C3.1 Turbulent Flow over a 2D Multi-Element Airfoil

1. Code description

XFlow is a high-order discontinuous Galerkin (DG) finite element solver written in ANSI C, intended to be run on Linux-type platforms. Relevant supported equation sets include compressible Euler, Navier-Stokes, and RANS with the Spalart-Allmaras model. High-order is achieved compactly within elements using various high-order bases on triangles, tetrahedra, quadrilaterals, and hexahedra. Parallel runs are supported using domain partitioning and MPI communication. Visual post-processing is performed with an in-house plotter. Output-based adaptivity is available using discrete adjoints.

2. Case summary

Convergence to steady state on each mesh was achieved by Reynolds number continuation starting from $Re = 100k$. This continuation yielded $p = 1$ solutions, from which high order solutions were obtained using order continuation. Line-preconditioned GMRES was used as the linear solver in pseudo-transient backward Euler nonlinear steps.

Runs were performed on the *nyx* supercomputing cluster at the University of Michigan. The number of cores ranged from 64 on the coarsest meshes to 192 on the finest meshes. On one core of the nyx machine, one TauBench unit is equivalent to 16.5 seconds of compute time.

3. Meshes

High-order curved meshes were generated by first creating a multiblock linear mesh using ICEM CFD (with the geometry provided on the workshop website), and then agglomerating 3×3 blocks of linear cells into $q = 3$ high-order elements. A portion of the initial mesh is shown in Figure 1.

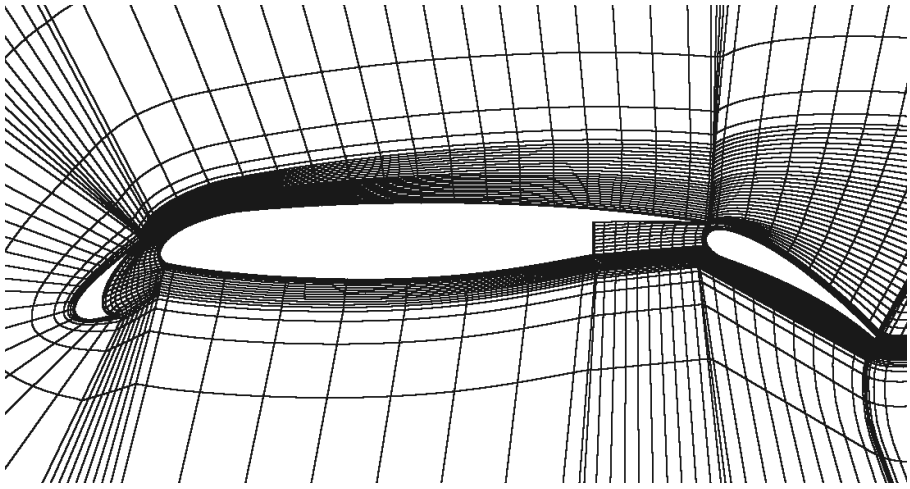
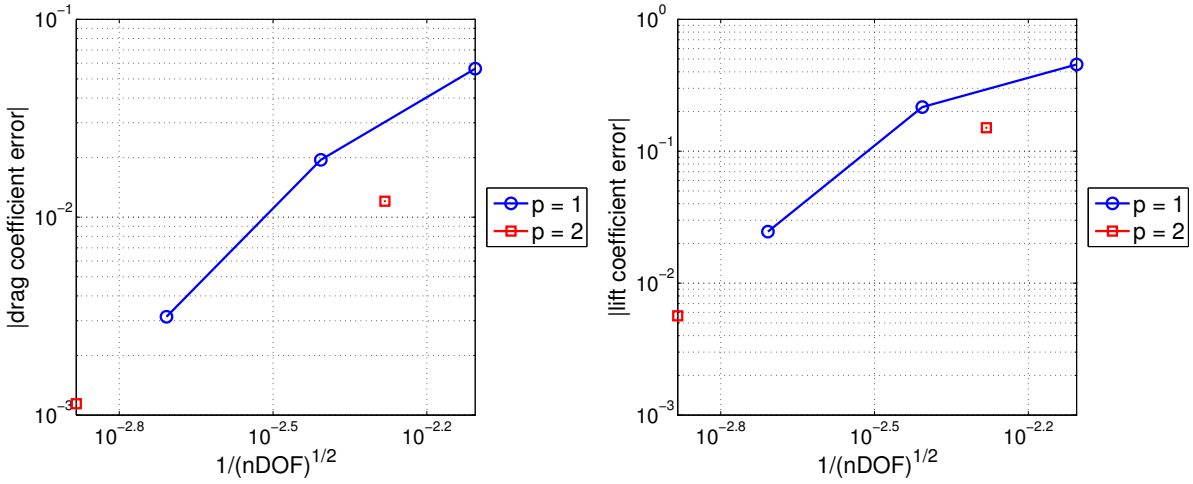


