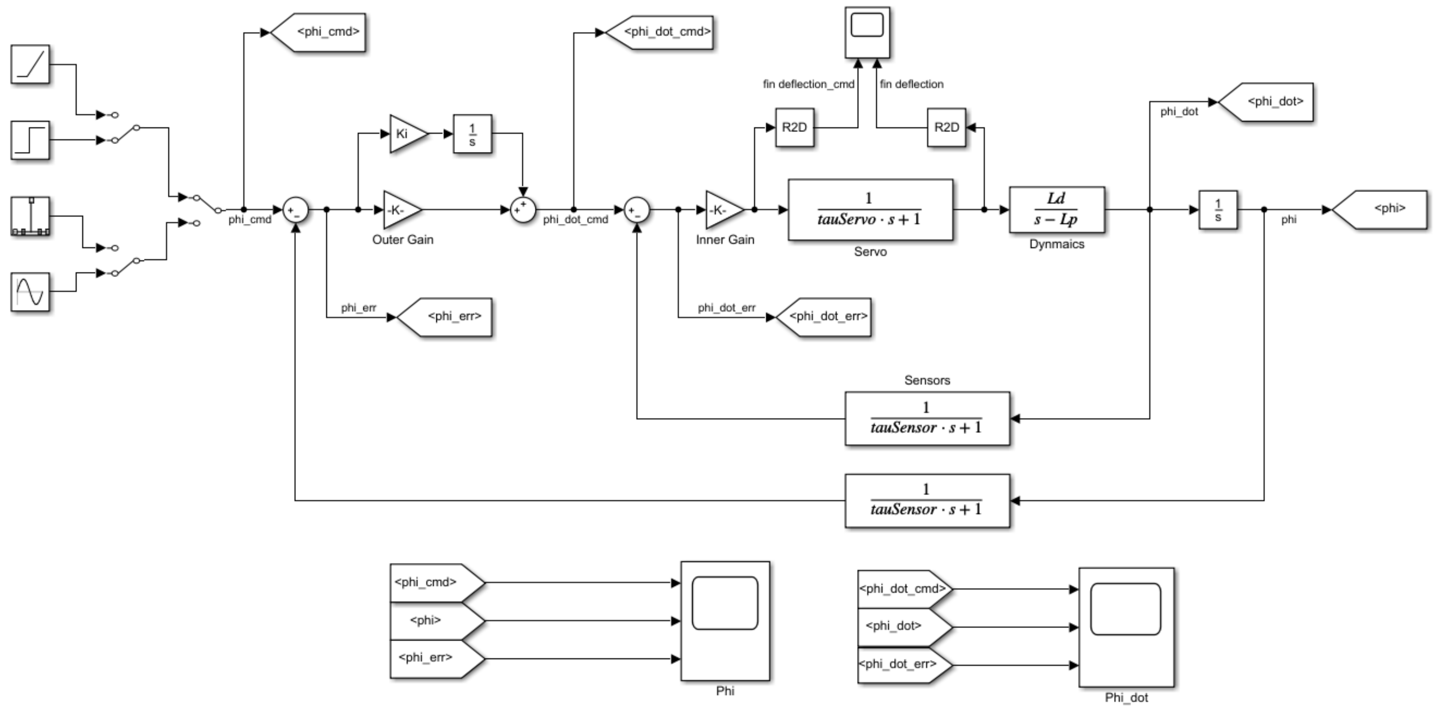
Roll Control:

Visual Representation of the entire control algorithm:



