Offset-Slider Crank Mechanism

(ME748 – Computer Aided Simulation of Machines)

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Section 1: Static Force Analysis

A force of 50N was applied on point A in the global negative-X direction. The four positions are as shown below for crank angles of 0°, 90°, 180° and 270°. The torque required on the input crank to maintain the mechanism in equilibrium in the four positions was estimated using ADAMS software.

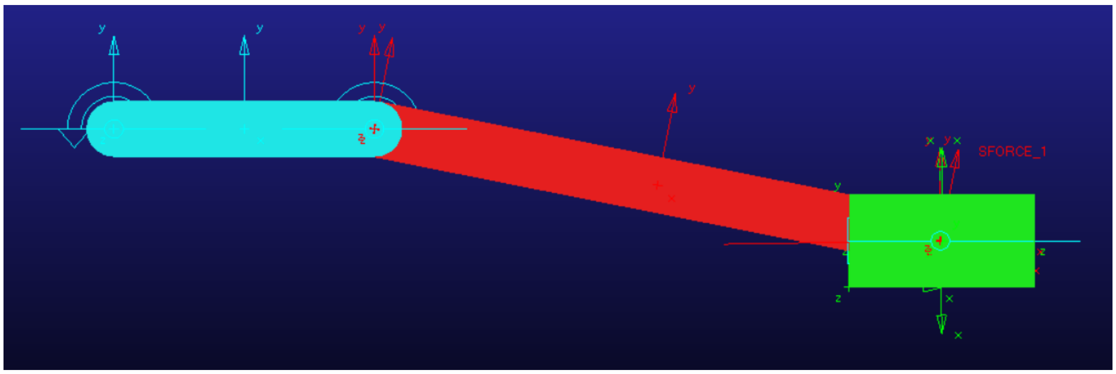

Figure 1:Static Force Analysis at 0°

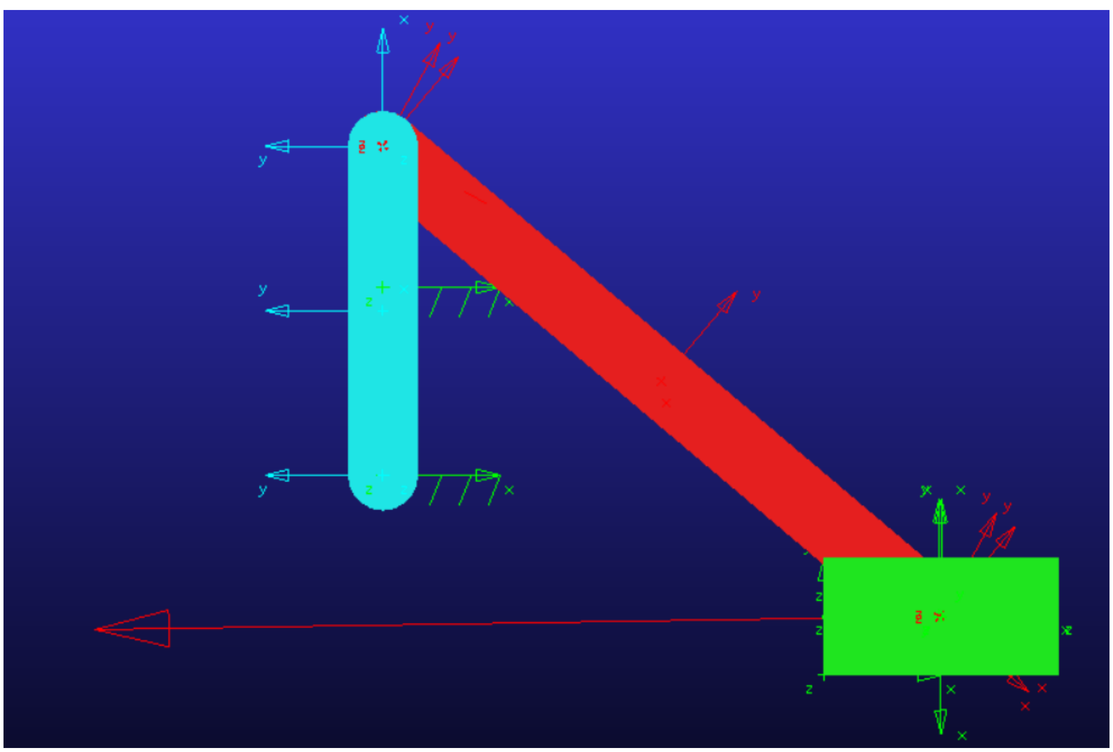

Figure 2:Static Force Analysis at 90°

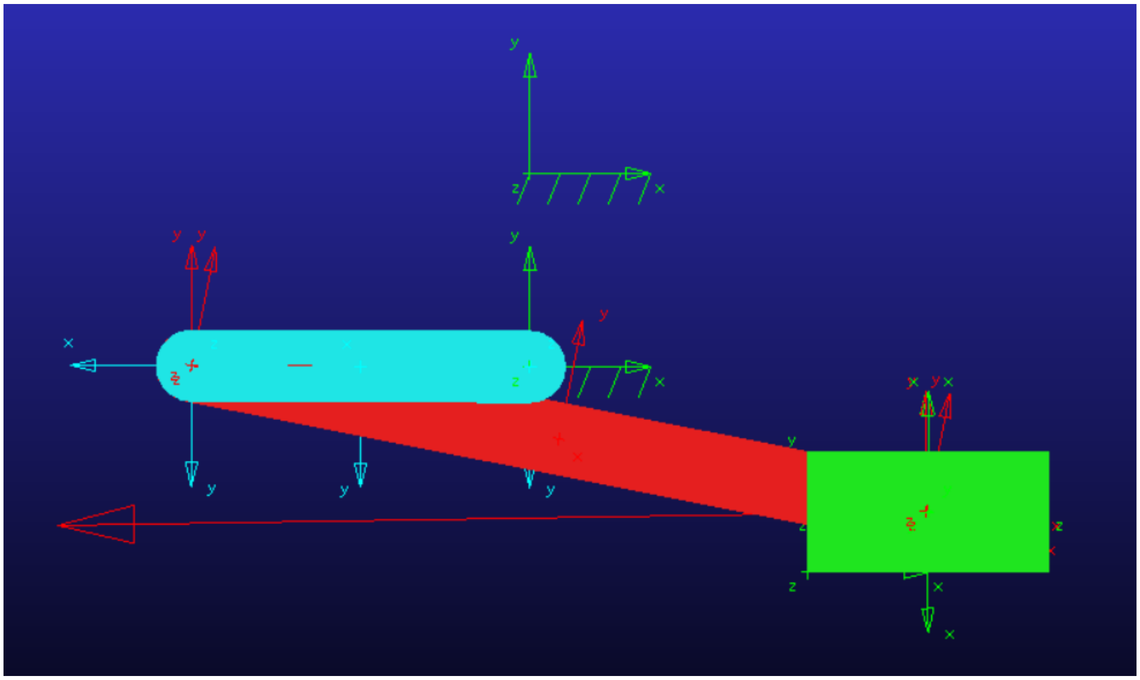

Figure 3:Static Force Analysis at 180°

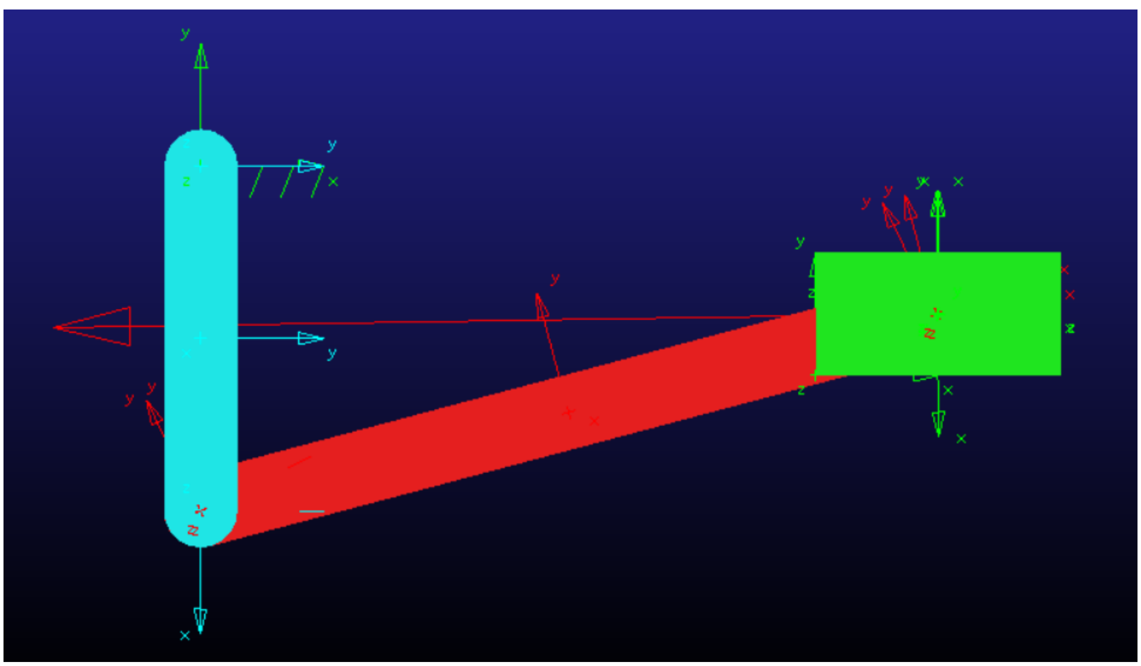

Figure 4:Static Force Analysis at 270°

The table below shows the torque required at input crank, Torque in an anti-clockwise sense is assumed positive.

Crank angle (°)	Torque on crank (N mm)
0°	-70.5
90°	-242.25
180°	75.54
270°	145.72

Section 2: Validation of Static Force Analysis

