Stability & Control Characterization of a guided projectile from Wind-Tunnel Testing

Solution:

1. **For body alone configuration**
   a.To calculate location of C.G.

To solve 1st question we have to know neutral point and hence we will first solve question 3.

1st I have plotted various plot of CM versus Alpha graph by iteratively incrementing the C.G location from nose of the missile to the tail and alalyzing the plot for different slopes CM versus alpha and interpreting the value of C.G based on slope which is horizonatal(whose moment does not change with angle of attack).

Thus from this we can conclude that the respective C.G location is neutral point.

Now we are having location of neutral point.

Here we will estimate location of C.G by assuming Static margin to be 15%.

Now we have location of C.G of projectile we can plot the variation of longitudinal force and moment coefficients with angle of attack, velocity, and control surface deflections for all cases.

MATLAB CODE: Calculation_X_cg_Body_Alone.m

```
% 6680 5/7/2010 11:02:55 AM
% Bomb Model-II Body Alone Configuration
%% Variation of Moment coefficient w.r.t. Center of gravity

% 6680 5/7/2010 11:02:55 AM

% Bomb Model-II Body Alone Configuration

%% Variation of Moment coefficient w.r.t. Center of gravity

format long g


g = 9.81;

Cl = [];

Alpha = [];
```

```
C_m = [];

%Balance load matrix

CM = [63.080043 0.144499 -0.206795 1.354260 1.630051 4.275882

-0.123649 150.309342 0.592082 -0.725847 0.030856 0.393628

0.024098 -0.689773 151.831777 0.096597 -0.571799 -4.414537

0.152944 -2.334107 0.037781 77.595997 0.445712 5.841784

-0.006030 0.114642 -0.574072 -0.065800 79.176337 0.322466

0.047415 0.466131 0.099431 0.208017 0.190935 44.877349 ];


% Model reference parameters

% Sref(sqm) Chord (m) Span (m)

Sref = 0.009677; c = 0.111; b = 0.111;


% Moment reference point (nose)

% X (m) Y (m) Z (m)

% 0 0 0


% Balance center location

%X (m) Y (m) Z (m)

X =-0.465; Y = 0; Z = 0;

X_bc = 0.465 ; % distance from Balence Center to Nose of missile


% Nowind data

% Ax N1 N2 S1 S2 Rm

NW = [-0.001023; 0.001298; 0.001474; -0.000501; -0.000191; -0.000147];


for i = 1:3

if i == 1
```

```
%Data for Speed 1

DyHi = 974.329545;

% Dyn. head Pitch Yaw Roll Ax N1 N2 S1 S2 Rm

DSi = [ 974.329545 -9.947917 0.000000 0.000000 0.002673 -0.006420 0.005058 -0.001114
0.000491 -0.000003 %1

974.329545 -8.052083 0.000000 0.000000 0.002539 -0.004903 0.004606 -0.000981 0.000274
-0.000041 %2

974.329545 -6.052083 0.000000 0.000000 0.002434 -0.003329 0.003960 -0.000981 0.000253
-0.000068 %3

974.329545 -4.062500 0.000000 0.000000 0.002377 -0.001724 0.003177 -0.000968 0.000107
-0.000071 %4

974.329545 -2.052083 0.000000 0.000000 0.002325 -0.000170 0.002245 -0.000885 0.000153
-0.000090 %5

974.329545 -0.052083 0.000000 0.000000 0.002249 0.001322 0.001340 -0.000831 0.000072
-0.000128 %6

974.329545 0.052083 0.000000 0.000000 0.002201 0.001334 0.001344 -0.000864 0.000120 -
0.000131 %7

974.329545 1.947917 0.000000 0.000000 0.002324 0.002779 0.000499 -0.000783 0.000108 -
0.000153 %8

974.329545 3.947917 0.000000 0.000000 0.002385 0.004320 -0.000380 -0.000745 -0.000003
-0.000158 %9

974.329545 5.947917 0.000000 0.000000 0.002458 0.005940 -0.001250 -0.000692 -0.000010
-0.000191 %10

974.329545 7.947917 0.000000 0.000000 0.002611 0.007523 -0.001939 -0.000602 -0.000087
-0.000206 %11

974.329545 9.947917 0.000000 0.000000 0.002765 0.009013 -0.002427 -0.000612 -0.000136
-0.000233 %12

974.329545 11.947917 0.000000 0.000000 0.002850 0.010588 -0.002839 -0.000578 -
0.000102 -0.000257 %13

974.329545 13.947917 0.000000 0.000000 0.002862 0.012207 -0.003176 -0.000626 -
0.000078 -0.000250 %14

974.329545 15.937500 0.000000 0.000000 0.002895 0.013871 -0.003436 -0.000631 -
0.000056 -0.000280 %15
```

```
974.329545 17.937500 0.000000 0.000000 0.002860 0.015556 -0.003610 -0.000583 -
0.000413 -0.000303 %16

974.329545 19.947917 0.000000 0.000000 0.002808 0.017221 -0.003662 -0.000535 -
0.000676 -0.000332 %17

974.329545 21.947917 0.000000 0.000000 0.002689 0.018903 -0.003702 -0.000579 -
0.000642 -0.000360 %18

974.329545 23.947917 0.000000 0.000000 0.002521 0.020650 -0.003677 -0.000634 -
0.000730 -0.000392 %19

974.329545 25.947917 0.000000 0.000000 0.002294 0.022447 -0.003645 -0.000538 -
0.001077 -0.000409];%20

end

if i == 2

%Data for Speed 2

DyHi = 1499.272727;

% Dyn. head Pitch Yaw Roll Ax N1 N2 S1 S2 Rm

DSi = [ 1499.272727 -9.947917 0.000000 0.000000 0.004587 -0.010519 0.006953 -0.001412
0.000946 -0.000015

1499.272727 -8.052083 0.000000 0.000000 0.004404 -0.008223 0.006295 -0.001239
0.000592 -0.000048

1499.272727 -6.052083 0.000000 0.000000 0.004210 -0.005792 0.005321 -0.001273
0.000473 -0.000069

1499.272727 -4.062500 0.000000 0.000000 0.004093 -0.003315 0.004037 -0.001198
0.000382 -0.000141

1499.272727 -2.052083 0.000000 0.000000 0.004003 -0.000914 0.002615 -0.001125
0.000283 -0.000183

1499.272727 -0.052083 0.000000 0.000000 0.003968 0.001367 0.001249 -0.000983 0.000286
-0.000204

1499.272727 0.052083 0.000000 0.000000 0.003890 0.001442 0.001190 -0.001057 0.000316
-0.000323

1499.272727 1.947917 0.000000 0.000000 0.004016 0.003680 -0.000143 -0.000923 0.000177
-0.000222

1499.272727 3.947917 0.000000 0.000000 0.004096 0.006063 -0.001533 -0.000902 0.000197
-0.000269
```

```
1499.272727 5.947917 0.000000 0.000000 0.004177 0.008541 -0.002856 -0.000859 0.000128
-0.000303

1499.272727 7.947917 0.000000 0.000000 0.004368 0.010913 -0.003881 -0.000755 -
0.000020 -0.000341

1499.272727 9.947917 0.000000 0.000000 0.004593 0.013239 -0.004599 -0.000664 -
0.000136 -0.000388

1499.272727 11.947917 0.000000 0.000000 0.004712 0.015682 -0.005213 -0.000669 -
0.000025 -0.000397

1499.272727 13.947917 0.000000 0.000000 0.004752 0.018147 -0.005713 -0.000716
0.000002 -0.000445

1499.272727 15.937500 0.000000 0.000000 0.004759 0.020667 -0.006095 -0.000655 -
0.000346 -0.000474

1499.272727 17.937500 0.000000 0.000000 0.004694 0.023277 -0.006399 -0.000509 -
0.000902 -0.000543

1499.272727 19.947917 0.000000 0.000000 0.004571 0.025917 -0.006611 -0.000528 -
0.001019 -0.000597

1499.272727 21.947917 0.000000 0.000000 0.004370 0.028594 -0.006665 -0.000663 -
0.001004 -0.000622

1499.272727 23.947917 0.000000 0.000000 0.004114 0.031377 -0.006636 -0.000697 -
0.001170 -0.000684

1499.272727 25.947917 0.000000 0.000000 0.003761 0.034218 -0.006530 -0.000258 -
0.002047 -0.000730 ];

end

if i == 3

% Data for Speed 3

DyHi = 2172.920455;

% Dyn. head Pitch Yaw Roll Ax N1 N2 S1 S2 Rm

DSi = [ 2172.920455 -9.947917 0.000000 0.000000 0.006916 -0.015706 0.009377 -0.001872
0.001380 -0.000105

2172.920455 -8.052083 0.000000 0.000000 0.006651 -0.012341 0.008425 -0.001672
0.001040 -0.000155

2172.920455 -6.052083 0.000000 0.000000 0.006393 -0.008838 0.006984 -0.001653
0.000856 -0.000195
```

2172.920455 -4.062500 0.000000 0.000000 0.006240 -0.005337 0.005156 -0.001549 0.000713 -0.000230

2172.920455 -2.062500 0.000000 0.000000 0.006160 -0.001847 0.003104 -0.001436 0.000613 -0.000284

2172.920455 -0.052083 0.000000 0.000000 0.006067 0.001535 0.001050 -0.001293 0.000493 -0.000336

2172.920455 0.052083 0.000000 0.000000 0.006014 0.001550 0.000960 -0.001306 0.000575 -0.000463

2172.920455 1.947917 0.000000 0.000000 0.006095 0.004862 -0.000972 -0.001223 0.000523 -0.000381

2172.920455 3.947917 0.000000 0.000000 0.006189 0.008310 -0.002973 -0.001107 0.000492 -0.000439

2172.920455 5.937500 0.000000 0.000000 0.006286 0.011904 -0.004877 -0.001010 0.000424 -0.000466

2172.920455 7.947917 0.000000 0.000000 0.006565 0.015344 -0.006404 -0.000883 0.000258 -0.000525

2172.920455 9.947917 0.000000 0.000000 0.006871 0.018639 -0.007381 -0.000782 0.000164 -0.000568

2172.920455 11.947917 0.000000 0.000000 0.006984 0.022162 -0.008318 -0.000734 0.000160 -0.000631

2172.920455 13.947917 0.000000 0.000000 0.007035 0.025766 -0.009044 -0.000795 -0.000042 -0.000673

2172.920455 15.937500 0.000000 0.000000 0.007042 0.029433 -0.009589 -0.000700 -0.000477 -0.000759

2172.920455 17.937500 0.000000 0.000000 0.006945 0.033266 -0.010124 -0.000538 -0.001151 -0.000813

2172.920455 19.947917 0.000000 0.000000 0.006745 0.037188 -0.010493 -0.000556 -0.001314 -0.000870

2172.920455 21.947917 0.000000 0.000000 0.006498 0.041137 -0.010671 -0.000674 -0.001308 -0.000959

2172.920455 23.937500 0.000000 0.000000 0.006105 0.045155 -0.010599 -0.000880 -0.001188 -0.001035

2172.920455 25.947917 0.000000 0.000000 0.005570 0.049182 -0.010379 -0.000121 -0.002440 -0.001125];

```
end

Le = 0.884;

% Transformation Matrix from CG to Body center

for x = -0.4:0.1:0.4 %0.1:0.01:0.18

% Xnp --> 0.2826 (x=0.15)

y = 0;

z = 0;

TM =[-1, 0, 0, 0, 0, 0

0, 1, 0, 0, 0, 0

0, 0, -1, 0, 0, 0

0, -z, y, 1, 0, 0

z, 0, -x, 0, 1, 0

-y, x, 0, 0, 0, 1];


Alpha = [];

C_m = [];

for j = 1:20

aj = [DSi(j,5) ; DSi(j,6) ; DSi(j,7) ; DSi(j,8) ; DSi(j,9) ; DSi(j,10)];

% Convert the obtained normalized voltage signals to kg

Aj = CM * (aj-NW);

% Calculate the forces and moments about the balance center.

fm = [Aj(1) ; (Aj(4)+Aj(5)) ; (Aj(2)+Aj(3)) ; Aj(6) ; (Aj(2)-Aj(3))*0.065 ; (Aj(4)-
Aj(5))*0.065].*g;

% Transform the forces and moments to the body axis

FM = [Aj(1) ; (Aj(4)+Aj(5)) ; (Aj(2)+Aj(3)) ; Aj(6) ; (Aj(2)-Aj(3))*0.065 ; (Aj(4)-
Aj(5))*0.065].*g;

% Transform the forces and moments to the C.G of the flight vehicle

FMcg = TM * FM;
```

```
% The variation of longitudinal force and moment coefficients

Cf = (1/(DyHi*Sref)).*[FMcg(1:3)];

Cm = (1/(DyHi*Sref*Le)).*[FMcg(4:6)];


Pitch = (DSi(j,2));

% Variation of Aerodynamic force coefficients with angle of attack

Aero_TM = [ sind(Pitch) 0 -cosd(Pitch)

-cosd(Pitch) 0 -sind(Pitch)

0 1 0];

Aero_Coeff = Aero_TM*Cf;

% Recording The Data

Alpha = [Alpha; Pitch];

C_m = [C_m; Cm'];


end

% Iterating the x (from Balance center) value to obtain Cm_\alpha

figure(i)

A = Alpha(:,1);

ct = C_m(:,2);

hold on

plot(A,ct)

hold off

xlabel('\alpha')

ylabel('Cm')

ylim([-2 2])

title('Iterating the x to obtain Cm_\alpha')

%legend('Xcg1=0.10','Xcg2=0.11','Xcg3=0.12','Xcg4=0.13','Xcg5=0.14','Xcg6=0.15','Xcg7
=0.16','Xcg8=0.17','Xcg9=0.18')
```

```
legend('Xcg1=-0.4','Xcg2=-0.3','Xcg3=-0.2','Xcg4=-
0.1','Xcg5=0','Xcg6=0.1','Xcg7=0.2','Xcg8=0.3','Xcg9=0.4')

grid on

end

end

% Most horizontal line of the Output Graph is for x = 0.1 to 0.2

% Let Neutral Point be

X_bnp = 0.15; %distance between Balence Center and Neutral Point

disp(['distance between Balence Center and Neutral Point is--> ', num2str(X_bnp) '
m'])


X_np = X_bc - X_bnp; % distance of Balence Center from Nose of missile

disp(['distance of Neutral Point from Nose of missile is--> ', num2str(X_np) ' m'])


% Assuming Static Margine ( = 15%Le )

disp('Assuming Static Margine 15% of length of missile')

SM = 0.15*Le;

disp(['Static Margine is--> ', num2str(SM) ' m'])


% distance between Balence Center and C.G

X_bg = X_bnp + SM;

disp(['distance between Balence Center and C.G is--> ', num2str(X_bg) ' m'])


X_cg = X_np-SM;

disp(['distance of C.G. from Nose of missile is--> ', num2str(X_cg) ' m'])
```

OUTPUT:

distance between Balence Center and Neutral Point is--> 0.15 m

distance of Neutral Point from Nose of missile is--> 0.315 m

Assuming Static Margine 15% of length of missile

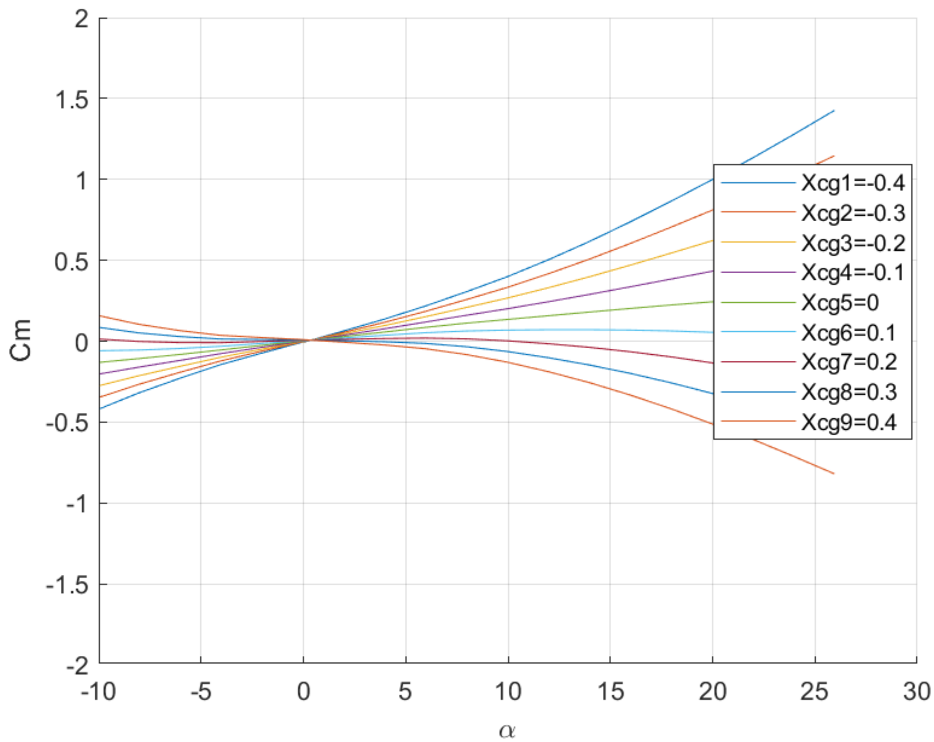
Static Margine is--> 0.1326 m

distance between Balence Center and C.G is--> 0.2826 m

distance of C.G. from Nose of missile is--> 0.1824 m

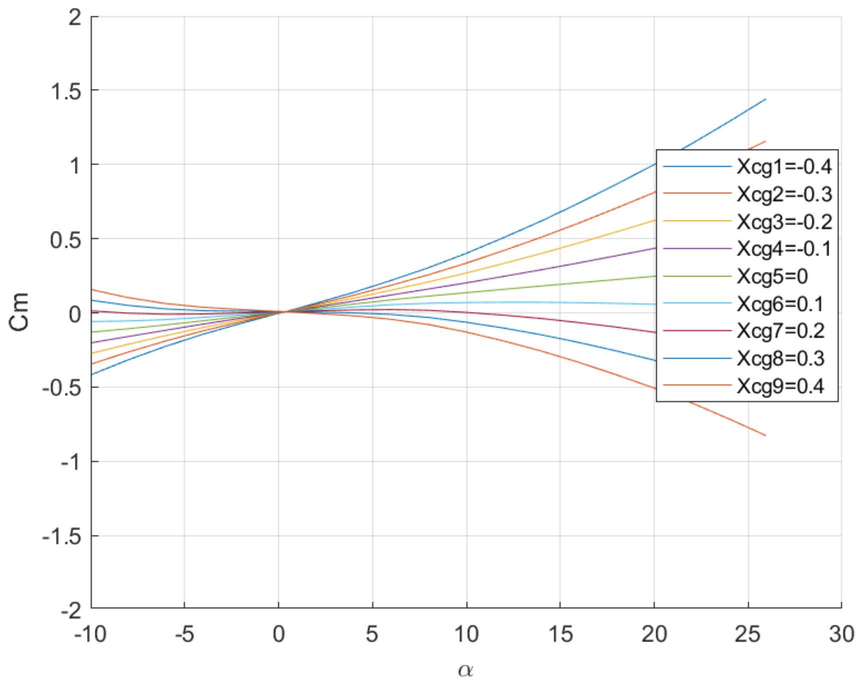
iterative the x to obtain C.G location

V1 = 40m/s

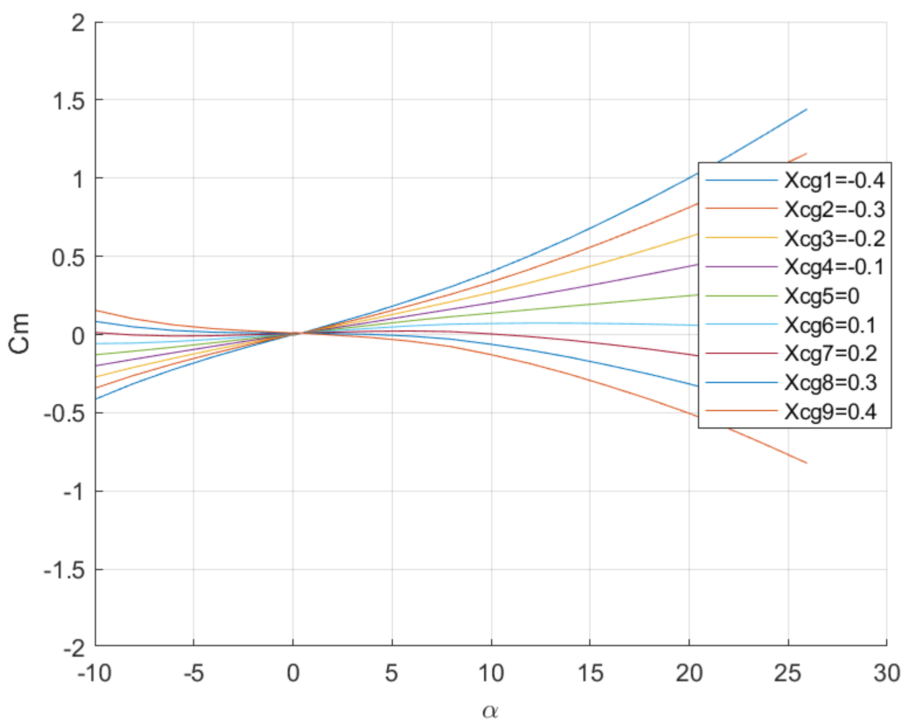


.

V2 = 50m/s


Cm
α
Xcg1=-0.4
Xcg2=-0.3
Xcg3=-0.2
Xcg4=-0.1
Xcg5=0
Xcg6=0.1
Xcg7=0.2
Xcg8=0.3
Xcg9=0.4

V3 = 60 m/s


Cm
α
Xcg1=-0.4
Xcg2=-0.3
Xcg3=-0.2
Xcg4=-0.1
Xcg5=0
Xcg6=0.1
Xcg7=0.2
Xcg8=0.3
Xcg9=0.4

Now we will calculate force and moment coefficients with use of location C.G we obtained above.

We will use formulas mentioned in PPT.

