C2.3 Analytical 3D Body of Revolution

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

The default implicit Newton solver was used for all runs in this case. The residual was converged to an absolute L_1 norm below 10^{-8} using a conservative state vector of unit density and pressure, and gas constant $R = 1.0$. Full-state boundary conditions, in combination with the Roe Riemann solver, were imposed on the farfield. Runs were performed on the *nyx* supercomputing cluster at the University of Michigan. The number of cores ranged from 32 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

Hexahedral meshes used for this case were taken from the workshop website. Specifically, meshes 1-3 of the Euler/Inviscid/Turbulent variety were used.

4. Results

The figures and tables below present a partial set of the requested refinement results. “Exact” values for the lift and drag coefficients were not computed independently; instead values provided by the workshop were used.

Inviscid: $M = 0.5, \alpha = 1^o$

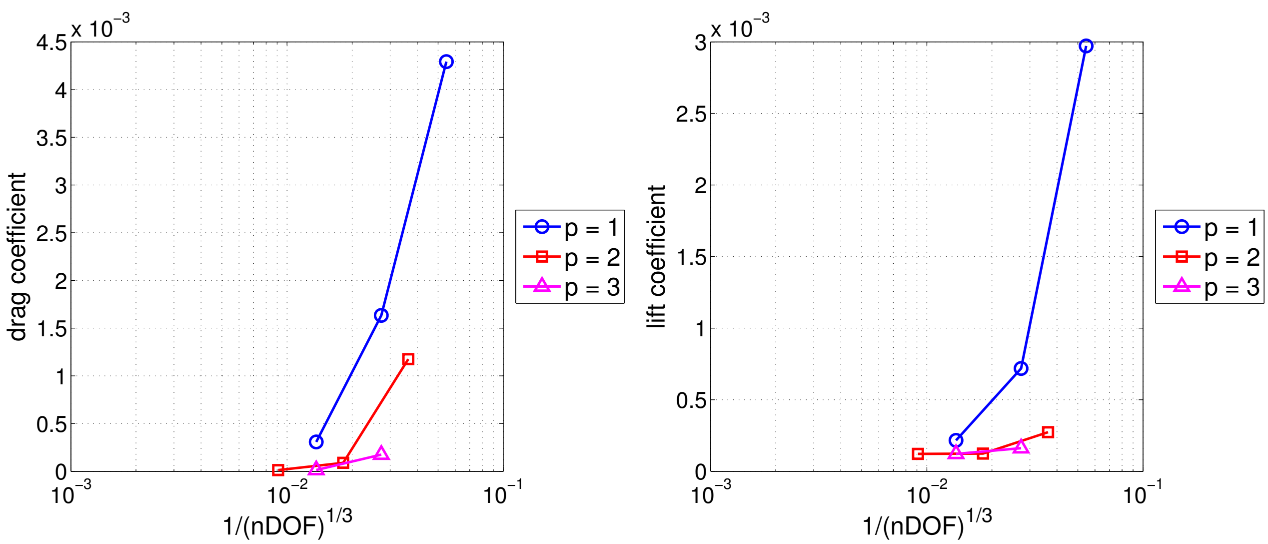
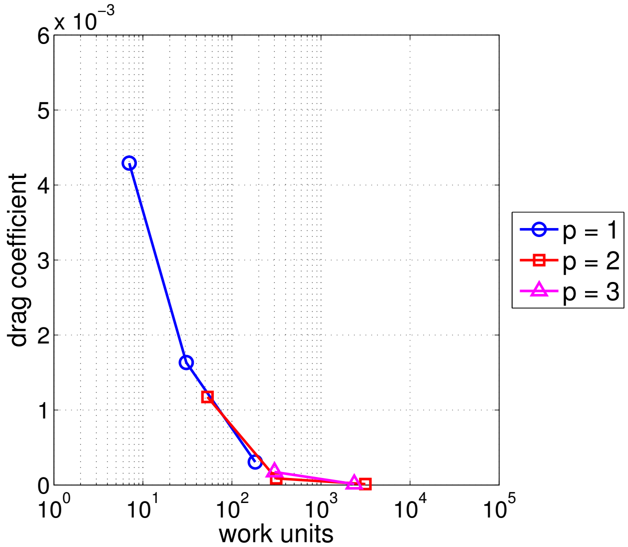


Figure 1: $M = 0.5, \alpha = 1^o$: drag and lift convergence with mesh h refinement.



