Far-field drag breakdown applied to the DLR-F6 configuration

In the framework of the 2nd CFD Drag Prediction Workshop

Presented by
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Context of the topic

• To tackle the issue of aircraft performance
  4 Optimal shape design
  need for reliable drag breakdown
  4 Cruise performance assessment
  need for accurate overall drag level

• Prevailing role of CFD
  4 Generation of well adapted grids
  4 Need for a breakthrough in drag assessment
    – information provided by near-field integration insufficient
    – far-field abilities very attractive in terms of
      • improvement of the accuracy
      • physical drag breakdown
      • spatial distribution of drag sources
Tools used by Airbus for the 2nd DPW

- **Structured multiblock solver**: elsA
  - Developed by ONERA
  - Oriented-object structure (C++)
  - Turbulence model: k-ε (Wilcox)
  - Centred scheme
    - Dissipation: Jameson type scalar scheme
    - Implicit time integration: LU-SSOR method

- **Far-field drag analysis tool**: FFD41
  - Developed by ONERA / Airbus France
    (van der Vooren / Destarac’s theory)
  - Industrialized by Airbus France
  - Daily used by shape designers and aerodynamic data engineers
  - Capability for dealing with patched grids (soon AMR grids)
Comparison elsA / TAU of the drag polars
(WB & WBPN configurations)

Drag polar (near-field integration)

10 drag counts

with forced transition

fully turbulent

Cd_total_WB (wind tunnel)
Cd_total_WB (elsA - ICEM grid)
Cd_total_WB (elsA - Airbus grid)
Cd_total_WB (TAU - medium)
Cd_total_WB (TAU - fine)
Cd_total_WBPN (wind tunnel)
Cd_total_WBPN (elsA - ICEM grid)
Cd_total_WBPN (elsA - Airbus grid)
Cd_total_WBPN (TAU - medium)
Cd_total_WBPN (TAU - fine)
Cd_total_WBPN (elsA; -1.0°; fully turb.)
Cp distributions (elsA, medium ICEM grid, WBPN, CL=0.50)

- with fixed transition
- fully turbulent

Wing

Nacelle
Physical and numerical drag breakdown

• Exact near-field/far-field balance
  ‣ no small disturbances assumption

\[
(D_p + D_f)_A = D_V + D_W + D_i
\]

• Numerical considerations
  ‣ production of spurious drag
    (connected to entropy variations in the flowfield)
  ‣ decay of axial vorticity in the wing-tip vortex
  ‣ transformation of induced drag into spurious drag

\[
(D_p + D_f)_A = D_V + D_W + D_i^{\text{app}} + D_i^{\text{sp}} + D_{sp}
\]
Far-field analysis

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<th>GridCDf</th>
<th>CDv</th>
<th>CDw</th>
<th>CDi</th>
<th>TAU</th>
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- Comments
  - lower overall far-field drag [removal of the spurious drag]
  - quite high discrepancy on the viscous terms [turbulence model ? role of the grid size ?]
  - good agreement on the wave drag magnitude
  - uncertainty on the induced drag : correction of the vortex decay ?
  - incremental drag better predicted than the near-field for elsA
    - TAU : $\Delta CD = 41.2 \times 10^{-4}$
    - elsA : $\Delta CD = 45.9 \times 10^{-4}$
Wave drag distribution

DLK-P6 Wing Body configuration
Volume Yw for wave drag integration
Clw=0.500, medium ICEM grid

DLR-P6 Wing Body Pylon Nacelle configuration
Volume Yw for wave drag integration
Clw=0.500, medium ICEM grid

Spanwise distribution of wave drag
Effect of engine installation (eisA computations)

Valuable plot for design improvement!

Spanwise distribution of wave drag
WBPN configuration, M=0.75, CL=0.50

Excellent agreement on the local drag rise!
Viscous drag distribution

Spanwise distribution of viscous drag

WBPN configuration, $M=0.75$, $CL=0.50$

The magnitude of the root separation in terms of drag is identically predicted!

Excellent agreement on the local drag rise!
Drag polar breakdown (elsA computations)

Drag breakdown from elsA computations (WB & WBPN configurations)

- Contribution of the lower side (interaction wing / pylon / nacelle)
- Low impact of the engine installation on the induced drag
- Issue with the enforced transition?
WBPN@-1.0° : an example of analysis

AoA = -1.0°

Wing root separation

AoA = 0.0°

Wing/Pylon separation

Physical intuition confirmed by the far-field analysis

very valuable information provided by FFD41

Spanwise distribution of viscous pressure drag

Comparison of different AoA on the WBPN configuration with enforced transition (eisA computations)
Conclusions

• Far-field drag analysis tools = an intelligent means of making the most of CFD
  ‣ shape design improvement (including optimisation)
  ‣ identification of CFD issues (grids, solvers, etc.)
  ‣ New sensors for automatic refinement

• Physical drag breakdown is available for both Airbus solvers (elsA & TAU)
  ‣ discrepancies remain to be addressed
  ‣ some obvious satisfactory trends

• The one-drag count accuracy: a utopia
  ‣ solver able to capture the flow features
  ‣ well-built grid
  ‣ far-field drag assessment tool

the 1 d.c. variation is at hand