NEUTRAL POINT ESTIMATION

Problem

Estimate the Neutral point using flight test data from the experimental aircraft.

Consider the following data of a light experimental fixed wing conventional aircraft:

m = 700 kg; s = 12.47 m^2; $\bar{c} = 1.411\ m$; b = 10.47

Using the following flight test data of from the experimental aircraft estimate the Neutra point of the configuration. The CG location is w.r.t leading edge of mean aerodynamic chord. Consider rounding off to four digits.

For X_cg1 = 1.2061 m

S.No	V (m/s)	$CL(trim)$	$\delta_{e(trim)}$
1	40	0.561920036659411	0.0348103115873433
2	44	0.464396724511910	0.0439548029647466
3	48	0.390222247680147	0.0509099386023218
4	52	0.332497063112078	0.0563226695783097
5	56	0.286693896254802	0.0606175059119099

For X_cg2 = 1.1698 m

S.No	V (m/s)	$C_{L(trim)}$	$\delta_{e(trim)}$
1	40	0.561920036659411	0.0167400623574207
2	44	0.464396724511910	0.0290207126920833
3	48	0.390222247680147	0.0383611544148755
4	52	0.332497063112078	0.0456302144126750
5	56	0.286693896254802	0.0513979909986841

For X_cg3 = 1.1335 m

S.No	V (m/s)	$C_{L(trim)}$	$\delta_{e(trim)}$
1	40	0.561920036659411	-0.00133018687250185
2	44	0.464396724511910	0.0140866224194200
3	48	0.390222247680147	0.0258123702274293
4	52	0.332497063112078	0.0349377592470403
5	56	0.286693896254802	0.0421784760854583

For X_cg4 = 1.0972 m

S.No	V (m/s)	$C_{L(trim)}$	$\delta_{e(trim)}$
1	40	0.561920036659411	-0.0194004361024244
2	44	0.464396724511910	-0.000847467853243328
3	48	0.390222247680147	0.0132635860399830
4	52	0.332497063112078	0.0242453040814057
5	56	0.286693896254802	0.0329589611722324

