

Drag Prediction Workshop Results Using the Parallel Multigrid Solver KFLOW3D

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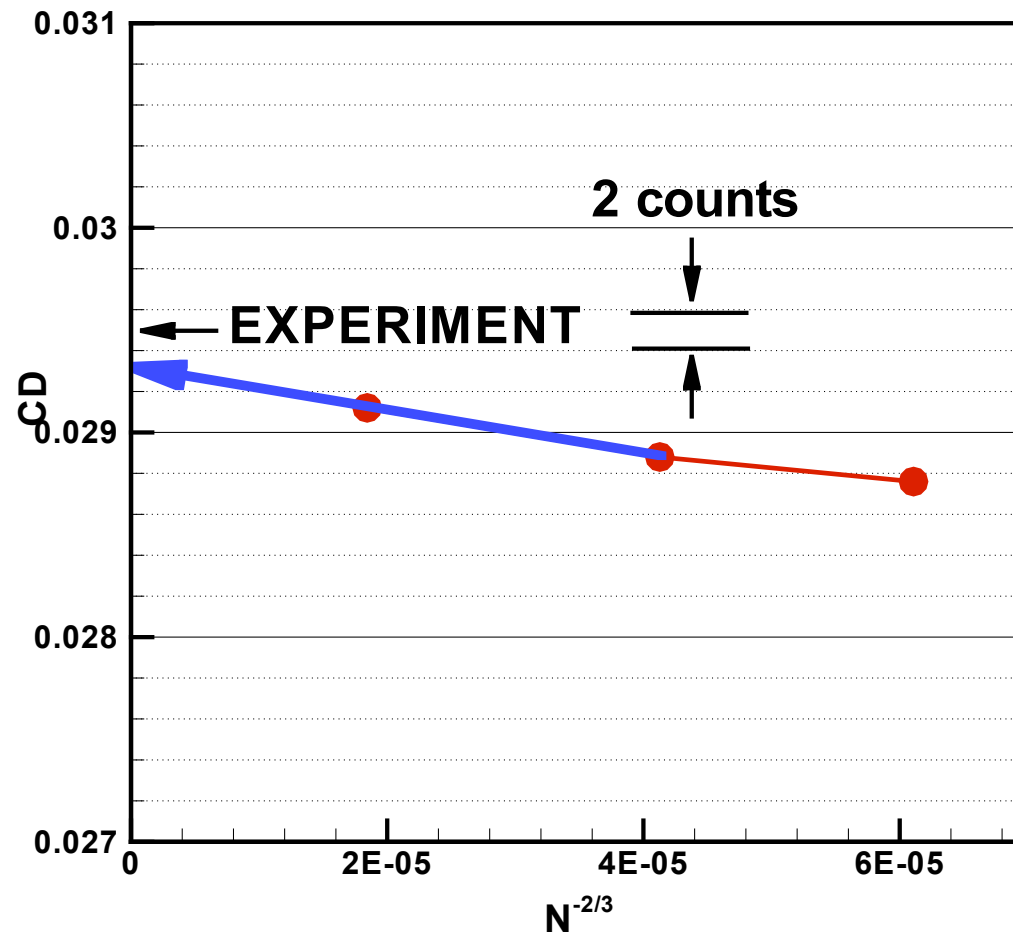
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Overview : KFLOW3D

