CALCULATION OF THE TORQUE FOR MOTOR

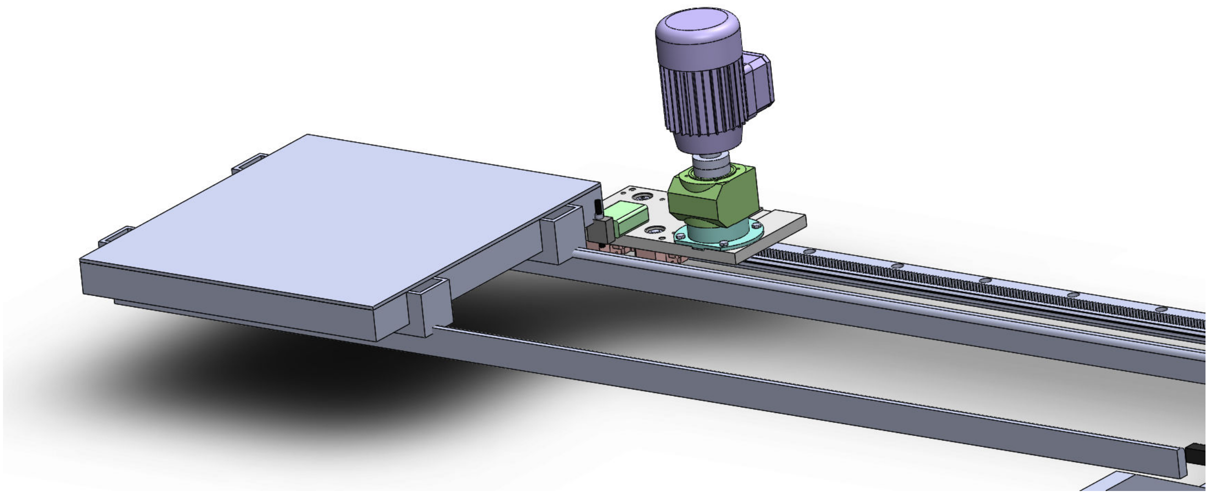


Figure 1: Assembly of rack and pinion

To find, a torque for Motor. We have to calculate all the torque individually.

So total torque:

TT = TL + Ts   ------------- Eq. no [1]

Where, TL = Load torque, Ts = Overall system torque

```
clc
clear variables;
```

```
%Pre defined values
stat_fric_coeff = 0.2;       % static friction coefficient of steel on steel with oil
Mass_Platform = 30;          % Total Mass of platfrom (Kg)
g = 9.81;                    % Gravitational Acc (m/s^2)
R = 0.16;                    % Perpendicular distace of cart from motor (m)
Ks = 1.0;                    % Safety Factor for motor torque
r = 0.078/2;                 % Radius of pinion (m)
```

---> So first, we will calculate for the load torque using force that is require to push a mold cart.

Load torque:

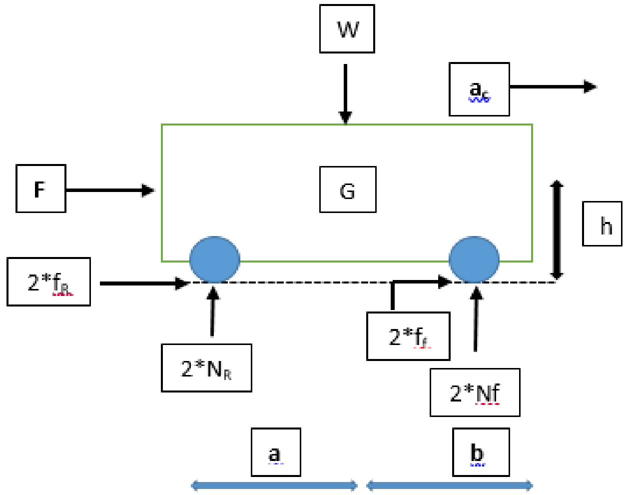


Figure 2: Force analysis of mold cart when it is in continuous motion or in steady state

