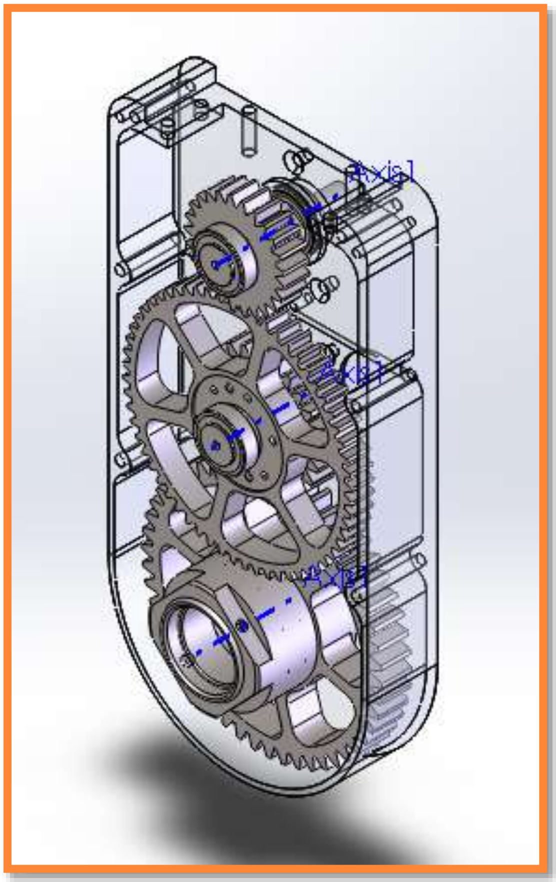
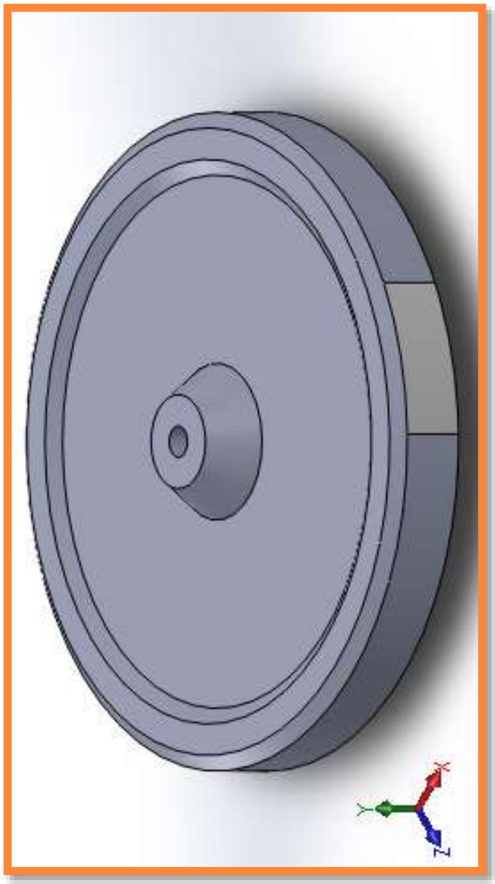
SOLIDWORKS MOTION STUDY ANALYSIS REPORT





Name: Wilson Lam

April 28, 2013

TABLE OF CONTENTS

List of Figures

List of Tables

Objective

In this lab we used motion study to test the four bar linkage, flywheel, and compound gears. In these testes we will be measuring applying a motor to certain joints or gear to power them a various angular speed. When doing this we also apply friction at time and measure the torque and power output by the motor. By completing these analyses we will become knowledgeable in motion analysis using Solidworks.

Four Bar Linkage Motion Analysis

In this Motion Analysis we are going to be using the Solidworks model as illustrated below to perform the analysis. This four bar linkage is assumed to be driven at one end. Torque is also applied to the other side. Friction and gravity is also going to be present during the run for the motion analysis.

