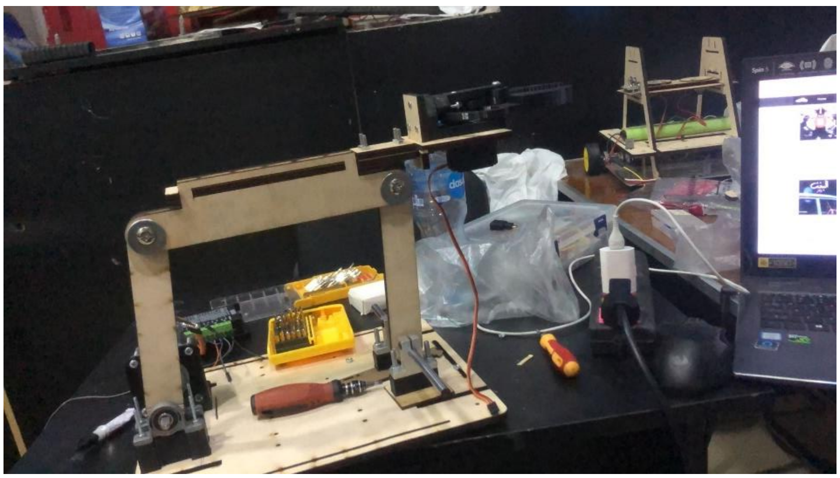
Contents

Project description:

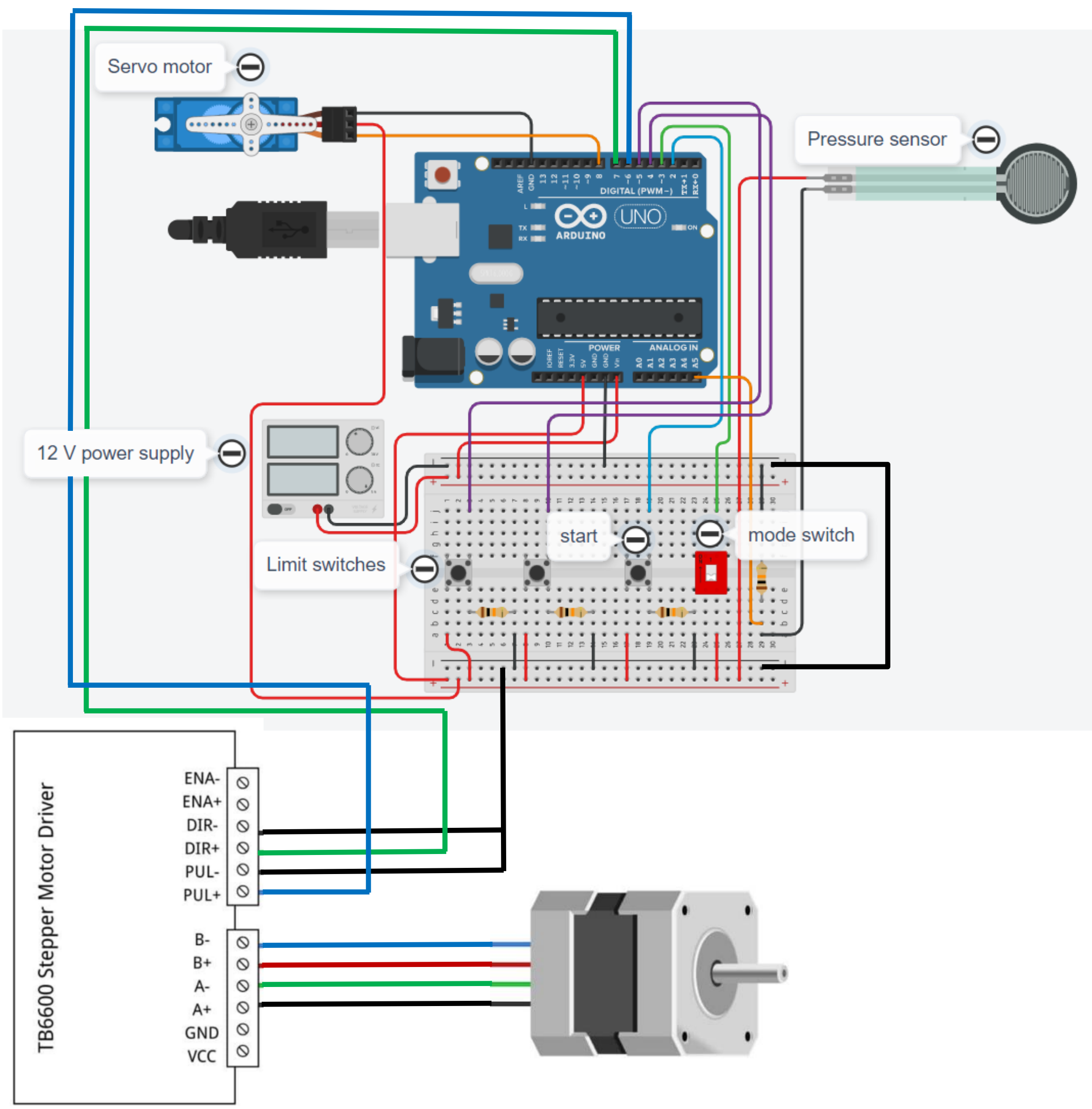
We are designing a 4-bar mechanism that has a 4-bar gripper mechanism. The gripper has PID control to apply the appropriate pressure on the object.

