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DLR-F4 Results using Bombardier Aerospace Full-Aircraft Navier-Stokes Code FANSC

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Outline

- **Description of FANSC**
- **DLRF4 Results:**
    - **Convergence**
    - **Pressure Distribution**
    - **Forces**
- **Conclusions**

FANSC

Developed in House under a multi-year Defense/Industry Research Program which included:

- Development of a grid-generation package (MBGRID)

- Development of structured and unstructured Navier-Stokes methods for full-aircraft configurations

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FANSC

Flow Solver

- **Multi-block structured domain decomposition**
- **Finite-volume discretization (cell-centered)**
- **Explicit artificial dissipation (JST, AUSM, CUSP)**
- **Explicit Runge-Kutta scheme**

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FANSC

Acceleration techniques

- Full-multigrid algorithm
- Local time stepping
- Implicit residual smoothing, directional scaling for high aspect ratio meshes
- Coarse-grain parallelization on blocks (3.6/4 CPU)
- Vectorization (94% efficient)

Boundary Conditions

- No-Slip/Slip Wall
- Transpiration Wall (Boundary-Layer Coupling)
- Symmetry, Degenerate line/point
- Riemann, Engine Inlet/Outlet
- Multiple boundary condition per block face

Turbulence Model

- Spalart-Allmaras one-equation with/without wall functions
- Discretized and solved as described in their 1992 paper
- Loosely coupled
- Computed on fine grid only (weighted-average and frozen on coarse grids)
- Zero turbulent eddy viscosity at solid walls on all grid levels

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Hardware

Run-time (for provided mesh)

- 9.0 hours on 4 CPU
- 2.4 Gbytes Memory Requirements

Hardware

- 8-CPU Cray SV1
- 8 Gbytes RAM
- 1.2 Gflops/CPU

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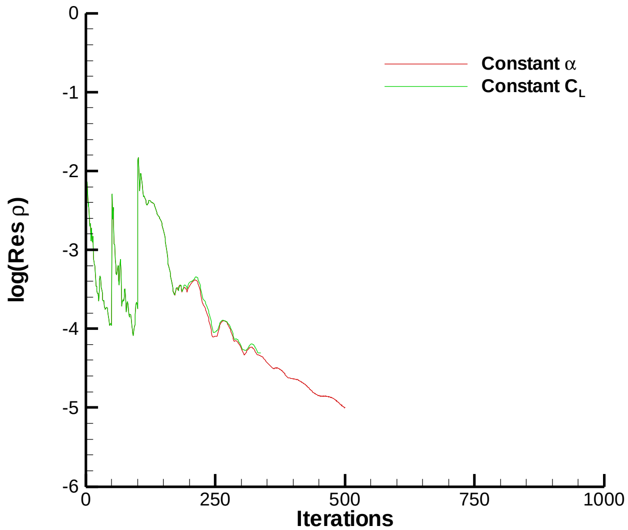
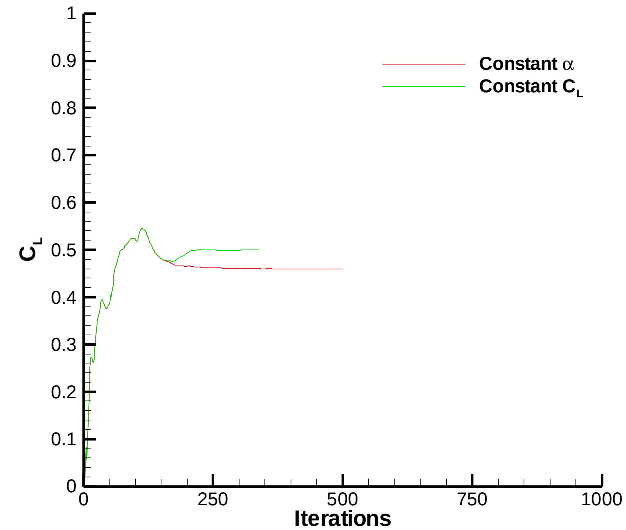
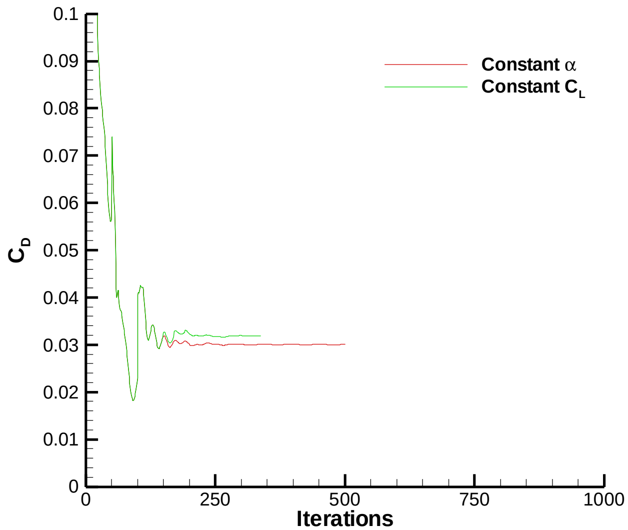
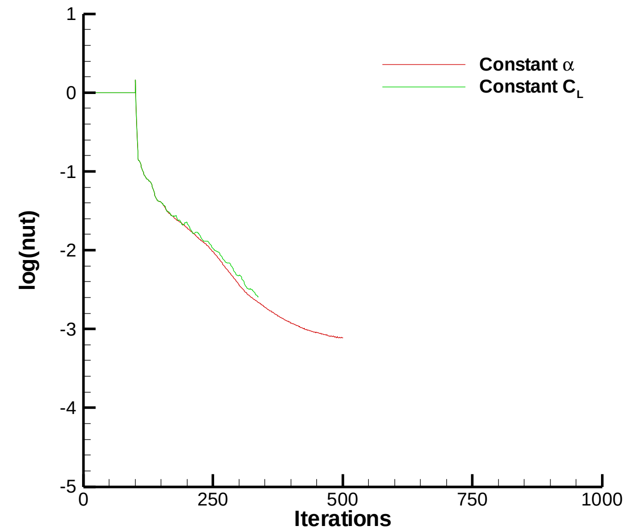
DLR-F4 Results: Convergence (DPW grid)









