CFD 96 Computer Code Validation Challenge -- Multiple Element Airfoil

by

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Introduction

Accurate calculations of steady, viscous flows around multiple-element high-lift airfoil configurations in two dimensions remains a challenge to the aerodynamics CFD community. Maximum lift, drag, and pitching moment are difficult to compute consistently and accurately, especially with the occurrence of local flow separation on one or more of the airfoil elements.

The multiple-element airfoil test case that was selected for the CFD 96 Code Validation Challenge is important for the following reasons:

1. The multiple-element airfoil is a practical configuration of current interest to the aircraft industry in Canada and abroad.

2. The viscous flow around the airfoil is complicated by features such as flow separation and the interaction of the wake with the boundary layer.

3. Reliable experimental data from wind-tunnel tests are available to compare to computational results.

The multiple-element airfoil test case is actually Case A-2 in the AGARD Advisory Report No. 303 entitled "A Selection of Experimental Test Cases for the Validation of CFD Codes," Volumes 1 and 2, August 1994. The experimental data contained therein are particularly valuable for CFD code validation because of the accuracy of the measurements for the two-dimensional configuration, which is due primarily to the high degree of two dimensionality of the wind-tunnel flowfield.

The airfoil consists of three elements: a slat, a main foil, and a single-slotted flap. [The configuration is depicted at the bottom of this page.]

Problem Specifications

1. Input Geometry: The surface coordinates (x, y) of the slat, main element and flap are tabulated at the end of this article.
2. Mach number: 0.195.
3. Reynolds number: 3.52x10e6
4. Transition on slat: free transition on upper and lower surfaces.
5. Transition on main element: fixed transition at distance x = 0.125 m on the upper and lower surfaces.
6. Transition on flap: free transition on upper and lower surfaces.
7. Angle of incidence: 0 to +23 degrees.
8. Non-dimensionalize results: Use sea-level atmospheric conditions and the unit chord.

Slat, Main Element and Flap Coordinates (x, y).

Slat coordinates		Main element coordinates (m)				Flap coordinates(m)	
0.027490	0.017991	0.899870	0.017200	0.052890	-0.021420	1.214624	-0.113530
0.021231	0.013241	0.871260	0.019430	0.048640	-0.021060	1.193291	-0.106968
0.011552	0.004325	0.835990	0.021190	0.043550	-0.019330	1.150970	-0.093895
-0.004135	-0.011795	0.802400	0.021820	0.039060	-0.015140	1.123617	-0.085397
-0.012160	-0.021418	0.766470	0.020920	0.037490	-0.009480	1.097197	-0.077260
-0.018975	-0.031128	0.753490	0.019960	0.039190	-0.001600	1.058932	-0.065674
-0.022844	-0.037478	0.735200	0.017900	0.043650	0.006190	1.034620	-0.058528
-0.027273	-0.046152	0.729540	0.017030	0.048240	0.010880	0.996129	-0.047562
-0.029451	-0.052343	0.718900	0.015170	0.055920	0.016870	0.967841	-0.039703
-0.030201	-0.061288	0.709580	0.013210	0.062110	0.020990	0.953663	-0.035852
-0.028411	-0.069148	0.701600	0.011010	0.072390	0.026910	0.940446	-0.032286

