torsion stress equation for shear stress and angle of twist to design for the radius **c** and the length of the shaft **L**

$$J = \frac{\pi}{2} * c^4 = 11.56\ mm^4$$

$$\tau = \frac{Tc}{j} = \frac{Tc}{\frac{\pi}{2}*c^4} = \frac{2T}{\pi*c^3} \rightarrow 140 = \frac{981*2}{\pi*c^3} \rightarrow \text{c = 1.647 mm}$$

$$\varphi\text{shaft} = \frac{TL}{GJ} \rightarrow 1\ \text{deg} = 0.01745\ rad = \frac{981*L}{79.3*10^3*11.56}$$

$$L \approx 16.31\ mm$$

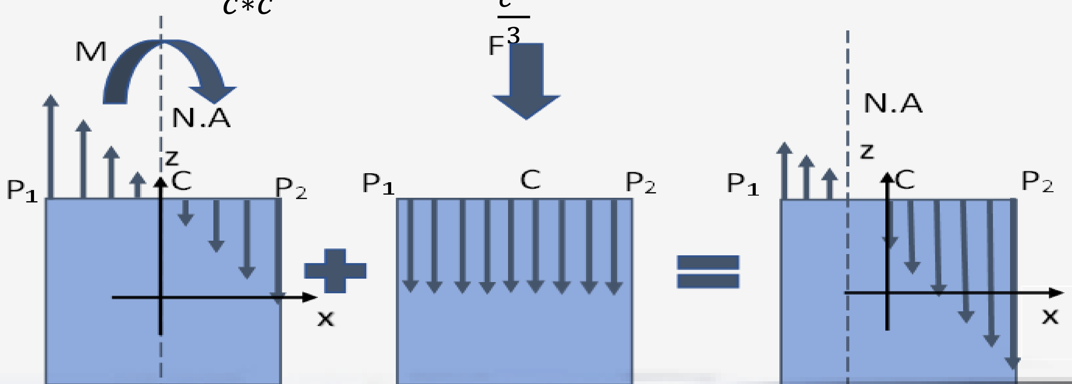
For bending, the max bending is when the weight at one of the corners (made of Cardboard) which is eccentric bending. We will study the bending moment on the opposite corner at its extrema point . We will design for length and width of the column

Roof: weight = 20N, width = 500 mm, length = 500 mm

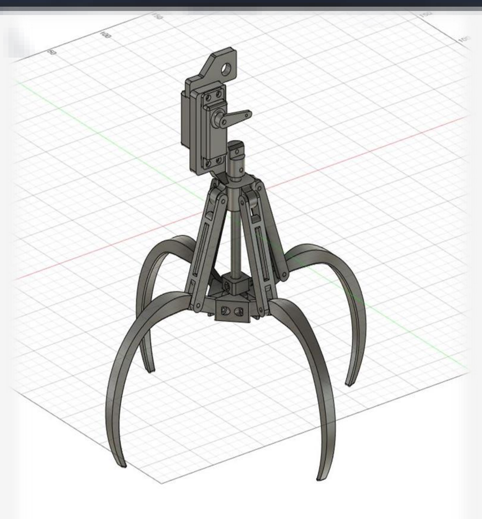
- Factor of safety n = 2, E = 0.93 GPa
- Cardboard: σ(ult)= 1.48 MPa → σ(all) = 0.74 MPa,

