Poznań University of Technology

Faculty of Control, Robotics
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Institute of Robotics and Machine Intelligence

Division of Control and Mechnaical Construction

Mechanical Construction of Gripper in Inventor

Mechanical Constrcutions

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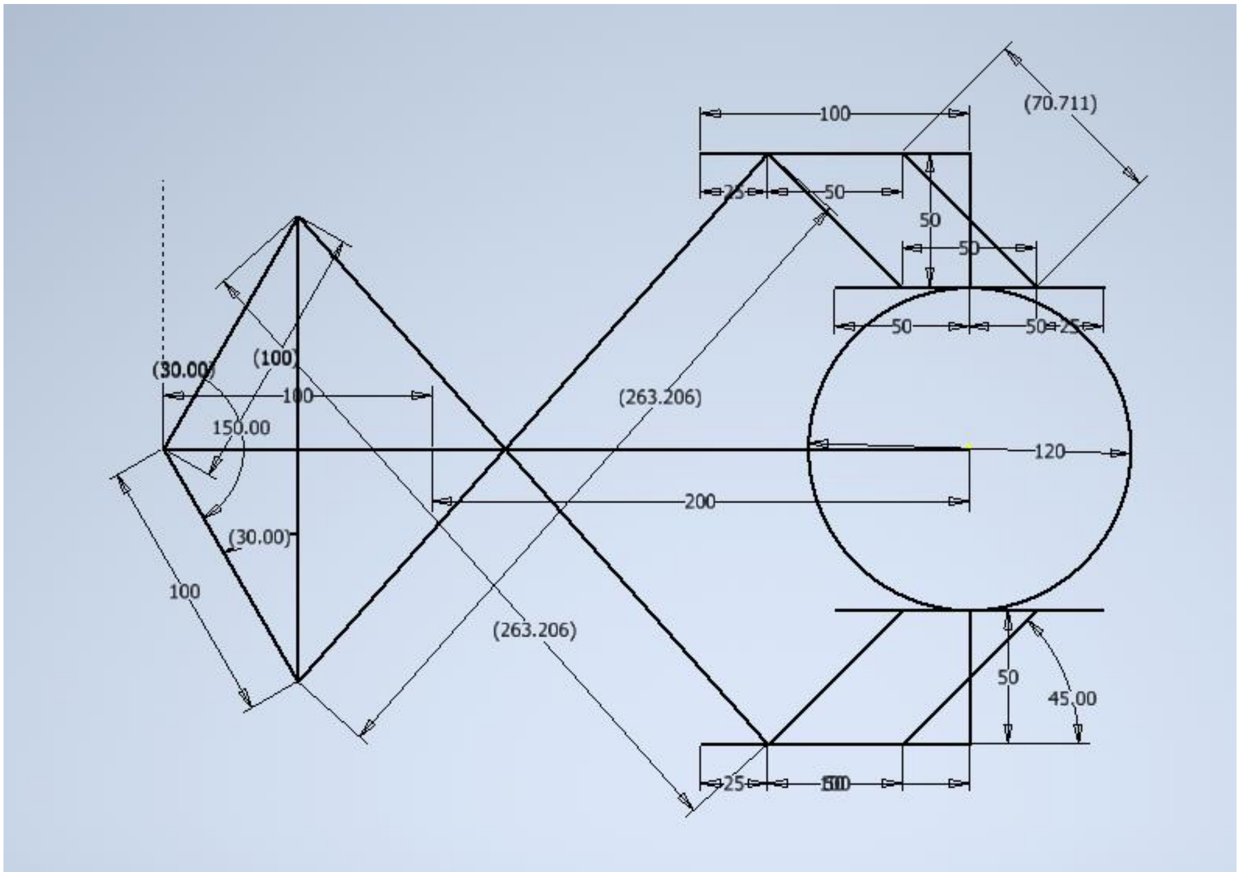
Free Body Diagram



