Drag Prediction of Engine-Airframe Interference Effects with CFX 5

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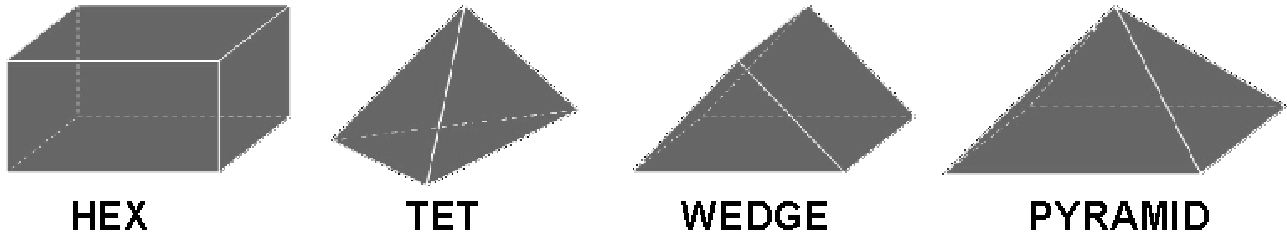
Outline

- CFX the company
- CFX-5 solver technology
- Results AIAA testcases

CFX – The Company

- CFX is one of the "big three" CFD companies worldwide
- 200 Full time employees
- 40 Software developers
- Recently part of ANSYS Inc. (Canonsburg PA)
- General Purpose software with all major models
  - Turbulence, Combustion, Radiation, Multi-phase, Real gas …
- Applications in all technical areas
  - Aeronautics and Aerospace
  - Power generation
  - Turbomachinery
  - Transportation …

CFX-5.6

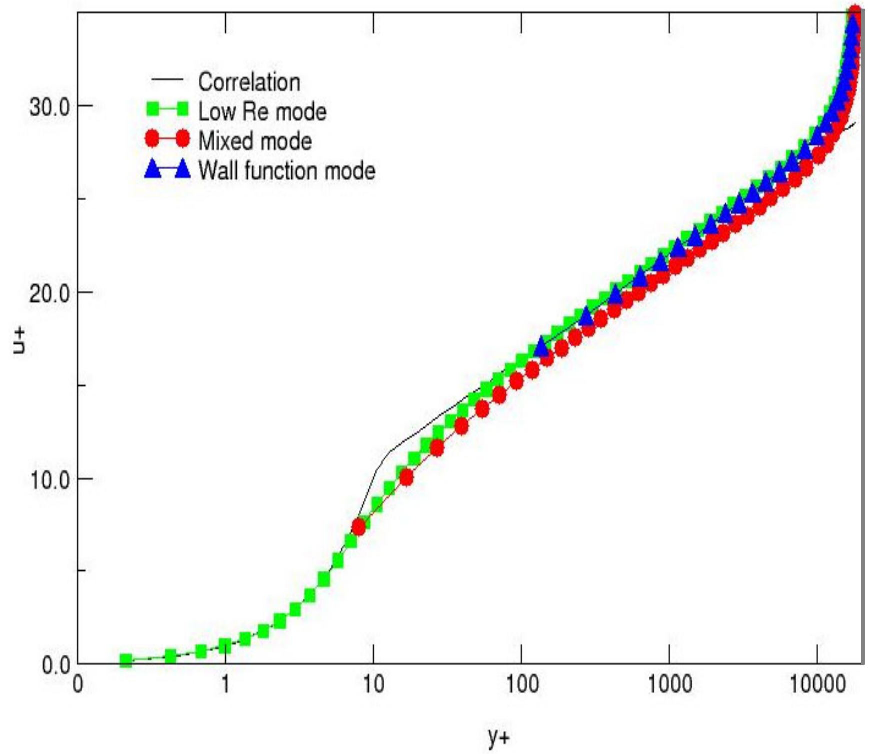


- **Finite volume method for mixed unstructured meshes**
- **Fully conservative vertex based discretisation**
- **Co-located variable arrangement (pressure based)**
- **Fully coupled equation system (mass and momentum coupling)**
- **Implicit formulation – 1st and 2nd order backward Euler**
- **Rhie & Chow velocity-pressure coupling**
- **Algebraic multigrid solver**
- **Scalable parallelisation**
- **Second order time- and space discretisation**
- **Entire Re and Mach number range**

Turbulence Models

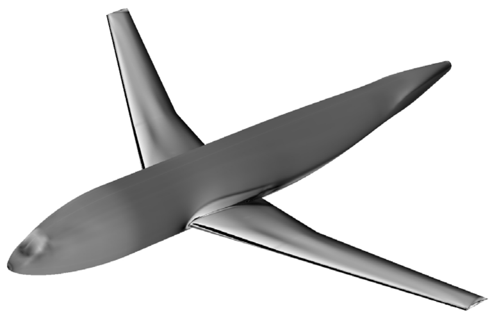
- **Wide range of turbulence models**
  - One-equation KE1E
  - Two-equation (k-ε, k-ω, SST ..)
  - RSM (LRR, SSG, SMC-ω,…)
  - LES, DES, SAS
- **AIAA drag prediction based on SST model:**
  - Reliable separation prediction
  - high accuracy near walls (automatic wall treatment) – heat transfer validation
  - Robustness