The 4-bar mechanism will move to a specific location, start grabbing the object, then will move to a different location. It will keep the object held for a little while, then return to the starting position, and release its grip on the product.



Components and circuit:

- One switches for two different objects
- Two limit switches
- Servo motor for gripper
- One stepper motor + fixations for the four bar mechanisms
- Pressure/Force sensor



Four bar mechanism calculations:

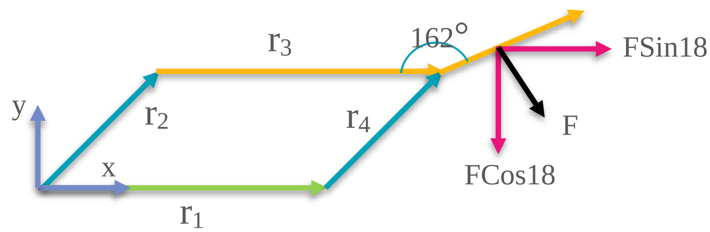
Here we calculate the torque made by the gripper by computing the links made by the gears in the gripper

GRIPPER CALCULATION:

$r_1 = r_3 = 36.81$ mm

$r_2 = r_4 = 40$ mm

$\theta_1 = 0°$



Vector loop: $r_1 + r_4 = r_2 + r_3$

position equations:

$$r_1 \cos\theta_1 + r_4 \cos\theta_4 = r_2 \cos\theta_2 + r_3 \cos\theta_3$$
$$r_1 \sin\theta_1 + r_4 \sin\theta_4 = r_2 \sin\theta_2 + r_3 \sin\theta_3$$

$\theta_2 = 68°$

$36.81 + 40\cos\theta4 - 40\cos(68) = 36.81\cos\theta_3$

$40\sin\theta_4 - 40\sin(68) = 36.81\sin\theta_3$

By squaring both sides and adding the equations

$(36.81)^2 + 2(36.81)(40\cos\theta_4 - 40\cos(68)) + (40)^2 - 2(40)^2\cos(68)\cos\theta_4 + (40)^2\cos^2(68) + (40)^2\sin^2(68) - 2(40)^2\sin(68)\sin\theta_4 = (36.81)^2$

Then, $\theta_4 = \theta_2 = 68°$

$\theta_3 = \theta_1 = 0°$, since shape is parallel

Differentiate Position with respect to θ_2:

$-r_4(\sin\theta_4)h_4 = -r_2\sin\theta_2 - r_3(\sin\theta_3)h_3$

$40\sin(68)h_4 = 40\sin(68) + 0$

Then, $h_4 = 1$

$r_4(\cos\theta_4)h_4 = r_2\cos\theta_2 + r_3(\cos\theta_3)h_3$

$40\cos(68)(1) = 40\cos(68) + 36.81h_3$

Then, $h_3 = 0$

$r_c(x) = r_4\cos\theta4 + r_c/\cos\theta_3$

$F_c(x) = - r_4(\sin\theta_4)h_4 – 0$, $F_c(x) = -40\sin(68)(1) = -37.1$

$r_c(y) = r_4\sin\theta_4 + r_c/\sin\theta_3$

$F_c(y) = r_4(\cos\theta_4)(h_4) + 0$, $F_c(y) = 40\cos(68)(1) = 15$

$$V_c = \begin{bmatrix} Fcx \\ Fcy \\ 0 \end{bmatrix} \dot{\theta}_2 = \begin{bmatrix} -37.1 \\ 15 \\ 0 \end{bmatrix} \dot{\theta}_2$$

