Document No.:   **NC00.00.00.002**

Engineering Report: **XFOIL Results Validation for NLF(1)-0215F Airfoil**

Applicable paragraphs of airworthiness requirements: N/A

	Name	Signature	Date
Author	-	AP	03.11.2011
Checked	-	-	-
Approved	-	-	-

Rev. No.	Description	Author	Date	Approved
-	Draft	AP	03.11.2011	-

SCOPE

The purpose of this report is to validate results generated by XFOIL software for further use in design and analysis of a subsonic airfoil developed based on NLF(1)-0215F.
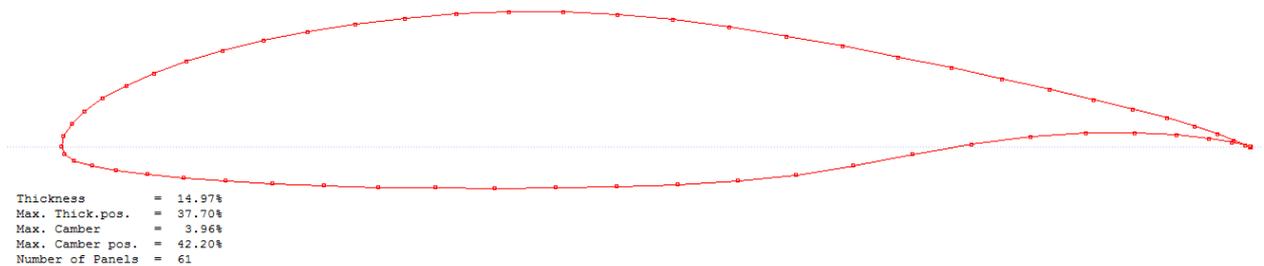
General

NASA TP 1865 "Design and Experimental Results for Flapped NLF Airfoil" report has been selected as a reference for validation.
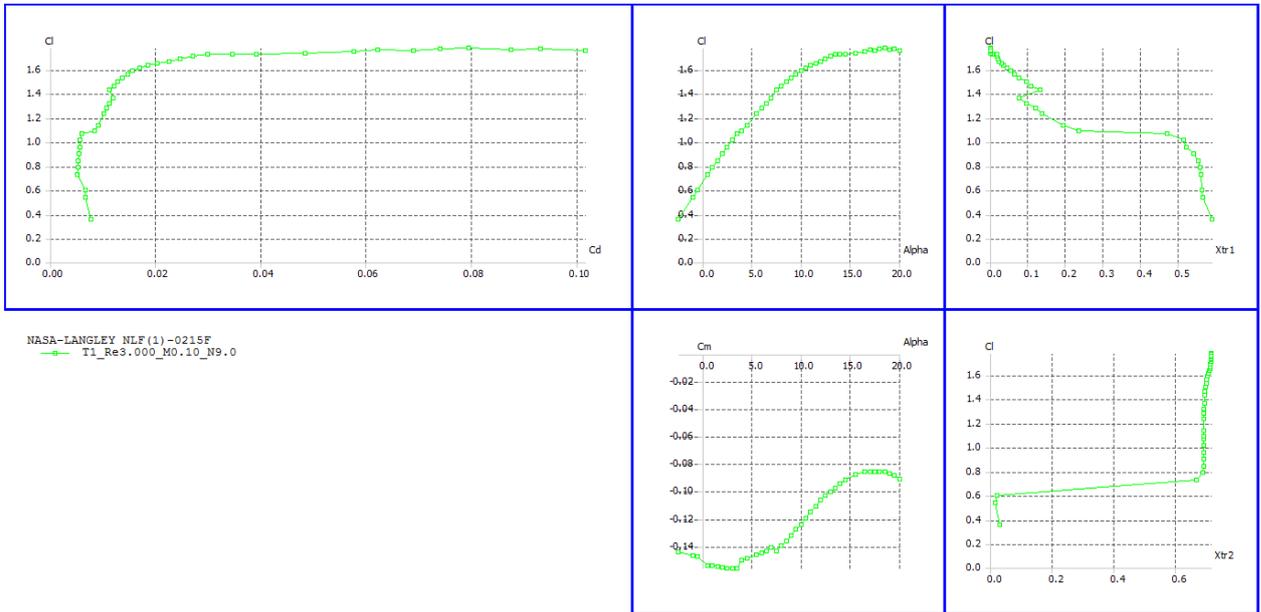
Conditions selected for analysis are as follows:

1. Re=3e6, 6e6, and 9e6
2. M=0.1 (the range M=0.1-0.3 discussed in ref. [1] shows no significant difference in airfoil data for AOA between -7 to 10 degrees)
3. Free transition

Initially NLF(1)-0215F has been used with original coordinates, however that led to poor accuracy of the results as shown below.

```
NASA-LANGLEY NLF(1)-0215F        0.51524  0.10784        0.00240   0.00917        0.51867  -0.03225
 1.00000   0.00000              0.46864  0.11219        0.00000   0.00006        0.56920  -0.02925
 0.99658   0.00126              0.42253  0.11427        0.00245  -0.00704        0.61825  -0.02441
 0.98710   0.00507              0.37702  0.11428        0.01099  -0.01211        0.66662  -0.01663
 0.97285   0.01082              0.33237  0.11240        0.02592  -0.01656        0.71614  -0.00705
 0.95409   0.01737              0.28894  0.10887        0.04653  -0.02052        0.76645   0.00167
 0.93044   0.02428              0.24720  0.10389        0.07242  -0.02399        0.81565   0.00804
 0.90193   0.03175              0.20758  0.09761        0.10324  -0.02699        0.86198   0.01155
 0.86902   0.03983              0.17050  0.09019        0.13854  -0.02954        0.90359   0.01198
 0.83222   0.04844              0.13635  0.08175        0.17788  -0.03166        0.93862   0.00990
 0.79206   0.05746              0.10546  0.07247        0.22073  -0.03334        0.96588   0.00655
 0.74914   0.06673              0.07816  0.06250        0.26654  -0.03456        0.98504   0.00323
 0.70408   0.07603              0.05469  0.05201        0.31473  -0.03531        0.99630   0.00086
 0.65752   0.08513              0.03527  0.04120        0.36468  -0.03554        1.00000   0.00000
 0.61010   0.09373              0.02004  0.03027        0.41576  -0.03519
 0.56247   0.10147              0.00909  0.01947        0.46731  -0.03415
```
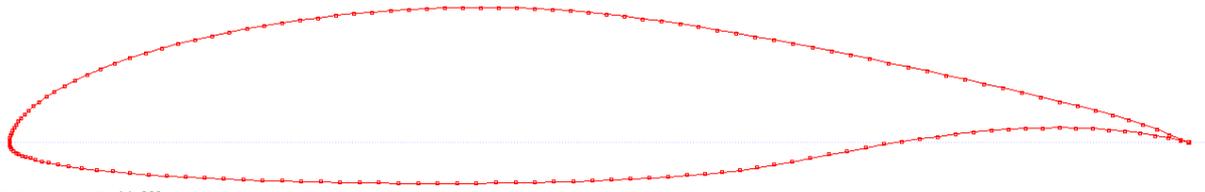


```
Thickness       =  14.97%
Max. Thick.pos. =  37.70%
Max. Camber     =   3.96%
Max. Camber pos.=  42.20%
Number of Panels =  61
```

NASA-LANGLEY NLF(1)-0215F
T1_Re3.000_M0.10_N9.0

Increased up to 160 number of panels gave a better picture.

NASA-LANGLEY		0.53764	0.10502	0.05594	0.05263	0.06136	-0.02264	0.59015	-0.02751
NLF(1)-0215F_1		0.52217	0.10701	0.04660	0.04781	0.07403	-0.02417	0.60505	-0.02599
1.00000	0.00000	0.50684	0.10878	0.03843	0.04315	0.08784	-0.02561	0.61970	-0.02422
0.99431	0.00214	0.49162	0.11032	0.03140	0.03869	0.10258	-0.02694	0.63432	-0.02214
0.98450	0.00614	0.47646	0.11162	0.02541	0.03449	0.11799	-0.02815	0.64915	-0.01974
0.97354	0.01055	0.46132	0.11267	0.02043	0.03059	0.13377	-0.02924	0.66430	-0.01706
0.96199	0.01476	0.44614	0.11348	0.01632	0.02703	0.14974	-0.03021	0.67973	-0.01414
0.94954	0.01879	0.43090	0.11405	0.01296	0.02377	0.16587	-0.03108	0.69533	-0.01109
0.93603	0.02273	0.41561	0.11440	0.01016	0.02074	0.18211	-0.03185	0.71098	-0.00804
0.92157	0.02667	0.40029	0.11452	0.00781	0.01786	0.19843	-0.03254	0.72659	-0.00509
0.90646	0.03060	0.38496	0.11442	0.00584	0.01512	0.21481	-0.03314	0.74211	-0.00232
0.89098	0.03449	0.36963	0.11410	0.00420	0.01252	0.23123	-0.03367	0.75750	0.00026
0.87525	0.03833	0.35427	0.11355	0.00286	0.01009	0.24770	-0.03412	0.77278	0.00262
0.85934	0.04213	0.33889	0.11279	0.00178	0.00783	0.26420	-0.03451	0.78798	0.00475
0.84332	0.04588	0.32348	0.11181	0.00097	0.00575	0.28072	-0.03483	0.80312	0.00665
0.82723	0.04958	0.30807	0.11063	0.00040	0.00380	0.29725	-0.03510	0.81818	0.00830
0.81109	0.05323	0.29269	0.10924	0.00008	0.00194	0.31379	-0.03530	0.83311	0.00969
0.79490	0.05683	0.27734	0.10765	-0.00000	0.00012	0.33032	-0.03544	0.84788	0.01078
0.77869	0.06039	0.26205	0.10585	0.00017	-0.00170	0.34686	-0.03552	0.86247	0.01157
0.76248	0.06389	0.24682	0.10384	0.00060	-0.00350	0.36340	-0.03554	0.87688	0.01203
0.74627	0.06734	0.23166	0.10162	0.00132	-0.00526	0.37993	-0.03550	0.89114	0.01216
0.73006	0.07072	0.21658	0.09918	0.00236	-0.00693	0.39645	-0.03540	0.90523	0.01194
0.71384	0.07405	0.20162	0.09652	0.00380	-0.00842	0.41294	-0.03523	0.91917	0.01135
0.69762	0.07732	0.18680	0.09365	0.00567	-0.00975	0.42941	-0.03499	0.93292	0.01040
0.68142	0.08053	0.17216	0.09056	0.00801	-0.01094	0.44583	-0.03468	0.94643	0.00910
0.66525	0.08366	0.15771	0.08723	0.01083	-0.01205	0.46222	-0.03429	0.95961	0.00746
0.64911	0.08671	0.14347	0.08365	0.01409	-0.01319	0.47855	-0.03381	0.97219	0.00555
0.63300	0.08967	0.12948	0.07984	0.01786	-0.01439	0.49483	-0.03325	0.98381	0.00347
0.61693	0.09254	0.11582	0.07579	0.02225	-0.01563	0.51106	-0.03259	0.99405	0.00136
0.60091	0.09530	0.10258	0.07151	0.02737	-0.01690	0.52722	-0.03184	1.00000	0.00000
0.58494	0.09795	0.08985	0.06701	0.03350	-0.01822	0.54329	-0.03096		
0.56905	0.10047	0.07775	0.06233	0.04100	-0.01961	0.55922	-0.02996		
0.55327	0.10283	0.06638	0.05751	0.05023	-0.02109	0.57488	-0.02881		