MATLAB CODE: force_and_moment_coefficient_Body_Alone.m

```
% 6680 5/7/2010 11:02:55 AM

% Bomb Model-II Body Alone Configuration

format long g


g = 9.81;

Cl = [];

Alpha = [];

C_m = [];


%Balance load matrix

CM = [63.080043 0.144499 -0.206795 1.354260 1.630051 4.275882

-0.123649 150.309342 0.592082 -0.725847 0.030856 0.393628

0.024098 -0.689773 151.831777 0.096597 -0.571799 -4.414537

0.152944 -2.334107 0.037781 77.595997 0.445712 5.841784

-0.006030 0.114642 -0.574072 -0.065800 79.176337 0.322466

0.047415 0.466131 0.099431 0.208017 0.190935 44.877349 ];


% Model reference parameters

% Sref(sqm) Chord (m) Span (m)

Sref = 0.009677; c = 0.111; b = 0.111;


% Moment reference point (nose)
```

```
% X (m) Y (m) Z (m)

% 0 0 0


% Balance center location

%X (m) Y (m) Z (m)

X =-0.465; Y = 0; Z = 0;


% Nowind data

% Ax N1 N2 S1 S2 Rm

NW = [-0.001023; 0.001298; 0.001474; -0.000501; -0.000191; -0.000147];


for i = 1:3

if i == 1

%Data for Speed 1

DyHi = 974.329545;

% Dyn. head Pitch Yaw Roll Ax N1 N2 S1 S2 Rm

DSi = [ 974.329545 -9.947917 0.000000 0.000000 0.002673 -0.006420 0.005058 -0.001114
0.000491 -0.000003 %1

974.329545 -8.052083 0.000000 0.000000 0.002539 -0.004903 0.004606 -0.000981 0.000274
-0.000041 %2

974.329545 -6.052083 0.000000 0.000000 0.002434 -0.003329 0.003960 -0.000981 0.000253
-0.000068 %3

974.329545 -4.062500 0.000000 0.000000 0.002377 -0.001724 0.003177 -0.000968 0.000107
-0.000071 %4

974.329545 -2.052083 0.000000 0.000000 0.002325 -0.000170 0.002245 -0.000885 0.000153
-0.000090 %5

974.329545 -0.052083 0.000000 0.000000 0.002249 0.001322 0.001340 -0.000831 0.000072
-0.000128 %6

974.329545 0.052083 0.000000 0.000000 0.002201 0.001334 0.001344 -0.000864 0.000120 -
0.000131 %7
```

```
974.329545 1.947917 0.000000 0.000000 0.002324 0.002779 0.000499 -0.000783 0.000108 -
0.000153 %8

974.329545 3.947917 0.000000 0.000000 0.002385 0.004320 -0.000380 -0.000745 -0.000003
-0.000158 %9

974.329545 5.947917 0.000000 0.000000 0.002458 0.005940 -0.001250 -0.000692 -0.000010
-0.000191 %10

974.329545 7.947917 0.000000 0.000000 0.002611 0.007523 -0.001939 -0.000602 -0.000087
-0.000206 %11

974.329545 9.947917 0.000000 0.000000 0.002765 0.009013 -0.002427 -0.000612 -0.000136
-0.000233 %12

974.329545 11.947917 0.000000 0.000000 0.002850 0.010588 -0.002839 -0.000578 -
0.000102 -0.000257 %13

974.329545 13.947917 0.000000 0.000000 0.002862 0.012207 -0.003176 -0.000626 -
0.000078 -0.000250 %14

974.329545 15.937500 0.000000 0.000000 0.002895 0.013871 -0.003436 -0.000631 -
0.000056 -0.000280 %15

974.329545 17.937500 0.000000 0.000000 0.002860 0.015556 -0.003610 -0.000583 -
0.000413 -0.000303 %16

974.329545 19.947917 0.000000 0.000000 0.002808 0.017221 -0.003662 -0.000535 -
0.000676 -0.000332 %17

974.329545 21.947917 0.000000 0.000000 0.002689 0.018903 -0.003702 -0.000579 -
0.000642 -0.000360 %18

974.329545 23.947917 0.000000 0.000000 0.002521 0.020650 -0.003677 -0.000634 -
0.000730 -0.000392 %19

974.329545 25.947917 0.000000 0.000000 0.002294 0.022447 -0.003645 -0.000538 -
0.001077 -0.000409];%20

end

if i == 2

%Data for Speed 2

DyHi = 1499.272727;

% Dyn. head Pitch Yaw Roll Ax N1 N2 S1 S2 Rm

DSi = [ 1499.272727 -9.947917 0.000000 0.000000 0.004587 -0.010519 0.006953 -0.001412
0.000946 -0.000015
```

1499.272727 -8.052083 0.000000 0.000000 0.004404 -0.008223 0.006295 -0.001239 0.000592 -0.000048

1499.272727 -6.052083 0.000000 0.000000 0.004210 -0.005792 0.005321 -0.001273 0.000473 -0.000069

1499.272727 -4.062500 0.000000 0.000000 0.004093 -0.003315 0.004037 -0.001198 0.000382 -0.000141

1499.272727 -2.052083 0.000000 0.000000 0.004003 -0.000914 0.002615 -0.001125 0.000283 -0.000183

1499.272727 -0.052083 0.000000 0.000000 0.003968 0.001367 0.001249 -0.000983 0.000286 -0.000204

1499.272727 0.052083 0.000000 0.000000 0.003890 0.001442 0.001190 -0.001057 0.000316 -0.000323

1499.272727 1.947917 0.000000 0.000000 0.004016 0.003680 -0.000143 -0.000923 0.000177 -0.000222

1499.272727 3.947917 0.000000 0.000000 0.004096 0.006063 -0.001533 -0.000902 0.000197 -0.000269

1499.272727 5.947917 0.000000 0.000000 0.004177 0.008541 -0.002856 -0.000859 0.000128 -0.000303

1499.272727 7.947917 0.000000 0.000000 0.004368 0.010913 -0.003881 -0.000755 -0.000020 -0.000341

1499.272727 9.947917 0.000000 0.000000 0.004593 0.013239 -0.004599 -0.000664 -0.000136 -0.000388

1499.272727 11.947917 0.000000 0.000000 0.004712 0.015682 -0.005213 -0.000669 -0.000025 -0.000397

1499.272727 13.947917 0.000000 0.000000 0.004752 0.018147 -0.005713 -0.000716 0.000002 -0.000445

1499.272727 15.937500 0.000000 0.000000 0.004759 0.020667 -0.006095 -0.000655 -0.000346 -0.000474

1499.272727 17.937500 0.000000 0.000000 0.004694 0.023277 -0.006399 -0.000509 -0.000902 -0.000543

1499.272727 19.947917 0.000000 0.000000 0.004571 0.025917 -0.006611 -0.000528 -0.001019 -0.000597

1499.272727 21.947917 0.000000 0.000000 0.004370 0.028594 -0.006665 -0.000663 -0.001004 -0.000622

```
1499.272727 23.947917 0.000000 0.000000 0.004114 0.031377 -0.006636 -0.000697 -
0.001170 -0.000684

1499.272727 25.947917 0.000000 0.000000 0.003761 0.034218 -0.006530 -0.000258 -
0.002047 -0.000730 ];

end

if i == 3

% Data for Speed 3

DyHi = 2172.920455;

% Dyn. head Pitch Yaw Roll Ax N1 N2 S1 S2 Rm

DSi = [ 2172.920455 -9.947917 0.000000 0.000000 0.006916 -0.015706 0.009377 -0.001872
0.001380 -0.000105

2172.920455 -8.052083 0.000000 0.000000 0.006651 -0.012341 0.008425 -0.001672
0.001040 -0.000155

2172.920455 -6.052083 0.000000 0.000000 0.006393 -0.008838 0.006984 -0.001653
0.000856 -0.000195

2172.920455 -4.062500 0.000000 0.000000 0.006240 -0.005337 0.005156 -0.001549
0.000713 -0.000230

2172.920455 -2.062500 0.000000 0.000000 0.006160 -0.001847 0.003104 -0.001436
0.000613 -0.000284

2172.920455 -0.052083 0.000000 0.000000 0.006067 0.001535 0.001050 -0.001293 0.000493
-0.000336

2172.920455 0.052083 0.000000 0.000000 0.006014 0.001550 0.000960 -0.001306 0.000575
-0.000463

2172.920455 1.947917 0.000000 0.000000 0.006095 0.004862 -0.000972 -0.001223 0.000523
-0.000381

2172.920455 3.947917 0.000000 0.000000 0.006189 0.008310 -0.002973 -0.001107 0.000492
-0.000439

2172.920455 5.937500 0.000000 0.000000 0.006286 0.011904 -0.004877 -0.001010 0.000424
-0.000466

2172.920455 7.947917 0.000000 0.000000 0.006565 0.015344 -0.006404 -0.000883 0.000258
-0.000525

2172.920455 9.947917 0.000000 0.000000 0.006871 0.018639 -0.007381 -0.000782 0.000164
-0.000568
```

```
2172.920455 11.947917 0.000000 0.000000 0.006984 0.022162 -0.008318 -0.000734
0.000160 -0.000631

2172.920455 13.947917 0.000000 0.000000 0.007035 0.025766 -0.009044 -0.000795 -
0.000042 -0.000673

2172.920455 15.937500 0.000000 0.000000 0.007042 0.029433 -0.009589 -0.000700 -
0.000477 -0.000759

2172.920455 17.937500 0.000000 0.000000 0.006945 0.033266 -0.010124 -0.000538 -
0.001151 -0.000813

2172.920455 19.947917 0.000000 0.000000 0.006745 0.037188 -0.010493 -0.000556 -
0.001314 -0.000870

2172.920455 21.947917 0.000000 0.000000 0.006498 0.041137 -0.010671 -0.000674 -
0.001308 -0.000959

2172.920455 23.937500 0.000000 0.000000 0.006105 0.045155 -0.010599 -0.000880 -
0.001188 -0.001035

2172.920455 25.947917 0.000000 0.000000 0.005570 0.049182 -0.010379 -0.000121 -
0.002440 -0.001125 ];


end

Le = 0.884;

% Transformation Matrix from CG to Body center

x = 0.2826; % Xnp --> 0.315 (Neutral point from nose)

y = 0;

z = 0;

TM =[-1, 0, 0, 0, 0, 0

0, 1, 0, 0, 0, 0

0, 0, -1, 0, 0, 0

0, -z, y, 1, 0, 0

z, 0, -x, 0, 1, 0

-y, x, 0, 0, 0, 1]; % Doubt
```

```
for j = 1:20

aj = [DSi(j,5) ; DSi(j,6) ; DSi(j,7) ; DSi(j,8) ; DSi(j,9) ; DSi(j,10)];

% Convert the obtained normalized voltage signals to kg

Aj = CM * (aj-NW);

% Calculate the forces and moments about the balance center

fm = [Aj(1) ; (Aj(4)+Aj(5)) ; (Aj(2)+Aj(3)) ; Aj(6) ; (Aj(2)-Aj(3))*0.065 ; (Aj(4)-
Aj(5))*0.065].*g;

% Transform the forces and moments to the body axis

FM = [Aj(1) ; (Aj(4)+Aj(5)) ; (Aj(2)+Aj(3)) ; Aj(6) ; (Aj(2)-Aj(3))*0.065 ; (Aj(4)-
Aj(5))*0.065].*g;

% Transform the forces and moments to the C.G of the flight vehicle

FMcg = TM * FM;

% The variation of longitudinal force and moment coefficients

Cf = (1/(DyHi*Sref)).*[FMcg(1:3)];

Cm = (1/(DyHi*Sref*Le)).*[FMcg(4:6)];

Pitch = (DSi(j,2));

% Variation of Aerodynamic force coefficients with angle of attack

Aero_TM = [ sind(Pitch) 0 -cosd(Pitch)

-cosd(Pitch) 0 -sind(Pitch)

0 1 0];

Aero_Coeff = Aero_TM*Cf;

% Recording The Data

Alpha = [Alpha; Pitch'];

Cl = [Cl; Aero_Coeff'];

C_m = [C_m; Cm'];


end

end
```

```
A1= Alpha(1:20);

B1= Cl(1:20,1);

C1= Cl(1:20,2);

D1= C_m(1:20,2);

A2= Alpha(21:40);

B2= Cl(21:40,1);

C2= Cl(21:40,2);

D2= C_m(21:40,2);

A3= Alpha(41:60);

B3= Cl(41:60,1);

C3= Cl(41:60,2);

D3= C_m(41:60,2);

E1 = B1./C1;

E2 = B2./C2;

E3 = B3./C3;

F1 = B1.^2;

F2 = B2.^2;

F3 = B3.^2;


% Calculating Slope of Moment Coefficient

%For V1

cc1=0;

Cm_Alpha1i = 0;

Cl_Alpha1i = 0;

k1_i=0;

for l = 2:1:20

D_Alpha1 = A1(l)-A1(l-1) ;
```

```
D_Cl1 = B1(l)-B1(l-1);

D_Cm1 = D1(l)-D1(l-1);

D_Cd1 = C1(l)-C1(l-1);

D_Cl_2= F1(l)-F1(l-1);

Cm_alpha1 = D_Cm1/D_Alpha1;

Cl_alpha1 = D_Cl1/D_Alpha1;

k1 = D_Cd1/D_Cl_2;

Cl_Alpha1i = Cl_Alpha1i + Cl_alpha1;

Cm_Alpha1i = Cm_Alpha1i + Cm_alpha1;

k1_i = k1_i + k1;

cc1 = cc1+1;

end

F_Cm_Alpha1 = Cm_Alpha1i/cc1;

F_Cl_Alpha1 = Cl_Alpha1i/cc1;

F_k1 = k1_i/cc1;

F_Cl_01 = (B1(7)+B1(6))./2;

F_Cd_01 = (C1(7)+C1(6))./2;

F_Cm_01 = (D1(6)+D1(7))./2;


disp('For V1 = 40 m/s')

disp('Average value of Cl_alpha')

disp(F_Cl_Alpha1)

disp('Average value of Cm_alpha')

disp(F_Cm_Alpha1)

disp('Average value of Cl_0')

disp(F_Cl_01)

disp('Average value of Cd_0')

disp(F_Cd_01)
```

```
disp('Average value of Cm_0')

disp(F_Cm_01)

disp('Average value of Oswald Factor')

disp(k1)

%For V2

cc2=0;

Cm_Alpha2i = 0;

Cl_Alpha2i = 0;

k2_i=0;

for l = 2:1:20

D_Alpha2 = A2(l)-A2(l-1) ;

D_Cl2 = B2(l)-B2(l-1);

D_Cm2 = D2(l)-D2(l-1);

D_Cd2 = C2(l)-C2(l-1);

D_Cl_22= F2(l)-F2(l-1);

Cm_alpha2 = D_Cm2/D_Alpha2;

Cl_alpha2 = D_Cl2/D_Alpha2;

k2 = D_Cd2/D_Cl_22;

Cl_Alpha2i = Cl_Alpha2i + Cl_alpha2;

Cm_Alpha2i = Cm_Alpha2i + Cm_alpha2;

k2_i = k2_i + k2;

cc2 = cc2+1;

end

F_Cm_Alpha2 = Cm_Alpha2i/cc2;

F_Cl_Alpha2 = Cl_Alpha2i/cc2;

F_k2 = k2_i/cc2;

F_Cl_02 = (B2(7)+B2(6))./2;

F_Cd_02 = (C2(7)+C2(6))./2;
```

```
F_Cm_02 = (D2(6)+D2(7))./2;

disp('For V2 = 50 m/s')

disp('Average value of Cl_alpha')

disp(F_Cl_Alpha2)

disp('Average value of Cm_alpha')

disp(F_Cm_Alpha2)

disp('Average value of Cl_0')

disp(F_Cl_02)

disp('Average value of Cd_0')

disp(F_Cd_02)

disp('Average value of Cm_0')

disp(F_Cm_02)

disp('Average value of Oswald Factor')

disp(k2)

%For V3

cc3=0;

Cm_Alpha3i = 0;

Cl_Alpha3i = 0;

k3_i=0;

for l = 2:1:20

D_Alpha3 = A3(l)-A3(l-1) ;

D_Cl3 = B3(l)-B3(l-1);

D_Cm3 = D3(l)-D3(l-1);

D_Cd3 = C3(l)-C3(l-1);

D_Cl_23= F3(l)-F3(l-1);

k3 = D_Cd3/D_Cl_23;

Cm_alpha3 = D_Cm3/D_Alpha3;

Cl_alpha3 = D_Cl3/D_Alpha3;
```

```
Cl_Alpha3i = Cl_Alpha3i + Cl_alpha3;

Cm_Alpha3i = Cm_Alpha3i + Cm_alpha3;

k3_i = k3_i + k3;

cc3 = cc3+1;

end

F_Cm_Alpha3 = Cm_Alpha3i/cc3;

F_Cl_Alpha3 = Cl_Alpha3i/cc3;

F_k3 = k3_i/cc3;

F_Cl_03 = (B3(7)+B3(6))./2;

F_Cd_03 = (C3(7)+C3(6))./2;

F_Cm_03 = (D3(6)+D3(7))./2;

disp('For V3 = 60 m/s')

disp('Average value of Cl_alpha')

disp(F_Cl_Alpha3)

disp('Average value of Cm_alpha')

disp(F_Cm_Alpha3)

disp('Average value of Cl_0')

disp(F_Cl_03)

disp('Average value of Cd_0')

disp(F_Cd_03)

disp('Average value of Cm_0')

disp(F_Cm_03)

disp('Average value of Oswald Factor')

disp(k3)


figure(1)

subplot(4,1,1)

hold on
```

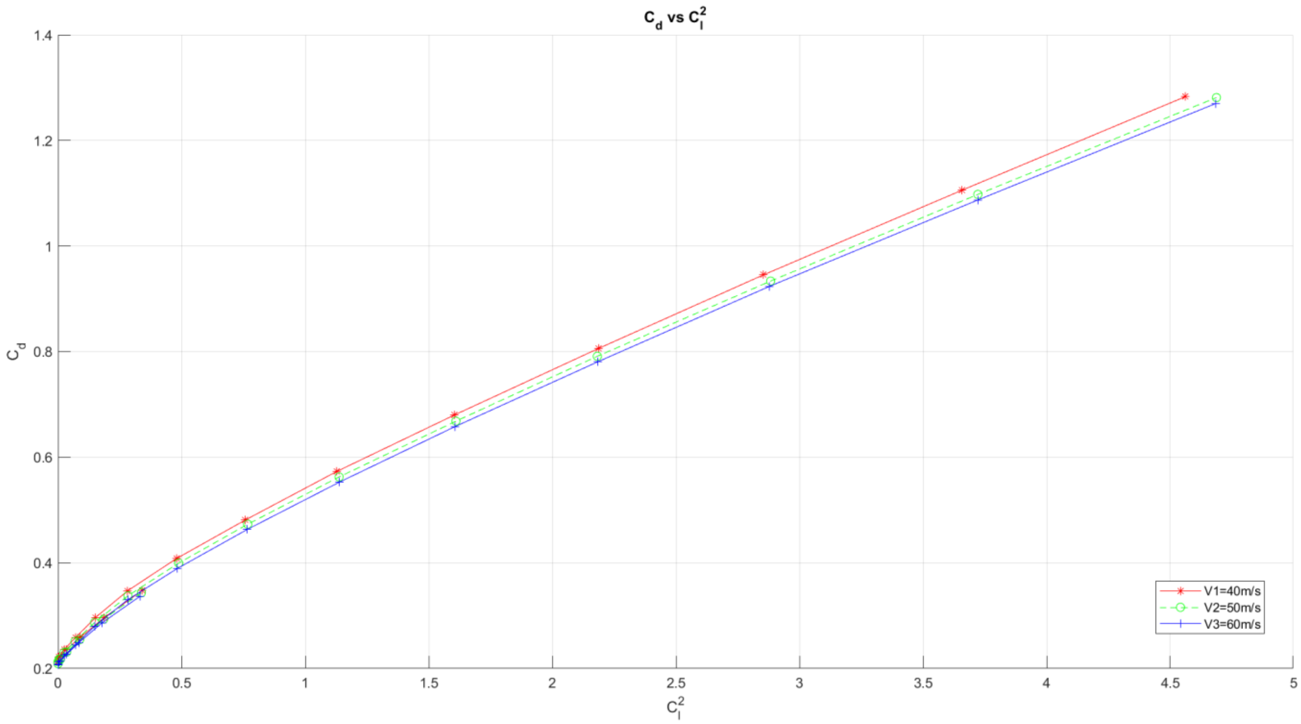
```
plot(A1,B1,'r-*',A2,B2,'g--o',A3,B3,'b-+')

hold off

%xlabel('\alpha')

ylabel('Cl')

title('C_l vs \alpha')

legend('V1=40m/s','V2=50m/s','V3=60m/s')

grid on

subplot(4,1,2)

hold on

plot(A1,C1,'r-*',A2,C2,'g--o',A3,C3,'b-+')

hold off

%xlabel('\alpha')

ylabel('C_d')

title('C_d vs \alpha')

legend('V1=40m/s','V2=50m/s','V3=60m/s')

grid on

subplot(4,1,3)

hold on

plot(A1,E1,'r-*',A2,E2,'g--o',A3,E3,'b-+')

hold off

%xlabel('\alpha')

ylabel('C_l/C_d')

title('C_l/C_d vs \alpha')

legend('V1=40m/s','V2=50m/s','V3=60m/s')

grid on

subplot(4,1,4)

hold on

plot(A1,D1,'r-*',A2,D2,'g--o',A3,D3,'b-+')
```

