EVALUATION OF NACA 2408 AIRFOIL AS A 2D GLIDER WING

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Introduction:

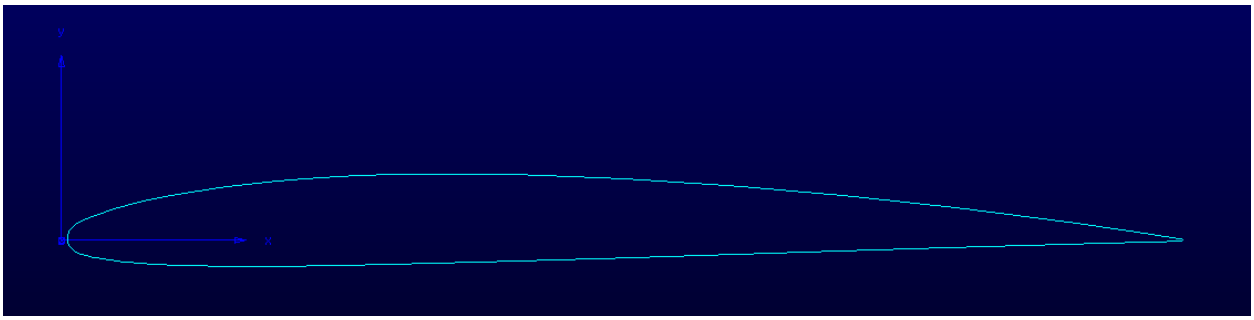


Figure 1: Airfoil Shape for NACA 2408

Table 1: Freestream Conditions

Pressure	1 atm / 101,300 Pa
Velocity	17.88 m/s
Density	1.225 kg/m3
Temperature	298 K
Reynolds Number	1,000,000

Table 2: XFOIL Estimates for Max Cl and Cl/Cd at Re = 1e6

Max Cl	12.75 deg	1.3714
Max Cl/Cd	2.5 deg	86.812

Methodology:

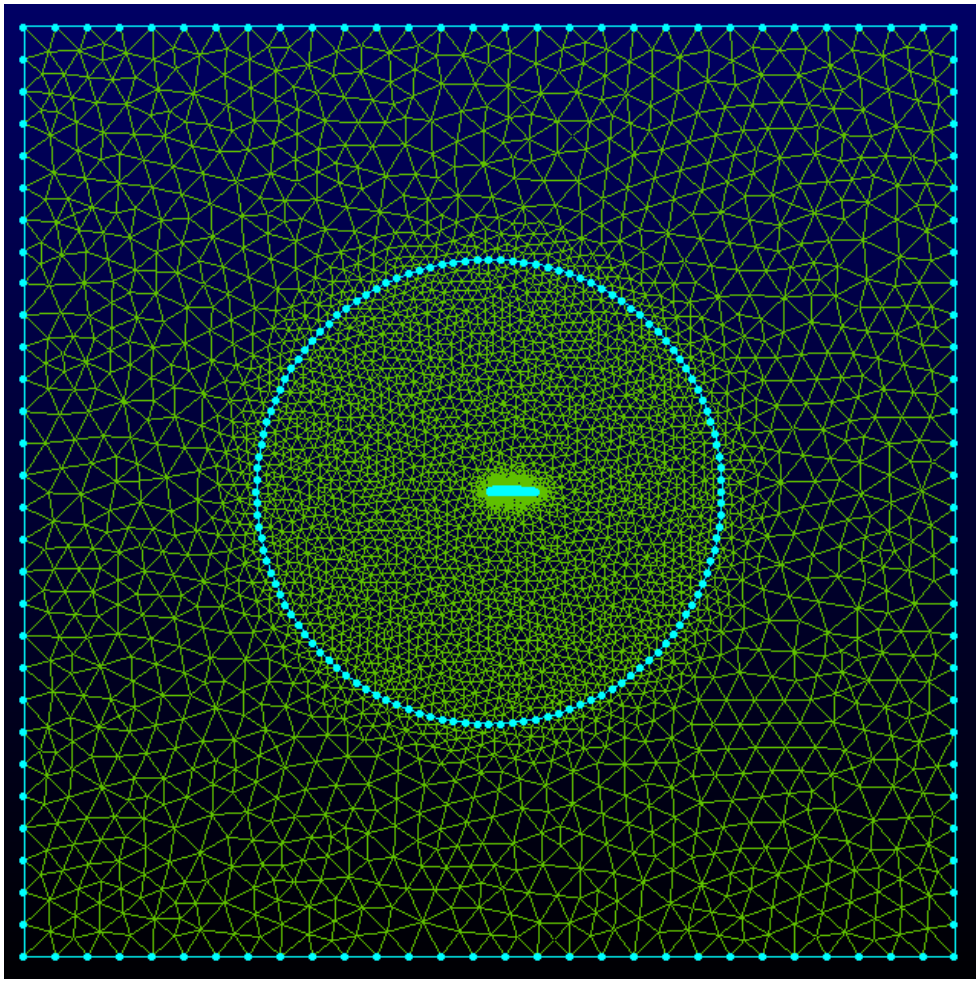


Figure 2: Computational Domain Grid

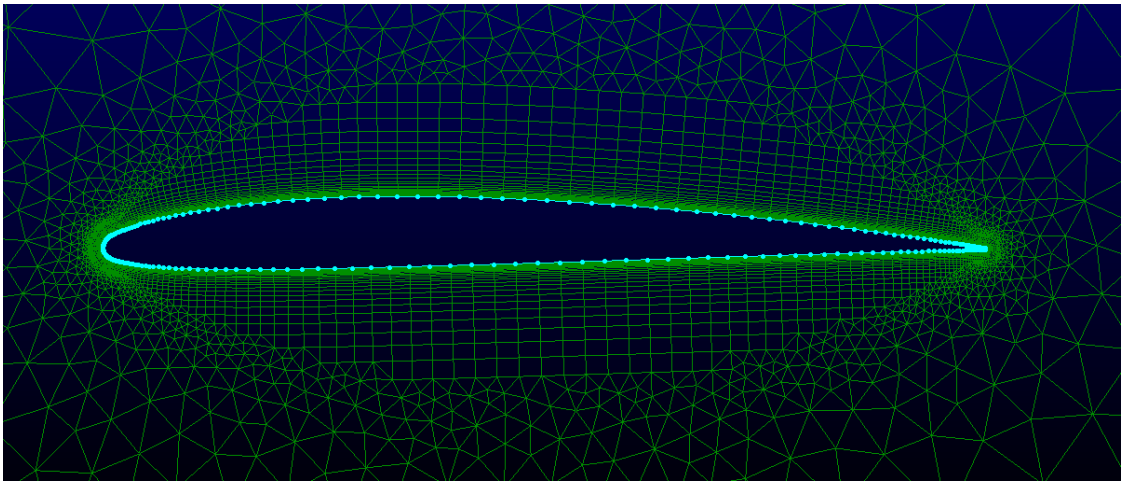


Figure 3: Near-Field Grid

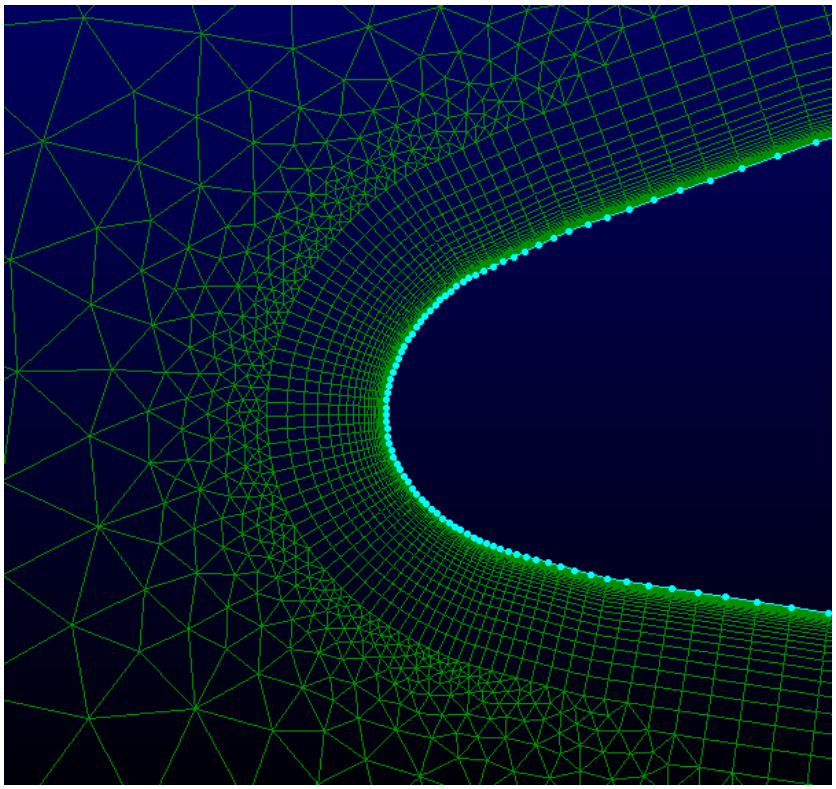


Figure 4: Leading Edge Grid

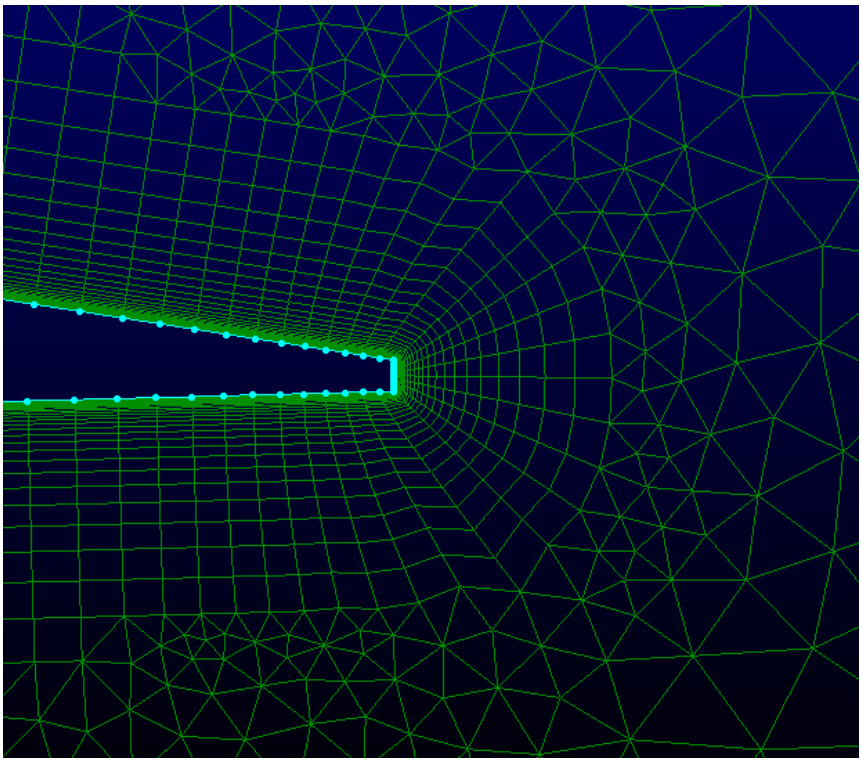


Figure 5: Trailing Edge Grid

Table 3: Grid Specifics

Cell Count	21,234
Normal-to-Wall Spacing	1e-5 m
Submodels Chosen	k-ω, SST
Numerical Scheme	SIMPLE
Spatial Accuracy	2nd Order