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ADA ADVANCED DESIGN ALLIANCE ENGINEERING CENTER	Project	Document Name	Document No.	Page
	-	XFOIL Results Validation for NLF(1)-0215F Airfoil	NC00.00.00.002	3

```
Thickness         =  14.99%
Max. Thick.pos.   =  39.60%
Max. Camber       =   3.96%
Max. Camber pos.  =  41.60%
Number of Panels  = 160
```


NASA-LANGLEY NLF(1)-0215F_1
T1_Re3.000_M0.10_N9.0
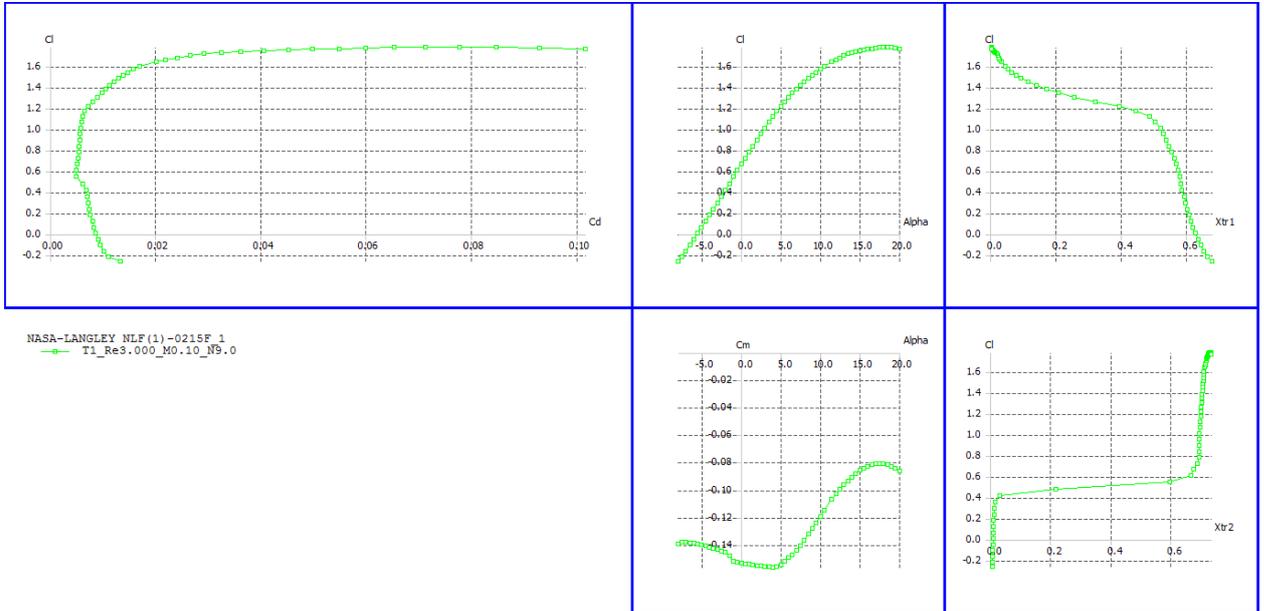
This airfoil designated as NASA-LANGLEY NLF(1)-0215F_1, with modified paneling, has eventually been analyzed.
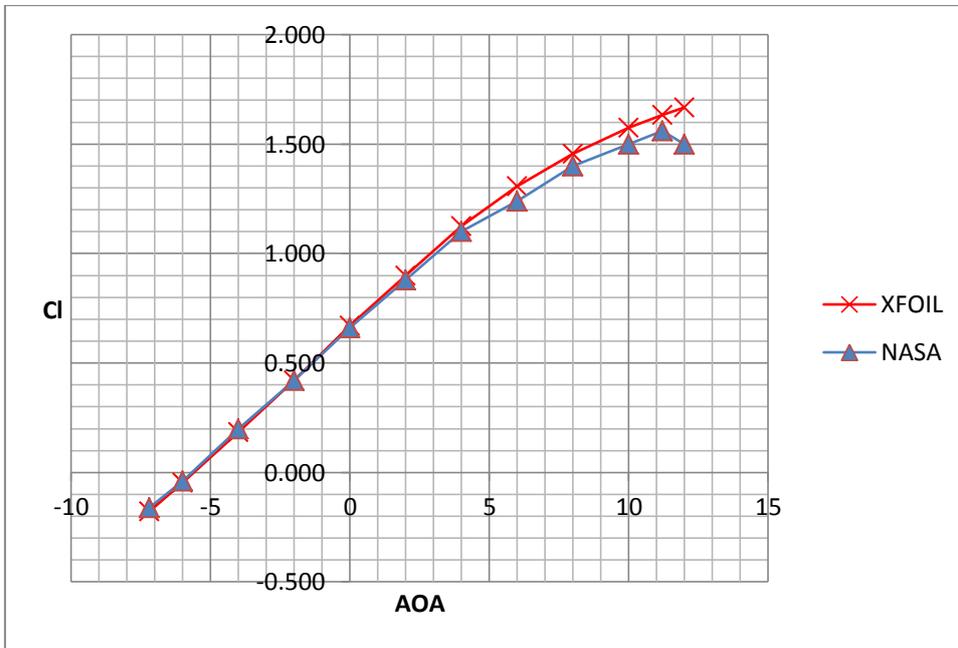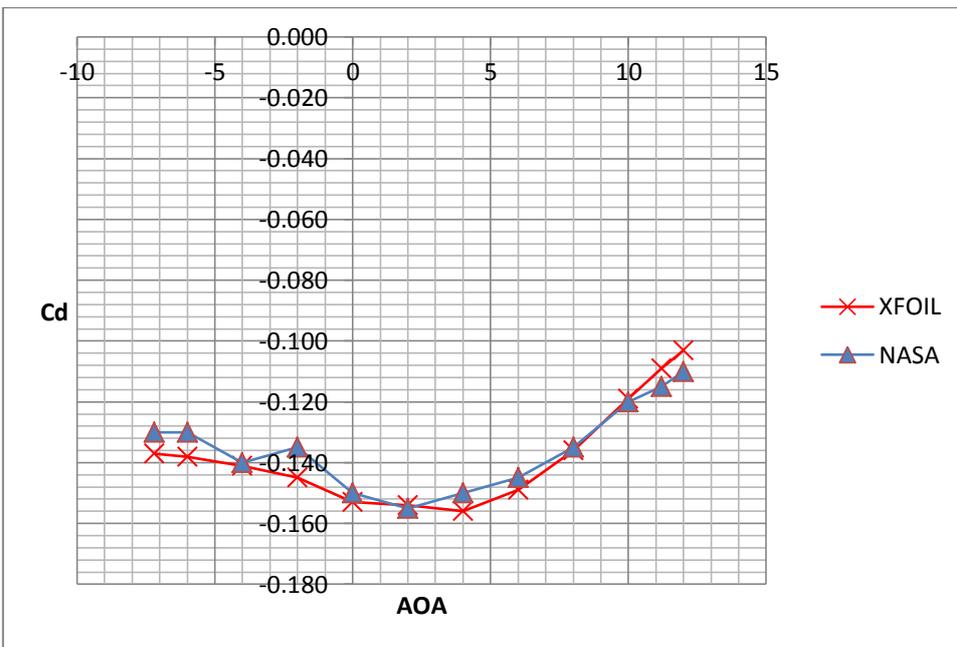
Results

Clean Airfoil Analysis

The tables below summarize Cl, Cd and Cm values for both XFOIL and NASA report as well as percentage of difference between each of the two corresponding values.

Each of the table is accompanied with appropriate charts.

