Machine Design Project

EDPT903

T-02

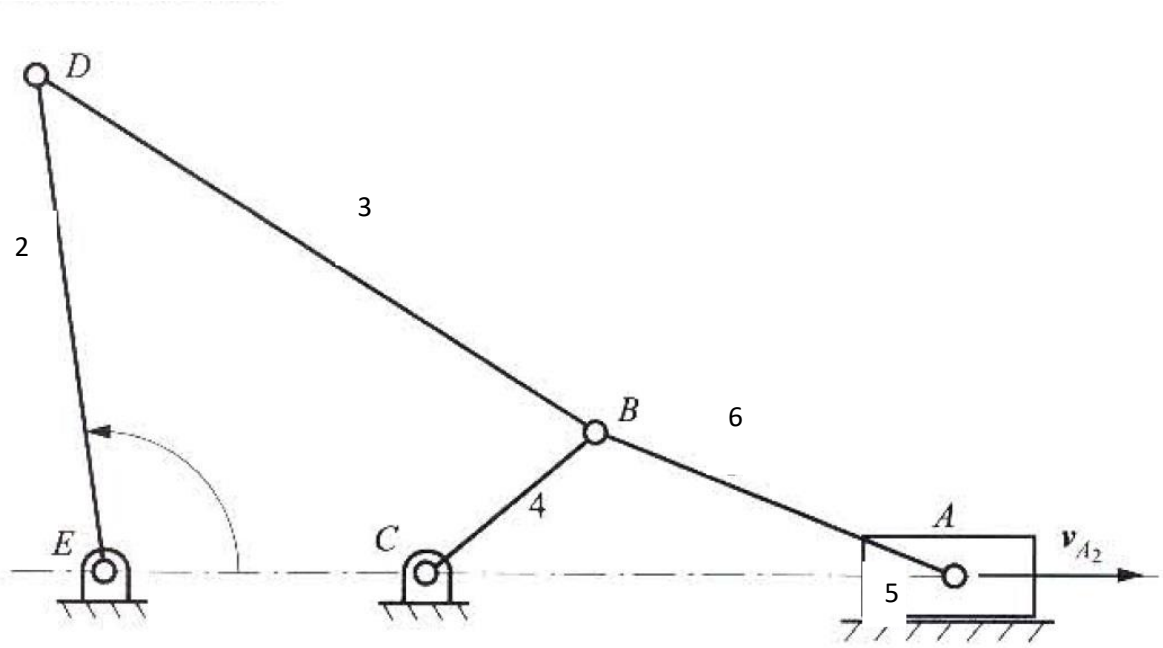
Ahmed Khaled Mady

Marwan Sallam

Youssef Almahdi

Ahmed Hossam Eldin

1. Mechanism



2. Loop Closure Equation 1

Position: $r_2 + r_3 = r_1 + r_4$

$$x:\ r_2 cos\theta_2 + r_3 cos\theta_3 = r_1 + r_4 cos\theta_4$$
$$y:\ r_2 sin\theta_2 + r_3 sin\theta_3 = r_4 sin\theta_4$$

$Velocity$:

$$x: -r_2 sin\theta_2 \omega_2 - r_3 sin\theta_3 \omega_3 = -r_4 sin\theta_4 \omega_4$$
$$y:\ r_2 cos\theta_2 \omega_2 + r_3 cos\theta_3 \omega_3 = r_4 cos\theta_4 \omega_4$$

$Acceleration$:

$$x: -r_2 cos\theta_2 \dot{\theta}_2^{\,2} - r_3 cos\theta_3 \dot{\theta}_3^{\,2} - r_3 sin\theta_3 \alpha_3 = -r_4 cos\theta_4 \dot{\theta}_4^{\,2} - r_4 sin\theta_4 \alpha_4$$
$$y: -r_2 sin\theta_2 \dot{\theta}_2^{\,2} - r_3 sin\theta_3 \dot{\theta}_3^{\,2} + r_3 cos\theta_3 \alpha_3 = -r_4 sin\theta_4 \dot{\theta}_4^{\,2} + r_4 cos\theta_4 \alpha_4$$

3. Loop Closure Equation 2

Position: $r_5 = r_6 + r_4$

$x: r_5 = r_4 cos\theta_4 + r_6 cos\theta_4$

$y: 0 = r_4 sin\theta_4 + r_6 sin\theta_6$

$Velocity$:

$x: \dot{r}_5 = -r_4 sin\theta_4 \omega_4 - r_6 sin\theta_6 \omega_6$

$y:\ r_4 cos\theta_4 \omega_4 + r_6 cos\theta_6 \omega_6$

$Acceleration$:

$x: \ddot{r}_5 = -r_4 cos\theta_4 \dot{\theta}^2{}_4 - r_4 sin\theta_4 \alpha_4 - r_6 cos\theta_6 \dot{\theta}^2{}_6 - r_6 sin\theta_6 \alpha_6$

$y: 0 = -r_4 sin\theta_4 \dot{\theta}^2{}_4 + r_4 cos\theta_4 \alpha_4 - r_6 sin\theta_6 \dot{\theta}^2{}_6 + r_6 cos\theta_6 \alpha_6$