Here, G = Centroid of mold cart, h = Distance of G from ground, a = Distance between G and rear wheel, b = Distance between G and front wheel, ac = Acceleration of cart, L = wheel base (i.e, L = a+b) and F = applied force

```
%Calculation of acceleration
Smax = 10;        % Total distance to cover (meter)
T = 20;           % Total time to cover Smax (sec)
t1 = 2;           % Acceleration Time (sec)
t2 = T-2;         % Deceleration Time (sec)

Vmax = (2*Smax)/(T+t2-t1)          % Max Velocity achieved while accelerating (m/s)
```

```
Vmax = 0.5556
```

```
Amax = Vmax/t1                     % Max Acceleration (m/s^2)
```

```
Amax = 0.2778
```

```
Omegamax = Vmax/r                  % Max Angular Velocity (rad/s)
```

```
Omegamax = 14.2450
```

```
Alphamax = Amax/r                  % Max Angular Acc (rad/s^2)
```

```
Alphamax = 7.1225
```

```
N = (Omegamax*60)/(2*pi)           % Speed of motor (RPM)
```

```
N = 136.0299
```

Mold Cart Force Analysis

```
% Given Data
Mass_Cart = 170;             % Mass of mold cart kg
slid_fric_coeff = 0.3;       % sliding friction coefficient
```

```
roll_fric_coeff = 0.002;    % Rolling Friction Coefficient
h = (3.05 + 3.5)/100;       % height of centre of gravity of cart from ground m
A = 18.15/100;              % distance of CoG from rear wheels meter
B = 18.15/100;              % distance of CoG from front wheels meter
Acc_cart = Amax;            % Max Acc of cart m/s^2
Dec_cart = -Amax;           % Max Dec of cart m/s^2
L = A + B;                  % Wheel Base meter
W = Mass_Cart*g;            % Weight of mold cart Newton
```

From the Force Body Diagram:

- On Rear side two wheels are there inline. Therefore, Normal forces is taken as [2*NR]
- Similarly, 2*Nf for front side

---> mac is inertia force and 2*fr & 2*ff is frictional force acting on rear and front side respectively.

So, if we balance force for Y- axis Ʃy = 0;

Finitial = 2 * µs * (NR + Nf) ---------- Eq. no [2]

When cart is stationary and steady speed that time acceleration will be zero and we are assuming that a sliding motion till acceleration is reached to Amax

Therefore, NR = (w*A) / (2*L)

```
% When Cart is stationary i.e. acceleration = 0
% Assuming Sliding motion till acceleration is reached to Amax
% Therefore, Force required to move cart is
Nor_Front = (W*A)/(2*L);
```

and Nf = (w*B) / (2*L)

```
Nor_Rear = (W*B)/(2*L);
```

From equation 2, Initial force will be:

Finitial = 2 * µs * ((w*A) / (2*L) + (w*B) / (2*L))

```
F_initial = (2*slid_fric_coeff*(Nor_Front + Nor_Rear))
```

```
F_initial = 500.3100
```

---> Now, Let's balance a moment ƩMp = 0;

-F*h – W*A + m*ac*h + 2*Nf*L = 0 --------- Eq. no [3]

ƩNF = (1 / 2*L) * (W*A - m*ac*h + F*h)

= (1 / 2*(A+B)) * (m*g*A - m*ac*h + F*h)

```
% When Cart is accelerating i.e acceleration is positive & equal to Amax
% Now considerng rolling friction
```

```
% Force required to continue motion is
Nor_Front = ((W*A) - (Mass_Cart*Acc_cart*h))/(2*L);
```

ΣNR = (1 / 2*L) * (W*B + m*ac*h + F*h)

= (1 / 2*(A+B)) * (m*g*B + m*ac*h + F*h)

```
Nor_Rear = ((W*B) + (Mass_Cart*Acc_cart*h))/(2*L);
```

---> when cart is accelerating ac is (+)ve. Therefore, NR will be greater and vice versa. Same is the case for frictional force.

If we balance a force for X - axis ΣFx = m*ac;

F + 2*fF + 2*fR = m*ac

F + 2* (fF + fR) = m*ac

F = m*ac – 2*fmax

And fmax = µR*N

So total force while cart is accelerating

ΣF = m*ac – 2* µR * [NF + NR] --------------- Eq. no [4]

```
F_acc = (Mass_Cart*Acc_cart) - (2*roll_fric_coeff*(Nor_Front + Nor_Rear))
```

```
F_acc = 43.8868
```

---> Now, we will calculate a torque for system

Ts = (Jm + Jl + Jpi)*Σmax ----------- Eq. no [5]

Where, Jm = Inertia of the Motor, Jl =Inertia of the load, and Jpi = Inertia of the pinion

Where, we are neglecting here a inertia of pinion.