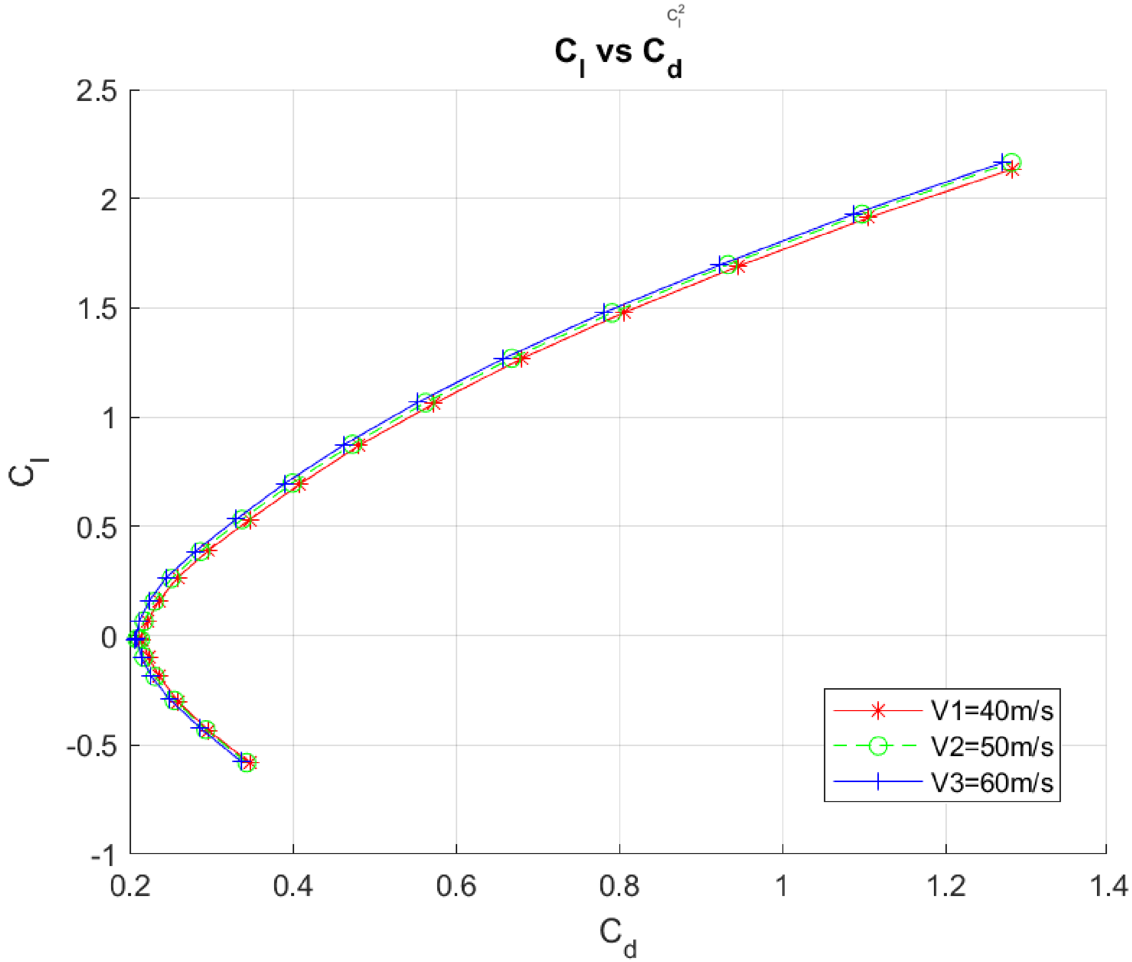
```
hold off
xlabel('\alpha')
ylabel('C_m')
%%%ylim([-2 2])
title('C_m vs \alpha')
legend('V1=40m/s','V2=50m/s','V3=60m/s')
grid on


figure(2)
hold on
plot(F1,C1,'r-*',F2,C2,'g--o',F3,C3,'b-+')
hold off
xlabel('C_l^2')
ylabel('C_d')
title('C_d vs C_l^2')
legend('V1=40m/s','V2=50m/s','V3=60m/s')
grid on

figure(3)
hold on
plot(C1,B1,'r-*',C2,B2,'g--o',C3,B3,'b-+')
hold off
xlabel('C_d')
ylabel('C_l')
title('C_l vs C_d')
legend('V1=40m/s','V2=50m/s','V3=60m/s')
grid on
```

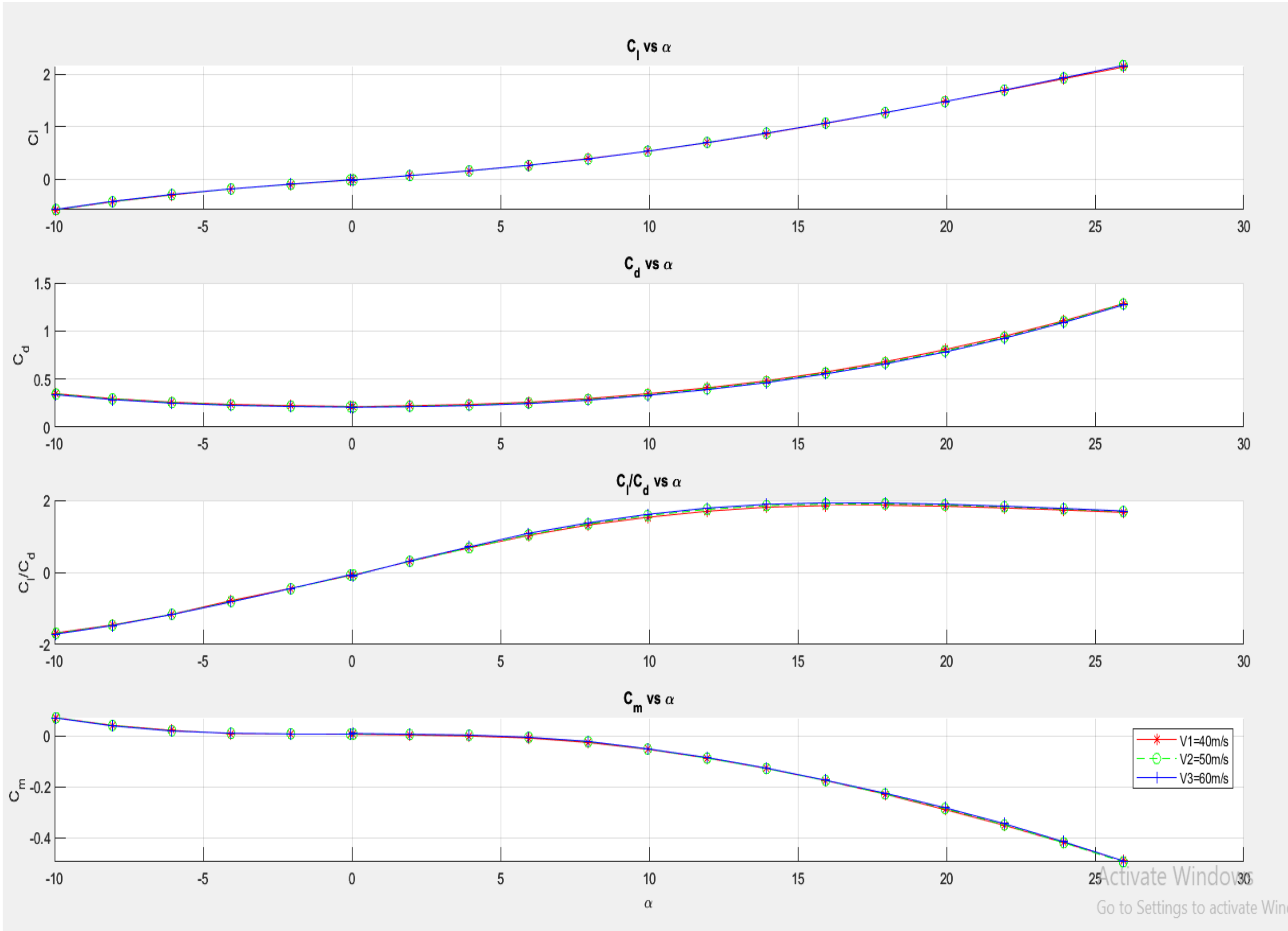
OUTPUT:

```
force_and_moment_coefficient_Body_Alone
For V1 = 40 m/s
Average value of Cl_alpha
        0.0728969115012749

Average value of Cm_alpha
       -0.0151795915834499

Average value of Cl_0
       -0.0166065764616073

Average value of Cd_0
         0.213282452770011

Average value of Cm_0
       0.00718791617937718

For V2 = 50 m/s
Average value of Cl_alpha
        0.0733013983311215

Average value of Cm_alpha
       -0.0147678688646993

Average value of Cl_0
       -0.0154292306888482

Average value of Cd_0
         0.210989754026491

Average value of Cm_0
       0.00761791887737838

For V3 = 60 m/s
Average value of Cl_alpha
         0.069813018287473

Average value of Cm_alpha
       -0.0137812880013573

Average value of Cl_0
       -0.0160864672953191

Average value of Cd_0
         0.207474637871017
```

```
Average value of Cm_0
       0.00880261669599957
```


C_d vs C_l^2
C_d
C_l^2
V1=40m/s
V2=50m/s
V3=60m/s


C_l vs C_d
C_l
C_d
V1=40m/s
V2=50m/s
V3=60m/s



C_l vs α
Cl
C_d vs α
C_d
C_l/C_d vs α
C_l/C_d
C_m vs α
C_m
α
V1=40m/s
V2=50m/s
V3=60m/s

MATLAB CODE: Calculation_X_cg_TF_0.m

```
% 6682 5/7/2010 12:18:07 PM

% Bomb Model-II Body + TailFins + delta 0

format long g


g = 9.81;

Cl = [];

Alpha = [];

C_m = [];


%Balance load matrix

CM = [63.080043 0.144499 -0.206795 1.354260 1.630051 4.275882

-0.123649 150.309342 0.592082 -0.725847 0.030856 0.393628

0.024098 -0.689773 151.831777 0.096597 -0.571799 -4.414537

0.152944 -2.334107 0.037781 77.595997 0.445712 5.841784

-0.006030 0.114642 -0.574072 -0.065800 79.176337 0.322466

0.047415 0.466131 0.099431 0.208017 0.190935 44.877349 ];


% Model reference parameters

% Sref(sqm) Chord (m) Span (m)

Sref = 0.009677; c = 0.111; b = 0.111;


% Moment reference point (nose)

% X (m) Y (m) Z (m)

% 0 0 0


% Balance center location

%X (m) Y (m) Z (m)
```

```
X =-0.465; Y = 0; Z = 0;

X_bc = 0.465 ; % distance from Balence Center to Nose of missile


% Nowind data

% Ax N1 N2 S1 S2 Rm

NW = [-0.000122 -0.000856 0.000737 -0.000887 -0.000321 0.000540];


for i = 1:3

if i == 1

% Data for Speed 1

DyHi = 963.625000;

% Dyn. head Pitch Yaw Roll Ax N1 N2 S1 S2 Rm

DSi = [ 963.625000 -9.947917 0.000000 0.000000 0.004041 0.010666 -0.025613 0.000252 -
0.001648 0.000556

963.625000 -8.052083 0.000000 0.000000 0.004303 0.008047 -0.019603 0.000321 -0.001890
0.000534

963.625000 -6.052083 0.000000 0.000000 0.004447 0.005590 -0.013974 0.000369 -0.002227
0.000534

963.625000 -4.062500 0.000000 0.000000 0.004555 0.003472 -0.009070 0.000284 -0.002226
0.000534

963.625000 -2.062500 0.000000 0.000000 0.004576 0.001695 -0.004794 0.000163 -0.002093
0.000550

963.625000 -0.052083 0.000000 0.000000 0.004651 0.000305 -0.001106 0.000120 -0.002148
0.000567

963.625000 0.052083 0.000000 0.000000 0.004584 0.000547 -0.001454 0.000067 -0.002030
0.000546

963.625000 1.947917 0.000000 0.000000 0.004693 -0.000915 0.002245 -0.000069 -0.001849
0.000555

963.625000 3.947917 0.000000 0.000000 0.004635 -0.002199 0.005815 -0.000038 -0.001871
0.000523

963.625000 5.947917 0.000000 0.000000 0.004555 -0.003961 0.010213 -0.000020 -0.002064
0.000510
```

```
963.625000 7.947917 0.000000 0.000000 0.004402 -0.006041 0.015162 0.000073 -0.002172
0.000510

963.625000 9.947917 0.000000 0.000000 0.004198 -0.008423 0.020711 0.000142 -0.002359
0.000489

963.625000 11.947917 0.000000 0.000000 0.003985 -0.011058 0.026797 0.000099 -0.002414
0.000472

963.625000 13.947917 0.000000 0.000000 0.003639 -0.013887 0.033287 -0.000001 -
0.002484 0.000497

963.625000 15.937500 0.000000 0.000000 0.003190 -0.016762 0.040025 -0.000171 -
0.002655 0.000532

963.625000 17.947917 0.000000 0.000000 0.002619 -0.019732 0.046936 -0.000346 -
0.002734 0.000544

963.625000 19.947917 0.000000 0.000000 0.002035 -0.022735 0.054030 -0.000156 -
0.003364 0.000573

963.625000 21.947917 0.000000 0.000000 0.001441 -0.025527 0.060936 0.000338 -0.004356
0.000604

963.625000 23.947917 0.000000 0.000000 0.000957 -0.028028 0.067456 0.000961 -0.005535
0.000605

963.625000 25.947917 0.000000 0.000000 0.000578 -0.030400 0.073778 0.001760 -0.006996
0.000559];%20

end

if i == 2

%Data for Speed 2

DyHi = 1499.386364;

% Dyn. head Pitch Yaw Roll Ax N1 N2 S1 S2 Rm

DSi = [ 1499.386364 -9.947917 0.000000 0.000000 0.006192 0.017118 -0.040181 0.000769
-0.002234 0.000427

1499.386364 -8.052083 0.000000 0.000000 0.006619 0.012885 -0.030711 0.000806 -
0.002535 0.000410

1499.386364 -6.052083 0.000000 0.000000 0.006860 0.009008 -0.021985 0.000831 -
0.002845 0.000420

1499.386364 -4.062500 0.000000 0.000000 0.006959 0.005793 -0.014346 0.000839 -
0.003119 0.000437
```

```
1499.386364 -2.062500 0.000000 0.000000 0.007005 0.003054 -0.007697 0.000672 -
0.002936 0.000459

1499.386364 -0.052083 0.000000 0.000000 0.007247 0.000935 -0.002148 0.000640 -
0.002946 0.000453

1499.386364 0.052083 0.000000 0.000000 0.007197 0.001408 -0.002803 0.000683 -0.003116
0.000353

1499.386364 1.947917 0.000000 0.000000 0.007292 -0.000859 0.002949 0.000351 -0.002659
0.000453

1499.386364 3.947917 0.000000 0.000000 0.007147 -0.002855 0.008485 0.000383 -0.002782
0.000404

1499.386364 5.947917 0.000000 0.000000 0.006977 -0.005520 0.015198 0.000453 -0.003028
0.000383

1499.386364 7.947917 0.000000 0.000000 0.006738 -0.008735 0.022893 0.000535 -0.003259
0.000389

1499.386364 9.947917 0.000000 0.000000 0.006384 -0.012340 0.031270 0.000529 -0.003350
0.000388

1499.386364 11.947917 0.000000 0.000000 0.005978 -0.016281 0.040472 0.000398 -
0.003254 0.000395

1499.386364 13.947917 0.000000 0.000000 0.005398 -0.020568 0.050442 0.000122 -
0.003142 0.000422

1499.386364 15.937500 0.000000 0.000000 0.004632 -0.024889 0.060678 -0.000161 -
0.003173 0.000425

1499.386364 17.947917 0.000000 0.000000 0.003812 -0.029468 0.071419 -0.000126 -
0.003874 0.000452

1499.386364 19.947917 0.000000 0.000000 0.002842 -0.034292 0.082750 0.000341 -
0.004938 0.000484

1499.386364 21.947917 0.000000 0.000000 0.001930 -0.038580 0.093416 0.000817 -
0.006238 0.000512

1499.386364 23.947917 0.000000 0.000000 0.001100 -0.042682 0.103847 0.001550 -
0.007834 0.000488

1499.386364 25.947917 0.000000 0.000000 0.000524 -0.046475 0.113832 0.002517 -
0.009531 0.000386];

end

if i == 3
```

```
% Data for Speed 3

DyHi = 2161.352273;

% Dyn. head Pitch Yaw Roll Ax N1 N2 S1 S2 Rm

DSi = [ 2161.352273 -9.947917 0.000000 0.000000 0.008836 0.024858 -0.057997 0.001269
-0.002600 0.000182

2161.352273 -8.052083 0.000000 0.000000 0.009400 0.018713 -0.044275 0.001252 -
0.003004 0.000222

2161.352273 -6.052083 0.000000 0.000000 0.009780 0.013089 -0.031601 0.001283 -
0.003549 0.000215

2161.352273 -4.062500 0.000000 0.000000 0.009910 0.008425 -0.020681 0.001316 -
0.003819 0.000239

2161.352273 -2.062500 0.000000 0.000000 0.010055 0.004581 -0.011271 0.001129 -
0.003798 0.000268

2161.352273 -0.052083 0.000000 0.000000 0.010363 0.001638 -0.003413 0.001218 -
0.003882 0.000298

2161.352273 0.052083 0.000000 0.000000 0.010244 0.002471 -0.004727 0.001314 -0.004084
0.000180

2161.352273 1.947917 0.000000 0.000000 0.010392 -0.000876 0.003781 0.000918 -0.003675
0.000277

2161.352273 3.947917 0.000000 0.000000 0.010159 -0.003681 0.011638 0.000994 -0.003892
0.000220

2161.352273 5.947917 0.000000 0.000000 0.009890 -0.007414 0.021119 0.001058 -0.004055
0.000184

2161.352273 7.947917 0.000000 0.000000 0.009468 -0.011798 0.031753 0.001049 -0.004277
0.000180

2161.352273 9.947917 0.000000 0.000000 0.008968 -0.016698 0.043510 0.000856 -0.004142
0.000195

2161.352273 11.947917 0.000000 0.000000 0.008362 -0.022478 0.057013 0.000479 -
0.003784 0.000237

2161.352273 13.947917 0.000000 0.000000 0.007455 -0.028467 0.071065 0.000064 -
0.003655 0.000255

2161.352273 15.947917 0.000000 0.000000 0.006470 -0.034854 0.085985 -0.000013 -
0.004102 0.000282
```

```
2161.352273 17.947917 0.000000 0.000000 0.005251 -0.041448 0.101465 0.000233 -
0.005264 0.000327

2161.352273 19.947917 0.000000 0.000000 0.003784 -0.048530 0.118006 0.000826 -
0.006890 0.000381

2161.352273 21.947917 0.000000 0.000000 0.002409 -0.054638 0.133241 0.001423 -
0.008337 0.000397

2161.352273 23.947917 0.000000 0.000000 0.001174 -0.060368 0.148189 0.002554 -
0.010377 0.000379

2161.352273 25.947917 0.000000 0.000000 0.000092 -0.065645 0.162470 0.003253 -
0.011682 0.000273];


end

Le = 0.884;

% Transformation Matrix from CG to Body center

for x = -0.4:0.1:0.4 % -0.2:0.01:-0.12

% Xnp --> 0.605 (x=-0.14)

y = 0;

z = 0;

TM =[-1, 0, 0, 0, 0, 0

0, 1, 0, 0, 0, 0

0, 0, -1, 0, 0, 0

0, -z, y, 1, 0, 0

z, 0, -x, 0, 1, 0

-y, x, 0, 0, 0, 1];


Alpha = [];

C_m = [];

for j = 1:20

aj = [DSi(j,5) ; DSi(j,6) ; DSi(j,7) ; DSi(j,8) ; DSi(j,9) ; DSi(j,10)];

% Convert the obtained normalized voltage signals to kg
```

```
Aj = CM * (aj-NW);

% Calculate the forces and moments about the balance center.

fm = [Aj(1) ; (Aj(4)+Aj(5)) ; (Aj(2)+Aj(3)) ; Aj(6) ; (Aj(2)-Aj(3))*0.065 ; (Aj(4)-
Aj(5))*0.065].*g;

% Transform the forces and moments to the body axis

FM = [Aj(1) ; (Aj(4)+Aj(5)) ; (Aj(2)+Aj(3)) ; Aj(6) ; (Aj(2)-Aj(3))*0.065 ; (Aj(4)-
Aj(5))*0.065].*g;

% Transform the forces and moments to the C.G of the flight vehicle

FMcg = TM * FM;

% The variation of longitudinal force and moment coefficients

Cf = (1/(DyHi*Sref)).*[FMcg(1:3)];

Cm = (1/(DyHi*Sref*Le)).*[FMcg(4:6)];


Pitch = (DSi(j,2));

% Variation of Aerodynamic force coefficients with angle of attack

Aero_TM = [ sind(Pitch) 0 -cosd(Pitch)

-cosd(Pitch) 0 -sind(Pitch)

0 1 0];

Aero_Coeff = Aero_TM*Cf;

% Recording The Data

Alpha = [Alpha; Pitch];

C_m = [C_m; Cm'];


end

% Iterating the x (from Balance center) value to obtain Cm_\alpha

figure(i)

A = Alpha(:,1);

ct = C_m(:,2);
```

```
hold on

plot(A,ct)

hold off

xlabel('\alpha')

ylabel('Cm')

ylim([-5 3])

title('Iterating the x to obtain Cm_\alpha')

%legend('Xcg1=0.10','Xcg2=0.11','Xcg3=0.12','Xcg4=0.13','Xcg5=0.14','Xcg6=0.15','Xcg7
=0.16','Xcg8=0.17','Xcg9=0.18')

legend('Xcg1=-0.4','Xcg2=-0.3','Xcg3=-0.2','Xcg4=-
0.1','Xcg5=0','Xcg6=0.1','Xcg7=0.2','Xcg8=0.3','Xcg9=0.4')

grid on

end

end

% Most horizontal line of the Output Graph is for x = -0.2 to -0.1

% Let Neutral Point be

X_bnp = -0.14; %distance between Balence Center and Neutral Point

disp(['distance between Balence Center and Neutral Point is--> ', num2str(X_bnp) '
m'])


X_np = X_bc - X_bnp; % distance of Balence Center from Nose of missile

disp(['distance of Neutral Point from Nose of missile is--> ', num2str(X_np) ' m'])


% Assuming Static Margine ( = 15%Le )

disp('Assuming Static Margine 15% of length of missile')

SM = 0.15*Le;

disp(['Static Margine is--> ', num2str(SM) ' m'])


% distance between Balence Center and C.G
```

```
X_bg = X_bnp + SM;

disp(['distance between Balence Center and C.G is--> ', num2str(X_bg) ' m'])


X_cg = X_np-SM;

disp(['distance of C.G. from Nose of missile is--> ', num2str(X_cg) ' m'])
```