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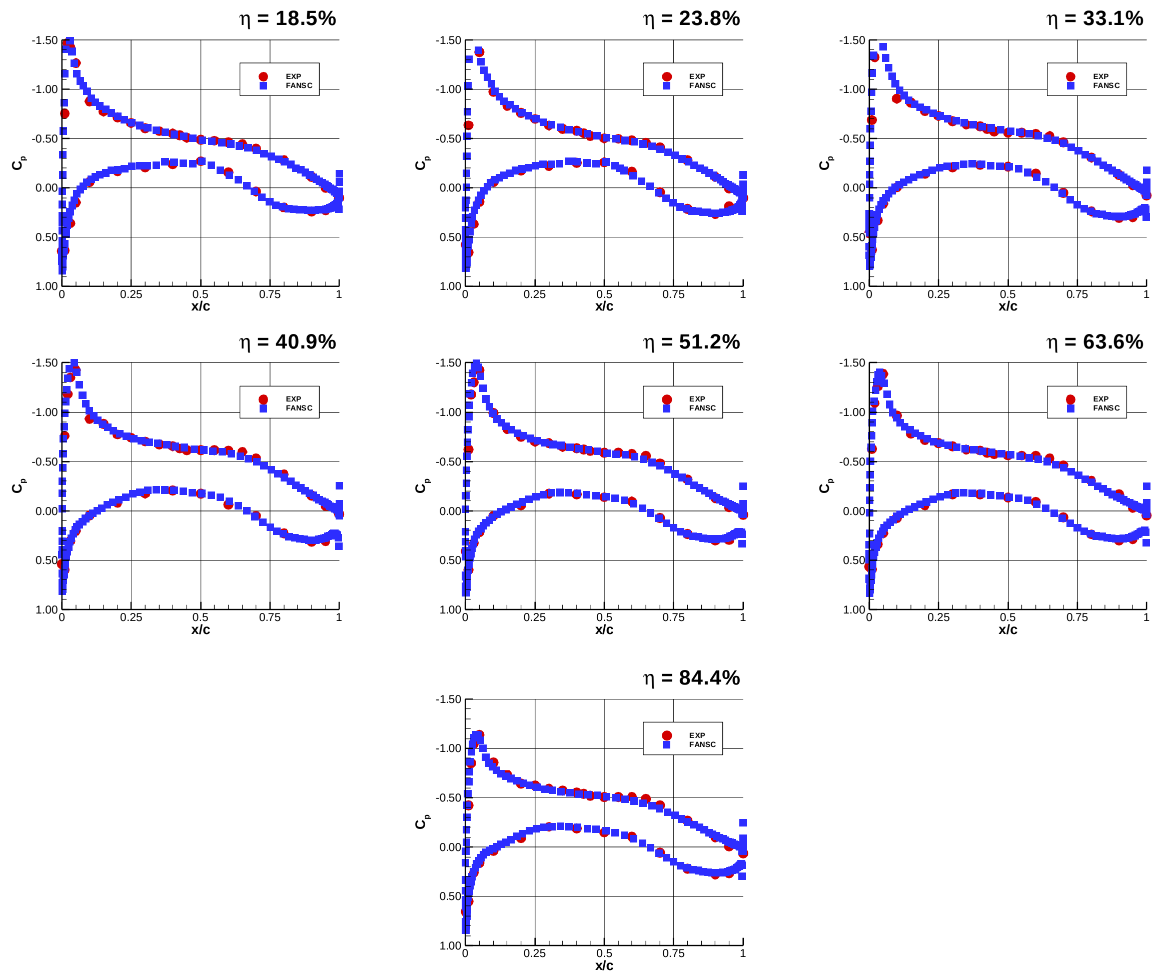