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	Project	Document Name	Document No.	Page
ADA ADVANCED DESIGN ALLIANCE ENGINEERING CENTER	-	XFOIL Results Validation for NLF(1)-0215F Airfoil	NC00.00.00.002	4

	Re=3e6	Free transition								
	M=0.1									
	XFOIL	NASA		XFOIL	NASA		XFOIL	NASA		
AOA	**Cl**	**Cl**	**Δ, %**	**Cd**	**Cd**	**Δ, %**	**Cm**	**Cm**	**Δ, %**
-7.2	-0.178	-0.160	10.1%	0.010	0.0094	6.0%	-0.137	-0.130	5.1%
-6	-0.046	-0.040	13.0%	0.009	0.0084	6.7%	-0.138	-0.130	5.8%
-4	0.185	0.200	-8.1%	0.008	0.0080	0.0%	-0.141	-0.140	0.7%
-2	0.421	0.420	0.2%	0.007	0.0068	2.9%	-0.145	-0.135	6.9%
0	0.670	0.660	1.5%	0.005	0.0052	-4.0%	-0.153	-0.150	2.0%
2	0.900	0.880	2.2%	0.006	0.0058	3.3%	-0.154	-0.155	-0.6%
4	1.126	1.100	2.3%	0.006	0.0068	-13.3%	-0.156	-0.150	3.8%
6	1.308	1.240	5.2%	0.009	0.0092	-2.2%	-0.149	-0.145	2.7%
8	1.456	1.400	3.8%	0.012	0.0140	-16.7%	-0.136	-0.135	0.7%
10	1.575	1.500	4.8%	0.016	0.0194	-21.3%	-0.119	-0.120	-0.8%
11.2	1.633	1.560	4.5%	0.019	0.0240	-26.3%	-0.109	-0.115	-5.5%
12	1.668	1.500	10.1%	0.022			-0.103	-0.110	-6.8%
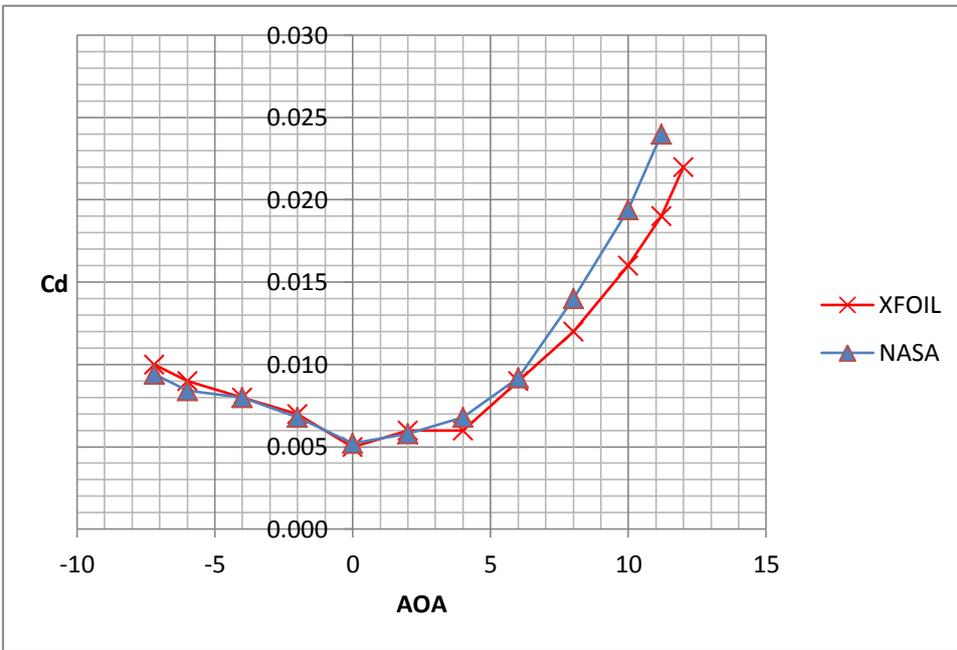
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	Project	**Document Name**	**Document No.**	**Page**
ADA ADVANCED DESIGN ALLIANCE ENGINEERING CENTER	-	XFOIL Results Validation for NLF(1)-0215F Airfoil	NC00.00.00.002	5

Advanced Design Alliance (www.adaexp.com)

ADA ADVANCED DESIGN ALLIANCE ENGINEERING CENTER	**Project**	**Document Name**	**Document No.**	**Page**
	-	XFOIL Results Validation for NLF(1)-0215F Airfoil	NC00.00.00.002	6

	Re=6e6	Free transition								
	M=0.1									
	XFOIL	NASA		XFOIL	NASA		XFOIL	NASA		
AOA	**Cl**	**Cl**	**Δ, %**	**Cd**	**Cd**	**Δ, %**	**Cm**	**Cm**	**Δ, %**
-12	-0.659	-0.240	63.6%	0.014			-0.143	0.000	100.0%
-10	-0.479	-0.440	8.1%	0.011	0.0120	-9.1%	-0.139	-0.125	10.1%
-8	-0.264	-0.230	12.9%	0.009	0.0090	0.0%	-0.139	-0.130	6.5%
-6	-0.036	-0.030	16.7%	0.008	0.0076	5.0%	-0.141	-0.130	7.8%
-4	0.198	0.200	-1.0%	0.007	0.0072	-2.9%	-0.145	-0.135	6.9%
-2	0.436	0.430	1.4%	0.006	0.0062	-3.3%	-0.148	-0.140	5.4%
0	0.685	0.660	3.6%	0.004	0.0042	-5.0%	-0.156	-0.145	7.1%
2	0.916	0.880	3.9%	0.005	0.0052	-4.0%	-0.158	-0.150	5.1%
4	1.127	1.080	4.2%	0.006	0.0072	-20.0%	-0.157	-0.150	4.5%
6	1.315	1.260	4.2%	0.009	0.0092	-2.2%	-0.151	-0.145	4.0%
8	1.485	1.420	4.4%	0.011	0.0124	-12.7%	-0.142	-0.140	1.4%
10	1.615	1.600	0.9%	0.014	0.0160	-14.3%	-0.126	-0.130	-3.2%
12	1.722	1.700	1.3%	0.019	0.0200	-5.3%	-0.109	-0.120	-10.1%
12.3	1.735	1.740	-0.3%	0.020	0.0272	-36.0%	-0.107	-0.110	-2.8%
14	1.781	1.600	10.2%	0.029			-0.094	-0.100	-6.4%
16	1.833	1.560	14.9%	0.043			-0.085	-0.090	-5.9%
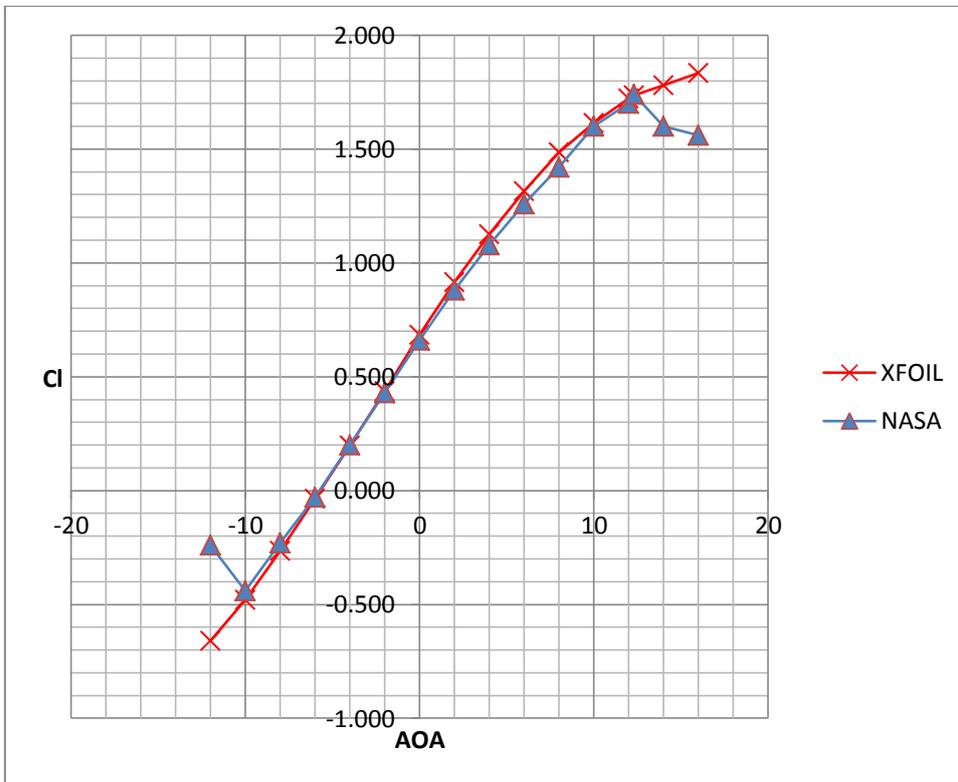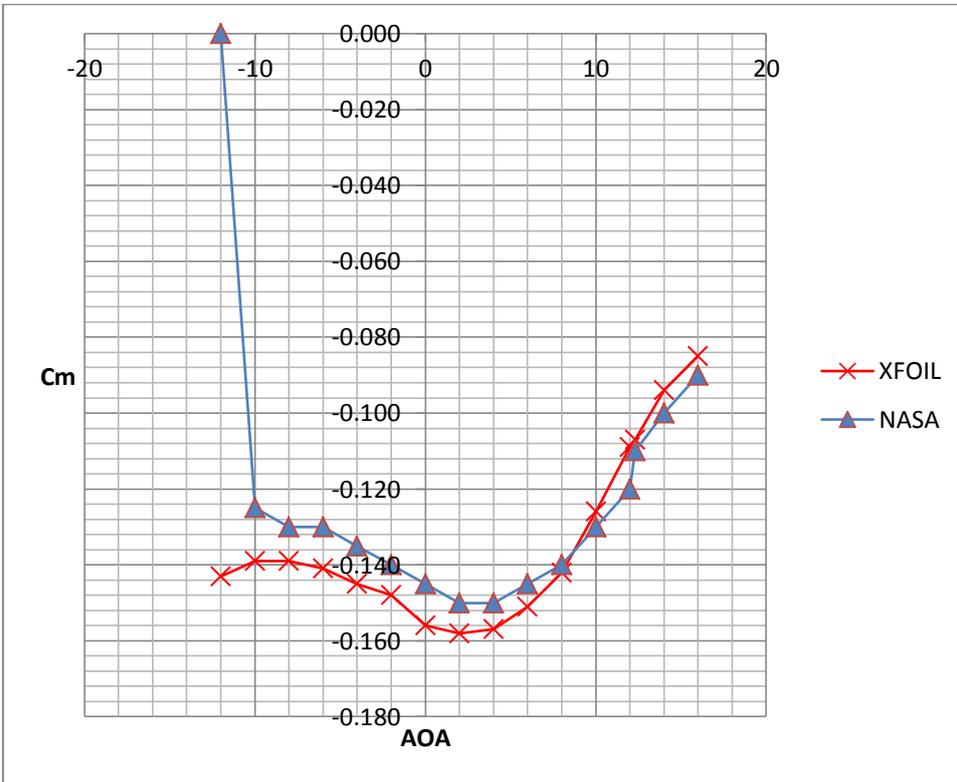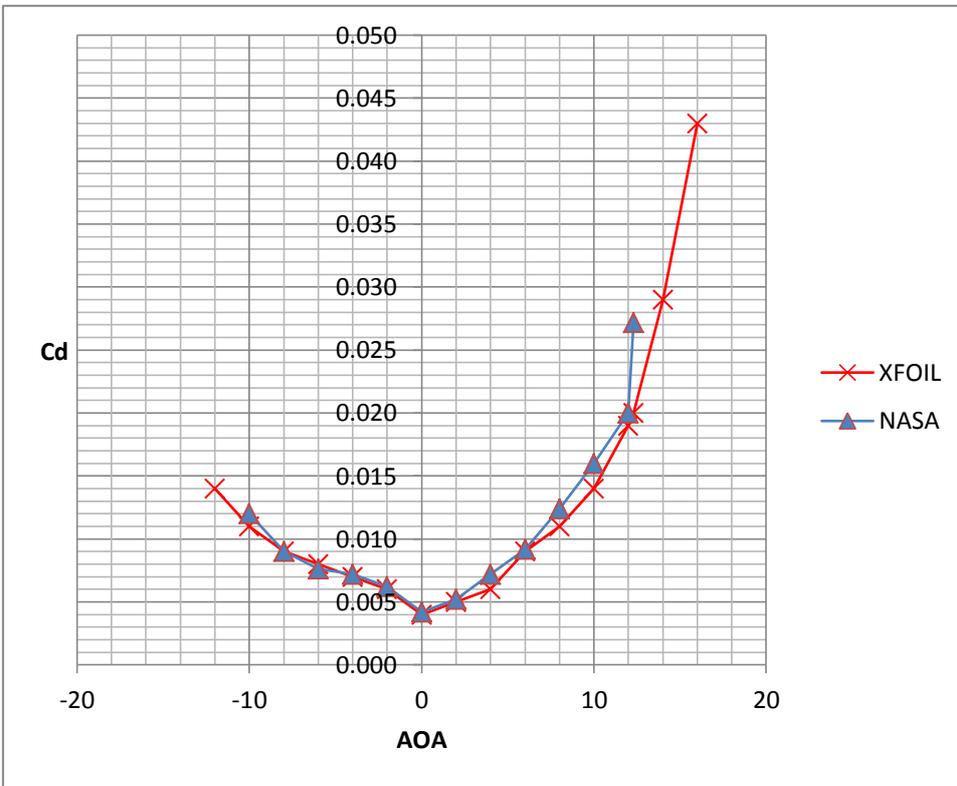
Advanced Design Alliance (www.adaexp.com)