OUTPUT:

distance between Balence Center and Neutral Point is--> -0.14 m

distance of Neutral Point from Nose of missile is--> 0.605 m

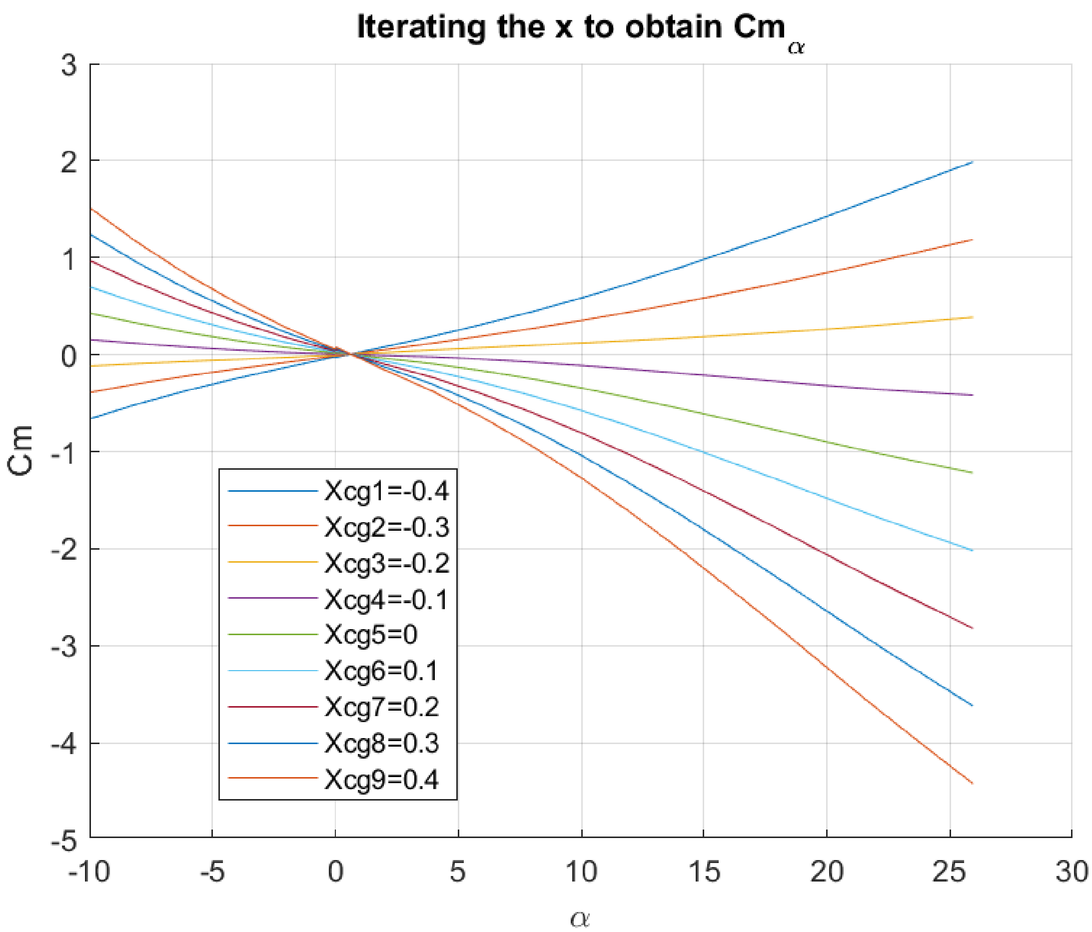
Assuming Static Margine 15% of length of missile

Static Margine is--> 0.1326 m

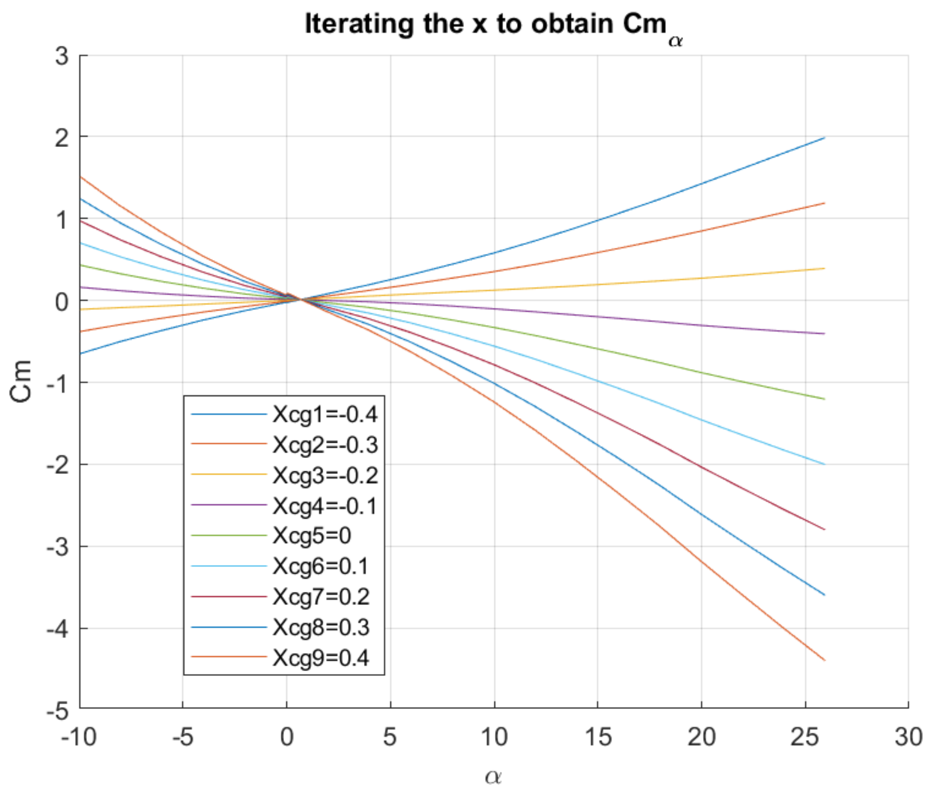
distance between Balence Center and C.G is--> -0.0074 m

distance of C.G. from Nose of missile is--> 0.4724 m

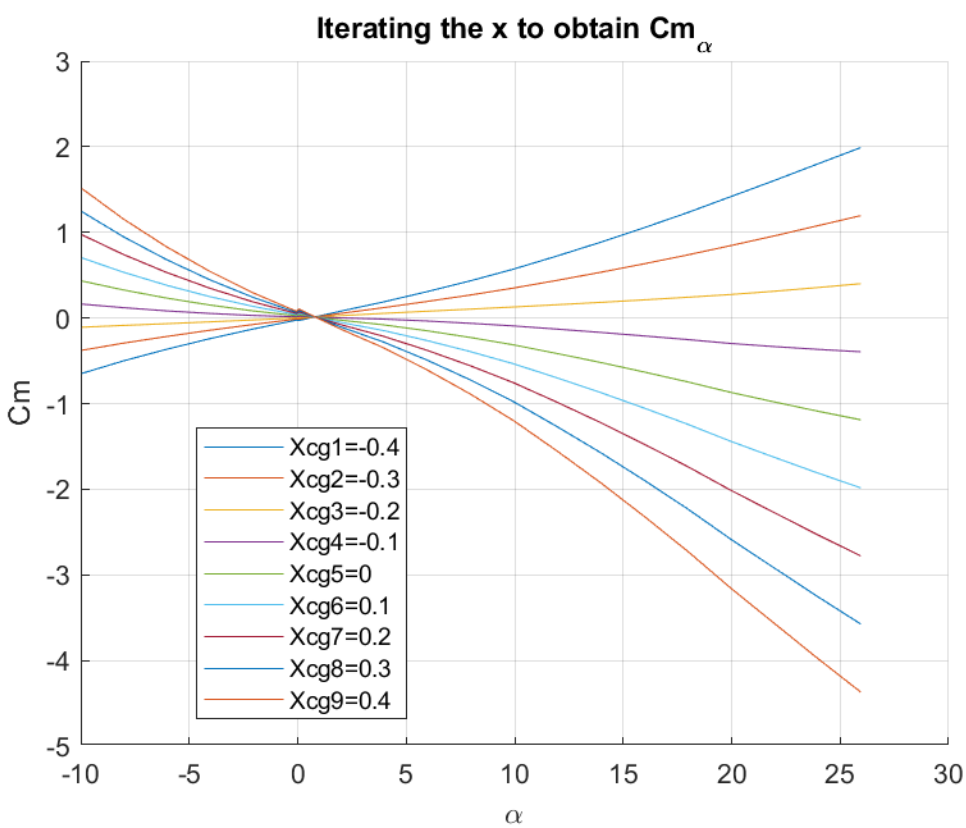
V1=40m/s


Iterating the x to obtain Cm_α
Cm
α
Xcg1=-0.4
Xcg2=-0.3
Xcg3=-0.2
Xcg4=-0.1
Xcg5=0
Xcg6=0.1
Xcg7=0.2
Xcg8=0.3
Xcg9=0.4
3
2
1
0
-1
-2
-3
-4
-5
-10
-5
0
5
10
15
20
25
30

V2=50m/s


Iterating the x to obtain Cm_α
Cm
α
Xcg1=-0.4
Xcg2=-0.3
Xcg3=-0.2
Xcg4=-0.1
Xcg5=0
Xcg6=0.1
Xcg7=0.2
Xcg8=0.3
Xcg9=0.4
3
2
1
0
-1
-2
-3
-4
-5
-10
-5
0
5
10
15
20
25
30

V3=60m/s


Iterating the x to obtain Cm_α
Cm
α
Xcg1=-0.4
Xcg2=-0.3
Xcg3=-0.2
Xcg4=-0.1
Xcg5=0
Xcg6=0.1
Xcg7=0.2
Xcg8=0.3
Xcg9=0.4
3
2
1
0
-1
-2
-3
-4
-5
-10
-5
0
5
10
15
20
25
30

Now we will calculate force and moment coefficients with use of location C.G we obtained above.

We will use formulas mentioned in PPT.

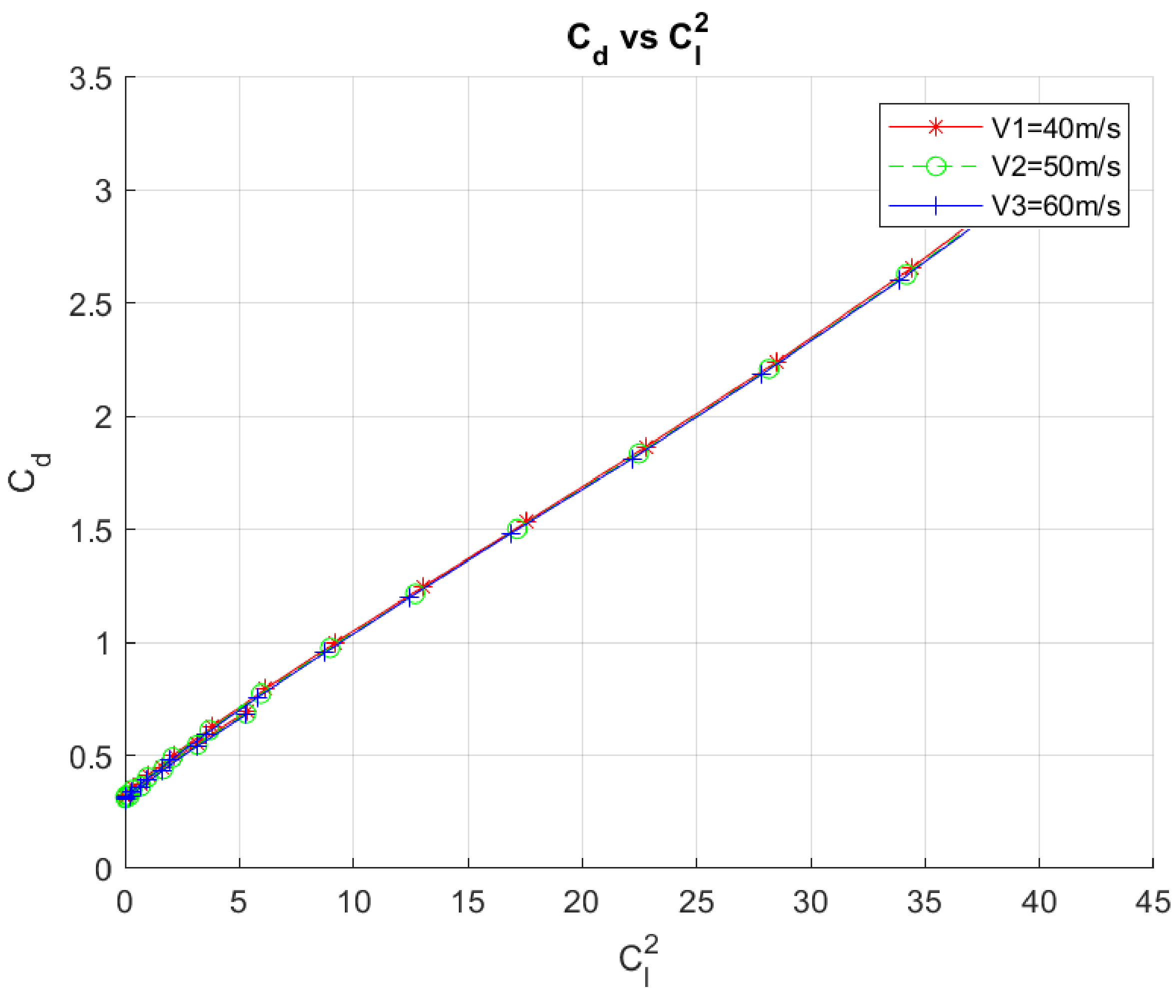
MATLAB CODE: force_and_moment_coefficient_TF_0.m

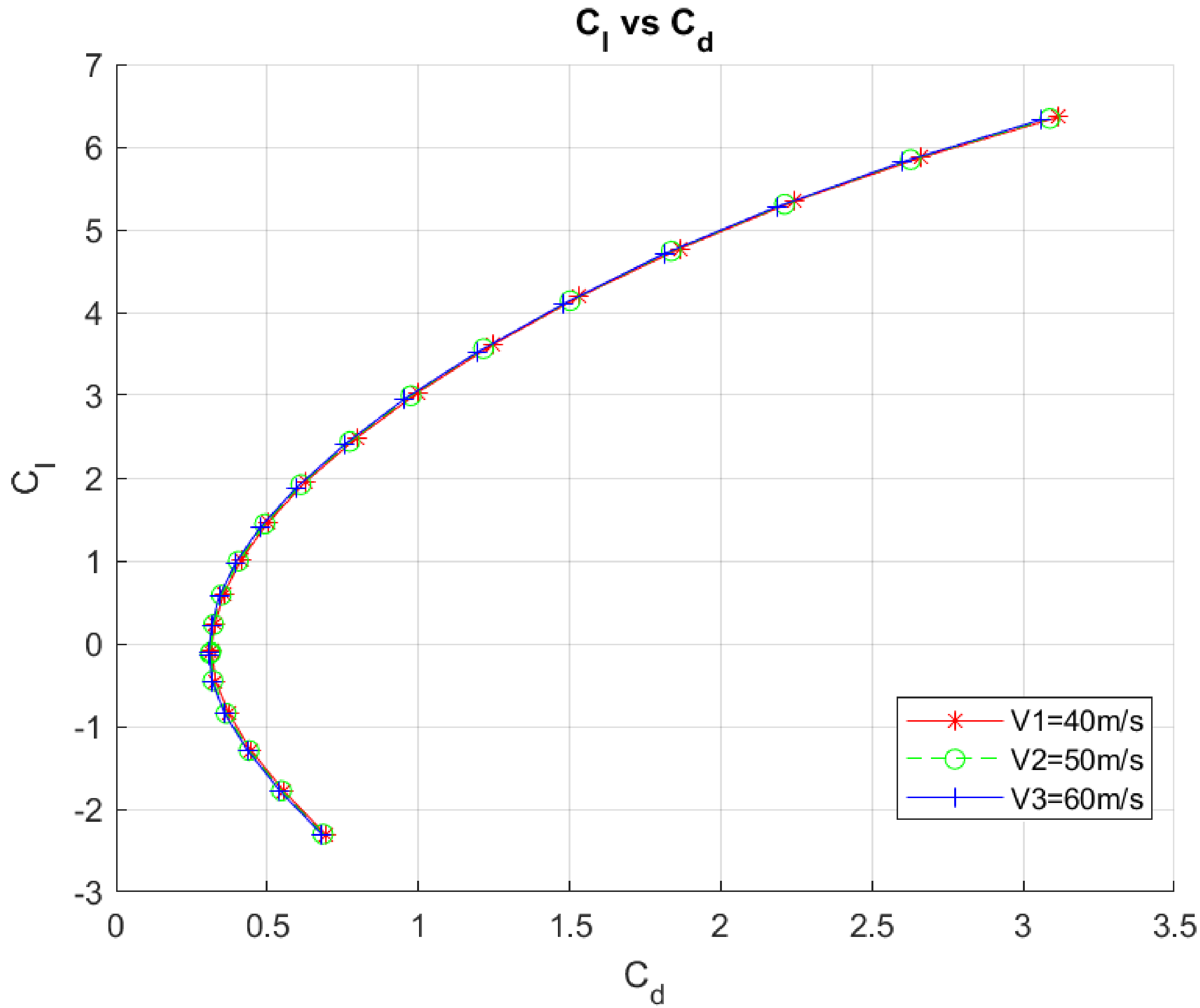
```
% 6682 5/7/2010 12:18:07 PM

% Bomb Model-II Body + TailFins + delta 0
```

OUTPUT:

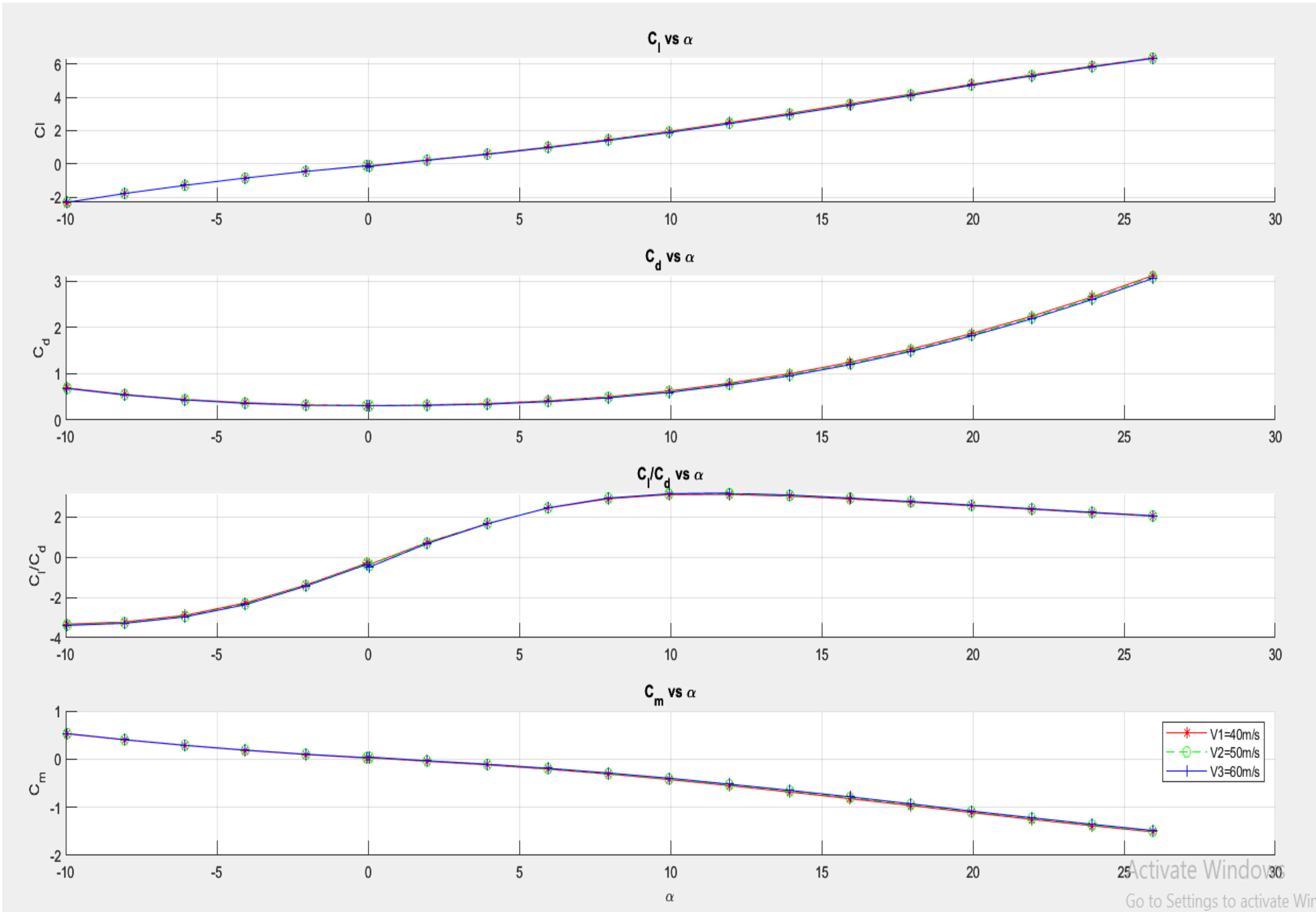
```
For V1 = 40 m/s
Average value of Cl_alpha
          0.220667003717302

Average value of Cm_alpha
        -0.0502461560405881

Average value of Cl_0
         -0.101818850424226

Average value of Cd_0
          0.314830532712512

Average value of Cm_0
         0.0242796966904196

Average value of Oswald Factor
         0.0760641911096402

For V2 = 50 m/s
Average value of Cl_alpha
          0.219274944183726

Average value of Cm_alpha
        -0.0492489745685202

Average value of Cl_0
         -0.112880223054962

Average value of Cd_0
          0.312688373486991

Average value of Cm_0
         0.0320566498493329

Average value of Oswald Factor
         0.0758735785958908
```

```
For V3 = 60 m/s
Average value of Cl_alpha
         0.211254553860318

Average value of Cm_alpha
       -0.0472286947767174

Average value of Cl_0
        -0.130106250276724

Average value of Cd_0
         0.307622863887675

Average value of Cm_0
         0.037230127402477

Average value of Oswald Factor
        0.0740574680229197
```





