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ASEN 2004 Lab 1 Milestone 1

```
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Started: 1/17/2022, 12:11 PM
Finished:

% Housekeeping
clc; clear; close all;

% Common constants
e = 0.9; % Wing span efficiency

% Extract names and number of Excel sheets
[sheetStatus, sheetNames] = xlsfinfo('Tempest UAS & B747 Airfoil and
 CFD Data for ASEN 2004 Aero Lab (Spr22).xlsx');
numSheets = length(sheetNames);

% Extract data
for k = 1:numSheets
    sheetData{k} = xlsread('Tempest UAS & B747 Airfoil and CFD Data
 for ASEN 2004 Aero Lab (Spr22).xlsx', sheetNames{k});
end

% Tempest UAS
Tempest2D = cell2mat(sheetData(1,2));
TempestTrue = cell2mat(sheetData(1,3));

% Boeing 747-200
Boeing2D = cell2mat(sheetData(1,5));
BoeingTrue = cell2mat(sheetData(1,6));
```

Tempest UAS Analysis and Plotting

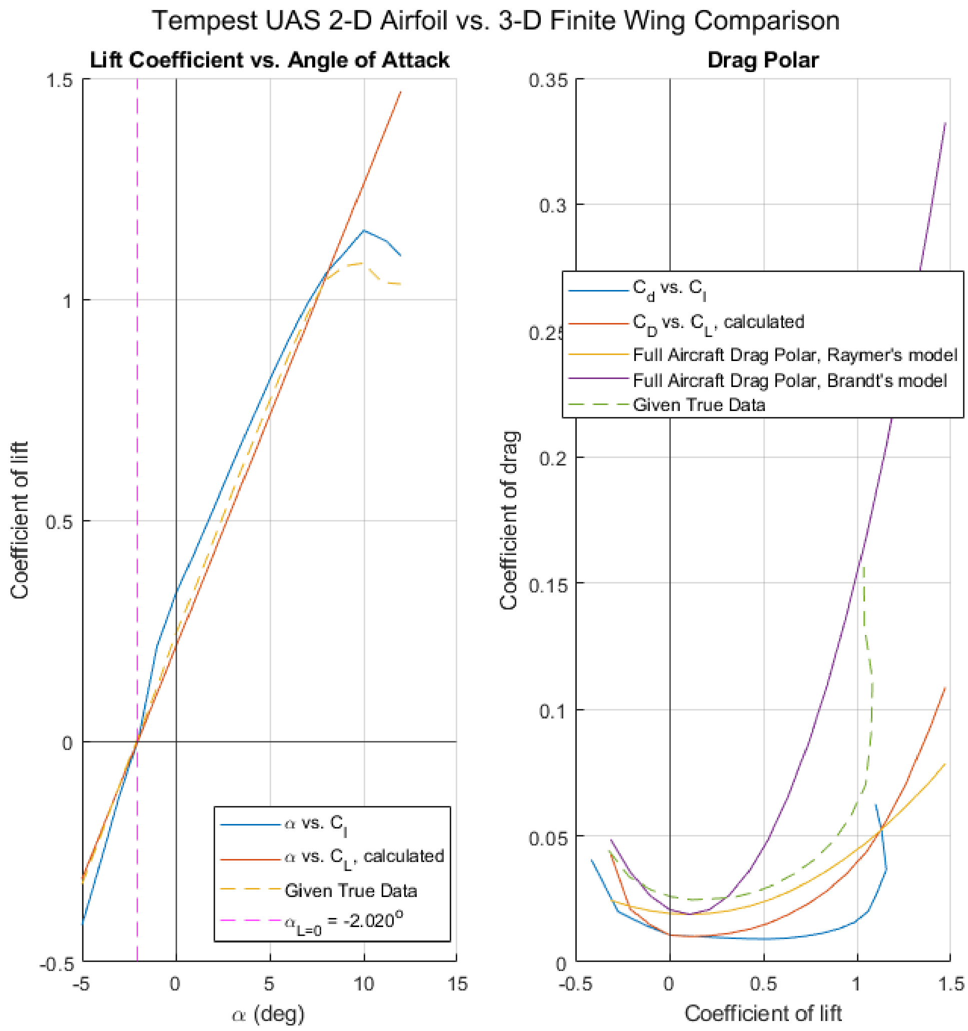
```
% Tempest Constants
SWetTempest = 2.285; % Approximation, m^2
SRefTempest = 0.667; % Approximation, m^2
CfeTempest = 0.0055; % Light, single prop aircraft
ARTempest = 16.5;
LESweepAngleTempest = 0; % Leading edge sweep angle for Brandt's
 method

% Analysis
```

```
% 2D airfoil
Tempest2DAlphas = Tempest2D(:,1);
TempestCl = Tempest2D(:,2);
TempestCd = Tempest2D(:,3);
TempestRe = Tempest2D(1,5);

% True data
TempestTrueAlphas = TempestTrue(:,1);
TempestTrueCL = TempestTrue(:,2);
TempestTrueCD = TempestTrue(:,3);

% Find a0
start = find(Tempest2DAlphas == -5);
stop = find(Tempest2DAlphas == 6);
[coef, ~] =
 leastSquares(Tempest2DAlphas(start:stop),TempestCl(start:stop),1);
a0 = coef(1)

% Find a
a = a0/(1+((57.3*a0)/(pi*e*ARTempest)))

% Find Alpha where L=0
[~, approxCurve] =
 leastSquares(Tempest2DAlphas(1:stop-7),TempestCl(1:stop-7),5);
alphaL0 = fzero(approxCurve, -2)

% Calculate CL from Cl
TempestCL = a*(Tempest2DAlphas - alphaL0);

% Calculate CD from Cd and CL