MATLAB code

```
clear all
close all
clc

%% Given Data
x_cg1 = 1.2061;
x_cg2 = 1.1698;
x_cg3 = 1.1335;
x_cg4 = 1.0972;

x1 = [0.561920037, 0.464396725, 0.390222248, 0.332497063, 0.286693896];
y1 = [0.034810312, 0.043954803, 0.050909939, 0.05632267, 0.060617506];

x2 = [0.561920037, 0.464396725, 0.390222248, 0.332497063, 0.286693896];
y2 = [0.016740062, 0.029020713, 0.038361154, 0.045630214, 0.051397991];

x3 = [0.561920037, 0.464396725, 0.390222248, 0.332497063, 0.286693896];
y3 = [-0.001330187, 0.014086622, 0.02581237, 0.034937759, 0.042178476];

x4 = [0.561920037, 0.464396725, 0.390222248, 0.332497063, 0.286693896];
y4 = [-0.019400436, -0.000847468, 0.013263586, 0.024245304, 0.032958961];

x = [x1; x2; x3; x4];
y = [y1; y2; y3; y4];

% figure(1)
figure('Name','Neutral Point Estimation');
plot(x(1,1:5),y(1,1:5), 'pentagram-r')
hold on
plot(x(2,1:5),y(2,1:5), 'o-g')
hold on
plot(x(3,1:5),y(3,1:5), 'square-b')
hold on
plot(x(4,1:5),y(4,1:5), '^-m')
hold on

xlim([0, 1])
ylim([-0.025, 0.1])
grid on


%% If coordinates are needed in plot

% for i=1:4
%   for j=1:5
%     textString = sprintf('(%.4f,\n%.4f)', x(i,j), y(i,j));
%     text(x(i,j)-0.002, y(i,j)+0.005, textString, 'FontSize', 7);
%     hold on;
%   end
% end


%% %%%%%%%%%%%%%%%%%%%%%%
```

```
p1 = polyfit(x1,y1,1);              % Finding slope and y axis intercept of line
p1(1);                        % Slope of Line
p1(2);                        % y intercept
CL_trim_1 = -p1(2)/p1(1);          % Trim angle of attack (x intercept)

x11 = [0, x1(5)];
y11 = p1(1)*x11 + p1(2);

x12 = [x1(1), CL_trim_1 + 0.1];
y12 = p1(1)*x12 + p1(2);

%%%%%%%%%%%%%%%%%%%%%

p2 = polyfit(x2,y2,1);
p2(1);    % Slope of Line
p2(2);    % y intercept
CL_trim_2 = -p2(2)/p2(1);

x21 = [0, x2(5)];
y21 = p2(1)*x21 + p2(2);

x22 = [x2(1), CL_trim_2 + 0.1];
y22 = p2(1)*x22 + p2(2);

%%%%%%%%%%%%%%%%%%%%%

p3 = polyfit(x3,y3,1);
p3(1);    % Slope of Line
p3(2);    % y intercept
CL_trim_3 = -p3(2)/p3(1);

x31 = [0, x3(5)];
y31 = p3(1)*x31 + p3(2);

x32 = [x3(1), CL_trim_3 + 0.1];
y32 = p3(1)*x32 + p3(2);

%%%%%%%%%%%%%%%%%%%%%%%

p4 = polyfit(x4,y4,1);
p4(1);    % Slope of Line
p4(2);    % y intercept
CL_trim_4 = -p4(2)/p4(1);

x41 = [0, x4(5)];
y41 = p4(1)*x31 + p4(2);

x42 = [x4(1), CL_trim_4 + 0.1];
y42 = p4(1)*x42 + p4(2);


%%%%%%%%%%%%%%%%%%%%%%%
```

```
plot([0, CL_trim_1 + 0.1],[0, 0],'k')
hold on
plot(x11,y11,'--r',x12,y12,'--r')
hold on
plot(x21,y21,'--g',x22,y22,'--g')
hold on
plot(x31,y31,'--b',x32,y32,'--b')
hold on
plot(x41,y41,'--m',x42,y42,'--m')
hold off

title('δe_t_r_i_m v/s (C_L_t_r_i_m - Cl_0)    **Neutral Point Estimation**')
xlabel('Coefficient of Lift [C_L_ _t_r_i_m - C_L_0]')
ylabel('Elevator deflection [δe_t_r_i_m]')
legend({'x_c_g1 = 1.2061 m','x_c_g2 = 1.1698 m','x_c_g3 = 1.1335 m','x_c_g4 = 1.0972
m'},'Location','northeast')

%%%%%%%%%%%%%%%%%%%%%%%%

% figure(2)
figure('Name','Neutral Point Estimation');
x_cg = [x_cg1, x_cg2, x_cg3, x_cg4];
de_Cl = [p1(1), p2(1), p3(1), p4(1)];

plot(x_cg,de_Cl, '*-r')
hold on

%%%%%%%%%%%%%%%%%%%%

p5 = polyfit(x_cg,de_Cl,1);
p5(1);    % Slope of Line
p5(2);    % y intercept
x_np = -p5(2)/p5(1);
x_npr = round(x_np,4);
fprintf('The neutral point (x_np) of aircraft is at %.4f m from leading edge of mean aerodynamic chord.\n',
x_npr);

%%%%%%%%%%%%%%%%%%%%

x_cg_1 = [x_cg(4) - 0.1, x_cg(4)];
de_Cl_1 = p5(1)*x_cg_1 + p5(2);

x_cg_2 = [x_cg(1), x_np + 0.05];
de_Cl_2 = p5(1)*x_cg_2 + p5(2);

%%%%%%%%%%%%%%%%%%%%

plot([x_cg(4) - 0.1, x_np + 0.05],[0, 0],'k')
hold on
plot(x_cg_1,de_Cl_1,'--r',x_cg_2,de_Cl_2,'--r')
hold on
plot(x_np,0,'pentagramb')
xlim([x_cg(4) - 0.1, x_np + 0.05])
ylim([-0.025, 0.1])
grid on

title('∂δe/∂C_L v/s x_c_g    **Neutral Point Estimation**')
xlabel('Location of C.G. from leading edge of mean aerodynamic chord [x_c_g in m]')
ylabel('(∂δe/∂C_L)_t_r_i_m')
```