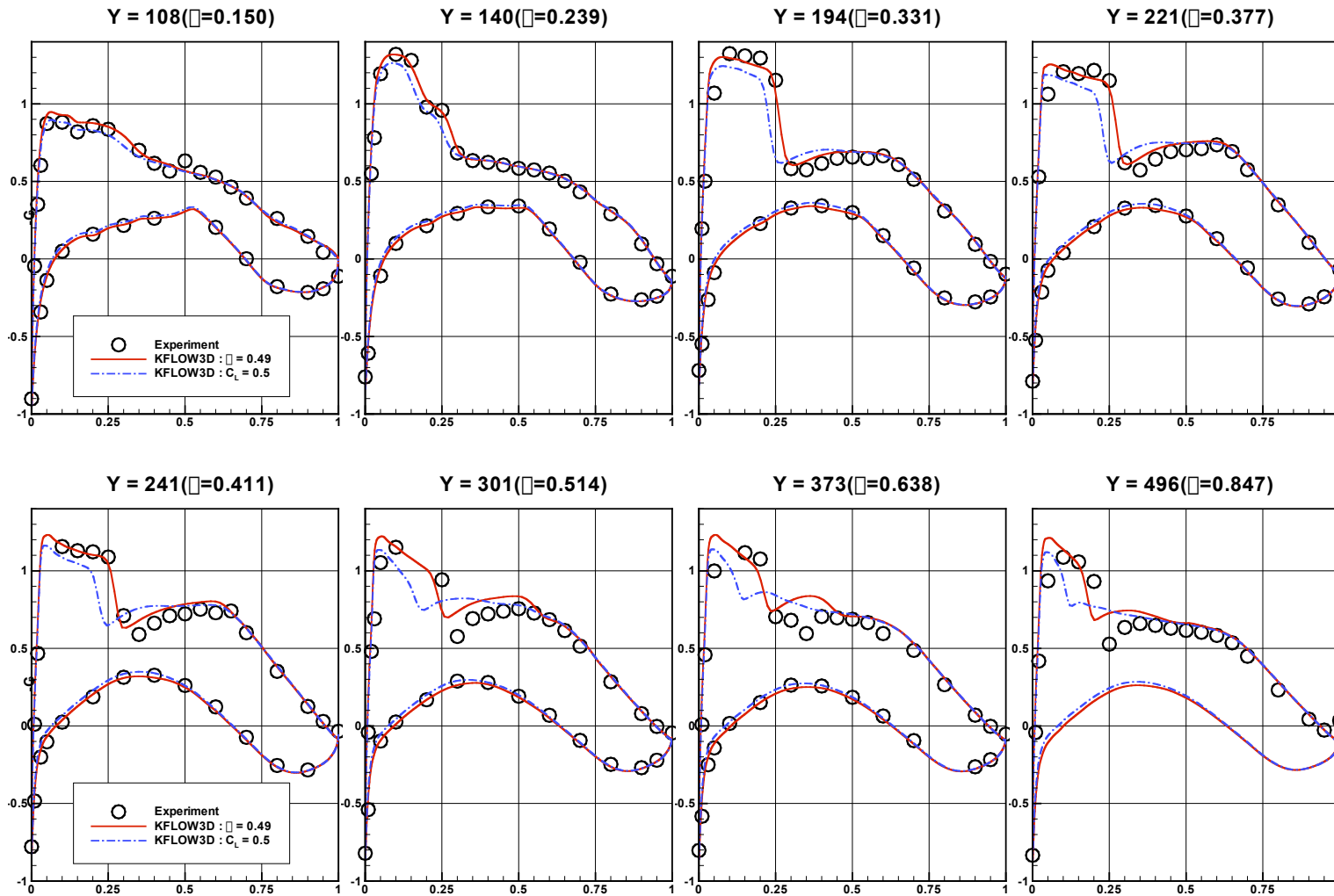
- Finite volume multi-block solver
- Roe FDS with Harten's entropy fix function
- Globally 2nd order MUSCL with van Albada limiter
- K-w Wilcox-Durbin+ model using a nonlinear eddy viscosity model("fully-turbulent" mode for all cases)
- Multigrid Diagonalized ADI method for both the N-S and k-w equations
- Parallel computing using MPI library
- Convergence criteria:
 - ✓ Fixed Alpha : Normalized RMS of density residual $< 1.e-05$
 - ✓ Fixed CL : $|CL - CL_{target}| < 1.e-04$ for 1000 iterations

CASE 1: Single Point Convergence Study(WB)



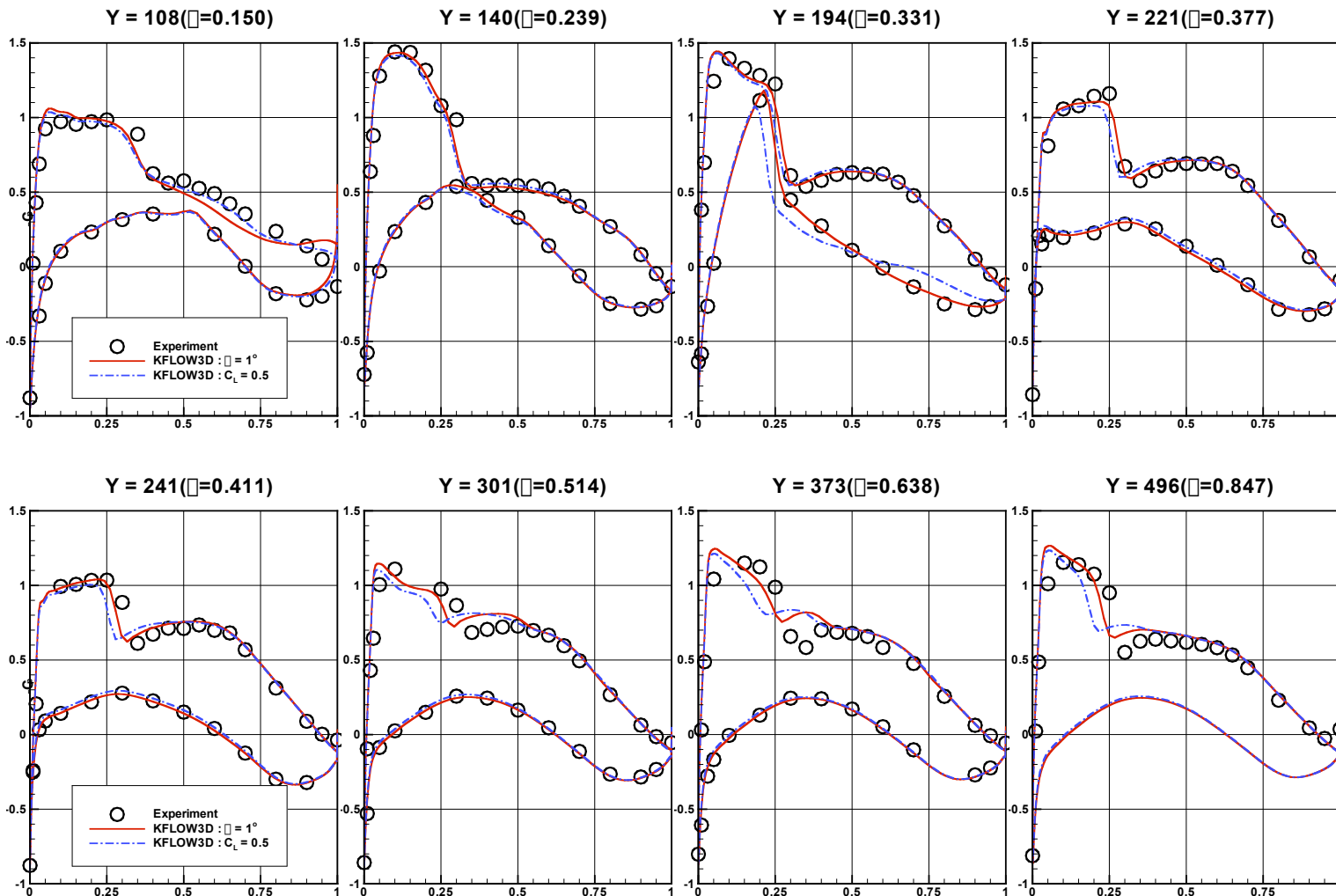
- Asymptotic C_D for 2nd order global accuracy is low by 2 counts.
- C_D on fine grid is low by 4 counts.