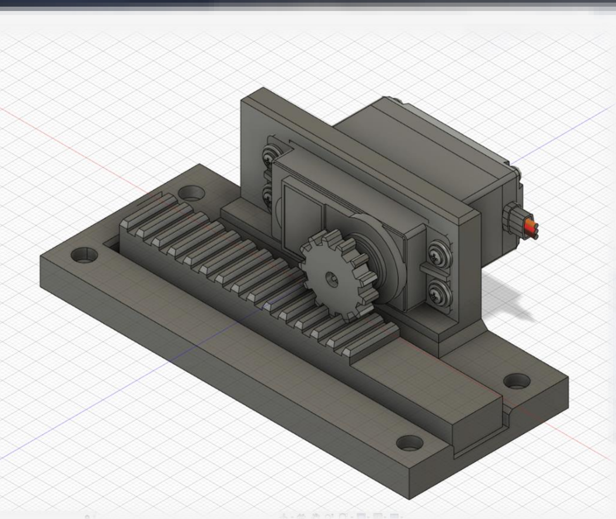
Column: diagonal = $c\sqrt{2}$ mm (with square cross sectional area, length and width = c)
Reducing this force into a Force-Couple System:

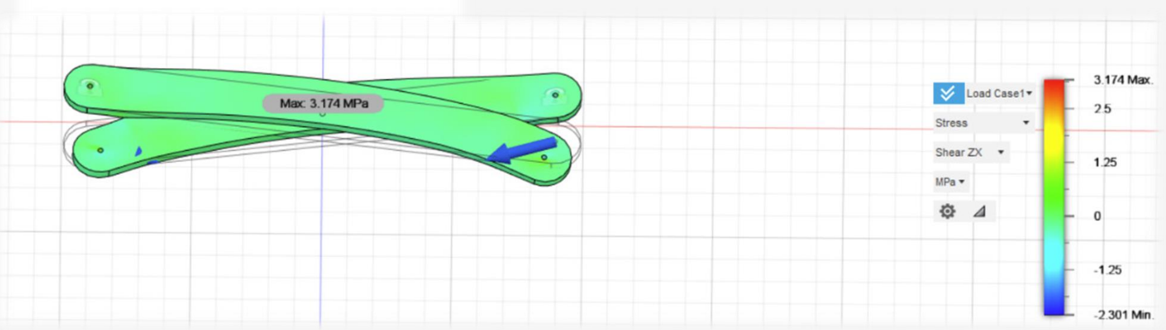
- $M_B = r_{(A/B)} \times F_A = (500\sqrt{2} - c\sqrt{2}) * 20 = 10000\sqrt{2} - 20c\sqrt{2}$
- $I = \frac{1}{12}bh^3 = \frac{(c\sqrt{2})^4}{12} = \frac{c^4}{3}, \qquad \sigma = -\frac{F}{A} - \frac{My}{I}$
- $-0.74 = -\frac{20}{c*c} - \frac{(10000\sqrt{2} - 20c\sqrt{2})*\frac{c\sqrt{2}}{2}}{\frac{c^4}{3}} \rightarrow c \approx 33.83\ mm$



