CFL3D and OVERFLOW Results on the DLR-F6 Configuration from the 3rd Drag Prediction Workshop

Christopher L. Rumsey

S. Melissa Rivers

Joseph H. Morrison

NASA Langley Research Center

Methods

- CFL3D – cell-based upwind Roe scheme
  - using supplied overset grids
  - SST turbulence model
  - thin layer or full N-S available (*new feature in 2005)
- OVERFLOW – node-based upwind Roe scheme
  - using supplied overset grids
  - SST turbulence model
  - thin-layer or full N-S available

Earlier work

- Previous similar study on DLR-F6 from DPW-II:
  - Lower Re (3 million)
  - Most comparisons between CFL3D and OVERFLOW for SA model (overset grids)
  - CFL3D runs on 1-to-1 grids explored other turbulence models (SST & EASM-ko)
  - *Computers & Fluids* 34 (2005) 785-816

Some conclusions from our DPW-II study

- Grid density studies inconclusive
  - 1-to-1 grids were poor quality and inconsistently refined
  - Overset grids indicated likelihood that medium-level grids still not in asymptotic region
  - Estimate: medium grids in error by ~10 counts from infinitely-refined grid
- Effect of viscous model
  - Full N-S predicted larger wing-root separation bubble than thin-layer
  - Other than this, no major global effect of t1 vs. t3 vs. full: max 5 drag counts difference

Some conclusions from our DPW-II study

- Effect of code
  - CFL3D predicted consistently lower C_L levels than OVERFLOW (by at most 0.036)
  - At C_L=0.5, C_D was different by 5 counts (WB) between the two codes on med or fine grid levels

DPW-III Grid Study – CL=0.5, fully turbulent, SST

Code	WB(c)	WB(m)	WB(f)	FX2B(c)	FX2B(m)	FX2B(f)
CFL3D, thin	o	o	o	o	o	o
CFL3D, full	o	o	o	o	o	o
OVERFLOW, thin	X	X	X	X	X	X
OVERFLOW, full	o	o	X	X	X	o

(red shaded = unsuccessful – would not run/converge)

DPW-III Drag polar – fully turbulent, SST

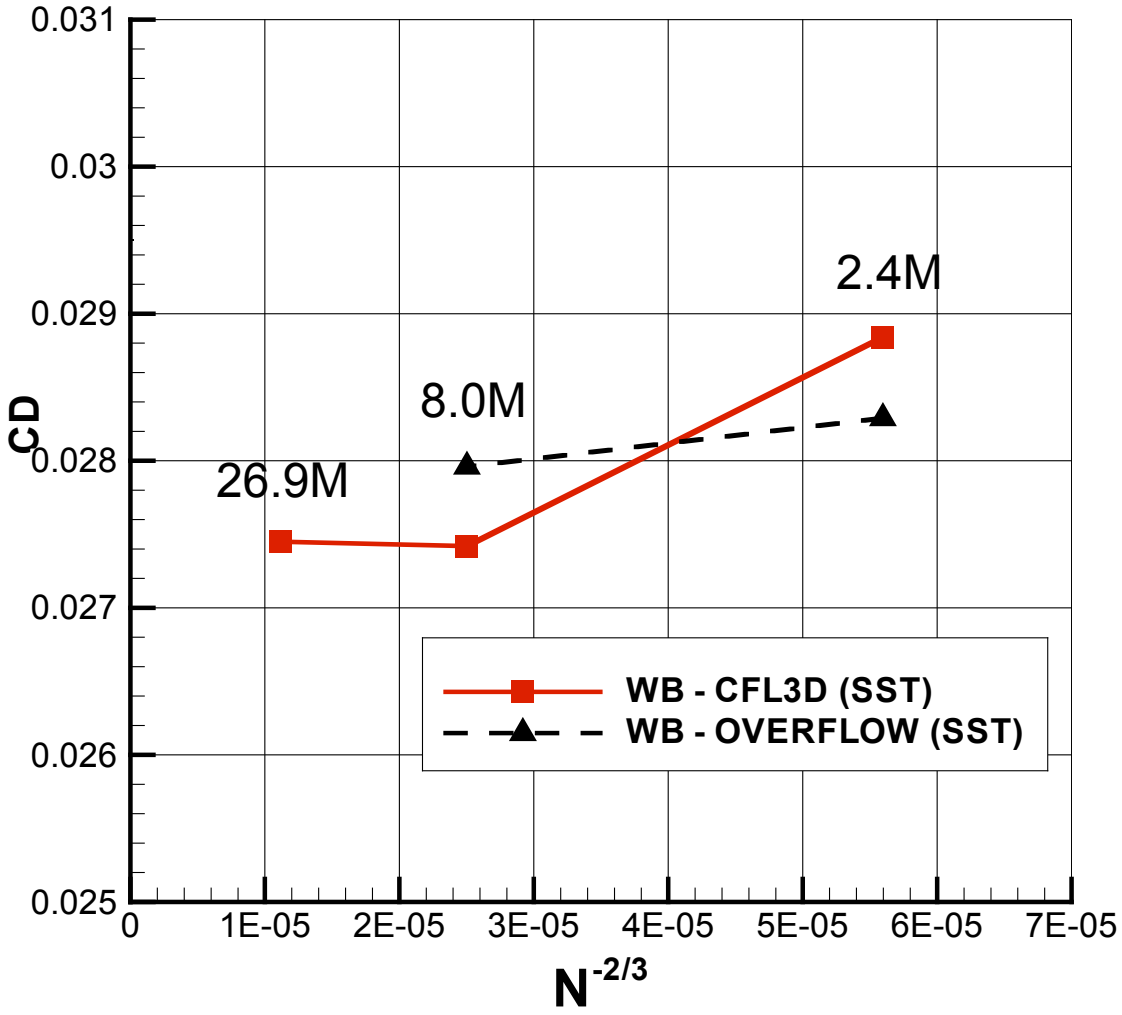
Code	Case	-3	-2	-1	-0.5	0	0.5	1	1.5
C, full	WB(m)	o	o	o	o	o	o	o	o
O, full	WB(m)	o	o	o	o	o	o	o	o
C, full	FX2B (m)	o	o	o	o	o	o	o	o
O, full	FX2B (m)	X	X	X	X	X	X	X	X
C, thin	WB(m)					o			
O, thin	WB(m)					X			
C, thin	FX2B (m)					o			
O, thin	FX2B (m)					X			