4. Code:

a. Main:

```
close
clc
options = optimset('display', 'off');
theta = 0:1:360;
for i = 1:1:361
Position34(:,i) = fsolve(@position1,[1
1],options,theta(i));
theta3 = Position34(1,i);
theta4 = Position34(2,i);

Position56(:,i) = fsolve(@position2,[1
1],options,theta4);
r5 = Position56(1,i);
theta6 = Position56(2,i);

omega2 = 10;
Omega34(:,i) = fsolve(@velocity1,[1 1],options,[theta(i)
theta3 theta4 omega2]);
omega3 = Omega34(1,i);
omega4 = Omega34(2,i);

Omega56(:,i) = fsolve(@velocity2,[1 1],options,[theta4
theta6 omega4]);
v5 = Omega56(1,i);
omega6 = Omega56(2,i);

Alpha34(:,i) = fsolve(@acceleration1,[1
1],options,[theta(i) theta3 theta4 omega2 omega3
omega4]);
alpha3 = Alpha34(1,i);
alpha4 = Omega56(1,i);

Alpha56(:,i) = fsolve(@acceleration2,[1
1],options,[theta4 theta6 omega4 omega6 alpha4]);
a5 = Alpha56(1,i);
alpha6 = Alpha56(2,i);
end
%plot(theta(1,:), Position34(1,:));
hold
%plot(theta(1,:), Position34(2,:));
hold
%plot(theta(1,:), Position56(1,:));
```

```
hold
%plot(theta(1,:), Position56(2,:));
hold
%plot(theta(1,:), Omega34(1,:));
hold
%plot(theta(1,:), Omega34(2,:));
hold
%plot(theta(1,:), Omega56(1,:));
hold
%plot(theta(1,:), Omega56(2,:));
hold
%plot(theta(1,:), Alpha34(1,:));
hold
%plot(theta(1,:), Alpha34(2,:));
hold
%plot(theta(1,:), Alpha56(1,:));
hold
%plot(theta(1,:), Alpha56(2,:));
hold
grid on
```

b. Position1:

```
function position1 = position1(output, input)
r1 = 45;
r2 = 11.26;
r3 = 40.628;
r4 = 17.117;
theta2 = input;
theta3 = output(1);
theta4 = output(2);
x = r1 + r4*cosd(theta4) - r2*cosd(theta2) -
r3*cosd(theta3);
y = r4*sind(theta4)- r2*sind(theta2) - r3*sind(theta3);
position1 = [x,y];
end
```

Position2:

```
function position2 = position2(output, input)
r4 = 17.117;
r6 = 57.602;
theta4 = input(1);
r5 = output(1);
theta6 = output(2);
x = r4*cosd(theta4) + r6*cosd(theta6) - r5;
y = r4*sind(theta4) + r6*sind(theta6);
position2 = [x,y];
end
```

Velocity1:

```
function velocity1 = velocity1(output, input)
r1 = 45;
r2 = 11.26;
r3 = 40.628;
r4 = 17.117;
theta2 = input(1);
theta3 = input(2);
theta4 = input(3);
omega2 = input(4);
omega3 = output(1);
omega4 = output(2);
x = r4*omega4*sind(theta4) - r2*omega2*sind(theta2) -
r3*omega3*sind(theta3);
y = -r4*omega4*cosd(theta4) + r2*omega2*cosd(theta2) +
r3*omega3*cosd(theta3);
velocity1 = [x,y];
end
```

Velocity2:

```
function velocity2 = velocity2(output, input)
r4 = 17.117;
r6 = 57.602;
theta4 = input(1);
theta6 = input(2);
omega4 = input(3);
v5 = output(1);
omega6 = output(2);
x = v5 + r4*omega4*sind(theta4) + r6*omega6*sind(theta6);
y = r4*omega4*cosd(theta4) + r6*omega6*cosd(theta6);
velocity2 = [x,y];
end
```

Acceleration1:

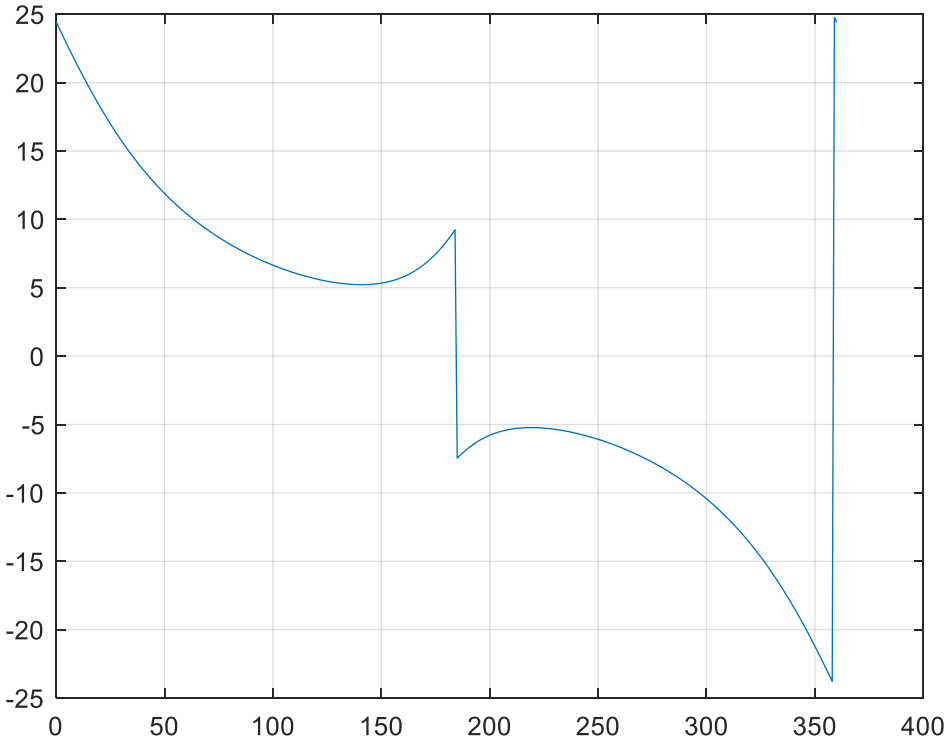
```
function acceleration1 = acceleration1(output, input)
r1 = 45;
r2 = 11.26;
r3 = 40.628;
r4 = 17.117;
theta2 = input(1);
theta3 = input(2);
theta4 = input(3);
omega2 = input(4);
omega3 = input(5);
omega4 = input(6);
alpha3 = output(1);
alpha4 = output(2);
x = -r2*(omega2^2)*cosd(theta2) -
r3*(omega3^2)*cosd(theta3) - r3*alpha3*sind(theta3) +
r4*(omega4^2)*cosd(theta4) + r4*alpha4*sind(theta4);
y = -r2*(omega2^2)*sind(theta2) -
r3*(omega3^2)*sind(theta3) + r3*alpha3*cosd(theta3) +
r4*(omega4^2)*sind(theta4) - r4*alpha4*cosd(theta4);
acceleration1 = [x,y];
end
```

Acceleration2:

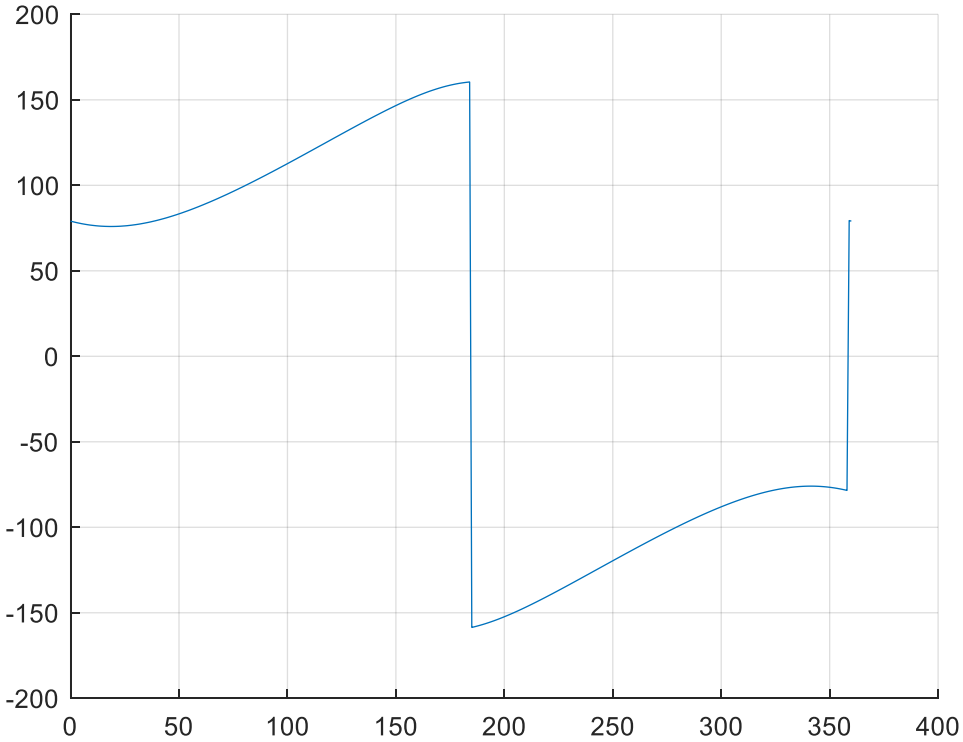
```
function acceleration2 = acceleration2(output, input)
r4 = 17.117;
r6 = 57.602;
theta4 = input(1);
theta6 = input(2);
omega4 = input(3);
omega6 = input(4);
alpha4 = input(5);
a5 = output(1);
alpha6 = output(2);
x = a5 + r4*(omega4^2)*cosd(theta4) +
r4*alpha4*sind(theta4) + r6*(omega6^2)*cosd(theta6) +
r6*alpha6*sind(theta6);
y = -r4*(omega4^2)*sind(theta4) + r4*alpha4*cosd(theta4)
- r6*(omega6^2)*sind(theta6) + r6*alpha6*cosd(theta6);
acceleration2 = [x,y];
end
```