Crank position of 0° is analysed to validate the simulated result. The following assumptions were made

- The mechanism is analyzed as a frame whose links are bars with masses concentrated at their centers.
- All link lengths are in mm and Torque in N mm, anti - clockwise torque is positive.

Forces along X and Y directions and Moments along Z direction are balanced i.e.,

ΣFx = 0, ΣFy = 0, ΣMz = 0

Link 1 is considered as a frame.

For Link 2,

$$F_{12_x} + F_{32_x} = m_2 a_{G_{2x}}$$

$$F_{12_y} + F_{32_y} = m_2 a_{G_{2y}}$$

$$T_{12} + \left(R_{12_x} F_{12_y} - R_{12_y} F_{12_x}\right) + \left(R_{32_x} F_{32_y} - R_{32_y} F_{32_x}\right) = I_{G_2} \alpha_2$$

For Link 3,

$$F_{43_x} - F_{32_x} = m_3 a_{G_{3x}}$$

$$F_{43_y} - F_{32_y} = m_3 a_{G_{3y}}$$

$$\left(R_{43_x} F_{43_y} - R_{43_y} F_{43_x}\right) - \left(R_{23_x} F_{32_y} - R_{23_y} F_{32_x}\right) = I_{G_3} \alpha_3$$

For Link 4,

$$F_{14_x} - F_{43_x} + F_{P_x} = m_4 a_{G_{4x}}$$

$$F_{14_y} - F_{43_y} + F_{P_y} = m_4 a_{G_{4y}}$$

$$\left(R_{14_x} F_{14_y} - R_{14_y} F_{14_x}\right) - \left(R_{34_x} F_{43_y} - R_{34_y} F_{43_x}\right) + \left(R_{P_x} F_{P_y} - R_{P_y} F_{P_x}\right) = I_{G_4} \alpha_4$$