(red shaded = unsuccessful – would not run/converge)

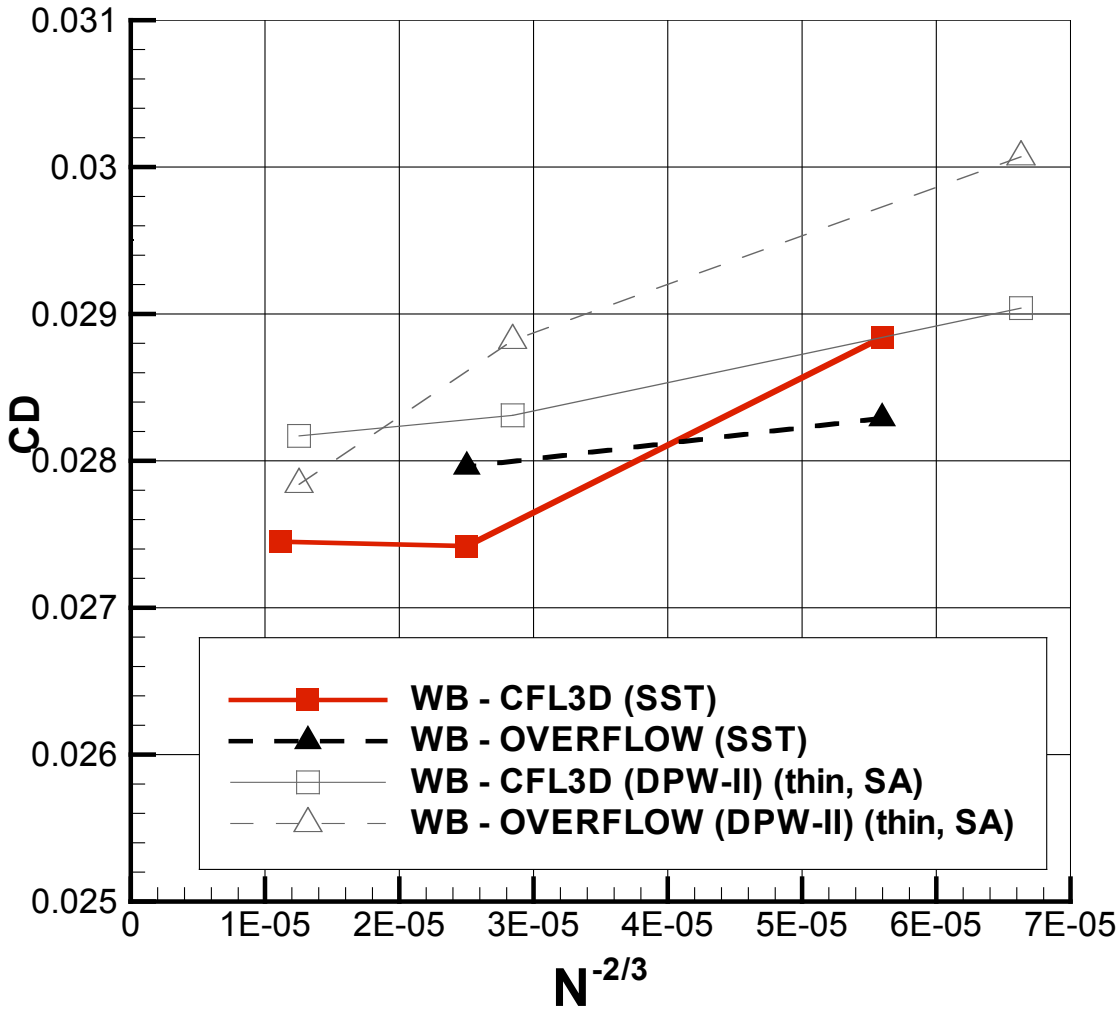
Summary of runs

- 60 runs planned (30 for each code)
- OVERFLOW had problems running SST turbulence model
  - Only 11 out of 30 cases worked
  - Particular difficulties with thin-layer and FX2B configuration