	Project	Document Name	Document No.	Page
ADA ADVANCED DESIGN ALLIANCE ENGINEERING CENTER	-	XFOIL Results Validation for NLF(1)-0215F Airfoil	NC00.00.00.002	7

Advanced Design Alliance (www.adaexp.com)

	Project	Document Name	Document No.	Page
ADA ADVANCED DESIGN ALLIANCE ENGINEERING CENTER	-	XFOIL Results Validation for NLF(1)-0215F Airfoil	NC00.00.00.002	8

	Re=9e6	Free transition							
	M=0.1								
	XFOIL	NASA		XFOIL	NASA		XFOIL	NASA	
AOA	**Cl**	**Cl**	**Δ, %**	**Cd**	**Cd**	**Δ, %**	**Cm**	**Cm**	**Δ, %**
-7	-0.147	-0.140	4.8%	0.007	0.0074	-5.7%	-0.142	-0.135	4.9%
-6	-0.030	-0.020	33.3%	0.007	0.0068	2.9%	-0.143	-0.135	5.6%
-4	0.206	0.200	2.9%	0.006	0.0068	-13.3%	-0.146	-0.140	4.1%
-2	0.443	0.420	5.2%	0.006	0.0060	0.0%	-0.150	-0.140	6.7%
0	0.691	0.660	4.5%	0.004	0.0040	0.0%	-0.157	-0.150	4.5%
1	0.807	0.760	5.8%	0.004	0.0044	-10.0%	-0.159	-0.150	5.7%
2	0.921	0.880	4.5%	0.004	0.0062	-55.0%	-0.159	-0.150	5.7%
3	1.027	0.960	6.5%	0.005	0.0068	-36.0%	-0.159	-0.150	5.7%
4	1.125	1.080	4.0%	0.006	0.0080	-33.3%	-0.157	-0.150	4.5%
6	1.320	1.280	3.0%	0.009	0.0094	-4.4%	-0.152	-0.150	1.3%
8	1.500	1.440	4.0%	0.011	0.0120	-9.1%	-0.145	-0.145	0.0%
10	1.638	1.640	-0.1%	0.013	0.0148	-13.8%	-0.130	-0.135	-3.8%
12	1.748	1.760	-0.7%	0.017	0.0204	-20.0%	-0.113	-0.125	-10.6%
13.2	1.787	1.800	-0.7%	0.022	0.0232	-5.5%	-0.102	-0.120	-17.6%
14	1.815	1.760	3.0%	0.026			-0.097	-0.100	-3.1%
16	1.878	1.640	12.7%	0.038			-0.087	-0.090	-3.4%

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	Project	**Document Name**	**Document No.**	**Page**
ADA ADVANCED DESIGN ALLIANCE ENGINEERING CENTER	-	XFOIL Results Validation for NLF(1)-0215F Airfoil	NC00.00.00.002	9

Advanced Design Alliance (www.adaexp.com)

	Project	Document Name	Document No.	Page
ADA ADVANCED DESIGN ALLIANCE ENGINEERING CENTER	-	XFOIL Results Validation for NLF(1)-0215F Airfoil	NC00.00.00.002	10

For the range of AOA that is of interest, the airfoil data for M=0.1...0.3 and Re=6e6 show similar behaivior for both the wind tunnel test results and XFOIL analysis as can bee seen below.
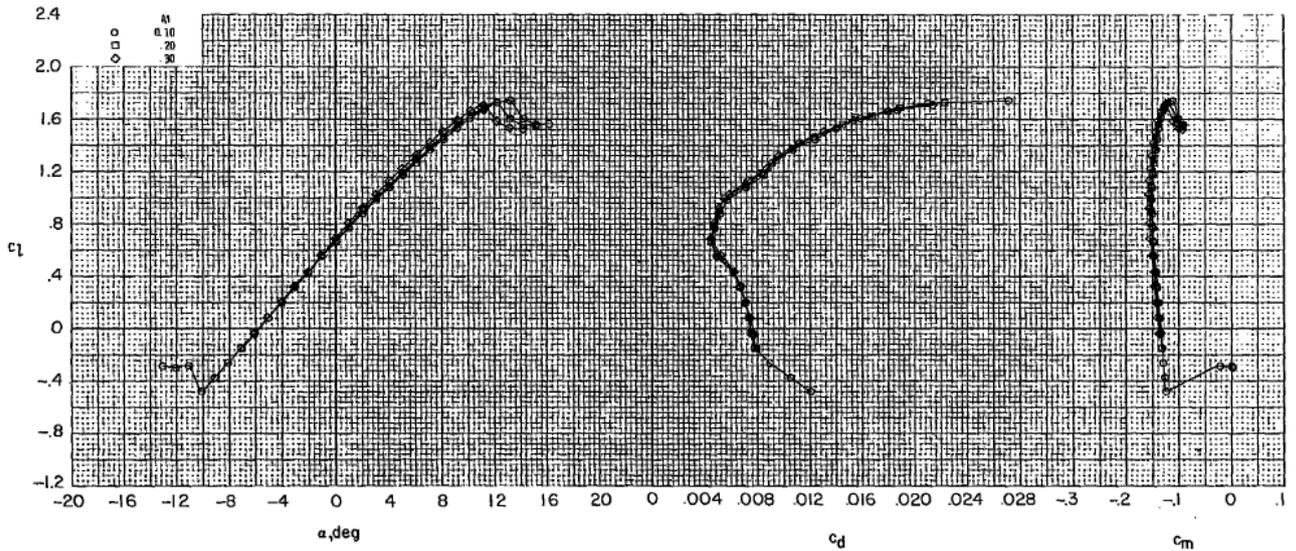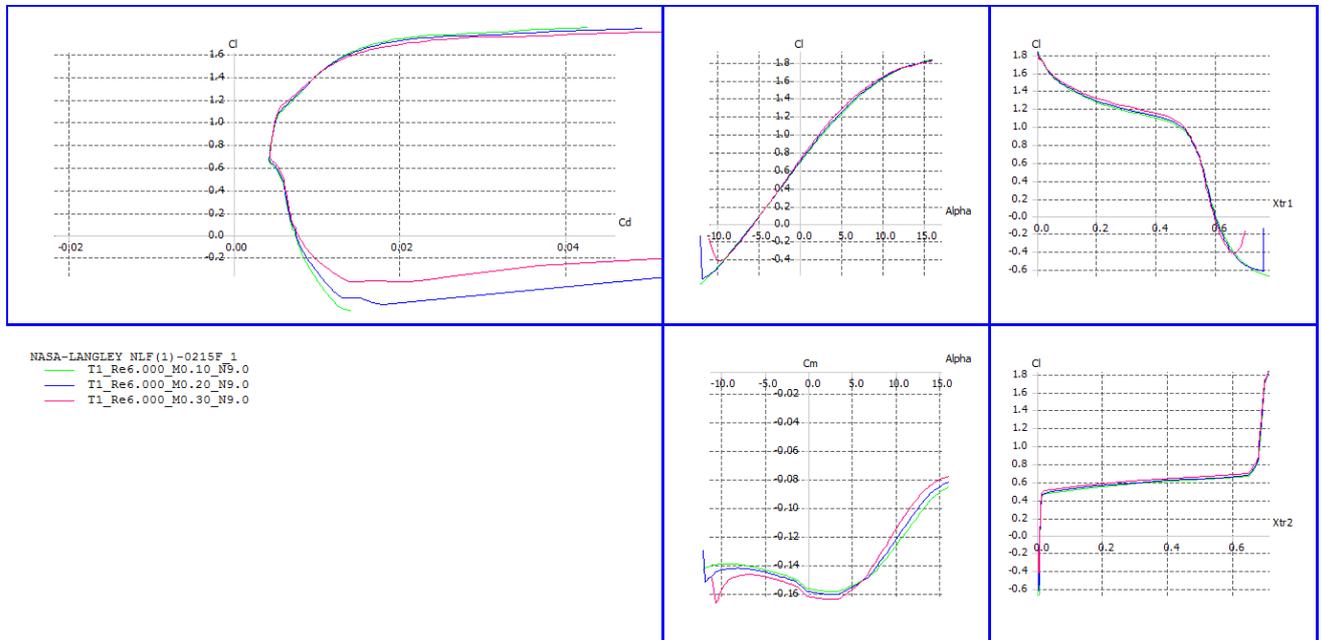