Cp Comp. with Matched C_L , Alpha(WB)



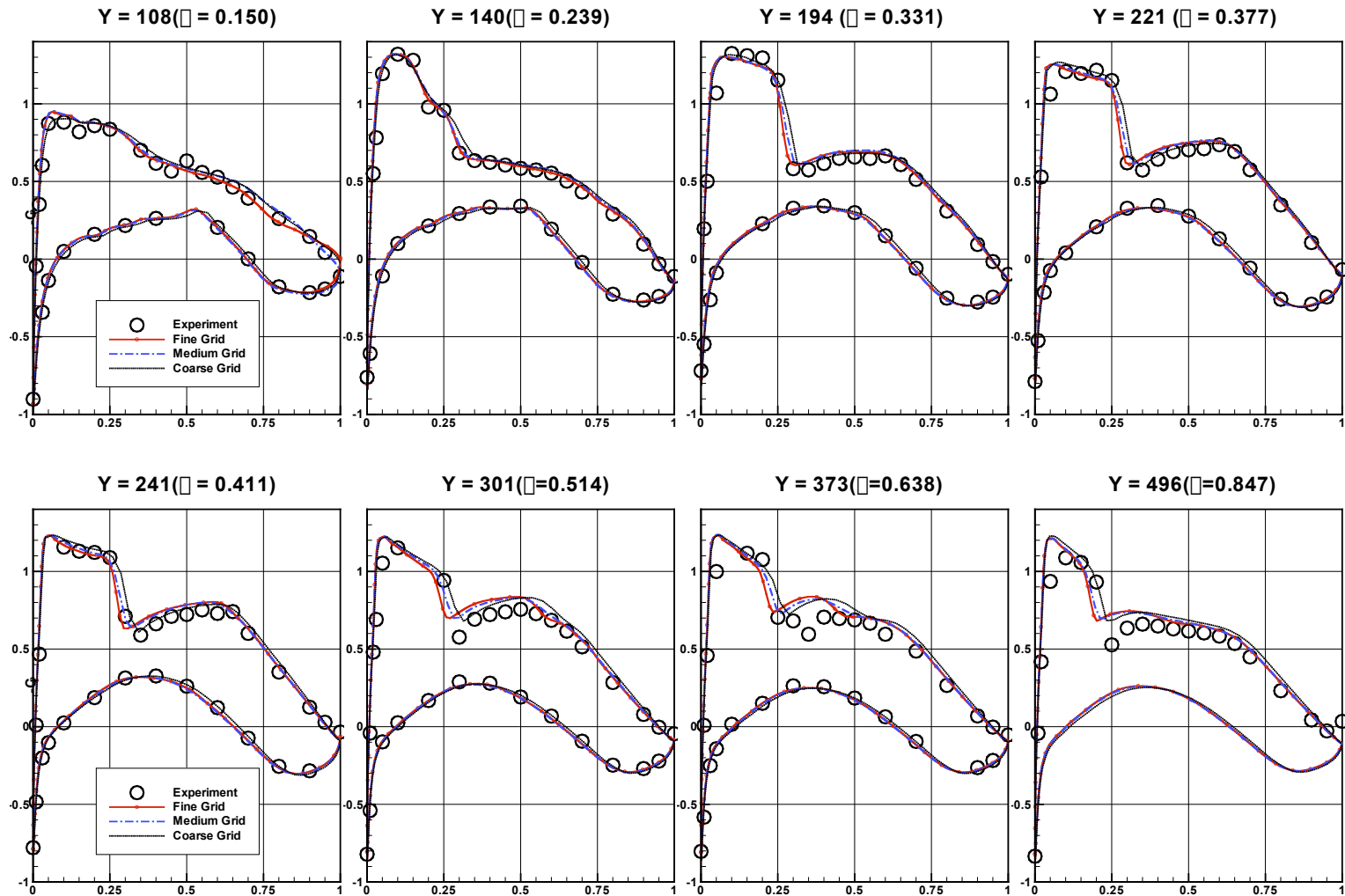
- Fixed-alpha results are in better agreement with experiment.