Time constants:

$$\tau_{sensor} = 0.01\ s$$

$$\tau_{servo} = 0.1\ s$$

Flight conditions:

$$U_0 = 228.4\frac{m}{s} \cong 0.67\ Ma$$

$$\alpha = \beta = 0$$

$$\rho = 1.225\frac{kg}{m^3}$$

Other Parameters

$$d = 0.08\ m$$

$$S = \frac{\pi d^2}{2} = 0.005\ \frac{m}{s}$$

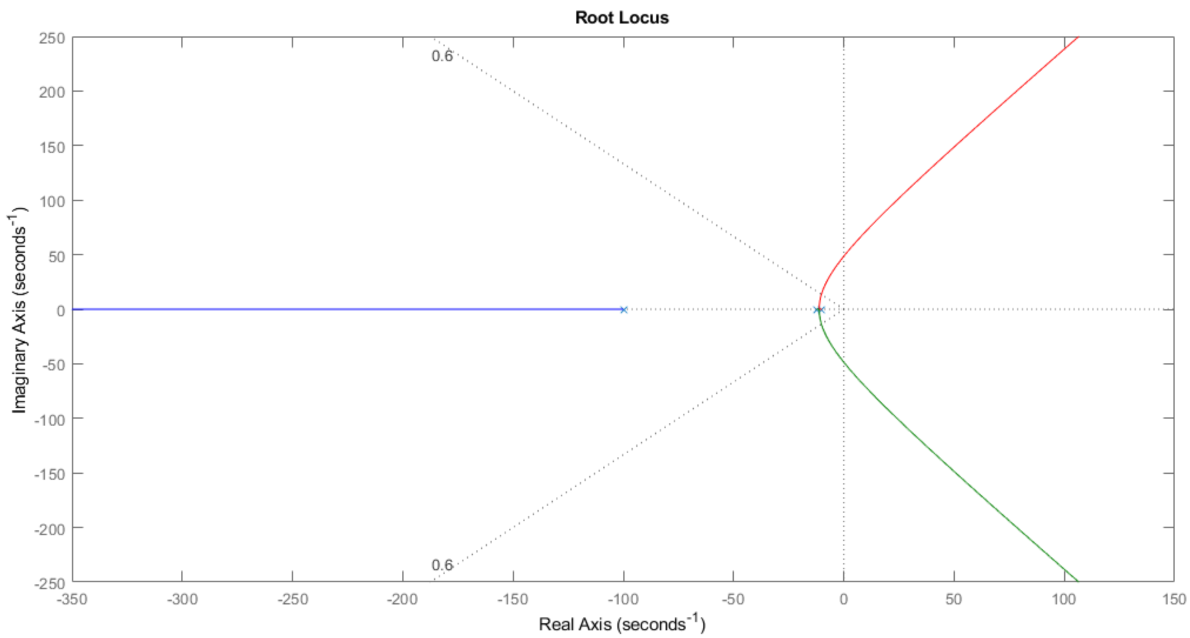
$$I_x = 3.7 * 10^{-3}\ kg\ m^2$$

$$C_{L_p} = -20.39$$

$$C_{L_\delta} = 0.1722$$

Inner loop design:

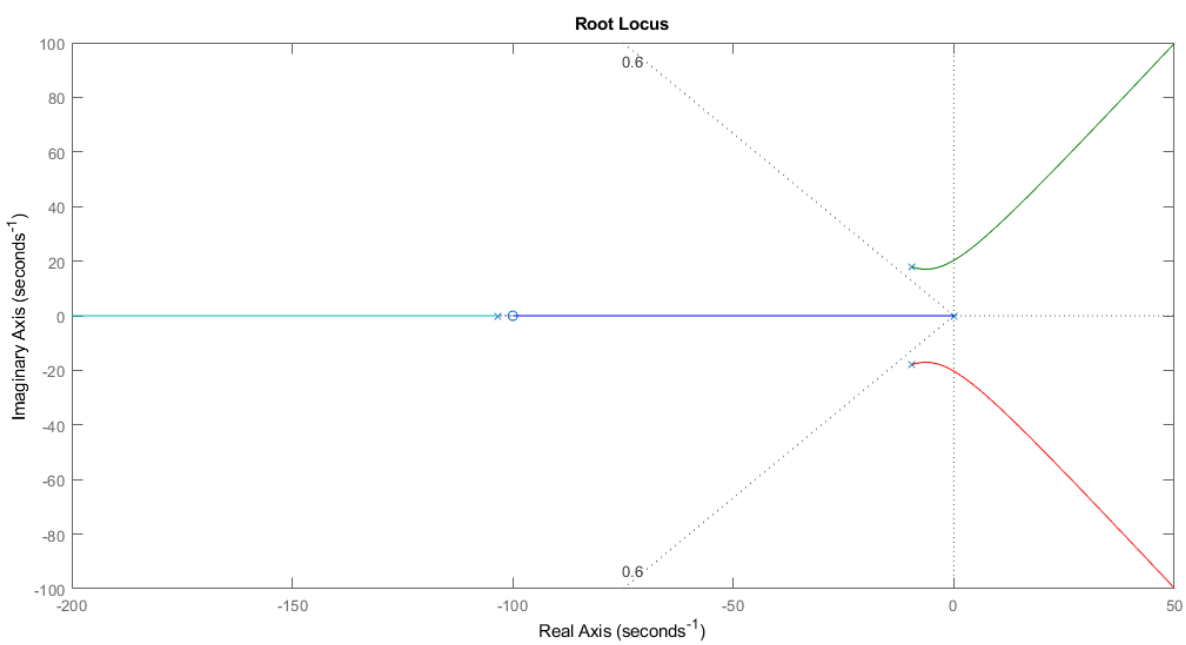
Root locus:



Choose an inner loop gain: $K_p = 0.1$

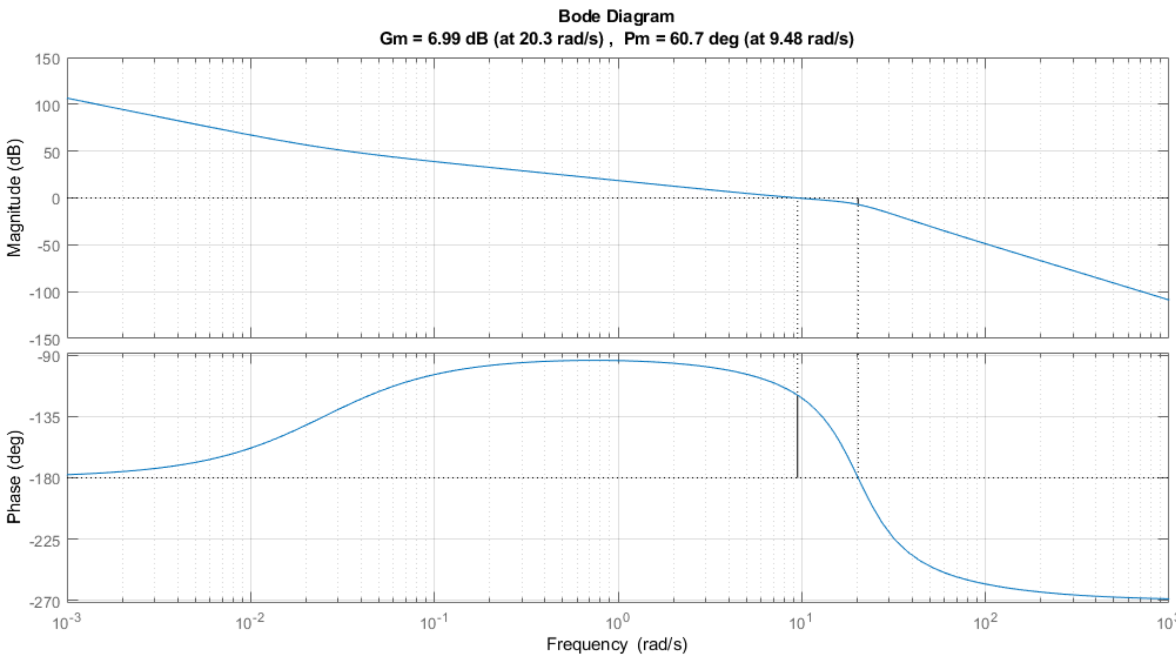
Outer Loop Design:

Root locus



Choose an outer loop gain: $K_p = 12$,
Add integral control for improved tracking of ramp input: $K_i = 0.3$

<u>Gain and Phase Plots of Outer Loop:</u>



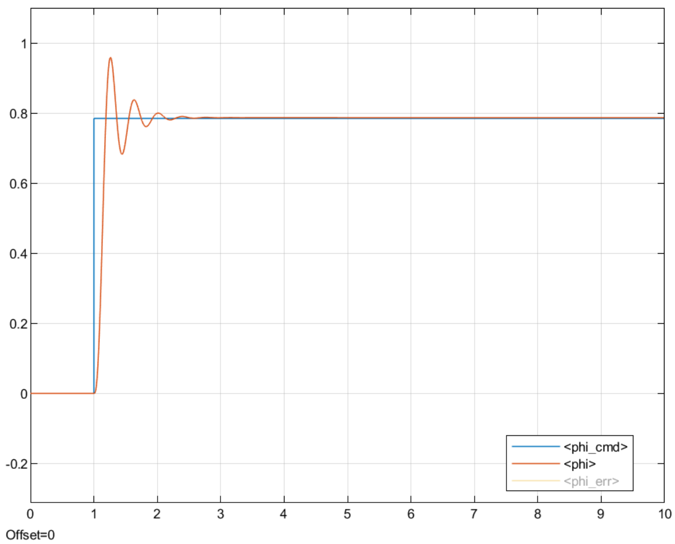