5. Plots:

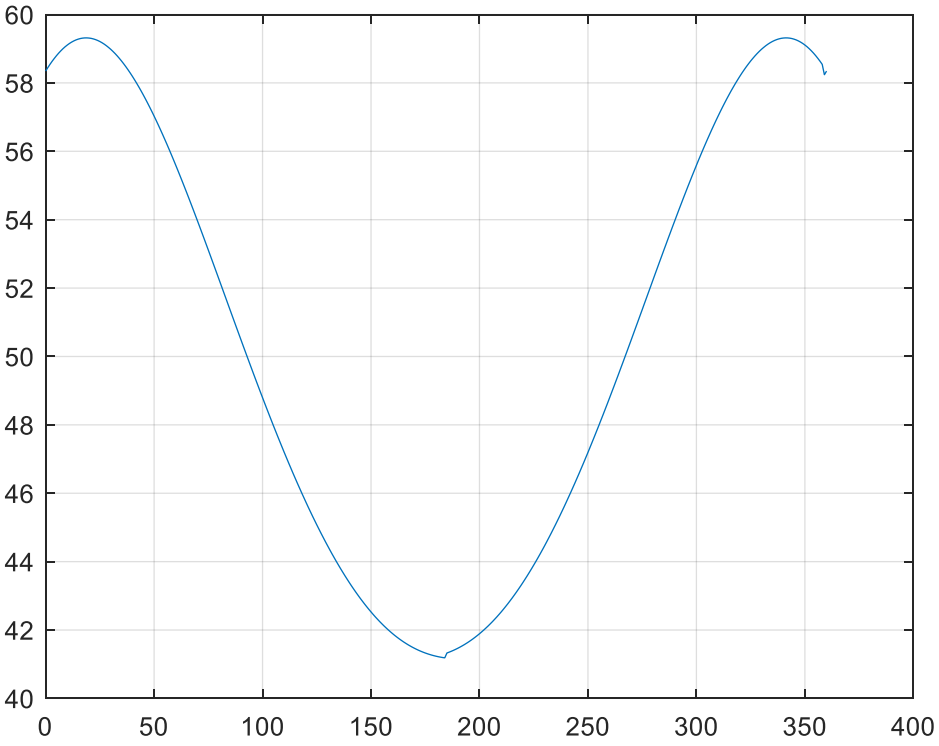
Theta3



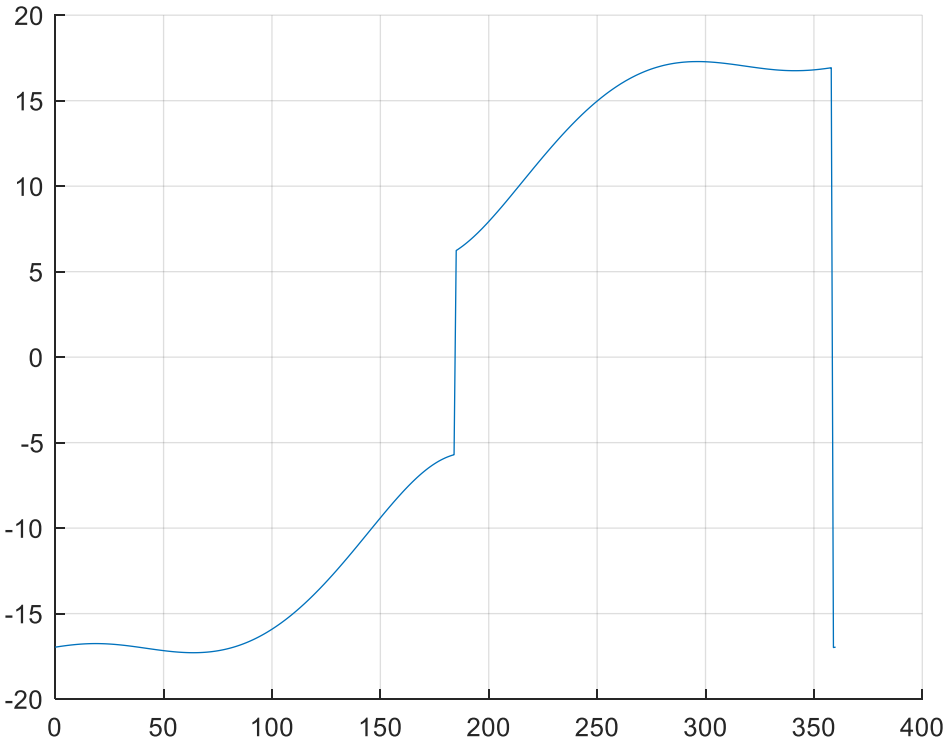
Theta4



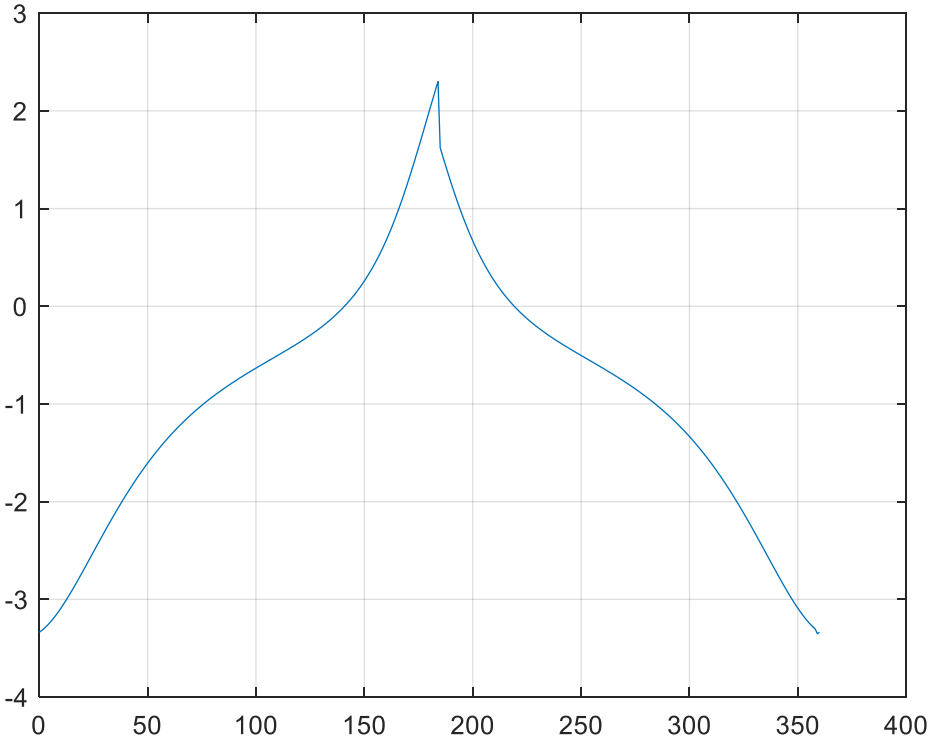
R5


60
58
56
54