TempestCD = TempestCd + ((TempestCL.^2)/(pi*e*ARTempest));

% Calculate full drag polar with Raymer's Oswald factor model
e0 = 1.78*(1-0.045*(ARTempest)^0.68)-0.64;
k1 = 1/(pi*e0*ARTempest);

CDmin = CfeTempest*(SWetTempest/SRefTempest);

[~, index] = min(TempestCD);

CLminD = TempestCL(index)
k2 = -2*k1*CLminD;

CDo = CDmin + k1*(CLminD)^2;

TempestFullCDRaymer = CDo + k1*TempestCL.^2 + k2*TempestCL;

% Calculate full drag polar with Brandt's Oswald factor model
e0 = 4.61*(1-0.045*(ARTempest)^0.68)*cos(LESweepAngleTempest)^0.15 -
 3.1;
k1 = 1/(pi*e0*ARTempest);

CDmin = CfeTempest*(SWetTempest/SRefTempest);
```

```
[~, index] = min(TempestCD);
CLminD = TempestCL(index)
k2 = -2*k1*CLminD;

CDo = CDmin + k1*(CLminD)^2;

TempestFullCDBrandt = CDo + k1*TempestCL.^2 + k2*TempestCL;

%-------------------------------------------------------------------------
%
% Plotting
T = figure();
T.Position = [100 100 740 740];

sgtitle("Tempest UAS 2-D Airfoil vs. 3-D Finite Wing Comparison")

% Cl/CL vs. alpha
subplot(1,2,1)
hold on;
grid on;

TempestAlphaCl2D = plot(Tempest2DAlphas, TempestCl);
TempestAlphaCL = plot(Tempest2DAlphas, TempestCL);
TempestAlphaCLTrue = plot(TempestTrueAlphas, TempestTrueCL, '--');

% Utility lines
%alphaTest = -5:0.001:0;
%plot(alphaTest, approxCurve(alphaTest));
%plot(Tempest2DAlphas, a0Curve(Tempest2DAlphas));
alpha0Line = xline(alphaL0,'m--');
alpha0Label = sprintf("\\alpha_{L=0} = %.3f^o", alphaL0);
xline(0);
yline(0);

% Title, legend, labels
subset = [TempestAlphaCl2D, TempestAlphaCL, TempestAlphaCLTrue,
 alpha0Line];
titles = ["\alpha vs. C_l", "\alpha vs. C_L, calculated", "Given True
 Data", alpha0Label];

title('Lift Coefficient vs. Angle of Attack')
xlabel('\alpha (deg)')
ylabel('Coefficient of lift')
legend(subset, titles, 'Location', 'best');
hold off;

% Drag polar
subplot(1,2,2)
grid on;
hold on;