Gripper calculations

Using matlab and simulation

```
clc;
%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%% 1 - FORCE %%%
%%%%%%%%%%%%%%%%%%%%%%
% material: brass

diameter = 120;
height = 300;
ro = 8470;    %[kg/m^3]

Volume = pi*(diameter/2)^2*height /(1000^3); %[m^3]
Mass = Volume * ro;                          %[kg]
```

```
Weight = Mass * 9.81                          %[N]

mi_friction1 =  0.51;  %copper - rubber friction
coefficient)

Force_1 = Weight/0.51;
Force_2 = Force_1/2;

b= 0.7707;
l= 0.26320;
theta = 30;
alpha= 45;

Force_3 = Force_2 *
(b*sind(theta)*sind(alpha))/(l*sind(alpha)*cos(alpha+theta)
);
disp("Force exerted on the screw: [N]");
F = 440;

%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%% 2 - SCREW %%%
%%%%%%%%%%%%%%%%%%%%%%

% % % % %  BUCKLING - screw diameter %%%%%%
L = 49;
L_w=L*0.5;
x=5;


% https://www.azom.com/properties.aspx?ArticleID=965


R_e = 300 *10^6;
E = 200*10^9;

% https://www.engineersedge.com/hardware/iso-metric-
trapezoidal-threads1.htm

d3 = 2*sqrt((F*x)/(pi*R_e)+(R_e*L_w^2)/(pi^2*E))

disp("normalized screw diameter: [mm]");


p_norm = 1.5;
```

```
d_1_norm = 6;
d_2_norm = 7.1;
d_3_norm = 8;

alpha_r_norm = 15;

% % % % %  slenderness condition %%%%%%
lambda_cr = pi*sqrt(E/R_e);
lambda = (4*L_w)/d_3_norm;
if lambda <  lambda_cr
    disp("slenderness ratio contidion is met")
end

% % % % % self-lockint %%%%%%%

mi_selfLock = 0.12;

gamma = atand(p_norm/(pi*d_3_norm));
ro_prim = atand(mi_selfLock/(cosd(alpha_r_norm)));

if( gamma < ro_prim)
        disp("self-locking contidion is met")
end

% % % % %  Critical stress %%%%%%%%%%%%%
D_avg = (8+7.1)/2;
mi_criticalStress=0.12;
T_t = F*mi_criticalStress*D_avg +
F*d_2_norm/2*tand(gamma+ro_prim);
tau_t =  (16*T_t)/(pi*d_3_norm^2);

sigma_c = (4*F)/(pi*d_3_norm^2);

sigma_allow = R_e/x /10^6;
sigma_red = sqrt(sigma_c^2+3*tau_t^2)

if( sigma_red < sigma_allow)
        disp("critical stress contidion is met")
end


%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%% 2 - NUT %%%
%%%%%%%%%%%%%%%%%%%%%%
```

```
% % % % %  height of the nut %%%%%%
P_allow =13 *10^6;
d = d_3_norm;
D1=d_1_norm;

A_coil = pi*(d^2-D1^2)/(4);
z = F/(P_allow*A_coil);
H_r = z*p_norm;

H_prop = 1.1*d;

if(H_r<H_prop)
    disp("height of the nut condiiton is met")
end

% % % % % %  outer diameter of the nut %%%%%%
E1=E;
E2 = 200 *10^9;

A1 = (pi*d^2)/4;
D0 = sqrt((4*E1*A1)/(pi*E2)+D1^2);
```

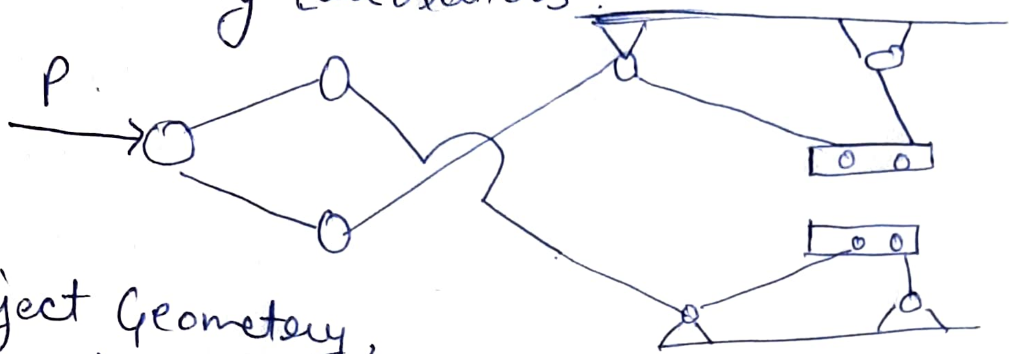
Solutions

Name	Value
A1	50.2655
A_coil	21.9911
alpha	45
alpha_r_norm	15
b	0.7707
d	8
D0	10
D1	6
d3	0.6041
d_1_norm	6
d_2_norm	7.1000
d_3_norm	8
D_avg	7.5500
diameter	120
E	2.0000e+11
E1	2.0000e+11
E2	2.0000e+11
F	440
Force_1	552.7845
Force_2	276.3923
Force_3	439.0173
gamma	3.4155
H_prop	8.8000
H_r	2.3086e-06
height	300
I	0.2632
L	49
L_w	24.5000
lambda	12.2500
lambda_cr	81.1156
Mass	28.7380
mi_criticalStre...	0.1200
mi_friction1	0.5100

Name	Value
mi_selfLock	0.1200
P_allow	13000000
p_norm	1.5000
R_e	300000000
ro	8470
ro_prim	7.0818
sigma_allow	60
sigma_c	8.7535
sigma_red	95.2404
T_t	688.0631
tau_t	54.7543
theta	30
Volume	0.0034
Weight	281.9201
x	5

- Gripper Calculations.

Preliminary Calculations



Object Geometry,

Diameter = 120 mm.

Height = 300 mm.

Density = 8470 kg/m³.

a) Volume $= \pi r^2 h = \pi \cdot 0.06^2 + 0.3 = 0.0033\ [m^3]$.

b) Mass $= V\rho = 0.0033 \cdot 8470 = 28.7\ [kg]$

c) Weight $= Q = mg = 28.7 \times 9.87 = 283.5\ [N]$.

d) Force,

Gripper. Force $= F_1 = \frac{Q}{2} = \frac{283.5}{2} = 141.75$

Force Required to hold the target object,

$$f_2 = \frac{1}{\mu_1} F_1$$

$\mu_1 =$ Friction coefficient in case of brass-steel,

$$F_2 = \frac{1}{\mu_1} F_1 = \frac{141}{0.51} \approx 276\ [N]$$

E) Gripper Dimension,

$b = 70.7$ mm

$\theta = 30^\circ$ $l = 263.20$ mm.

