••• Q–1, Variation of longitudinal force and moment coefficients •••

Problem

Plot the variation of longitudinal force and moment coefficients with angle of attack, velocity, and control surface deflections for all cases.

PROCEDURE

Step 1: Find the values of C_L & C_{My} for any one Angle of Attack.

Step 2: Repeat step 1 for different elevator deflections.

Step 3: Collect all the data for different deflections.

Step 4: Plot “Cm v/s δe”.

MATLAB code

(1) Body alone case

>> main_projectile.m

```
clear all
close all
clc

Initial_conditions_projectile

dummy1 = [];

for i = 1:1:3
   k = wind_tunnel_data_projectile(i);
   q = head(i);
   conversion_projectile;
end

plot_projectile
```

>> Initial_conditions_projectile.m

```
% Geometric data
S = 0.009677;
% l = 0.111;
l = 0.884;
```

```
span = 0.111;
b = 0;  % Beta is 0 degree

% Balance center location(m)
x = -0.24915;
y = 0;
z = 0;

v1 = 40;    % m/s
v2 = 50;    % m/s
v3 = 60;    % m/s
v = [v1, v2, v3];

q1 = 974.329545;    % Dynamic head [in kg/m*s2]
q2 = 1499.272727;    % Dynamic head
q3 = 2172.920455;    % Dynamic head
head = [q1, q2, q3];

g = 9.81;
```

>> wind_tunnel_data_projectile.m

```
%% 6680_Bomb Model-II_Body Alone

function k = wind_tunnel_data_projectile(int)

switch int

   case 1  % 6680_Bomb Model-II_Body Alone (1-3)

k = [-9.9479170.002673      -0.006420       0.005058        -0.001114       0.000491        -
0.000003;
    -8.052083   0.002539      -0.004903       0.004606        -0.000981       0.000274        -
0.000041;
    -6.052083   0.002434      -0.003329       0.003960        -0.000981       0.000253        -
0.000068;
    -4.062500   0.002377      -0.001724       0.003177        -0.000968       0.000107        -
0.000071;
    -2.052083   0.002325      -0.000170       0.002245        -0.000885       0.000153        -
0.000090;
    -0.052083   0.002249      0.001322        0.001340        -0.000831       0.000072        -
0.000128;
    0.052083    0.002201      0.001334        0.001344        -0.000864       0.000120        -
0.000131;
    1.947917    0.002324      0.002779        0.000499        -0.000783       0.000108        -
0.000153;
    3.947917    0.002385      0.004320        -0.000380       -0.000745       -0.000003       -
0.000158;
```

```
    5.947917  0.002458  0.005940  -0.001250  -0.000692  -0.000010  -
0.000191;
    7.947917  0.002611  0.007523  -0.001939  -0.000602  -0.000087  -
0.000206;
    9.947917  0.002765  0.009013  -0.002427  -0.000612  -0.000136  -
0.000233;
    11.947917 0.002850  0.010588  -0.002839  -0.000578  -0.000102  -
0.000257;
    13.947917 0.002862  0.012207  -0.003176  -0.000626  -0.000078  -
0.000250;
    15.937500 0.002895  0.013871  -0.003436  -0.000631  -0.000056  -
0.000280;
    17.937500 0.002860  0.015556  -0.003610  -0.000583  -0.000413  -
0.000303;
    19.947917 0.002808  0.017221  -0.003662  -0.000535  -0.000676  -
0.000332;
    21.947917 0.002689  0.018903  -0.003702  -0.000579  -0.000642  -
0.000360;
    23.947917 0.002521  0.020650  -0.003677  -0.000634  -0.000730  -
0.000392;
    25.947917 0.002294  0.022447  -0.003645  -0.000538  -0.001077  -
0.000409];
```