-0.024596	-0.073614	0.690290	0.007120	0.083730	0.032240	0.926244	-0.028500
-0.018756	-0.075514	0.682300	0.003430	0.104760	0.040220	0.917211	-0.026096
-0.017118	-0.075335	0.676980	-0.000170	0.117300	0.044210	0.909167	-0.023871
-0.016780	-0.076060	0.672990	-0.004160	0.134530	0.047900	0.905108	-0.022393
-0.025493	-0.079097	0.669990	-0.011380	0.153460	0.050670	0.901391	-0.019944
-0.035315	-0.082430	0.673320	-0.019060	0.168330	0.052460	0.900339	-0.012133
-0.042170	-0.084269	0.677310	-0.020330	0.172890	0.052960	0.907722	-0.004509
-0.049084	-0.085176	0.677310	-0.020960	0.182440	0.054030	0.915378	-0.001953
-0.055933	-0.084663	0.668660	-0.021720	0.200270	0.055850	0.920255	-0.001185
-0.059101	-0.083382	0.634730	-0.024850	0.203160	0.056150	0.926453	-0.000706
-0.062122	-0.081635	0.602130	-0.028010	0.234300	0.058920	0.930333	-0.000745
-0.066395	-0.076400	0.567860	-0.031570	0.266130	0.061280	0.937713	-0.000877
-0.067831	-0.070173	0.534930	-0.034700	0.301060	0.063370	0.941848	-0.001212
-0.067150	-0.063754	0.500670	-0.037820	0.335000	0.064970	0.950351	-0.002146
-0.066302	-0.060865	0.466730	-0.040350	0.366270	0.066030	0.960400	-0.003718
-0.063478	-0.055113	0.432470	-0.042250	0.401530	0.066770	0.971630	-0.005932
-0.059726	-0.049766	0.400200	-0.043450	0.434460	0.067000	0.977522	-0.007257
-0.053690	-0.043024	0.368260	-0.043910	0.468400	0.066730	0.989221	-0.010143
-0.046491	-0.036434	0.333670	-0.043750	0.499000	0.066030	0.995344	-0.011797
-0.034454	-0.026043	0.300070	-0.042880	0.533270	0.064740	1.001430	-0.013554
-0.019737	-0.014303	0.267800	-0.041420	0.567860	0.062840	1.020150	-0.019516
-0.006940	-0.004739	0.232870	-0.039160	0.599800	0.060480	1.034272	-0.024486
0.008486	0.006239	0.202590	-0.036530	0.635400	0.057520	1.063809	-0.035726
0.013998	0.010012	0.167000	-0.032930	0.668660	0.053560	1.097886	-0.050076
0.019714	0.013891	0.136730	-0.029770	0.701260	0.049500	1.125638	-0.063296
0.027025	0.018988	0.101460	-0.026280	0.734530	0.044940	1.155608	-0.079195
		0.084170	-0.024550	0.765140	0.040450	1.183517	-0.094908
		0.071120	-0.023250	0.799070	0.035100	1.214740	-0.113210
		0.067860	-0.022820	0.833330	0.029440		
		0.061240	-0.022290	0.867930	0.023520		
		0.054720	-0.021660	0.899870	0.017900		

Desired Results

1. Cl versus a (lift coefficient as a function of the angle of incidence).

2. Cd versus a (drag coefficient as a function of the angle of incidence).
3. Cm versus a (pitching moment coefficient about x = 0.25m as a function of the angle of incidence).
4. Cp versus x (surface pressure coefficient distribution) at a = 4 degrees.
5. Cp versus x (surface pressure coefficient distribution) at a = 20 degrees.
6. Boundary layer profiles of total pressure coefficient Cp_tot, for both angles of incidence (4 and 20 degrees) normal to the upper surface at:
    i. x = 0.35m on the main element,
    ii. main element shroud trailing edge,
    iii. 50% flap chord,
    iv. flap trailing edge.

The following information is requested of participants:

- name and affiliation,
- brief description of code and solution algorithm,
- brief description of turbulence model and handling of near-wall effects,
- brief description of grid and grid-generation techniques,
- description of any modifications to the specified geometry,
- definition and level of convergence,
- computational times.

Comments

In addition to the airfoil geometry defined herein, both a multiple-block structured grid (provided by Tom E. Nelson of de Havilland Inc.) and an unstructured mesh (provided by Denis J. Jones of IAR/NRC) are available to participants. In both of these grides, the element trailing edges have been closed; this is not expected to appreciably affect the computational results. Of course, participants may generate their own meshes. But, they are nevertheless encouraged to also perform and provide solutions on the grids provided, if feasible, so as to eliminate the effects of grid variations in the comparison of results from different participants.

Files containing the airfoil coordinates, as well as the Nelson's and Jones' meshes can be obtained via e-mail (ifejteck@dehavilland.ca) from Ian G. Fejtek at de Havilland Inc. Also, please address all enquiries regarding the Computer Code Validation Challenge to Ian G. Fejtek at the e-mail address given or the postal address included on the last page of this Bulletin.

Please submit all results by May 6, 1996, to Ian G. Fejtek via e-mail, if possible, or to Fejtek's postal address on the Bulletin's last page.