here, alpha_4 =0 and a_G4y is also zero. The third equation for link 4 is essentially 0=0 and is not needed.

$$\begin{bmatrix} 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 \\ -R_{12_y} & R_{12_x} & -R_{32_y} & R_{32_x} & 0 & 0 & 0 & 1 \\ 0 & 0 & -1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 0 & 1 & 0 & 0 \\ 0 & 0 & R_{23_y} & -R_{23_x} & -R_{43_y} & R_{43_x} & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 0 & \pm\mu & 0 \\ 0 & 0 & 0 & 0 & 0 & -1 & 1 & 0 \end{bmatrix} \times \begin{bmatrix} F_{12_x} \\ F_{12_y} \\ F_{32_x} \\ F_{32_y} \\ F_{43_x} \\ F_{43_y} \\ F_{14_y} \\ T_{12} \end{bmatrix} =$$

$$\begin{bmatrix} m_2 a_{G_{2_x}} \\ m_2 a_{G_{2_y}} \\ I_{G_2}\alpha_2 \\ m_3 a_{G_{3_x}} \\ m_3 a_{G_{3_y}} \\ I_{G_3}\alpha_3 \\ m_4 a_{G_{4_x}} - F_{P_x} \\ -F_{P_y} \end{bmatrix}$$

In these equations, we will take Fpy=0 as only force is acting in negative-X direction. Also, we are not considering friction in our case. So, the coefficient of friction is also zero.

