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

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1 Code description

SUNWinT [1] is a high-order Discontinuous Galerkin CFD solver which solves the Euler, Navier-Stokes and Reynolds-Averaged Navier-Stokes equations with the Spalart-Allmaras model. We employ modal basis functions up to a polynomial degree $p = 5$ which are implemented for triangle, quadrilateral, tetrahedral and hexahedral elements. For temporal discretisation explicit Runge-Kutta schemes upto 4th order, an implicit BDF2 method and an implicit Backward Euler method can be used. The inviscid flux over element faces is calculated with a HLL Riemann solver, while for viscous fluxes we use the BR2 scheme. The code is parallelised via MPI and meshes for the parallel runs are split with metis. Linear meshes are created with Gridgen and a higher-order mesh can be created based on normals [2] or by aggregation.

2 Case description

The case is run with the Spalart-Allmaras turbulence model with a Backward Euler for temporal discretisation. To reach the steady state fast we solve the system with a Newton method with one iteration per time-step. The resulting linear system is solved with an ILU preconditioned GMRES method. The spatial discretisation ranges from $P1$ to $P4$.

3 Meshes

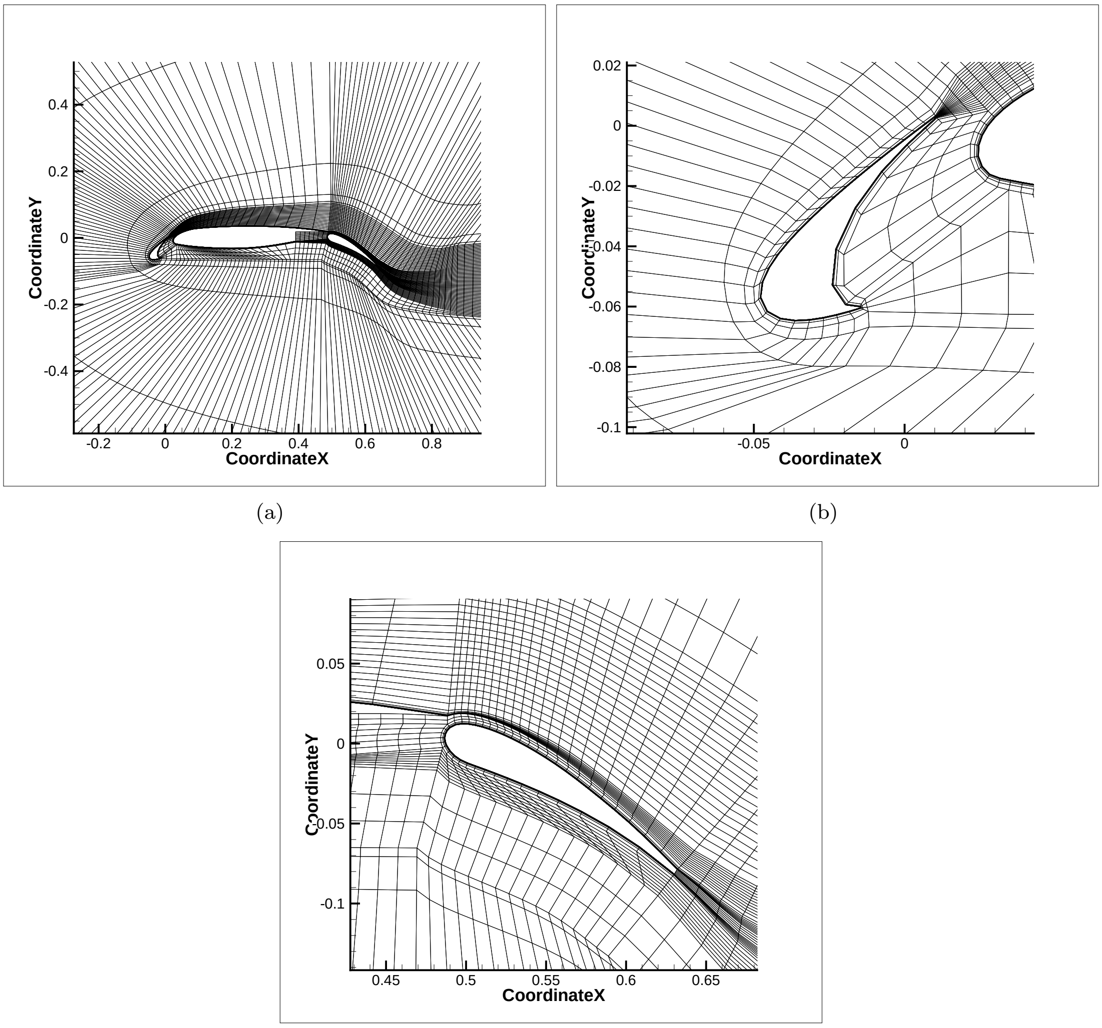
A mesh consisting of 6139 cells curved by quartic polynomials was created with Gridgen. The farfield is located 50 chords from the airfoil (compare figure 1).