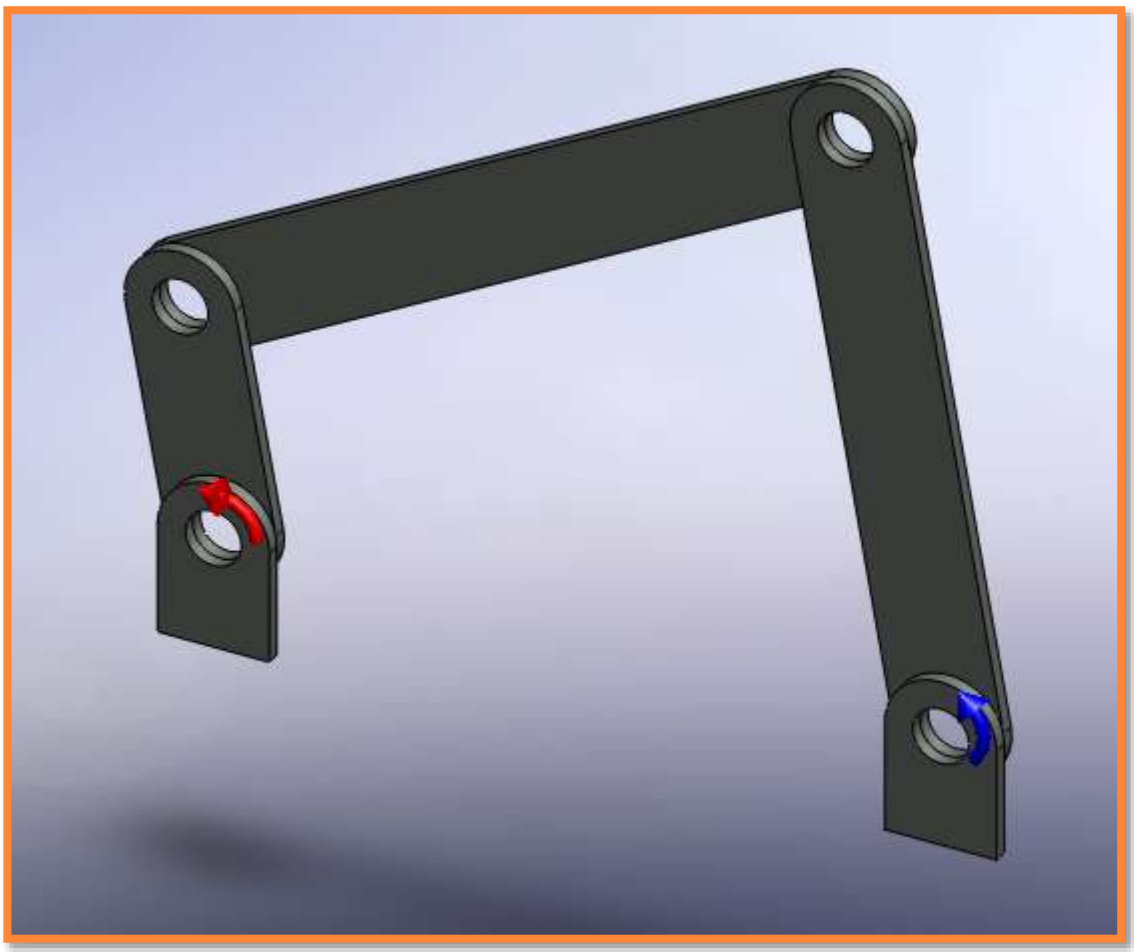


Figure 1: Solidworks Flywheel Model used in FEM analysis. (Fixtures shown in enlarged image.)

Assumptions

To begin the FEA we first have to make certain assumptions about the type of motion. We assume the motor applies the torque (red) at one joint with friction and torque (blue) present on the other side.

Exercise 2.1

Table 1: Four bar linkage assumptions for motion analysis exercise 2.1.

Analysis type	Motion Analysis
Material type	Pure Lead
Gravity	9806.65 mm/s^2
Motor Speed	100 RPM

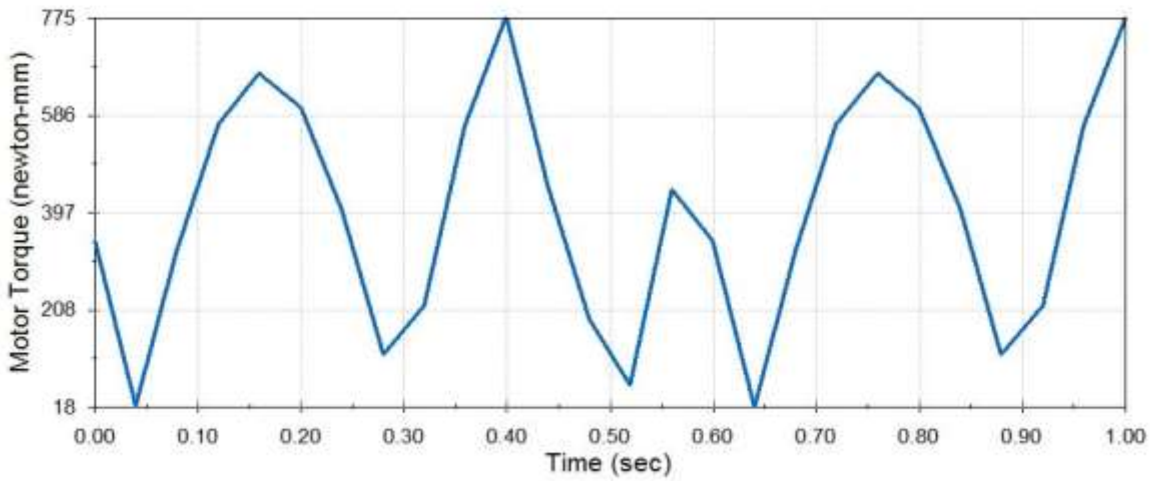


Figure 2: Motor torque graph for exercise 2.1

Exercise 2.2

Table 2: Four bar linkage assumptions for motion analysis exercise 2.2.

Analysis type	Motion Analysis
Material type	Pure Lead
Gravity	9806.65 mm/s^2
Motor Speed	100 RPM
Friction	Dry Steel

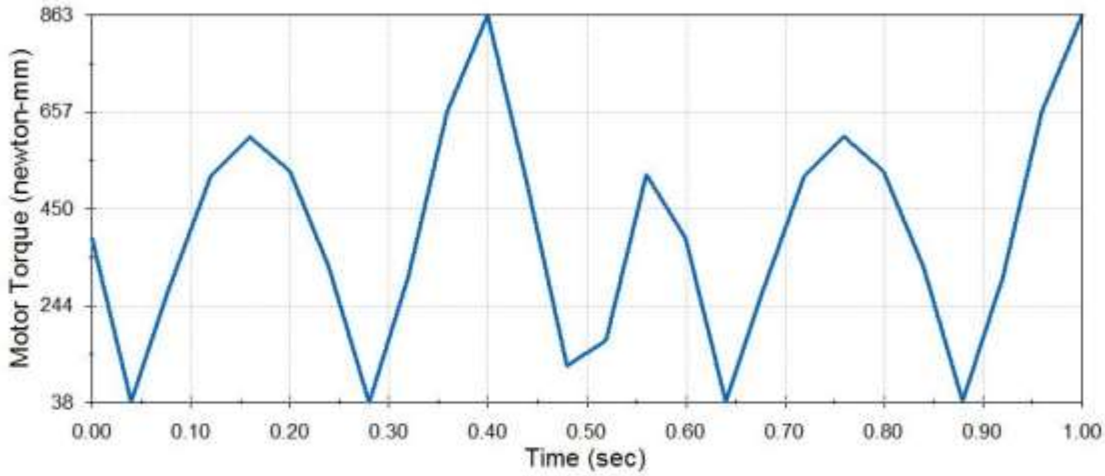


Figure 3: Motor torque graph for exercise 2.2

Exercise 2.3

Table 3: Four bar linkage assumptions for motion analysis exercise 2.3.