Table 4: Boundary Conditions

Airfoil Surface	Wall, no-slip
Tunnel Floor/Ceiling	Symmetry
Inlet	Velocity inlet
Outlet	Pressure outlet

Table 5: Reference Values

Area	1 m2
Density	1.225 kg/m3
Depth	1 m
Enthalpy	0 J/kg
Length	1 m
Pressure	0 Pa
Temperature	298 K
Velocity	17.88 m/s
Viscosity	1.7894e-5 kg/m-s
Gamma	1.4

Results:

AoA (deg)	Cl	Cd	Cl/Cd	Cm	Lift (N)	Drag (N)	Mom (N-m)
-2.25	-0.0230	0.0101	-2.3278	0.0492	-4.5893	1.9715	9.6441
0	0.2151	0.0101	21.194	0.0489	42.122	1.9875	9.5842
3.5	0.5823	0.0121	48.317	0.0478	114.04	2.3601	9.3606
7	0.9359	0.0166	56.518	0.0454	183.26	3.2425	8.8981
10.5	1.2618	0.0261	48.344	0.0407	247.09	5.1110	7.9666
12.5	1.3882	0.0378	36.699	0.0370	271.83	7.4070	7.2373

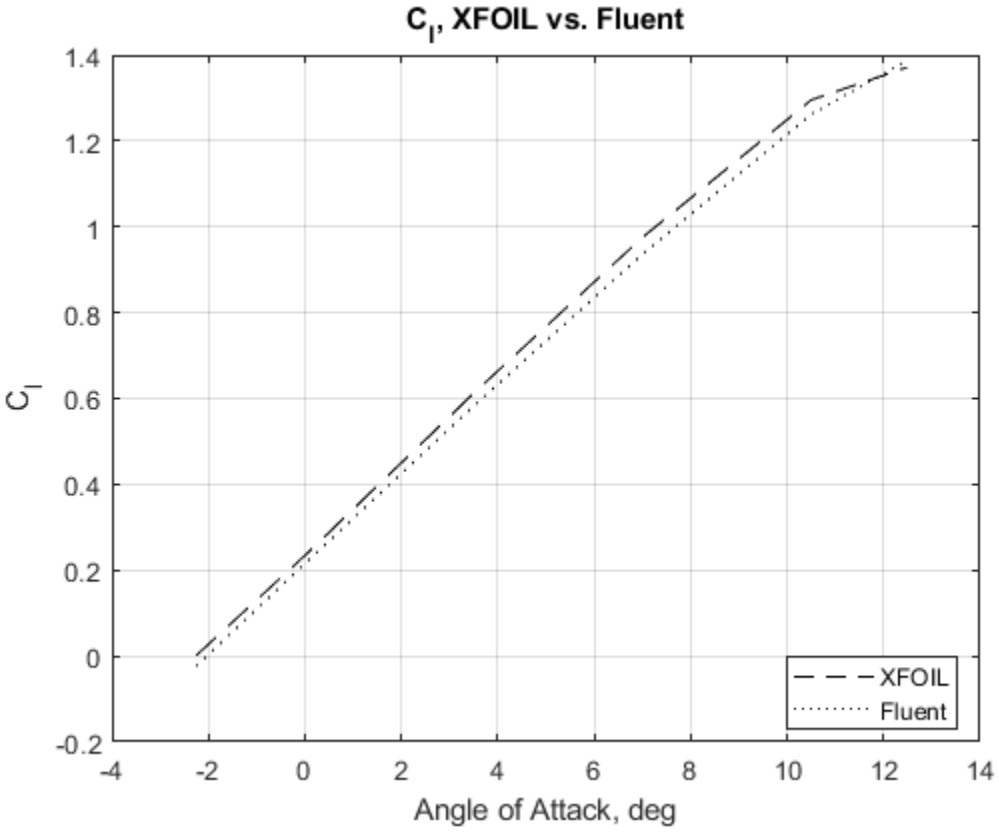


Figure 6: Lift coefficient comparison.

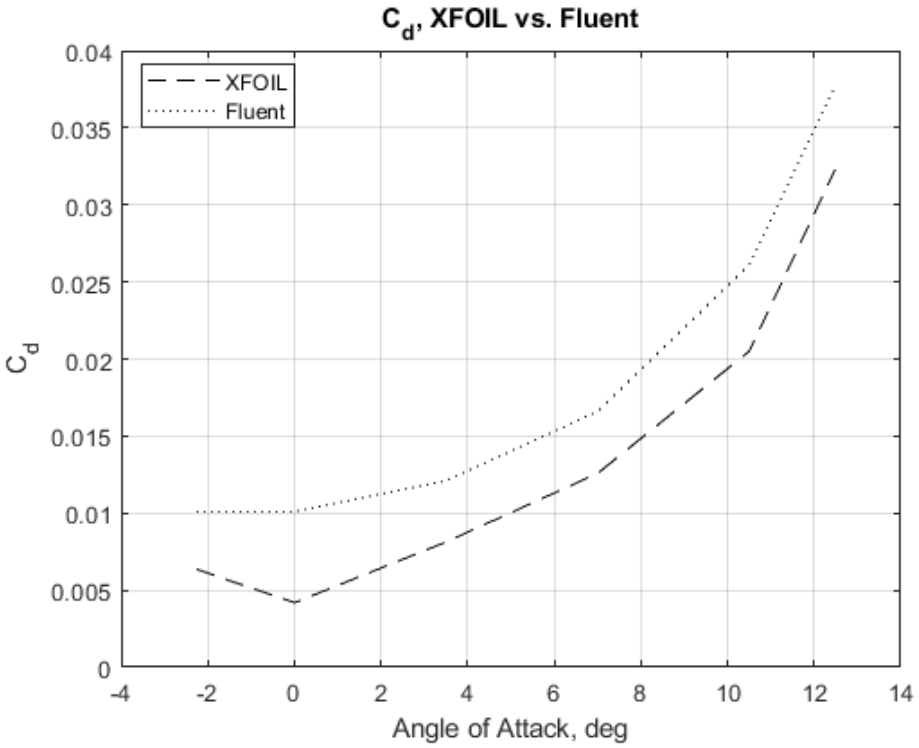


Figure 7: Drag coefficient comparison

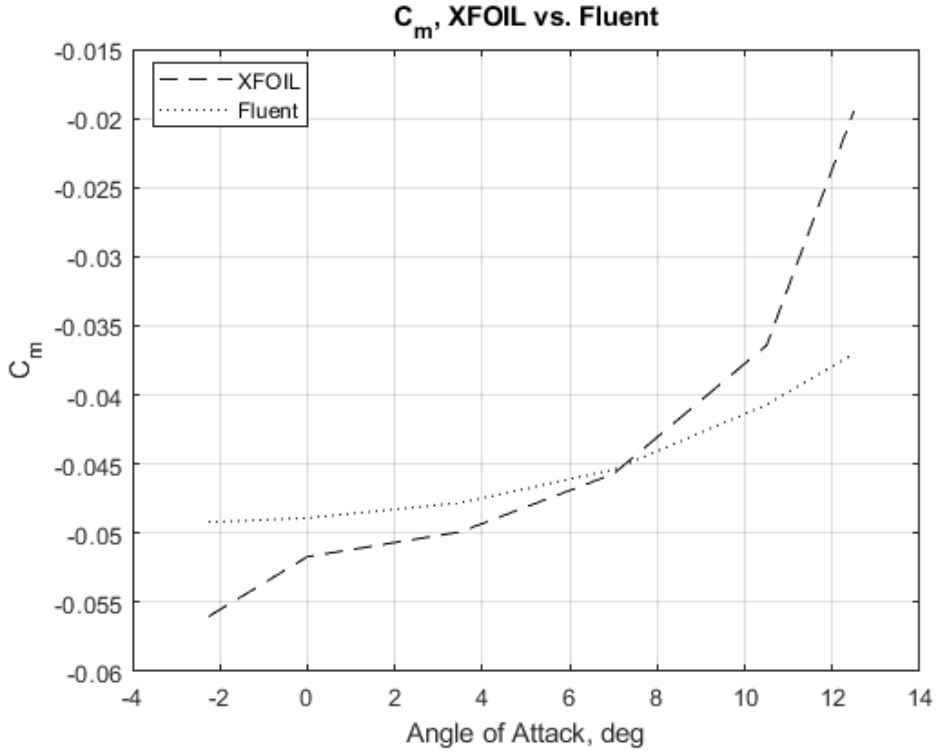


Figure 8: Moment coefficient comparison.