case 2

```
k = [-9.947917 0.004587  -0.010519  0.006953  -0.001412  0.000946  -
0.000015;
   -8.052083  0.004404  -0.008223  0.006295  -0.001239  0.000592  -
0.000048;
   -6.052083  0.00421    -0.005792  0.005321  -0.001273  0.000473  -
0.000069;
   -4.0625    0.004093  -0.003315  0.004037  -0.001198  0.000382  -
0.000141;
   -2.052083  0.004003  -0.000914  0.002615  -0.001125  0.000283  -
0.000183;
   -0.052083  0.003968  0.001367  0.001249  -0.000983  0.000286  -
0.000204;
    0.052083  0.00389    0.001442  0.00119    -0.001057  0.000316  -
0.000323;
    1.947917  0.004016  0.00368    -0.000143  -0.000923  0.000177  -
0.000222;
    3.947917  0.004096  0.006063  -0.001533  -0.000902  0.000197  -
0.000269;
    5.947917  0.004177  0.008541  -0.002856  -0.000859  0.000128  -
0.000303;
    7.947917  0.004368  0.010913  -0.003881  -0.000755  -0.00002  -
0.000341;
    9.947917  0.004593  0.013239  -0.004599  -0.000664  -0.000136  -
0.000388;
```

11.947917 0.004712 0.015682 -0.005213 -0.000669 -0.000025 -0.000397;
13.947917 0.004752 0.018147 -0.005713 -0.000716 0.000002 -0.000445;
15.9375 0.004759 0.020667 -0.006095 -0.000655 -0.000346 -0.000474;
17.9375 0.004694 0.023277 -0.006399 -0.000509 -0.000902 -0.000543;
19.947917 0.004571 0.025917 -0.006611 -0.000528 -0.001019 -0.000597;
21.947917 0.00437 0.028594 -0.006665 -0.000663 -0.001004 -0.000622;
23.947917 0.004114 0.031377 -0.006636 -0.000697 -0.00117 -0.000684;
25.947917 0.003761 0.034218 -0.00653 -0.000258 -0.002047 -0.00073];

case 3

k = [-9.9479170.006916 -0.015706 0.009377 -0.001872 0.00138 -0.000105;
-8.052083 0.006651 -0.012341 0.008425 -0.001672 0.00104 -0.000155;
-6.052083 0.006393 -0.008838 0.006984 -0.001653 0.000856 -0.000195;
-4.0625 0.00624 -0.005337 0.005156 -0.001549 0.000713 -0.00023;
-2.0625 0.00616 -0.001847 0.003104 -0.001436 0.000613 -0.000284;
-0.052083 0.006067 0.001535 0.00105 -0.001293 0.000493 -0.000336;
0.052083 0.006014 0.00155 0.00096 -0.001306 0.000575 -0.000463;
1.947917 0.006095 0.004862 -0.000972 -0.001223 0.000523 -0.000381;
3.947917 0.006189 0.00831 -0.002973 -0.001107 0.000492 -0.000439;
5.9375 0.006286 0.011904 -0.004877 -0.00101 0.000424 -0.000466;
7.947917 0.006565 0.015344 -0.006404 -0.000883 0.000258 -0.000525;
9.947917 0.006871 0.018639 -0.007381 -0.000782 0.000164 -0.000568;
11.947917 0.006984 0.022162 -0.008318 -0.000734 0.00016 -0.000631;
13.947917 0.007035 0.025766 -0.009044 -0.000795 -0.000042 -0.000673;
15.9375 0.007042 0.029433 -0.009589 -0.0007 -0.000477 -0.000759;

```
   17.9375        0.006945    0.033266      -0.010124     -0.000538     -0.001151     -
0.000813;
   19.947917   0.006745     0.037188      -0.010493     -0.000556     -0.001314     -
0.00087;
   21.947917   0.006498     0.041137      -0.010671     -0.000674     -0.001308     -
0.000959;
   23.9375        0.006105    0.045155      -0.010599     -0.00088      -0.001188     -
0.001035;
   25.947917   0.00557        0.049182      -0.010379     -0.000121     -0.00244      -
0.001125];

end
end
```