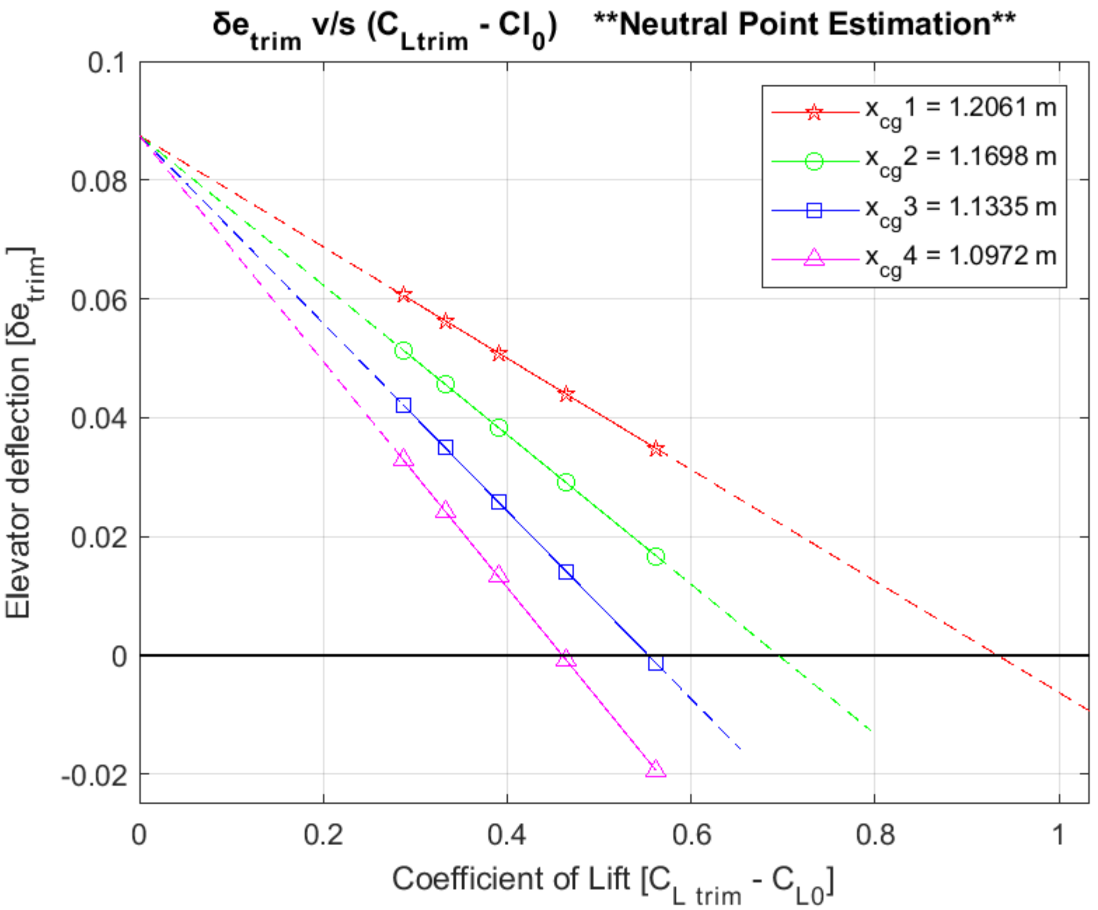
```
%% If coordinates are needed in plot
for i=1:4
    textString = sprintf('(%.4f, %.4f)', x_cg(i), de_Cl(i));
    text(x_cg(i), de_Cl(i)-0.009, textString, 'FontSize', 10);
    hold on;
end

textString = sprintf('x_n_p = \n%.4f', x_np);
text(x_np, -0.025, textString, 'FontSize', 10);

hold off
```