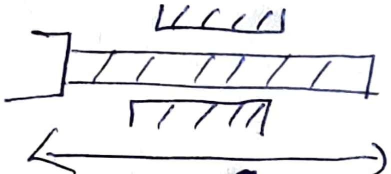
$\alpha = 45$

P = force required to close the gripper,

$$\frac{P}{f} = \frac{B\sin\theta\sin\alpha}{d\sin\alpha\cos(\alpha+\theta)} = 439.01\ N.$$

2. Screw Calculation..

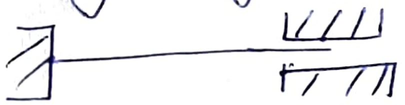
→ Lead Screw mechanism,,.



$l = 1\cancel{5}70$.

→ Buckling Mechanism,.

Buckling length,.

→  $\alpha = 0.5$.

So, Screw Dimension Calculation.

Critical stress,

$$\sigma_{CR} = \frac{F}{A} x = \frac{Fx}{\frac{\pi d_3^2}{2}} = \frac{4Fx}{\pi d_3^2} x = 295[N].$$

So, F = Force.

x = safety factor, = 5.

d_3 = screw inner dineter.

$Re = 300 \times 10^6\ Pa$.

$E = 180\ (GPa) = 180 \times 10^9$.

$$\cancel{B}\ D_3 = 2\sqrt{\frac{Fx}{\pi Re} + \frac{ReLw^2}{\pi^2 E}} = 0.5974.[[mm]]$$

$P\ (nom) = 1.6$, Chose Screw $= Tr8 \times 1.5$.

Slenderness:

$$\lambda_{cr} = \pi\sqrt{\frac{E}{Re}} = \lambda = \frac{L_w}{i} = \frac{4\,L_w}{d_3} = 8\cancel{5}$$

$\lambda < \lambda_{cr}$, Slenderness ratio is promised and provoked.

condition fulfil.

Checking Self locking.

γ = lead angle.

ρ' = angle of friction.

α = Profile Angle.

μ = Steel-brass friction coefficient.

$\mu = 0.11$.

$$\gamma = a\tan\left(\frac{P}{\pi d_2}\right) = 3.42^{\circ}.$$

$$\rho' = a\tan\left(\frac{\mu}{\cos\alpha_1}\right) = 6.57^{\circ}.$$

Condition is fullfiled and met.

Critical stress, $(\sigma_{in}) < \sigma(\text{allowable})$.

$$\sigma_c = \frac{4F}{\pi d_3{}^2}. \qquad \tau_t = \frac{V}{A} = \frac{T_t}{\pi d.}$$

$$16\,t_t)(P_1 \times d_3{}^3)$$

$$= \underline{1.331}.$$

$\sigma(\text{allow}) > \sigma(\text{re})$

Criticale stress condition is met.

NUT Calculation

$P(\text{allowable}) = 12\ MPa.$

$d = d_3 (\text{nom})$ $\qquad$ $H(\text{prop}) = 1.2 \times d;$

$D_1 = d_1 (\text{nom})$

So, $H_{cr} < H.$

So, Height of the nut condition is met.

Outer Diameter of the nut.

$E_1 = E.$

$E_2 = 239 \times 10^9.$

$A_1 = (\pi . d^2) . 4$

$= 52.267.$

$$D_0 = \sqrt{\frac{4 E_1 A_1}{(\pi E_2)} + D_1^2} = 10.4 [mm].$$

Spigot calculation,

$Re = 250 [MPa]$

$F = 437 [N]$ $\qquad$ $\sigma\ \text{allow} = \frac{Re}{X} = \frac{250}{5} = 50 [MPa]$

$\sigma = \frac{T_{o\,net}}{Z_r} < \sigma_{ab}.$ $\qquad$ $d = 3\sqrt{\frac{12 C F}{\pi \sigma_{bb}}} = 3\sqrt{\frac{124 F}{\pi \sigma_{ala}}}$

$T_{omax} = \frac{3 L F}{8}.$ $\qquad$ $d = 0.2089 [mm].$

$Z_b = \frac{\pi d^3}{32}. =$

Checking Contact Pressure,

$P_{allow} = 0.96\,ab = 95\,[MPa]$.

$P_{cos} < P_{allow}$. condition is fulfilled.

Motor,

$T_T = 526\,[Nmm] = 0.57\,[Nm]$.

Motor = Stepomotor.

Holding Torque = 945 [Nm] $> T_T$

Detent Torque = 39 [Nm] $> T_T$

So,

In the end.

The minimal required Dimensions for the arms,

I choose the arms in the slider form,

Used length,

$l = 375$ mm (slider rotation)

$b = 45$ (mm) (width).