Analysis type	Motion Analysis
Material type	Pure Lead
Gravity	9806.65 mm/s^2
Motor Speed	100 RPM
Friction	Dry Steel
External torque	1000 N-mm

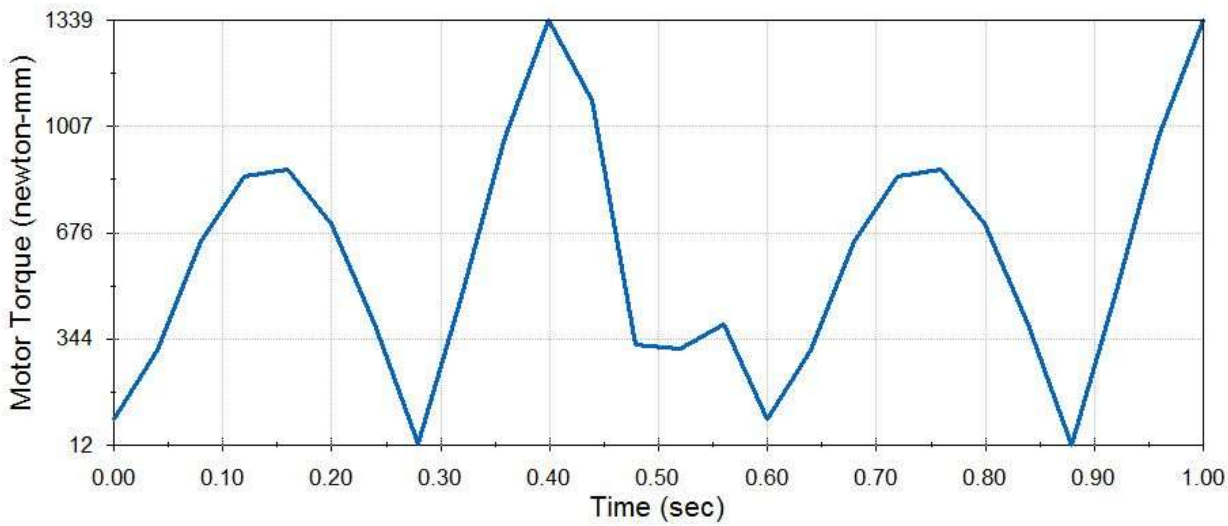


Figure 4: Motor torque graph for exercise 2.3

Exercise 2.4

Table 4: Four bar linkage assumptions for motion analysis exercise 2.4.

Analysis type	Motion Analysis
Material type	Pure Lead
Gravity	9806.65 mm/s^2
Friction	Dry Steel
External torque	1000 N-mm

Below is the the data point value for the following 4 bar linkage motor driven in various deg/s.