Grid effect, WB, C_L=0.5

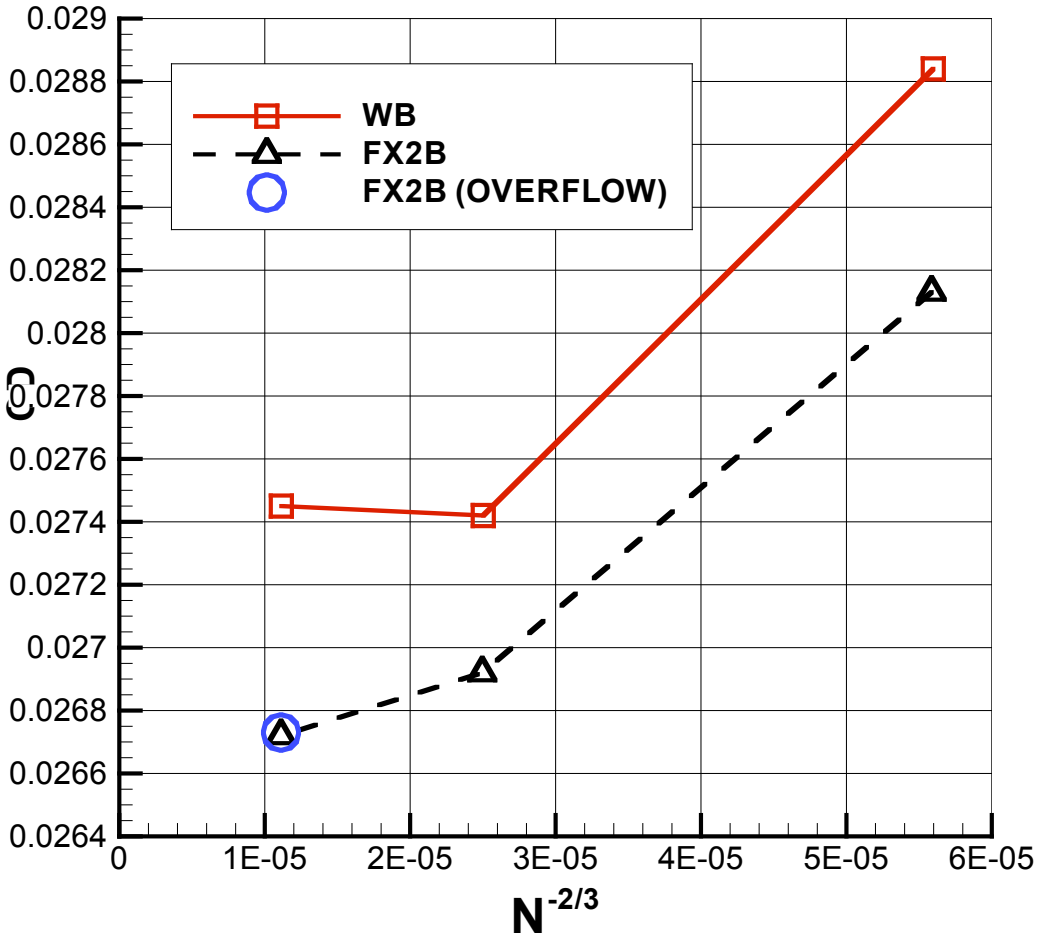


Grid effect, WB, C_L=0.5



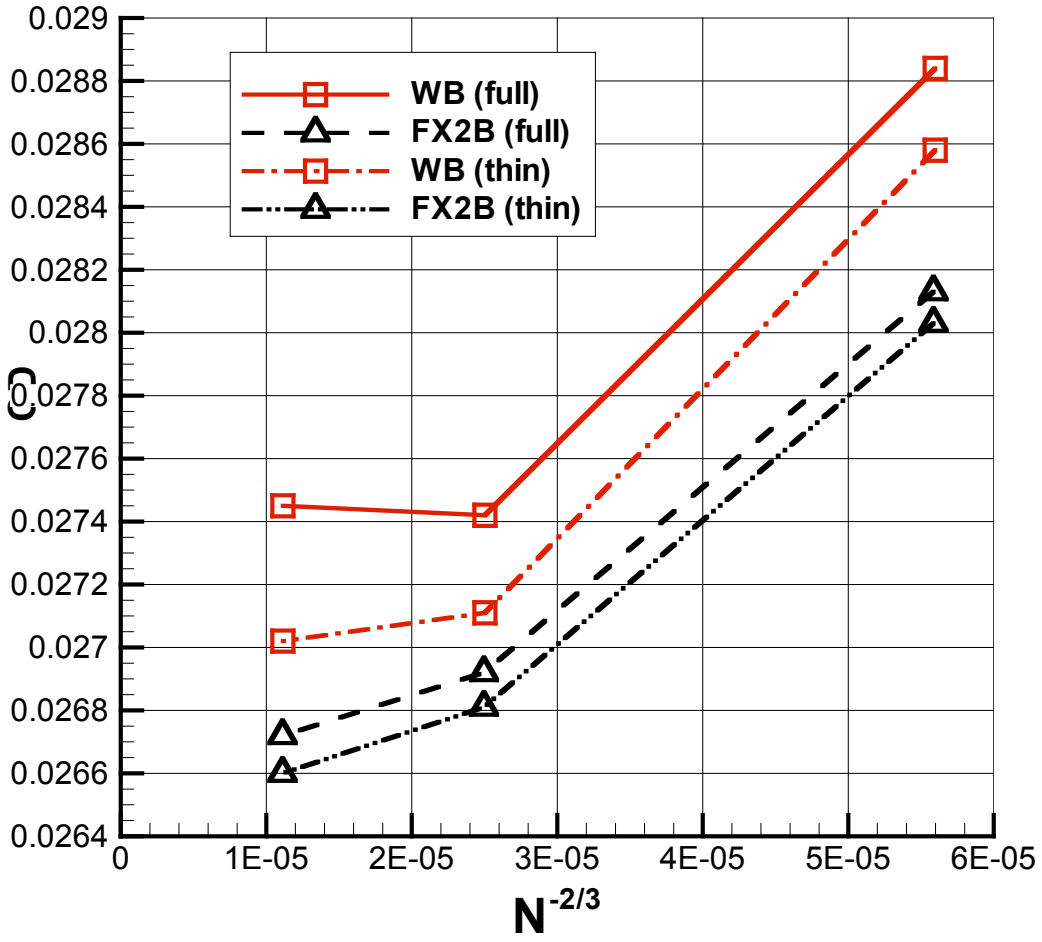
Grid effect, C_L=0.5

comparing WB and FX2B configurations, CFL3D (full N-S)