For, rack and pinion system

x = rΣ--------- Eq. no [6]

where, r = radius of pinion, x = linear displacement travelled by platform, Σ= angular displacement of pinion

now, we will do differentiation of eq. no [7]

dx/dt = r * (dΣ/dt) ----------- Eq. no [8]

---> Then, we will balance both the energy,

Rotational kinetic energy = Translation kinetic energy

1/2 * J1 * (dΣdt)^2 = 1/2 * M * (dx/dt)^2

So, for Load Inertia,

Jl = m*r^2

= (mp + mm + ma) * r^2

where, m = total mass experiencing translational displacement x

mp = Mass of the platform

ma = Mass of the actuator

mm = Mass of the motor

```
%Inertia Calculation
%Assumption 1: Neglecting inertia of pinion

J = Mass_Platform*r*r;      % Inertia due to platform mass (kg.m^2)
```

Also, we are considering that motor inertia is 10:1 of platform inertia

So, Jm = 10*J1

```
Jm = J/10;                  % Inertia of the motor (kg.m^2)
```

So, From eq. [5] Total inerta:

```
Total_J = J + Jm            % Total Inertia (kg.m^2)
```

```
Total_J = 0.0502
```

---> Now, we will do torque calculation

So, Initial torque to push a cart = Tinitial = Finitial*R

```
% Torque Calculation

T_push_initial = F_initial*R                    % Torque required to push the cart (N.m
```

```
T_push_initial = 80.0496
```

and torque to push a cart while it in motion Tacc = Facc*R

```
T_push_acc = F_acc*R
```

```
T_push_acc = 7.0219
```

Total torque of the system:

Ts = TJ * Σmax

```
Ts = Total_J*Alphamax;                                    % Torque due to inertia of platform (N.
```

Torque for the platform

Tplatform= m * g * r * µs

```
T_platwt = stat_fric_coeff*Mass_Platform*g*r    % Torque required to move the platform
```

```
T_platwt = 2.2955
```

Now, we will find total initial torque

Ttotal-initial = Tinitial + Ts + Tplatform

```
% Total Torque (N.m)
total_T_initial = T_push_initial + Ts + T_platwt
```

```
total_T_initial = 82.7026
```

Now, we will find acceleration torque

Ttotal-acceleration= Tacc + Ts + Tplatform

```
total_T_acc = T_push_acc + Ts + T_platwt
```

```
total_T_acc = 9.6749
```

```

% Motor Torque (N.m)
Tm_initial = ceil(Ks*total_T_initial)
```

```
Tm_initial = 83
```

```
Tm_acc = ceil(Ks*total_T_acc)
```

```
Tm_acc = 10
```

```

disp ("Initial torque required to accelerate cart is "+Tm_initial+" N.m")
```

```
Initial torque required to accelerate cart is 83 N.m
```

```
disp ("Torque required to keep the cart in motion is "+Tm_acc+" N.m")
```

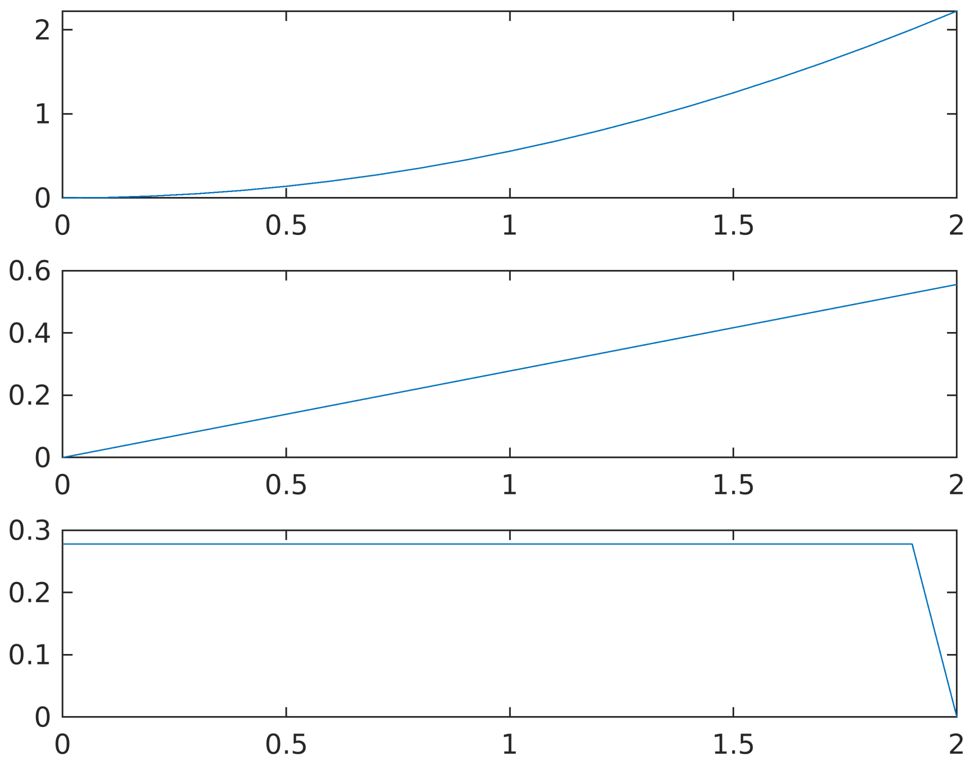
```
Torque required to keep the cart in motion is 10 N.m
```