52
50
48
46
44
42
40
0
50
100
150
200
250
300
350
400

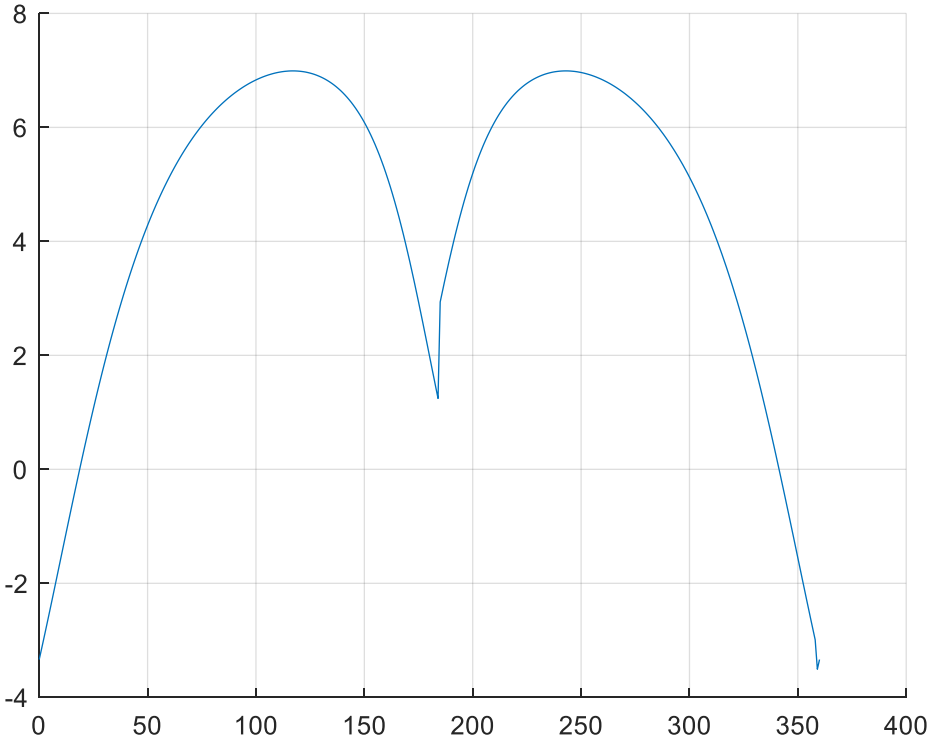
Theta6


20
15
10
5
0
-5
-10
-15
-20
0
50
100
150
200
250
300
350
400

