C2.2 Steady Turbulent Transonic flow over an 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. The turbulence model employed in our code does not yet contain trip terms, and hence the flow was modeled as fully turbulent.

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 128 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

The high-order quadrilateral meshes provided on the workshop site were used for this case. Specifically, the current results are for meshes 2, 3, 4.

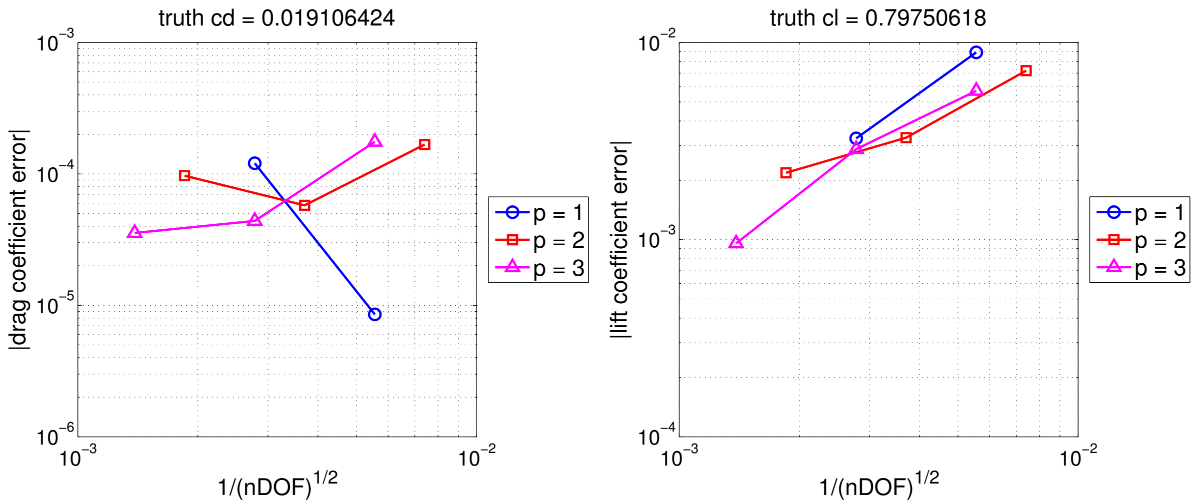
4. Results

The figures and tables below present results organized as requested in the case description. Figure 1 shows convergence of the lift and drag coefficient errors for the three meshes tested. Raw data is given in Table 1 and 2.

Table 1: Tabulated drag coefficient errors.

nelem	p = 1	p = 2	p = 3
2024	NaN	1.6771e-04	1.7563e-04
rate	-	-	-
8096	8.5377e-06	5.7761e-05	4.3943e-05
rate	NaN	1.54	2.00
32384	1.2075e-04	9.7119e-05	3.5565e-05
rate	-3.82	-0.75	0.31

