

# UCL Mechanical Engineering 2020/2021

## MECH0011 Final Coursework

NCWT3

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# 1 Question 1

## 1.1 a

The data was imported into MATLAB and the shape of the hydrofoil, the chord line and the mean camber line were plotted for all four hydrofoils.

```
1  clc
2  clear
3  close all
4
5  %define vars
6  i = ["EPPLER 818 Hydrofoil", "NACA 63-412 Aifoil", "RG 8 Airfoil", "YS
      930 Hydrofoil"]; %index hydrofoil names from sheets for ease
7  data = zeros(122,2,4); %initialise matrix
8  counter = 0; %initialise counter
9  x = linspace(0,1,100); %interpolation range initialisation
10
11 %import data
12 for j = 1:4 %index all data for plots
13     counter = counter + 1; %increment counter
14     data(:,:,counter) = readmatrix('suppFiles.xlsx','Sheet',i(j),'Range',
        'A3:B124'); %loop through sheets and pull data
15 end
16
17 %camber line calculation
18 %pull positive and negative coordinate points
19 %eppler
20 dataPos1 = readmatrix('suppFiles.xlsx','Sheet',i(1),'Range','A3:B37');
21 dataNeg1 = readmatrix('suppFiles.xlsx','Sheet',i(1),'Range','A38:B70');
22
23 %naca
24 dataPos2 = readmatrix('suppFiles.xlsx','Sheet',i(2),'Range','A3:B28');
25 dataNeg2 = readmatrix('suppFiles.xlsx','Sheet',i(2),'Range','A29:B54');
26
27 %rg
28 dataPos3 = readmatrix('suppFiles.xlsx','Sheet',i(3),'Range','A3:B34');
29 dataNeg3 = readmatrix('suppFiles.xlsx','Sheet',i(3),'Range','A35:B64');
30
31 %ys
32 dataPos4 = readmatrix('suppFiles.xlsx','Sheet',i(4),'Range','A3:B65');
33 dataNeg4 = readmatrix('suppFiles.xlsx','Sheet',i(4),'Range','A66:B124');
34
35 %interpolate hydrofoil shape with 100 data points from 0 to 1
36 %eppler
37 dataIntPos1 = interp1(dataPos1(:,1), dataPos1(:,2), x);
38 dataIntNeg1 = interp1(dataNeg1(:,1), dataNeg1(:,2), x);
39
40 %naca
41 dataIntPos2 = interp1(dataPos2(:,1), dataPos2(:,2), x);
42 dataIntNeg2 = interp1(dataNeg2(:,1), dataNeg2(:,2), x);
43
44 %rg
```

```

45 dataIntPos3 = interp1(dataPos3(:,1), dataPos3(:,2), x);
46 dataIntNeg3 = interp1(dataNeg3(:,1), dataNeg3(:,2), x);
47
48 %ys
49 dataIntPos4 = interp1(dataPos4(:,1), dataPos4(:,2), x);
50 dataIntNeg4 = interp1(dataNeg4(:,1), dataNeg4(:,2), x);
51
52 %calculate camber line
53 %eppler
54 camber1 = (dataIntPos1 + dataIntNeg1)./2;
55
56 %naca
57 camber2 = (dataIntPos2 + dataIntNeg2)./2;
58
59 %rg
60 camber3 = (dataIntPos3 + dataIntNeg3)./2;
61
62 %ys
63 camber4 = (dataIntPos4 + dataIntNeg4)./2;
64
65 %plot data
66 subplot(4,1,1)
67 plot(data(:,1,1), data(:,2,1), x, camber1)
68 axis image
69 grid on
70 xlabel('Chord')
71 ylabel('Z(x)')
72 title('Plot of ' + i(1))
73 xlim([-0.05 1.05])
74 ylim([-0.05 0.1])
75 legend('Hydrofoil profile and chord line','Mean camber line')
76
77 subplot(4,1,2)
78 plot(data(:,1,2), data(:,2,2), x, camber2)
79 axis image
80 grid on
81 xlabel('Chord')
82 ylabel('Z(x)')
83 title('Plot of ' + i(2))
84 xlim([-0.05 1.05])
85 ylim([-0.05 0.1])
86 legend('Hydrofoil profile and chord line','Mean camber line')
87
88 subplot(4,1,3)
89 plot(data(:,1,3), data(:,2,3), x, camber3)
90 axis image
91 grid on
92 xlabel('Chord')
93 ylabel('Z(x)')
94 title('Plot of ' + i(3))
95 xlim([-0.05 1.05])
96 ylim([-0.05 0.1])
97 legend('Hydrofoil profile and chord line','Mean camber line')