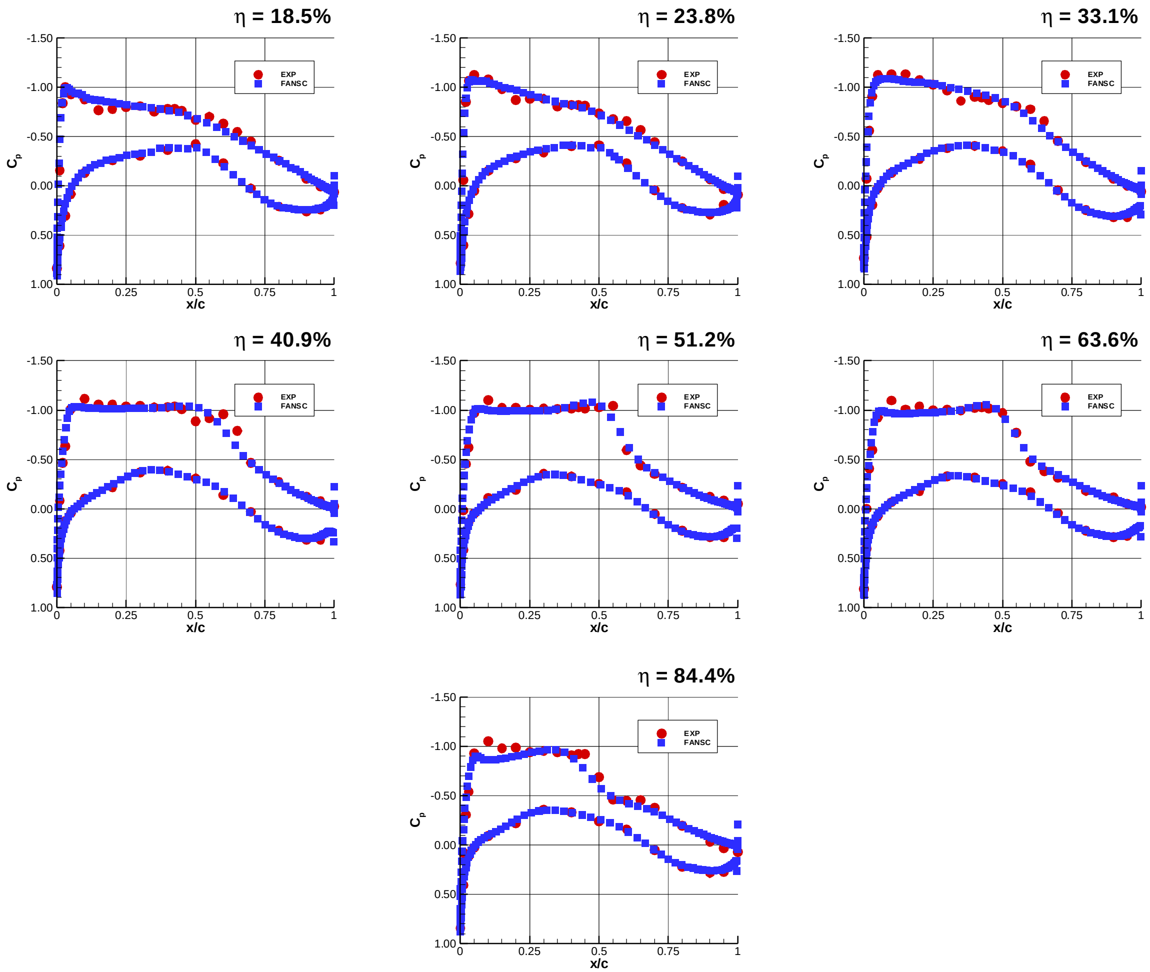
DLR-F4 Results (M 0.60 CL 0.50)