C_l vs C_d
C_l
C_d
V1=40m/s
V2=50m/s
V3=60m/s



Cl vs α
Cd vs α
Cl/Cd vs α
Cm vs α
Cl
Cd
Cl/Cd
Cm
α
V1=40m/s
V2=50m/s
V3=60m/s

MATLAB CODE: Calculation_X_cg_TF_NF_0.m

```
% 6694 5/8/2010 10:50:12 AM

% Bomb Model-II Test with Body + NoseFins + TailFins + delta 0

%% Variation of Moment coefficient w.r.t. Center of gravity

format long g


g = 9.81;

Cl = [];

Alpha = [];

C_m = [];


%Balance load matrix

CM = [63.080043 0.144499 -0.206795 1.354260 1.630051 4.275882

-0.123649 150.309342 0.592082 -0.725847 0.030856 0.393628

0.024098 -0.689773 151.831777 0.096597 -0.571799 -4.414537

0.152944 -2.334107 0.037781 77.595997 0.445712 5.841784

-0.006030 0.114642 -0.574072 -0.065800 79.176337 0.322466

0.047415 0.466131 0.099431 0.208017 0.190935 44.877349 ];


% Model reference parameters

% Sref(sqm) Chord (m) Span (m)

Sref = 0.009677; c = 0.111; b = 0.111;


% Moment reference point (nose)

% X (m) Y (m) Z (m)

% 0 0 0


% Balance center location
```

```
%X (m) Y (m) Z (m)

X =-0.465; Y = 0; Z = 0;

X_bc = 0.465 ; % distance from Balence Center to Nose of missile


% Nowind data

% Ax N1 N2 S1 S2 Rm

NW = [-0.000060 0.000720 -0.000535 -0.000702 0.000175 -0.000938];


for i = 1:3

if i == 1

% Data for Speed 1

DyHi = 980.386364;

% Dyn. head Pitch Yaw Roll Ax N1 N2 S1 S2 Rm

DSi = [ 980.386364 -9.947917 0.000000 0.000000 0.005824 -0.018730 -0.003349 -0.000120
-0.000445 -0.000447

980.386364 -8.052083 0.000000 0.000000 0.005779 -0.018470 0.000780 0.000486 -0.001005
-0.000446

980.386364 -6.052083 0.000000 0.000000 0.005848 -0.015727 0.002675 0.001113 -0.001597
-0.000533

980.386364 -4.052083 0.000000 0.000000 0.005919 -0.010716 0.002267 0.001595 -0.002072
-0.000610

980.386364 -2.052083 0.000000 0.000000 0.006174 -0.005618 0.001225 0.002030 -0.002352
-0.000731

980.386364 -0.052083 0.000000 0.000000 0.006382 0.000178 -0.000973 0.002233 -0.002247
-0.000805

980.386364 0.052083 0.000000 0.000000 0.006418 0.000622 -0.001537 0.002333 -0.002409
-0.000828

980.386364 1.947917 0.000000 0.000000 0.006301 0.005986 -0.003291 0.002541 -0.002314
-0.000872

980.386364 3.947917 0.000000 0.000000 0.006000 0.011205 -0.004648 0.002760 -0.002287
-0.000951
```

```
980.386364 5.947917 0.000000 0.000000 0.005786 0.016277 -0.005346 0.003033 -0.002387
-0.001062

980.386364 7.947917 0.000000 0.000000 0.005650 0.020372 -0.004799 0.003231 -0.002487
-0.001154

980.386364 9.958333 0.000000 0.000000 0.005792 0.020911 -0.001107 0.003629 -0.002522
-0.001206

980.386364 11.947917 0.000000 0.000000 0.005782 0.019842 0.004121 0.003848 -0.002633
-0.001215

980.386364 13.947917 0.000000 0.000000 0.005569 0.018813 0.009425 0.004079 -0.002668
-0.001259

980.386364 15.947917 0.000000 0.000000 0.005211 0.017681 0.014868 0.004138 -0.002628
-0.001260

980.386364 17.947917 0.000000 0.000000 0.004741 0.017236 0.020059 0.004069 -0.002389
-0.001278

980.386364 19.947917 0.000000 0.000000 0.004227 0.016561 0.025673 0.003951 -0.002322
-0.001245

980.386364 21.947917 0.000000 0.000000 0.003654 0.016103 0.031224 0.003849 -0.002502
-0.001226

980.386364 23.947917 0.000000 0.000000 0.003050 0.016164 0.036243 0.003657 -0.002624
-0.001240

980.386364 25.947917 0.000000 0.000000 0.002483 0.016457 0.040852 0.004120 -0.003231
-0.001296];%20

end

if i == 2

%Data for Speed 2

DyHi = 1503.238636;

% Dyn. head Pitch Yaw Roll Ax N1 N2 S1 S2 Rm

DSi = [ 1503.238636 -9.947917 0.000000 0.000000 0.008672 -0.029165 -0.004914 -
0.000077 -0.000414 -0.000311

1503.238636 -8.052083 0.000000 0.000000 0.008730 -0.029110 0.001760 0.000991 -
0.001441 -0.000276

1503.238636 -6.052083 0.000000 0.000000 0.008875 -0.024977 0.004733 0.001999 -
0.002528 -0.000371
```

```
1503.238636 -4.052083 0.000000 0.000000 0.009019 -0.017260 0.004091 0.002831 -
0.003249 -0.000504

1503.238636 -2.052083 0.000000 0.000000 0.009410 -0.009170 0.002185 0.003521 -
0.003766 -0.000601

1503.238636 -0.052083 0.000000 0.000000 0.009866 -0.000294 -0.001190 0.003980 -
0.003718 -0.000728

1503.238636 0.052083 0.000000 0.000000 0.009806 0.000650 -0.002243 0.004068 -0.003786
-0.000868

1503.238636 1.947917 0.000000 0.000000 0.009634 0.008807 -0.004948 0.004488 -0.003806
-0.000846

1503.238636 3.947917 0.000000 0.000000 0.009064 0.016918 -0.007061 0.004863 -0.003809
-0.001007

1503.238636 5.947917 0.000000 0.000000 0.008705 0.024919 -0.008314 0.005317 -0.004052
-0.001171

1503.238636 7.947917 0.000000 0.000000 0.008391 0.031412 -0.007677 0.005684 -0.004145
-0.001335

1503.238636 9.947917 0.000000 0.000000 0.008504 0.032596 -0.002311 0.006242 -0.004257
-0.001430

1503.238636 11.947917 0.000000 0.000000 0.008532 0.031188 0.005413 0.006732 -0.004278
-0.001513

1503.238636 13.947917 0.000000 0.000000 0.008216 0.029086 0.013746 0.006902 -0.004357
-0.001548

1503.238636 15.947917 0.000000 0.000000 0.007643 0.027572 0.021870 0.007058 -0.004498
-0.001615

1503.238636 17.947917 0.000000 0.000000 0.006965 0.026547 0.030059 0.006797 -0.003870
-0.001538

1503.238636 19.947917 0.000000 0.000000 0.006100 0.025577 0.038565 0.006591 -0.003663
-0.001523

1503.238636 21.947917 0.000000 0.000000 0.005224 0.024703 0.047349 0.006408 -0.003872
-0.001488

1503.238636 23.947917 0.000000 0.000000 0.004296 0.024660 0.055195 0.006309 -0.004261
-0.001527

1503.238636 25.947917 0.000000 0.000000 0.003412 0.024635 0.062857 0.006864 -0.005023
-0.001578];

end
```

```
if i == 3

% Data for Speed 3

DyHi = 2155.477273;

% Dyn. head Pitch Yaw Roll Ax N1 N2 S1 S2 Rm

DSi = [ 2155.477273 -9.947917 0.000000 0.000000 0.012224 -0.043297 -0.006181 -
0.000401 0.000118 -0.000044

2155.477273 -8.052083 0.000000 0.000000 0.012382 -0.043300 0.003434 0.001114 -
0.001542 0.000027

2155.477273 -6.052083 0.000000 0.000000 0.012492 -0.037048 0.007539 0.002741 -
0.003228 -0.000118

2155.477273 -4.052083 0.000000 0.000000 0.012852 -0.026257 0.006930 0.003982 -
0.004439 -0.000348

2155.477273 -2.052083 0.000000 0.000000 0.013389 -0.014235 0.003861 0.005388 -
0.005434 -0.000540

2155.477273 -0.052083 0.000000 0.000000 0.014060 -0.001266 -0.001222 0.006043 -
0.005342 -0.000732

2155.477273 0.052083 0.000000 0.000000 0.013911 0.000759 -0.003306 0.006368 -0.005640
-0.000822

2155.477273 1.947917 0.000000 0.000000 0.013731 0.012064 -0.006754 0.006798 -0.005611
-0.000923

2155.477273 3.947917 0.000000 0.000000 0.012750 0.024123 -0.010274 0.007539 -0.005805
-0.001135

2155.477273 5.947917 0.000000 0.000000 0.012157 0.035754 -0.012153 0.008187 -0.006238
-0.001378

2155.477273 7.947917 0.000000 0.000000 0.011812 0.045210 -0.011220 0.008632 -0.006314
-0.001616

2155.477273 9.958333 0.000000 0.000000 0.011769 0.047922 -0.004543 0.009309 -0.006195
-0.001753

2155.477273 11.947917 0.000000 0.000000 0.011876 0.046518 0.005962 0.009825 -0.005895
-0.001883

2155.477273 13.947917 0.000000 0.000000 0.011479 0.042350 0.018673 0.010167 -0.006151
-0.001922

2155.477273 15.947917 0.000000 0.000000 0.010666 0.040216 0.030442 0.010338 -0.006394
-0.002040
```

```
2155.477273 17.937500 0.000000 0.000000 0.009717 0.038464 0.042449 0.010045 -0.005459
-0.001934

2155.477273 19.947917 0.000000 0.000000 0.008543 0.036833 0.054952 0.009845 -0.005513
-0.001877

2155.477273 21.947917 0.000000 0.000000 0.007323 0.035552 0.067531 0.008894 -0.005253
-0.001782

2155.477273 23.947917 0.000000 0.000000 0.006033 0.035056 0.079428 0.009108 -0.006263
-0.001820

2155.477273 25.947917 0.000000 0.000000 0.004720 0.034759 0.090736 0.009236 -0.007105
-0.001772];


end

Le = 0.884;

% Transformation Matrix from CG to Body center

for x = -0.4:0.1:0.4 % -0.2:0.01:-0.12

% Xnp --> 0.605 (x=-0.14)

y = 0;

z = 0;

TM =[-1, 0, 0, 0, 0, 0

0, 1, 0, 0, 0, 0

0, 0, -1, 0, 0, 0

0, -z, y, 1, 0, 0

z, 0, -x, 0, 1, 0

-y, x, 0, 0, 0, 1];


Alpha = [];

C_m = [];

for j = 1:20

aj = [DSi(j,5) ; DSi(j,6) ; DSi(j,7) ; DSi(j,8) ; DSi(j,9) ; DSi(j,10)];

% Convert the obtained normalized voltage signals to kg
```

```
Aj = CM * (aj-NW);

% Calculate the forces and moments about the balance center.

fm = [Aj(1) ; (Aj(4)+Aj(5)) ; (Aj(2)+Aj(3)) ; Aj(6) ; (Aj(2)-Aj(3))*0.065 ; (Aj(4)-
Aj(5))*0.065].*g;

% Transform the forces and moments to the body axis

FM = [Aj(1) ; (Aj(4)+Aj(5)) ; (Aj(2)+Aj(3)) ; Aj(6) ; (Aj(2)-Aj(3))*0.065 ; (Aj(4)-
Aj(5))*0.065].*g;

% Transform the forces and moments to the C.G of the flight vehicle

FMcg = TM * FM;

% The variation of longitudinal force and moment coefficients

Cf = (1/(DyHi*Sref)).*[FMcg(1:3)];

Cm = (1/(DyHi*Sref*Le)).*[FMcg(4:6)];


Pitch = (DSi(j,2));

% Variation of Aerodynamic force coefficients with angle of attack

Aero_TM = [ sind(Pitch) 0 -cosd(Pitch)

-cosd(Pitch) 0 -sind(Pitch)

0 1 0];

Aero_Coeff = Aero_TM*Cf;

% Recording The Data

Alpha = [Alpha; Pitch];

C_m = [C_m; Cm'];


end

% Iterating the x (from Balance center) value to obtain Cm_\alpha

figure(i)

A = Alpha(:,1);

ct = C_m(:,2);
```

```
hold on

plot(A,ct)

hold off

xlabel('\alpha')

ylabel('Cm')

ylim([-6 6])

title('Iterating the x to obtain Cm_\alpha')

%legend('Xcg1=0.10','Xcg2=0.11','Xcg3=0.12','Xcg4=0.13','Xcg5=0.14','Xcg6=0.15','Xcg7
=0.16','Xcg8=0.17','Xcg9=0.18')

legend('Xcg1=-0.4','Xcg2=-0.3','Xcg3=-0.2','Xcg4=-
0.1','Xcg5=0','Xcg6=0.1','Xcg7=0.2','Xcg8=0.3','Xcg9=0.4')

grid on

end

end

% Most horizontal line of the Output Graph is for x = -0.2 to -0.1

% Let Neutral Point be

X_bnp = 0.08; %distance between Balence Center and Neutral Point

disp(['distance between Balence Center and Neutral Point is--> ', num2str(X_bnp) '
m'])


X_np = X_bc - X_bnp; % distance of Balence Center from Nose of missile

disp(['distance of Neutral Point from Nose of missile is--> ', num2str(X_np) ' m'])


% Assuming Static Margine ( = 15%Le )

disp('Assuming Static Margine 15% of length of missile')

SM = 0.15*Le;

disp(['Static Margine is--> ', num2str(SM) ' m'])


% distance between Balence Center and C.G
```

```
X_bg = X_bnp + SM;

disp(['distance between Balence Center and C.G is--> ', num2str(X_bg) ' m'])


X_cg = X_np-SM;

disp(['distance of C.G. from Nose of missile is--> ', num2str(X_cg) ' m'])
```

OUTPUT:

distance between Balence Center and Neutral Point is--> 0.08 m

distance of Neutral Point from Nose of missile is--> 0.385 m

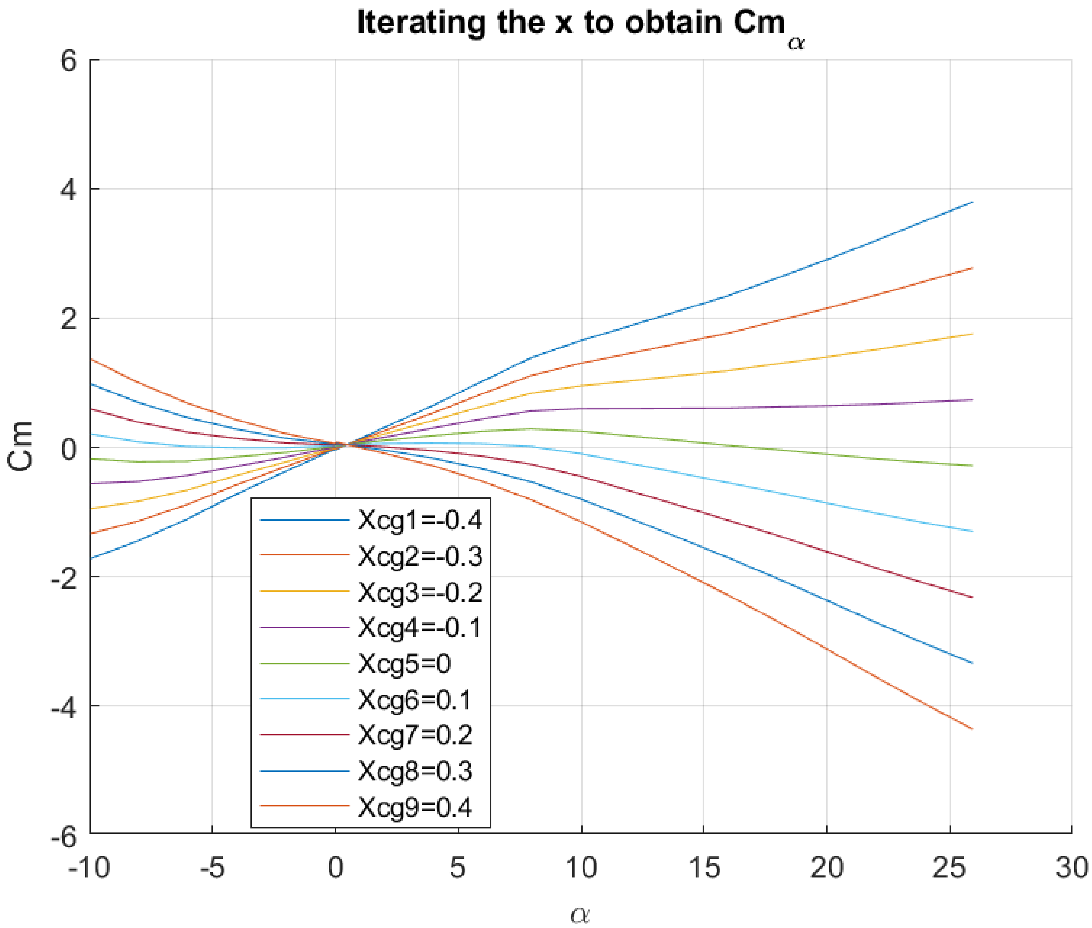
Assuming Static Margine 15% of length of missile

Static Margine is--> 0.1326 m

distance between Balence Center and C.G is--> 0.2126 m

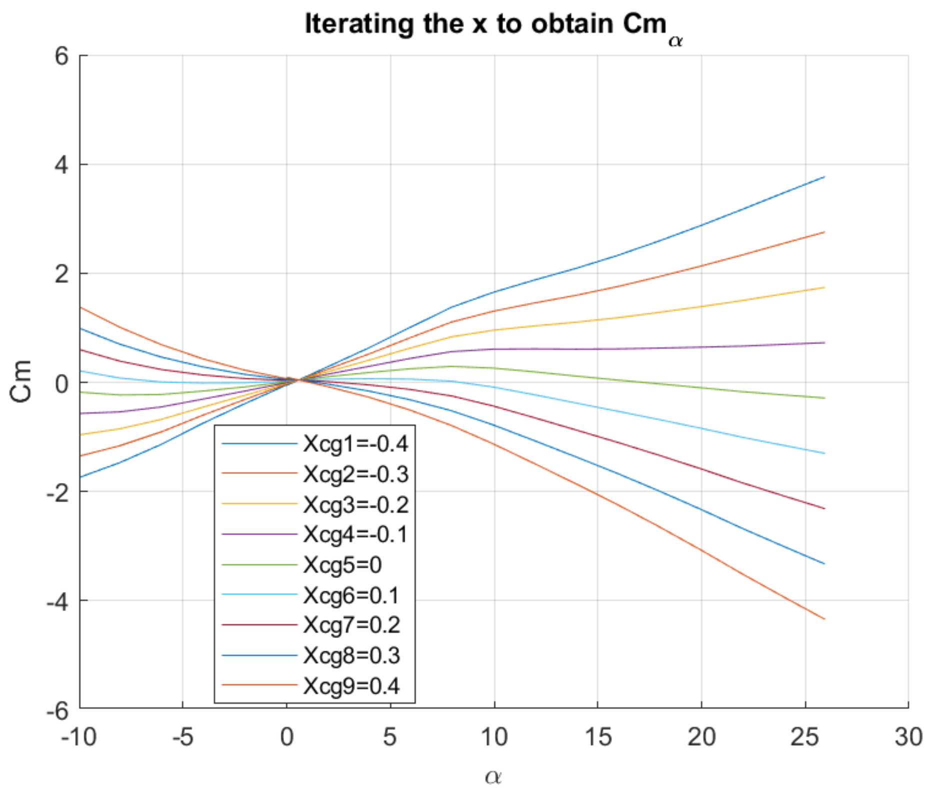
distance of C.G. from Nose of missile is--> 0.2524 m

V1=40m/s

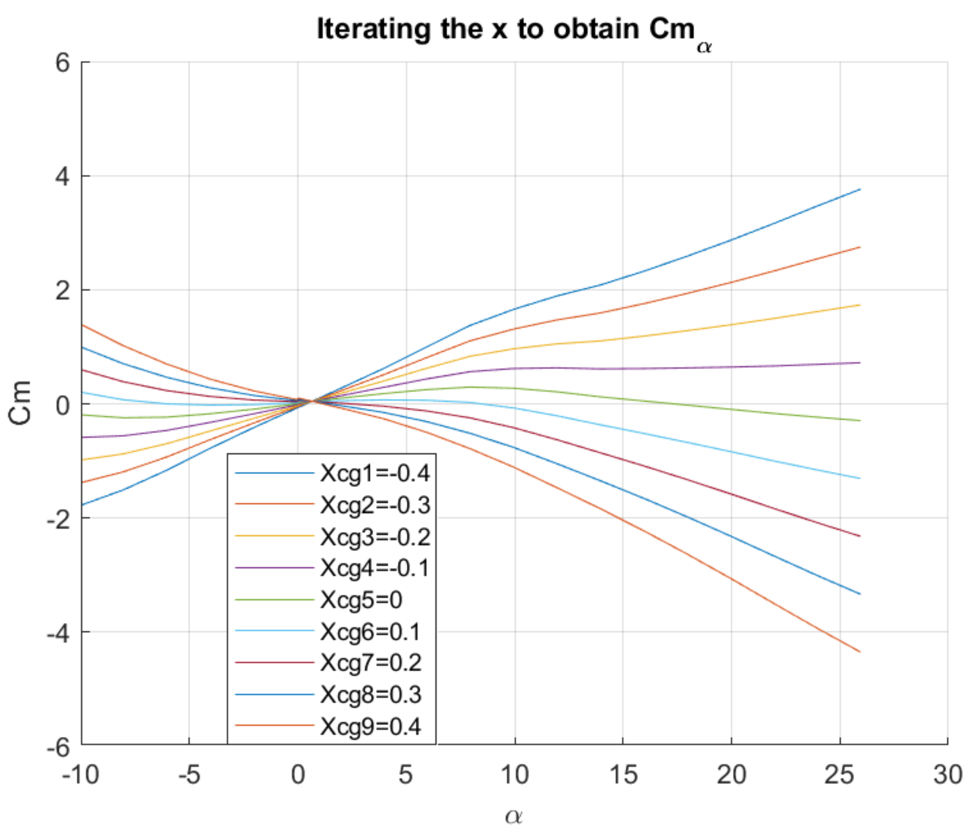


Iterating the x to obtain Cm$_\alpha$
Cm
α
6
4
2
0
-2
-4
-6
-10
-5
0
5
10
15
20
25
30
Xcg1=-0.4
Xcg2=-0.3
Xcg3=-0.2
Xcg4=-0.1
Xcg5=0
Xcg6=0.1
Xcg7=0.2
Xcg8=0.3
Xcg9=0.4

V2=50m/s


Iterating the x to obtain Cm_α
Cm
α
Xcg1=-0.4
Xcg2=-0.3
Xcg3=-0.2
Xcg4=-0.1
Xcg5=0
Xcg6=0.1
Xcg7=0.2
Xcg8=0.3
Xcg9=0.4

V3=60m/s


Iterating the x to obtain Cm_α
Cm
α
Xcg1=-0.4
Xcg2=-0.3
Xcg3=-0.2
Xcg4=-0.1
Xcg5=0
Xcg6=0.1
Xcg7=0.2
Xcg8=0.3
Xcg9=0.4

Now we will calculate force and moment coefficients with use of location C.G we obtained above.