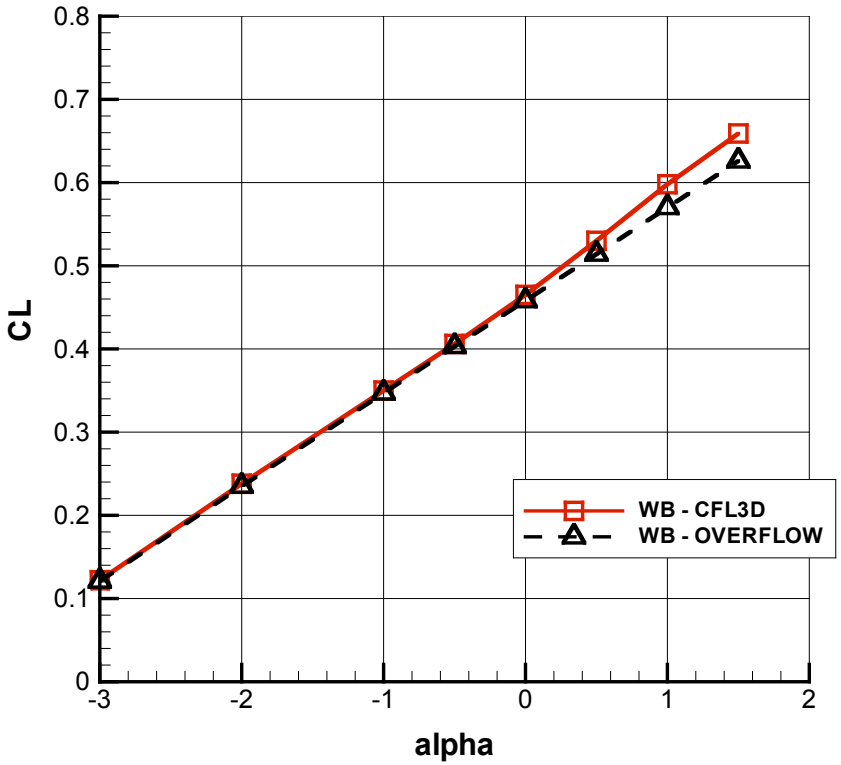
Grid effect, C_L=0.5

comparing WB and FX2B configurations, CFL3D



Lift curve on medium grid

WB, both codes



Lift curve on medium grid

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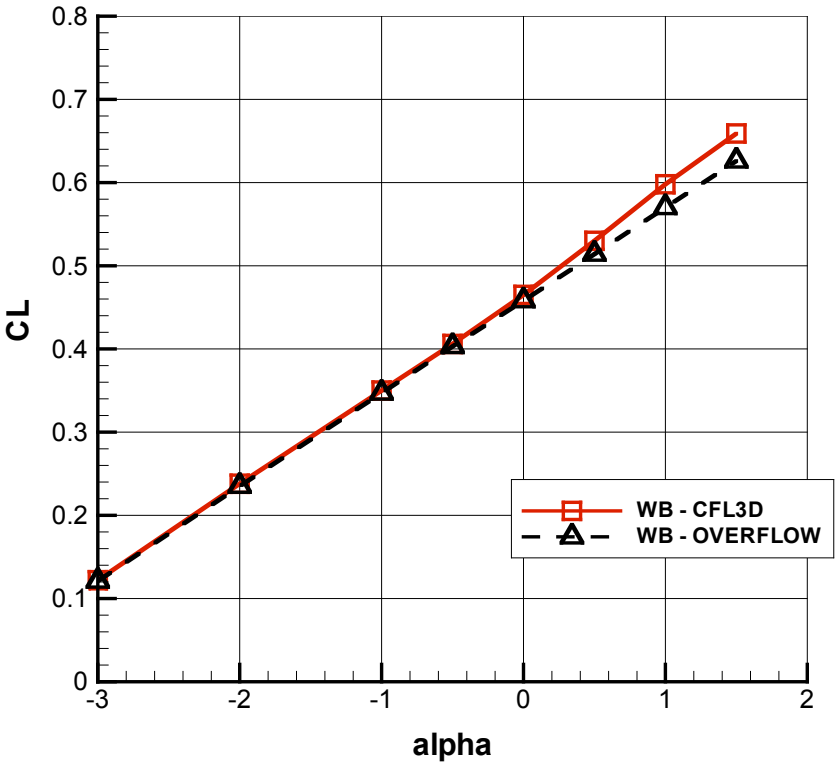
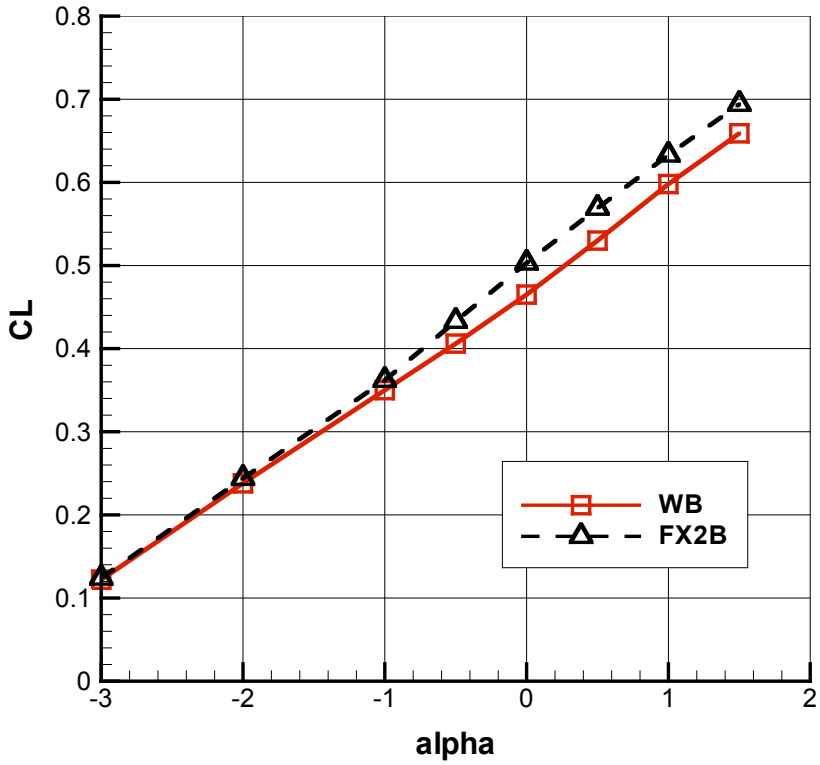
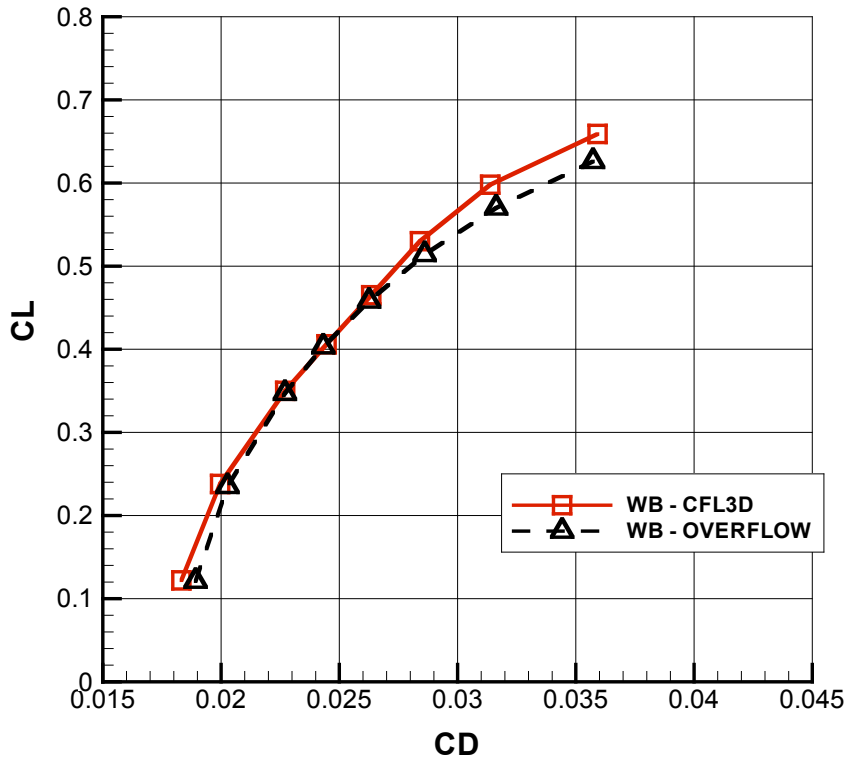