DLR-F4 Results (M 0.80 CL 0.50)



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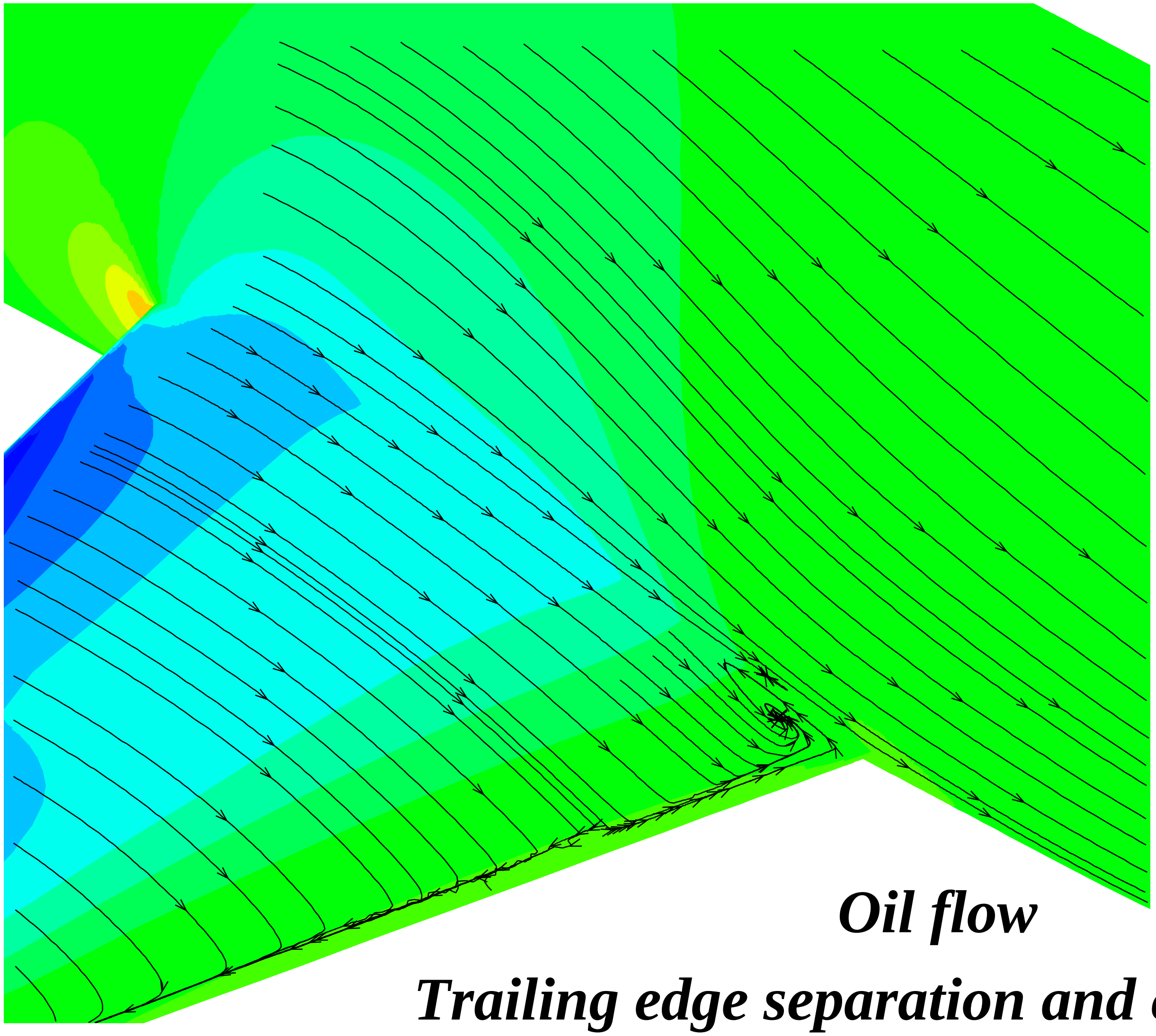
DLR-F4 Results (M 0.75 a = 1.0 deg.)