--->Now, we will find a value of max from position, velocity and acceleration graph.

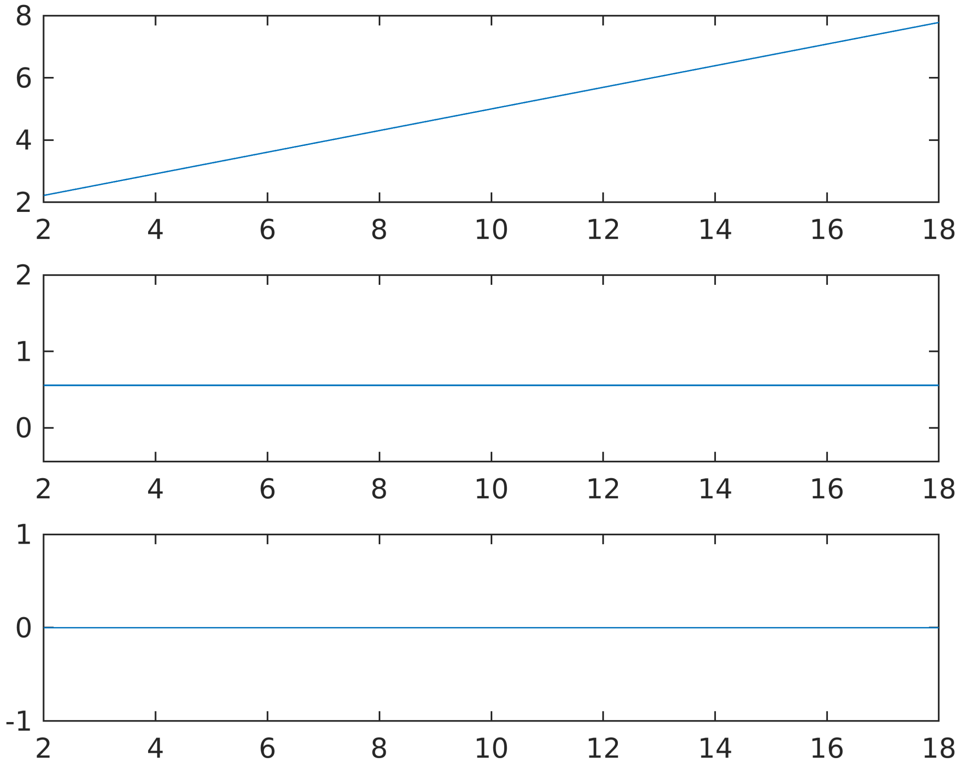
```
%Calculating S,V & A at each point

t = 0:0.1:T;          %Vector to store Time in seconds
L = length(t);
```

```
S = zeros(L);
V = zeros(L);
A = zeros(L);

for i=1:L

    if (t(i)<=t1)                      %Condition to calculate Velocity & Acc while motor
                                       %  accelerating

    V(i) = (Vmax/t1)*t(i);             %Using equation y = mx where y = velocity & x = tim
    S(i) = (Vmax/2*t1)*t(i)*t(i);      %By integrating Velocity Equation
    A(i) = Amax;                       %Acc is constant

    if (t(i)==(t1))
        s1 = S(i);
        i1 = i;
    end

    else
        if (t(i)>=t2)                          %Calculation during deceleration

            V(i) = (Vmax/(T-t2))*(T-t(i));
            S(i) = Smax + ((Vmax/2*(T-t2))*((-t(i)*t(i))+(2*T*t(i))-(T*T)));
            A(i) = -Amax;

            if (t(i)==t2)
                s2 = S(i);
                i2 = i;
            end
        end
    end
end


for i=1:L

    if ((t(i)>=t1)&&(t(i)<=t2))

        V(i) = Vmax;
        S(i) = s1 + (((s2-s1)/(t2-t1))*(t(i)-t1));
        A(i) = 0;
    end
end
```