Cp Comp. with Matched CL, Alpha(WBNP)



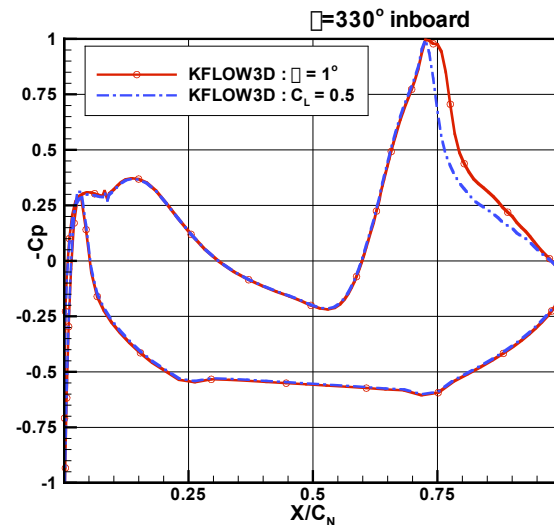
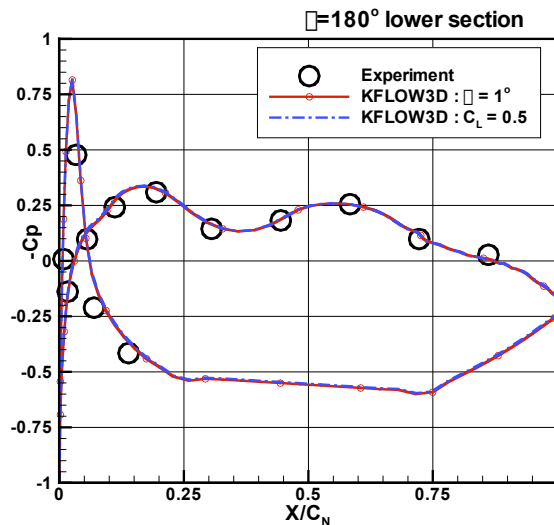
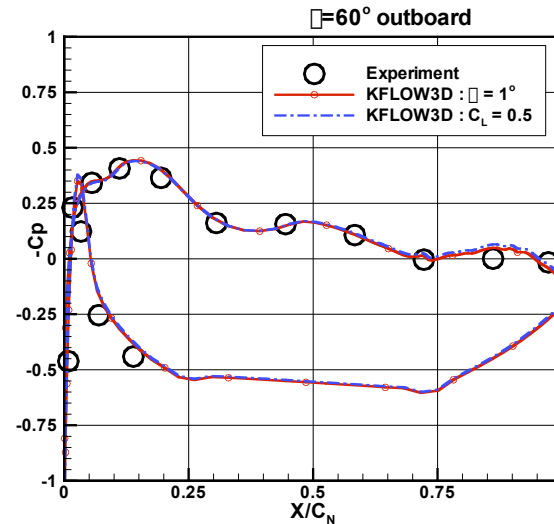
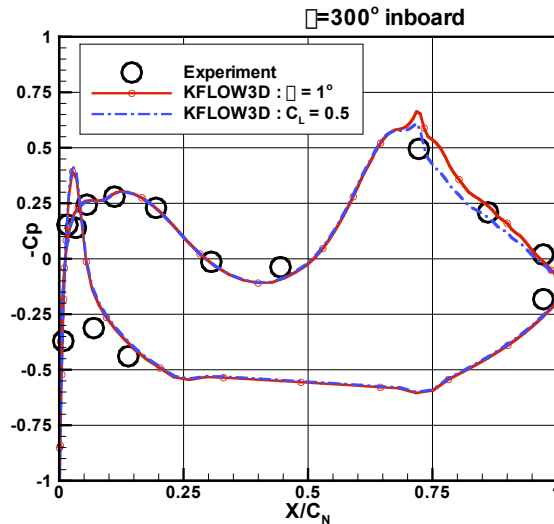
- $Y=140\sim 220$: effect of the pylon-nacelle
: weak shock generated just at inboard side

Cp Comparison by Grid(WB)



- Fixed-alpha results are in better agreement on fine grid.
- The visible differences are shown around the shock.