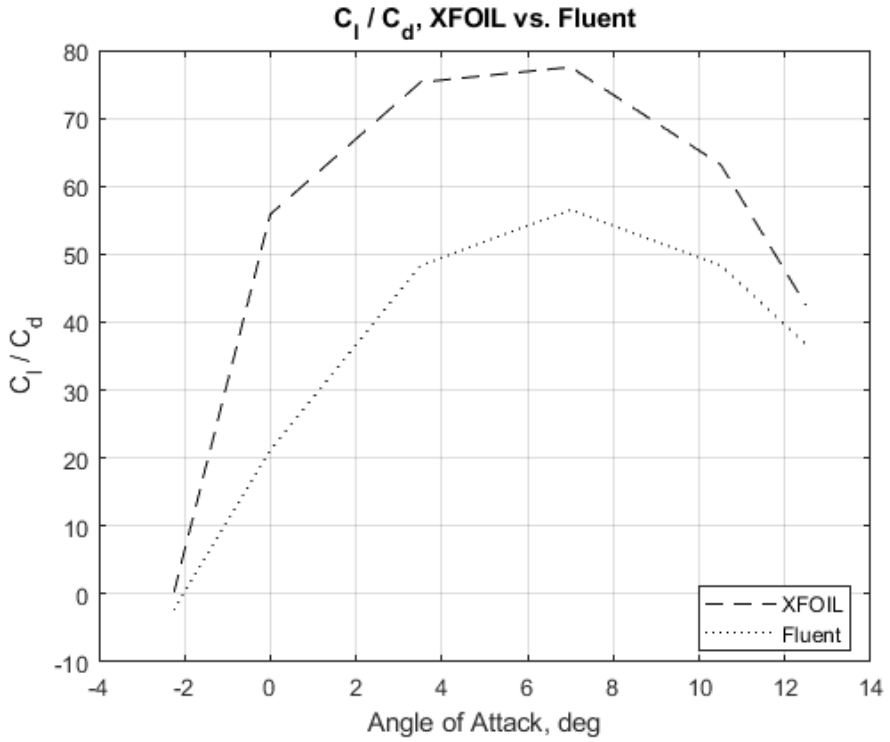


Figure 9: Coefficient ratio comparison.

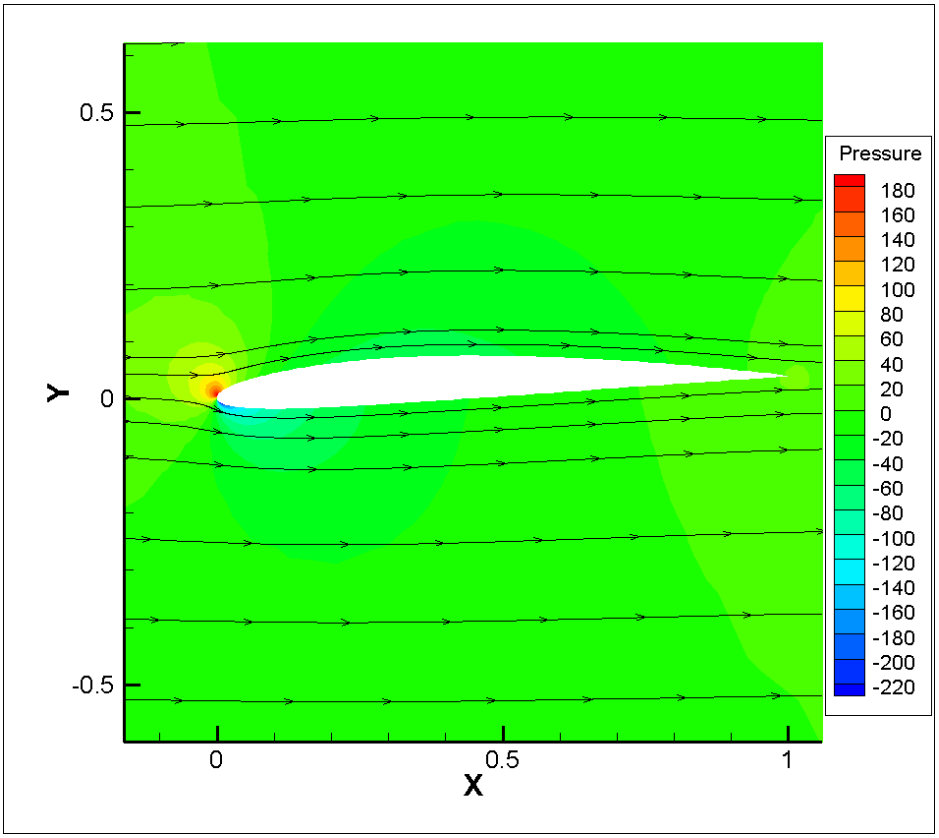


Figure 10: Zero-lift (-2.25 deg AoA) pressure contour and streamlines.

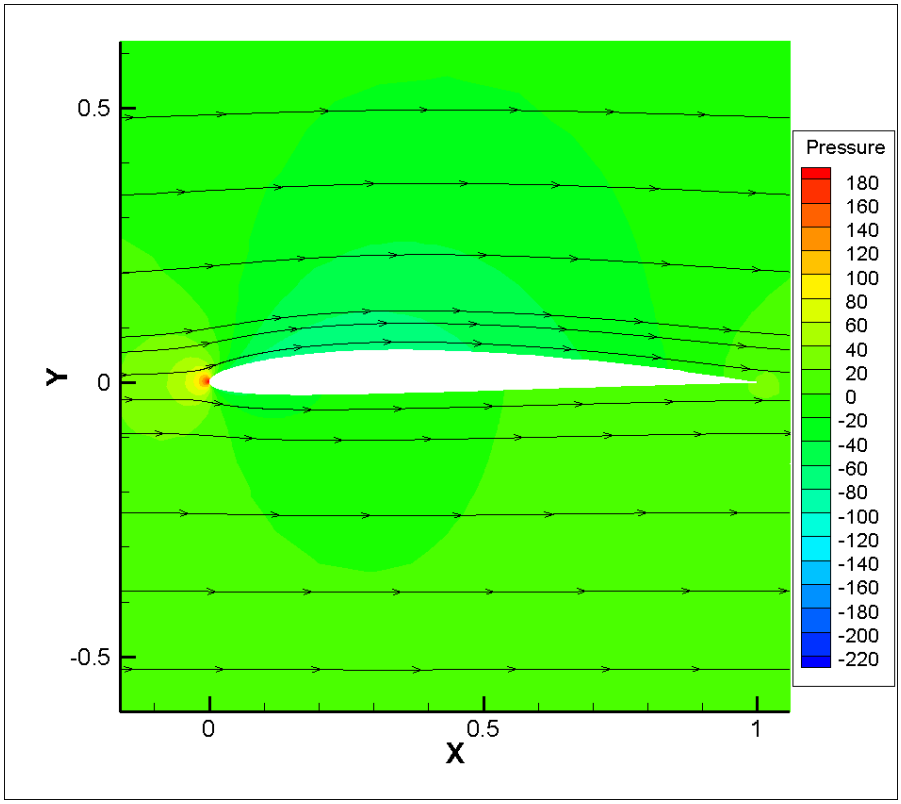


Figure 11: 0 deg AoA pressure contours and streamlines.

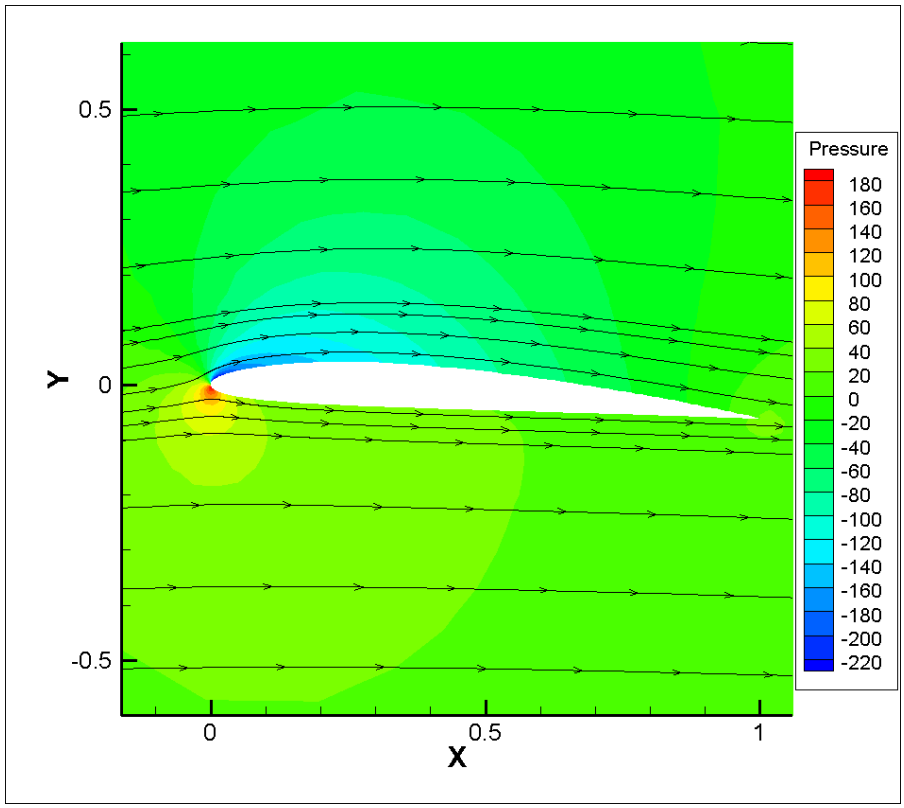


Figure 12: 3.5 deg AoA pressure contours and streamlines.

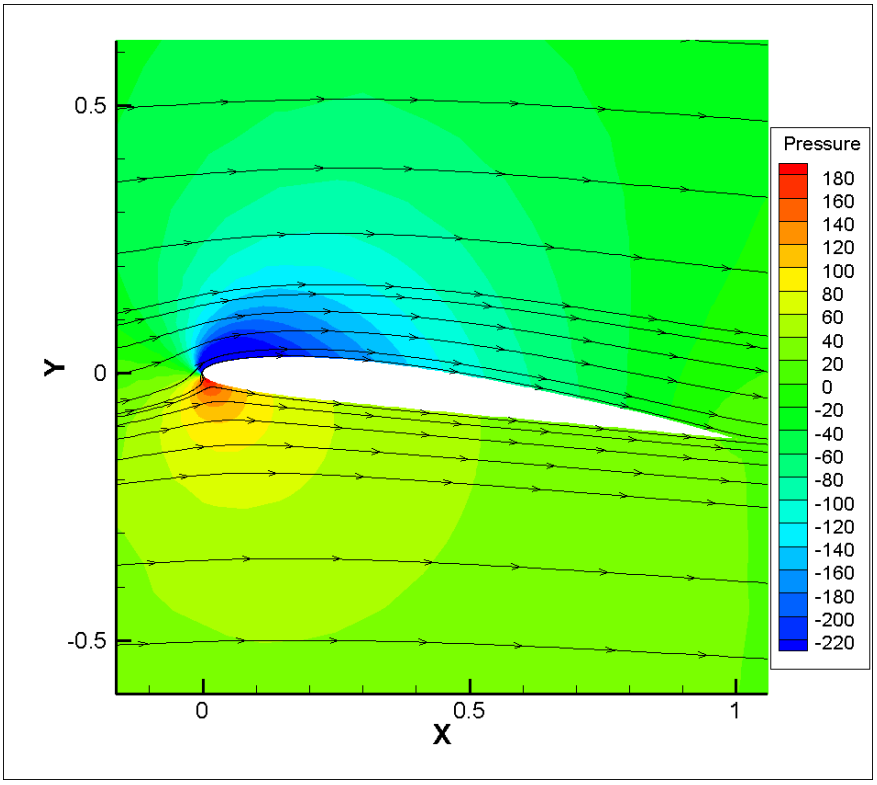


Figure 13: 7 deg AoA pressure contours and streamlines.