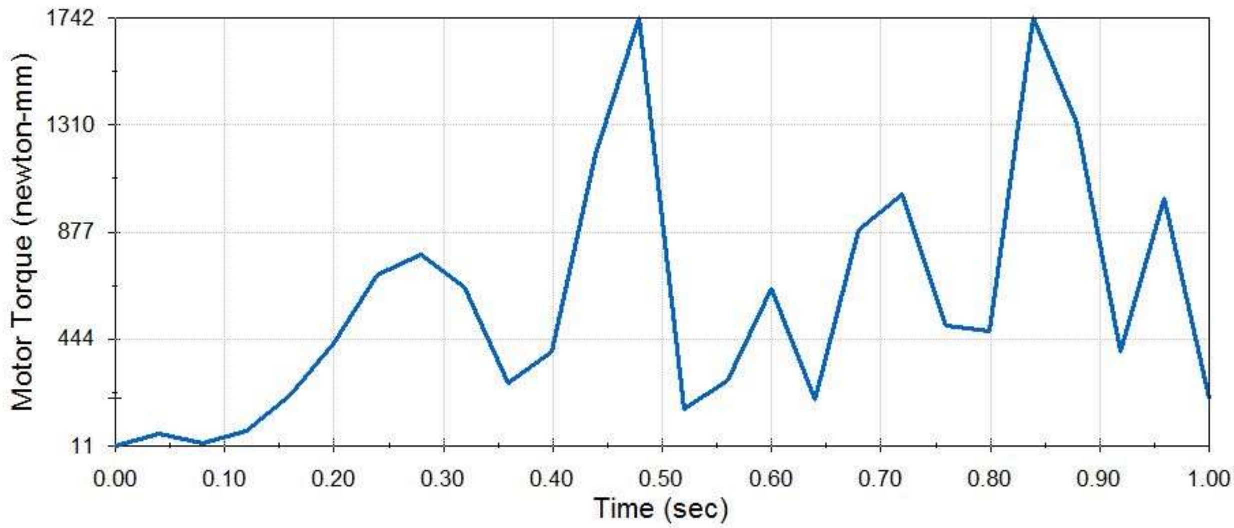


Figure 5: Motor torque graph for exercise 2.4

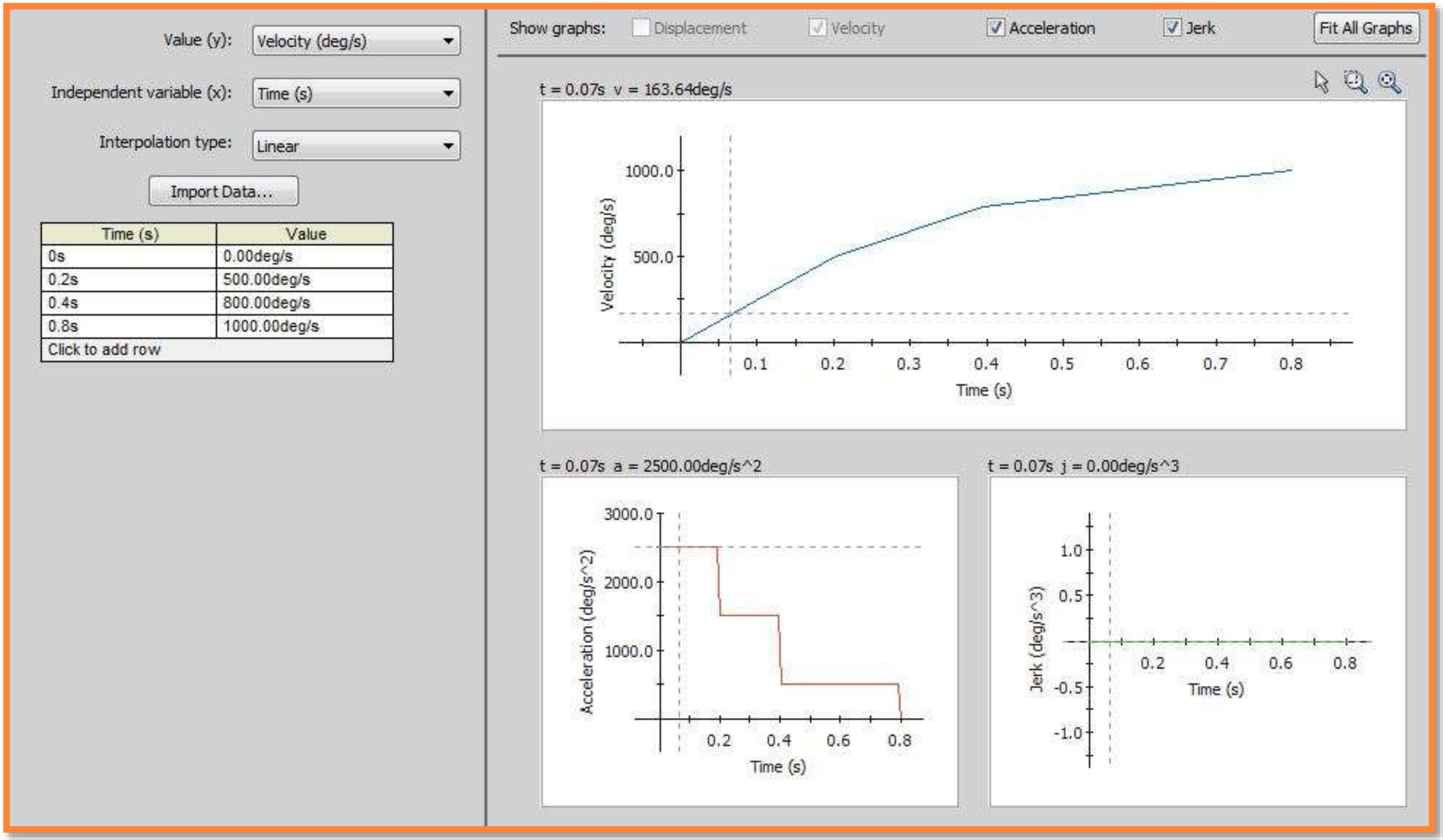


Figure 6: Motor torque angular speed (given as data point), acceleration, and jerk graph for exercise 2.4.

Flywheel Motion Analysis

In this Finite Element Analysis (FEA) we are going to be using the Solidworks model as illustrated below to perform the analysis. In this lab we assumed the flywheel is made of pure lead and goes through an angular acceleration to a certain angular velocity.

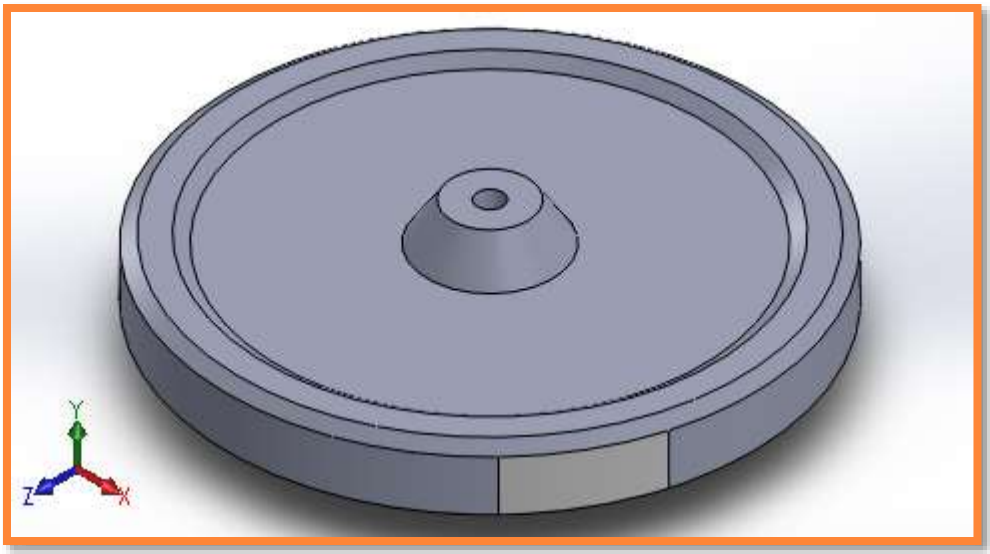


Figure 7: Flywheel Model used in motion analysis.