4 Results

The pressure coefficient and the absolute value of the shear coefficient (absolute value) are presented in figure 2. Both are compared with the Finite Volume solution of Langer (DLR) from the last workshop. The values of the drag and lift coefficient can be seen in table 1.

Order	$P1$	$P2$	$P3$	$P4$
c_d	0.250514	0.070525	0.055692	0.054575
c_l	3.41321	4.08617	4.14884	4.14225

Table 1: Drag and lift coefficient.



(a) (b)

(c)

Figure 1: Details of the mesh.

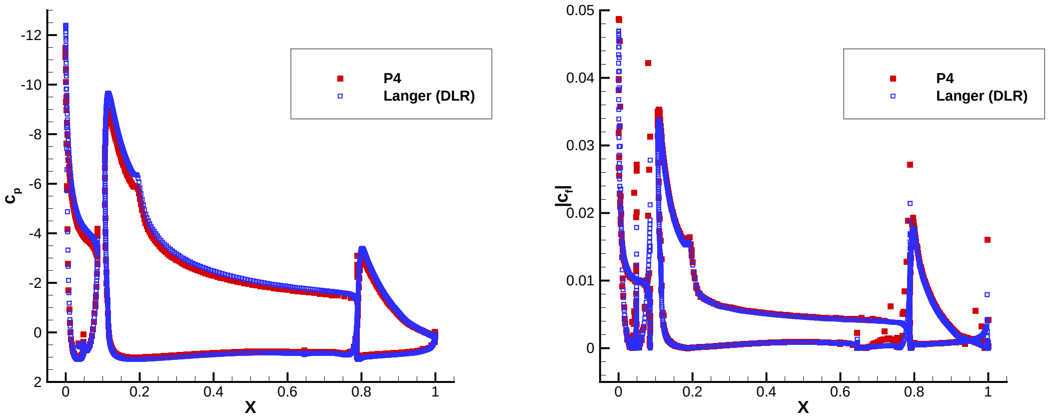
4.1 Computational costs

The simulations were run on the Cray Hermit cluster at the High Performance Computing Center in Stuttgart, Germany. All simulations were run on 8 cores. On the cluster TauBench took 9.1098 s on average. The work units and the degrees of freedom per equation for different polynomial orders are presented in table 2. As the lower order was used as initialisation for the higher order the work units are summed up.

References

[1] B. Landmann, M. Keßler, S. Wagner, and E. Krämer. A parallel, high-order Discontinuous Galerkin code for laminar and turbulent flows. *Computers & Fluids*, 37(4):427 – 438, 2008.

[2] C. Lübon, M. Kessler, S. Wagner, and E. Krämer. High-order boundary discretization for Discontinuous Galerkin codes. In *24th AIAA Applied Aerodynamics Conference, San Fransisco, AIAA Paper 2006.2822*, 2006.



(a) c_p (b) c_f

Figure 2: Pressure and wall shear coefficient.

Order	$P1$	$P2$	$P3$	$P4$
nDOFs	17337	34674	57790	86685
Work units	1289	4470	9702	19931

Table 2: Work units for different orders.