Oil flow

Trailing edge separation and corner vortex

MBGRID mesh

- An internally generated mesh of the DLRF4 configuration using Bombardier Aerospace MBGRID grid-generation package was produced:

  Orthogonality of the mesh on the body surface

  10e-6 wall spacing

  3 Million mesh points, open wing-tip, blunt trailing edge

- Similar convergence as when the DPW mesh is used

DLR-F4 Results (M 0.75)

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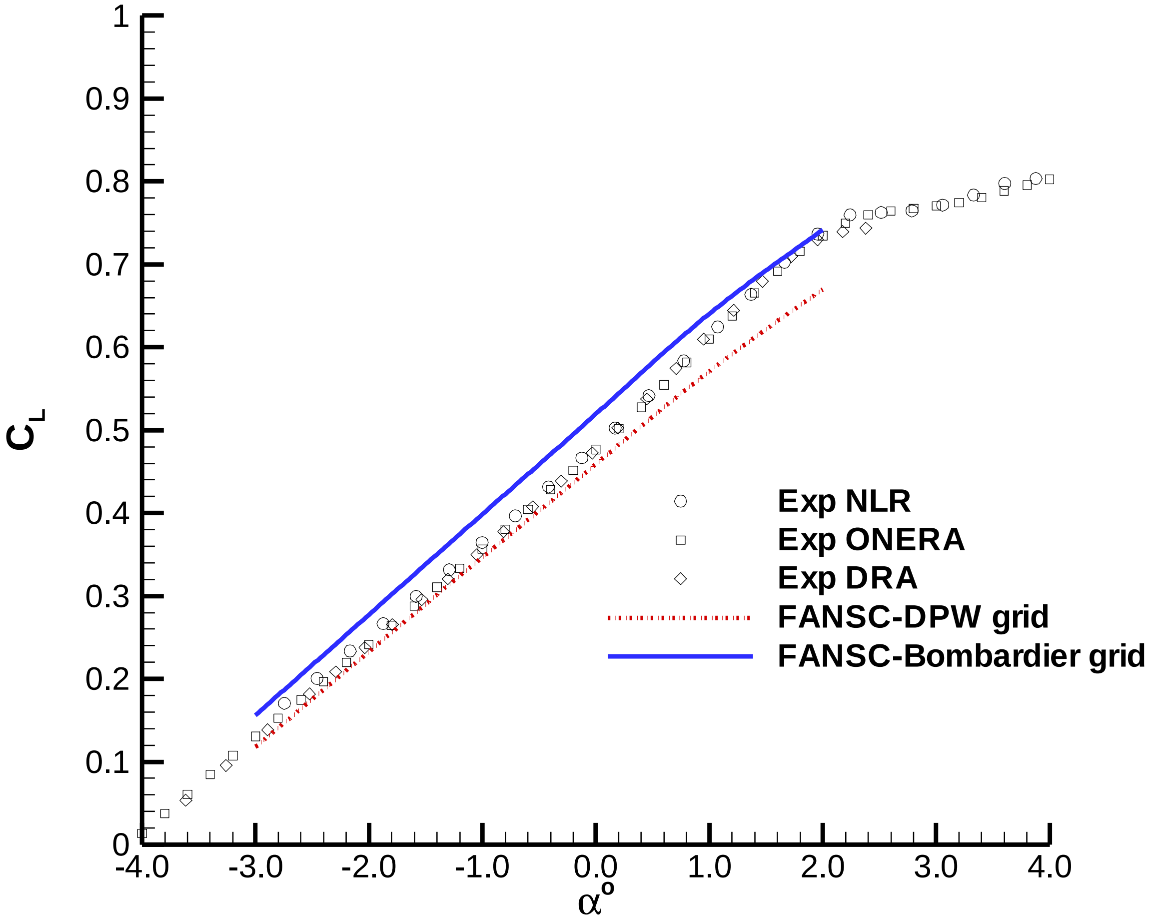
The solid line prediction lies in line with the most accurate unstructured CFD results presented at the DPW.