>> conversion_projectile.m

```
%% Conversion from Voltage signal to kg

CM = [63.080043 0.144499   -0.206795   1.35426        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;
     -0.00603   0.114642    -0.574072  -0.0658        79.176337  0.322466;
     0.047415   0.466131    0.099431   0.208017    0.190935   44.877349];

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

a2 = k(:,2)';
a3 = k(:,3)';
a4 = k(:,4)';
a5 = k(:,5)';
a6 = k(:,6)';
a7 = k(:,7)';

a = [a2; a3; a4; a5; a6; a7];

dummy_A = [];

for i = 1:1:20
   A = CM*[a(:,i) - NW];
   dummy_A = [dummy_A, A];
end

A = dummy_A;       % Each column indicates the values of [Af; N1; N2; S1; S2; Rm] for 20
different AOA

calc_projectile
```

>> calc_projectile.m

```
CL_dummy = [];
CD_dummy = [];
CM_dummy = [];
alpha_dummy = [];

for i = 1:1:20

%     x = 0.45;   % The CG is varied from 0.45 to -0.45 to find NP of configuration

    alpha = k(i,1);
    alpha_dummy = [alpha_dummy, alpha];

    Af = A(1,i);
    N1 = A(2,i);
    N2 = A(3,i);
    S1 = A(4,i);
    S2 = A(5,i);
    Rm = A(6,i);

    % [Ax, Sf, Nf, Rm, Pm, Ym] = [Af*g; (S1 + S2)*g; (N1 + N2)*g; Rm*g; (N1 -
N2)*0.065*g; (S1 - S2)*0.065*g];
    Ax = Af*g;
    Sf = (S1 + S2)*g;
    Nf = (N1 + N2)*g;
    Rm = Rm*g;
    Pm = (N1 - N2)*0.065*g;
    Ym = (S1 - S2)*0.065*g;

    % [fx, fy, fz, mx, my, mz] = [-Ax; Sf; -Nf; Rm; Pm; Ym];
    fx = Ax;
    fy = Sf;
    fz = Nf;
    mx = Rm;
    my = Pm;
    mz = Ym;

    F = [-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]*[fx; fy; fz;
mx; my; mz];
    Fx = F(1);
    Fy = F(2);
    Fz = F(3);
    Mx = F(4);
    My = F(5);
    Mz = F(6);

%     Cf = (1/(q*S))*(-1)*[Fx; Fy; Fz];
    Cf = (1/(q*S))*[Fx; Fy; Fz];
    Cfx = Cf(1);
```

```
    Cfy = Cf(2);
    Cfz = Cf(3);

%     Cm = (1/(q*S*l))*(-1)*[Mx; My; Mz];
    Cm = (1/(q*S*l))*(-1)*[Mx; My; Mz];
    Cmx = Cm(1);
    Cmy = Cm(2);
    Cmz = Cm(3);

    C = [sind(alpha), 0, -cosd(alpha); -cosd(alpha), 0, -sind(alpha); 0, cosd(alpha), 0]*[Cfx;
Cfy; Cfz];
    CL_dummy = [CL_dummy, C(1)];
    CD_dummy = [CD_dummy, C(2)];
    CM_dummy = [CM_dummy, Cm(2)];

%     x = x - 0.045;

end

dummy = [CL_dummy;CD_dummy;CM_dummy]

data_collect_projectile
```