```

```

98
99 subplot(4,1,4)
100 plot(data(:,1,4), data(:,2,4), x, camber4)
101 axis image
102 grid on
103 xlabel('Chord')
104 ylabel('Z(x)')
105 title('Plot of ' + i(4))
106 xlim([-0.05 1.05])
107 ylim([-0.05 0.1])
108 legend('Hydrofoil profile and chord line','Mean camber line')

```

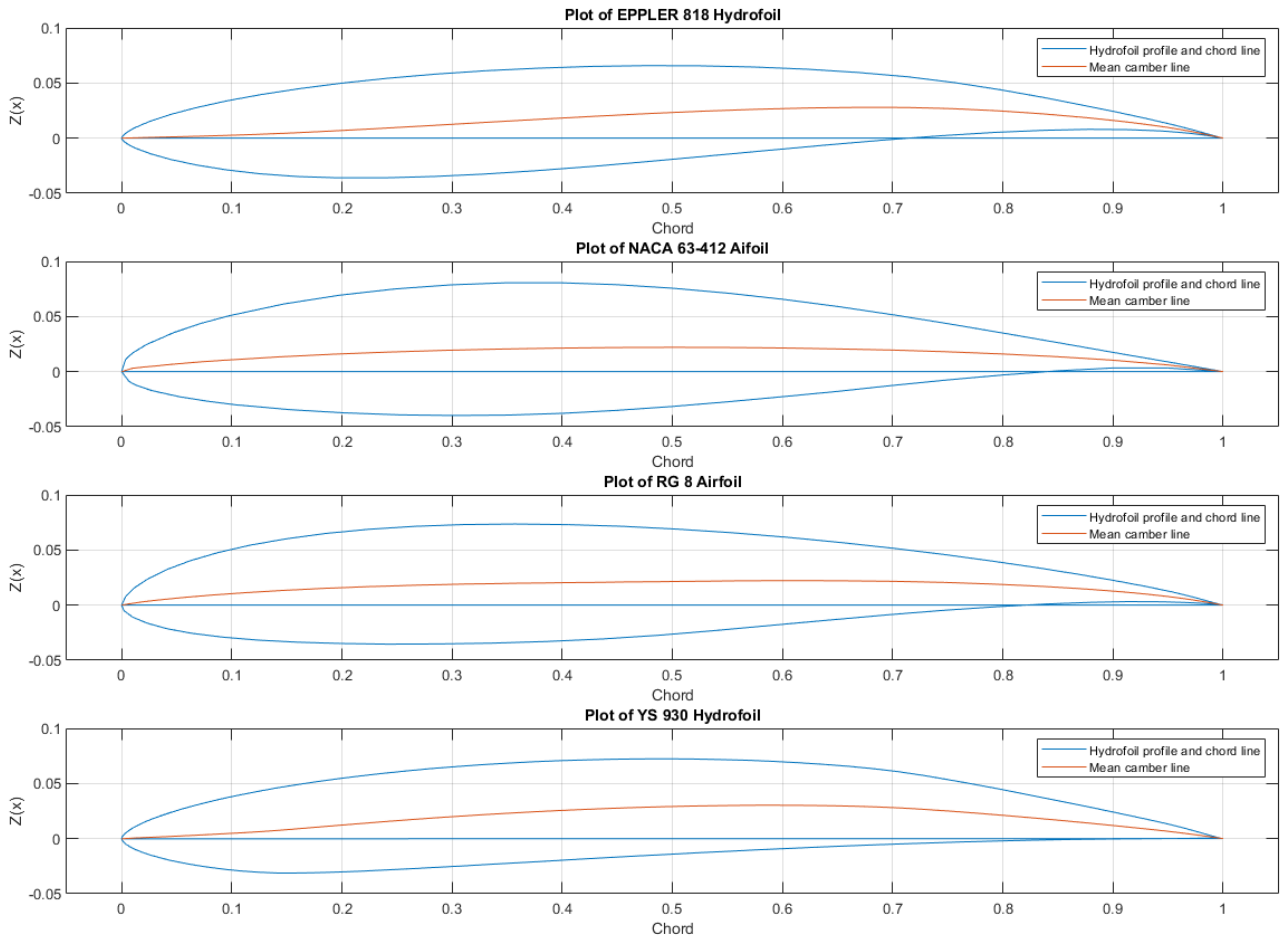


Figure 1: Graphs to show hydrofoil shape, chord line and mean camber line for four different hydrofoils.

