Improved adjoint solver for complex flow conditions

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I. Introduction to design under complex flow conditions

The essential step in performing gradient-based shape optimisation using the Reynolds-averaged Navier–Stokes equations is to compute the adjoint solution. For complex flow conditions such as flows exhibiting large separation, the resulting adjoint equation could be extremely stiff to solve, while shape optimization is as interesting under these conditions as for design condition.

II. Deflated Krylov methods for solving the adjoint equation

In this work, a deflated Krylov subspace linear solver, GCRO-DR, preconditioned with either incomplete LU factorisation or multigrid, is used to solve the adjoint equation. The DLR–TAU code is used in this work.

III. Results for DLR F6 at both cruise and off-design conditions

The steady-state flow solutions for the DLR F6 transonic turbulent case are shown on the left in Figs. 1 and 2 where the stationary separation bubbles at the wing-body junction towards the wing trailing edge are clearly visible. The convergence history of the adjoint equations for both flow conditions using GMRES and GCRO-DR are shown on the right in Figs. 1 and 2. All adjoint solves are performed on 48 cores. For cruise condition, GCRO-DR moderately speeds up the convergence with less memory. The speedup and memory reduction is much more significant for the more complex flow at 4.5 deg angle of attack.

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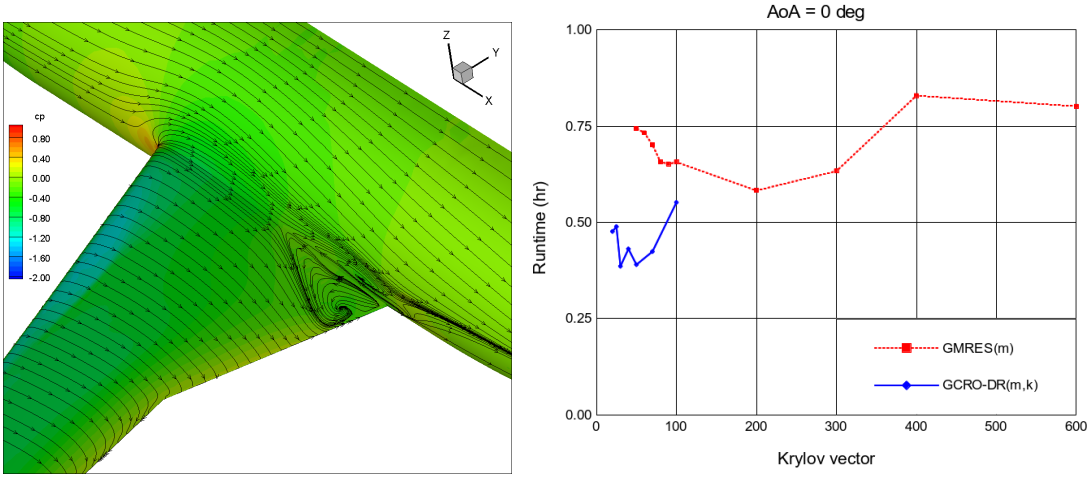

Figure 1. Left: flow solution at zero deg angle of attack. Skin friction lines plotted based on the surface shear force vector field. Right: Runtime of both linear solver plotted against the number of Krylov vectors used.

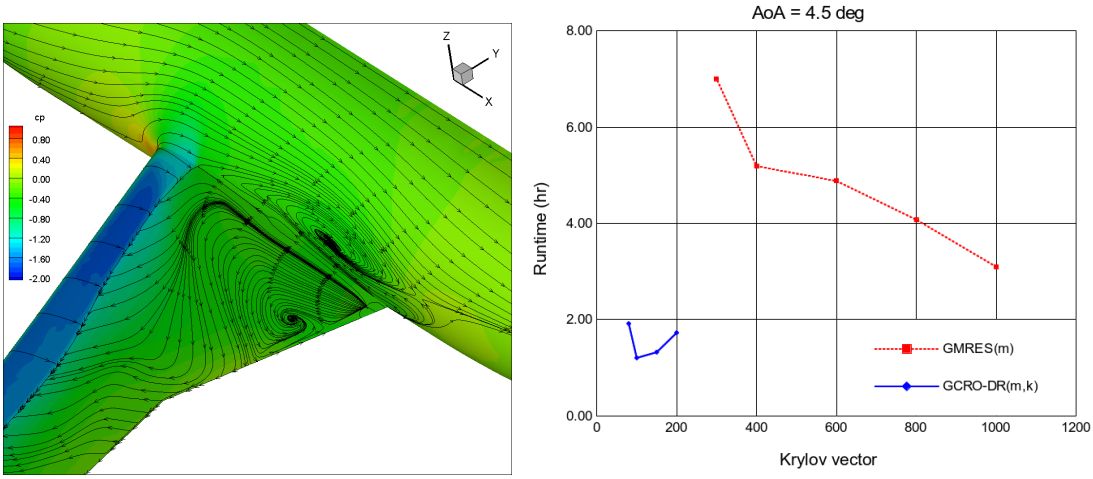

Figure 2. Left: flow solution at 4.5 deg angle of attack. Skin friction lines plotted based on the surface shear force vector field. Right: Runtime of both linear solver plotted against the number of Krylov vectors used.