Figure 18.- Effects of Mach number on section characteristics with $\delta_f = 0^o$
for $R = 6.0 \times 10^6$.

NASA-LANGLEY NLF(1)-0215F_1
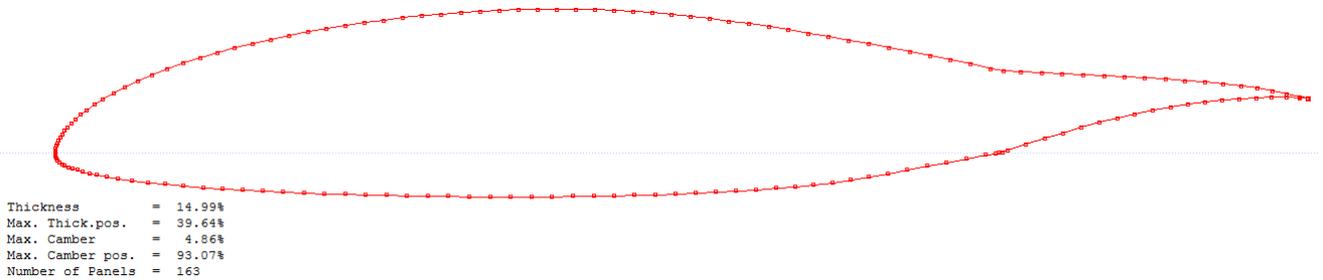T1_Re6.000_M0.10_N9.0
T1_Re6.000_M0.20_N9.0
T1_Re6.000_M0.30_N9.0

Flapped Airfoil Analysis

A 0.25c flap has been placed with hinge axis located at x/c=0.75, y/c=0.0328. Hinge axis coordinates have been transformed into XFOIL coordinates as follows:

Hinge X position = 75% of chord

Hinge Y position = y/c*c/t=y/t=0.0328/0.1499=21.88% of thickness

Two configurations have been analyzed 10 degrees (down) and -10 degrees (up).

```
Thickness       =  14.99%
Max. Thick.pos. =  39.65%
Max. Camber     =  -4.27%
Max. Camber pos. =  99.28%
Number of Panels =  164
```

```
Thickness       =  14.99%
Max. Thick.pos. =  39.64%
Max. Camber     =   4.86%
Max. Camber pos. =  93.07%
Number of Panels =  163
```

Advanced Design Alliance (www.adaexp.com)

	Project	Document Name	Document No.	Page
ADA ADVANCED DESIGN ALLIANCE ENGINEERING CENTER	-	XFOIL Results Validation for NLF(1)-0215F Airfoil	NC00.00.00.002	12