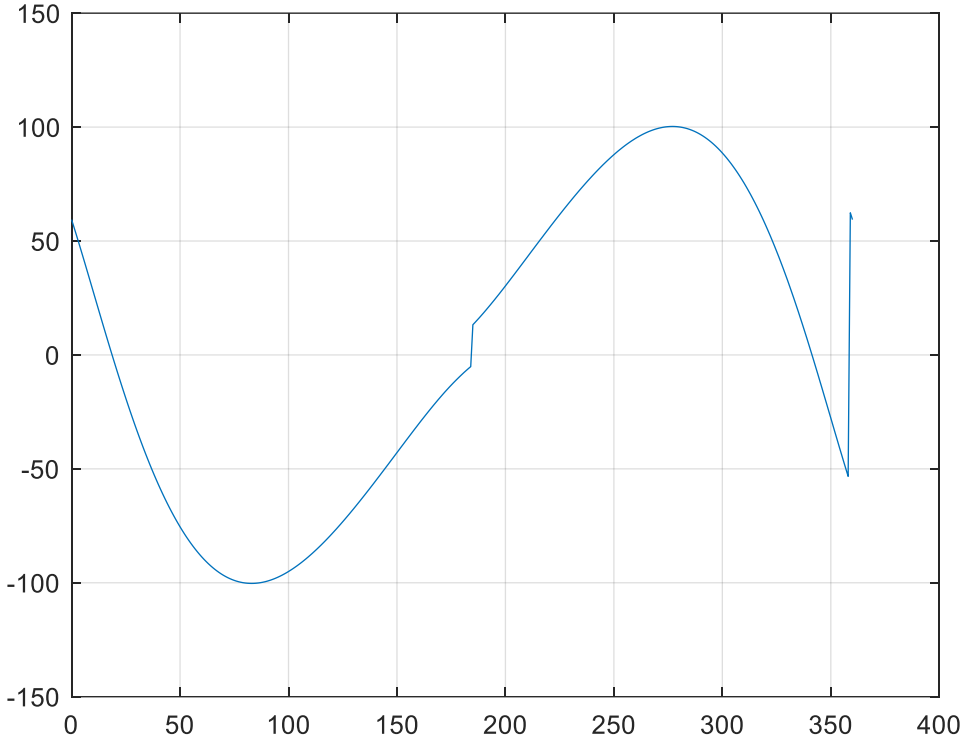
Omega3



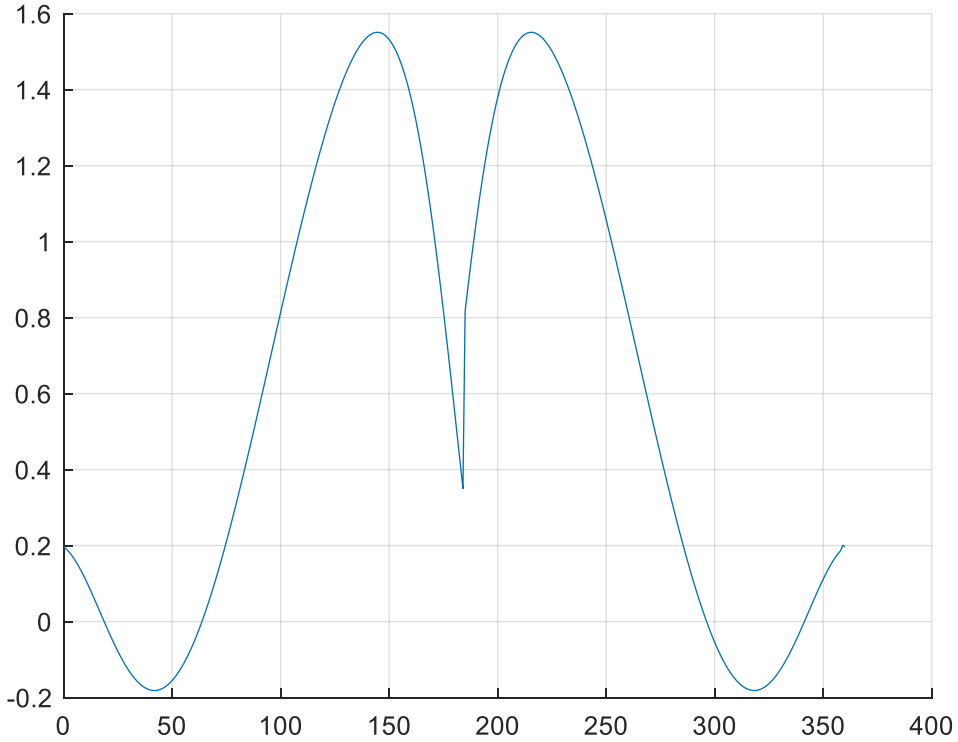
Omega4



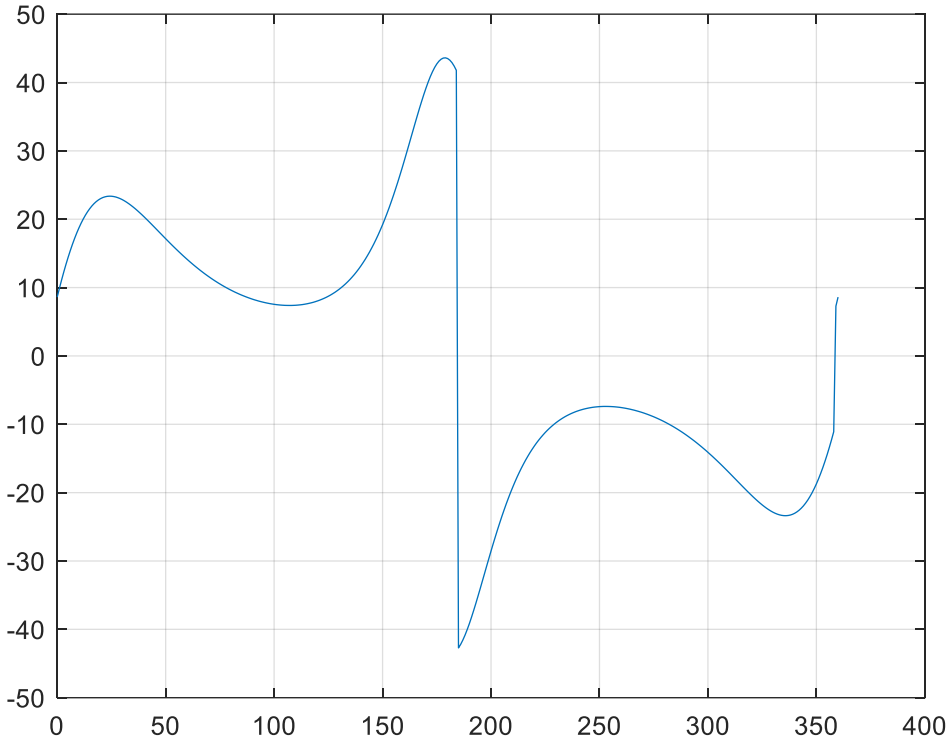
V5


150
100
50
0
-50
-100
-150
0