## 1.2 b

MATLAB was used to calculate the lift-to-drag ratio for each hydrofoil.

```

1 clc
2 clear
3 close all
4
5 %define vars

```

```

6 i = ["EPPLER 818 Hydrofoil", "NACA 63-412 Aifoil", "RG 8 Airfoil", "YS
    930 Hydrofoil"]; %index hydrofoil names from sheets for ease
7
8 %pull cl and cd from data
9 %eppler
10 epplerCL = readmatrix('suppFiles.xlsx', 'Sheet', i(1), 'Range', 'E2:E79');
11 epplerCD = readmatrix('suppFiles.xlsx', 'Sheet', i(1), 'Range', 'F2:F79');
12
13 %naca
14 nacaCL = readmatrix('suppFiles.xlsx', 'Sheet', i(2), 'Range', 'E2:E107');
15 nacaCD = readmatrix('suppFiles.xlsx', 'Sheet', i(2), 'Range', 'F2:F107');
16
17 %rg
18 rgCL = readmatrix('suppFiles.xlsx', 'Sheet', i(3), 'Range', 'E2:E101');
19 rgCD = readmatrix('suppFiles.xlsx', 'Sheet', i(3), 'Range', 'F2:F101');
20
21 %ys
22 ysCL = readmatrix('suppFiles.xlsx', 'Sheet', i(4), 'Range', 'E2:E78');
23 ysCD = readmatrix('suppFiles.xlsx', 'Sheet', i(4), 'Range', 'F2:F78');
24
25 %plot data
26 subplot(2,2,1)
27 plot(epplerCD, epplerCL)
28 axis square
29 grid on
30 xline(0)
31 yline(0)
32 xlabel('CD')
33 ylabel('CL')
34 title('Plot of lift-to-drag ratio for ' + i(1))
35
36 subplot(2,2,2)
37 plot(nacaCD, nacaCL)
38 axis square
39 grid on
40 xline(0)
41 yline(0)
42 xlabel('CD')
43 ylabel('CL')
44 title('Plot of lift-to-drag ratio for ' + i(2))
45
46 subplot(2,2,3)
47 plot(rgCD, rgCL)
48 axis square
49 grid on
50 xline(0)
51 yline(0)
52 xlabel('CD')
53 ylabel('CL')
54 title('Plot of lift-to-drag ratio for ' + i(3))
55
56 subplot(2,2,4)
57 plot(ysCD, ysCL)

```

```

58 axis square
59 grid on
60 xline(0)
61 yline(0)
62 xlabel('CD')
63 ylabel('CL')
64 title('Plot of lift-to-drag ratio for ' + i(4))