Automatic Wall Treatment

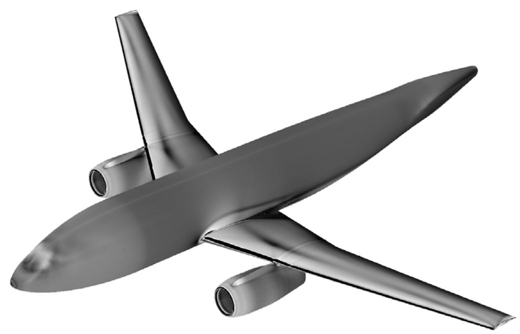


Testcases

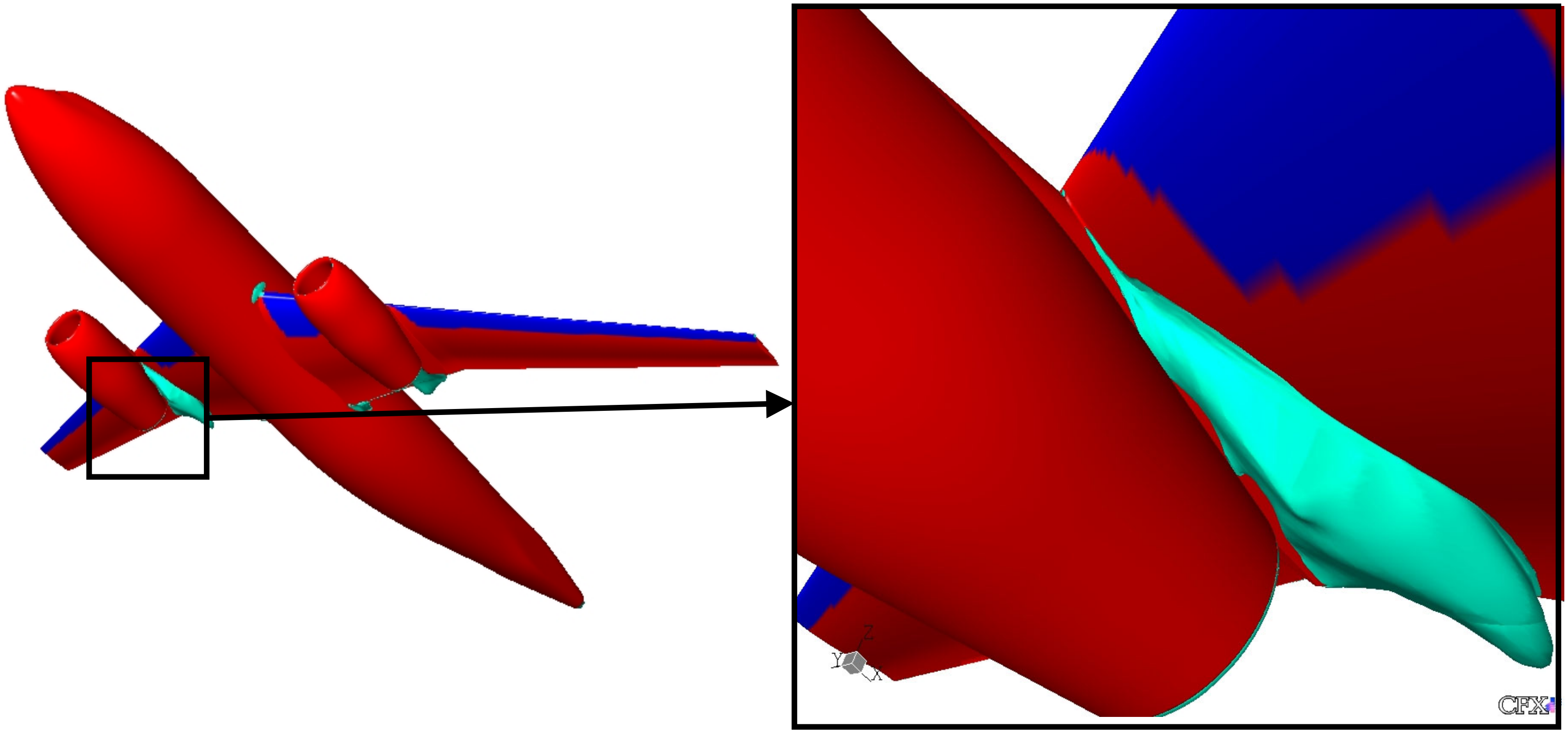
- **WB – Case**
  - **Single point convergence study (Ma=0.75, Re=3x10^6, c_l =0.5, fully turbulent, 3.45m, 5.82m, 10.13m nodes)**
  - **Drag polar a=-3°,-2°,-1.5°,0°,1.0°,1.5° - medium grid**
  - **Boundary layer transition specified – (P_k=0). Upper 5% at root, 15% at kink, 15% at η=0.844, 5% at tip. Lower 25%**



- **WBNP – Case**
  - **Single point convergence study (Ma=0.75, Re=3x10^6, c_l =0.5, fully turbulent, 4.89m, 8.43m, 13.68m)**
  - **Drag polar a=-3°,-2°,-1.5°,0°,1.0°,1.5° - medium grid**
  - **Boundary layer transition specified – P_k=0, Upper: 5% at root, 15% at kink, 15% at η=0.844, 5% at tip. Lower 25%**
  - **Boundary layer transition critical at wing-pylon intersection – potential for laminar separation at negative angles of attack**