We will solve the above system of equations using Matlab code. Please refer to the code below for the case with theta = 0. All the kinematic parameters(required) are generated from the Matlab code shared earlier in Term project 1.

Solving the equations in the form Ax = b, and computing x = A^(-1)b

```
%% Appropriate Link Dimensions and their Components
r = 0.14;
l= 0.31;
theta = 0;
R12x= r*cosd(theta)/2;
R12y= r*sind(theta)/2;
R32x= r*cosd(theta)/2;
R32y= r*sind(theta)/2;
R23x= l*cosd(11.1599368)/2;
R23y= l*sind(11.1599368)/2;
R43x= R23x;
R43y= R23y;
Fpx = 50;
```

```
%% Masses of all links
m2 = 0.7637;
m3 = 1.559464;
m4 = 1.95025;
```

```
%% Moment of inertias
IG2 = 80.6 *10^(-06);
IG3 = 166.8085 *10^(-06);
```

```
%% Angular accelerations
alpha2 = 76.663;
alpha3 = 35.29055;
```

```
%% Linear accelerations
aG2x= 0;
aG2y= 5.3665;
aG3x= 1.05855;
```

```
aG3y= 5.3665;

aG4x= 0;
```

```
syms F12x F12y F32x F32y F43x F43y F14y T12
```

```
A = [1  0  1  0  0  0  0  0;
    0  1  0  1  0  0  0  0;
-R12y R12x -R32y -R32x  0  0  0  1;
    0  0  -1  0  1  0  0  0;
    0  0  0  -1  0  1  0  0;
    0  0  R23y -R23x -R43y R43x  0  0;
    0  0  0  0  -1  0  0  0;
    0  0  0  0  0  -1  1  0];
```

```
x = [F12x F12y F32x F32y F43x F43y F14y T12]';
```

```
B= [m2*aG2x m2*aG2y IG2*alpha2 m3*aG3x m3*aG3y IG3*alpha3 m4*aG4x-Fpx
0]';
```

```
x = pinv(A)*B
```

here, all the forces are in N and Torque is in Nm.

Variables	***Values***
F_{12x}	-48.3136
F_{12y}	7.1431
F_{32x}	-48.3136
F_{32y}	-3.0447
F_{43x}	50.00
F_{43y}	5.1434
F_{14x}	5.1434
T_{12}	-0.07070

The torque required to maintain the mechanism in equilibrium in the first position, analytically obtained is 70.70 N mm, which is similar to torque of 70.5 N mm estimated through simulation.

Section 3: Dynamic Motion Analysis

For this section, a torque of 250 N mm was applied on the crank AB to get the required percentage increment in the velocity.

Velocity and acceleration plots of output A are plotted for both 250 and 500 N mm and simulation time is 2.25 s.