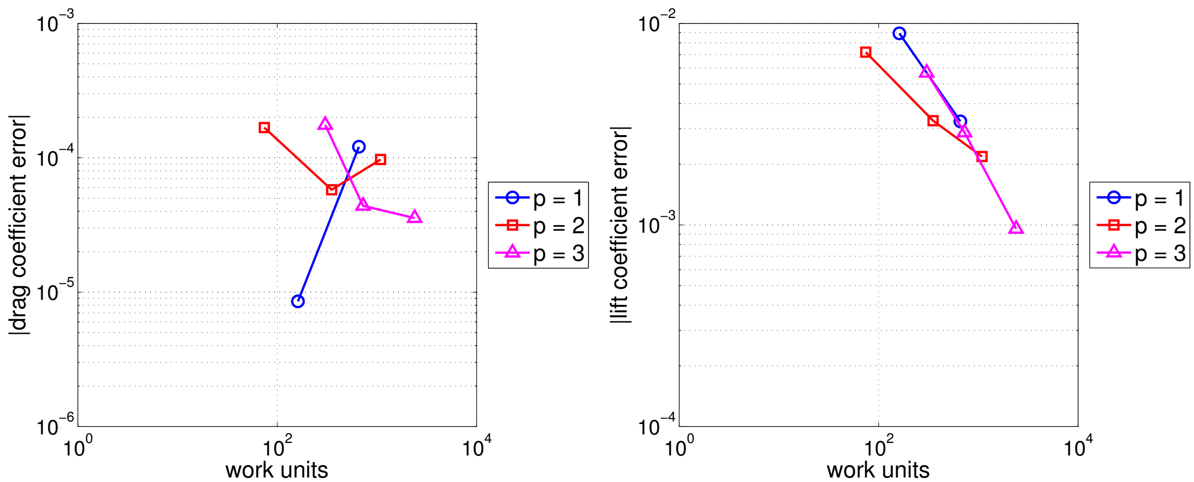
In addition, pressure and skin friction coefficients from the finest run are plotted in Figure 3. In the final data submission these data will be compared with experiment, and converged truth values for lift and drag coefficient will be determined.



(a) drag coefficient error

(b) lift coefficient error

Figure 1: Drag and lift coefficients for three uniformly-refined meshes, plotted against degrees of freedom.



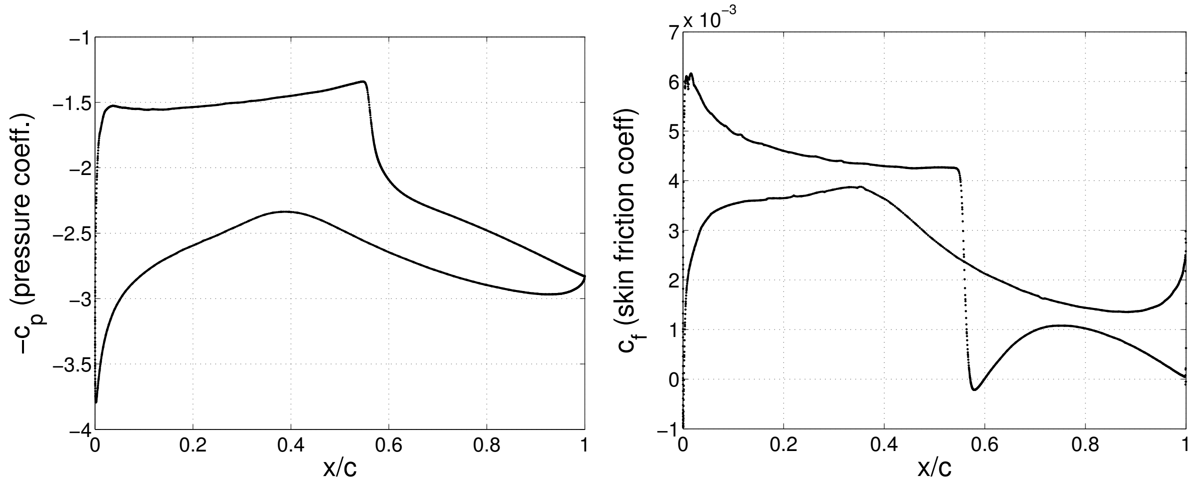
(a) drag coefficient error

(b) lift coefficient error

Figure 2: Drag and lift coefficients for three uniformly-refined meshes, plotted against work units.

Table 2: Tabulated lift coefficient errors.

nelem	p = 1	p = 2	p = 3
2024	NaN	7.2006e-03	5.6896e-03
rate	-	-	-
8096	8.9149e-03	3.2920e-03	2.8770e-03
rate	NaN	1.13	0.98
32384	3.2657e-03	2.1842e-03	9.5744e-04
rate	1.45	0.59	1.59



(a) pressure coefficient distribution

(b) skin coefficient distribution

Figure 3: Pressure and skin friction coefficient distributions.