P = T*w + F*V=0

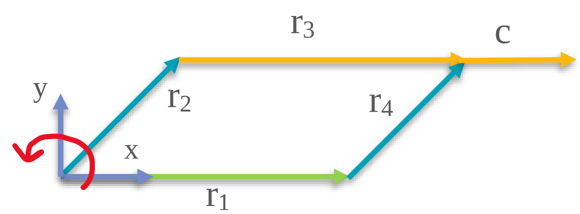
$$P = T * \dot{\theta}_2 + F * \begin{bmatrix} \sin 18 \\ -\cos 18 \\ 0 \end{bmatrix} * \begin{bmatrix} -37.1 \\ 15 \\ 0 \end{bmatrix} \dot{\theta}_2 = 0$$

Then, $T_1 = 31.65 * 15*\cos18 + 31.65 *37.1\sin18 = 814$ N.mm

$T_{\text{for both gears}} = 8.14*2 = 16.28$ kg.cm

$T_2 = T_1$ / Reduction rate = 16.28 / 1.5 = **10.85 kg.cm**

FOUR BAR MECHANISM :



- $r_1 = r_3 = 20cm$
- $r_2 = r_4 = 15cm$
- $\theta_1 = 0$
- $\theta_2 = 30$

Vector Loop:

$$r_1 + r_4 = r_2 + r_3$$

Position equations:

$$r_1\cos\theta_1 + r_4\cos\theta_4 = r_2\cos\theta_2 + r_3\cos\theta_3$$
$$r_1\sin\theta_1 + r_4\sin\theta_4 = r_2\sin\theta_2 + r_3\sin\theta_3$$

by substituting:

$20 + 15 \cos \theta_4 -15 \cos 30 = 20 \cos \theta_3$

$15 \sin \theta_4 – 15 \sin 30 = 20 \sin \theta_3$

By squaring both sides and adding:

$(20)^2 + 2(20)(15\cos\theta_4 – 15\cos(30)) + (15)^2 – 2(15)^2\cos(30) \cos\theta_4 + (15)^2 \cos^2(30) + (15)^2 \sin^2(30) – 2(15)^2\sin(30) \sin\theta_4 = (20)^2$

Then,

$\theta_4 = \theta_2 = 30$
$\theta_3 = 0$

Vector loop: $\boldsymbol{rc}=\boldsymbol{r4}+\boldsymbol{r5}$
Position:
$r_c(x) = r_4\cos\theta_4 + r_5\cos\theta_5 = 15\cos(30) + 20\cos(0) = 33$ cm
$r_c(y) = r_4\sin\theta_4 + r_5\sin\theta_5 = 15\sin(30) + 20\sin(0) = 7.5$ cm
$F_c(x) = - r_4(\sin\theta_4)h_4 = - 15(\sin(30))h_4 = - 7.5h_4$
$F_c(y) = r_4(\cos\theta_4)(h_4) = 15(\cos(30))h_4 = 13h_4$

$$V_o = \begin{bmatrix} fcx \\ fcy \\ 0 \end{bmatrix} \dot{\theta}_2, \qquad w = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} \dot{\theta}_2, \qquad \overrightarrow{T_D} = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} T_D, \qquad \overrightarrow{F_L} = \begin{bmatrix} -1 \\ 0 \\ 0 \end{bmatrix} F_L$$

Differentiate position equations to get h3, h4 with respect to θ2:

$$-\boldsymbol{r4h4sin\theta4} = -\boldsymbol{r2sin\theta2} - \boldsymbol{r3h3sin\theta3}$$
$$\boldsymbol{r4h4cos\theta4} = \boldsymbol{r2cos\theta2} + \boldsymbol{r3h3cos\theta3}$$

Substitution:

$$-\boldsymbol{15h4sin30} = -\boldsymbol{15sin30} - \boldsymbol{20h3sin0}$$
$$\boldsymbol{15h4cos30} = \boldsymbol{15cos30} + \boldsymbol{20h3cos0}$$

Solve to get h_3 & h_4:

- $h_3 = 0$
- $h_4 = 1$

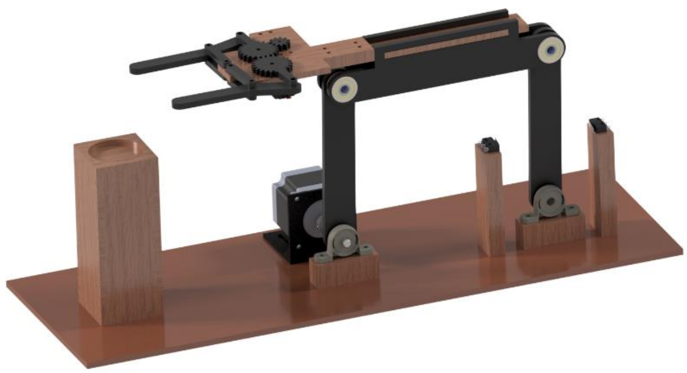
Solve to get fc_x & fc_y:

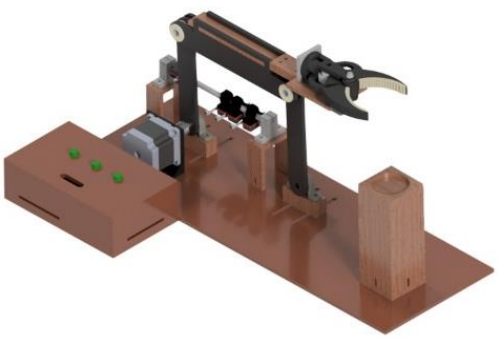
$fc_x = -7.5$
$fc_y = 13$

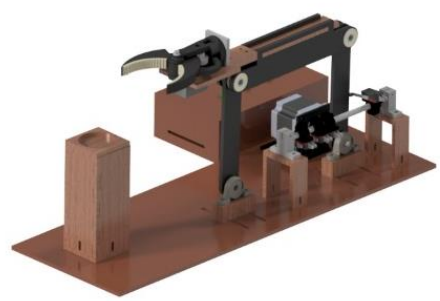
P = T*w + F*V= 0

$$\boldsymbol{Mech\ Adv. = \frac{F}{T} = 1}$$

CAD Model :







Gripper Pressure PID control

The PID is used to control the gripping pressure using the servo angle, The Gripping force is calculated as:

$$F_k = \frac{mgsin(\propto 1)}{\mu(\sin(\propto 1\ ) + \sin(\propto 2\ ) + \sin(\propto 3\ ))}$$

Where $\propto_1$, $\propto_2$, $\propto_3$ = 120 , 30, 30, and they represent gripper parameters