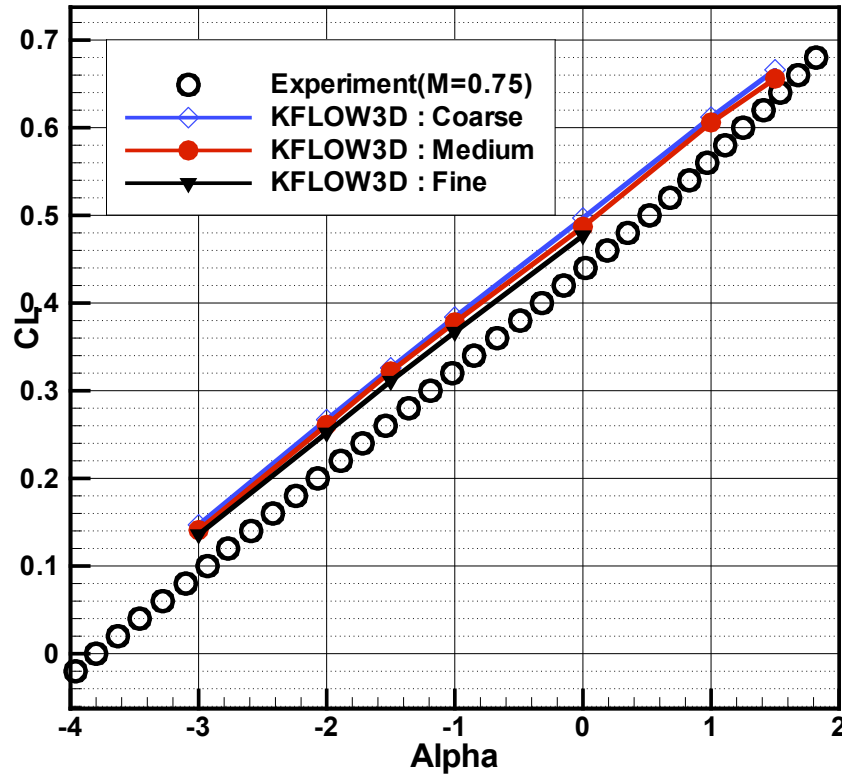
Cp Comp. with Matched C_L , Alpha(Nacelle Surface)



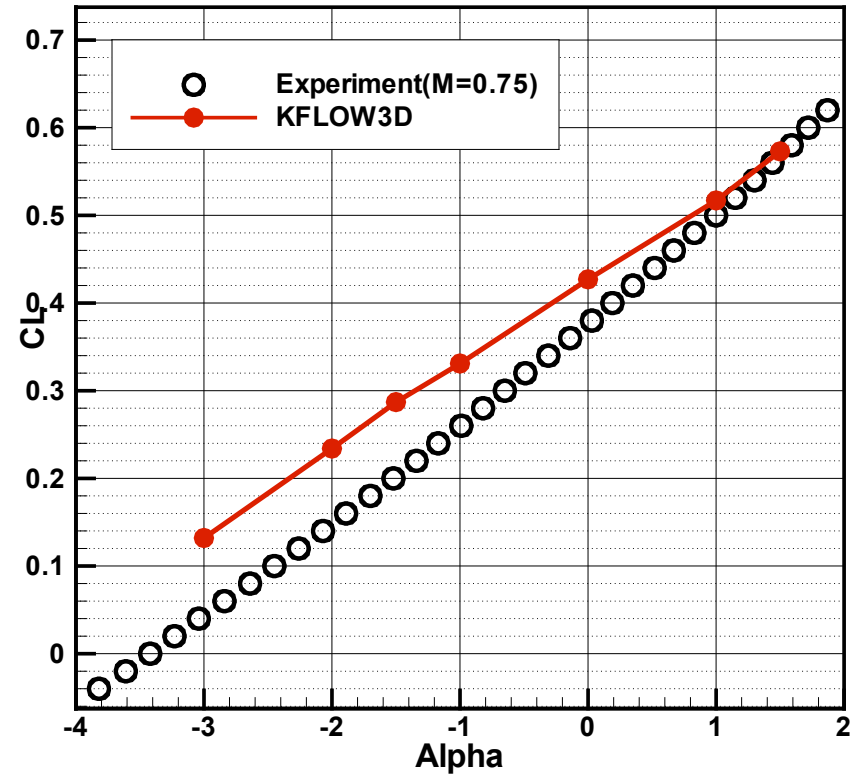
- Cp distributions at inner and outer surface of the nacelle
- Weak shock at 330 degrees near the pylon