50
100
150
200
250
300
350
400

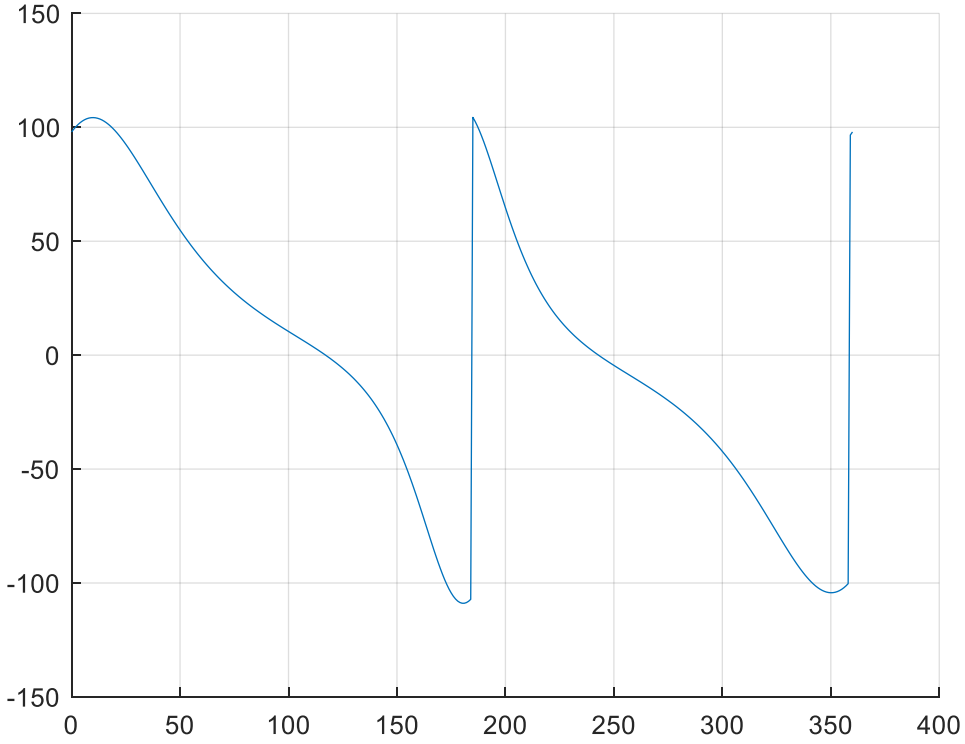
Omega6


1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
0
50
100
150
200
250
300
350
400