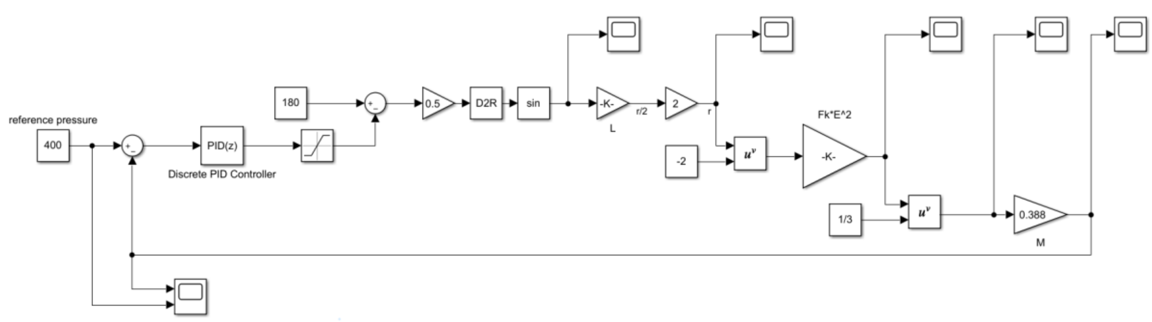
m = 1 kg
$F_k = 15.17\ N$

$$P = M\sqrt[3]{F_k * \frac{E^2}{r^2}}$$

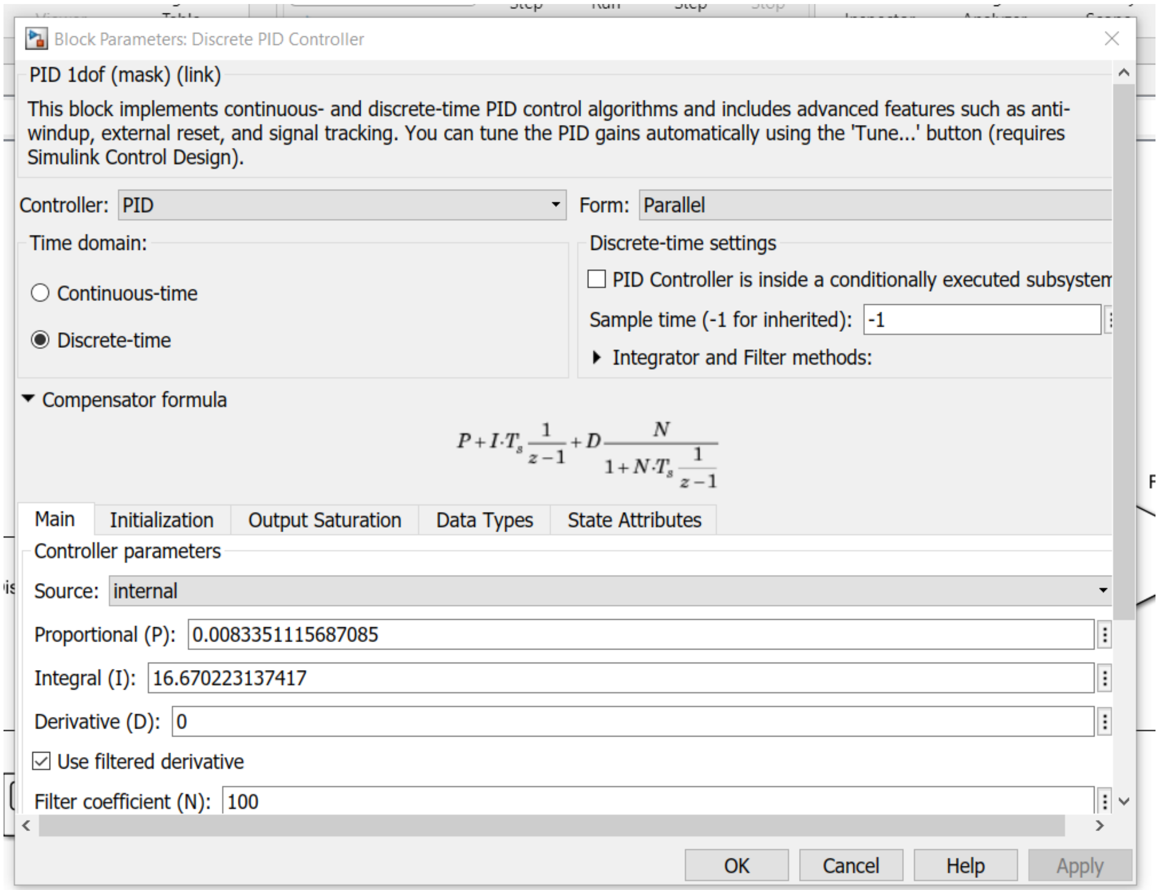
$$r = \sin(theta) * l * 2$$

Where E = 0.5 GPa, M = 0.388, μ = 0.3, L= 0.35.

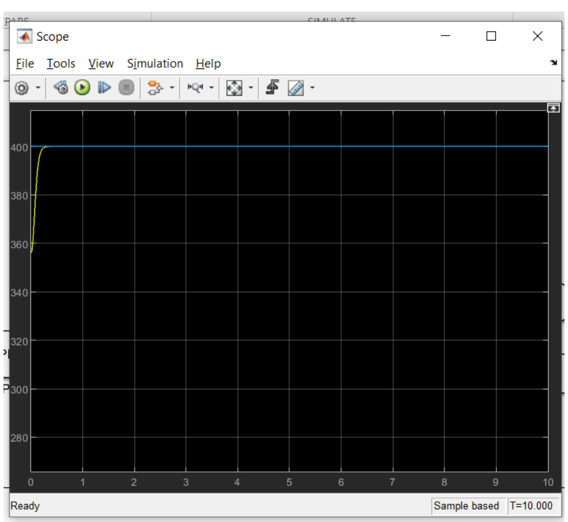
System model on matlab:

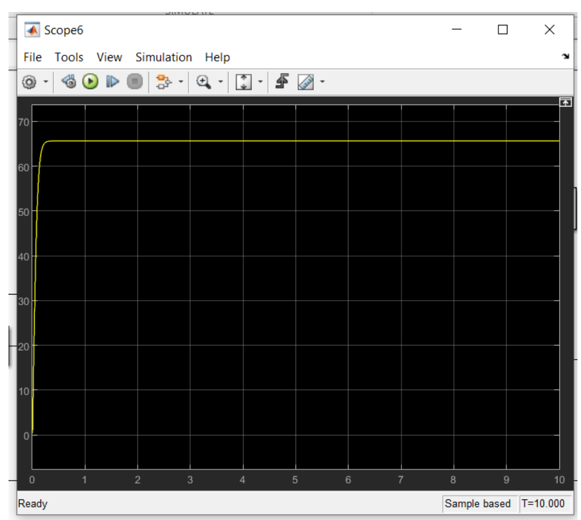


PID TUNING:



PRESSURE OUTPUT AND SERVO ANGLE





Matlab contact forces simulation :