Section 3.1: Constant Driving Torque

Section 3.1.1: Plots for 250 N mm torque

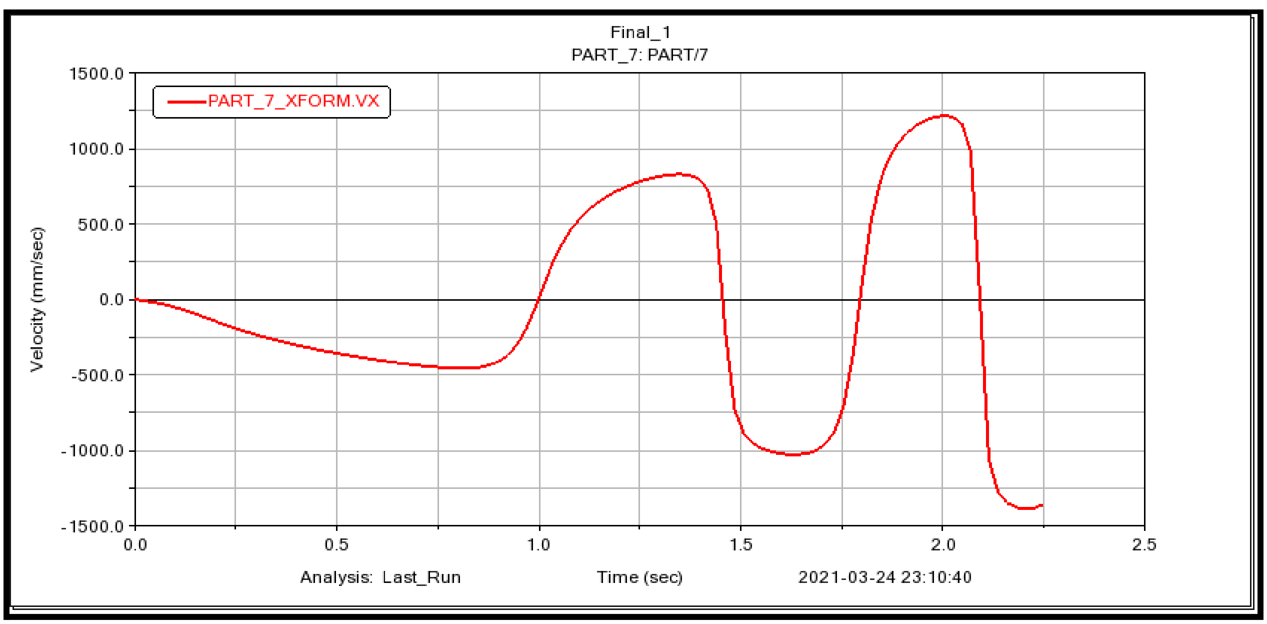

Figure 5: X-Direction Velocity of Output (Slider D)

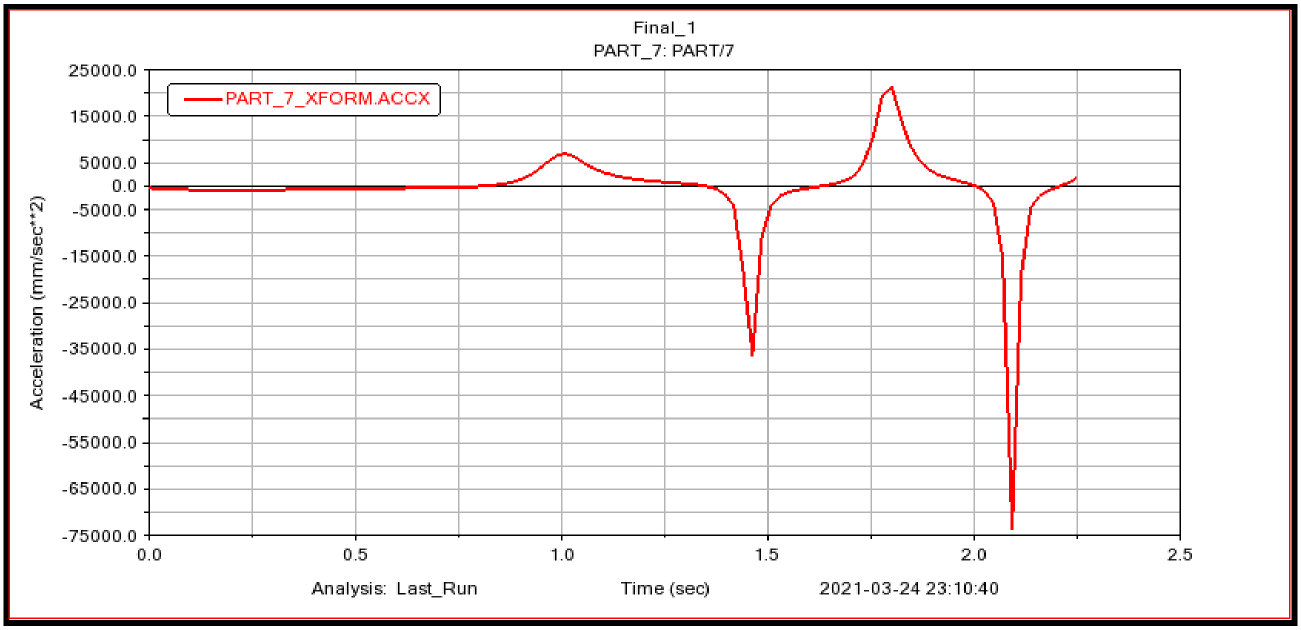

Figure 6: X-Direction Acceleration of Output (Slider D)

Section 3.2.2: Doubled Constant Torque

(Here, blue indicates plot for 500 N mm)