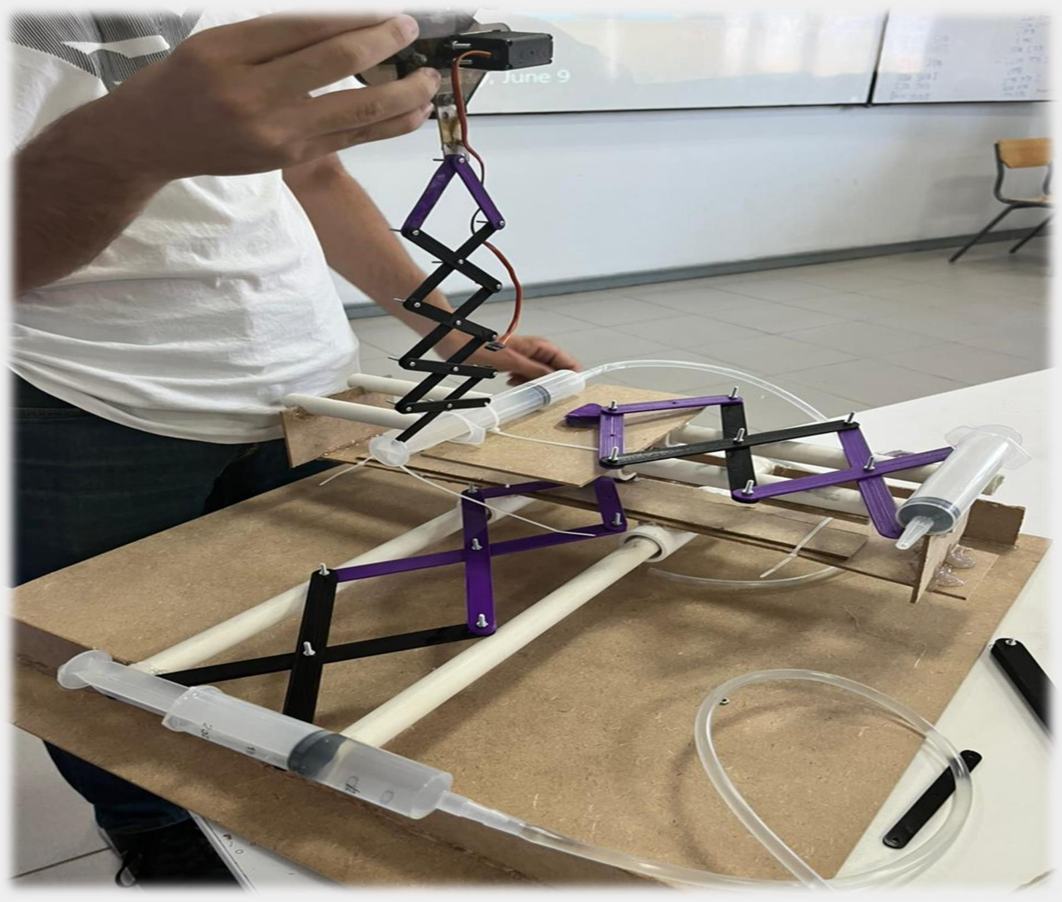
III. Conceptual Design based on a Fusion 360 model

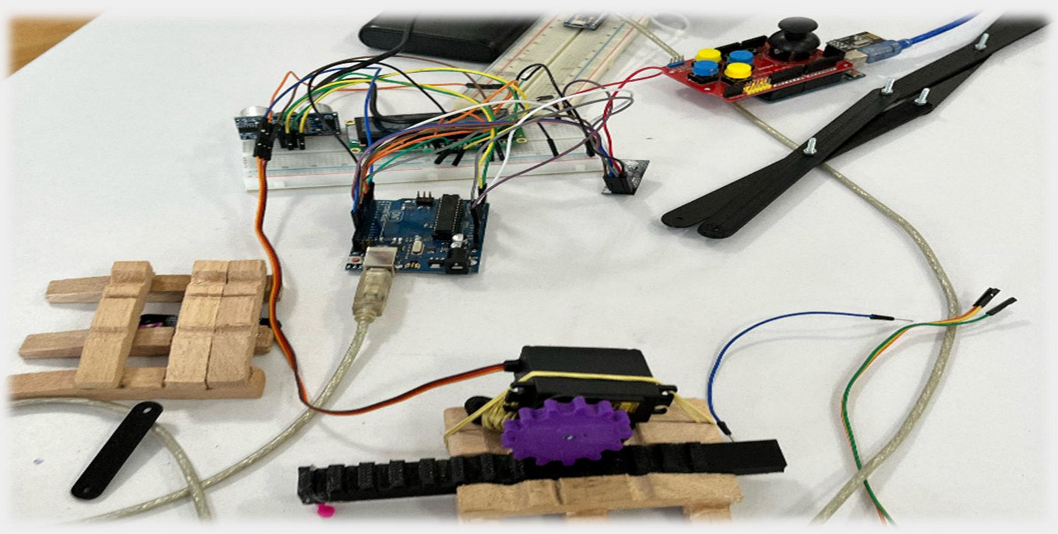






IV. Experimental Work





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