We will use formulas mentioned in PPT.

MATLAB CODE: force_and_moment_coefficient_TF_NF_0.m

```
% 6694 5/8/2010 10:50:12 AM

% Bomb Model-II Test with Body + NoseFins + TailFins + delta 0

format long g


g = 9.81;

Cl = [];

Alpha = [];

C_m = [];


%Balance load matrix

CM = [63.080043 0.144499 -0.206795 1.354260 1.630051 4.275882

-0.123649 150.309342 0.592082 -0.725847 0.030856 0.393628

0.024098 -0.689773 151.831777 0.096597 -0.571799 -4.414537

0.152944 -2.334107 0.037781 77.595997 0.445712 5.841784

-0.006030 0.114642 -0.574072 -0.065800 79.176337 0.322466

0.047415 0.466131 0.099431 0.208017 0.190935 44.877349 ];


% Model reference parameters

% Sref(sqm) Chord (m) Span (m)

Sref = 0.009677; c = 0.111; b = 0.111;


% Moment reference point (nose)

% X (m) Y (m) Z (m)
```

```
% 0 0 0

% Balance center location
%X (m) Y (m) Z (m)
X =-0.465; Y = 0; Z = 0;

% Nowind data
% Ax N1 N2 S1 S2 Rm
NW = [-0.000060 0.000720 -0.000535 -0.000702 0.000175 -0.000938];

for i = 1:3
if i == 1
% Data for Speed 1
DyHi = 980.386364;
% Dyn. head Pitch Yaw Roll Ax N1 N2 S1 S2 Rm
DSi = [ 980.386364 -9.947917 0.000000 0.000000 0.005824 -0.018730 -0.003349 -0.000120
-0.000445 -0.000447

980.386364 -8.052083 0.000000 0.000000 0.005779 -0.018470 0.000780 0.000486 -0.001005
-0.000446

980.386364 -6.052083 0.000000 0.000000 0.005848 -0.015727 0.002675 0.001113 -0.001597
-0.000533

980.386364 -4.052083 0.000000 0.000000 0.005919 -0.010716 0.002267 0.001595 -0.002072
-0.000610

980.386364 -2.052083 0.000000 0.000000 0.006174 -0.005618 0.001225 0.002030 -0.002352
-0.000731

980.386364 -0.052083 0.000000 0.000000 0.006382 0.000178 -0.000973 0.002233 -0.002247
-0.000805

980.386364 0.052083 0.000000 0.000000 0.006418 0.000622 -0.001537 0.002333 -0.002409
-0.000828

980.386364 1.947917 0.000000 0.000000 0.006301 0.005986 -0.003291 0.002541 -0.002314
-0.000872
```

```
980.386364 3.947917 0.000000 0.000000 0.006000 0.011205 -0.004648 0.002760 -0.002287
-0.000951

980.386364 5.947917 0.000000 0.000000 0.005786 0.016277 -0.005346 0.003033 -0.002387
-0.001062

980.386364 7.947917 0.000000 0.000000 0.005650 0.020372 -0.004799 0.003231 -0.002487
-0.001154

980.386364 9.958333 0.000000 0.000000 0.005792 0.020911 -0.001107 0.003629 -0.002522
-0.001206

980.386364 11.947917 0.000000 0.000000 0.005782 0.019842 0.004121 0.003848 -0.002633
-0.001215

980.386364 13.947917 0.000000 0.000000 0.005569 0.018813 0.009425 0.004079 -0.002668
-0.001259

980.386364 15.947917 0.000000 0.000000 0.005211 0.017681 0.014868 0.004138 -0.002628
-0.001260

980.386364 17.947917 0.000000 0.000000 0.004741 0.017236 0.020059 0.004069 -0.002389
-0.001278

980.386364 19.947917 0.000000 0.000000 0.004227 0.016561 0.025673 0.003951 -0.002322
-0.001245

980.386364 21.947917 0.000000 0.000000 0.003654 0.016103 0.031224 0.003849 -0.002502
-0.001226

980.386364 23.947917 0.000000 0.000000 0.003050 0.016164 0.036243 0.003657 -0.002624
-0.001240

980.386364 25.947917 0.000000 0.000000 0.002483 0.016457 0.040852 0.004120 -0.003231
-0.001296];%20

end

if i == 2

%Data for Speed 2

DyHi = 1503.238636;

% Dyn. head Pitch Yaw Roll Ax N1 N2 S1 S2 Rm

DSi = [ 1503.238636 -9.947917 0.000000 0.000000 0.008672 -0.029165 -0.004914 -
0.000077 -0.000414 -0.000311

1503.238636 -8.052083 0.000000 0.000000 0.008730 -0.029110 0.001760 0.000991 -
0.001441 -0.000276
```

1503.238636 -6.052083 0.000000 0.000000 0.008875 -0.024977 0.004733 0.001999 -0.002528 -0.000371

1503.238636 -4.052083 0.000000 0.000000 0.009019 -0.017260 0.004091 0.002831 -0.003249 -0.000504

1503.238636 -2.052083 0.000000 0.000000 0.009410 -0.009170 0.002185 0.003521 -0.003766 -0.000601

1503.238636 -0.052083 0.000000 0.000000 0.009866 -0.000294 -0.001190 0.003980 -0.003718 -0.000728

1503.238636 0.052083 0.000000 0.000000 0.009806 0.000650 -0.002243 0.004068 -0.003786 -0.000868

1503.238636 1.947917 0.000000 0.000000 0.009634 0.008807 -0.004948 0.004488 -0.003806 -0.000846

1503.238636 3.947917 0.000000 0.000000 0.009064 0.016918 -0.007061 0.004863 -0.003809 -0.001007

1503.238636 5.947917 0.000000 0.000000 0.008705 0.024919 -0.008314 0.005317 -0.004052 -0.001171

1503.238636 7.947917 0.000000 0.000000 0.008391 0.031412 -0.007677 0.005684 -0.004145 -0.001335

1503.238636 9.947917 0.000000 0.000000 0.008504 0.032596 -0.002311 0.006242 -0.004257 -0.001430

1503.238636 11.947917 0.000000 0.000000 0.008532 0.031188 0.005413 0.006732 -0.004278 -0.001513

1503.238636 13.947917 0.000000 0.000000 0.008216 0.029086 0.013746 0.006902 -0.004357 -0.001548

1503.238636 15.947917 0.000000 0.000000 0.007643 0.027572 0.021870 0.007058 -0.004498 -0.001615

1503.238636 17.947917 0.000000 0.000000 0.006965 0.026547 0.030059 0.006797 -0.003870 -0.001538

1503.238636 19.947917 0.000000 0.000000 0.006100 0.025577 0.038565 0.006591 -0.003663 -0.001523

1503.238636 21.947917 0.000000 0.000000 0.005224 0.024703 0.047349 0.006408 -0.003872 -0.001488

1503.238636 23.947917 0.000000 0.000000 0.004296 0.024660 0.055195 0.006309 -0.004261 -0.001527

```
1503.238636 25.947917 0.000000 0.000000 0.003412 0.024635 0.062857 0.006864 -0.005023
-0.001578];

end

if i == 3

% Data for Speed 3

DyHi = 2155.477273;

% Dyn. head Pitch Yaw Roll Ax N1 N2 S1 S2 Rm

DSi = [ 2155.477273 -9.947917 0.000000 0.000000 0.012224 -0.043297 -0.006181 -
0.000401 0.000118 -0.000044

2155.477273 -8.052083 0.000000 0.000000 0.012382 -0.043300 0.003434 0.001114 -
0.001542 0.000027

2155.477273 -6.052083 0.000000 0.000000 0.012492 -0.037048 0.007539 0.002741 -
0.003228 -0.000118

2155.477273 -4.052083 0.000000 0.000000 0.012852 -0.026257 0.006930 0.003982 -
0.004439 -0.000348

2155.477273 -2.052083 0.000000 0.000000 0.013389 -0.014235 0.003861 0.005388 -
0.005434 -0.000540

2155.477273 -0.052083 0.000000 0.000000 0.014060 -0.001266 -0.001222 0.006043 -
0.005342 -0.000732

2155.477273 0.052083 0.000000 0.000000 0.013911 0.000759 -0.003306 0.006368 -0.005640
-0.000822

2155.477273 1.947917 0.000000 0.000000 0.013731 0.012064 -0.006754 0.006798 -0.005611
-0.000923

2155.477273 3.947917 0.000000 0.000000 0.012750 0.024123 -0.010274 0.007539 -0.005805
-0.001135

2155.477273 5.947917 0.000000 0.000000 0.012157 0.035754 -0.012153 0.008187 -0.006238
-0.001378

2155.477273 7.947917 0.000000 0.000000 0.011812 0.045210 -0.011220 0.008632 -0.006314
-0.001616

2155.477273 9.958333 0.000000 0.000000 0.011769 0.047922 -0.004543 0.009309 -0.006195
-0.001753

2155.477273 11.947917 0.000000 0.000000 0.011876 0.046518 0.005962 0.009825 -0.005895
-0.001883
```

```
2155.477273 13.947917 0.000000 0.000000 0.011479 0.042350 0.018673 0.010167 -0.006151
-0.001922

2155.477273 15.947917 0.000000 0.000000 0.010666 0.040216 0.030442 0.010338 -0.006394
-0.002040

2155.477273 17.937500 0.000000 0.000000 0.009717 0.038464 0.042449 0.010045 -0.005459
-0.001934

2155.477273 19.947917 0.000000 0.000000 0.008543 0.036833 0.054952 0.009845 -0.005513
-0.001877

2155.477273 21.947917 0.000000 0.000000 0.007323 0.035552 0.067531 0.008894 -0.005253
-0.001782

2155.477273 23.947917 0.000000 0.000000 0.006033 0.035056 0.079428 0.009108 -0.006263
-0.001820

2155.477273 25.947917 0.000000 0.000000 0.004720 0.034759 0.090736 0.009236 -0.007105
-0.001772];


end

Le = 0.884;

% Transformation Matrix from CG to Body center

x = 0.2126; % Xnp --> 0.605 (Neutral point from nose)

y = 0;

z = 0;

TM =[-1, 0, 0, 0, 0, 0

0, 1, 0, 0, 0, 0

0, 0, -1, 0, 0, 0

0, -z, y, 1, 0, 0

z, 0, -x, 0, 1, 0

-y, x, 0, 0, 0, 1];



for j = 1:20

aj = [DSi(j,5) ; DSi(j,6) ; DSi(j,7) ; DSi(j,8) ; DSi(j,9) ; DSi(j,10)];
```

```
% Convert the obtained normalized voltage signals to kg

Aj = CM * (aj-NW);

% Calculate the forces and moments about the balance center

fm = [Aj(1) ; (Aj(4)+Aj(5)) ; (Aj(2)+Aj(3)) ; Aj(6) ; (Aj(2)-Aj(3))*0.065 ; (Aj(4)-
Aj(5))*0.065].*g;

% Transform the forces and moments to the body axis

FM = [Aj(1) ; (Aj(4)+Aj(5)) ; (Aj(2)+Aj(3)) ; Aj(6) ; (Aj(2)-Aj(3))*0.065 ; (Aj(4)-
Aj(5))*0.065].*g;

% Transform the forces and moments to the C.G of the flight vehicle

FMcg = TM * FM;

% The variation of longitudinal force and moment coefficients

Cf = (1/(DyHi*Sref)).*[FMcg(1:3)];

Cm = (1/(DyHi*Sref*Le)).*[FMcg(4:6)];

Pitch = (DSi(j,2));

% Variation of Aerodynamic force coefficients with angle of attack

Aero_TM = [ sind(Pitch) 0 -cosd(Pitch)

-cosd(Pitch) 0 -sind(Pitch)

0 1 0];

Aero_Coeff = Aero_TM*Cf;

% Recording The Data

Alpha = [Alpha; Pitch'];

Cl = [Cl; Aero_Coeff'];

C_m = [C_m; Cm'];


end

end


A1= Alpha(1:20);
```

```
B1= Cl(1:20,1);

C1= Cl(1:20,2);

D1= C_m(1:20,2);

A2= Alpha(21:40);

B2= Cl(21:40,1);

C2= Cl(21:40,2);

D2= C_m(21:40,2);

A3= Alpha(41:60);

B3= Cl(41:60,1);

C3= Cl(41:60,2);

D3= C_m(41:60,2);

E1 = B1./C1;

E2 = B2./C2;

E3 = B3./C3;

F1 = B1.^2;

F2 = B2.^2;

F3 = B3.^2;


% Calculating Slope of Moment Coefficient

%For V1

cc1=0;

Cm_Alpha1i = 0;

Cl_Alpha1i = 0;

k1_i=0;

for l = 2:1:20

D_Alpha1 = A1(l)-A1(l-1) ;

D_Cl1 = B1(l)-B1(l-1);

D_Cm1 = D1(l)-D1(l-1);
```

```
D_Cd1 = C1(l)-C1(l-1);

D_Cl_2= F1(l)-F1(l-1);

Cm_alpha1 = D_Cm1/D_Alpha1;

Cl_alpha1 = D_Cl1/D_Alpha1;

k1 = D_Cd1/D_Cl_2;

Cl_Alpha1i = Cl_Alpha1i + Cl_alpha1;

Cm_Alpha1i = Cm_Alpha1i + Cm_alpha1;

k1_i = k1_i + k1;

cc1 = cc1+1;

end

F_Cm_Alpha1 = Cm_Alpha1i/cc1;

F_Cl_Alpha1 = Cl_Alpha1i/cc1;

F_k1 = k1_i/cc1;

F_Cl_01 = (B1(7)+B1(6))./2;

F_Cd_01 = (C1(7)+C1(6))./2;

F_Cm_01 = (D1(6)+D1(7))./2;


disp('For V1 = 40 m/s')

disp('Average value of Cl_alpha')

disp(F_Cl_Alpha1)

disp('Average value of Cm_alpha')

disp(F_Cm_Alpha1)

disp('Average value of Cl_0')

disp(F_Cl_01)

disp('Average value of Cd_0')

disp(F_Cd_01)

disp('Average value of Cm_0')

disp(F_Cm_01)
```

```
disp('Average value of Oswald Factor')
disp(k1)
%For V2
cc2=0;
Cm_Alpha2i = 0;
Cl_Alpha2i = 0;
k2_i=0;
for l = 2:1:20
D_Alpha2 = A2(l)-A2(l-1) ;
D_Cl2 = B2(l)-B2(l-1);
D_Cm2 = D2(l)-D2(l-1);
D_Cd2 = C2(l)-C2(l-1);
D_Cl_22= F2(l)-F2(l-1);
Cm_alpha2 = D_Cm2/D_Alpha2;
Cl_alpha2 = D_Cl2/D_Alpha2;
k2 = D_Cd2/D_Cl_22;
Cl_Alpha2i = Cl_Alpha2i + Cl_alpha2;
Cm_Alpha2i = Cm_Alpha2i + Cm_alpha2;
k2_i = k2_i + k2;
cc2 = cc2+1;
end
F_Cm_Alpha2 = Cm_Alpha2i/cc2;
F_Cl_Alpha2 = Cl_Alpha2i/cc2;
F_k2 = k2_i/cc2;
F_Cl_02 = (B2(7)+B2(6))./2;
F_Cd_02 = (C2(7)+C2(6))./2;
F_Cm_02 = (D2(6)+D2(7))./2;
disp('For V2 = 50 m/s')
```

```
disp('Average value of Cl_alpha')

disp(F_Cl_Alpha2)

disp('Average value of Cm_alpha')

disp(F_Cm_Alpha2)

disp('Average value of Cl_0')

disp(F_Cl_02)

disp('Average value of Cd_0')

disp(F_Cd_02)

disp('Average value of Cm_0')

disp(F_Cm_02)

disp('Average value of Oswald Factor')

disp(k2)

%For V3

cc3=0;

Cm_Alpha3i = 0;

Cl_Alpha3i = 0;

k3_i=0;

for l = 2:1:20

D_Alpha3 = A3(l)-A3(l-1) ;

D_Cl3 = B3(l)-B3(l-1);

D_Cm3 = D3(l)-D3(l-1);

D_Cd3 = C3(l)-C3(l-1);

D_Cl_23= F3(l)-F3(l-1);

k3 = D_Cd3/D_Cl_23;

Cm_alpha3 = D_Cm3/D_Alpha3;

Cl_alpha3 = D_Cl3/D_Alpha3;

Cl_Alpha3i = Cl_Alpha3i + Cl_alpha3;

Cm_Alpha3i = Cm_Alpha3i + Cm_alpha3;
```

```
k3_i = k3_i + k3;

cc3 = cc3+1;

end

F_Cm_Alpha3 = Cm_Alpha3i/cc3;

F_Cl_Alpha3 = Cl_Alpha3i/cc3;

F_k3 = k3_i/cc3;

F_Cl_03 = (B3(7)+B3(6))./2;

F_Cd_03 = (C3(7)+C3(6))./2;

F_Cm_03 = (D3(6)+D3(7))./2;

disp('For V3 = 60 m/s')

disp('Average value of Cl_alpha')

disp(F_Cl_Alpha3)

disp('Average value of Cm_alpha')

disp(F_Cm_Alpha3)

disp('Average value of Cl_0')

disp(F_Cl_03)

disp('Average value of Cd_0')

disp(F_Cd_03)

disp('Average value of Cm_0')

disp(F_Cm_03)

disp('Average value of Oswald Factor')

disp(k3)


figure(1)

subplot(4,1,1)

hold on

plot(A1,B1,'r-*',A2,B2,'g--o',A3,B3,'b-+')

hold off
```

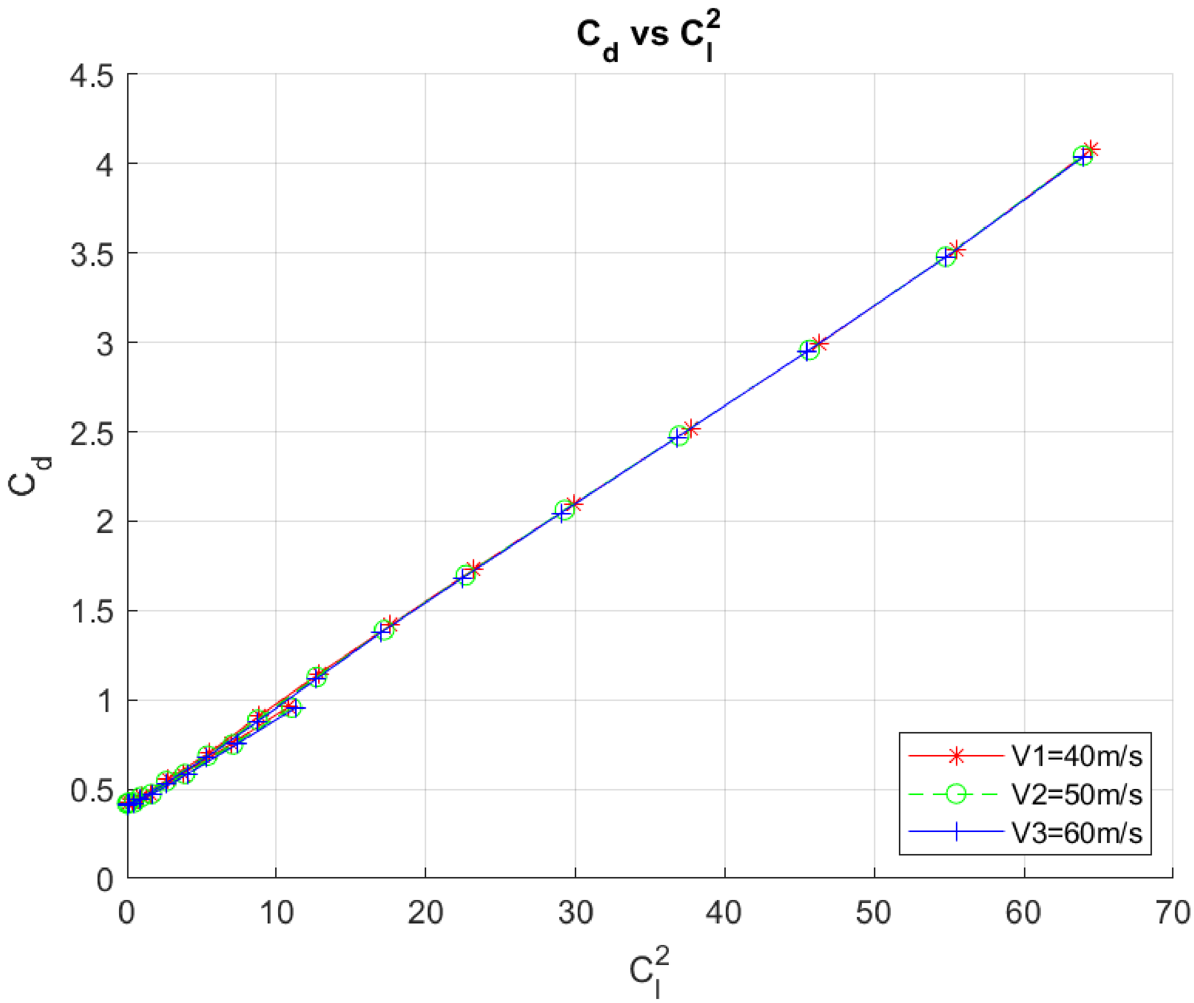
```
%xlabel('\alpha')

ylabel('Cl')

title('C_l vs \alpha')

legend('V1=40m/s','V2=50m/s','V3=60m/s')

grid on

subplot(4,1,2)

hold on

plot(A1,C1,'r-*',A2,C2,'g--o',A3,C3,'b-+')

hold off

%xlabel('\alpha')

ylabel('C_d')

title('C_d vs \alpha')

legend('V1=40m/s','V2=50m/s','V3=60m/s')

grid on

subplot(4,1,3)

hold on

plot(A1,E1,'r-*',A2,E2,'g--o',A3,E3,'b-+')

hold off

%xlabel('\alpha')

ylabel('C_l/C_d')

title('C_l/C_d vs \alpha')

legend('V1=40m/s','V2=50m/s','V3=60m/s')

grid on

subplot(4,1,4)

hold on

plot(A1,D1,'r-*',A2,D2,'g--o',A3,D3,'b-+')

hold off

xlabel('\alpha')
```