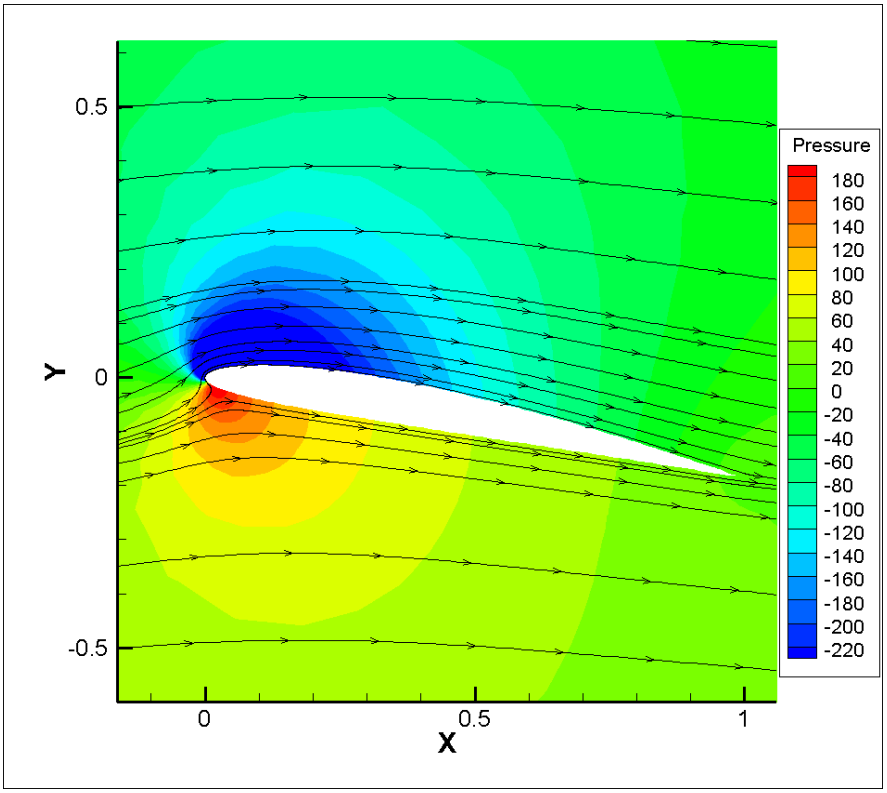


Figure 14: 10.5 deg AoA pressure contours and streamlines.

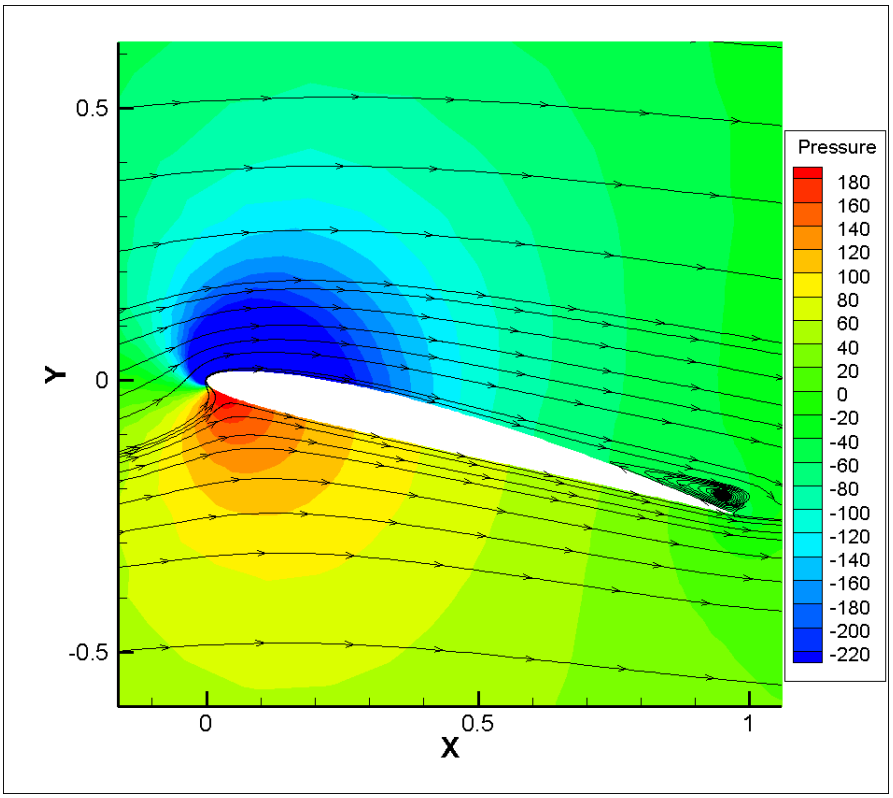


Figure 15: Max lift (12.5 deg AoA) pressure contours and streamlines.

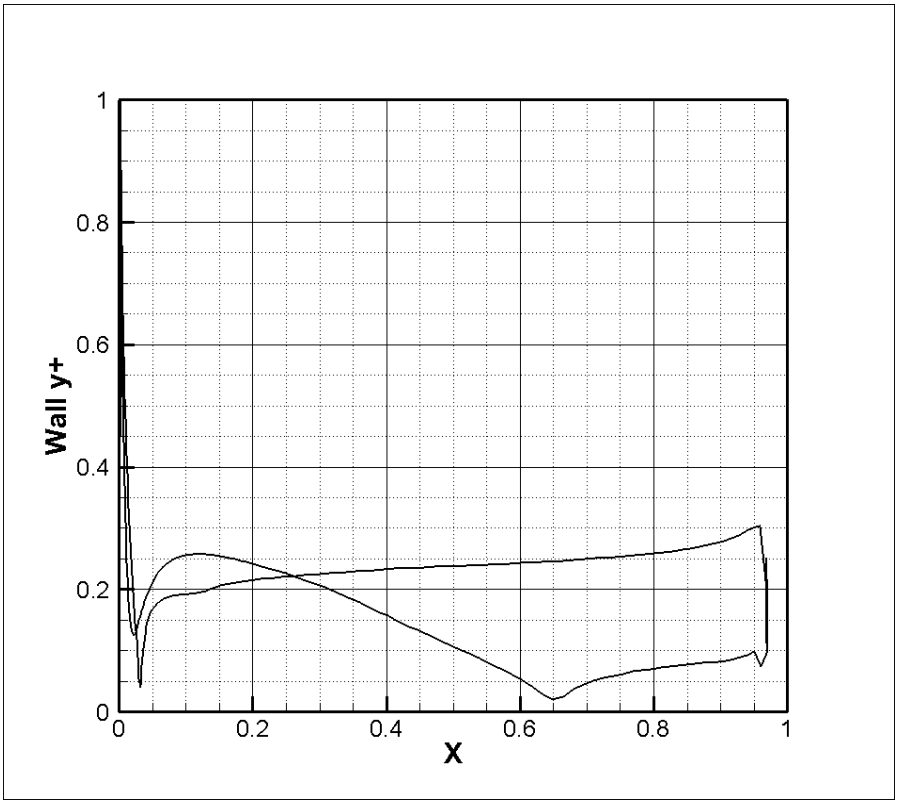


Figure 16: Wall y+ along airfoil.