```

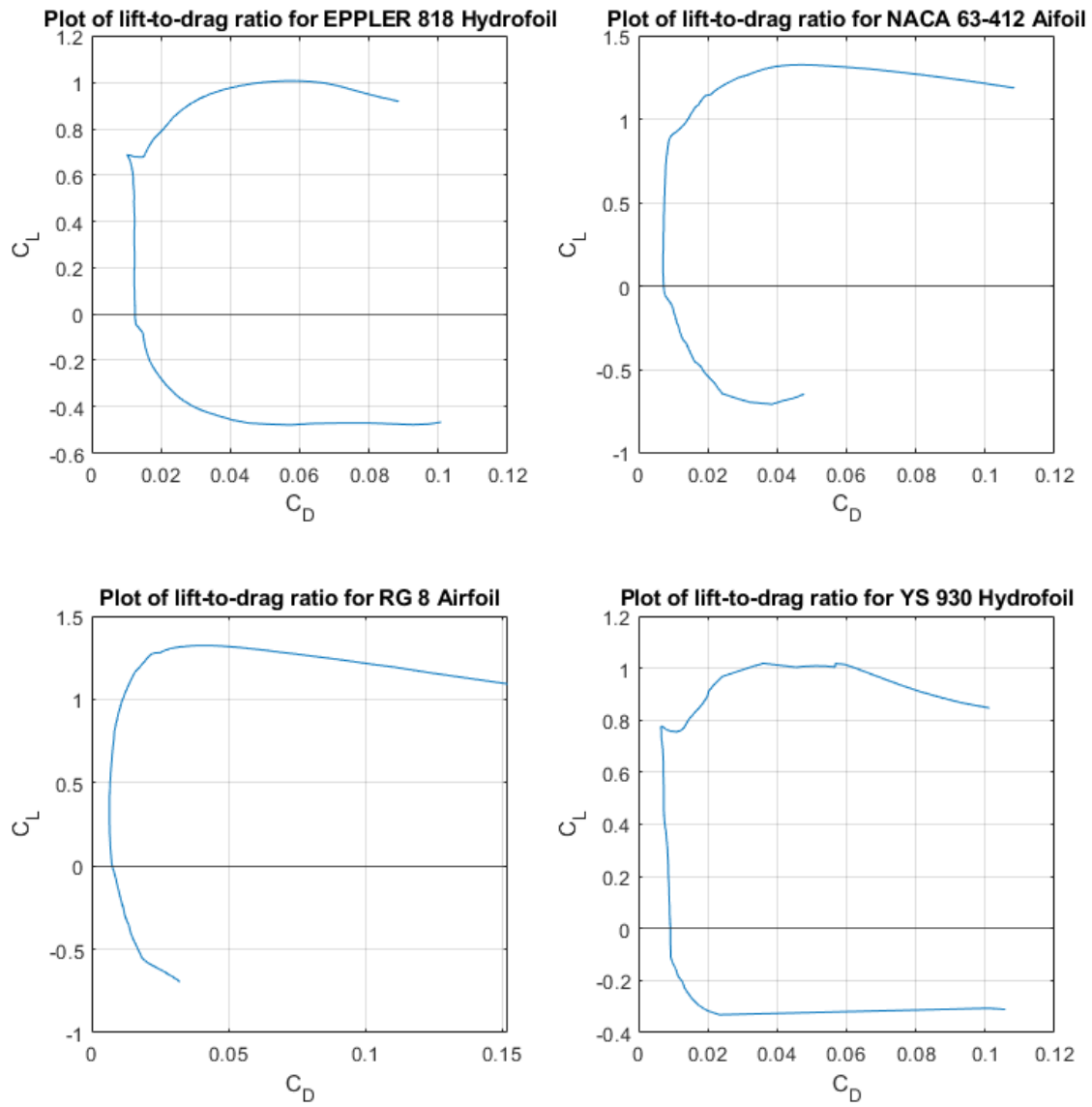


Figure 2: Graphs to show lift-to-drag ratio for four different hydrofoils.

