# C2.4 Laminar Flow around a Delta Wing

## 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 $10^{-7}$ using a conservative state vector of $\mathcal{O}(1)$ freestream density, velocity, and pressure, and gas constant $R = 1.0$. Runs were performed on the *nyx* supercomputing cluster at the University of Michigan. The number of cores ranged from 16 on the coarsest meshes to 160 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 were used. These meshes contained degenerate hexahedra, which were handled by not computing face integrals on faces with zero measure.

## 4. Results

The figures and tables below present the requested uniform refinement set of results. "Exact" values for the lift and drag coefficients were obtained from the Leicht+Hartmann reference paper.

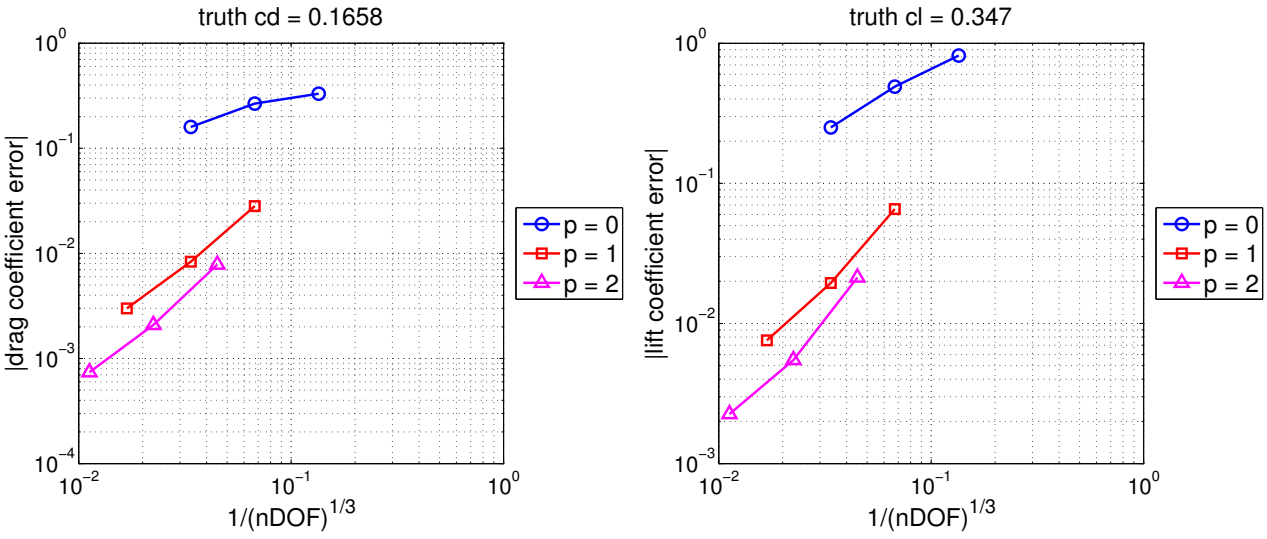


Figure 1: $M = 0.3, \alpha = 12.5^o$: drag and lift error convergence with mesh $h$ refinement.

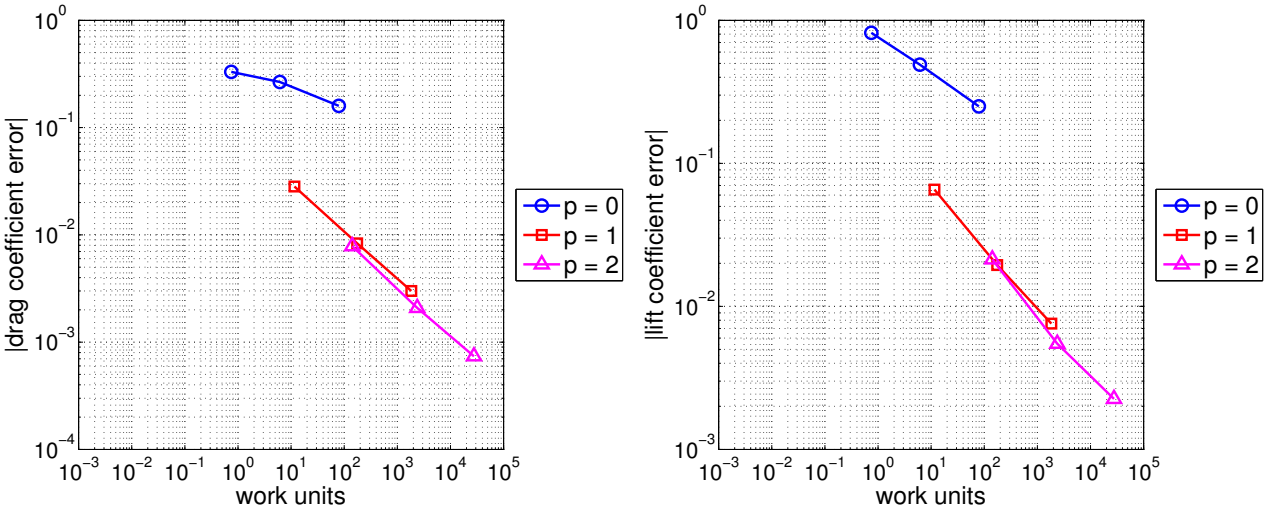


Figure 2: $M = 0.3, \alpha = 12.5^o$: drag and lift error convergence with work units.

Table 1: $M = 0.3, \alpha = 12.5^o$: drag coefficient errors and rates.

| nelem | p = 0 | p = 1 | p = 2 |
|---|---|---|---|
| 408 | 3.3068e-01 | 2.8197e-02 | 7.8349e-03 |
| *rate* | - | - | - |
| 3264 | 2.6635e-01 | 8.3339e-03 | 2.0866e-03 |
| *rate* | 0.31 | 1.76 | 1.91 |
| 26112 | 1.5955e-01 | 2.9974e-03 | 7.3907e-04 |
| *rate* | 0.74 | 1.48 | 1.50 |

Table 2: $M = 0.3, \alpha = 12.5^o$: lift coefficient errors and rates.

| nelem | p = 0 | p = 1 | p = 2 |
|---|---|---|---|
| 408 | 8.1769e-01 | 6.5553e-02 | 2.1307e-02 |
| *rate* | - | - | - |
| 3264 | 4.9004e-01 | 1.9441e-02 | 5.4885e-03 |
| *rate* | 0.74 | 1.75 | 1.96 |
| 26112 | 2.5046e-01 | 7.5812e-03 | 2.2550e-03 |
| *rate* | 0.97 | 1.36 | 1.28 |