>> data_collect_projectile.m

```
dummy1 = [dummy1, dummy];
```

>> plot_projectile

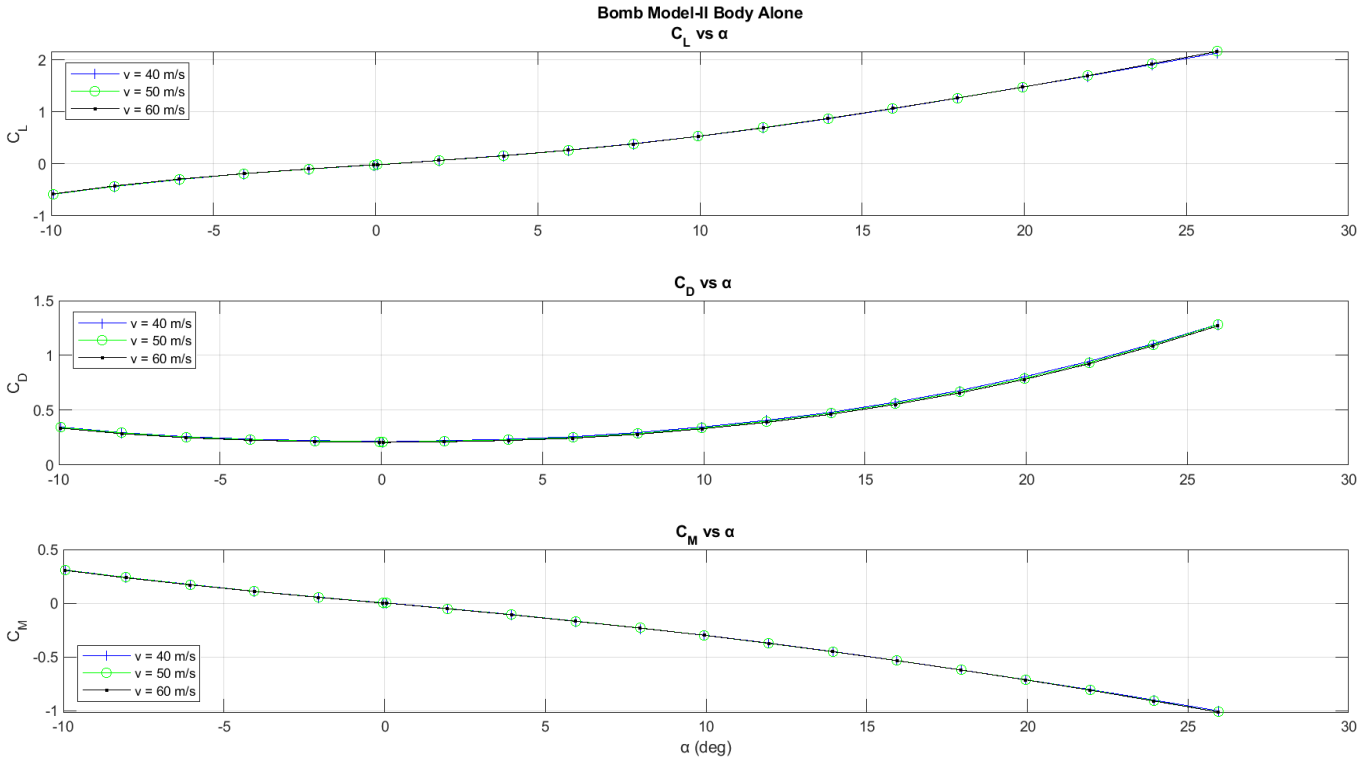
```
%     figure(1)
    figure('Name','6680_Bomb Model-II_Body Alone','NumberTitle','off');
    subplot(3,1,1)
    plot(alpha_dummy,dummy1(1,1:20),'|-b')
    hold on
    plot(alpha_dummy,dummy1(1,21:40),'o-g')
    hold on
    plot(alpha_dummy,dummy1(1,41:60),'.-k')
    hold off
    grid on
    title({'Bomb Model-II Body Alone','C_L vs α'})
    ylabel('C_L')
    legend({'v = 40 m/s','v = 50 m/s','v = 60 m/s'},'Location','northwest')

%     figure(2)
    subplot(3,1,2)
    plot(alpha_dummy,dummy1(2,1:20),'|-b')
    hold on
    plot(alpha_dummy,dummy1(2,21:40),'o-g')
```

```
hold on
plot(alpha_dummy,dummy1(2,41:60),'.-k')
hold off
grid on
title('C_D vs α')
ylabel('C_D')
legend({'v = 40 m/s','v = 50 m/s','v = 60 m/s'},'Location','northwest')

%    figure(3)
subplot(3,1,3)
plot(alpha_dummy,dummy1(3,1:20),'|-b')
hold on
plot(alpha_dummy,dummy1(3,21:40),'o-g')
hold on
plot(alpha_dummy,dummy1(3,41:60),'.-k')
hold off
grid on
title('C_M vs α')
xlabel('α (deg)')
ylabel('C_M')
legend({'v = 40 m/s','v = 50 m/s','v = 60 m/s'},'Location','southwest')
```