Assumptions

To begin the motion analysis we first have to make certain assumptions about the type of motion analysis we are going to add to the flywheel.

Table 5: Flywheel assumptions for motion analysis.

Material type	Pure Lead
Acceleration	0 to 1000 RPM
Max Angular Velocity (after)	100 revolutions

Using these equations:

$\omega_f^2 = \omega_o^2 + 2\alpha\theta$ [eq. 1]

$\omega_f = \omega_o + \alpha t$ [eq. 2]

$T = I\alpha$ [eq. 3]

$P = T\omega$ [eq. 4]

I was able to find the following:

- Moment of inertia $\boxed{I = 0.048\ kg * m^2}$
- Angular velocity $\boxed{\omega_f = 33.3\pi \text{ rad/s}}$ or $\boxed{\omega_f = 6000\ deg/s}$
- Degree and radians to reach ω_f $\boxed{\text{Degrees: } 36000°}$ and $\boxed{\text{Radians: } 200\,\pi}$
- Angular acceleration calculated from eq. 2. $\boxed{\alpha = 8.725 \frac{rad}{s^2}}$
- Required torque calculated from eq. 3. $\boxed{T = 0.4194\ N * m}$

- Required power calculated from eq. 4. $\boxed{P = 43.92\ W}$

Base on the values we calculated above for torque and power they match with the graphs below. The moment of inertia is taken from the solidworks model as well.

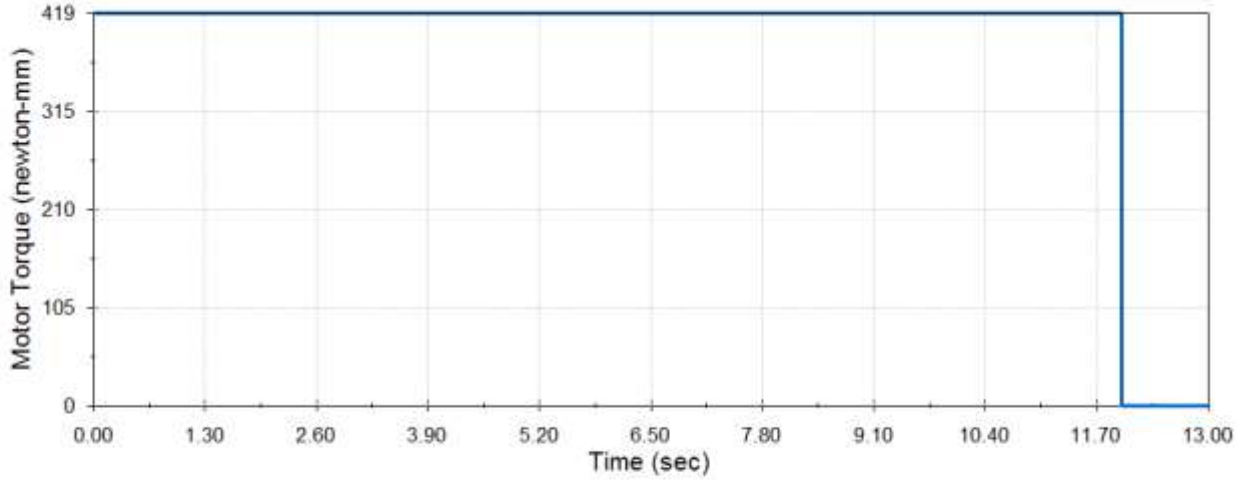


Figure 8: Flywheel torque graph vs. time.

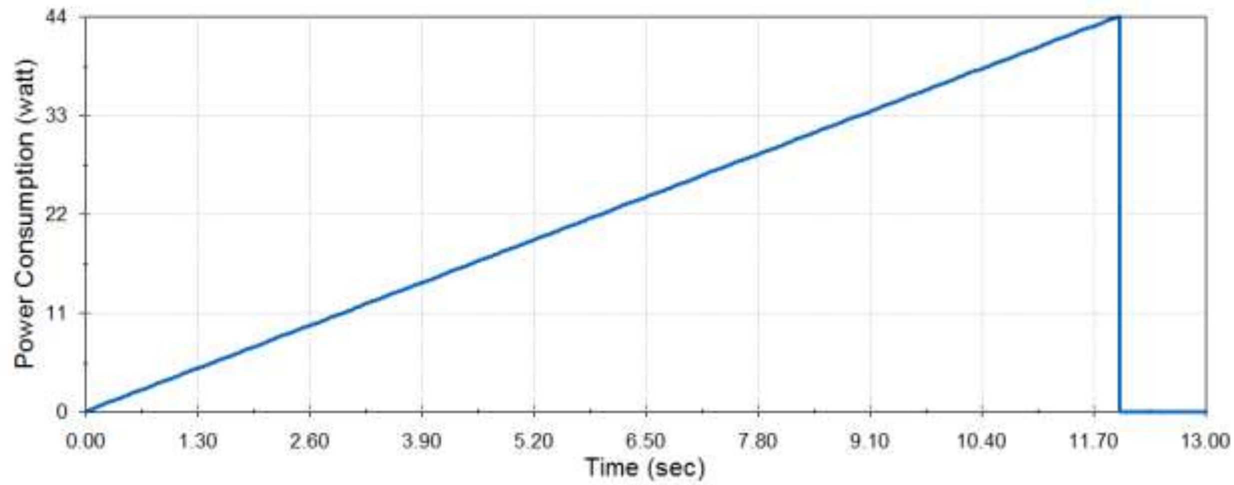


Figure 9: Flywheel power graph vs. time.