TempestDragPolar2D = plot(TempestCl, TempestCd);
TempestDragPolar3D = plot(TempestCL, TempestCD);
TempestRaymerFullDragPolar = plot(TempestCL, TempestFullCDRaymer);
```

```
TempestBrandtFullDragPolar = plot(TempestCL, TempestFullCDBrandt);
TempestDragPolarTrue = plot(TempestTrueCL, TempestTrueCD, '--');

% Utility lines
xline(0);
yline(0);

% Title, legend, labels
subset = [TempestDragPolar2D, TempestDragPolar3D,
 TempestRaymerFullDragPolar, TempestBrandtFullDragPolar,
 TempestDragPolarTrue];
titles = ["C_d vs. C_l", "C_D vs. C_L, calculated", "Full Aircraft
 Drag Polar, Raymer's model", "Full Aircraft Drag Polar, Brandt's
 model", "Given True Data"];

title('Drag Polar')
xlabel('Coefficient of lift')
ylabel('Coefficient of drag')
legend(subset, titles, 'Location', 'best')

hold off;
```

```
a0 =

    0.1203


a =

    0.1048


alphaL0 =

   -2.0203


CLminD =

    0.1070


CLminD =

    0.1070
```



Boeing 747-200 Analysis and Plotting

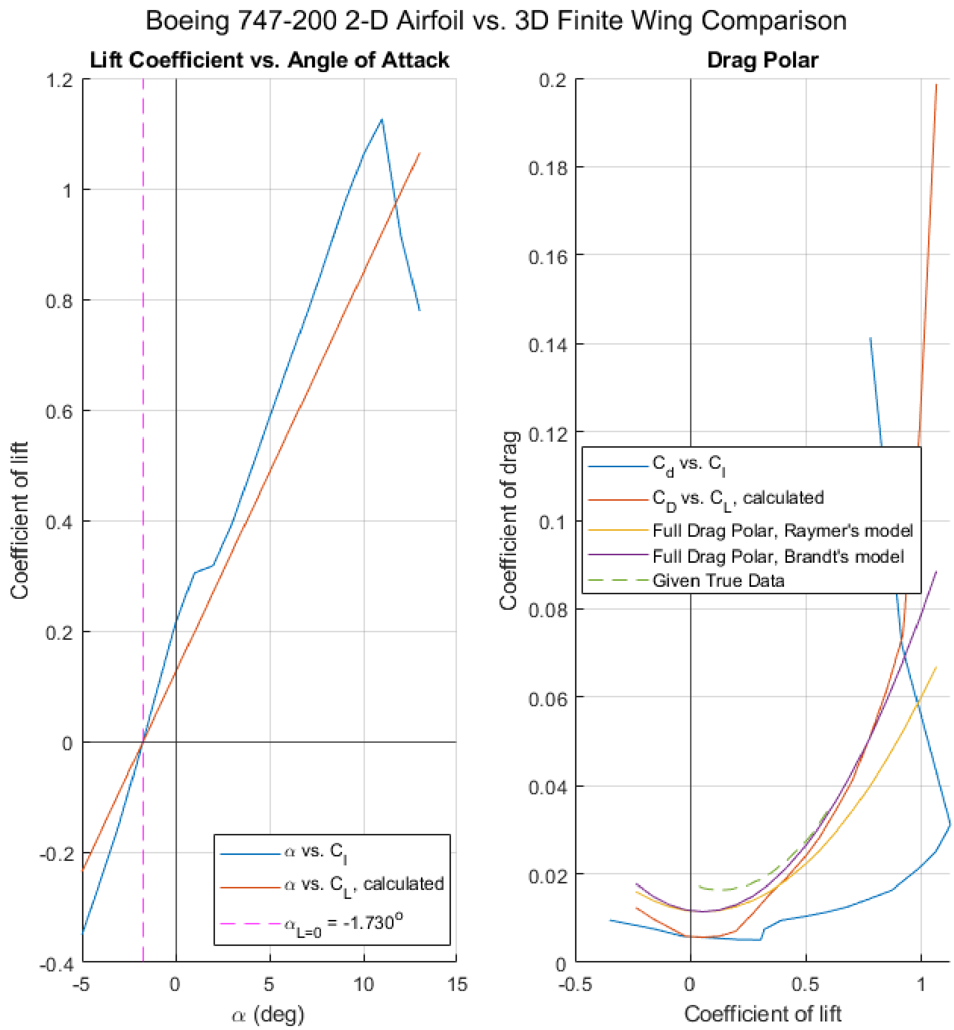
```
% Boeing Constants
SWetBoeing = 2175.93; % Approximation, m^2
SRefBoeing = 569.52; % Approximation, m^2
CfeBoeing = 0.003; % Civil transport
ARBoeing = 7;
% Leading edge sweep angle for Brandt's method, Boeing wing angle runs
% horizontally 75 feet, then vertically 100 feet, leading edge sweep
 angle
% is characterized by horizontal/vertical
LESweepAngleBoeing = atan2(75, 100);

% Analysis

% 2D airfoil
Boeing2DAlphas = Boeing2D(:,1);
```

```
BoeingCl = Boeing2D(:,2);
BoeingCd = Boeing2D(:,3);
BoeingRe = Boeing2D(1,5);

% True data
BoeingTrueCL = BoeingTrue(:,1);
BoeingTrueCD = BoeingTrue(:,2);

% Find a0
start = find(Boeing2DAlphas == -5);
stop = find(Boeing2DAlphas == 9);
[coef, ~] =
 leastSquares(Boeing2DAlphas(start:stop),BoeingCl(start:stop),1);
a0 = coef(1)

% Find a
a = a0/(1+((57.3*a0)/(pi*e*ARBoeing)))

% Find Alpha where L=0
[~, approxCurve] =
 leastSquares(Boeing2DAlphas(1:stop-7),BoeingCl(1:stop-7),5);