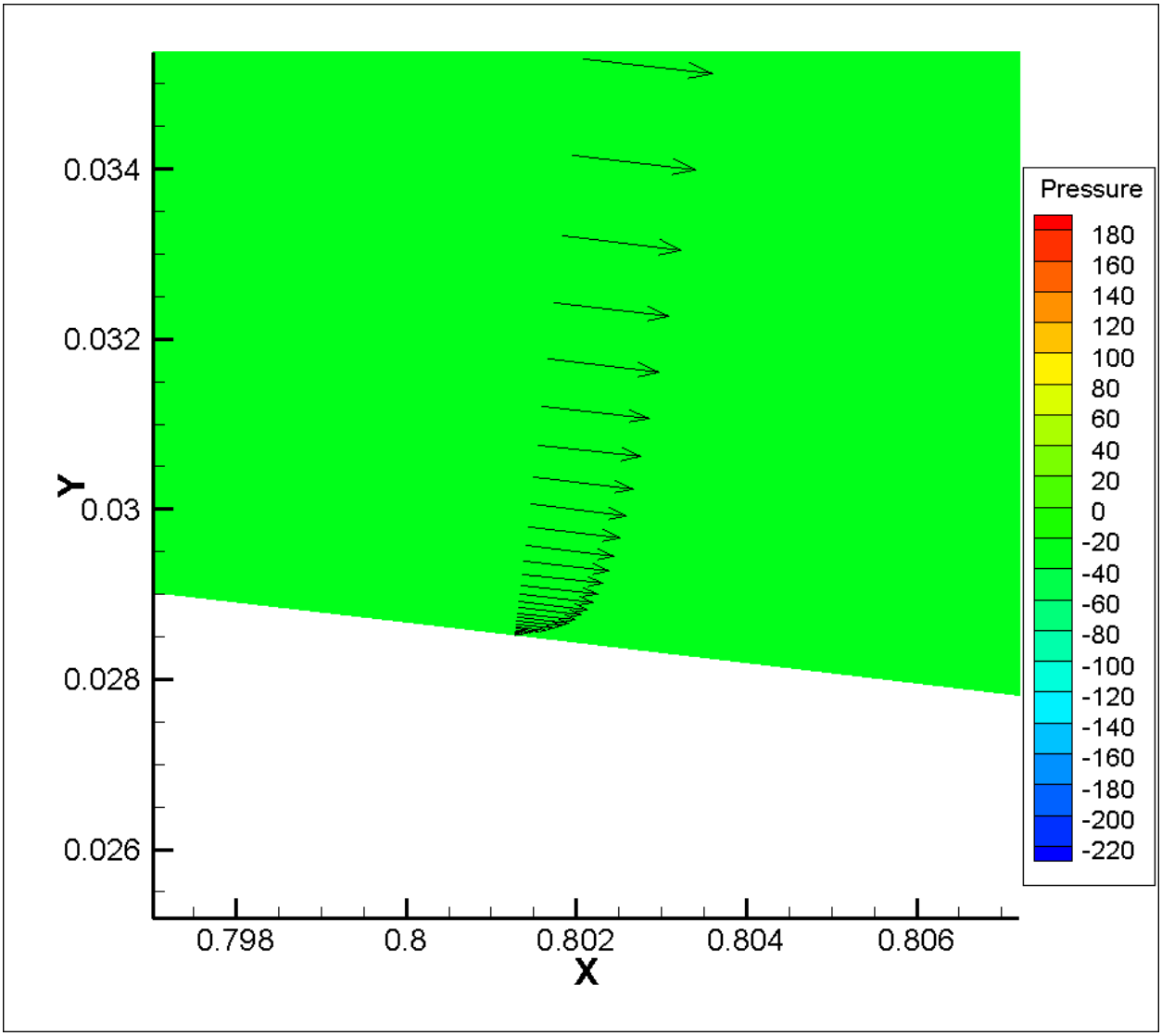


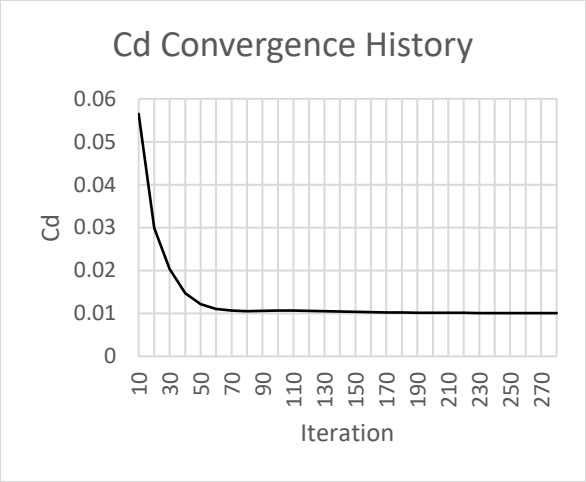
Figure 17: Boundary layer development toward TE of airfoil.

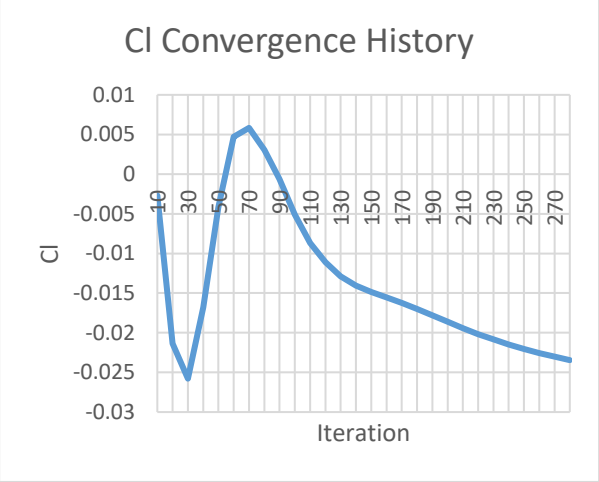
Discussion:

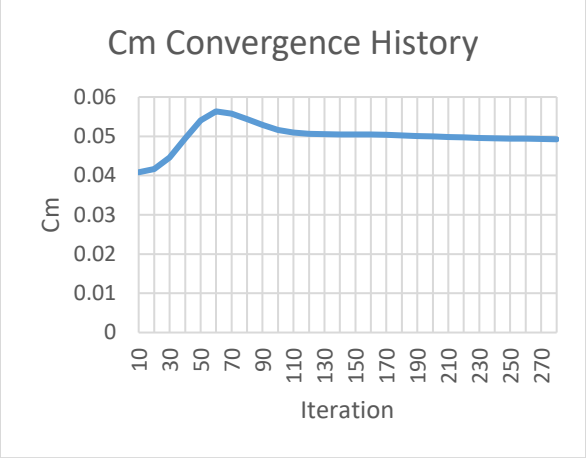
The XFOIL and Fluent lift coefficient curves match quite well (<10% difference). The drag, moment, and ratio of coefficients do not match as closely. This is likely due to differences in turbulence or viscosity models for the flow. NACA 2408 is a thin airfoil, and therefore does not create much form drag; the remaining sources of drag are induced drag, which, being a function of lift, should be quite accurate, and viscous drag. Differences in how XFOIL calculates turbulence will result in significant differences in resultant drag.

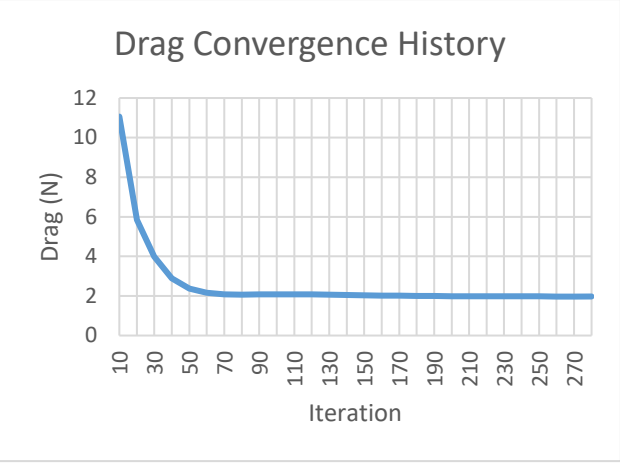
Appendix: Convergence Histories

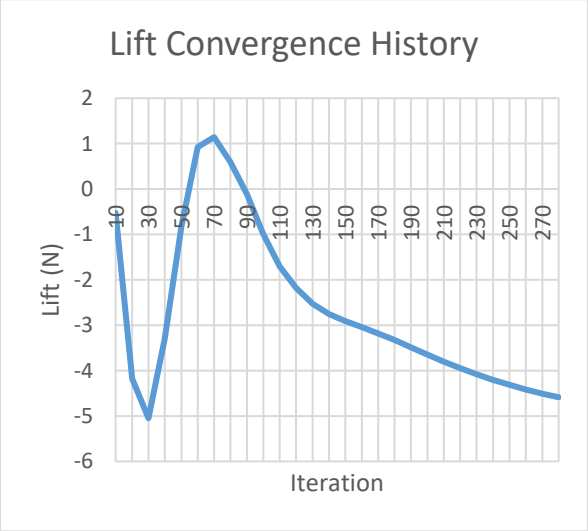
-2.2 deg AoA:

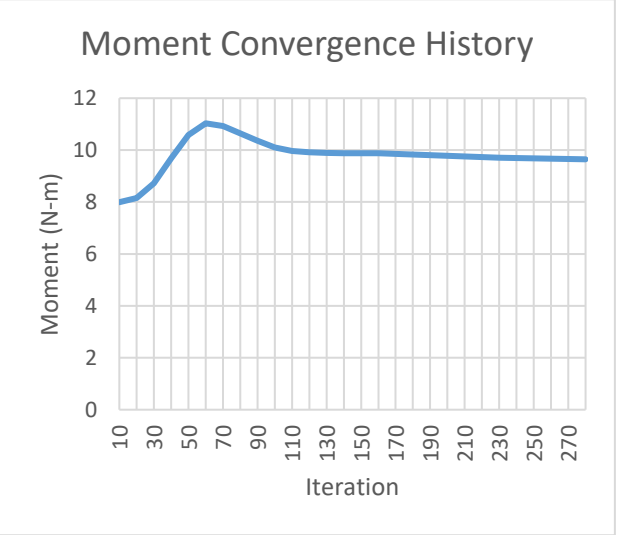




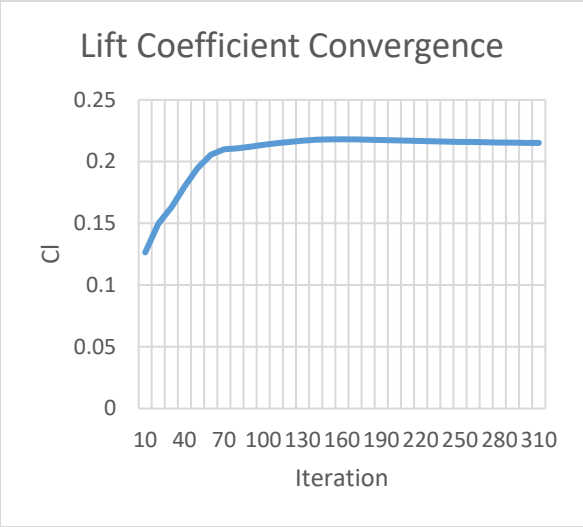


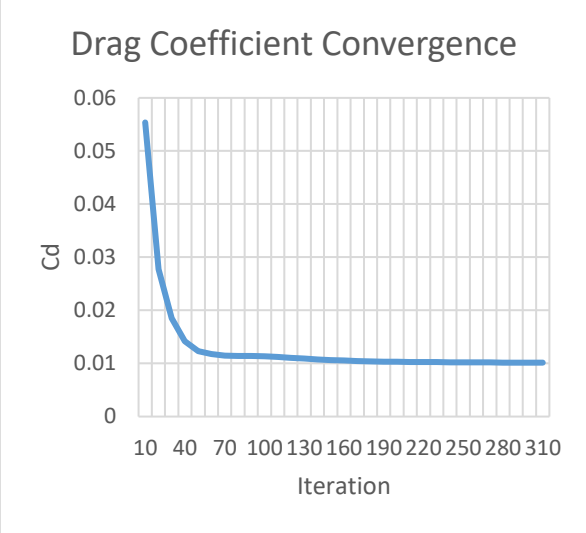


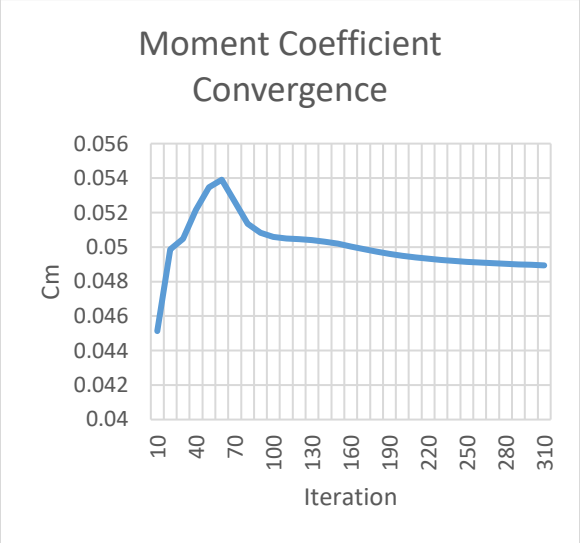


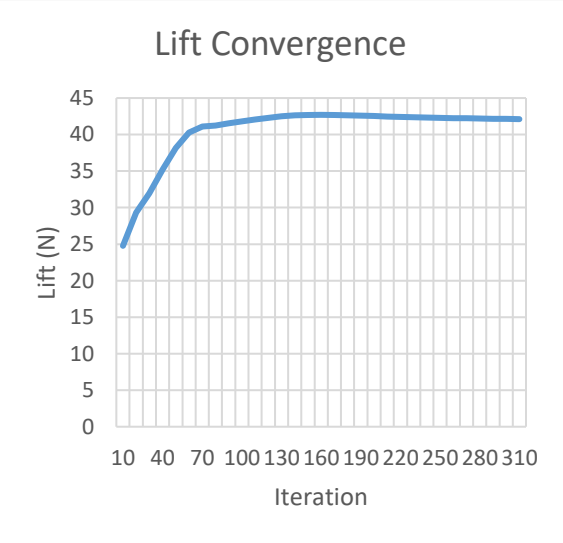


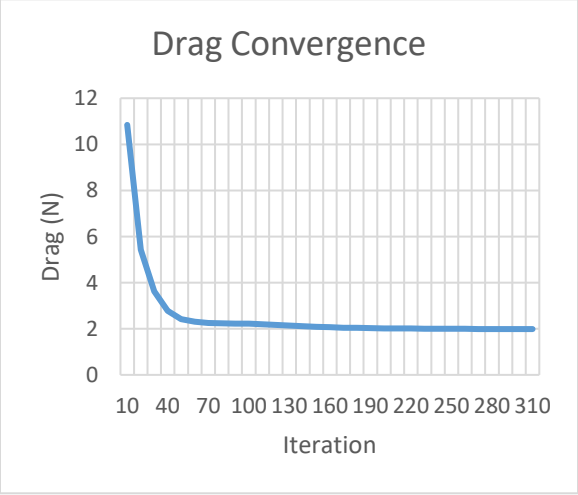
0 deg AoA:

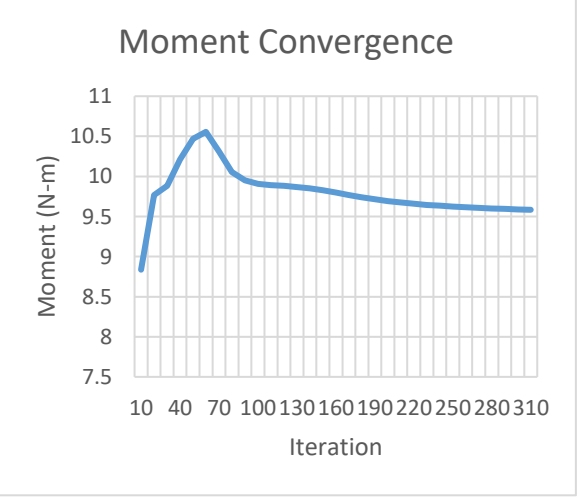

Lift Coefficient Convergence
Cl
0.25
0.2
0.15
0.1
0.05
0
10 40 70 100 130 160 190 220 250 280 310
Iteration


Drag Coefficient Convergence
Cd
0.06
0.05
0.04
0.03
0.02
0.01
0
10 40 70 100 130 160 190 220 250 280 310
Iteration

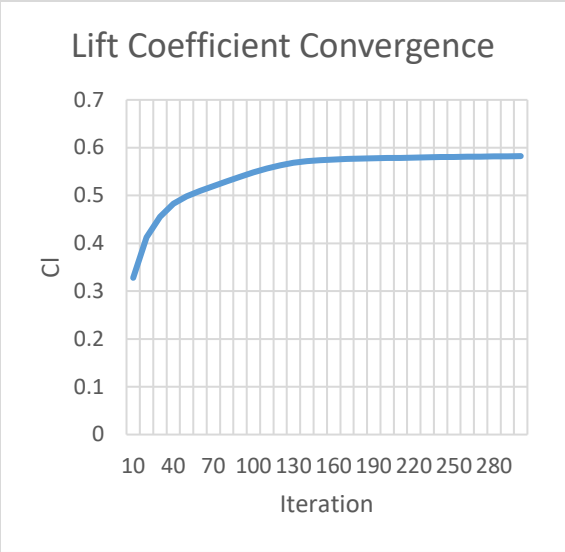

Moment Coefficient Convergence
Cm
0.056
0.054
0.052
0.05
0.048
0.046
0.044
0.042
0.04
10 40 70 100 130 160 190 220 250 280 310
Iteration

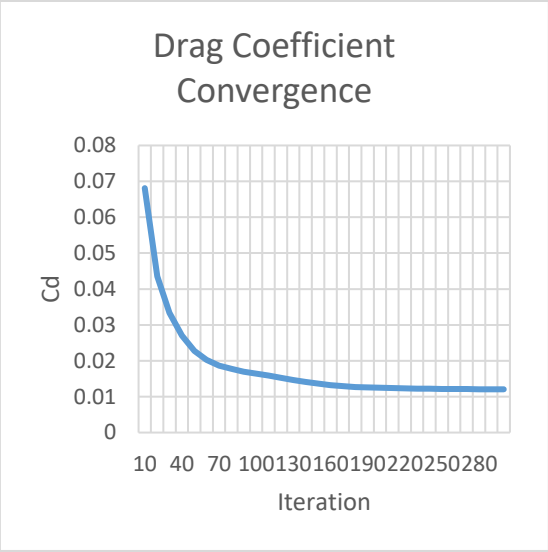

Lift Convergence
Lift (N)
45
40
35
30
25
20
15
10
5
0
10 40 70 100 130 160 190 220 250 280 310
Iteration

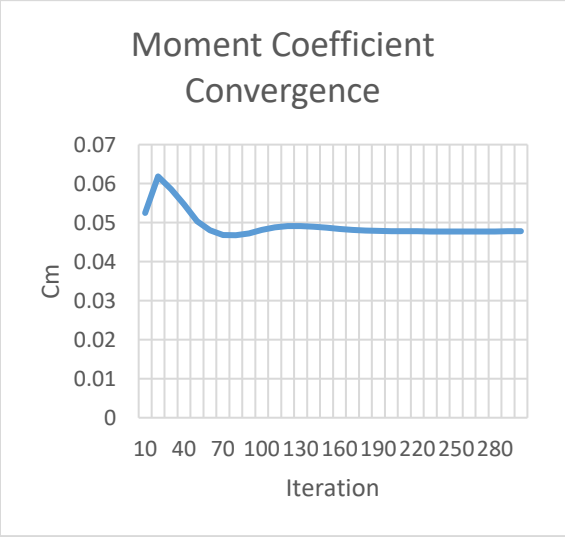

Drag Convergence
Drag (N)
12
10
8
6
4
2
0
10 40 70 100 130 160 190 220 250 280 310
Iteration

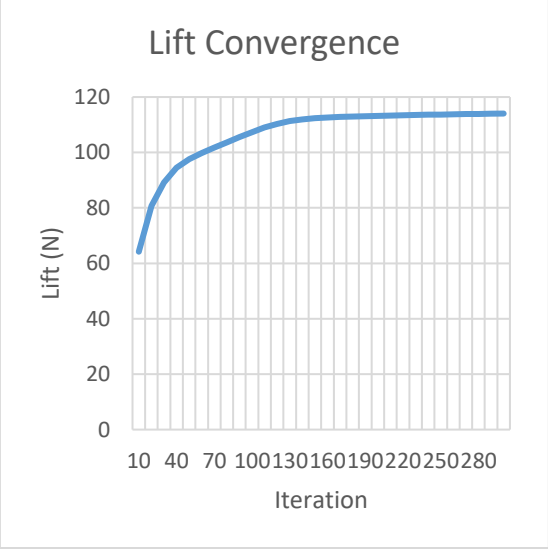

Moment Convergence
Moment (N-m)
11
10.5
10
9.5
9
8.5
8
7.5
10 40 70 100 130 160 190 220 250 280 310
Iteration

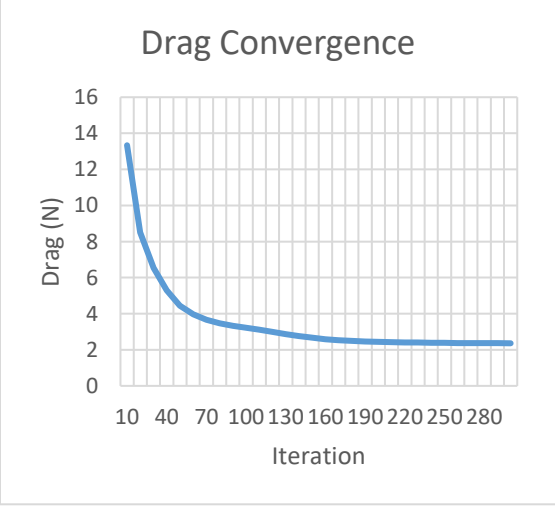
3.5 deg AoA

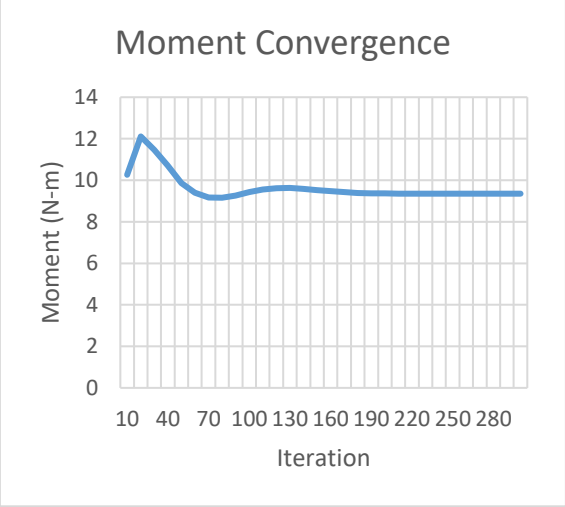

Lift Coefficient Convergence
Cl
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10 40 70 100 130 160 190 220 250 280
Iteration