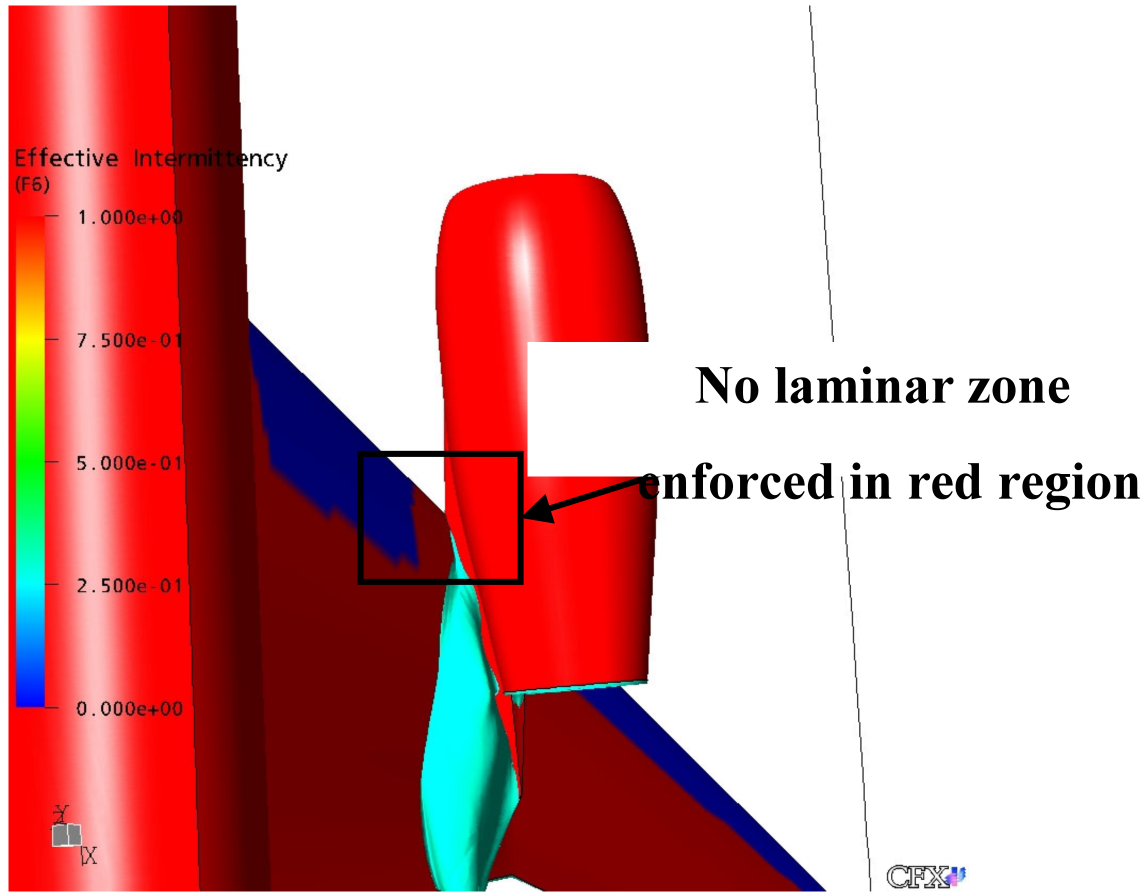
Pylon Separation - Transition



Separated Flow, α=-2°

Pylon Separation - Transition

- Laminar zone on lower surface was not enforced at wing-pylon intersection
- Otherwise a large separation was observed
- Separation induced transition likely in the experiments

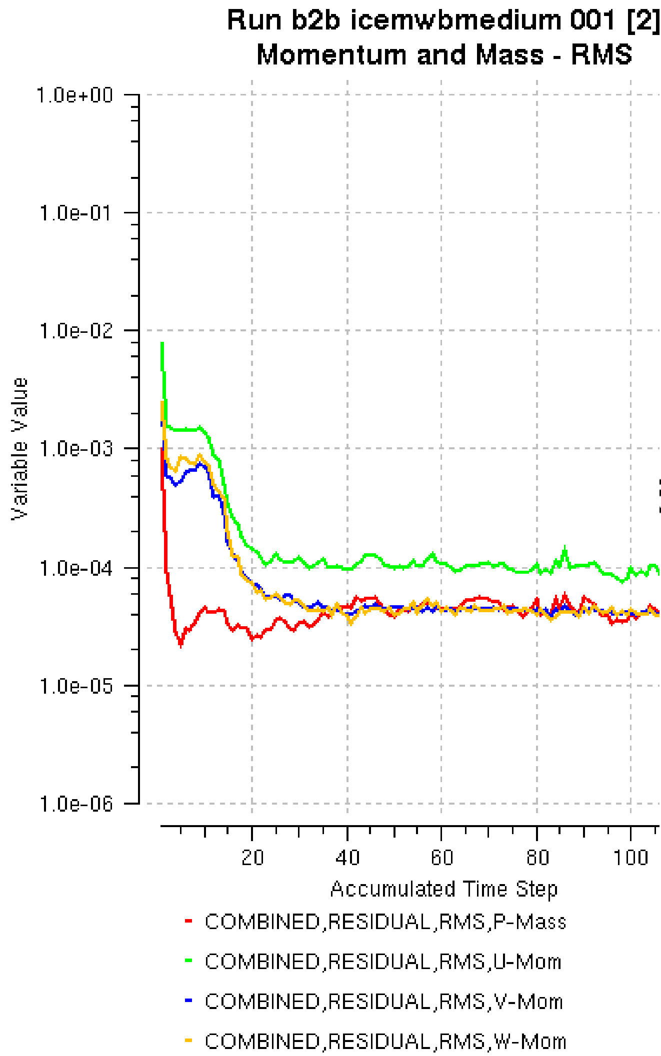


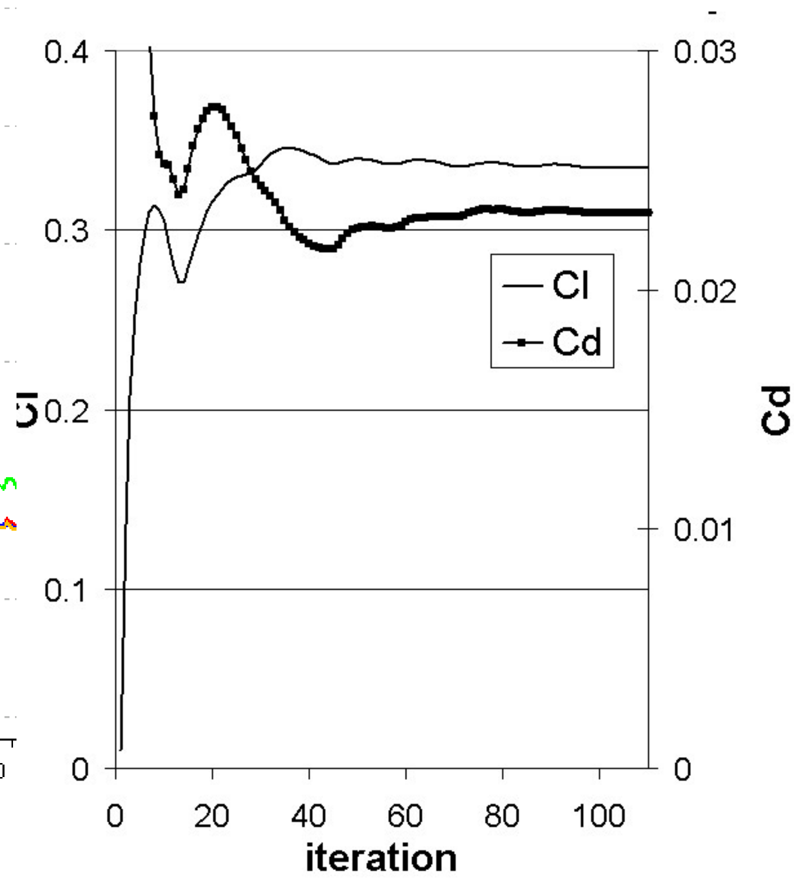
Time Integration

- Solution for most cases would not converge to machine zero.
- For small time steps ($\Delta t \sim 1.x10^{-5}$) unsteady oscillations are observed at the wing-body separated zone.
- Computations carried out in unsteady mode (3 coefficient loops) but with larger time step ($\Delta t=2.x10^{-4}$) to damp unsteadiness.
- Convergence reached in ~120 time steps
- Computing times ~20-24h for 5.82 m nodes on 16 Proc AMD 1900 + Linux cluster.
- Note that steady state simulations are factor 3 faster (no coefficient loops).