Output Plot

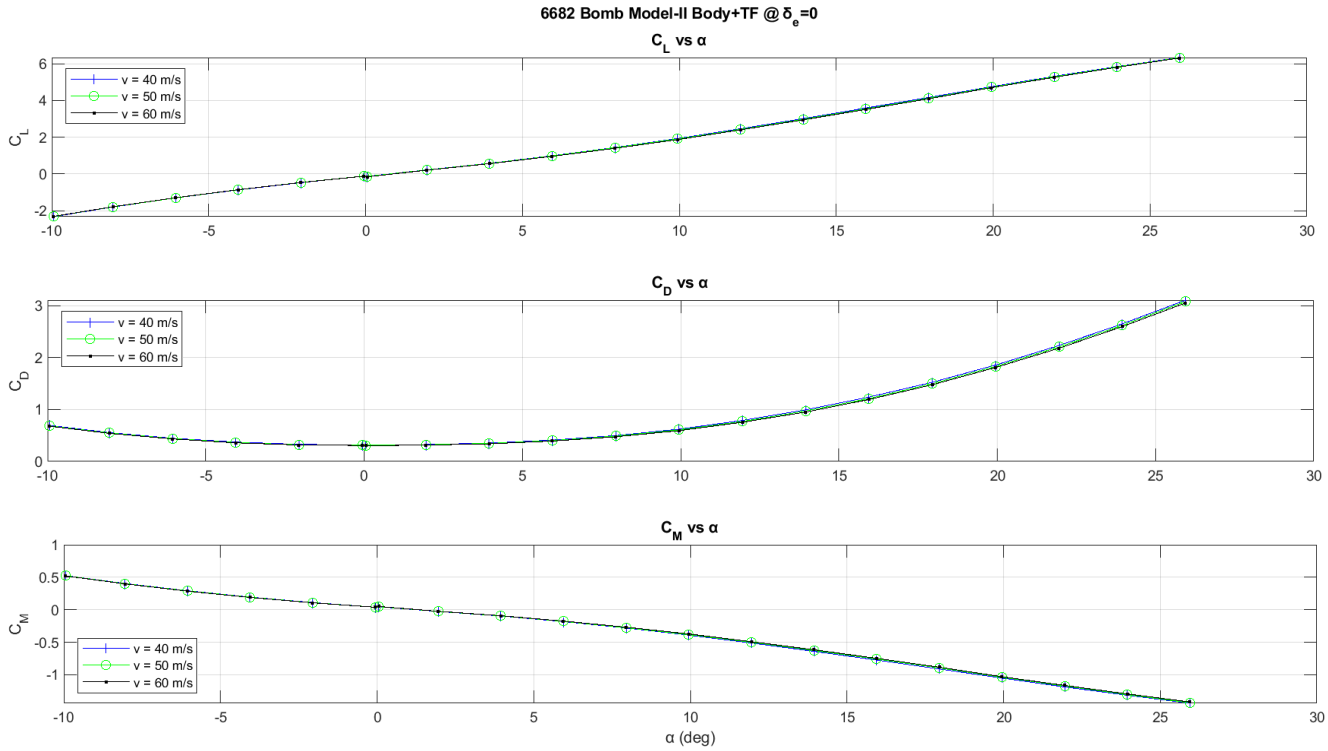


Variation of CL, CD and Cm with α for body alone configuration

(2) Body + Tail fin

- The MATLAB code is similar as shown for Body alone configuration, Only No wind data, Wind tunnel data and dynamic head will change for Body + Tail Fin configuration.