alphaL0 = fzero(approxCurve, -2)

% Calculate CL from Cl
BoeingCL = a*(Boeing2DAlphas - alphaL0);

% Calculate CD from Cd and CL
BoeingCD = BoeingCd + ((BoeingCL.^2)/(pi*e*ARBoeing));

% Calculate full drag polar with Raymer's Oswald factor model
e0 = 1.78*(1-0.045*(ARBoeing)^0.68)-0.64;
k1 = 1/(pi*e0*ARBoeing);

CDmin = CfeBoeing*(SWetBoeing/SRefBoeing);

[~, index] = min(BoeingCD);
CLminD = BoeingCL(index)
k2 = -2*k1*CLminD;

CDo = CDmin + k1*(CLminD)^2;

BoeingFullCD = CDo + k1*BoeingCL.^2 + k2*BoeingCL;

% Calculate full drag polar with Brandt's Oswald factor model
e0 = 4.61*(1-0.045*(ARBoeing)^0.68)*cos(LESweepAngleBoeing)^0.15 -
 3.1;
k1 = 1/(pi*e0*ARBoeing);

CDmin = CfeBoeing*(SWetBoeing/SRefBoeing);

[~, index] = min(BoeingCD);
CLminD = BoeingCL(index)
k2 = -2*k1*CLminD;
```

```
CDo = CDmin + k1*(CLminD)^2;

BoeingFullCDBrandt = CDo + k1*BoeingCL.^2 + k2*BoeingCL;

%-------------------------------------------------------------------------
%
% Plotting
B = figure();
B.Position = [940 100 740 740];

sgtitle("Boeing 747-200 2-D Airfoil vs. 3D Finite Wing Comparison")

% Cl/CL vs. alpha
subplot(1,2,1)
hold on;
grid on;

BoeingAlphaCl2D = plot(Boeing2DAlphas, BoeingCl);
BoeingAlphaCL = plot(Boeing2DAlphas, BoeingCL);

% Utility lines
%alphaTest = -5:0.001:0;
%plot(alphaTest, approxCurve(alphaTest));
%plot(Tempest2DAlphas, a0Curve(Tempest2DAlphas));
alpha0Line = xline(alphaL0,'m--');
alpha0Label = sprintf("\\alpha_{L=0} = %.3f^o", alphaL0);
xline(0);
yline(0);

% Title, legend, labels
subset = [BoeingAlphaCl2D, BoeingAlphaCL, alpha0Line];
titles = ["\alpha vs. C_l", "\alpha vs. C_L, calculated",
 alpha0Label];

title('Lift Coefficient vs. Angle of Attack')
xlabel('\alpha (deg)')
ylabel('Coefficient of lift')
legend(subset, titles, 'Location', 'best');
hold off;

% Drag polar
subplot(1,2,2)
grid on;
hold on;