Mass properties of Flywheel (Assembly Configuration - Default)

Output coordinate System: -- default --

Mass = 8656.66 grams

Volume = 786968.96 cubic millimeters

Surface area = 88307.82 square millimeters

Center of mass: (millimeters)
X = 0.00
Y = 0.00
Z = 0.00

Principal axes of inertia and principal moments of inertia: (grams * square millimeters)
Taken at the center of mass.

Ix = (0.00, 0.00, 1.00)	Px = 24483957.02
Iy = (1.00, 0.00, 0.00)	Py = 24483957.02
Iz = (0.00, 1.00, 0.00)	Pz = 48064498.35

Moments of inertia: (grams * square millimeters)
Taken at the center of mass and aligned with the output coordinate system.

Lxx = 24483957.02	Lxy = 0.00	Lxz = 0.00
Lyx = 0.00	Lyy = 48064498.35	Lyz = 0.00
Lzx = 0.00	Lzy = 0.00	Lzz = 24483957.02

Moments of inertia: (grams * square millimeters)
Taken at the output coordinate system.

Ixx = 24483957.02	Ixy = 0.00	Ixz = 0.00
Iyx = 0.00	Iyy = 48064498.35	Iyz = 0.00
Izx = 0.00	Izy = 0.00	Izz = 24483957.02

Figure 10: Flywheel mass properties and moment of inertia.

Compound Gear Motion Analysis

To begin the motion analysis we first have to make certain assumptions about motion and friction within the compound gear. We will be using the motion analysis to obtain the graph for the torque and power.

Assumptions

In our motion analysis we will assume friction on gear in some of out testes. Using this motion analysis data we can better understand the effect of friction on the gears and compare it with the scenario without friction.

- Angular velocity $\boxed{\omega_f = 33.3\pi \text{ rad/s}}$
- Degree and radians to reach ω_f $\boxed{\text{Degrees: } 36000°}$ and $\boxed{\text{Radians: } 200\,\pi}$
- Angular acceleration calculated from eq. 2. $\boxed{\alpha = 8.725 \frac{rad}{s^2}}$

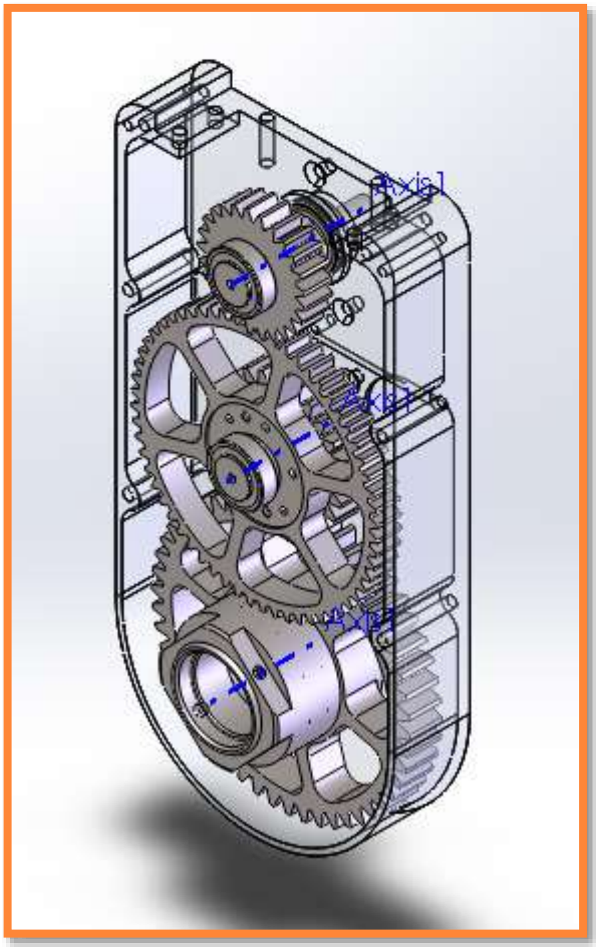


Figure 11: Compound gears used for the motion analysis.

Table 6: Compound gears assumptions for motion analysis.

Analysis type	Motion Analysis
Material type	Housing Al2014 – Gears 4130 Steel

Acceleration	0 to 1000 RPM
Max Angular Velocity (after)	100 revolutions
Exercise 4.2 (torque)	1000 N-mm
Exercise 4.3 (friction)	Dry Steel (gear mates - concentric)

Table 7: Compound gears angular velocity data points (exercise 4.1).