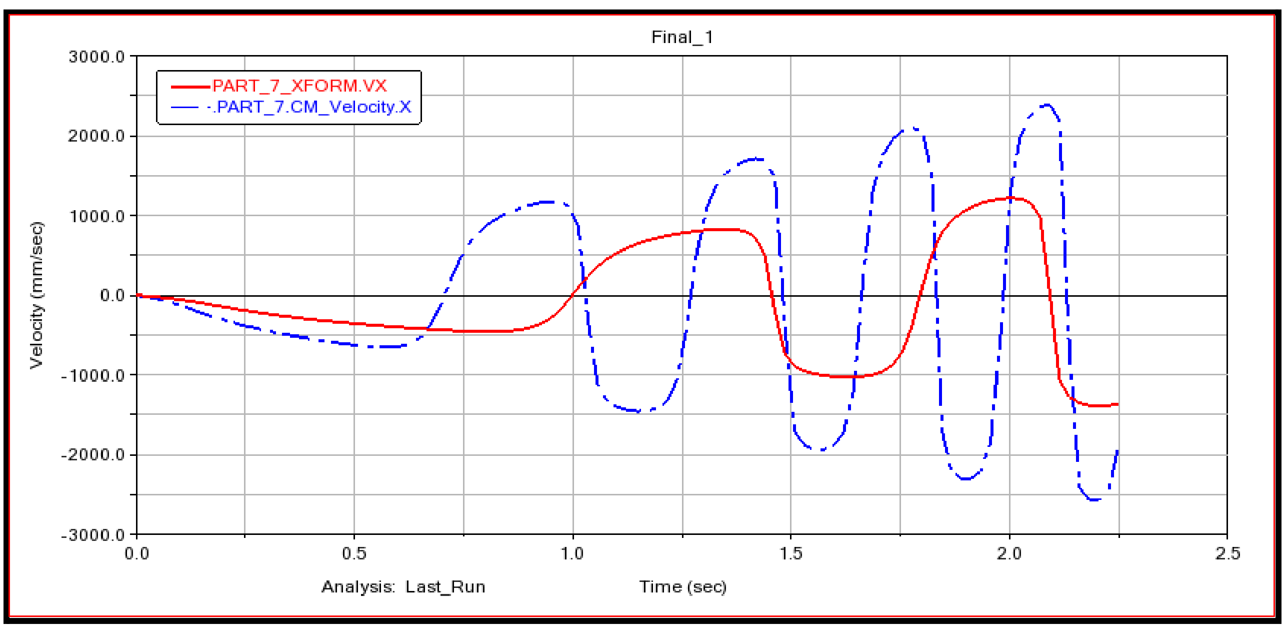

Figure 7: X-Direction Velocity of Output (Slider D)

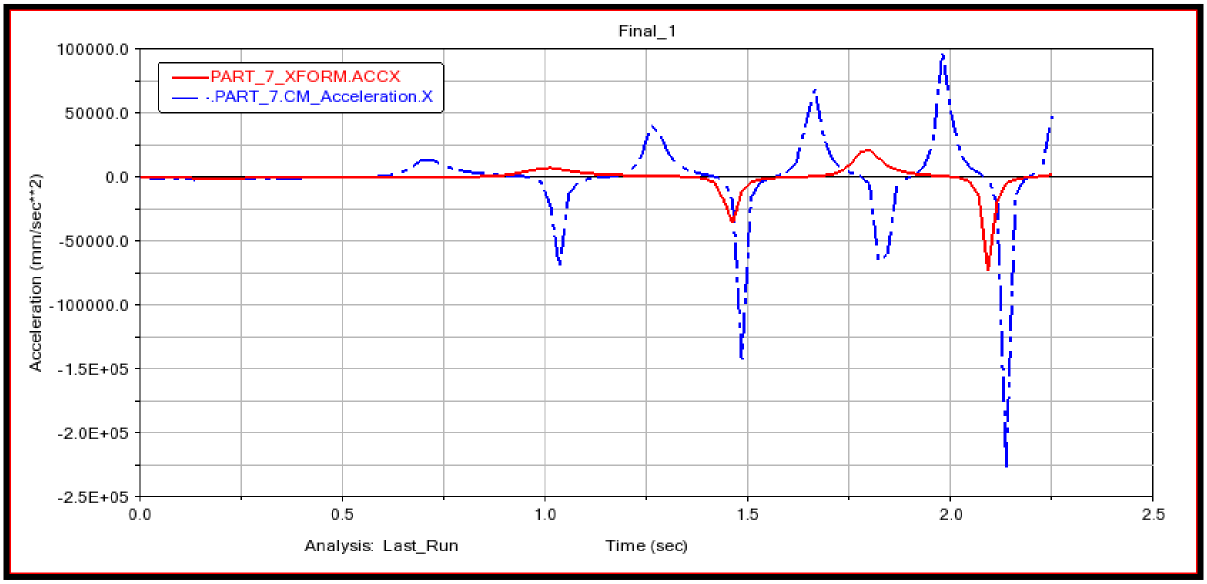

Figure 8: X-Direction Acceleration of Output (Slider D)