### 1.3 c

### 1.4 d

MATLAB was used to calculate each of the variables for each hydrofoil.

```
1  clc
2  clear
3  close all
4
5  %define vars
6  i = ["EPPLER 818 Hydrofoil", "NACA 63-412 Aifoil", "RG 8 Airfoil", "YS
      930 Hydrofoil"]; %index hydrofoil names from sheets for ease
7  x = linspace(0,1,100); %interpolation range initialisation
8
9  %max percentage camber line calculation
10 %camber line calculation
11 %pull positive and negative coordinate points
12 %eppler
13 dataPos1 = readmatrix('suppFiles.xlsx', 'Sheet', i(1), 'Range', 'A3:B37');
14 dataNeg1 = readmatrix('suppFiles.xlsx', 'Sheet', i(1), 'Range', 'A38:B70');
15
16 %naca
17 dataPos2 = readmatrix('suppFiles.xlsx', 'Sheet', i(2), 'Range', 'A3:B28');
18 dataNeg2 = readmatrix('suppFiles.xlsx', 'Sheet', i(2), 'Range', 'A29:B54');
19
20 %rg
21 dataPos3 = readmatrix('suppFiles.xlsx', 'Sheet', i(3), 'Range', 'A3:B34');
22 dataNeg3 = readmatrix('suppFiles.xlsx', 'Sheet', i(3), 'Range', 'A35:B64');
23
24 %ys
25 dataPos4 = readmatrix('suppFiles.xlsx', 'Sheet', i(4), 'Range', 'A3:B65');
26 dataNeg4 = readmatrix('suppFiles.xlsx', 'Sheet', i(4), 'Range', 'A66:B124');
27
28 %interpolate hydrofoil shape with 100 data points from 0 to 1
29 %eppler
30 dataIntPos1 = interp1(dataPos1(:,1), dataPos1(:,2), x);
31 dataIntNeg1 = interp1(dataNeg1(:,1), dataNeg1(:,2), x);
32
33 %naca
34 dataIntPos2 = interp1(dataPos2(:,1), dataPos2(:,2), x);
35 dataIntNeg2 = interp1(dataNeg2(:,1), dataNeg2(:,2), x);
36
37 %rg
38 dataIntPos3 = interp1(dataPos3(:,1), dataPos3(:,2), x);
39 dataIntNeg3 = interp1(dataNeg3(:,1), dataNeg3(:,2), x);
40
41 %ys
42 dataIntPos4 = interp1(dataPos4(:,1), dataPos4(:,2), x);
43 dataIntNeg4 = interp1(dataNeg4(:,1), dataNeg4(:,2), x);
44
45 %calculate camber line
46 %eppler
```

```

47 camber1 = (dataIntPos1 + dataIntNeg1)./2;
48
49 %naca
50 camber2 = (dataIntPos2 + dataIntNeg2)./2;
51
52 %rg
53 camber3 = (dataIntPos3 + dataIntNeg3)./2;
54
55 %ys
56 camber4 = (dataIntPos4 + dataIntNeg4)./2;
57
58 %maximum camber per hydrofoil
59 %eppler
60 percCamber1 = max(camber1);
61
62 %naca
63 percCamber2 = max(camber2);
64
65 %rg
66 percCamber3 = max(camber3);
67
68 %ys
69 percCamber4 = max(camber4);
70
71 %clean-up output
72 percCamber = 100.*[percCamber1 percCamber2 percCamber3 percCamber4];
73
74 %maximum percentage thickness calculation
75 %eppler
76 thickness1 = (abs(dataIntPos1) + abs(dataIntNeg1));
77
78 %naca
79 thickness2 = (abs(dataIntPos2) + abs(dataIntNeg2));
80
81 %rg
82 thickness3 = (abs(dataIntPos3) + abs(dataIntNeg3));
83
84 %ys
85 thickness4 = (abs(dataIntPos4) + abs(dataIntNeg4));
86
87 %max thickness per hydrofoil
88 %eppler
89 maxThick1 = max(thickness1);
90
91 %naca
92 maxThick2 = max(thickness2);
93
94 %rg
95 maxThick3 = max(thickness3);
96
97 %ys
98 maxThick4 = max(thickness4);
99

```



```

100 %clean-up output
101 maxThick = 100.*[maxThick1 maxThick2 maxThick3 maxThick4];
102
103 %maximum lift coefficient
104 %pull angle of attack, cl and cd from data
105 %eppler
106 epplerData = readmatrix('suppFiles.xlsx','Sheet',i(1),'Range','D2:F79');
107
108 %naca
109 nacaData = readmatrix('suppFiles.xlsx','Sheet',i(2),'Range','D2:F107');
110
111 %rg
112 rgData = readmatrix('suppFiles.xlsx','Sheet',i(3),'Range','D2:F101');
113
114 %ys
115 ysData = readmatrix('suppFiles.xlsx','Sheet',i(4),'Range','D2:F78');
116
117 %find max cl
118 %eppler
119 maxEpplerCL = max(epplerData(:,2));
120
121 %naca
122 maxNacaCL = max(nacaData(:,2));
123
124 %rg
125 maxRgCL = max(rgData(:,2));
126
127 %ys
128 maxYsCL = max(ysData(:,2));
129
130 %clean-up output
131 maxCL = [maxEpplerCL maxNacaCL maxRgCL maxYsCL];
132
133 %find angle of attack at max cl
134 %eppler
135 critEppler = epplerData(epplerData(:,2) == maxEpplerCL,1);
136
137 %naca
138 critNaca = nacaData(nacaData(:,2) == maxNacaCL,1);
139
140 %rg
141 critRg = rgData(rgData(:,2) == maxRgCL,1);
142
143 %ys
144 critYs = ysData(ysData(:,2) == maxYsCL,1);
145
146 %clean-up output
147 crit = [critEppler critNaca critRg critYs];
148
149 %lift coefficient for alpha = 0
150 %eppler
151 liftAlpha0Eppler = epplerData(epplerData(:,1) == 0,2);
152