Gain margin: 6.99 dB

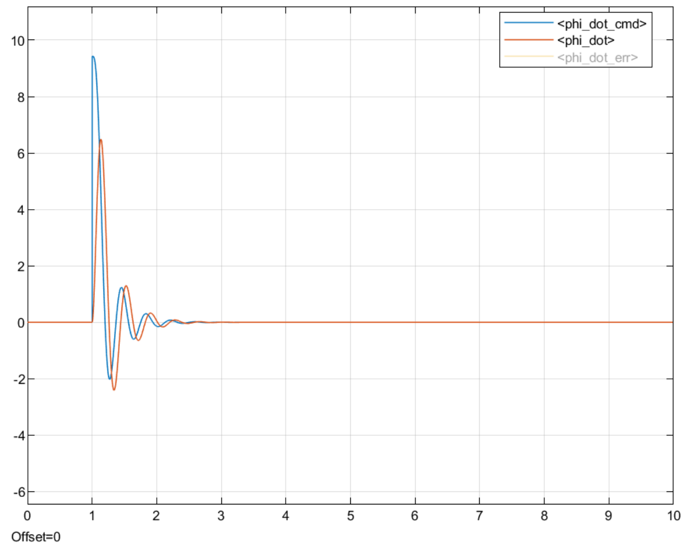
Phase margin: 60.7 deg

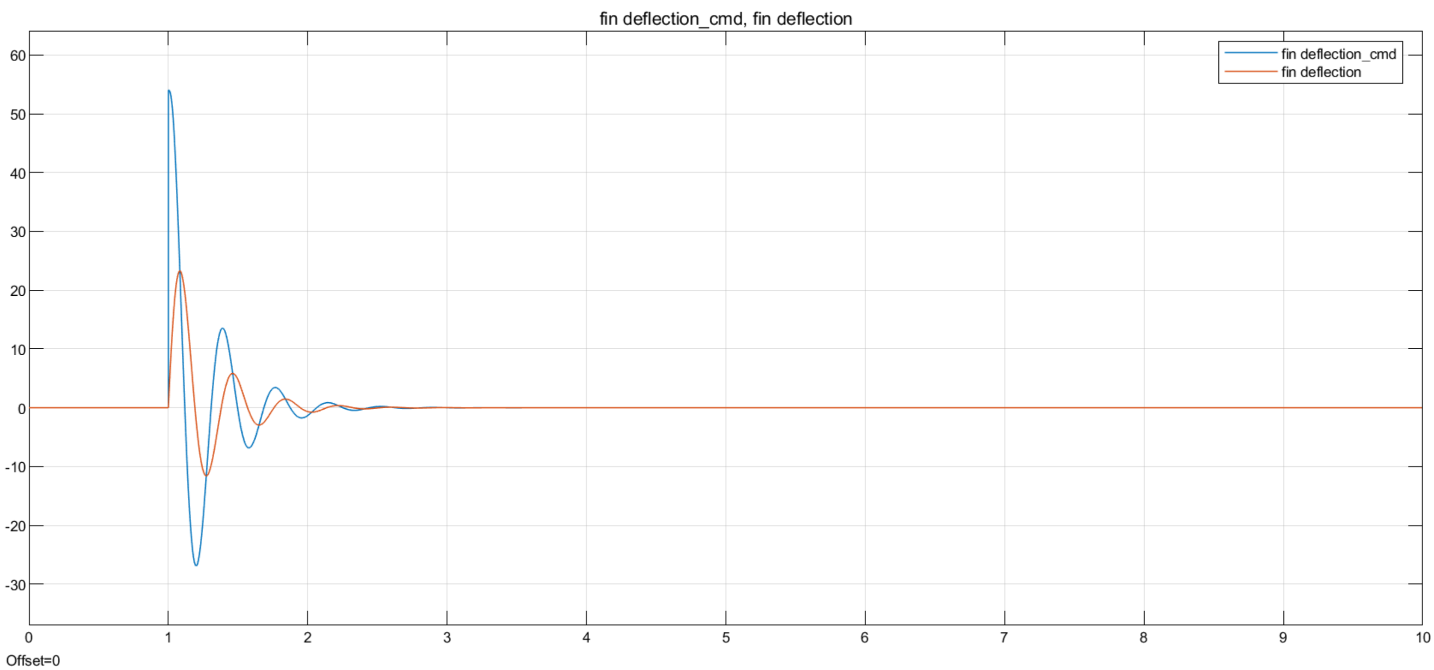
Bandwidth (-3dB): 20.7 rad/s

Simulation:

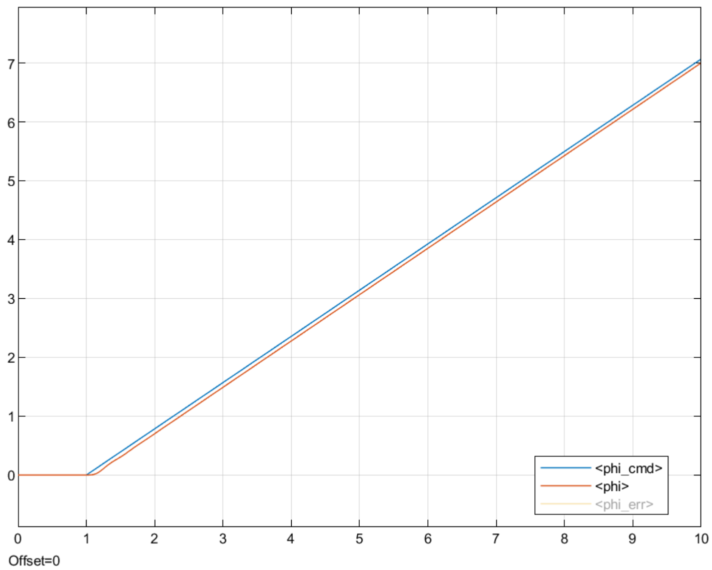
Test 1: Step input of 45 deg

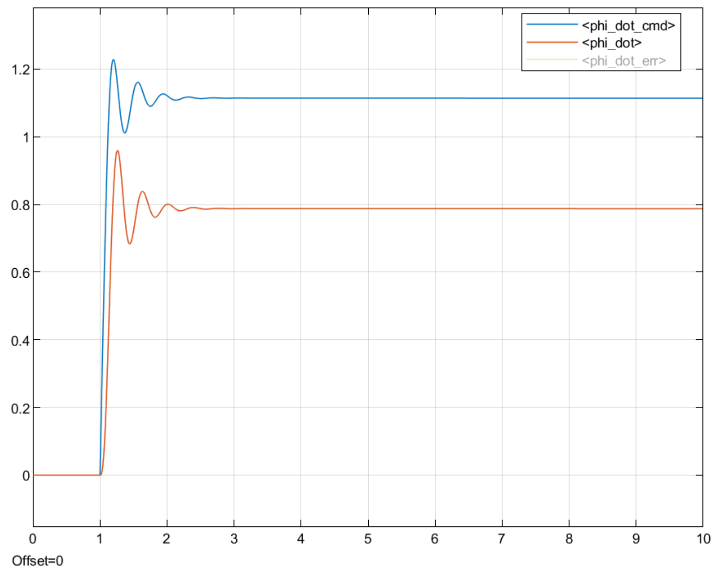


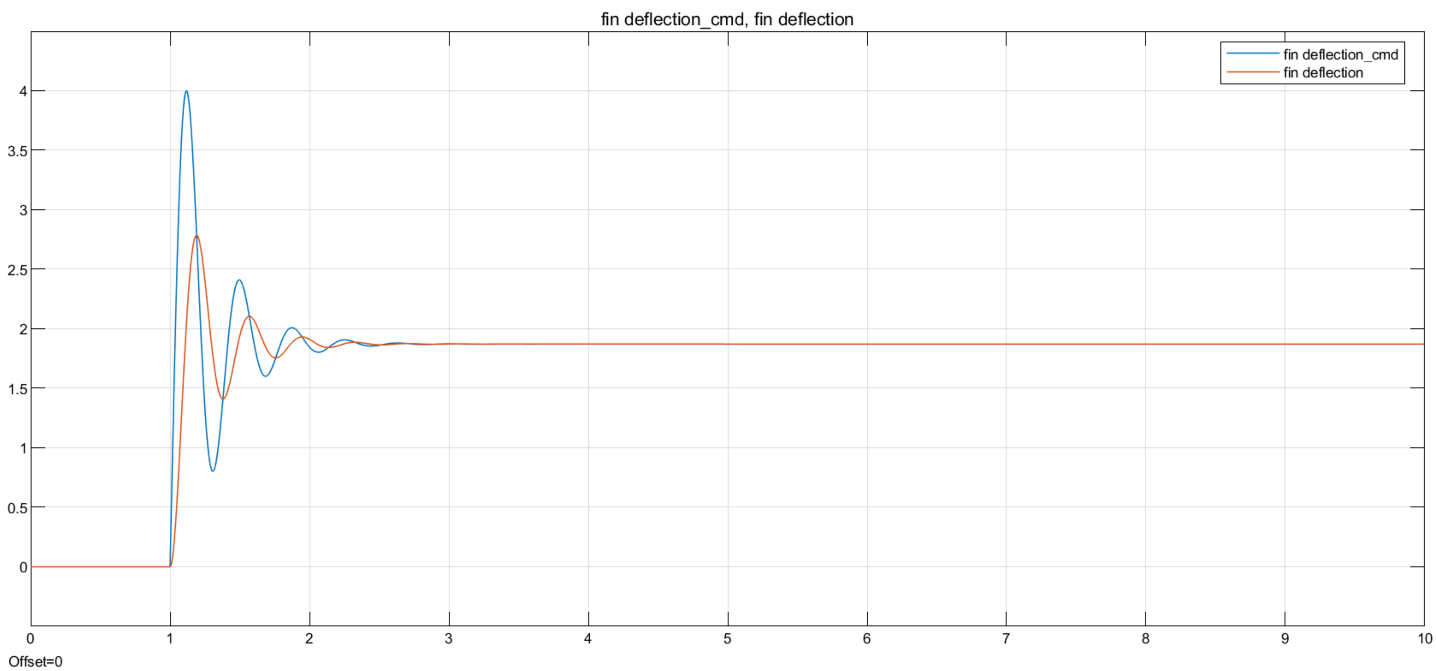




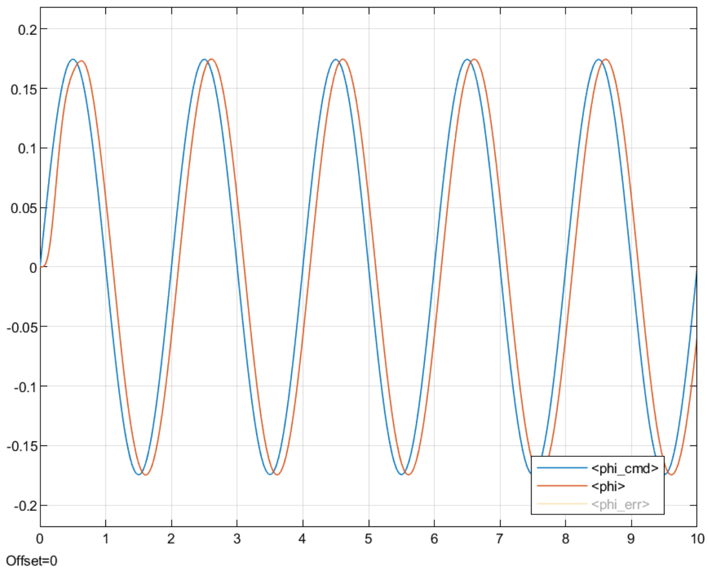
Test 2: Ramp input of 45 deg/s

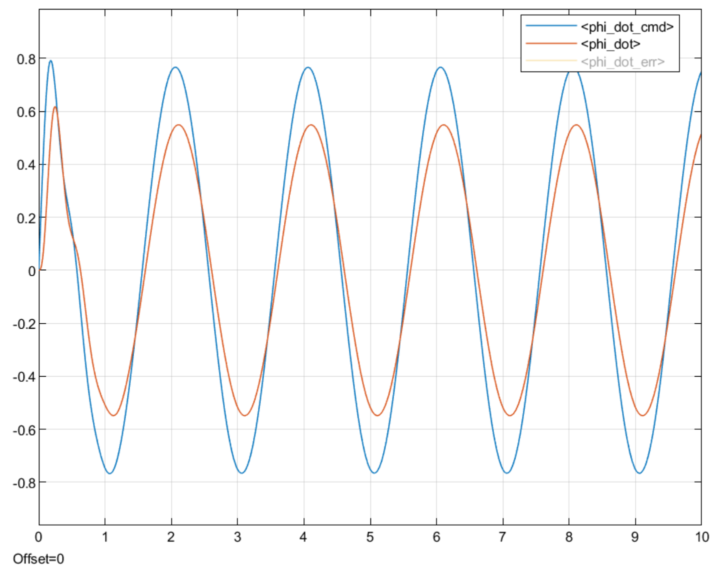


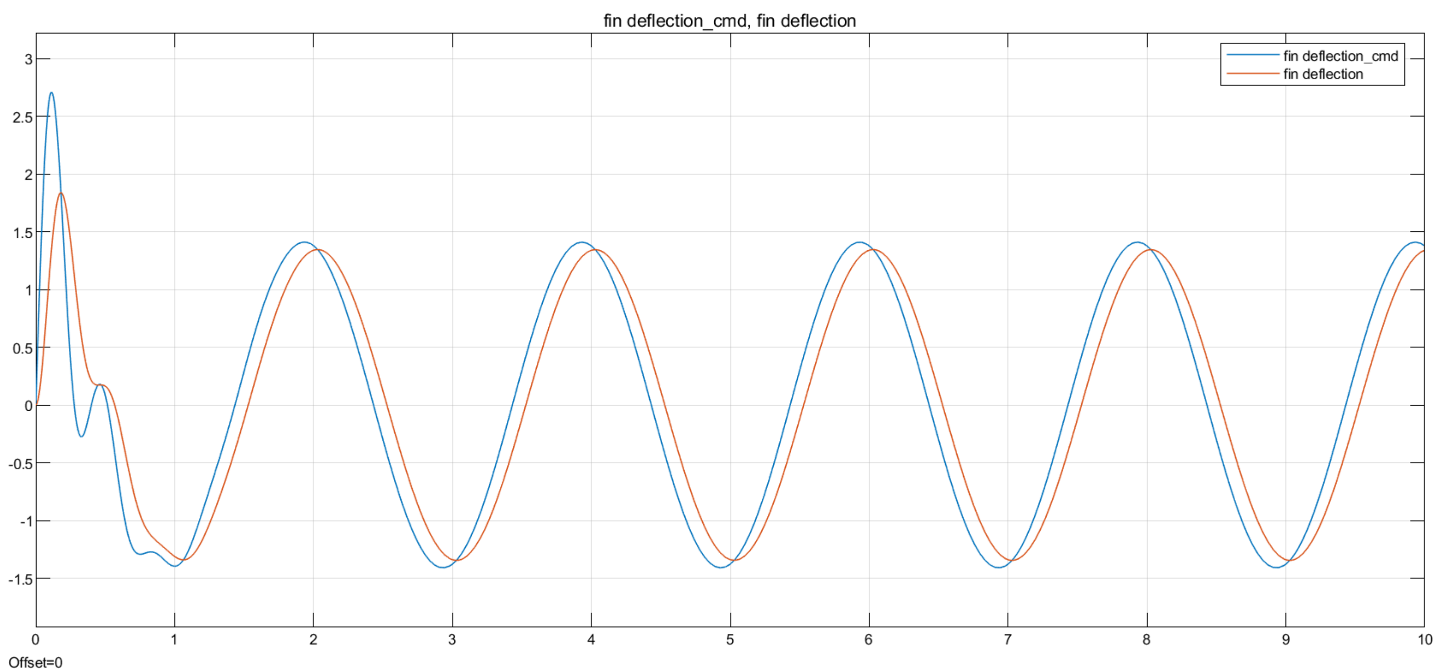




Test 3: Sine input (amplitude: 45 deg, Frequency: Pi rad/s)







Matlab Code:

```
clear,clc