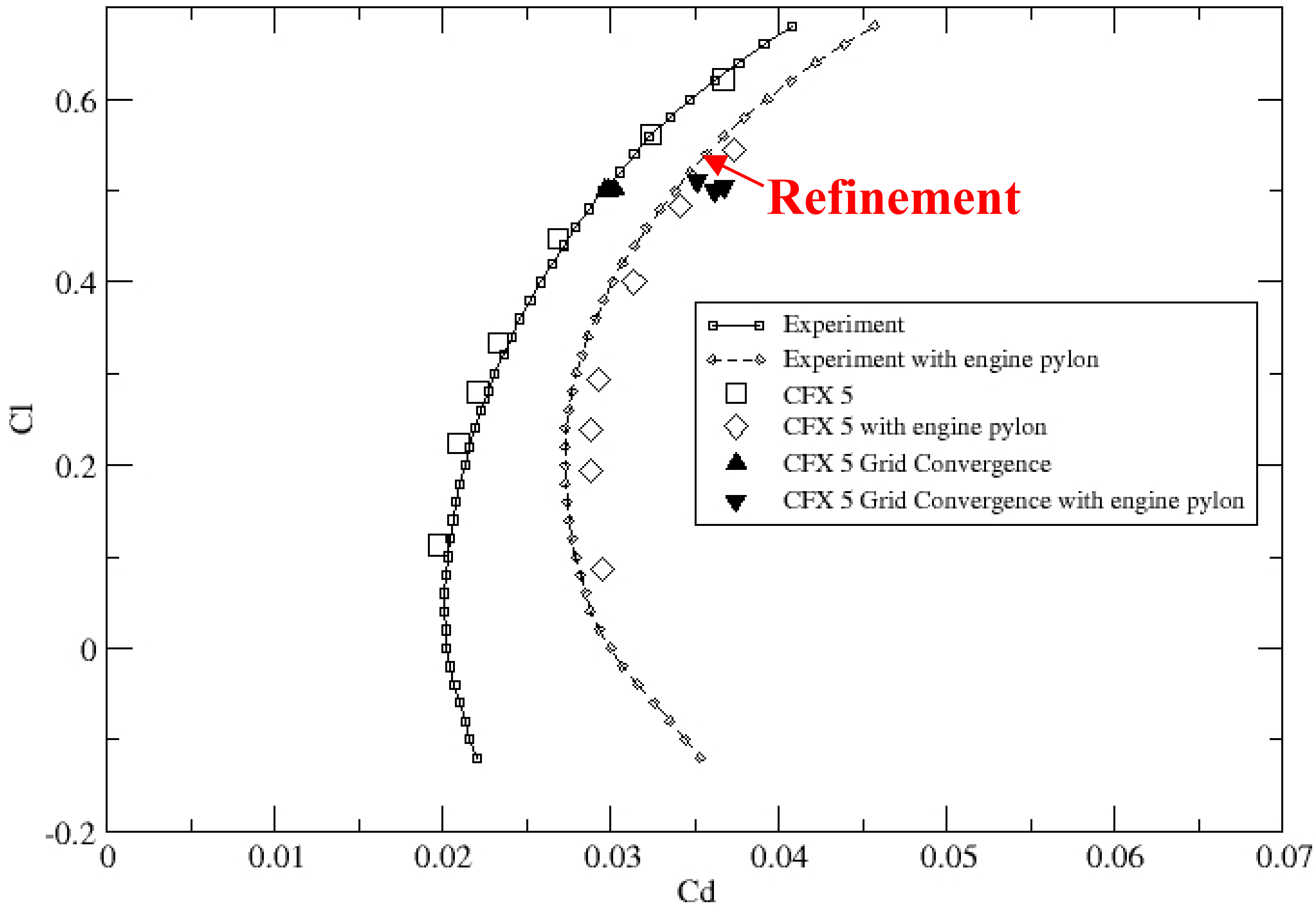
Convergence History

- **Unsteadiness due to oscillating separation at wing-body damped by use of large time step $\Delta t=2x10^{-4}$**
- **Good convergence in the forces after 100-150 time steps for all cases**