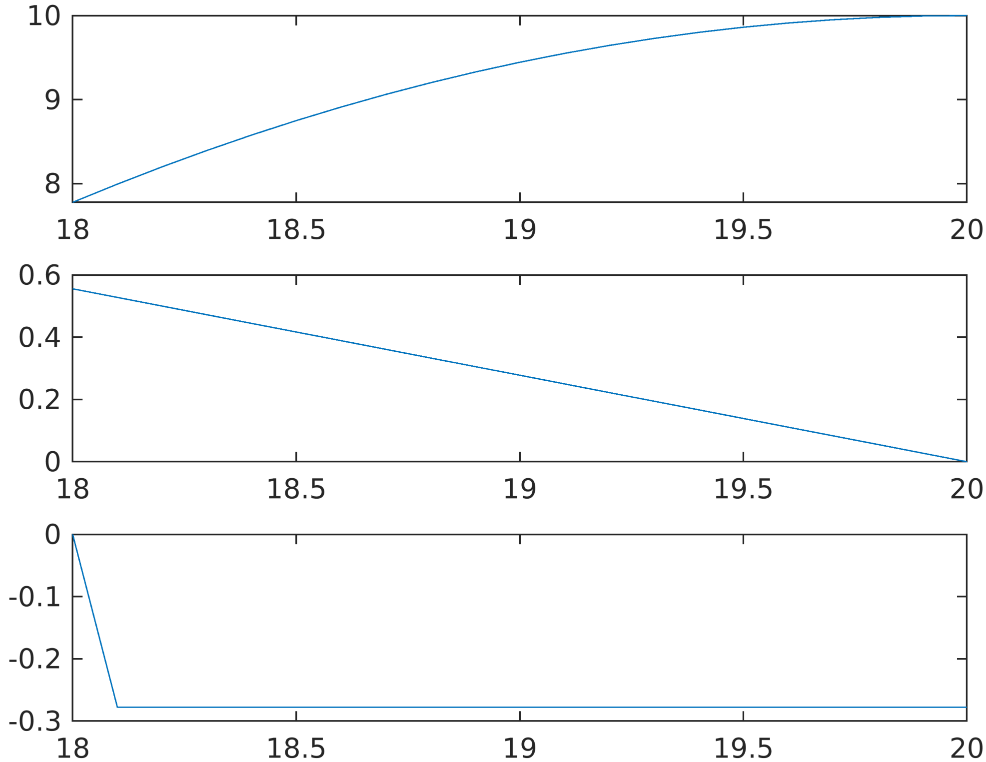
```
% Plot of S,V & A wrt time

figure;
subplot(3,1,1)
plot (t(1:i1),S(1:i1,1));
subplot(3,1,2)
plot (t(1:i1),V(1:i1,1));
subplot(3,1,3)
plot (t(1:i1),A(1:i1,1));
```




```
figure;
subplot(3,1,1)
plot (t(i1:i2),S(i1:i2,1));
subplot(3,1,2)
plot (t(i1:i2),V(i1:i2,1));
subplot(3,1,3)
plot (t(i1:i2),A(i1:i2,1));
```




```
figure;
subplot(3,1,1)
plot (t(i2:L),S(i2:L,1));
subplot(3,1,2)
plot (t(i2:L),V(i2:L,1));
subplot(3,1,3)
plot (t(i2:L),A(i2:L,1));
```


10
9
8
18
18.5
19
19.5
20
0.6
0.4
0.2
0
18
18.5
19
19.5
20
0
-0.1
-0.2
-0.3
18
18.5
19
19.5
20