Drag Coefficient Convergence
Cd
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
10 40 70 100130160190220250280
Iteration

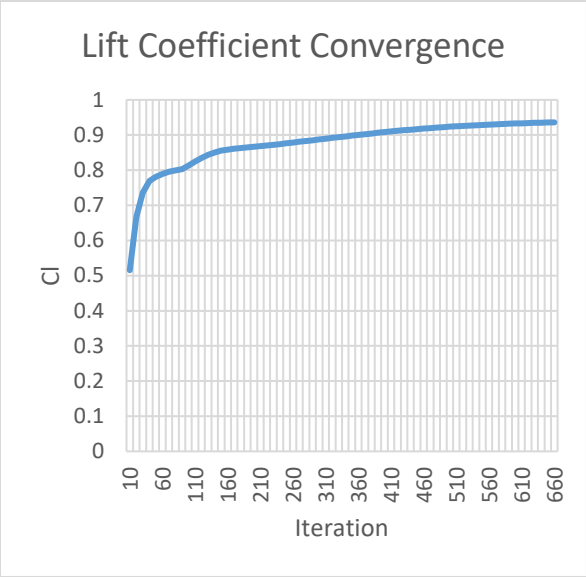

Moment Coefficient Convergence
Cm
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
10 40 70 100 130 160 190 220 250 280
Iteration

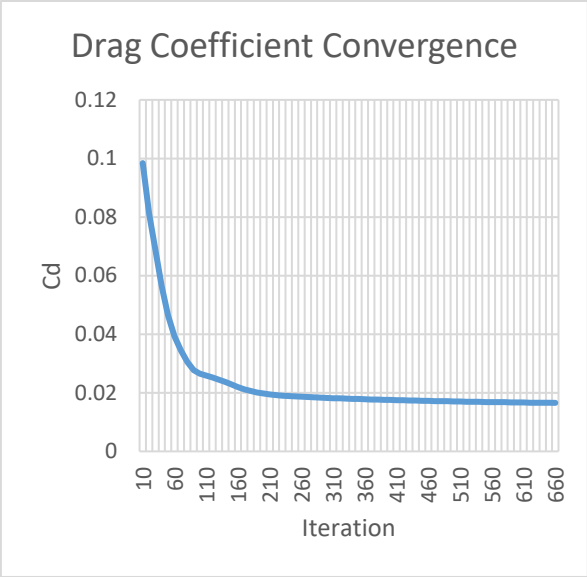

Lift Convergence
Lift (N)
120
100
80
60
40
20
0
10 40 70 100130160190220250280
Iteration

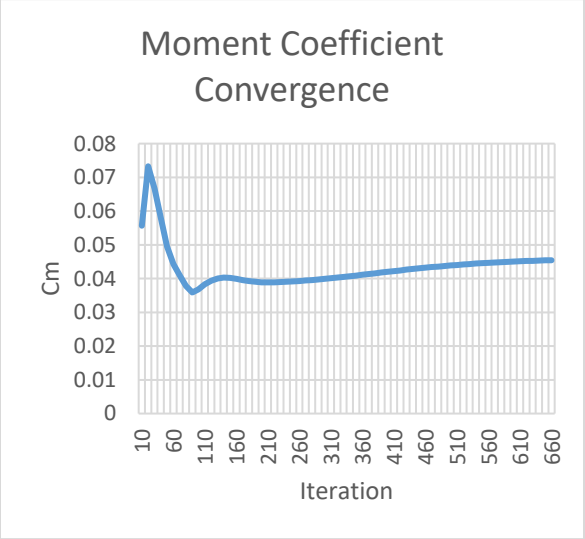

Drag Convergence
Drag (N)
16
14
12
10
8
6
4
2
0
10 40 70 100 130 160 190 220 250 280
Iteration

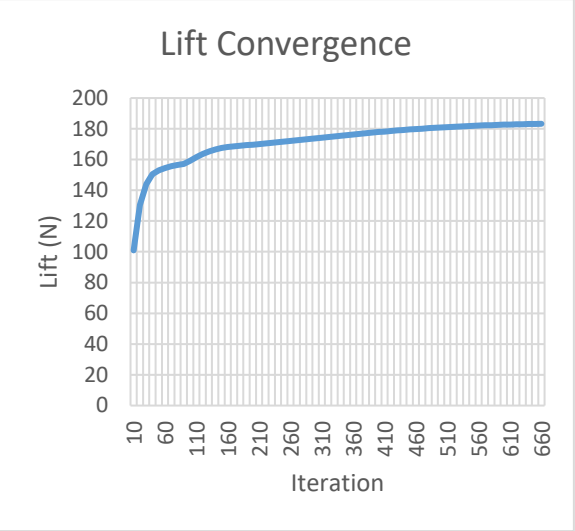

Moment Convergence
Moment (N-m)
14
12
10
8
6
4
2
0
10 40 70 100 130 160 190 220 250 280
Iteration

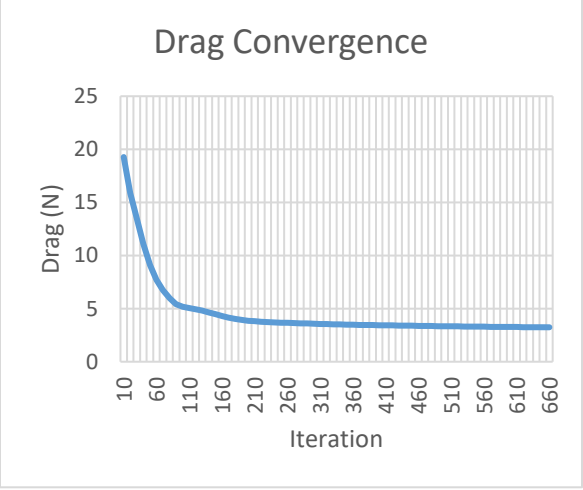
7 deg AoA:

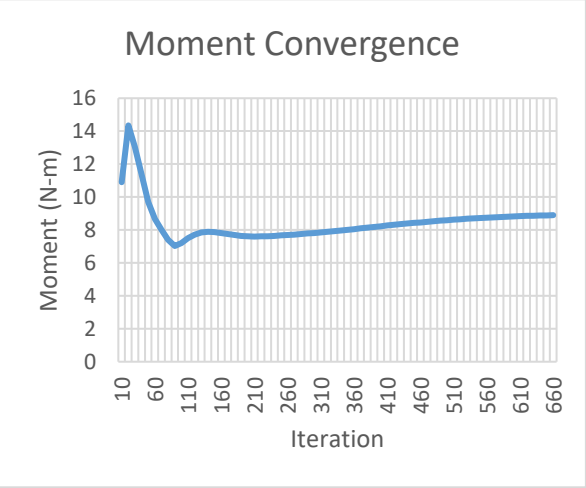

Lift Coefficient Convergence
Cl
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10 60 110 160 210 260 310 360 410 460 510 560 610 660
Iteration


Drag Coefficient Convergence
Cd
0.12
0.1
0.08
0.06
0.04
0.02
0
10 60 110 160 210 260 310 360 410 460 510 560 610 660
Iteration

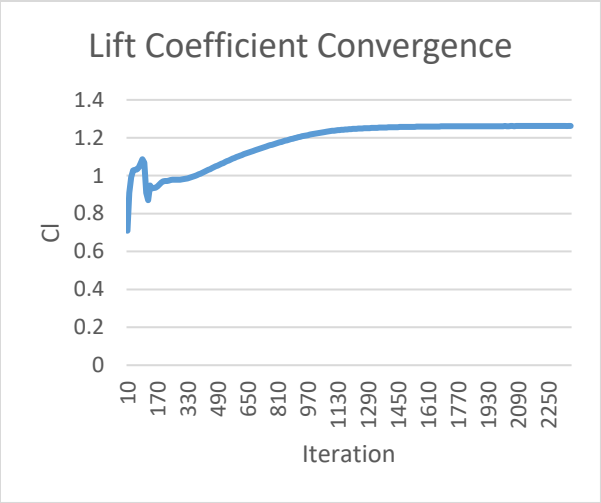

Moment Coefficient Convergence
Cm
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
10 60 110 160 210 260 310 360 410 460 510 560 610 660
Iteration

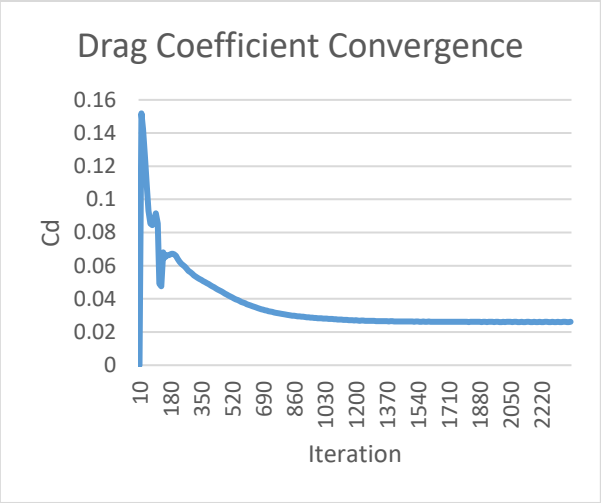

Lift Convergence
Lift (N)
200
180
160
140
120
100
80
60
40
20
0
10 60 110 160 210 260 310 360 410 460 510 560 610 660
Iteration

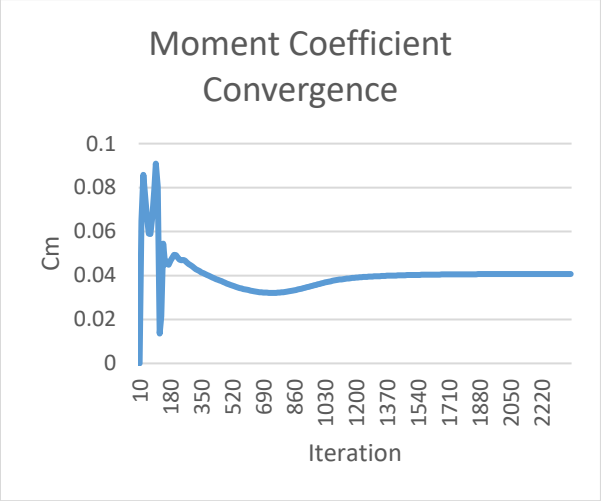

Drag Convergence
Drag (N)
25
20
15
10
5
0
10 60 110 160 210 260 310 360 410 460 510 560 610 660
Iteration