Both configs, CFL3D



Drag polar on medium grid

WB, both codes



Drag polar on medium grid

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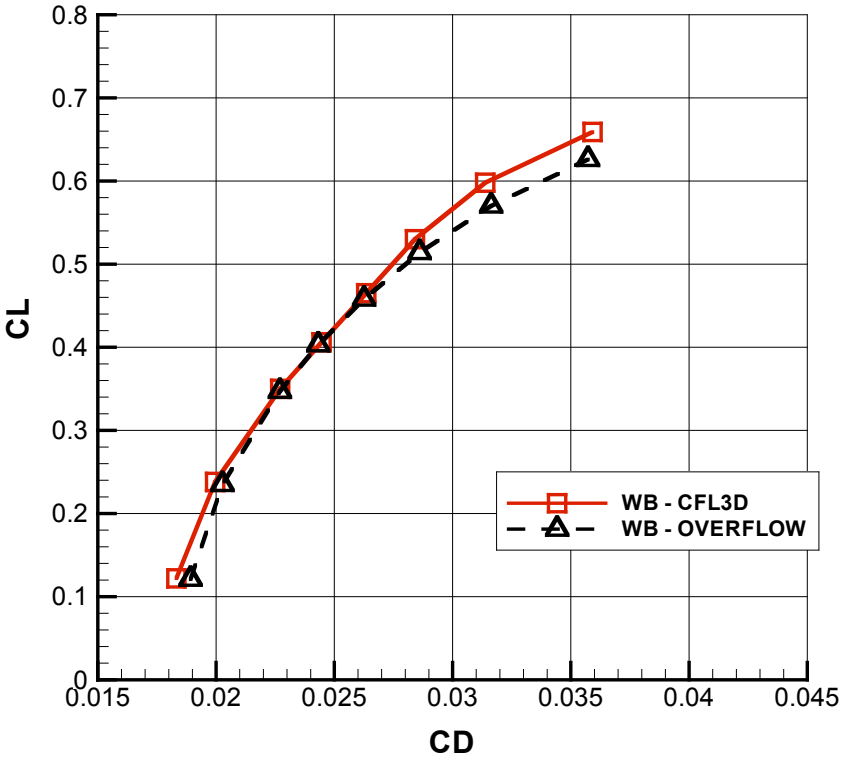

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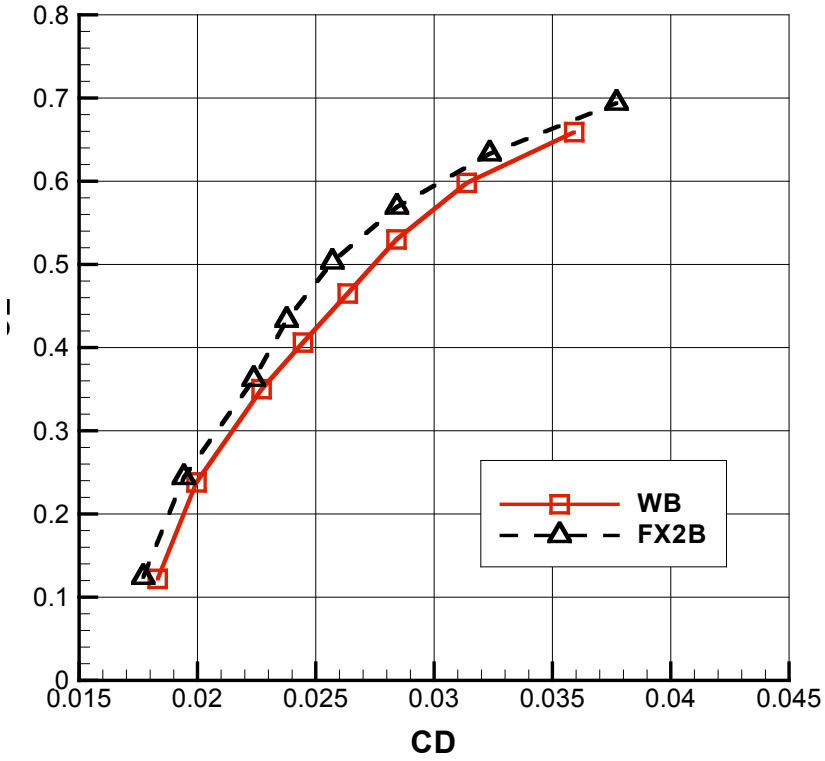