Output

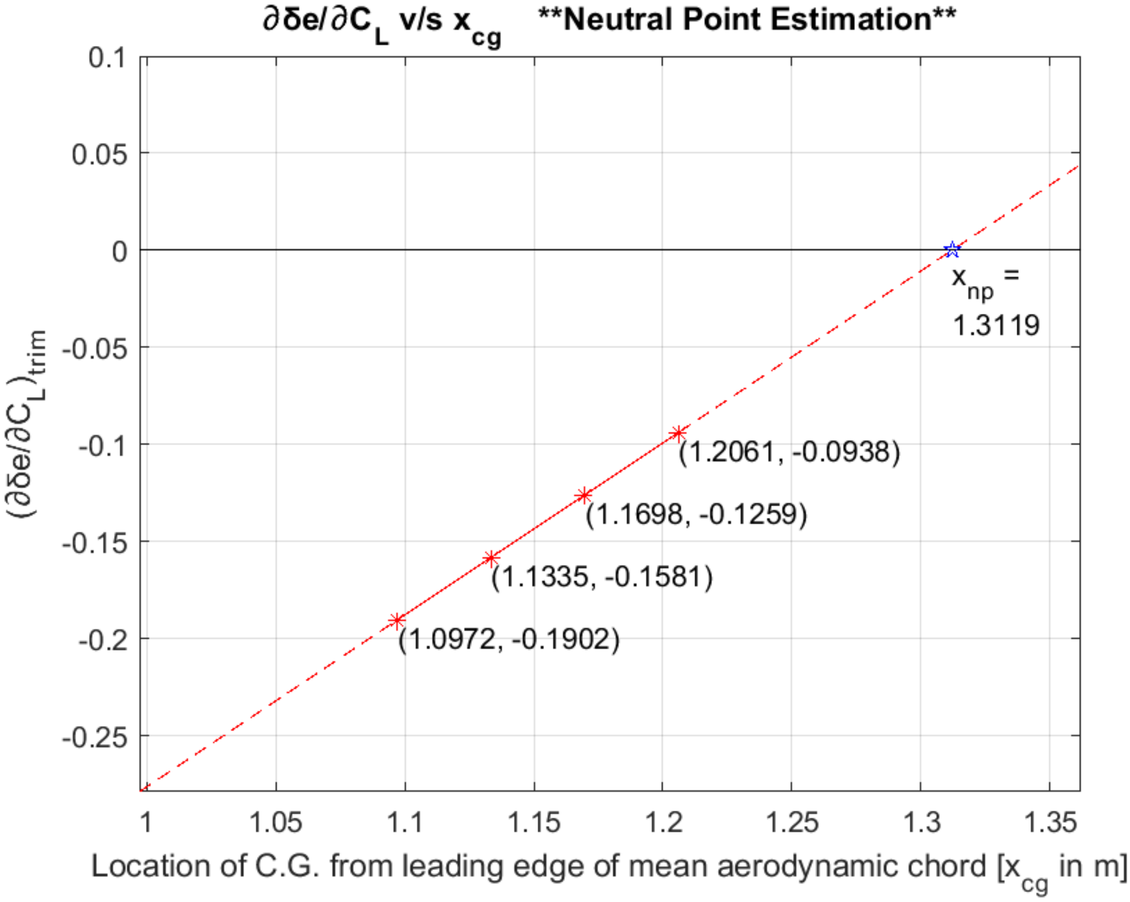
>> The neutral point (x_np) of aircraft is at 1.3119 m from leading edge of mean aerodynamic chord.

Plots

1. **Figure (1)** : δe_{trim} v/s C_{Ltrim}



2. Figure (2) : $\frac{\partial \delta_e}{\partial C_L}$ v/s x_{cg}



Procedure to determine neutral point of aircraft experimentally

1. Setting the cg, carry out the cruise at different velocities and record values of $\boldsymbol{\delta_e}$ and $\boldsymbol{\alpha_{trim}}$.
2. Again set cg by changing location of passengers or adjusting the weight and repeat the step 1.
3. The $\boldsymbol{C_{L_{trim}}}$ can be determined from the linear relation of the coefficient of the lift and Angle of attack

   $$\boldsymbol{C_{L_{trim}} = C_{L_0} + C_{L_\alpha}\,\alpha_{trim}}$$

   Provided $\boldsymbol{C_{L_0}}$ and $\boldsymbol{\frac{\partial C_L}{\partial \alpha}}$ is known.

   (The data for $\boldsymbol{C_{L_{trim}}}$ and $\boldsymbol{\delta_e}$ is given in problem)
4. Plot $\boldsymbol{\delta_e}$ v/s $\boldsymbol{C_{L_{trim}}}$ for all values of cg. (We get four lines for four $\boldsymbol{x_{cg}}$)
5. Find the slope of the lines for respective cg location.
6. Plot $\boldsymbol{(\frac{\partial \delta_e}{\partial C_L})_{trim}}$ v/s $\boldsymbol{x_{cg}}$.
7. Extrapolate or extend the curve to $\boldsymbol{x_{cg}}$ axis.
8. The point where it intersects the $\boldsymbol{x_{cg}}$ axis is the location of neutral point of aircraft ($\boldsymbol{x_{np}}$).