Output Plot

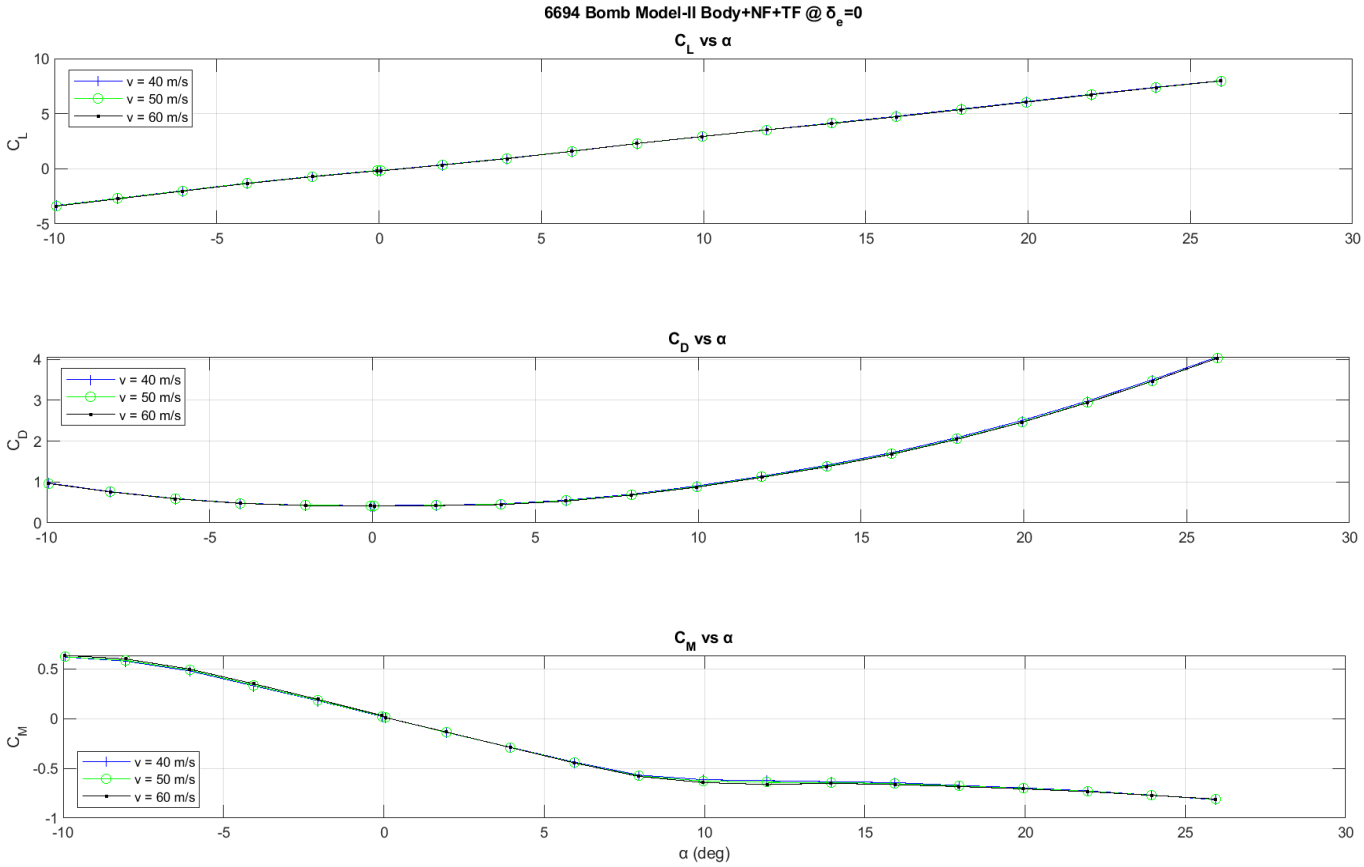


Variation of CL, CD and Cm with for body with Tail fin configuration

(3) Body + Nose fin + Tail fin

- Only No wind data, Wind tunnel data and dynamic head will change for Body + Nose fin + Tail Fin configuration.

Output Plot



Variation of CL, CD and Cm with for body + Nose fin + Tail fin configuration