Flap 10° Configuration

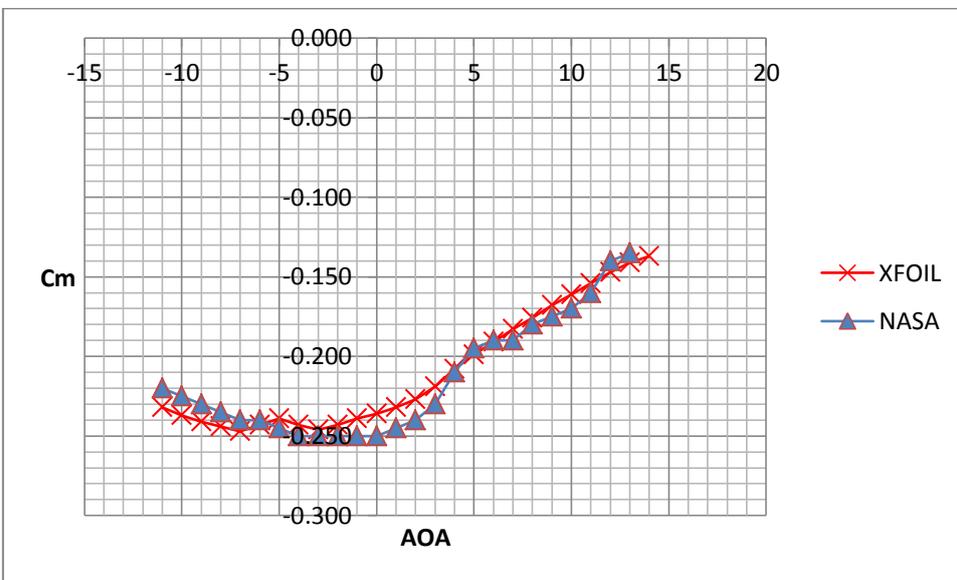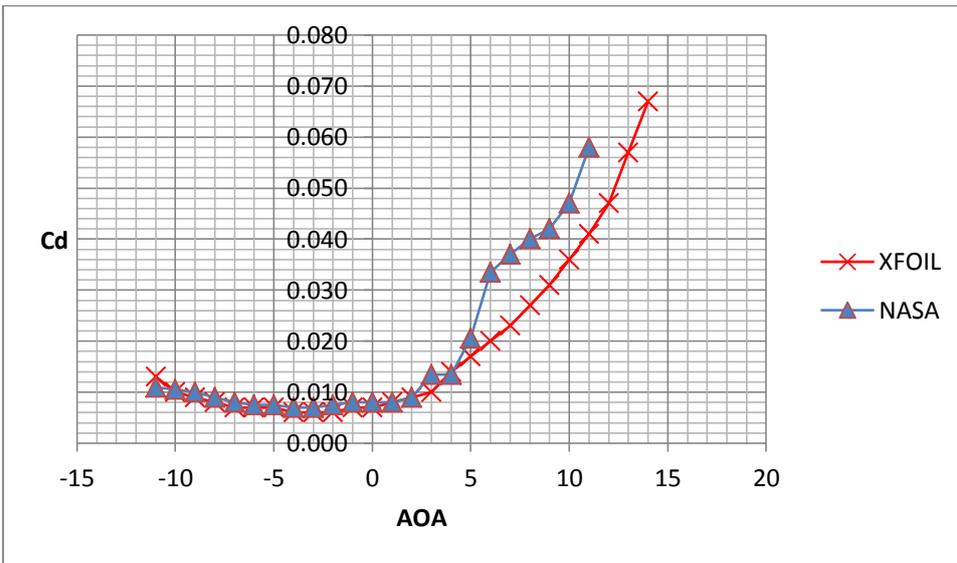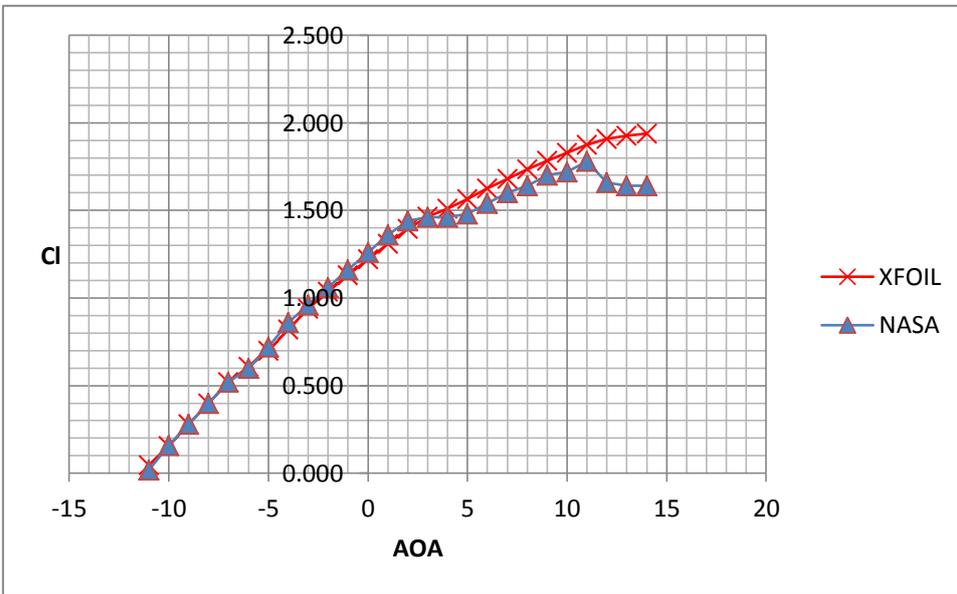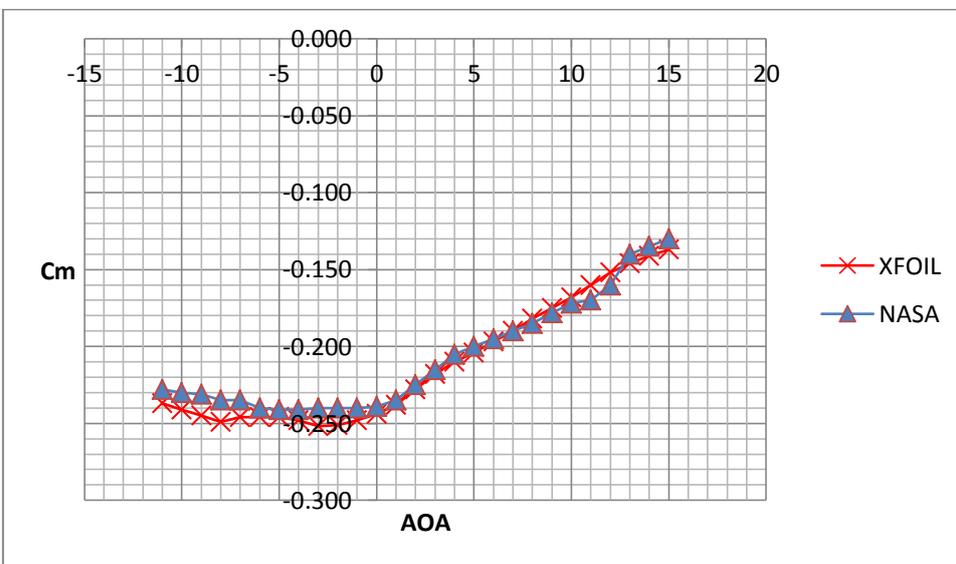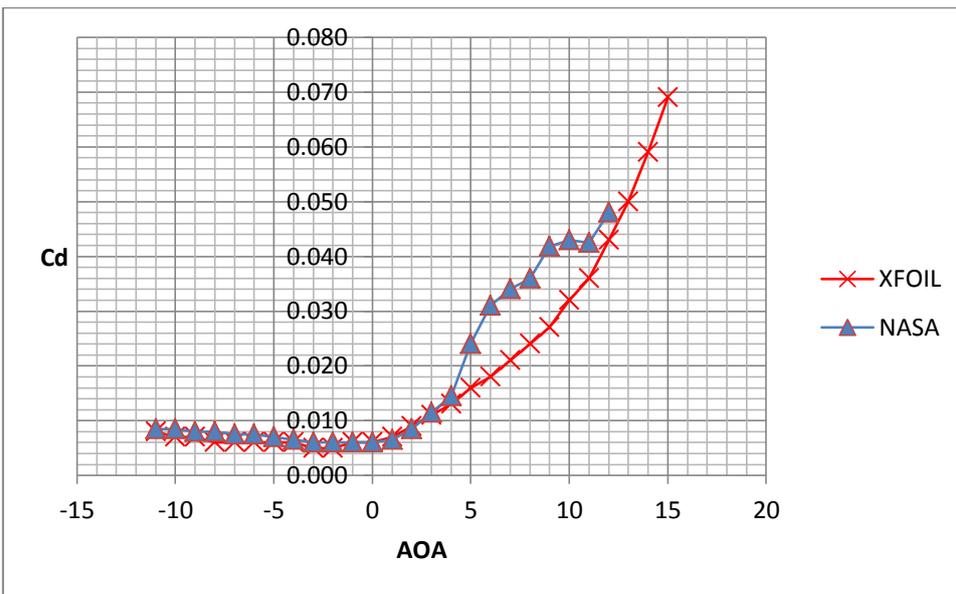|	Re=2e6	Free transition							
	M=0.1								
	XFOIL	NASA		XFOIL	NASA		XFOIL	NASA	
AOA	**Cl**	**Cl**	**Δ, %**	**Cd**	**Cd**	**Δ, %**	**Cm**	**Cm**	**Δ, %**
-11	0.054	0.060	-11.1%	0.016		100.0%	-0.233	-0.150	35.6%
-10	0.160	0.140	12.5%	0.013	0.0130	0.0%	-0.236	-0.225	4.7%
-9	0.271	0.260	4.1%	0.011	0.0120	-9.1%	-0.238	-0.230	3.4%
-8	0.392	0.400	-2.0%	0.009	0.0100	-11.1%	-0.242	-0.240	0.8%
-7	0.516	0.500	3.1%	0.008	0.0090	-12.5%	-0.246	-0.245	0.4%
-6	0.633	0.660	-4.3%	0.007	0.0085	-21.4%	-0.248	-0.250	-0.8%
-5	0.697	0.740	-6.2%	0.007	0.0070	0.0%	-0.239	-0.250	-4.6%
-4	0.817	0.860	-5.3%	0.006	0.0070	-16.7%	-0.243	-0.260	-7.0%
-3	0.919	0.980	-6.6%	0.007	0.0075	-7.1%	-0.242	-0.260	-7.4%
-2	1.010	1.080	-6.9%	0.007	0.0080	-14.3%	-0.237	-0.255	-7.6%
-1	1.100	1.180	-7.3%	0.008	0.0085	-6.3%	-0.233	-0.255	-9.4%
0	1.190	1.260	-5.9%	0.009	0.0090	0.0%	-0.229	-0.250	-9.2%
1	1.280	1.360	-6.3%	0.009	0.0090	0.0%	-0.225	-0.250	-11.1%
2	1.369	1.440	-5.2%	0.010	0.0100	0.0%	-0.221	-0.245	-10.9%
3	1.451	1.500	-3.4%	0.011	0.0095	13.6%	-0.216	-0.235	-8.8%
4	1.515	1.500	1.0%	0.013	0.0110	15.4%	-0.208	-0.215	-3.4%
5	1.555	1.500	3.5%	0.017	0.0190	-11.8%	-0.197	-0.200	-1.5%
6	1.607	1.560	2.9%	0.021	0.0290	-38.1%	-0.188	-0.195	-3.7%
7	1.655	1.600	3.3%	0.024	0.0370	-54.2%	-0.179	-0.190	-6.1%
8	1.704	1.660	2.6%	0.029	0.0420	-44.8%	-0.171	-0.185	-8.2%
9	1.753	1.720	1.9%	0.033	0.0450	-36.4%	-0.164	-0.180	-9.8%
10	1.797	1.760	2.1%	0.038	0.0550	-44.7%	-0.157	-0.170	-8.3%
11	1.838	1.720	6.4%	0.044			-0.150	-0.155	-3.3%
12	1.868	1.660	11.1%	0.051			-0.144	-0.145	-0.7%
13	1.89	1.640	13.2%	0.06			-0.139	-0.140	-0.7%
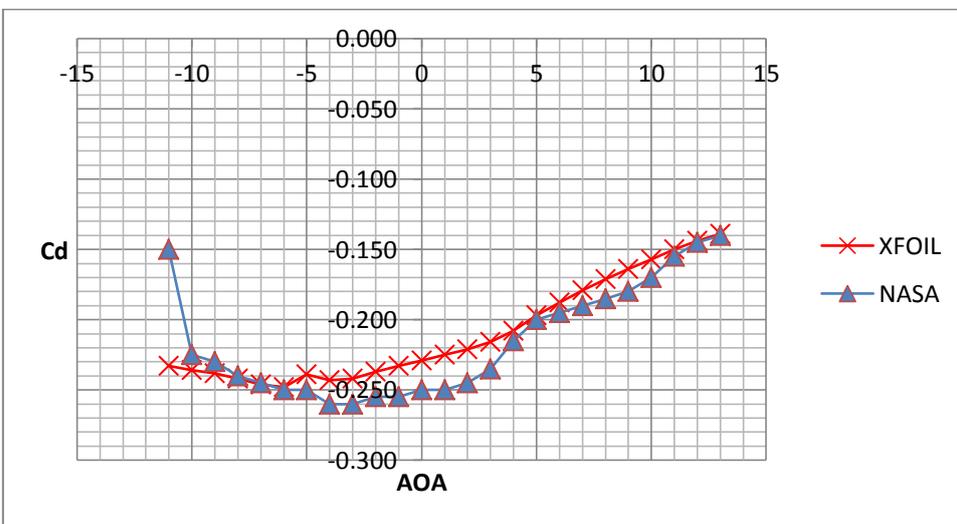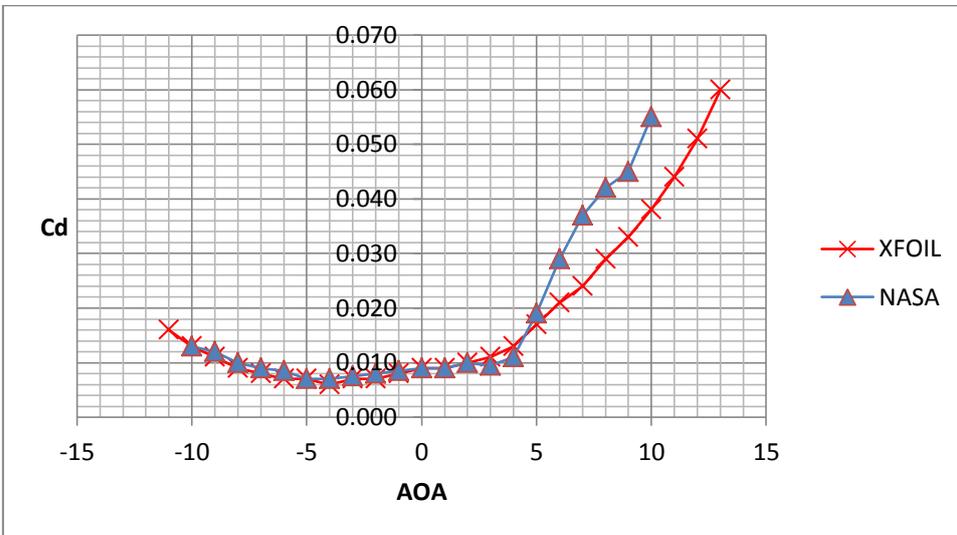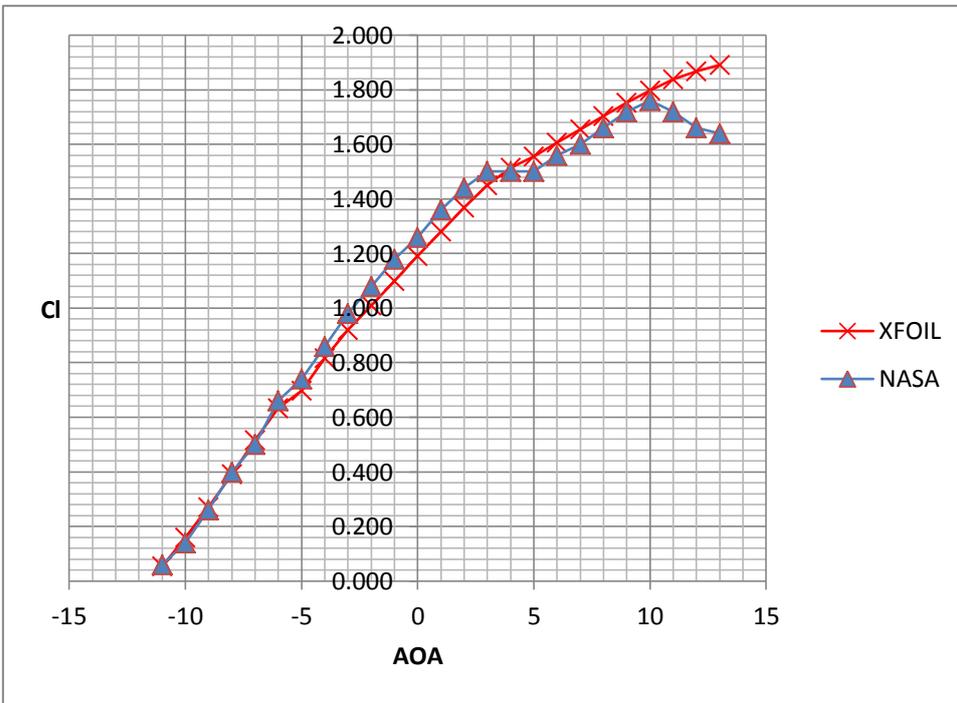
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	ADVANCED DESIGN ALLIANCE ENGINEERING CENTER	**Project**	**Document Name**	**Document No.**	**Page**
		-	XFOIL Results Validation for NLF(1)-0215F Airfoil	NC00.00.00.002	13