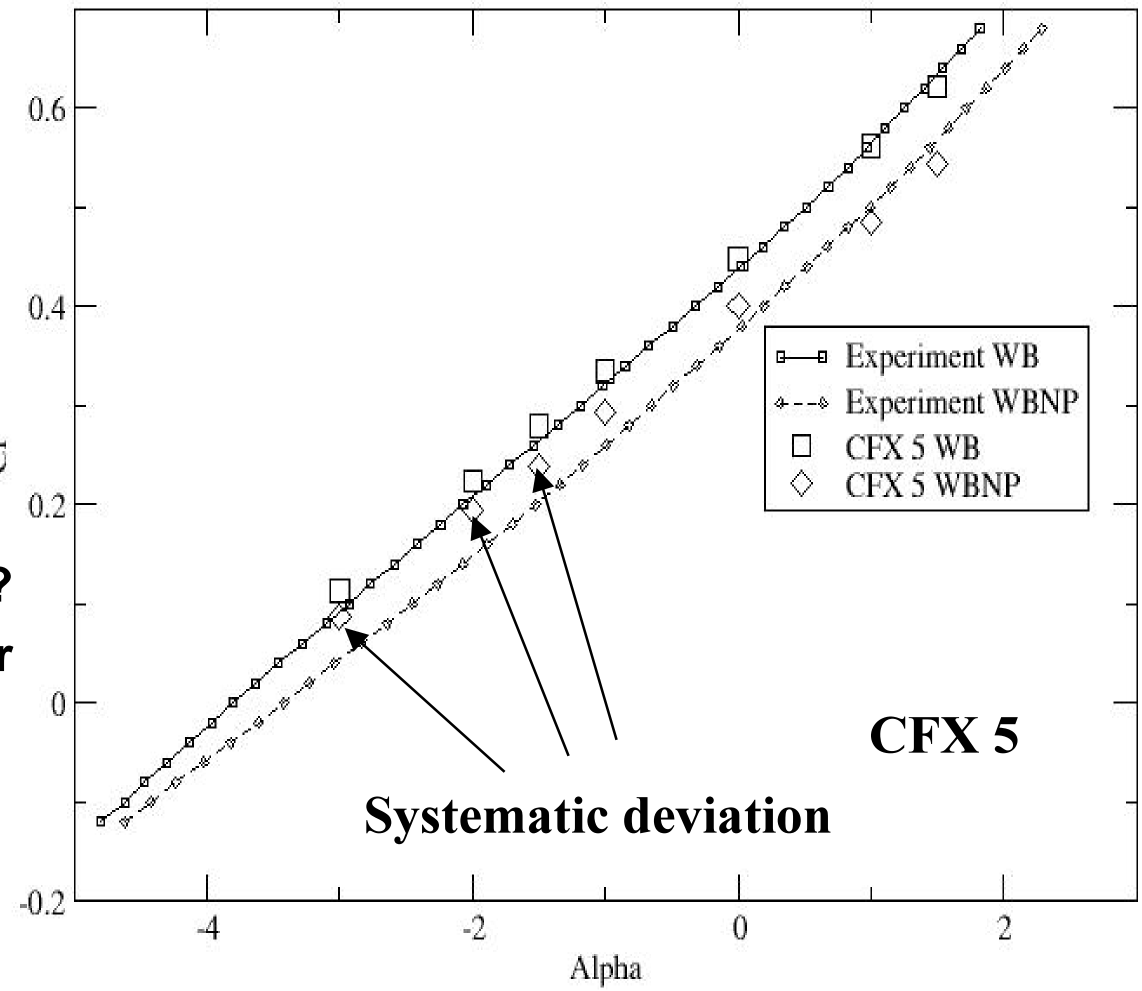


Grid Convergence

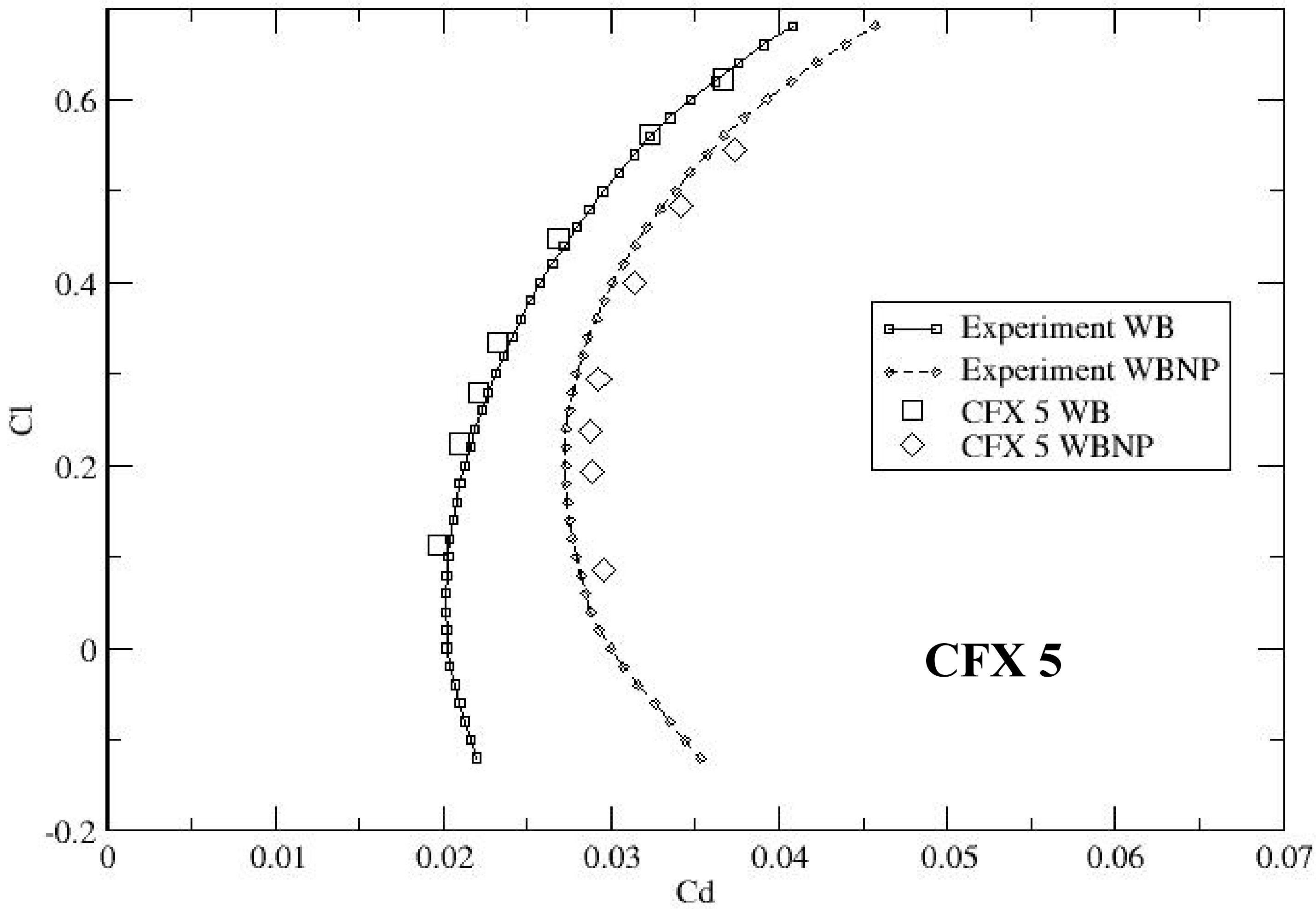


Lift Curve Slope

- **Accurate predictions for WB over entire α range**
- **Systematic deviations for negative a for WBNP case**
  - **Transition?**
  - **Wall interference?**
  - **Also seen in other simulations**