C_M on medium grid

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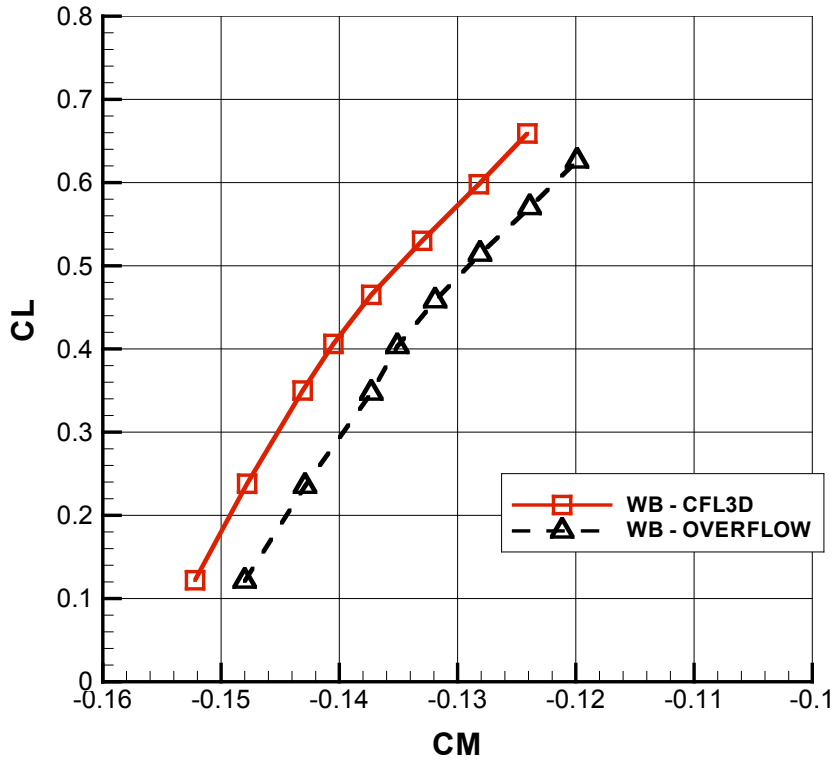

C_M on medium grid

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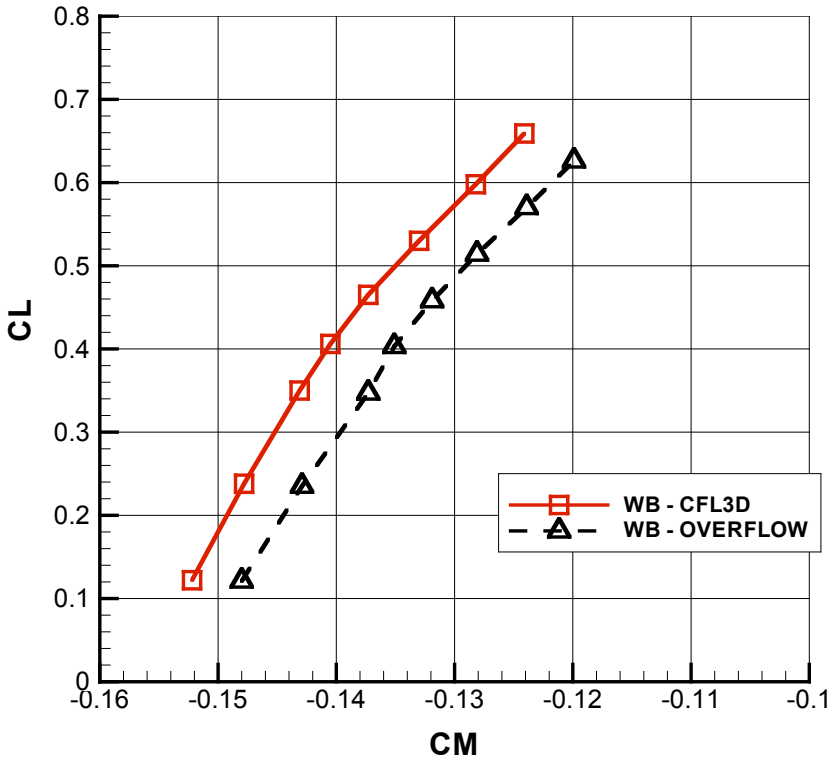