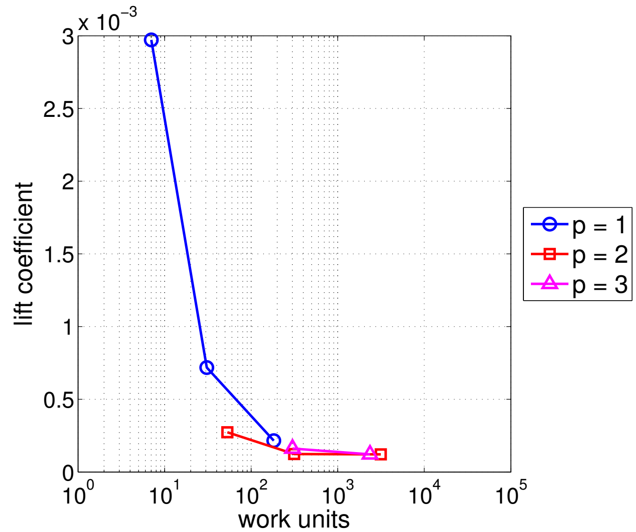


Figure 2: $M = 0.5, \alpha = 1^o$: drag and lift convergence with work units.

Table 1: $M = 0.5, \alpha = 1^o$: drag coefficients.

nelem	p = 1	p = 2	p = 3
768	4.2928e-03	1.1750e-03	1.7506e-04
rate	-	-	-
6144	1.6337e-03	8.9131e-05	1.3832e-05
rate	-	-	-
49152	3.0767e-04	1.2903e-05	NaN
rate	-	-	-

Table 2: $M = 0.5, \alpha = 1^o$: lift coefficients.

nelem	p = 1	p = 2	p = 3
768	2.9710e-03	2.7357e-04	1.6154e-04
rate	-	-	-
6144	7.1816e-04	1.2396e-04	1.2147e-04
rate	-	-	-
49152	2.1571e-04	1.2186e-04	NaN
rate	-	-	-