Section 3.1: Constant Driving Torque

The sinusoidal torque function is defined as T = 350 * (1 - cos (30t)). This gives an amplitude of 350 (1.4 times 250) and the minimum value of zero at t = 0. Simulation time is 2.0 s.

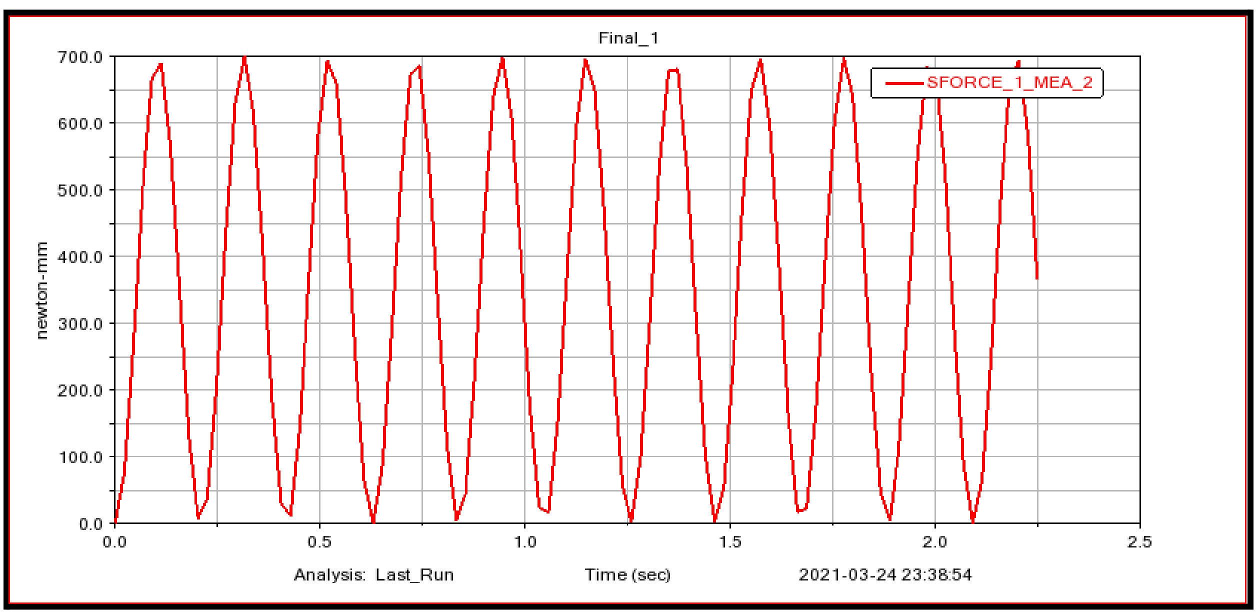