CL vs. Alpha

Wing-Body



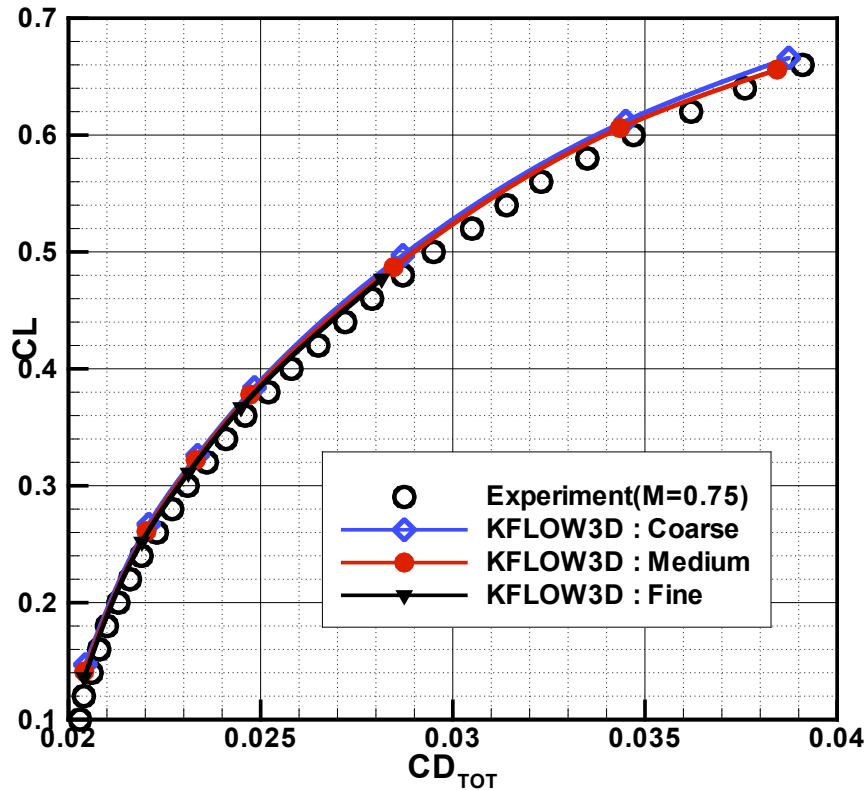
Wing-Body-Nacelle-Pylon



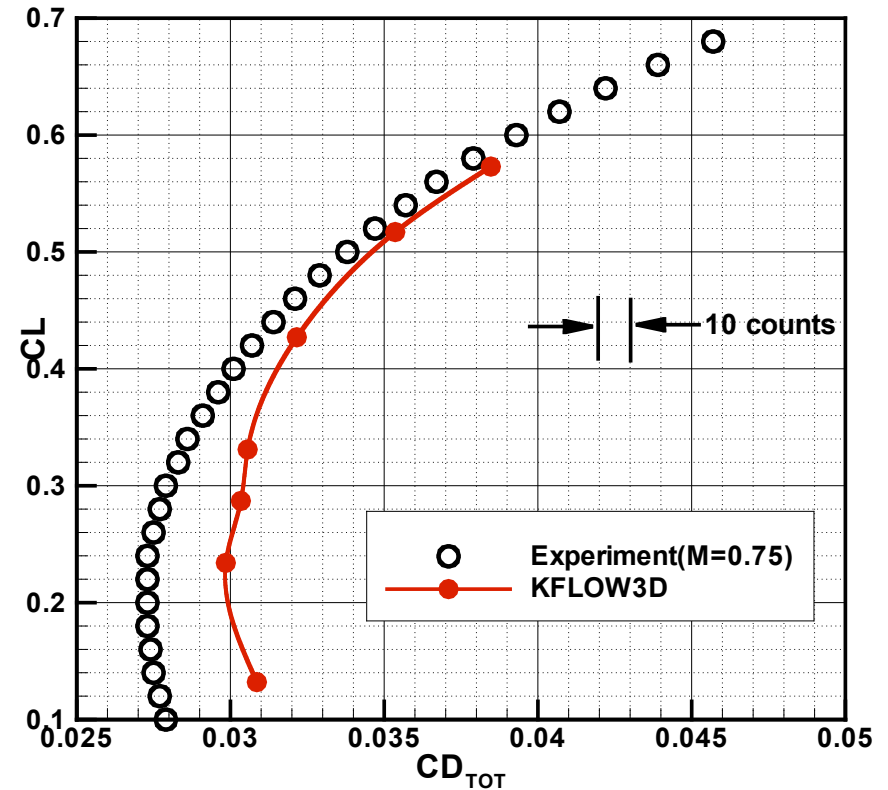
- CL is higher than the experiment for both WB and WBNP.
- CL on fine grid is in best agreement with experimental data.