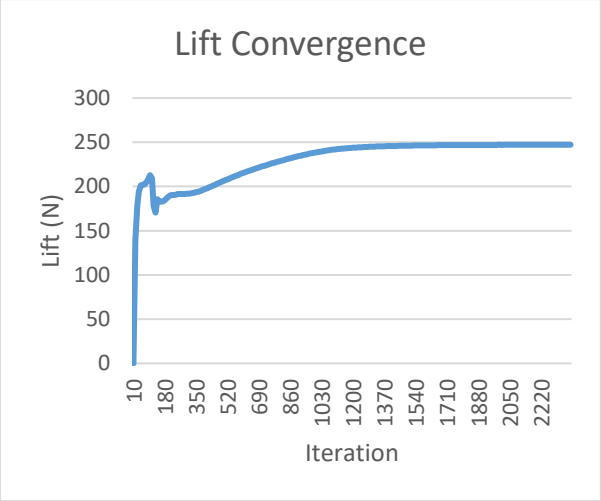

Moment Convergence
Moment (N-m)
16
14
12
10
8
6
4
2
0
10 60 110 160 210 260 310 360 410 460 510 560 610 660
Iteration

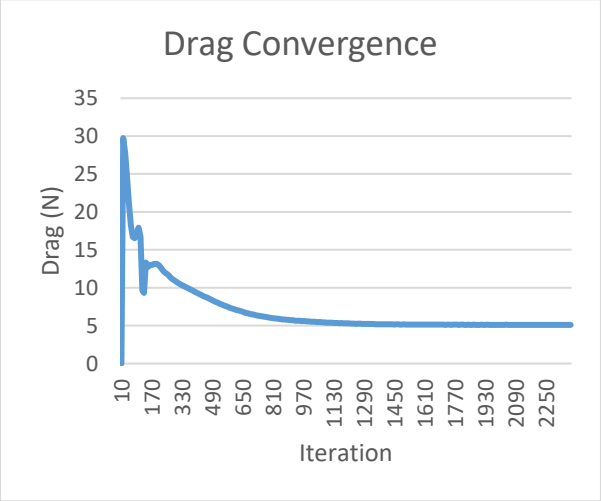
10.5 deg AoA:

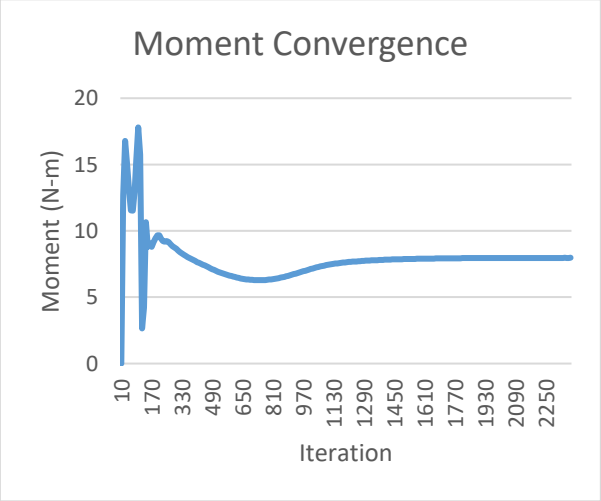

Lift Coefficient Convergence
Cl
1.4
1.2
1
0.8
0.6
0.4
0.2
0
10 170 330 490 650 810 970 1130 1290 1450 1610 1770 1930 2090 2250
Iteration


Drag Coefficient Convergence
Cd
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
10 180 350 520 690 860 1030 1200 1370 1540 1710 1880 2050 2220
Iteration

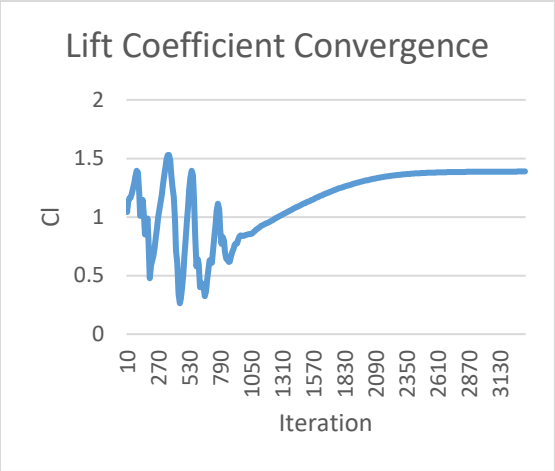

Moment Coefficient Convergence
Cm
0.1
0.08
0.06
0.04
0.02
0
10 180 350 520 690 860 1030 1200 1370 1540 1710 1880 2050 2220
Iteration

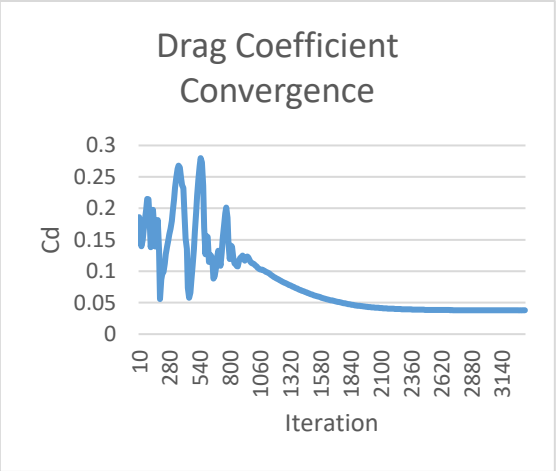

Lift Convergence
Lift (N)
300
250
200
150
100
50
0
10 180 350 520 690 860 1030 1200 1370 1540 1710 1880 2050 2220
Iteration

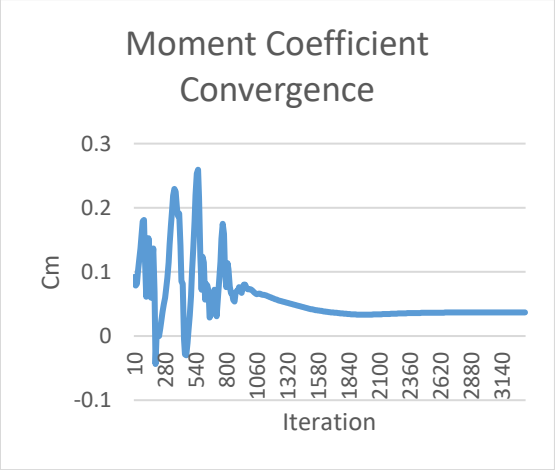

Drag Convergence
Drag (N)
35
30
25
20
15
10
5
0
10 170 330 490 650 810 970 1130 1290 1450 1610 1770 1930 2090 2250
Iteration

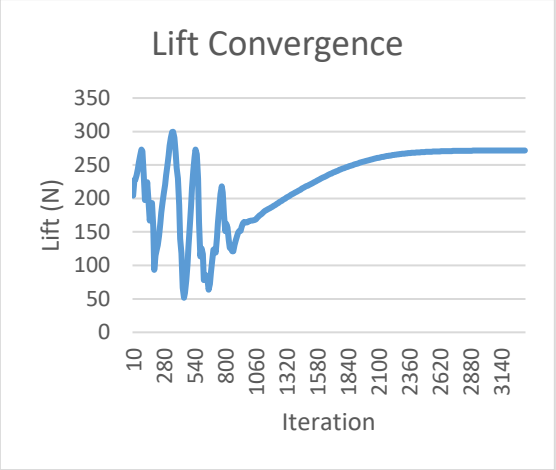

Moment Convergence
Moment (N-m)
20
15
10
5
0
10 170 330 490 650 810 970 1130 1290 1450 1610 1770 1930 2090 2250
Iteration

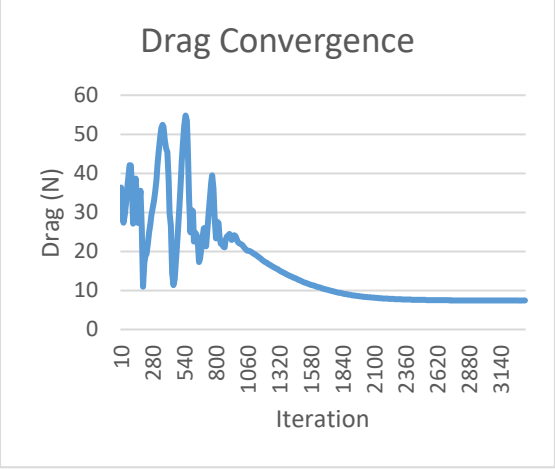
12.5 deg AoA:

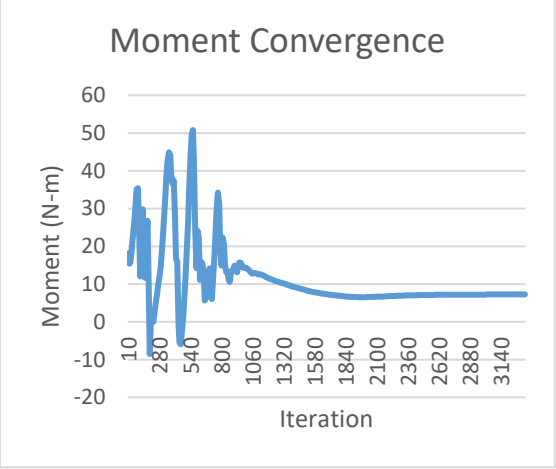

Lift Coefficient Convergence
Cl
2
1.5
1
0.5
0
10
270
530
790
1050
1310
1570
1830
2090
2350
2610
2870
3130
Iteration


Drag Coefficient Convergence
Cd
0.3
0.25
0.2
0.15
0.1
0.05
0
10
280
540
800
1060
1320
1580
1840
2100
2360
2620
2880
3140
Iteration


Moment Coefficient Convergence
Cm
0.3
0.2
0.1
0
-0.1
10
280
540
800
1060
1320
1580
1840
2100
2360
2620
2880
3140
Iteration


Lift Convergence
Lift (N)
350
300
250
200
150
100
50
0
10
280
540
800
1060
1320
1580
1840
2100
2360
2620
2880
3140
Iteration


Drag Convergence
Drag (N)
60
50
40
30
20
10
0
10
280
540
800
1060
1320
1580
1840
2100
2360
2620
2880
3140
Iteration


Moment Convergence
Moment (N-m)
60
50
40
30
20
10
0
-10
-20
10
280
540
800
1060
1320
1580
1840
2100
2360
2620
2880
3140
Iteration