Viscous, Laminar: $M = 0.5, \alpha = 1^o, Re = 5000$

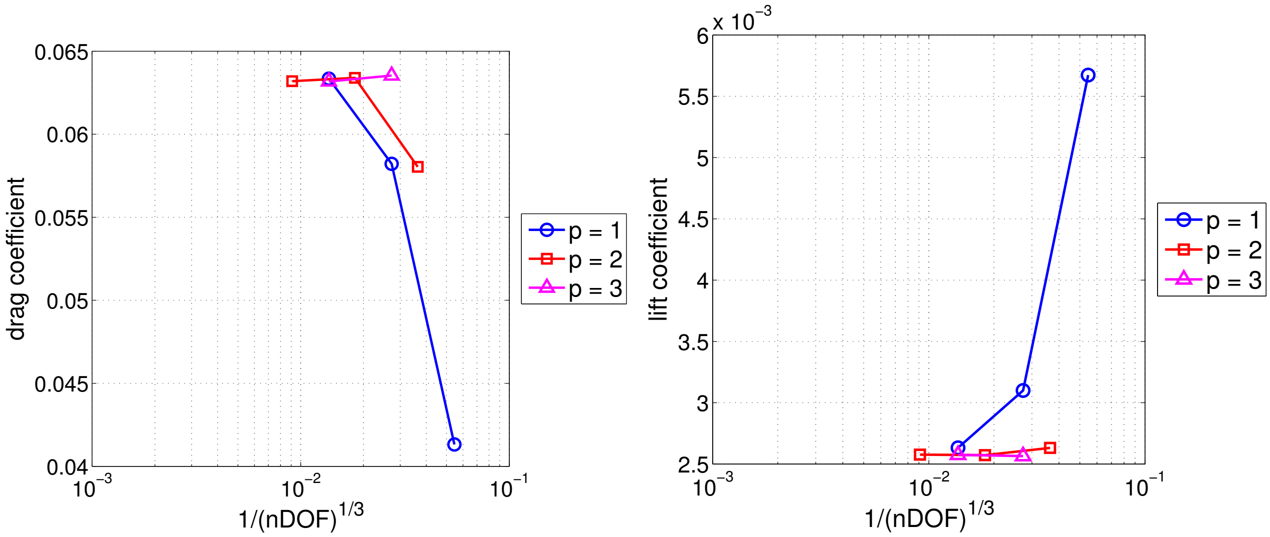


Figure 3: $M = 0.5, \alpha = 1^o, Re = 5000$: drag and lift convergence with mesh h refinement.

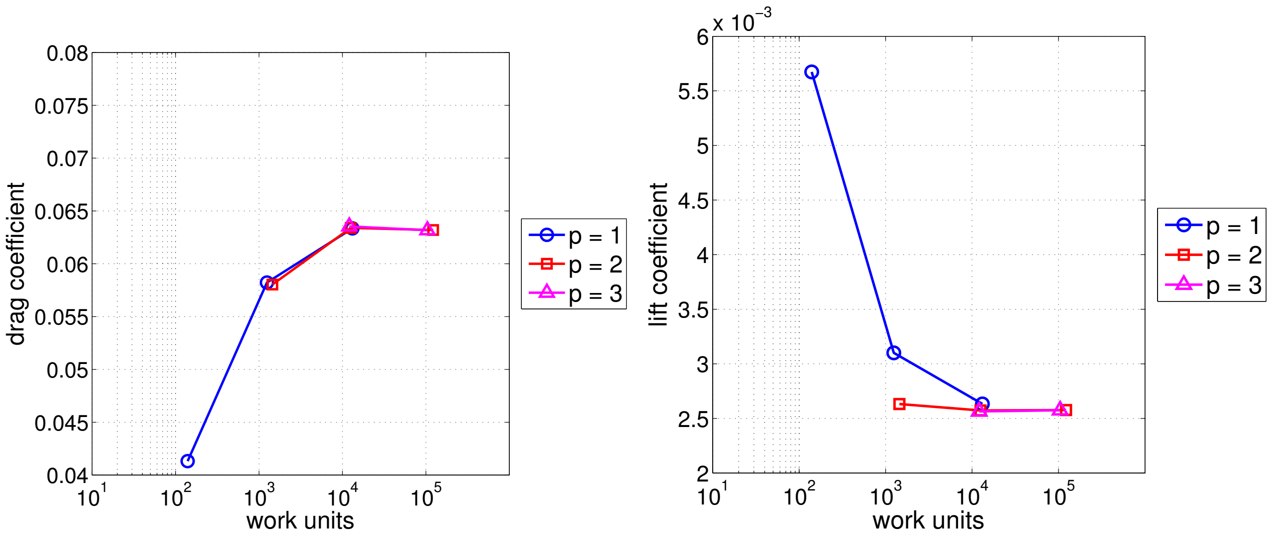


Figure 4: $M = 0.5, \alpha = 1^o, Re = 5000$: drag and lift convergence with work units.

Table 3: $M = 0.5, \alpha = 1^o, Re = 5000$: drag coefficients.

nelem	p = 1	p = 2	p = 3
768	4.1314e-02	5.8035e-02	6.3534e-02
rate	-	-	-
6144	5.8219e-02	6.3395e-02	6.3178e-02
rate	-	-	-
49152	6.3344e-02	6.3192e-02	NaN
rate	-	-	-

Table 4: $M = 0.5, \alpha = 1^o, Re = 5000$: lift coefficients.

nelem	p = 1	p = 2	p = 3
768	5.6730e-03	2.6316e-03	2.5644e-03
rate	-	-	-
6144	3.1003e-03	2.5725e-03	2.5752e-03
rate	-	-	-
49152	2.6329e-03	2.5765e-03	NaN
rate	-	-	-