Drag Polar

Wing-Body

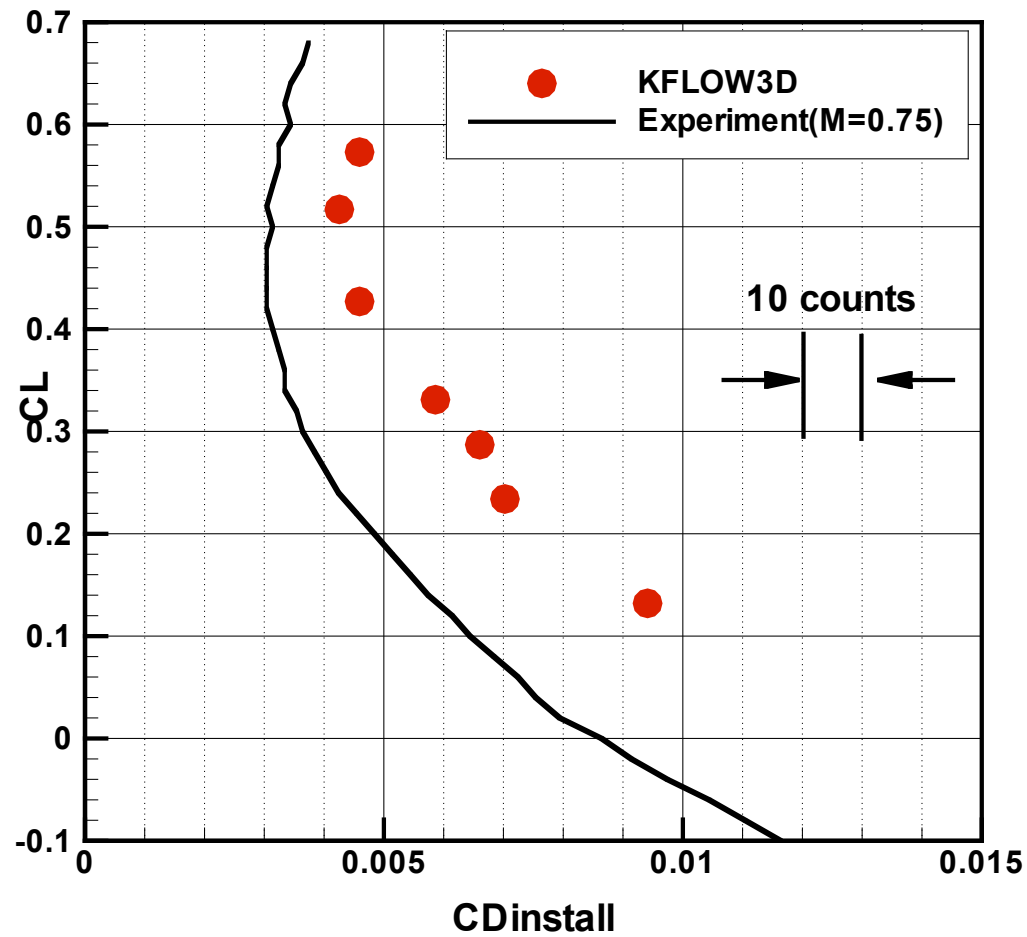


Wing-Body-Nacelle-Pylon



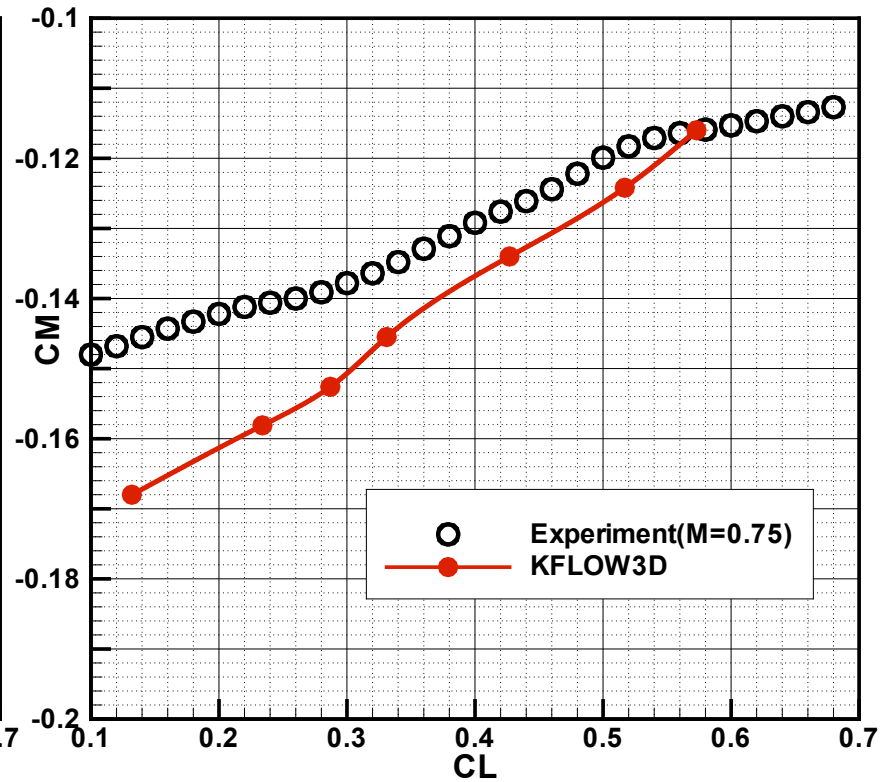
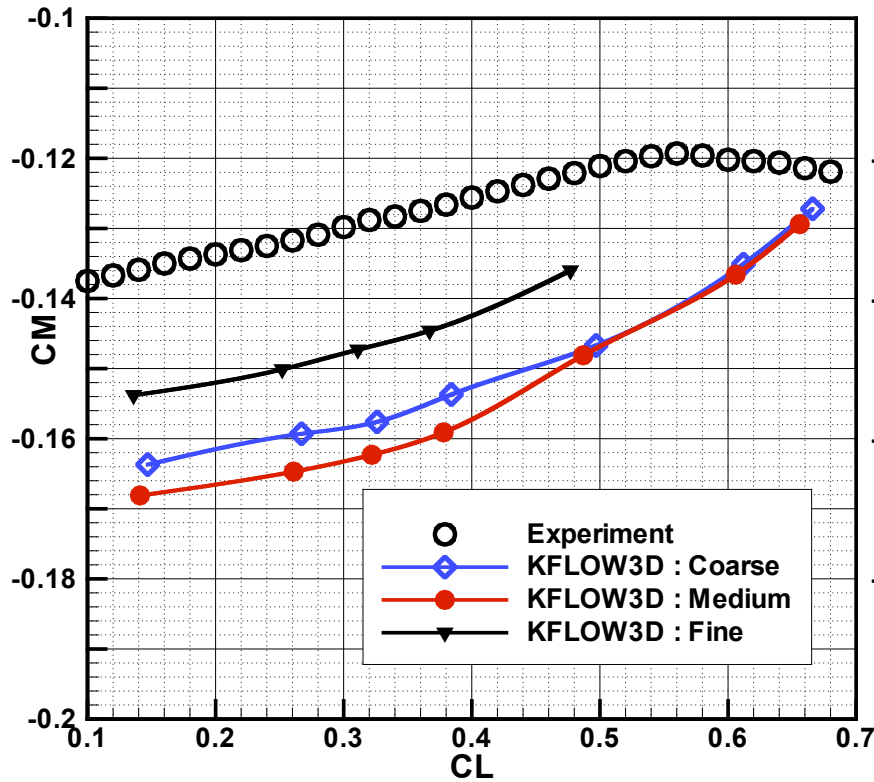
- Drag polar is excellent for WB, but shows about 30 counts difference for WBNP.