Figure 1: Coarse mesh used for study.

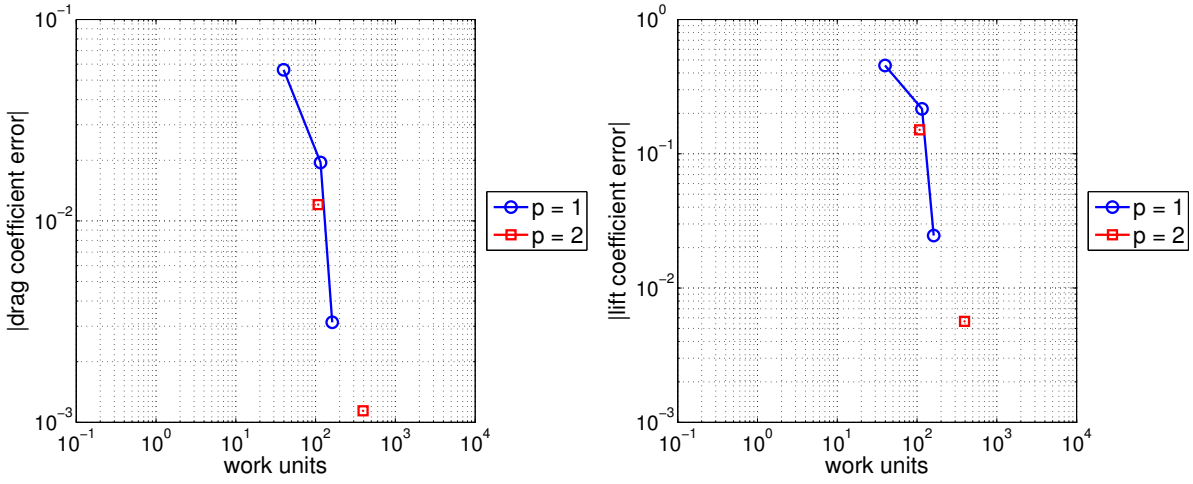
4. Results

The figures and tables below present results organized as requested in the case description.



(a) drag coefficient (b) lift coefficient

Figure 2: Drag and lift coefficient errors versus degrees of freedom for three uniformly-refined meshes.



(a) drag coefficient (b) lift coefficient

Figure 3: Drag and lift coefficient errors versus work units for three uniformly-refined meshes.

Table 1: Tabulated drag coefficient errors.

nelem	p = 1	p = 2
4070	5.6278e-02	1.2042e-02
rate	-	-
16280	1.9491e-02	NaN
rate	1.53	NaN
65120	3.1376e-03	1.1408e-03
rate	2.64	NaN

Table 2: Tabulated lift coefficient.

nelem	p = 1	p = 2
4070	4.5466e-01	1.5062e-01
rate	-	-
16280	2.1596e-01	NaN
rate	1.07	NaN
65120	2.4579e-02	5.6503e-03
rate	3.14	NaN