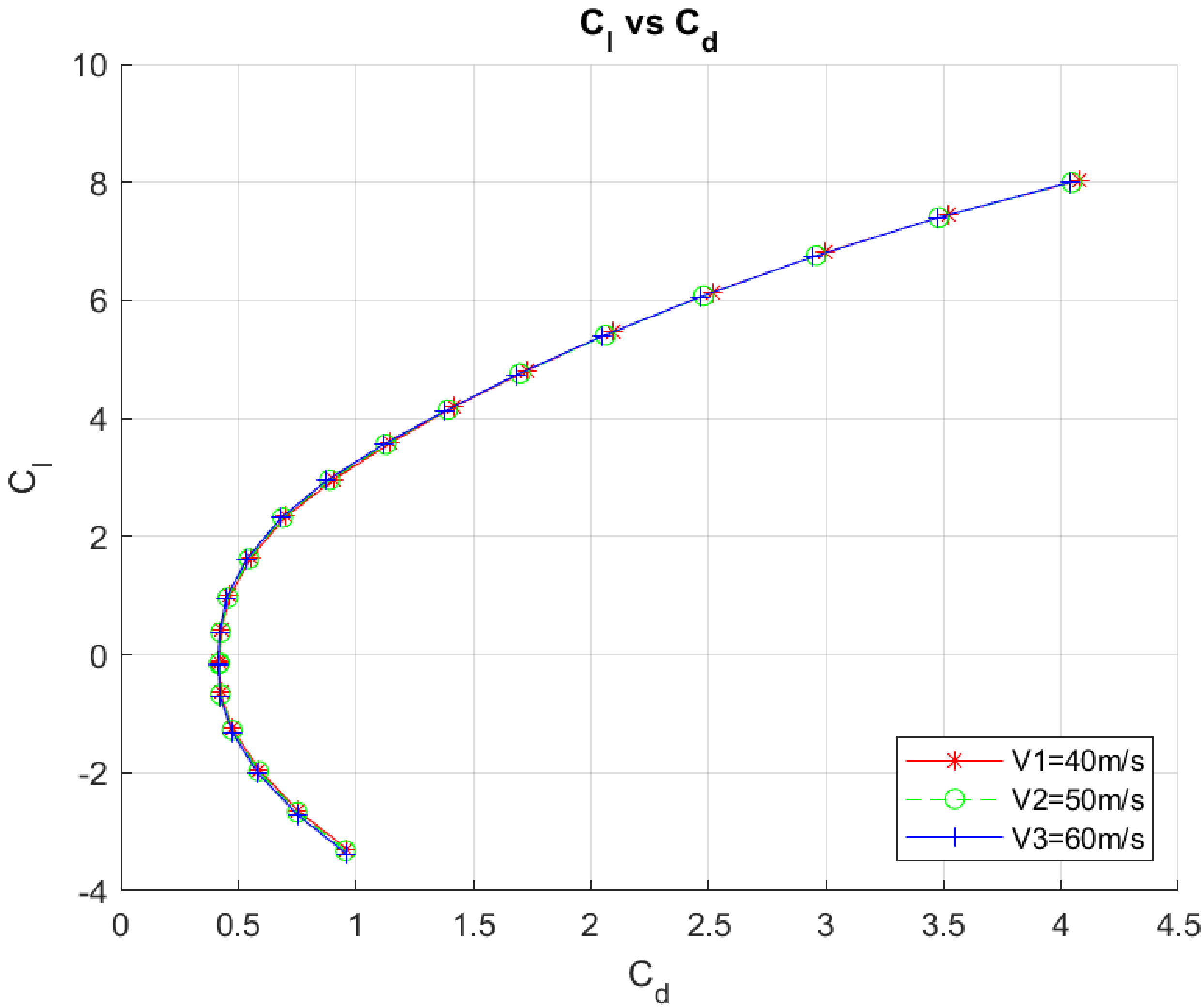
```
ylabel('C_m')
%%%ylim([-2 2])
title('C_m vs \alpha')
legend('V1=40m/s','V2=50m/s','V3=60m/s')
grid on

figure(2)
hold on
plot(F1,C1,'r-*',F2,C2,'g--o',F3,C3,'b-+')
hold off
xlabel('C_l^2')
ylabel('C_d')
title('C_d vs C_l^2')
legend('V1=40m/s','V2=50m/s','V3=60m/s')
grid on

figure(3)
hold on
plot(C1,B1,'r-*',C2,B2,'g--o',C3,B3,'b-+')
hold off
xlabel('C_d')
ylabel('C_l')
title('C_l vs C_d')
legend('V1=40m/s','V2=50m/s','V3=60m/s')
grid on
```

OUTPUT:

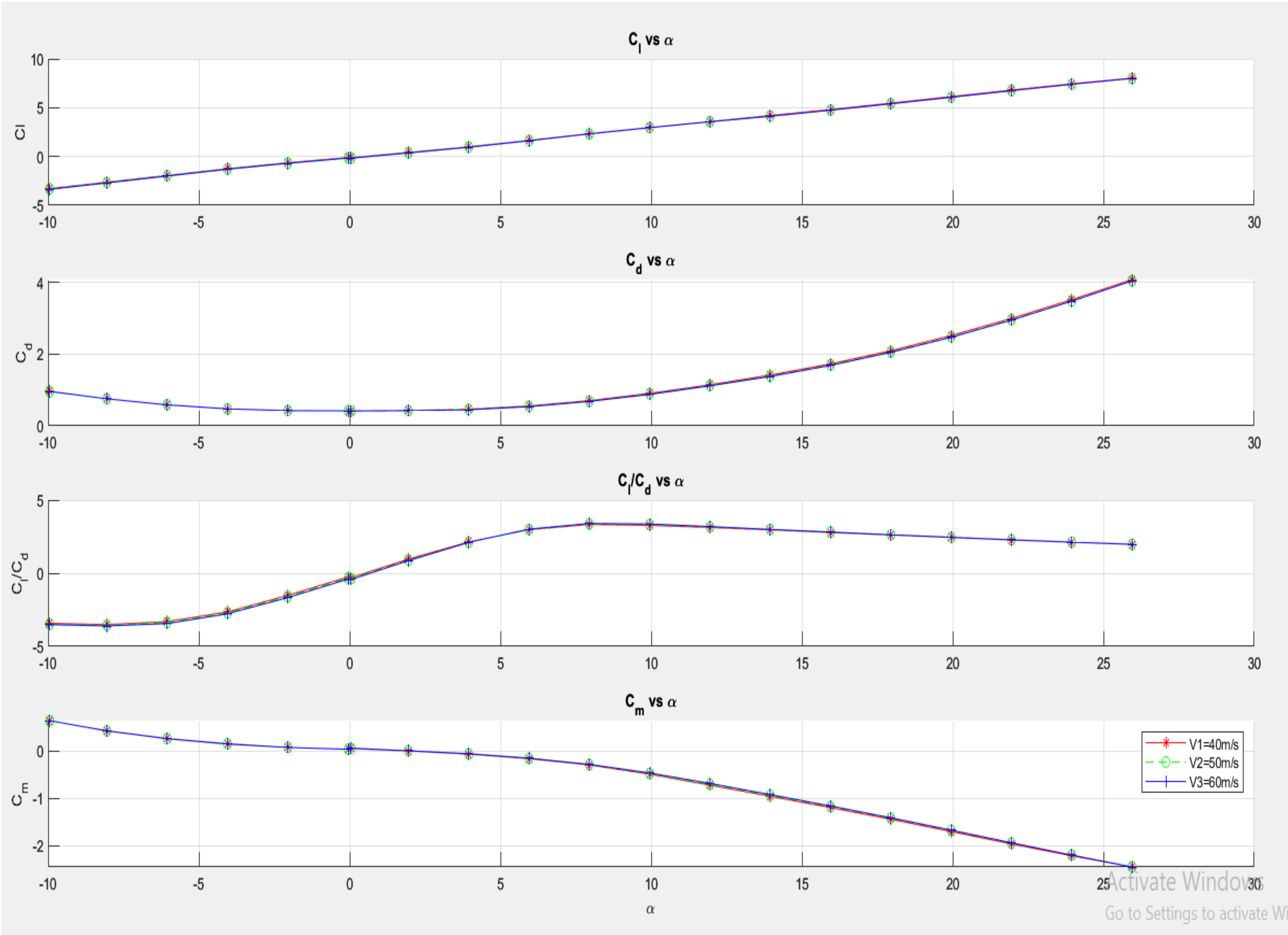
```
For V1 = 40 m/s
Average value of Cl_alpha
         0.289651313523897

Average value of Cm_alpha
       -0.0738563946746899

Average value of Cl_0
        -0.114953822730447

Average value of Cd_0
         0.417790574650793

Average value of Cm_0
        0.0460686750898652

Average value of Oswald Factor
        0.0620769400745473

For V2 = 50 m/s
Average value of Cl_alpha
         0.293152964329226

Average value of Cm_alpha
       -0.0730337804510235

Average value of Cl_0
        -0.145306644900576

Average value of Cd_0
         0.418762416218388

Average value of Cm_0
        0.0486256908273066

Average value of Oswald Factor
        0.0613826685175149

For V3 = 60 m/s
Average value of Cl_alpha
         0.297243996853772

Average value of Cm_alpha
        -0.070728671704105

Average value of Cl_0
        -0.171385547950948

Average value of Cd_0
         0.415274046293853

Average value of Cm_0
        0.0512527205030981

Average value of Oswald Factor
```

0.0609559460912554





C_l vs C_d
C_l
C_d
10
8
6
4
2
0
-2
-4
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
V1=40m/s
V2=50m/s
V3=60m/s



C_l vs α
Cl
C_d vs α
C_d
C_l/C_d vs α
C_l/C_d
C_m vs α
C_m
V1=40m/s
V2=50m/s
V3=60m/s
α
Activate Windows
Go to Settings to activate Win

For calculating the moement coefficient with respect to Delta E deflection We need to extrapolate the data for various DeltaE but with same pitch angle. Then we will obtain the moment coefficient and lift coefficient for respective delta E deflection and plot them for respective velocities.

MATLAB CODE: Cm_delta_e_TF .m

```
% Bomb Model-II Body + TailFins

%% Variation of Moment coefficient w.r.t. Elevator deflection

format long g


g = 9.81;

Cl = [];

Alpha = [];

C_m = [];


%Balance load matrix

CM = [63.080043 0.144499 -0.206795 1.354260 1.630051 4.275882

-0.123649 150.309342 0.592082 -0.725847 0.030856 0.393628

0.024098 -0.689773 151.831777 0.096597 -0.571799 -4.414537

0.152944 -2.334107 0.037781 77.595997 0.445712 5.841784

-0.006030 0.114642 -0.574072 -0.065800 79.176337 0.322466

0.047415 0.466131 0.099431 0.208017 0.190935 44.877349 ];


% Model reference parameters

% Sref(sqm) Chord (m) Span (m)

Sref = 0.009677; c = 0.111; b = 0.111;


% Moment reference point (nose)

% X (m) Y (m) Z (m)
```

```
% 0 0 0

% Balance center location
%X (m) Y (m) Z (m)
X =-0.465; Y = 0; Z = 0;

% Nowind data
% Ax N1 N2 S1 S2 Rm
NW = [-0.000655 0.000580 -0.000061 0.001303 0.000511 0.000551 %-25
0.000727 0.001383 -0.000710 0.000064 0.001230 0.000460 %-20
0.000234 0.001138 -0.000113 0.000821 0.000607 0.000418 %-15
0.001164 -0.000152 -0.001091 -0.000283 -0.000726 -0.001041 %-10
0.000761 -0.000269 -0.000213 0.000323 0.001154 0.001504 %-5
-0.000122 -0.000856 0.000737 -0.000887 -0.000321 0.000540 %0
0.000176 -0.000758 0.000311 0.001223 0.000471 0.000796 %+5
0.000913 -0.000361 -0.000542 0.000175 0.001508 0.001359 %+10
-0.000581 0.000769 0.000178 0.001345 0.000025 -0.000342 %+15
0.000648 0.001307 -0.000417 0.000376 0.001049 0.000623 %+20
-0.000356 0.000863 0.000397 -0.001130 0.000920 0.000653];%-25

Pitchi = -4.062500;

for i = 1:3
if i == 1
% Data for Speed 1
% Dyn. head Elevator Yaw Roll Ax N1 N2 S1 S2 Rm
DSi = [ 959.215909 -25 0.000000 0.000000 0.020809 0.035519 -0.056306 0.000113
0.003513 0.000338
```

```
945.375000 -20 0.000000 0.000000 0.017000 0.032764 -0.051806 -0.001380 0.004308
0.000178

969.715909 -15 0.000000 0.000000 0.012300 0.027724 -0.044101 -0.000783 0.003810
0.000219

955.397727 -10 0.000000 0.000000 0.008789 0.016792 -0.030323 0.000179 -0.001099 -
0.000978

946.000000 -5 0.000000 0.000000 0.006074 0.009475 -0.018501 0.001110 0.000089
0.001411

963.625000 0 0.000000 0.000000 0.004555 0.003472 -0.009070 0.000284 -0.002226
0.000534

968.113636 5 0.000000 0.000000 0.005048 -0.002249 -0.000300 0.002634 -0.001922
0.000944

958.181818 10 0.000000 0.000000 0.006581 -0.006434 0.006048 0.002046 -0.001971
0.001487

971.136364 15 0.000000 0.000000 0.007039 -0.010792 0.015021 0.002501 -0.002428
0.000009

952.795455 20 0.000000 0.000000 0.011158 -0.016412 0.023965 0.001802 -0.001871
0.000739

972.090909 25 0.000000 0.000000 0.016034 -0.025392 0.037407 -0.000543 -0.001439
0.001005];%20



end

if i == 2

%Data for Speed 2

% Dyn. head Elevator Yaw Roll Ax N1 N2 S1 S2 Rm

DSi = [ 1508.863636 -25 0.000000 0.000000 0.032557 0.055046 -0.087883 -0.001548
0.006623 0.000179

1479.590909 -20 0.000000 0.000000 0.025762 0.050157 -0.080249 -0.002414 0.006471 -
0.000063

1493.329545 -15 0.000000 0.000000 0.018344 0.041720 -0.067317 -0.001995 0.005961 -
0.000101

1499.204545 -10 0.000000 0.000000 0.012839 0.026321 -0.046709 0.000167 -0.000801 -
0.001099
```

```
1501.136364 -5 0.000000 0.000000 0.008936 0.014733 -0.028551 0.001414 -0.000326
0.001182

1499.386364 0 0.000000 0.000000 0.006959 0.005793 -0.014346 0.000839 -0.003119
0.000437

1508.818182 5 0.000000 0.000000 0.007640 -0.003056 -0.000694 0.003504 -0.003566
0.000874

1496.454545 10 0.000000 0.000000 0.009508 -0.009560 0.009225 0.003080 -0.003873
0.001424

1501.613636 15 0.000000 0.000000 0.010937 -0.016761 0.022506 0.003050 -0.003537
0.000094

1494.534091 20 0.000000 0.000000 0.016665 -0.026030 0.037008 0.002546 -0.003395
0.000550

1493.204545 25 0.000000 0.000000 0.024246 -0.039097 0.056697 -0.000615 -0.002430
0.001169];



end

if i == 3

% Data for Speed 3

% Dyn. head Pitch Yaw Roll Ax N1 N2 S1 S2 Rm

DSi = [2155.909091 -25 0.000000 0.000000 0.046215 0.078035 -0.125042 -0.003401
0.010173 -0.000063

2155.625000 -20 0.000000 0.000000 0.036439 0.071775 -0.115743 -0.003705 0.009093 -
0.000500

2160.931818 -15 0.000000 0.000000 0.025840 0.059415 -0.096672 -0.003945 0.009431 -
0.000463

2155.000000 -10 0.000000 0.000000 0.017529 0.037600 -0.066252 -0.000126 -0.000171 -
0.001421

2158.284091 -5 0.000000 0.000000 0.012240 0.021072 -0.040698 0.001573 -0.000301
0.000988

2161.352273 0 0.000000 0.000000 0.009910 0.008425 -0.020681 0.001316 -0.003819
0.000239

2169.738636 5 0.000000 0.000000 0.010722 -0.004133 -0.001082 0.004393 -0.005198
0.000746
```

```
2162.159091 10 0.000000 0.000000 0.013050 -0.013332 0.012940 0.004307 -0.006105
0.001305

2156.000000 15 0.000000 0.000000 0.015555 -0.023918 0.031557 0.003639 -0.004768
0.000206

2150.534091 20 0.000000 0.000000 0.023154 -0.037656 0.052766 0.003409 -0.005389
0.000411

2164.659091 25 0.000000 0.000000 0.034736 -0.056819 0.081326 -0.000750 -0.003101
0.001401];


end

Le = 0.884;

% Transformation Matrix from CG to Body center

x = -0.0074; % Xnp --> 0.605 (Neutral point from nose)

y = 0;

z = 0;

TM =[-1, 0, 0, 0, 0, 0

0, 1, 0, 0, 0, 0

0, 0, -1, 0, 0, 0

0, -z, y, 1, 0, 0

z, 0, -x, 0, 1, 0

-y, x, 0, 0, 0, 1];



for j = 1:11

aj = [DSi(j,5) ; DSi(j,6) ; DSi(j,7) ; DSi(j,8) ; DSi(j,9) ; DSi(j,10)];

% Convert the obtained normalized voltage signals to kg

Aj = CM * (aj-(NW(j,1:6))');

% Calculate the forces and moments about the balance center

fm = [Aj(1) ; (Aj(4)+Aj(5)) ; (Aj(2)+Aj(3)) ; Aj(6) ; (Aj(2)-Aj(3))*0.065 ; (Aj(4)-
Aj(5))*0.065].*g;
```

```
% Transform the forces and moments to the body axis

FM = [Aj(1) ; (Aj(4)+Aj(5)) ; (Aj(2)+Aj(3)) ; Aj(6) ; (Aj(2)-Aj(3))*0.065 ; (Aj(4)-
Aj(5))*0.065].*g;

% Transform the forces and moments to the C.G of the flight vehicle

FMcg = TM * FM;

% The variation of longitudinal force and moment coefficients

Cf = (1/(DSi(j,1)*Sref)).*[FMcg(1:3)];

Cm = (1/(DSi(j,1)*Sref*Le)).*[FMcg(4:6)];

Ele = (DSi(j,2));

% Variation of Aerodynamic force coefficients with angle of attack

Aero_TM = [ sind(Pitchi) 0 -cosd(Pitchi)

-cosd(Pitchi) 0 -sind(Pitchi)

0 1 0];

Aero_Coeff = Aero_TM*Cf;

% Recording The Data

Alpha = [Alpha; Ele'];

Cl = [Cl; Aero_Coeff'];

C_m = [C_m; Cm'];


end

end


A1= Alpha(1:11);

B1= Cl(1:11,1);

D1= C_m(1:11,2);

A2= Alpha(12:22);

B2= Cl(12:22,1);

D2= C_m(12:22,2);
```

```
A3= Alpha(23:33);

B3= Cl(23:33,1);

D3= C_m(23:33,2);


figure(1)

hold on

plot(A1,B1,'r-*',A2,B2,'g--o',A3,B3,'b-+')

hold off

xlabel('\delta_e')

ylabel('Cl')

title('C_l vs \delta_e')

legend('V1=40m/s','V2=50m/s','V3=60m/s')

grid on


figure(2)

hold on

plot(A1,D1,'r-*',A2,D2,'g--o',A3,D3,'b-+')

hold off

xlabel('\delta_e')

ylabel('C_m')

%%%ylim([-2 2])

title('C_m vs \delta_e')

legend('V1=40m/s','V2=50m/s','V3=60m/s')

grid on


% Calculating Slope of Moment Coefficient

% For V1

cc1=0;
```