Installation Drag



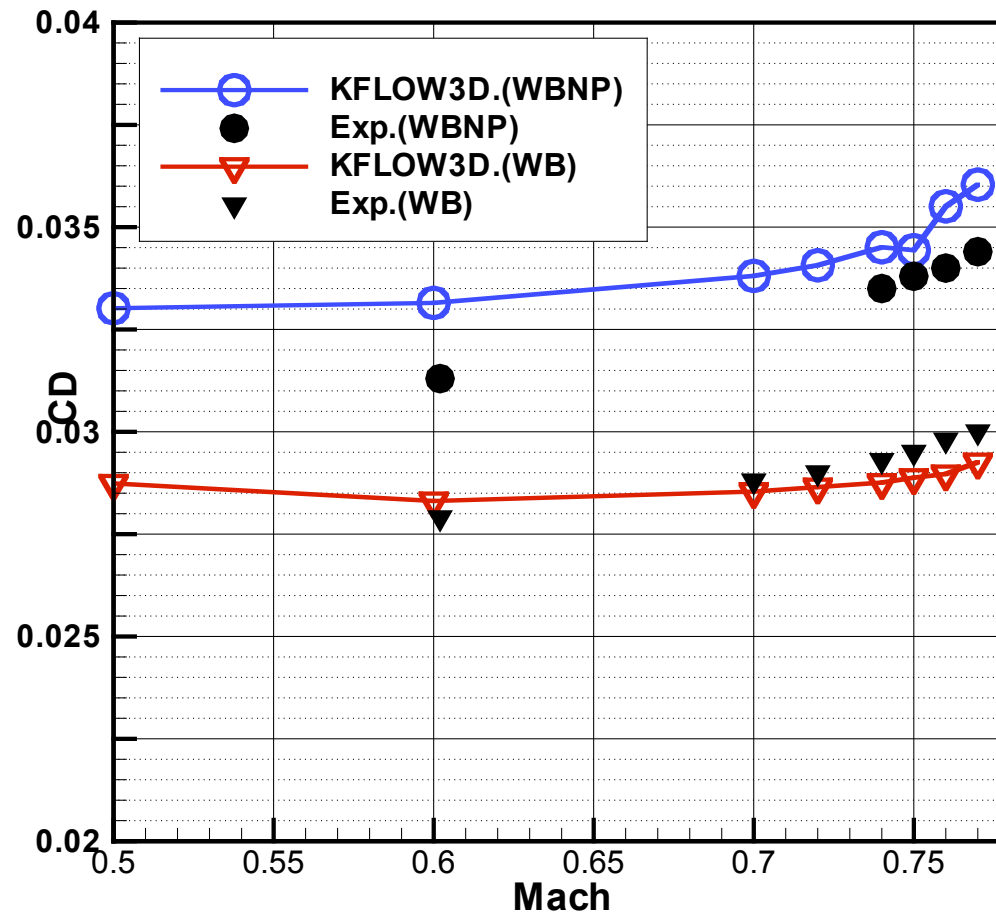
- Installation drag : about 30 counts by WBNP result.
- Finer grid near the pylon-nacelle needed?

CL vs. CM



- Fine grid gives highly improved results for CM

CASE 4: Drag Rise



- Increased discrepancies at higher Mach number for WB

Summary

- **Single point grid convergence study for WB case shows good agreement with experimental data(only 4 counts discrepancy for fine grid)**
- **Shock location and strength are sensitive to the grid density or quality**
 - ➔ **More accurate results may be achieved by improved grid for WBNP**