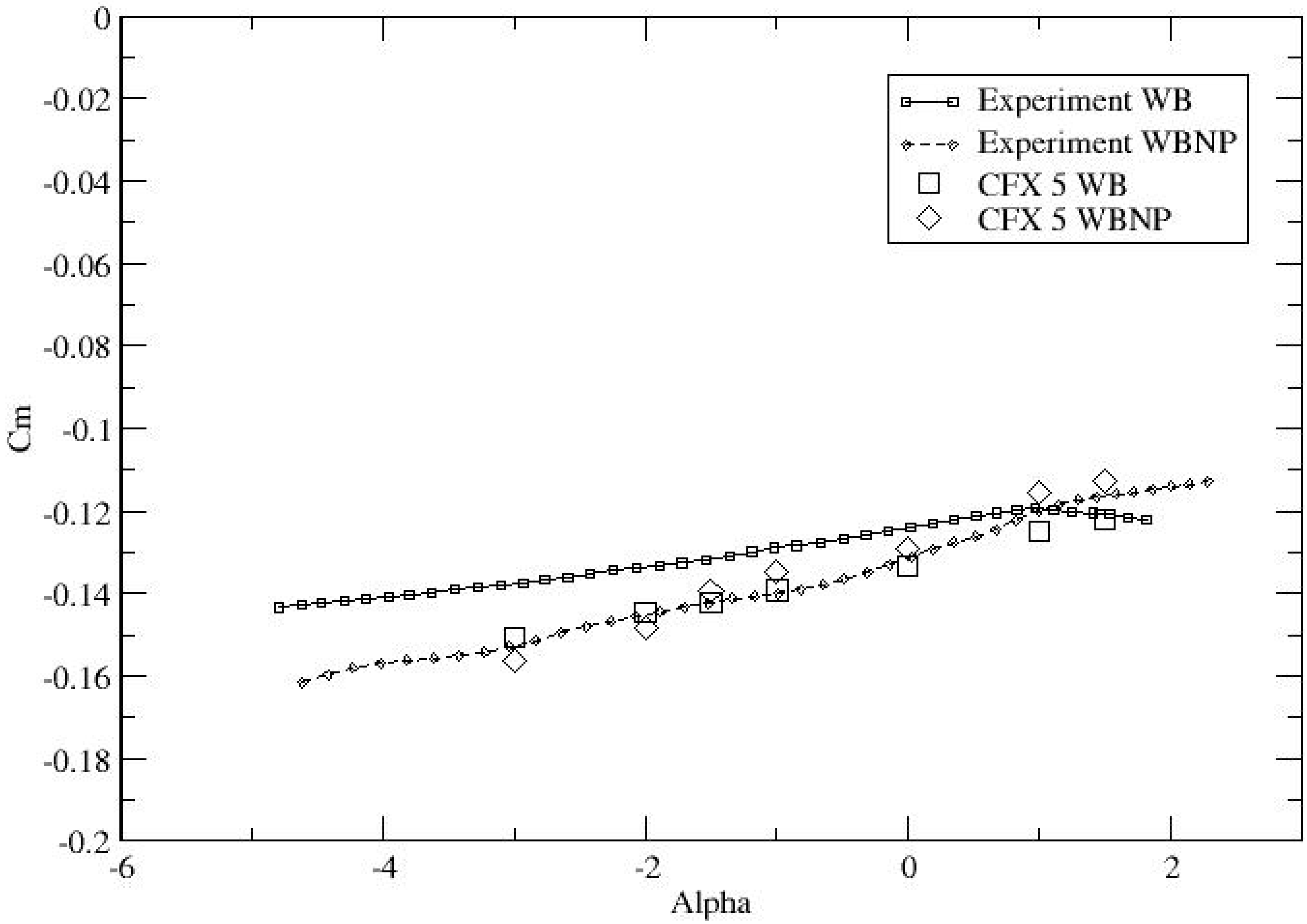


Drag Polar

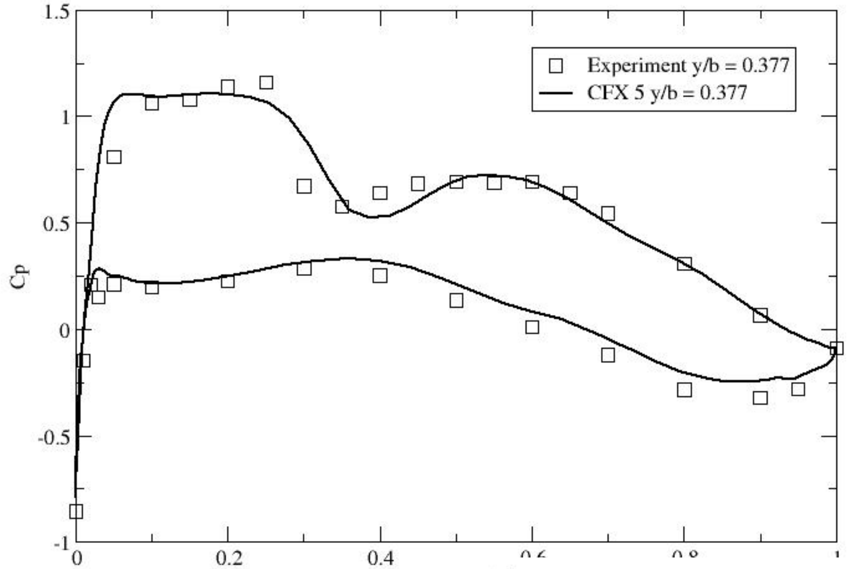


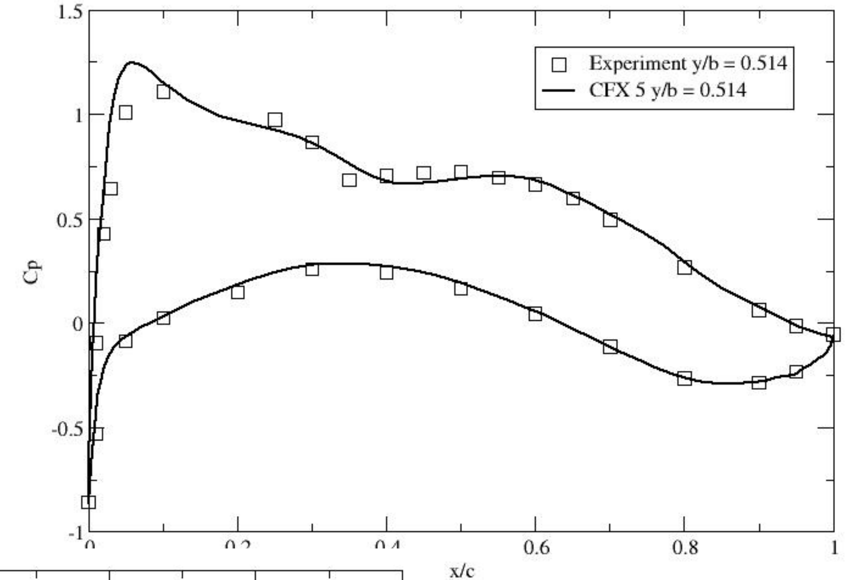
Cl
0.6
0.4
0.2
0
-0.2
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
Cd
Experiment WB