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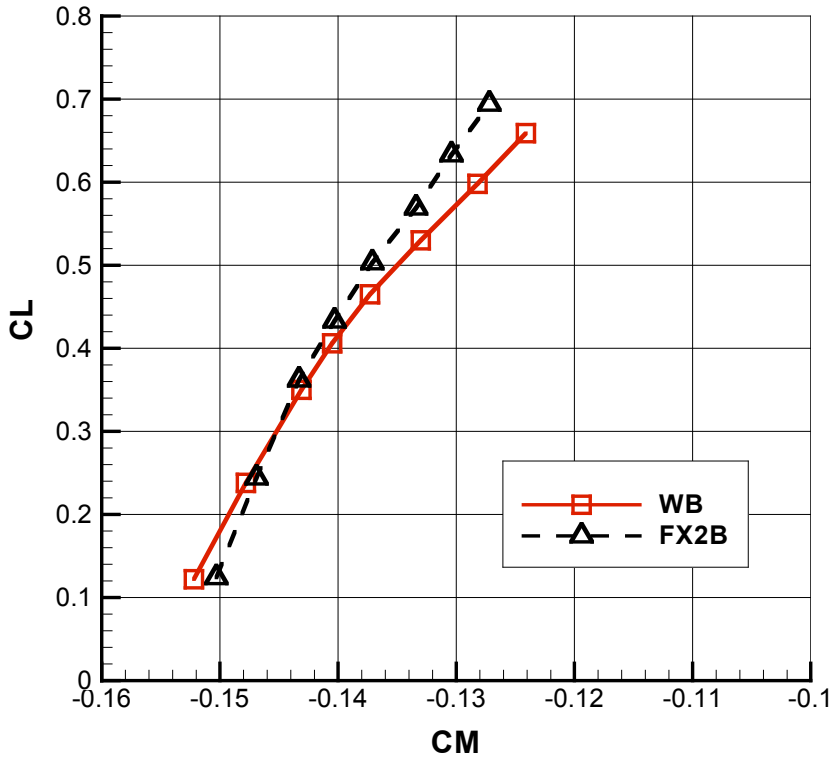
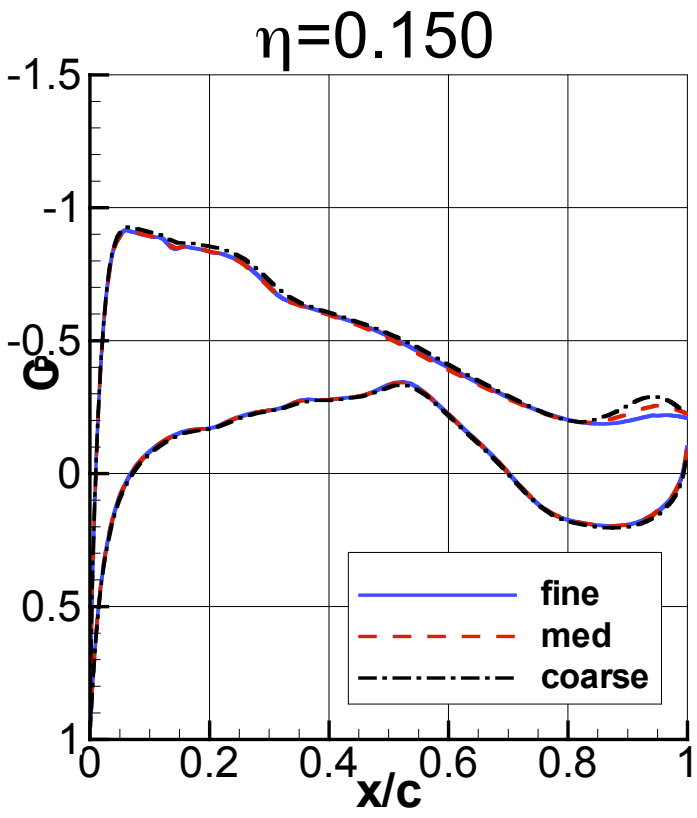
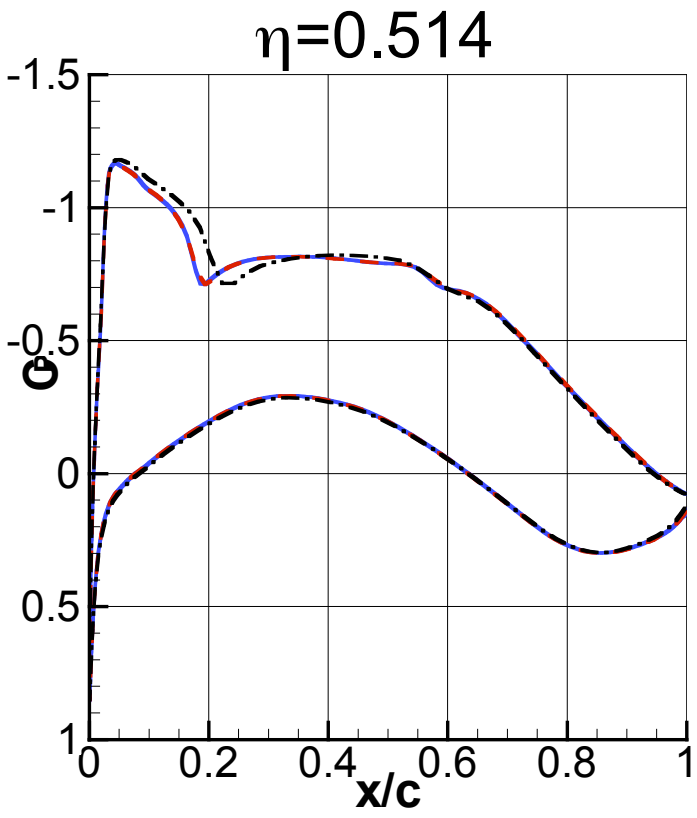
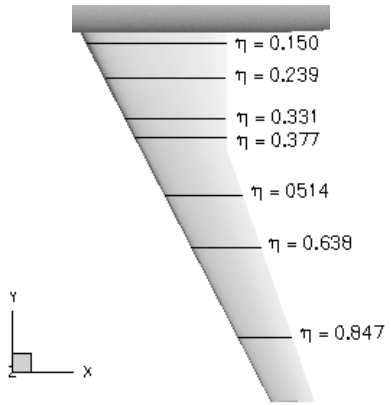