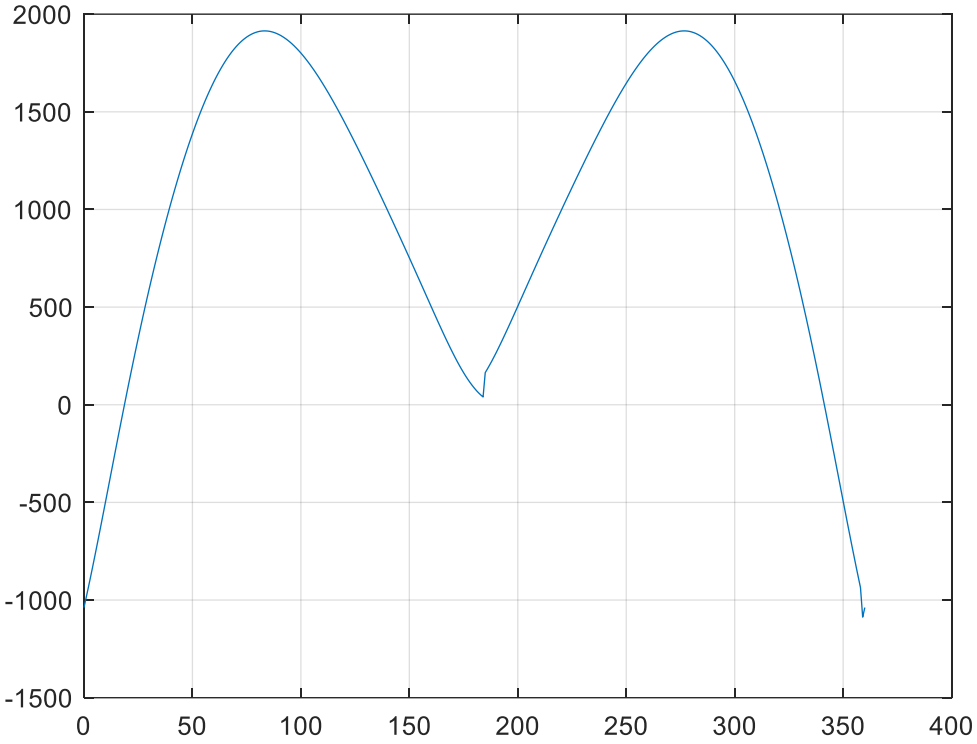
Alpha3



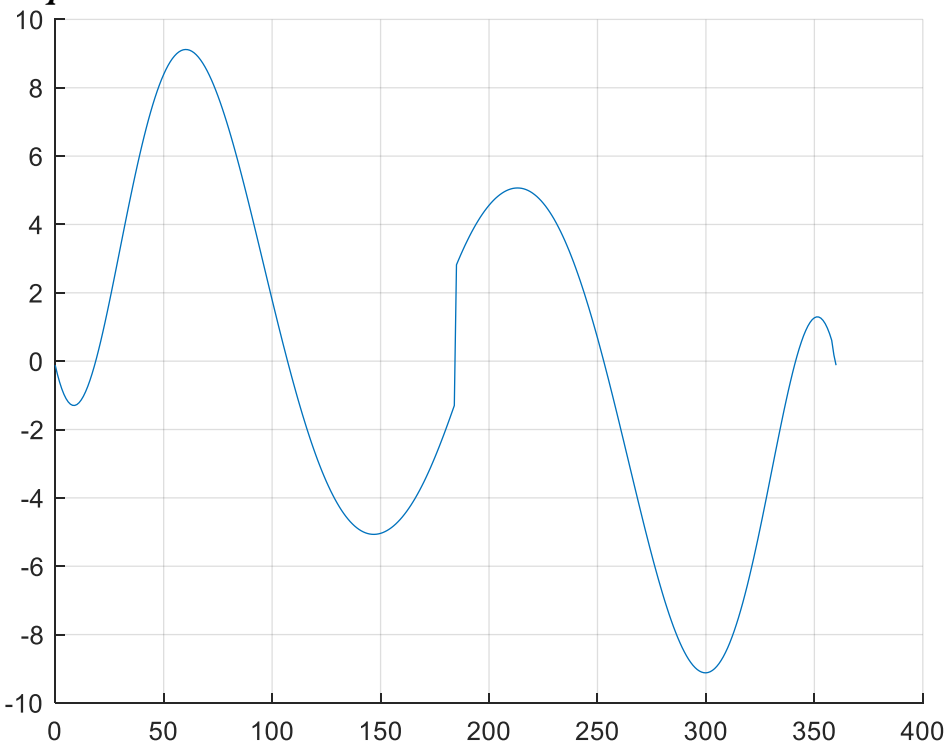
Alpha4



A5


2000
1500
1000
500
0
-500
-1000
-1500
0
50
100
150
200
250
300
350
400

Alpha6


10
8
6
4
2
0
-2
-4
-6
-8
-10
0
50
100
150
200
250
300
350
400

Proofing
Convention
CW +
CCW –
Right –
Left +
From graphical solution at theta2=63 and omega2=+10 CW and alpha2=0 using AutocAD in a file called linkage.dwg
Thetas
Theta3= 10
Theta4= 90
Theta6 = -17
R5= 55
Omegas
Omega3= +1.278
Omega4= +5.335
Omega6= 0
V5= -91.314
Alphas
Alpha3=-13.41
Alpha4=-39.21
Alpha6=+8.689
A5=+525

From matlab solution at theta2=63 and omega2=+10 CW and alpha2=0
Thetas
Theta3=10.04
Theta4=89.61
Theta6=-17.29
R5=55.12
Omegas
Omega3=-1.262
Omega4=+5.339
Omega6=-0.01142
V5=-91.58
Alphas
Alpha3=+13.08
Alpha4=+38.89
Alpha6=+9.067
A5=+1713

Most values are very close each other and their respective directions are correct.
There is a huge difference between A5 as due to w6 being zero in graphical analysis this would lead to a huge difference in answers.
And the direction of Alpha3 and Alpha4 are not the same in both analysis but values are very close to each other.