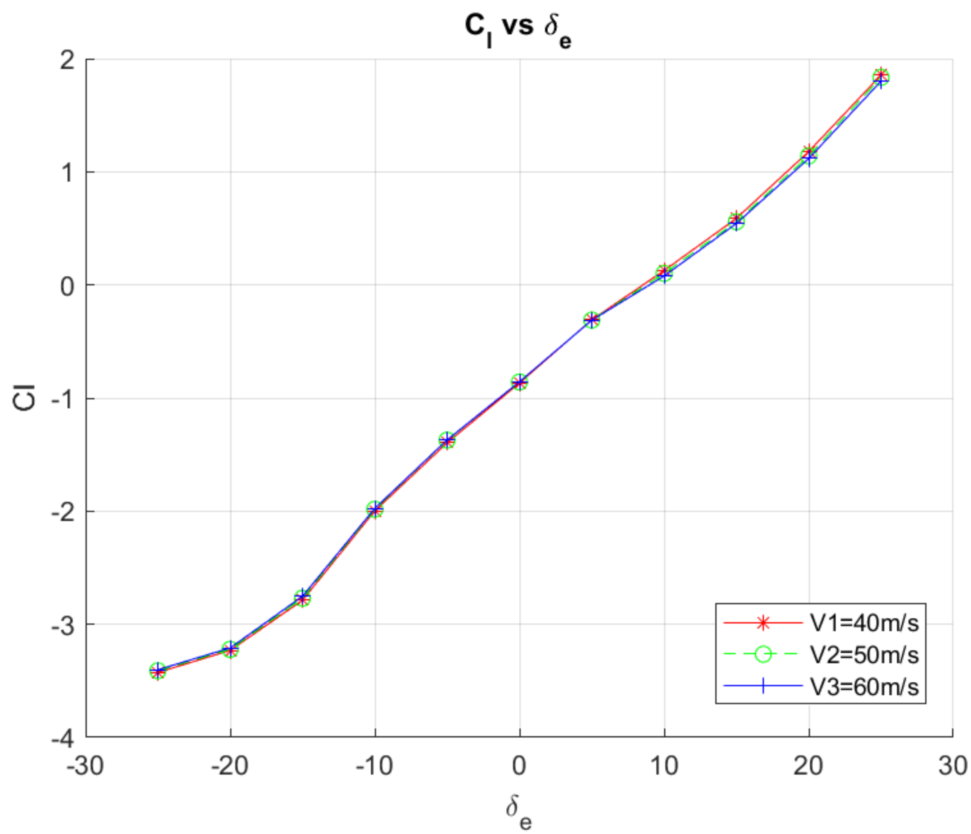
```
Cm_Alpha1i = 0;

Cl_Alpha1i = 0;

for l = 2:1:11

D_Alpha1 = A1(l)-A1(l-1) ;

D_Cl1 = B1(l)-B1(l-1);

D_Cm1 = D1(l)-D1(l-1);

Cm_alpha1 = D_Cm1/D_Alpha1;

Cl_alpha1 = D_Cl1/D_Alpha1;

Cl_Alpha1i = Cl_Alpha1i + Cl_alpha1;

Cm_Alpha1i = Cm_Alpha1i + Cm_alpha1;

cc1 = cc1+1;

end

F_Cm_Alpha1 = Cm_Alpha1i/cc1;

F_Cl_Alpha1 = Cl_Alpha1i/cc1;

disp('For V1 = 40 m/s')

disp('Average value of Cl_delta_e')

disp(F_Cl_Alpha1)

disp('Average value of Cm_delta_e')

disp(F_Cm_Alpha1)


% For V2

cc2=0;

Cm_Alpha2i = 0;

Cl_Alpha2i = 0;

for l = 2:1:11

D_Alpha2 = A2(l)-A2(l-1) ;

D_Cl2 = B2(l)-B2(l-1);

D_Cm2 = D2(l)-D2(l-1);
```

```
Cm_alpha2 = D_Cm2/D_Alpha2;

Cl_alpha2 = D_Cl2/D_Alpha2;

Cl_Alpha2i = Cl_Alpha2i + Cl_alpha2;

Cm_Alpha2i = Cm_Alpha2i + Cm_alpha2;

cc2 = cc2+1;

end

F_Cm_Alpha2 = Cm_Alpha2i/cc2;

F_Cl_Alpha2 = Cl_Alpha2i/cc2;

disp('For V2 = 50 m/s')

disp('Average value of Cl_delta_e')

disp(F_Cl_Alpha2)

disp('Average value of Cm_delta_e')

disp(F_Cm_Alpha2)


% For V3

cc3=0;

Cm_Alpha3i = 0;

Cl_Alpha3i = 0;

for l = 2:1:11

D_Alpha3 = A3(l)-A3(l-1) ;

D_Cl3 = B3(l)-B3(l-1);

D_Cm3 = D3(l)-D3(l-1);

Cm_alpha3 = D_Cm3/D_Alpha3;

Cl_alpha3 = D_Cl3/D_Alpha3;

Cl_Alpha3i = Cl_Alpha3i + Cl_alpha3;

Cm_Alpha3i = Cm_Alpha3i + Cm_alpha3;

cc3 = cc3+1;

end
```

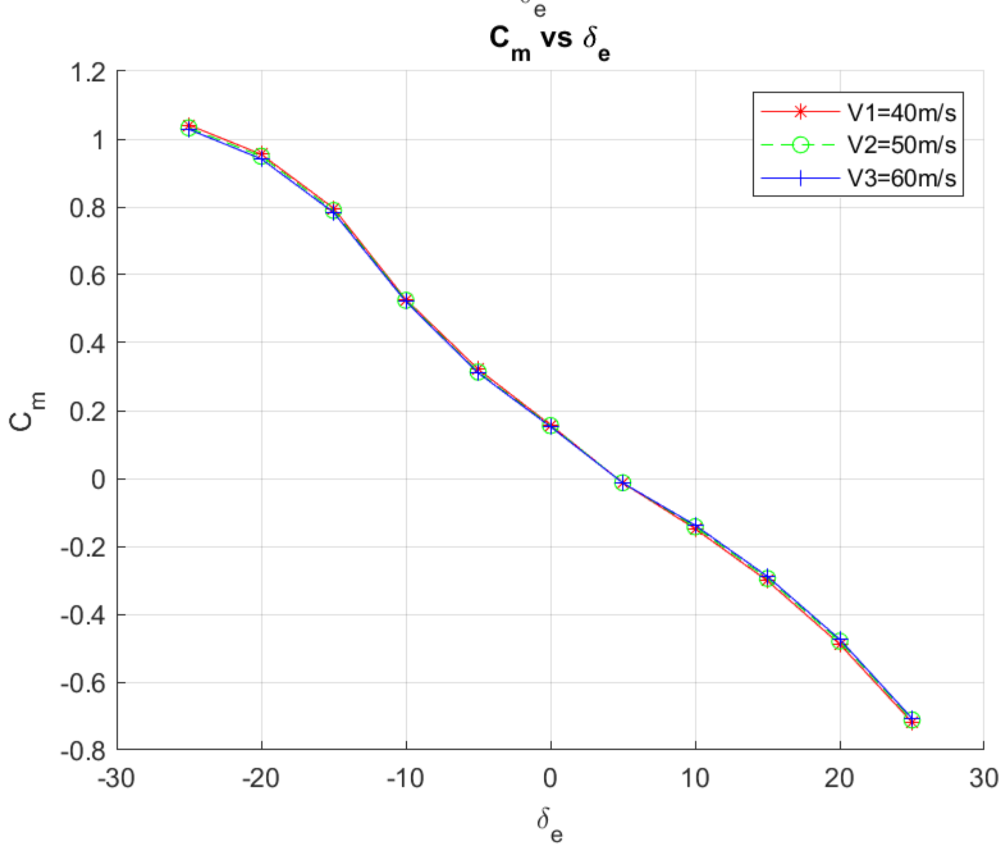
```
F_Cm_Alpha3 = Cm_Alpha3i/cc3;

F_Cl_Alpha3 = Cl_Alpha3i/cc3;

disp('For V3 = 60 m/s')

disp('Average value of Cl_delta_e')

disp(F_Cl_Alpha3)

disp('Average value of Cm_delta_e')

disp(F_Cm_Alpha3)
```

OUTPUT:

```
For V1 = 40 m/s
Average value of Cl_delta_e
          0.10562687525943

Average value of Cm_delta_e
       -0.0351950634576969

For V2 = 50 m/s
Average value of Cl_delta_e
          0.10489761748853

Average value of Cm_delta_e
       -0.0348923130330476

For V3 = 60 m/s
Average value of Cl_delta_e
         0.104059255120107

Average value of Cm_delta_e
       -0.0347111212501249
```



Cl vs δe
Cl
δe
V1=40m/s
V2=50m/s
V3=60m/s



Cm vs δe
Cm
δe
V1=40m/s
V2=50m/s
V3=60m/s

.MATLAB CODE: Cm_delta_e_TF_NF.m

```
% Body + NoseFins + TailFins + NoseFins

%% Variation of Moment coefficient w.r.t. Elevator deflection

format long g


g = 9.81;

Cl = [];

Alpha = [];

C_m = [];


%Balance load matrix

CM = [63.080043 0.144499 -0.206795 1.354260 1.630051 4.275882

-0.123649 150.309342 0.592082 -0.725847 0.030856 0.393628

0.024098 -0.689773 151.831777 0.096597 -0.571799 -4.414537

0.152944 -2.334107 0.037781 77.595997 0.445712 5.841784

-0.006030 0.114642 -0.574072 -0.065800 79.176337 0.322466

0.047415 0.466131 0.099431 0.208017 0.190935 44.877349];


% Model reference parameters

% Sref(sqm) Chord (m) Span (m)

Sref = 0.009677; c = 0.111; b = 0.111;


% Moment reference point (nose)

% X (m) Y (m) Z (m)

% 0 0 0


% Balance center location

%X (m) Y (m) Z (m)
```

```
X =-0.465; Y = 0; Z = 0;

% Nowind data
% Ax N1 N2 S1 S2 Rm
NW = [-0.000285 -0.000793 -0.000714 0.001382 0.001304 -0.000896 % -10
0.000770 0.000858 0.000866 0.000727 -0.000826 0.000939 % -05
-0.000060 0.000720 -0.000535 -0.000702 0.000175 -0.000938 % 00
0.000584 0.000924 0.001203 0.000854 -0.001032 0.000897 % 05
0.001288 0.001094 0.000372 0.000063 -0.000004 0.001433];% 10

Pitchi = 3.947917;

for i = 1:3
if i == 1
% Data for Speed 1
% Dyn. head Elevator Yaw Roll Ax N1 N2 S1 S2 Rm
DSi = [956.613636 -10 0.000000 0.000000 0.008969 0.014374 -0.016207 0.003729 0.000641
-0.000555
962.477273 -05 0.000000 0.000000 0.007567 0.015164 -0.010113 0.005263 -0.003927
0.001079
980.386364 00 0.000000 0.000000 0.006000 0.011205 -0.004648 0.002760 -0.002287 -
0.000951
963.318182 05 0.000000 0.000000 0.007266 0.006149 0.005136 0.005586 -0.005078
0.000798
951.579545 10 0.000000 0.000000 0.009792 0.000265 0.013822 0.005092 -0.004629
0.001546];



end
if i == 2
```

```
%Data for Speed 2

% Dyn. head Elevator Yaw Roll Ax N1 N2 S1 S2 Rm

DSi = [1484.375000 -10 0.000000 0.000000 0.013694 0.024866 -0.026298 0.004252
0.000996 -0.000635

1497.863636 -05 0.000000 0.000000 0.011547 0.021348 -0.014914 0.008450 -0.005916
0.001035

1503.238636 00 0.000000 0.000000 0.009064 0.016918 -0.007061 0.004863 -0.003809 -
0.001007

1492.897727 05 0.000000 0.000000 0.010794 0.009277 0.006837 0.008420 -0.007463
0.000730

1514.727273 10 0.000000 0.000000 0.014524 0.000673 0.020373 0.008270 -0.007440
0.001494];



end

if i == 3

% Data for Speed 3

% Dyn. head Pitch Yaw Roll Ax N1 N2 S1 S2 Rm

DSi = [2155.170455 -10 0.000000 0.000000 0.019466 0.037130 -0.038417 0.004791
0.001493 -0.000757

2148.931818 -05 0.000000 0.000000 0.016331 0.034577 -0.025182 0.011087 -0.007623
0.000859

2155.477273 00 0.000000 0.000000 0.012750 0.024123 -0.010274 0.007539 -0.005805 -
0.001135

2150.988636 05 0.000000 0.000000 0.015385 0.012956 0.008959 0.012206 -0.010416
0.000700

2152.750000 10 0.000000 0.000000 0.019810 0.001425 0.027528 0.011871 -0.010392
0.001382];


end


Le = 0.884;
```

```
% Transformation Matrix from CG to Body center

x = 0.2126; % Xnp --> 0.605 (Neutral point from nose)

y = 0;

z = 0;

TM =[-1, 0, 0, 0, 0, 0

0, 1, 0, 0, 0, 0

0, 0, -1, 0, 0, 0

0, -z, y, 1, 0, 0

z, 0, -x, 0, 1, 0

-y, x, 0, 0, 0, 1];


for j = 1:5

aj = [DSi(j,5) ; DSi(j,6) ; DSi(j,7) ; DSi(j,8) ; DSi(j,9) ; DSi(j,10)];

% Convert the obtained normalized voltage signals to kg

Aj = CM * (aj-(NW(j,1:6))');

% Calculate the forces and moments about the balance center

fm = [Aj(1) ; (Aj(4)+Aj(5)) ; (Aj(2)+Aj(3)) ; Aj(6) ; (Aj(2)-Aj(3))*0.065 ; (Aj(4)-
Aj(5))*0.065].*g;

% Transform the forces and moments to the body axis

FM = [Aj(1) ; (Aj(4)+Aj(5)) ; (Aj(2)+Aj(3)) ; Aj(6) ; (Aj(2)-Aj(3))*0.065 ; (Aj(4)-
Aj(5))*0.065].*g;

% Transform the forces and moments to the C.G of the flight vehicle

FMcg = TM * FM;

% The variation of longitudinal force and moment coefficients

Cf = (1/(DSi(j,1)*Sref)).*[FMcg(1:3)];

Cm = (1/(DSi(j,1)*Sref*Le)).*[FMcg(4:6)];

Ele = (DSi(j,2));

% Variation of Aerodynamic force coefficients with angle of attack
```

```
Aero_TM = [ sind(Pitchi) 0 -cosd(Pitchi)
-cosd(Pitchi) 0 -sind(Pitchi)
0 1 0];
Aero_Coeff = Aero_TM*Cf;
% Recording The Data
Alpha = [Alpha; Ele'];
Cl = [Cl; Aero_Coeff'];
C_m = [C_m; Cm'];

end
end

A1= Alpha(1:5);
B1= Cl(1:5,1);
D1= C_m(1:5,2);

A2= Alpha(6:10);
B2= Cl(6:10,1);
D2= C_m(6:10,2);

A3= Alpha(11:15);
B3= Cl(11:15,1);
D3= C_m(11:15,2);
figure(1)
hold on
plot(A1,B1,'r-*',A2,B2,'g--o',A3,B3,'b-+')
hold off
xlabel('\delta_e')
```

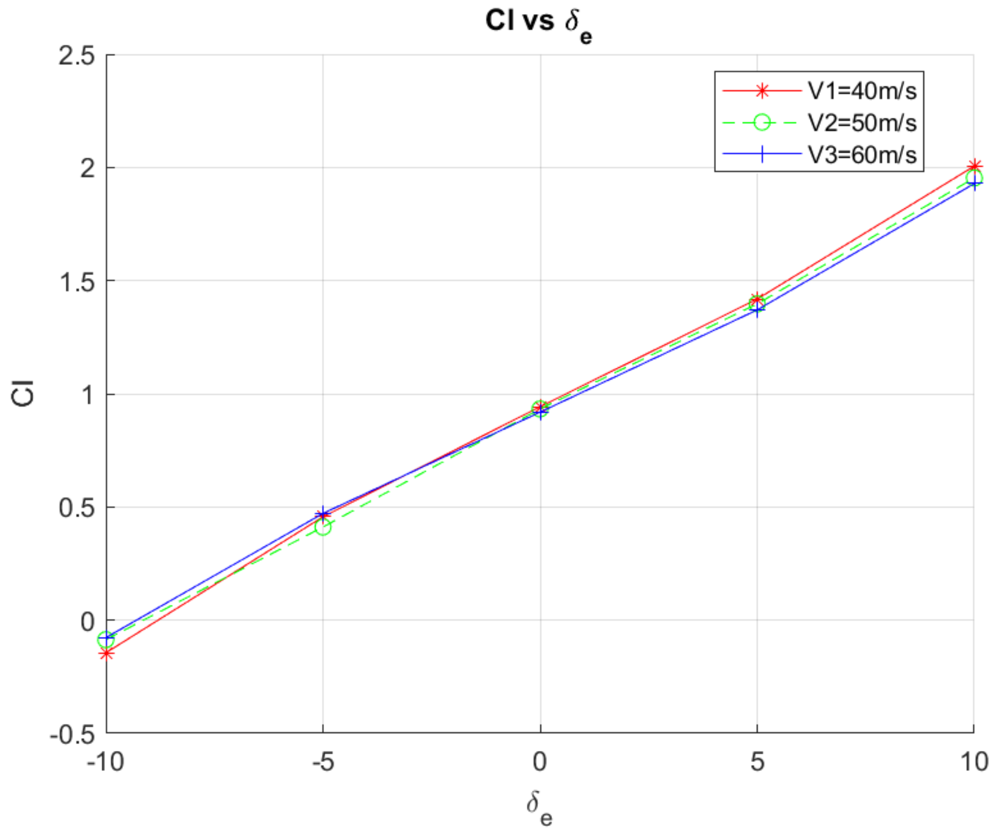
```
ylabel('Cl')
title('Cl vs \delta_e')
legend('V1=40m/s','V2=50m/s','V3=60m/s')
grid on

figure(2)
hold on
plot(A1,D1,'r-*',A2,D2,'g--o',A3,D3,'b-+')
hold off
xlabel('\delta_e')
ylabel('Cm')
title('Cm vs \delta_e')
legend('V1=40m/s','V2=50m/s','V3=60m/s')
grid on

% Calculating Slope of Moment Coefficient
%For V1
cc1=0;
Cm_Alpha1i = 0;
Cl_Alpha1i = 0;
for l = 2:1:5
D_Alpha1 = A1(l)-A1(l-1) ;
D_Cl1 = B1(l)-B1(l-1);
D_Cm1 = D1(l)-D1(l-1);
Cm_alpha1 = D_Cm1/D_Alpha1;
Cl_alpha1 = D_Cl1/D_Alpha1;
Cl_Alpha1i = Cl_Alpha1i + Cl_alpha1;
Cm_Alpha1i = Cm_Alpha1i + Cm_alpha1;
```

```
cc1 = cc1+1;
end
F_Cm_Alpha1 = Cm_Alpha1i/cc1;
F_Cl_Alpha1 = Cl_Alpha1i/cc1;
disp('For V1 = 40 m/s')
disp('Average value of Cl_delta_e')
disp(F_Cl_Alpha1)
disp('Average value of Cm_delta_e')
disp(F_Cm_Alpha1)

%For V2
cc2=0;
Cm_Alpha2i = 0;
Cl_Alpha2i = 0;
for l = 2:1:5
D_Alpha2 = A2(l)-A2(l-1) ;
D_Cl2 = B2(l)-B2(l-1);
D_Cm2 = D2(l)-D2(l-1);
Cm_alpha2 = D_Cm2/D_Alpha2;
Cl_alpha2 = D_Cl2/D_Alpha2;
Cl_Alpha2i = Cl_Alpha2i + Cl_alpha2;
Cm_Alpha2i = Cm_Alpha2i + Cm_alpha2;
cc2 = cc2+1;
end
F_Cm_Alpha2 = Cm_Alpha2i/cc2;
F_Cl_Alpha2 = Cl_Alpha2i/cc2;
disp('For V2 = 50 m/s')
disp('Average value of Cl_delta_e')
```

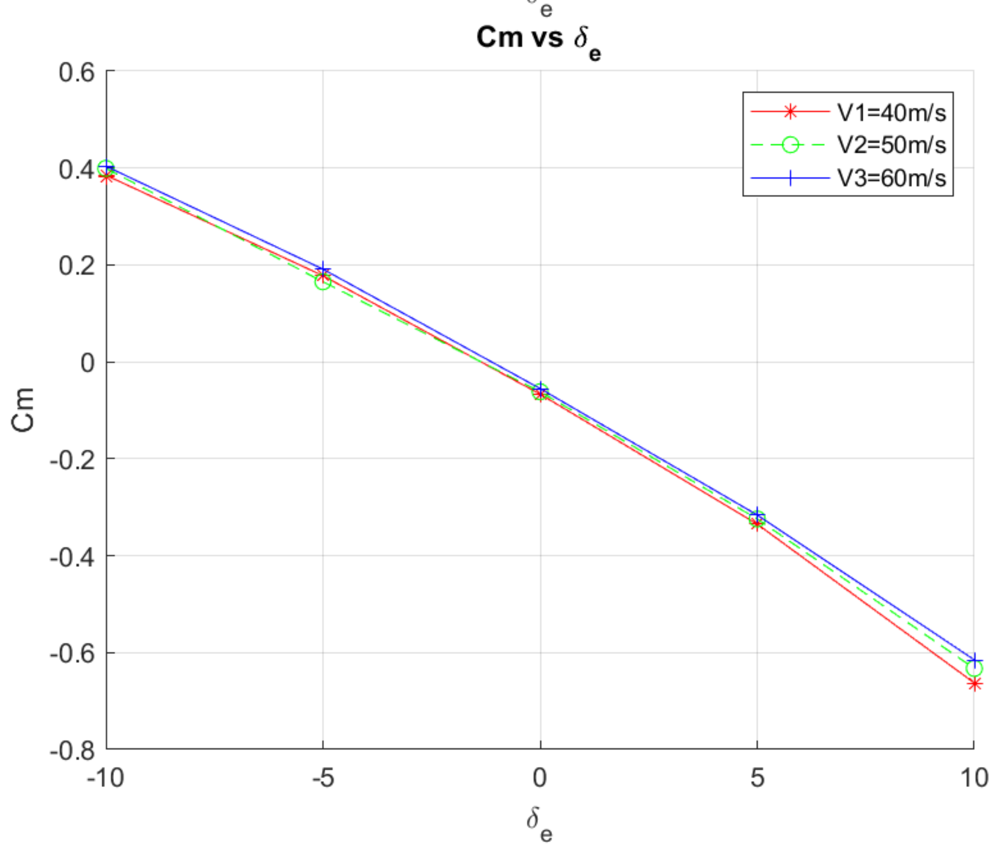
```
disp(F_Cl_Alpha2)

disp('Average value of Cm_delta_e')

disp(F_Cm_Alpha2)


%For V3

cc3=0;

Cm_Alpha3i = 0;

Cl_Alpha3i = 0;

for l = 2:1:5

D_Alpha3 = A3(l)-A3(l-1) ;

D_Cl3 = B3(l)-B3(l-1);

D_Cm3 = D3(l)-D3(l-1);

Cm_alpha3 = D_Cm3/D_Alpha3;

Cl_alpha3 = D_Cl3/D_Alpha3;

Cl_Alpha3i = Cl_Alpha3i + Cl_alpha3;

Cm_Alpha3i = Cm_Alpha3i + Cm_alpha3;

cc3 = cc3+1;

end

F_Cm_Alpha3 = Cm_Alpha3i/cc3;

F_Cl_Alpha3 = Cl_Alpha3i/cc3;

disp('For V3 = 60 m/s')

disp('Average value of Cl_delta_e')

disp(F_Cl_Alpha3)

disp('Average value of Cm_delta_e')

disp(F_Cm_Alpha3)
```

OUTPUT:

```
For V1 = 40 m/s
Average value of Cl_delta_e
         0.107508425961022

Average value of Cm_delta_e
       -0.0523983099256104

For V2 = 50 m/s
Average value of Cl_delta_e
         0.101974303055021

Average value of Cm_delta_e
       -0.0516024004717748

For V3 = 60 m/s
Average value of Cl_delta_e
         0.100295489197539

Average value of Cm_delta_e
       -0.0509503846812724
```



Cl vs δ_e
2.5
2
1.5
1
0.5
0
-0.5
Cl
-10
-5
0
5
10
δ_e
V1=40m/s
V2=50m/s
V3=60m/s



Cm vs δ_e
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Cm
-10
-5
0
5
10
δ_e
V1=40m/s
V2=50m/s
V3=60m/s