BoeingDragPolar2D = plot(BoeingCl, BoeingCd);
BoeingDragPolar3D = plot(BoeingCL, BoeingCD);
BoeingRaymerFullDragPolar = plot(BoeingCL, BoeingFullCD);
BoeingBrandtFullDragPolar = plot(BoeingCL, BoeingFullCDBrandt);
BoeingDragPolarTrue = plot(BoeingTrueCL, BoeingTrueCD, '--');

% Utility lines
xline(0);
yline(0);
```

```
% Title, legend, labels
subset = [BoeingDragPolar2D, BoeingDragPolar3D,
 BoeingRaymerFullDragPolar, BoeingBrandtFullDragPolar,
 BoeingDragPolarTrue];
titles = ["C_d vs. C_l", "C_D vs. C_L, calculated", "Full Drag Polar,
 Raymer's model", "Full Drag Polar, Brandt's model", "Given True
 Data"];

title('Drag Polar')
xlabel('Coefficient of lift')
ylabel('Coefficient of drag')
legend(subset, titles, 'Location', 'best')

hold off;

%-------------------------------------------------------------------------
%

% Function from ASEN 2012

function [X,f] = leastSquares(t,y,p)
    % for writing this function, some skeleton code has been provided
 to
    % help you design the function to serve your purposes
    A = [];
    % write an expression for A, the input matrix
    for ii = 0:p
        col = t.^ii;
        A = [col, A];
    end
    % compute coefficient vector, x_hat
    x_hat = A\y;
    X = x_hat;

    % do not change the following lines of code. This will generate
 the
    % anonymous function handle "f" for you
%     f = '@(x)';
%     for i = 0:p
%         f = strcat(f,'+',strcat(string(x_hat(i+1)),'.*x.^',string(p-
i)));
%     end
%     eval(strcat('f = ',f,';'))

    while length(x_hat) < 7
        x_hat = [0;x_hat];
    end
    % workaround for MATLAB grader
    f = @(x) x_hat(1)*x.^6 + x_hat(2)*x.^5 + x_hat(3)*x.^4 +
 x_hat(4)*x.^3 + x_hat(5)*x.^2 + x_hat(6)*x + x_hat(7);

end
```

```
a0 =

    0.0914

a =

    0.0723

alphaL0 =

   -1.7297

CLminD =

    0.0527

CLminD =

    0.0527
```



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