```

```

153 %naca
154 liftAlpha0Naca = nacaData(nacaData(:,1) == 0,2);
155
156 %rg
157 liftAlpha0Rg = rgData(rgData(:,1) == 0,2);
158
159 %ys
160 liftAlpha0Ys = ysData(ysData(:,1) == 0,2);
161
162 %clean-up output
163 liftAlpha0 = [liftAlpha0Eppler liftAlpha0Naca liftAlpha0Rg liftAlpha0Ys];
164
165 %angle of attack corresponding to cl = 0
166 %find min cl
167 %eppler
168 minEpplerCL = min(epplerData(:,2));
169
170 %naca
171 minNacaCL = min(nacaData(:,2));
172
173 %rg
174 minRgCL = min(rgData(:,2));
175
176 %ys
177 minYsCL = min(ysData(:,2));
178
179 %find angle of attack at min cl
180 %eppler
181 AOAMinEppler = epplerData(epplerData(:,2) == minEpplerCL,1);
182
183 %naca
184 AOAMinNaca = nacaData(nacaData(:,2) == minNacaCL,1);
185
186 %rg
187 AOAMinRg = rgData(rgData(:,2) == minRgCL,1);
188
189 %ys
190 AOAMinYs = ysData(ysData(:,2) == minYsCL,1);
191
192 %clean-up output
193 AOAMin = [AOAMinEppler AOAMinNaca AOAMinRg AOAMinYs];
194
195 %generate table
196 T = table(i', percCamber', maxThick', maxCL', crit', liftAlpha0', AOAMin
    ');

```

Hydrofoil	Maximum		
	% camber	% thickness	lift coefficient
EPPLER 818 Hydrofoil	2.792	9.362	1.008
NACA 63-412 Aifoil	2.204	11.992	1.330
RG 8 Airfoil	2.226	10.795	1.323
YS 930 Hydrofoil	3.028	9.088	1.018

Table 1: Table to show maximum percentage camber and thickness and the maximum lift coefficient for four hydrofoils.

Hydrofoil	Stall angle	Lift coefficient	Angle of attack $\alpha_0$
		for $\alpha = 0^\circ$	corresponding to $C_L = 0$
EPPLER 818 Hydrofoil	$7.75^\circ$	0.361	$-8^\circ$
NACA 63-412 Aifoil	$13^\circ$	0.338	$-9.5^\circ$
RG 8 Airfoil	$12.75^\circ$	0.382	$-8.25^\circ$
YS 930 Hydrofoil	$7.5^\circ$	0.391	$-7.25^\circ$

Table 2: Table to show the stall angle, lift coefficient for  $\alpha = 0^\circ$  and the angle of attack  $\alpha_0$  corresponding to  $C_L = 0$  for four hydrofoils.

## 2 Question 2

## 3 Question 3

### 3.1 a

MATLAB was used to plot the boundary layer velocity profile.

```

1  clc
2  clear
3  close all
4
5  %import data
6  data = readmatrix('suppFiles.xlsx','Sheet','Boundary Layer','Range','A2:
    B102');
7
8  %plot data
9  plot(data(:,2), data(:,1))
10 axis image
11 grid on
12 xlim([0 1])
13 ylim([0 1])
14 xlabel('y/\delta')
15 ylabel('u/U')
16 title('Graph to show the boundary layer velocity profile')

```

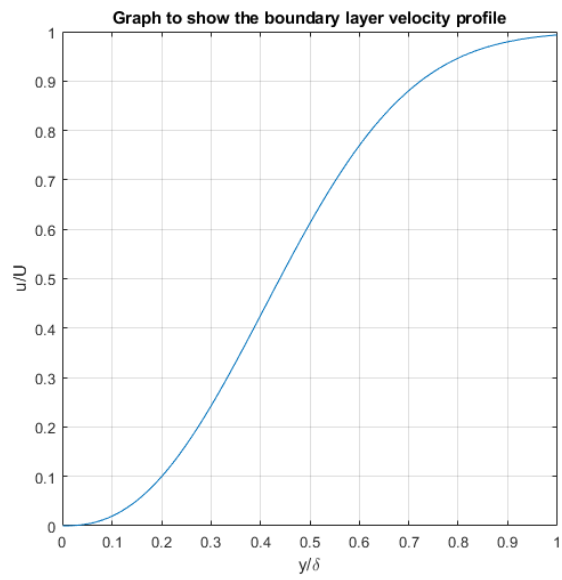


Figure 3: Graph to show boundary layer velocity profile.