Time (s)	Angular Velocity (deg/s)
0	0
12	6000
15	6000

Exercise 4.1

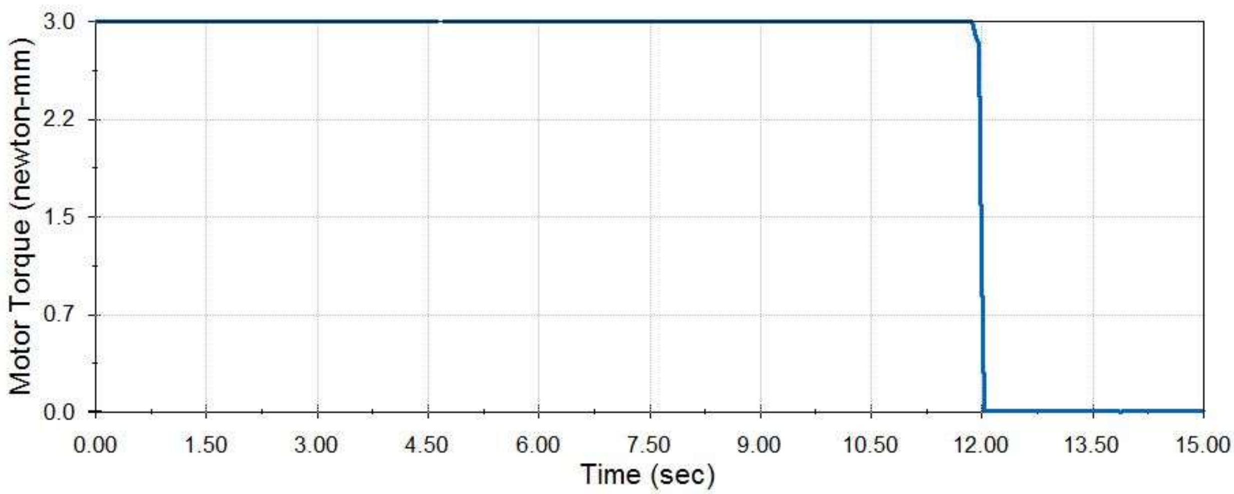


Figure 12: Compound gears torque vs. time.

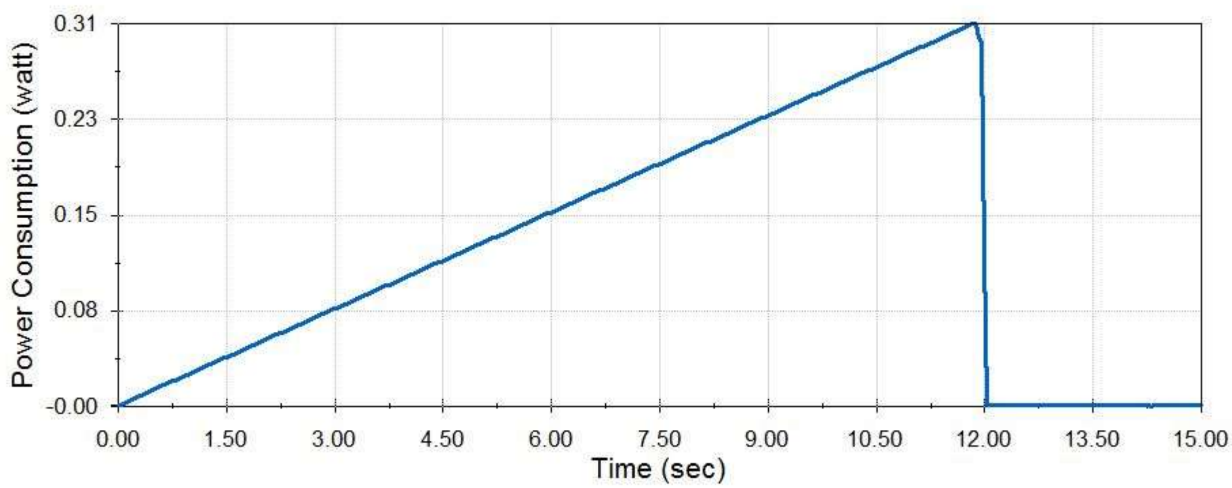


Figure 13: Compound gears power vs. time.

Exercise 4.2

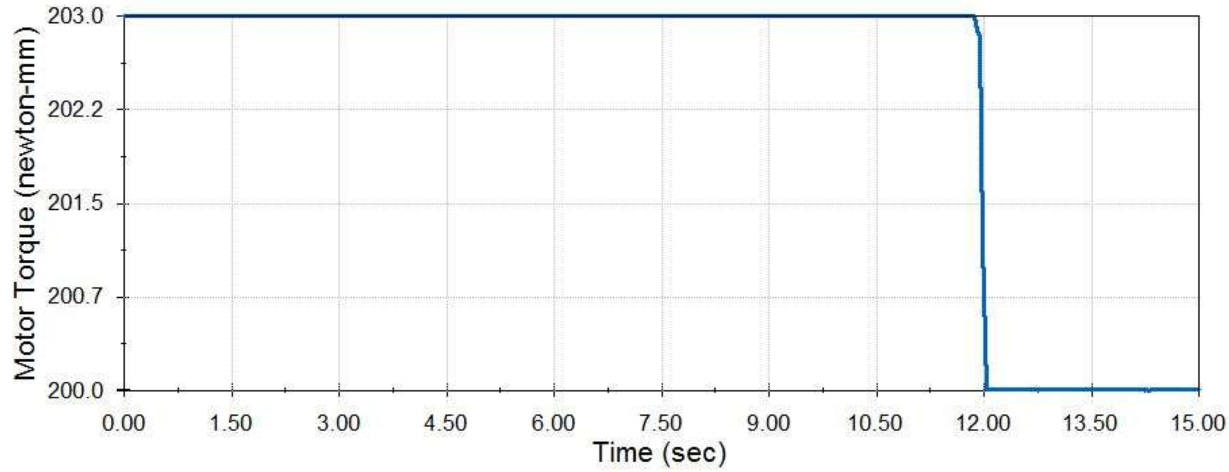


Figure 14: Compound gears torque vs. time with torque.