Advanced Design Alliance (www.adaexp.com)

	Project	Document Name	Document No.	Page
ADA ADVANCED DESIGN ALLIANCE ENGINEERING CENTER	-	XFOIL Results Validation for NLF(1)-0215F Airfoil	NC00.00.00.002	14

	Re=3e6	Free transition							
	M=0.1								
	XFOIL	NASA		XFOIL	NASA		XFOIL	NASA	
AOA	**Cl**	**Cl**	**Δ, %**	**Cd**	**Cd**	**Δ, %**	**Cm**	**Cm**	**Δ, %**
-11	0.045	0.020	55.6%	0.013	0.0110	15.4%	-0.232	-0.220	5.2%
-10	0.157	0.160	-1.9%	0.010	0.0105	-5.0%	-0.237	-0.225	5.1%
-9	0.279	0.280	-0.4%	0.009	0.0100	-11.1%	-0.241	-0.230	4.6%
-8	0.399	0.400	-0.3%	0.008	0.0090	-12.5%	-0.244	-0.235	3.7%
-7	0.519	0.520	-0.2%	0.007	0.0080	-14.3%	-0.247	-0.240	2.8%
-6	0.607	0.600	1.2%	0.007	0.0075	-7.1%	-0.243	-0.240	1.2%
-5	0.698	0.720	-3.2%	0.007	0.0075	-7.1%	-0.239	-0.245	-2.5%
-4	0.822	0.860	-4.6%	0.006	0.0070	-16.7%	-0.243	-0.250	-2.9%
-3	0.939	0.960	-2.2%	0.006	0.0070	-16.7%	-0.246	-0.250	-1.6%
-2	1.036	1.060	-2.3%	0.006	0.0075	-25.0%	-0.243	-0.250	-2.9%
-1	1.129	1.160	-2.7%	0.007	0.0080	-14.3%	-0.239	-0.250	-4.6%
0	1.221	1.260	-3.2%	0.007	0.0080	-14.3%	-0.236	-0.250	-5.9%
1	1.311	1.360	-3.7%	0.008	0.0080	0.0%	-0.232	-0.245	-5.6%
2	1.396	1.440	-3.2%	0.009	0.0090	0.0%	-0.227	-0.240	-5.7%
3	1.465	1.460	0.3%	0.010	0.0135	-35.0%	-0.219	-0.230	-5.0%
4	1.511	1.460	3.4%	0.014	0.0135	3.6%	-0.208	-0.210	-1.0%
5	1.565	1.480	5.4%	0.017	0.0205	-20.6%	-0.199	-0.195	2.0%
6	1.624	1.540	5.2%	0.020	0.0335	-67.5%	-0.191	-0.190	0.5%
7	1.679	1.600	4.7%	0.023	0.0370	-60.9%	-0.183	-0.190	-3.8%
8	1.734	1.640	5.4%	0.027	0.0400	-48.1%	-0.176	-0.180	-2.3%
9	1.784	1.700	4.7%	0.031	0.0420	-35.5%	-0.168	-0.175	-4.2%
10	1.830	1.720	6.0%	0.036	0.0470	-30.6%	-0.161	-0.170	-5.6%
11	1.874	1.780	5.0%	0.041	0.0580	-41.5%	-0.154	-0.160	-3.9%
12	1.909	1.660	13.0%	0.047			-0.147	-0.140	4.8%
13	1.925	1.640	14.8%	0.057			-0.141	-0.135	4.3%
14	1.938	1.640	15.4%	0.067			-0.137		

Advanced Design Alliance (www.adaexp.com)

	Project	**Document Name**	**Document No.**	**Page**
ADA ADVANCED DESIGN ALLIANCE ENGINEERING CENTER	-	XFOIL Results Validation for NLF(1)-0215F Airfoil	NC00.00.00.002	15

Advanced Design Alliance (www.adaexp.com)

	Project	**Document Name**	**Document No.**	**Page**
ADA ADVANCED DESIGN ALLIANCE ENGINEERING CENTER	-	XFOIL Results Validation for NLF(1)-0215F Airfoil	NC00.00.00.002	16

	Re=6e6	Free transition							
	M=0.1								
	XFOIL	NASA		XFOIL	NASA		XFOIL	NASA	
AOA	**Cl**	**Cl**	**Δ, %**	**Cd**	**Cd**	**Δ, %**	**Cm**	**Cm**	**Δ, %**
-11	0.046	0.060	-30.4%	0.008	0.0085	-6.3%	-0.237	-0.228	3.8%
-10	0.169	0.180	-6.5%	0.007	0.0085	-21.4%	-0.241	-0.230	4.6%
-9	0.291	0.280	3.8%	0.007	0.0080	-14.3%	-0.245	-0.231	5.7%
-8	0.417	0.390	6.5%	0.006	0.0080	-33.3%	-0.249	-0.235	5.6%
-7	0.509	0.500	1.8%	0.006	0.0075	-25.0%	-0.246	-0.235	4.5%
-6	0.620	0.600	3.2%	0.006	0.0075	-25.0%	-0.246	-0.240	2.4%
-5	0.728	0.720	1.1%	0.006	0.0070	-16.7%	-0.246	-0.241	2.0%
-4	0.844	0.820	2.8%	0.006	0.0065	-8.3%	-0.248	-0.241	2.8%
-3	0.966	0.930	3.7%	0.005	0.0060	-20.0%	-0.252	-0.240	4.8%
-2	1.070	1.020	4.7%	0.005	0.0060	-20.0%	-0.251	-0.240	4.4%
-1	1.167	1.180	-1.1%	0.006	0.0060	0.0%	-0.248	-0.240	3.2%
0	1.258	1.220	3.0%	0.006	0.0060	0.0%	-0.244	-0.239	2.0%
1	1.342	1.300	3.1%	0.007	0.0065	7.1%	-0.238	-0.235	1.3%
2	1.400	1.360	2.9%	0.009	0.0085	5.6%	-0.228	-0.225	1.3%
3	1.456	1.400	3.8%	0.011	0.0115	-4.5%	-0.218	-0.215	1.4%
4	1.521	1.440	5.3%	0.013	0.0145	-11.5%	-0.210	-0.205	2.4%
5	1.589	1.500	5.6%	0.016	0.0240	-50.0%	-0.204	-0.200	2.0%
6	1.655	1.580	4.5%	0.018	0.0310	-72.2%	-0.197	-0.195	1.0%
7	1.717	1.600	6.8%	0.021	0.0340	-61.9%	-0.190	-0.190	0.0%
8	1.776	1.680	5.4%	0.024	0.0360	-50.0%	-0.182	-0.185	-1.6%
9	1.833	1.740	5.1%	0.027	0.0418	-54.8%	-0.175	-0.178	-1.7%
10	1.883	1.800	4.4%	0.032	0.0430	-34.4%	-0.168	-0.172	-2.4%
11	1.928	1.840	4.6%	0.036	0.0425	-18.1%	-0.160	-0.170	-6.3%
12	1.958	1.880	4.0%	0.043	0.0480	-11.6%	-0.152	-0.160	-5.3%
13	1.988	1.780	10.5%	0.050			-0.146	-0.140	4.1%
14	2.011	1.740	13.5%	0.059			-0.141	-0.135	4.3%
15	2.032	1.720	15.4%	0.069			-0.137	-0.130	5.1%