Figure 9: Sinusoidal Torque on input crank

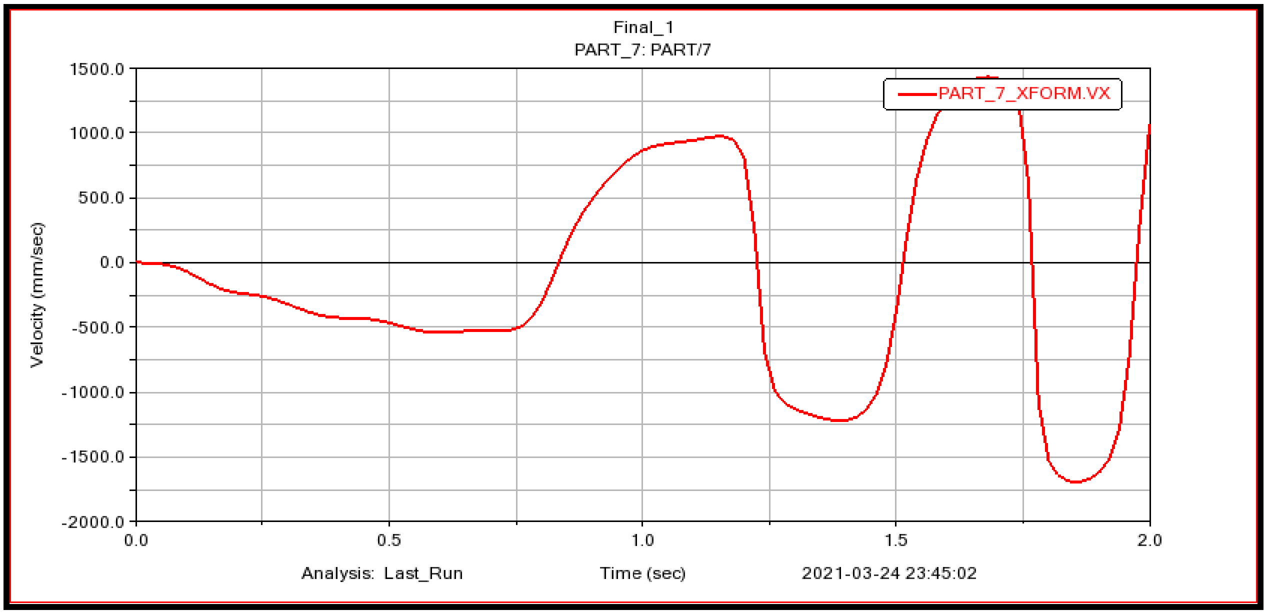

Figure 10: X-Direction Velocity of Output (Slider D)

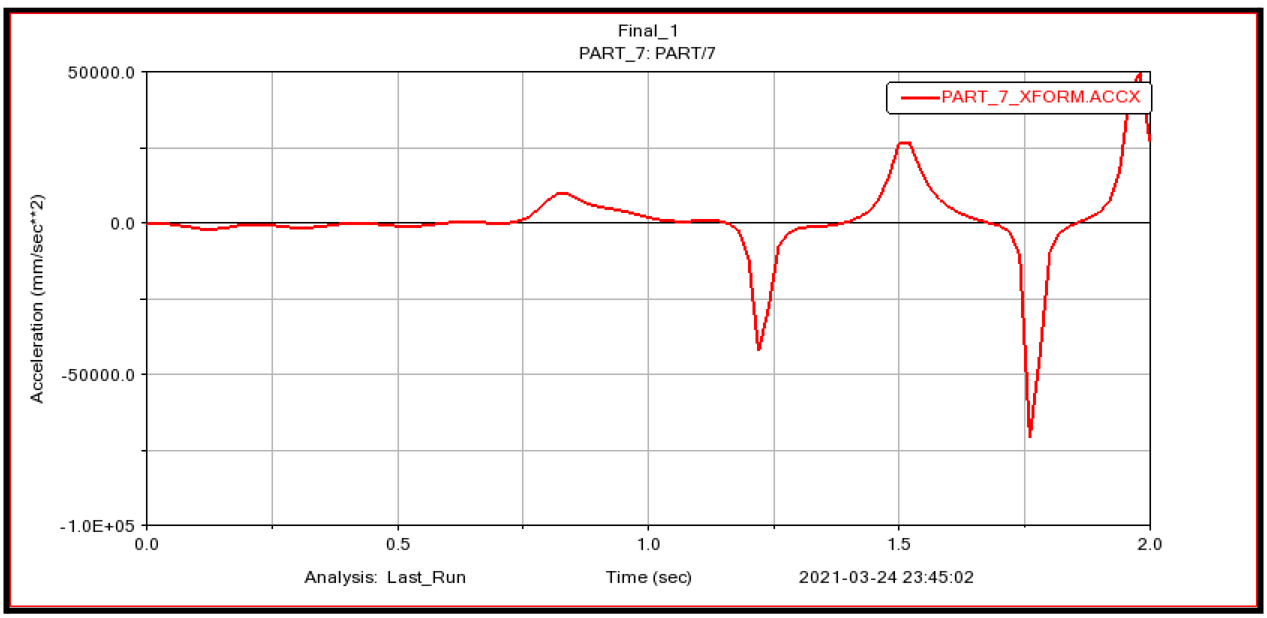

Figure 11: X-Direction Acceleration of Output (Slider D)