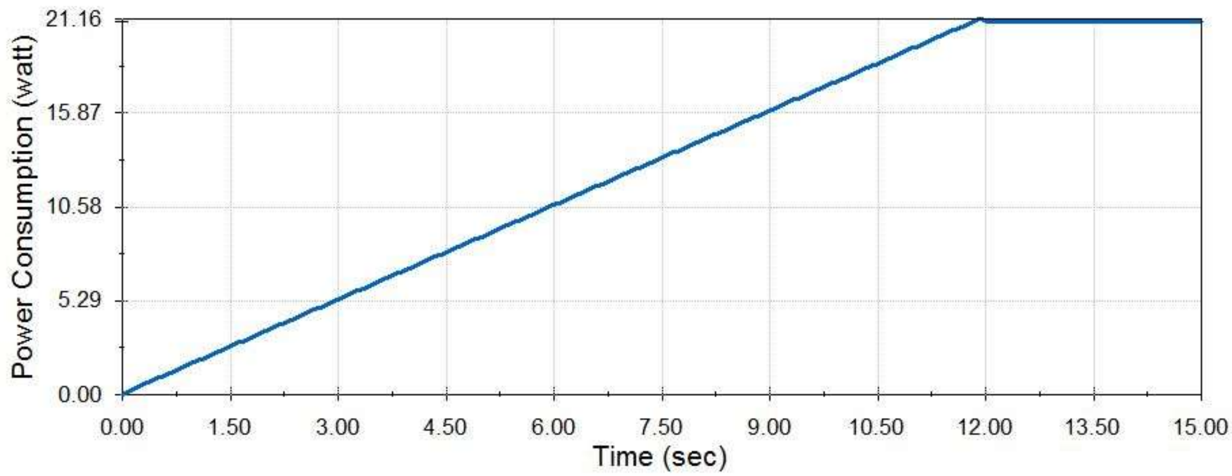


Figure 15: Compound gears power vs. time with torque.

Exercise 4.3

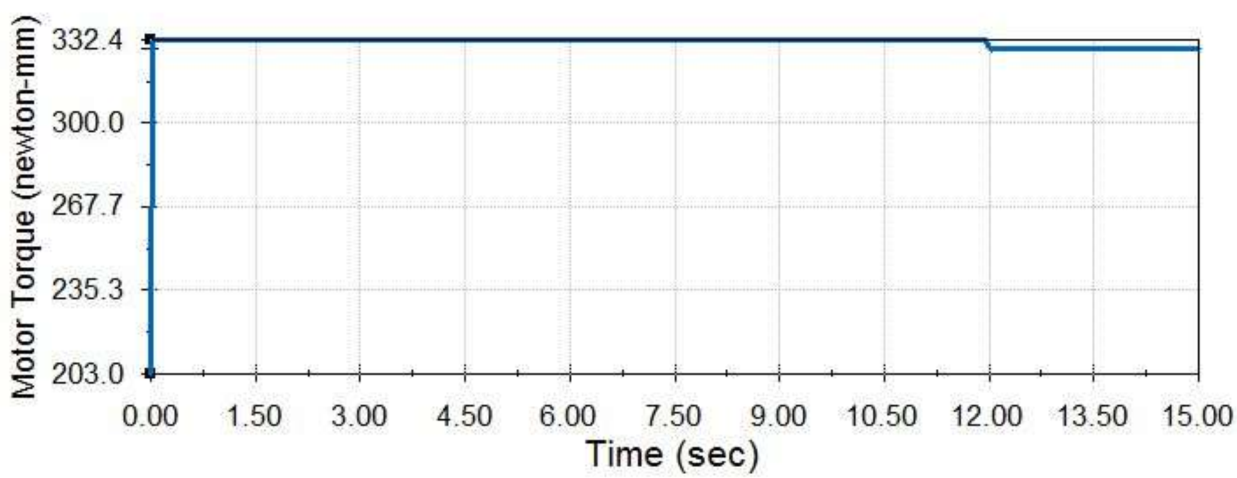


Figure 16: Compound gears torque vs. time with torque and friction.

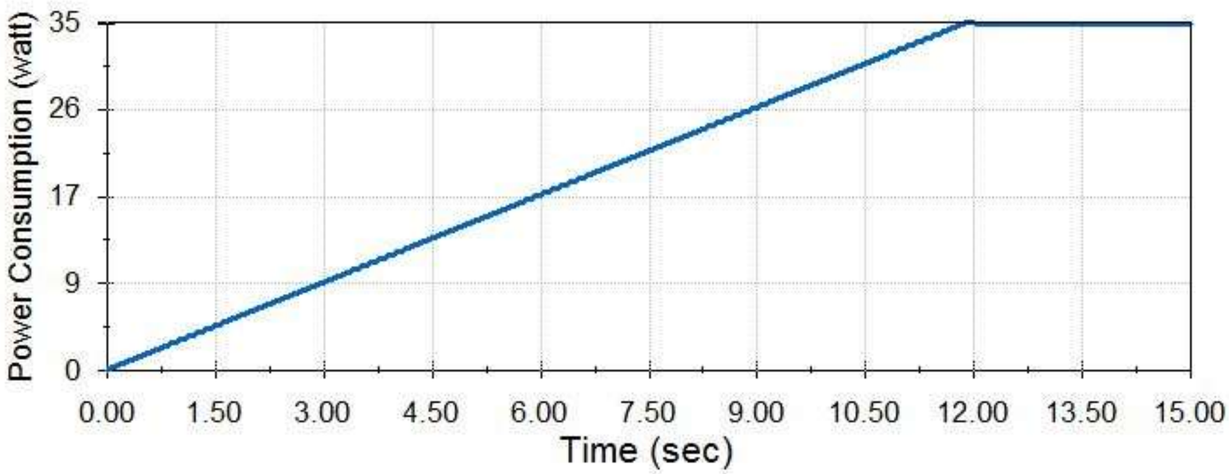


Figure 17: Compound gears power vs. time with torque and friction.

From the graphs we can see that once we added torque the graph jumped to 203 N*mm when accelerating and to 200N*mm once the acceleration stops. Applying a constant friction to the gears there is a 129.4N*mm increase in torque on top of the ex. 4.2. The power comes out to what we expect to occur. Power goes to zeros after 12 sec because torque is not applied for ex. 4.1. In the same way ex 4.2 and 4.3 makes logical sense as well since torque and friction are there constant power must be applied to keep the compound gears spinning. As we expect there is constant power.