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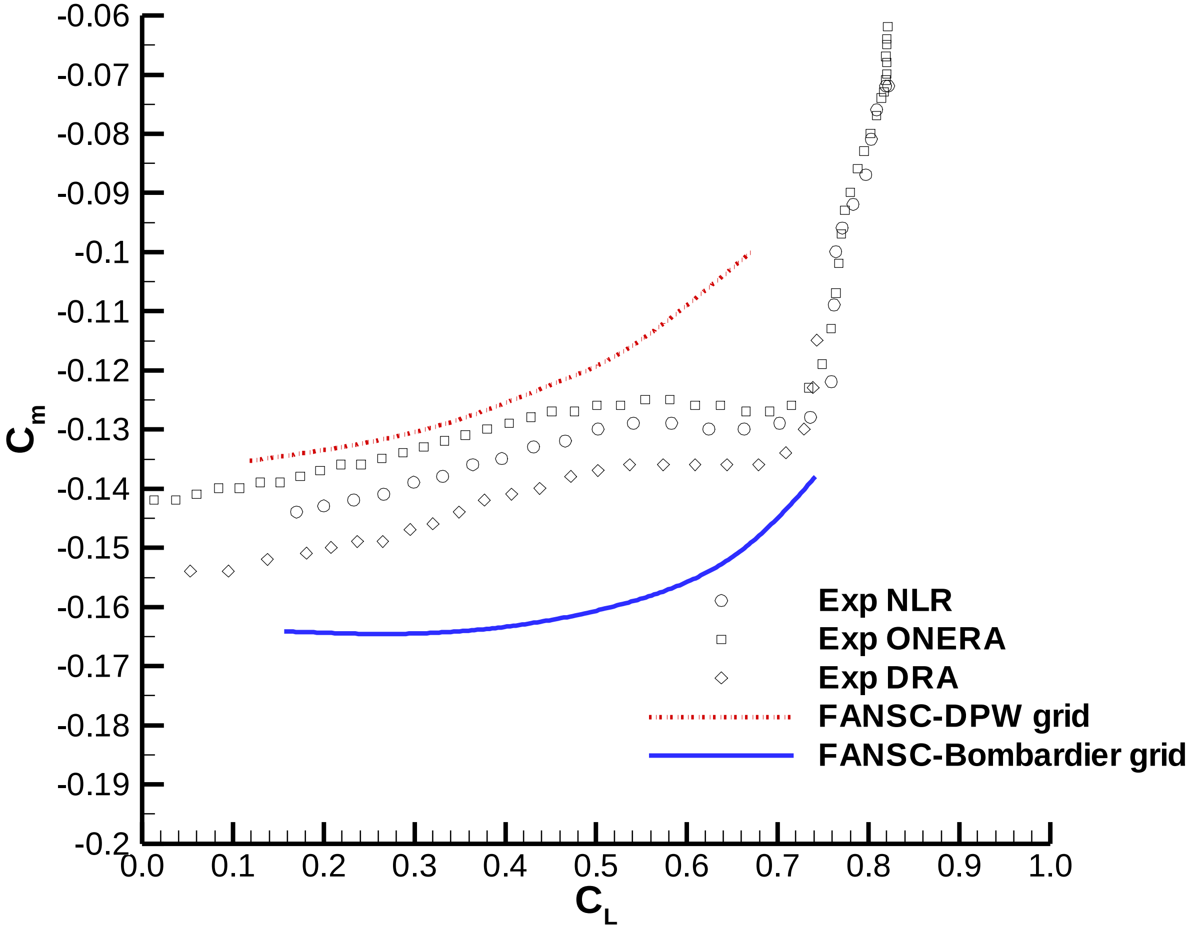