Experiment WBNP
CFX 5 WB
CFX 5 WBNP
CFX 5

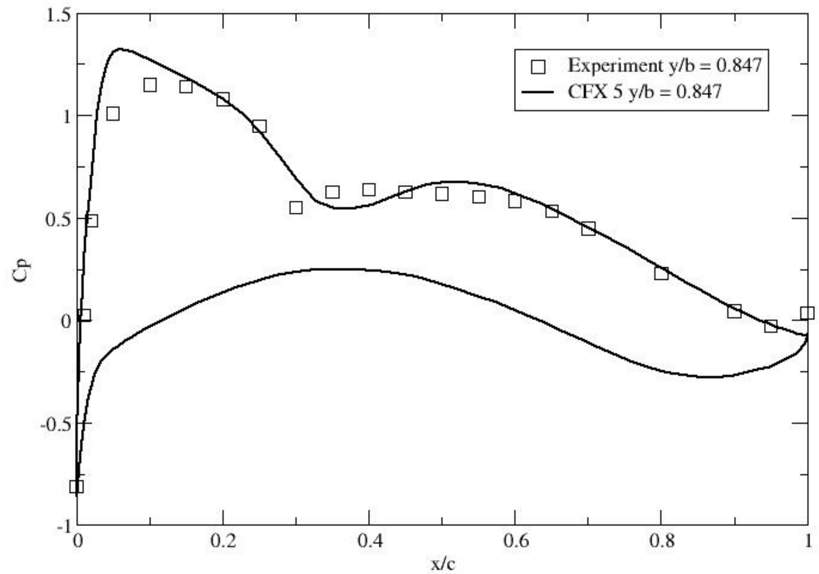
Pitching Momentum



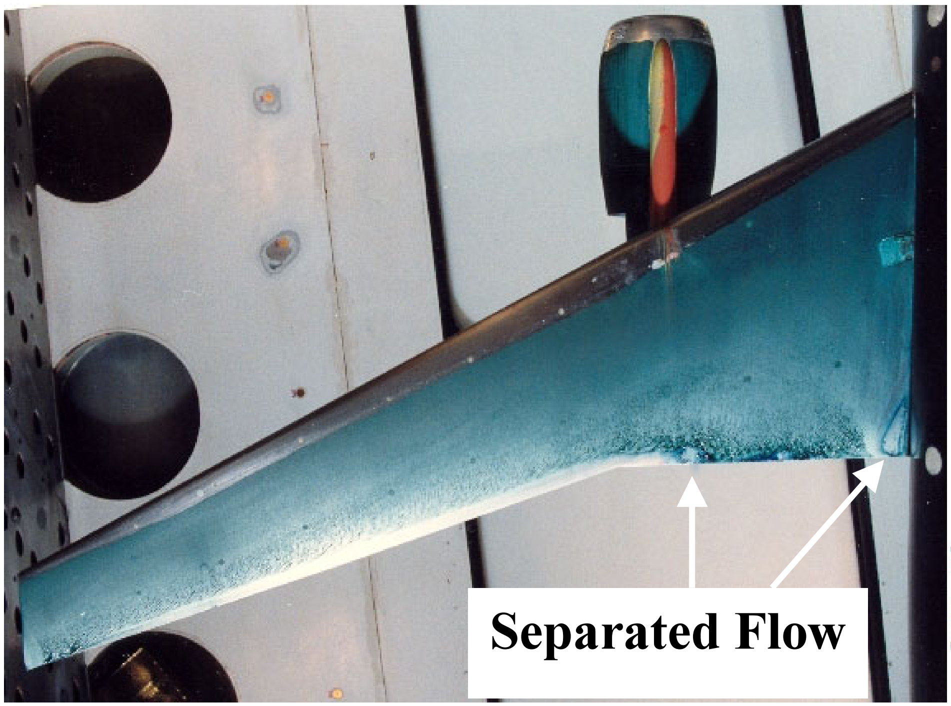
Cp Distributions WBNP



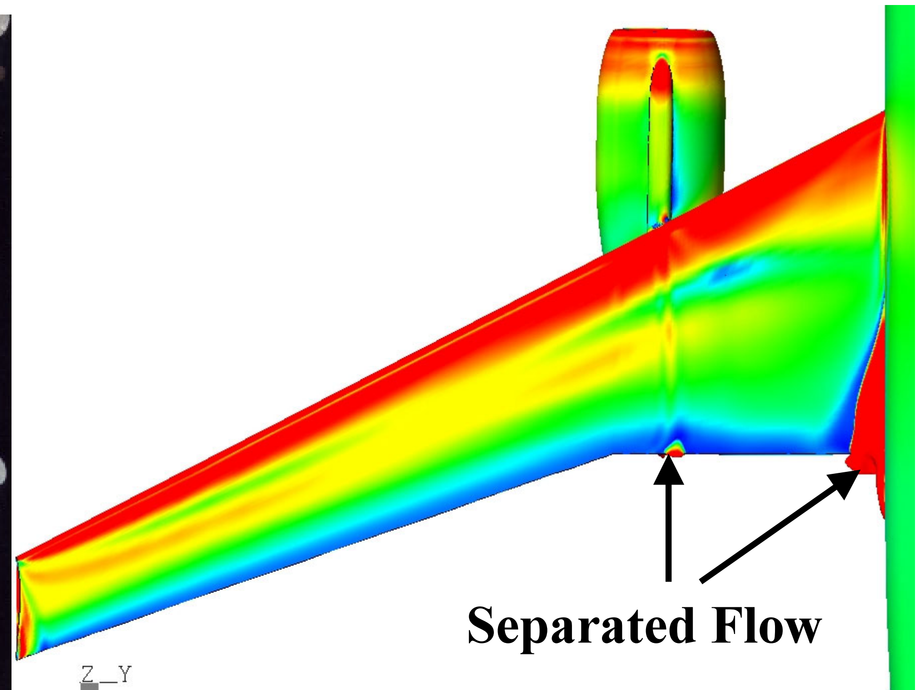




Upper Surface Flow Vis.