%% Parameteres
d = 0.08;
S = pi*d^2/4;
U0 = 228.4;  % ~~ 0.67Ma
Ix = 6.331e-3;
rho = 1.225;
TechnionConfig = 1;

if (TechnionConfig)
    Clp = -51;
    Cld = 4.03;
else
    load('aero.mat','Clp','Cl_delta_l');
    Clp = Clp(6,9,9);
    Cld = -Cl_delta_l(6,9,9);
end

Lp =rho*S*U0*d^2*Clp/(4*Ix);
Ld =rho*S*U0^2*d*Cld/(4*Ix);

tauServo = 0.1;
tauSensor = 0.01;

%% Inner Loop Design
dyn = tf(Ld,[1 -Lp]);
servo = tf(1,[tauServo 1]);
sensor = tf(1,[tauSensor 1]);
rlocus(dyn*servo*sensor)
sgrid(0.6,1e10)
Kinner=0.01;

%% Outer Loop Design
innerLoop = feedback((Kinner*dyn*servo),sensor);
int = tf(1,[1 0]);
rlocus(innerLoop*int)
sgrid(0.6,1e10)
Kouter = 3;
Ki = 0.5;
s = tf('s');
outerLoop = feedback((Kouter+Ki/s)*innerLoop*int,sensor);

%% Stability margins
margin(outerLoop)
systemBandwidth = bandwidth(outerLoop)
grid
sim('roll_control_loop');
```