Advanced Design Alliance (www.adaexp.com)

	Project	**Document Name**	**Document No.**	**Page**
ADA ADVANCED DESIGN ALLIANCE ENGINEERING CENTER	-	XFOIL Results Validation for NLF(1)-0215F Airfoil	NC00.00.00.002	17

Advanced Design Alliance (www.adaexp.com)

ADA ADVANCED DESIGN ALLIANCE ENGINEERING CENTER	Project	Document Name	Document No.	Page
	-	XFOIL Results Validation for NLF(1)-0215F Airfoil	NC00.00.00.002	18

Flap -10° Configuration

	Re=6e6	Free transition							
	M=0.1								
	XFOIL	NASA		XFOIL	NASA		XFOIL	NASA	
AOA	**Cl**	**Cl**	**Δ, %**	**Cd**	**Cd**	**Δ, %**	**Cm**	**Cm**	**Δ, %**
-11	-1.037	-0.500	51.8%	0.020			-0.070	0.075	207.1%
-10	-0.970	-0.520	46.4%	0.018			-0.064	0.070	209.4%
-9	-0.917	-0.540	41.1%	0.014			-0.056	0.050	189.3%
-8	-0.847	-0.840	0.8%	0.013	0.0144	-10.8%	-0.049	-0.035	28.6%
-7	-0.755	-0.740	2.0%	0.012	0.0130	-8.3%	-0.045	-0.035	22.2%
-6	-0.658	-0.640	2.7%	0.011	0.0118	-7.3%	-0.043	-0.035	18.6%
-5	-0.558	-0.540	3.2%	0.010	0.0104	-4.0%	-0.041	-0.035	14.6%
-4	-0.453	-0.440	2.9%	0.009	0.0090	0.0%	-0.039	-0.035	10.3%
-3	-0.345	-0.320	7.2%	0.008	0.0080	0.0%	-0.039	-0.035	10.3%
-2	-0.235	-0.200	14.9%	0.007	0.0072	-2.9%	-0.039	-0.040	-2.6%
-1	-0.122	-0.100	18.0%	0.007	0.0070	0.0%	-0.039	-0.040	-2.6%
0	-0.007	0.020	385.7%	0.007	0.0070	0.0%	-0.040	-0.042	-5.0%
1	0.109	0.140	-28.4%	0.006	0.0060	0.0%	-0.041	-0.045	-9.8%
2	0.225	0.260	-15.6%	0.005	0.0044	12.0%	-0.043	-0.050	-16.3%
3	0.344	0.380	-10.5%	0.004	0.0044	-10.0%	-0.046	-0.050	-8.7%
4	0.463	0.480	-3.7%	0.004	0.0045	-12.5%	-0.048	-0.050	-4.2%
5	0.581	0.600	-3.3%	0.004	0.0048	-20.0%	-0.049	-0.055	-12.2%
6	0.695	0.700	-0.7%	0.005	0.0054	-8.0%	-0.050	-0.060	-20.0%
7	0.803	0.820	-2.1%	0.006	0.0068	-13.3%	-0.051	-0.060	-17.6%
8	0.909	0.920	-1.2%	0.007	0.0080	-14.3%	-0.051	-0.060	-17.6%
9	1.015	1.020	-0.5%	0.008	0.0090	-12.5%	-0.051	-0.060	-17.6%
10	1.118	1.120	-0.2%	0.009	0.0100	-11.1%	-0.050	-0.060	-20.0%
11	1.218	1.220	-0.2%	0.010	0.0106	-6.0%	-0.050	-0.060	-20.0%
12	1.315	1.320	-0.4%	0.011	0.0122	-10.9%	-0.048	-0.060	-25.0%
13	1.406	1.410	-0.3%	0.012	0.0138	-15.0%	-0.046	-0.060	-30.4%
14	1.486	1.500	-0.9%	0.014	0.0164	-17.1%	-0.043	-0.060	-39.5%
15	1.532	1.560	-1.8%	0.016	0.0214	-33.8%	-0.033	-0.060	-81.8%
16	1.542	1.500	2.7%	0.021			-0.026	-0.060	-130.8%
17	1.560	1.420	9.0%	0.027			-0.021	-0.060	-185.7%
18	1.58	1.400	11.4%	0.033			-0.018	-0.060	-233.3%

Advanced Design Alliance (www.adaexp.com)

	Project	**Document Name**	**Document No.**	**Page**
ADA ADVANCED DESIGN ALLIANCE ENGINEERING CENTER	-	XFOIL Results Validation for NLF(1)-0215F Airfoil	NC00.00.00.002	19

ADA ADVANCED DESIGN ALLIANCE ENGINEERING CENTER	Project	Document Name	Document No.	Page
	-	XFOIL Results Validation for NLF(1)-0215F Airfoil	NC00.00.00.002	20

	Re=9e6	Free transition							
	M=0.1								
	XFOIL	NASA		XFOIL	NASA		XFOIL	NASA	
AOA	Cl	Cl	Δ, %	Cd	Cd	Δ, %	Cm	Cm	Δ, %
-1	-0.121	-0.200	-65.3%	0.006	0.0064	-6.7%	-0.040	-0.041	-2.5%
0	-0.005	0.000	100.0%	0.006	0.0064	-6.7%	-0.041	-0.045	-9.8%
1	0.112	0.140	-25.0%	0.006	0.0060	0.0%	-0.042	-0.047	-11.9%
2	0.229	0.260	-13.5%	0.005	0.0040	20.0%	-0.044	-0.050	-13.6%
3	0.348	0.380	-9.2%	0.004	0.0040	0.0%	-0.047	-0.053	-12.8%
4	0.466	0.500	-7.3%	0.004	0.0042	-5.0%	-0.049	-0.055	-12.2%
5	0.582	0.600	-3.1%	0.004	0.0050	-25.0%	-0.050	-0.057	-14.0%
6	0.693	0.700	-1.0%	0.005	0.0060	-20.0%	-0.050	-0.060	-20.0%
7	0.803	0.820	-2.1%	0.006	0.0068	-13.3%	-0.051	-0.060	-17.6%
8	0.910	0.920	-1.1%	0.007	0.0076	-8.6%	-0.051	-0.060	-17.6%
9	1.018	1.040	-2.2%	0.007	0.0090	-28.6%	-0.051	-0.060	-17.6%
10	1.128	1.140	-1.1%	0.009	0.0092	-2.2%	-0.051	-0.060	-17.6%
11	1.225	1.240	-1.2%	0.009	0.0096	-6.7%	-0.051	-0.060	-17.6%
12	1.324	1.340	-1.2%	0.011	0.0112	-1.8%	-0.050	-0.060	-20.0%
13	1.418	1.440	-1.6%	0.012	0.0128	-6.7%	-0.048	-0.060	-25.0%
14	1.504	1.540	-2.4%	0.013	0.0150	-15.4%	-0.046	-0.060	-30.4%
15	1.554	1.600	-3.0%	0.015	0.0180	-20.0%	-0.037	-0.060	-62.2%
16	1.578	1.620	-2.7%	0.019		100.0%	-0.028	-0.060	-114.3%
17	1.599	1.540	3.7%	0.024		100.0%	-0.023	-0.070	-204.3%
18	1.626	1.460	10.2%	0.030		100.0%	-0.020		

Advanced Design Alliance (www.adaexp.com)

ADA ADVANCED DESIGN ALLIANCE ENGINEERING CENTER	Project	Document Name	Document No.	Page
	-	XFOIL Results Validation for NLF(1)-0215F Airfoil	NC00.00.00.002	21

Cl vs AOA — XFOIL and NASA

Cd vs AOA — XFOIL and NASA

Cm vs AOA — XFOIL and NASA

Advanced Design Alliance (www.adaexp.com)

	Project	**Document Name**	**Document No.**	**Page**
ADA ADVANCED DESIGN ALLIANCE ENGINEERING CENTER	-	XFOIL Results Validation for NLF(1)-0215F Airfoil	NC00.00.00.002	22

Conclusion

1. XFOIL can be used only for subsonic applications. It fails as soon as air velocity locally reaches speed of sound [3].
2. XFOIL does not predict stall correctly.
3. For a clean airfoil XFOIL generates reasonably accurate results within range of AOA from -10 degrees until about stall.

   For the flap 10deg down configuration Cl and Cm demonstrate reasonable proximity to wind tunnel test. Use of calculated Cd should be limited to about 5-6 degrees.

   For the flap 10deg up configuration Cl and Cd show good coincidence within AOA range -8…14. Use of calculated Cm should be limited to about -6…6 degress.

Configuration	Airfoil Data	Re=2e6, M=0.0	Re=3e6, M=0.1	Re=6e6, M=0.1	Re=9e6, M=0.2
Clean	Cl		-7…11	-10…12	-7…14
	Cd		-7…8	-10…12	-7…13
	Cm		-7…12	-10…16	-7…12
Flap 10deg down	Cl	-11…10	-11…11	-11…12	
	Cd	-10…6	-11…5	-10…5	
	Cm	-10…13	-11…13	-11…15	
Flap 10deg up	Cl			-8…16	-1…16
	Cd			-8…14	-1…15
	Cm			-6…6	-1…11

References

1. NASA TP 1865 "Design and Experimental Results for Flapped NLF Airfoil"
2. XFOIL 6.96 User Guide
3. NC00.00.00.001 "XFOIL Software Validation".

Advanced Design Alliance (www.adaexp.com)

ADA ADVANCED DESIGN ALLIANCE ENGINEERING CENTER	Project	Document Name	Document No.	Page
	-	XFOIL Results Validation for NLF(1)-0215F Airfoil	NC00.00.00.002	23