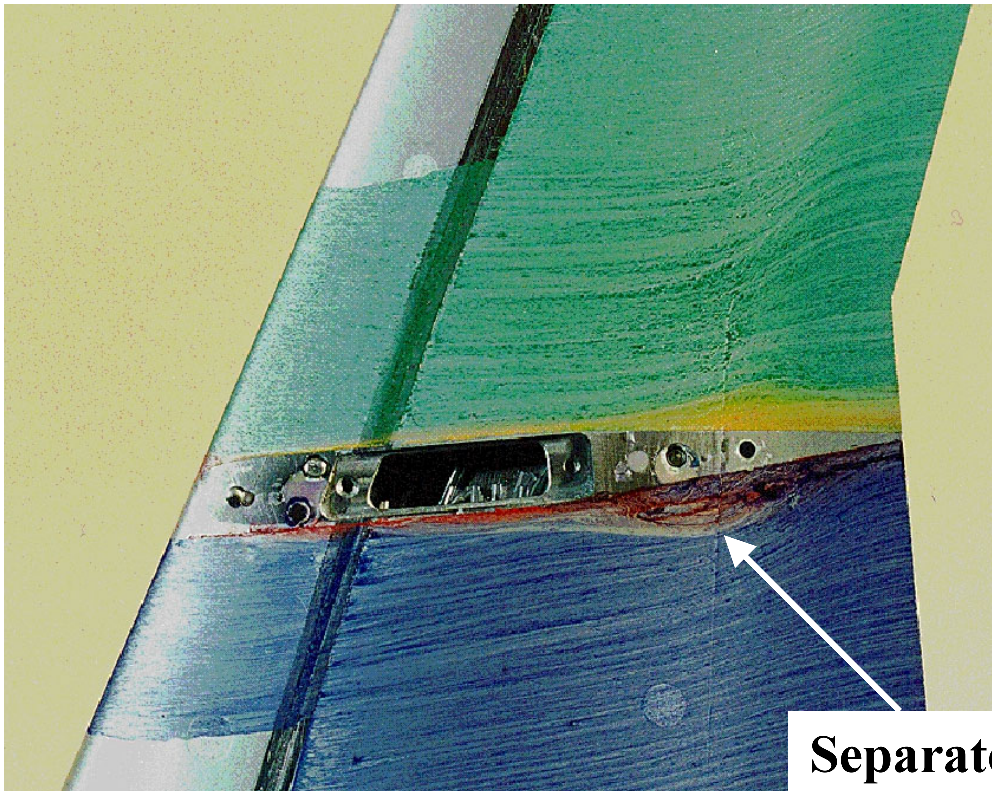


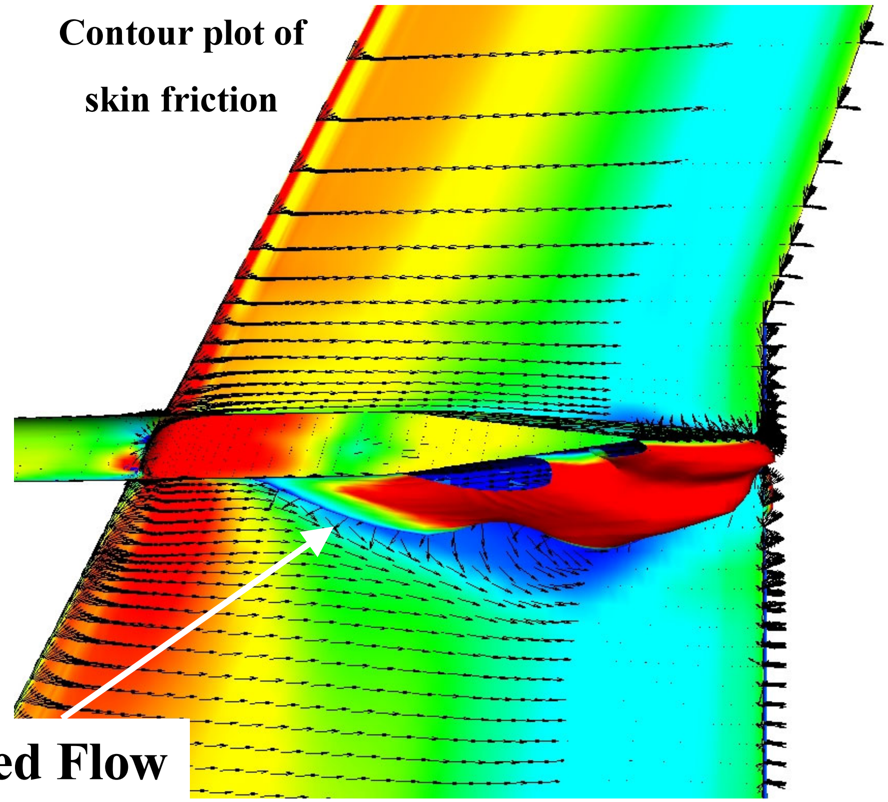
Experimental Oil Flow



CFX 5

Lower Surface Flow Vis.





Experimental Oil Flow **CFX 5**

Summary

- Simulations carried out within the Flomania project
- Small grid sensitivity for both cases
- Unsteady simulation performed due to unsteadiness in wing-body separated zone
- Convergence typically in ~120 time steps
- Good agreement with experiments for drag polar for both cases
- Transition location specification problematic for negative α for WBNP case due to separation at the pylon
- Systematic differences for WBNP c_l-α curve at negative α (seen also in other simulations)