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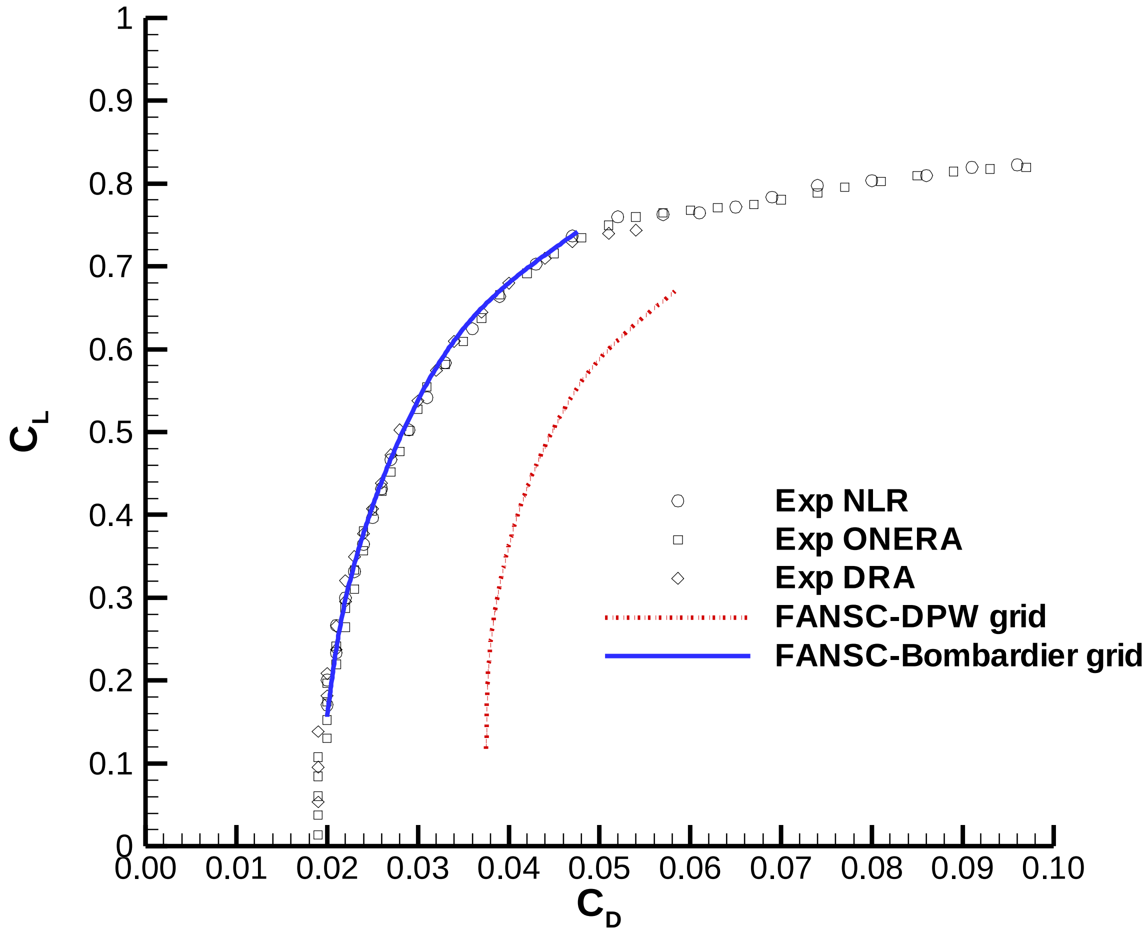

CONCLUSIONS

- FANSC showed excellent convergence characteristics (density and turbulent viscosity) on the required grid, despite its excessive skewness

- Integrated lift and pitching moment predictions on the required grid were accurate, but mesh skewness introduced discretization errors on the skin-friction evaluations (Pressure drag was correctly predicted)

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CONCLUSIONS

- Results obtained with FANSC on an internally generated mesh using the MBGRID grid-generation package resulted in accurate lift, pitching moment and drag prediction, as was expected from our industrial experience.

- The overall performance of FANSC in terms of robustness, convergence and accuracy at this drag workshop ranks it as one of the best Navier-Stokes code available.

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CONCLUSIONS

- It was unfortunate that the DPW structured mesh was not better suited for the problem in hand. However, it did provide a basis for evaluating the robustness of the structured codes.

- The enthusiasm present at the workshop was very encouraging and demonstrated the need to pursue further research in this area.

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CONCLUSIONS

- Bombardier Aerospace whishes to thank the DPW committee for their efforts in organizing the event.