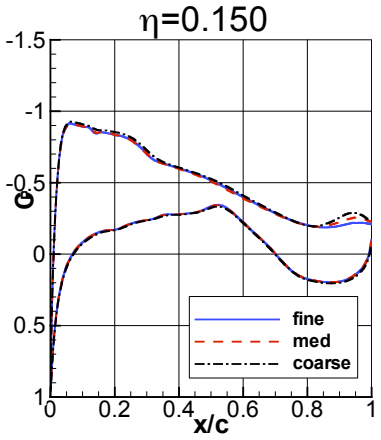
Grid density effect on Cp

WB case, CFL3D, full N-S





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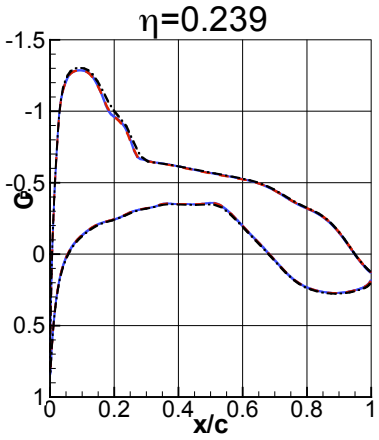
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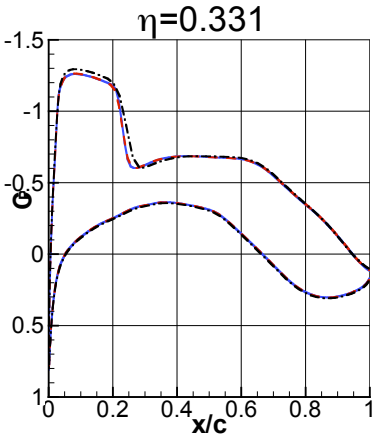
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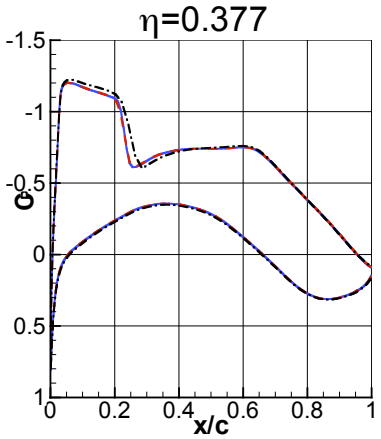
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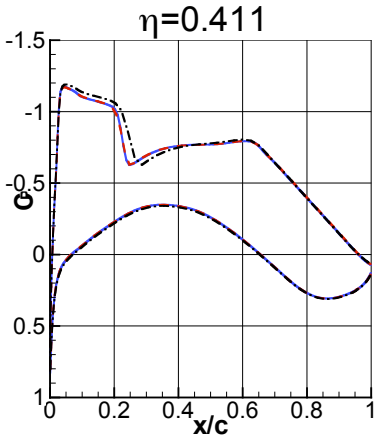
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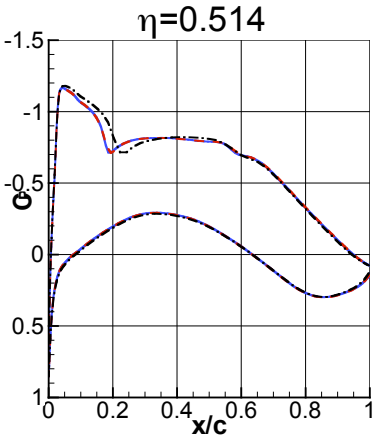
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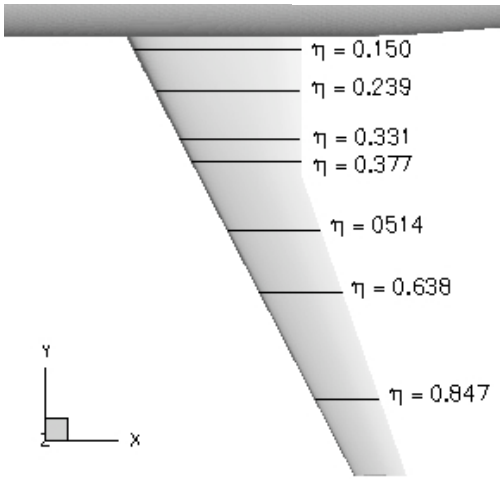
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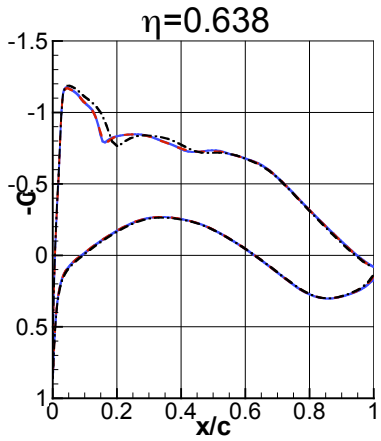
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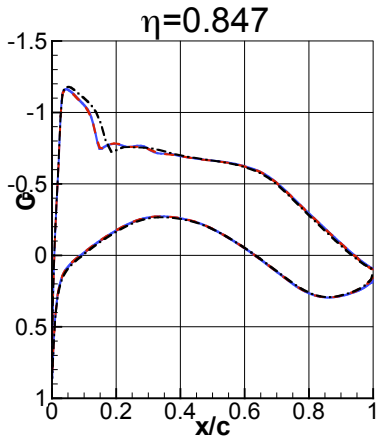
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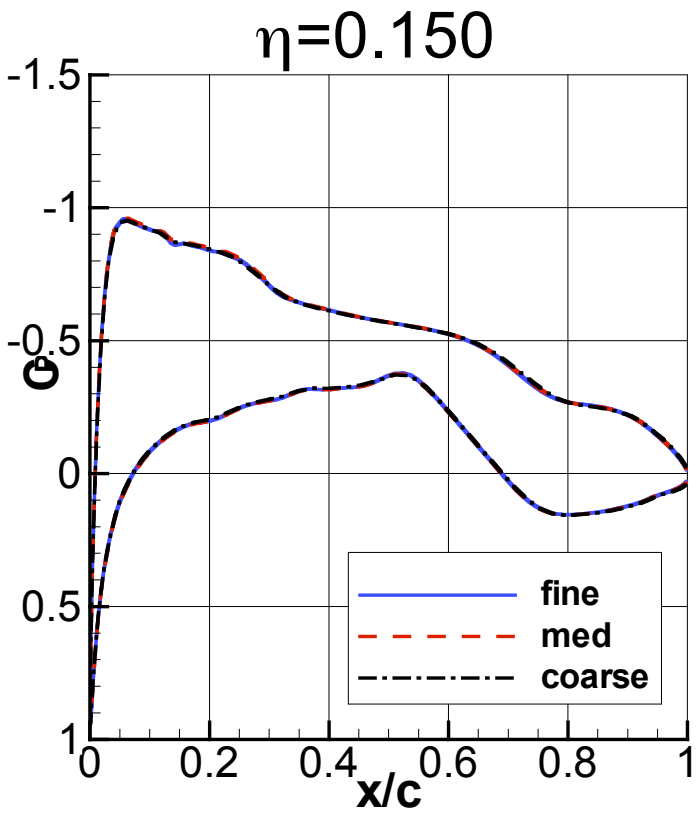
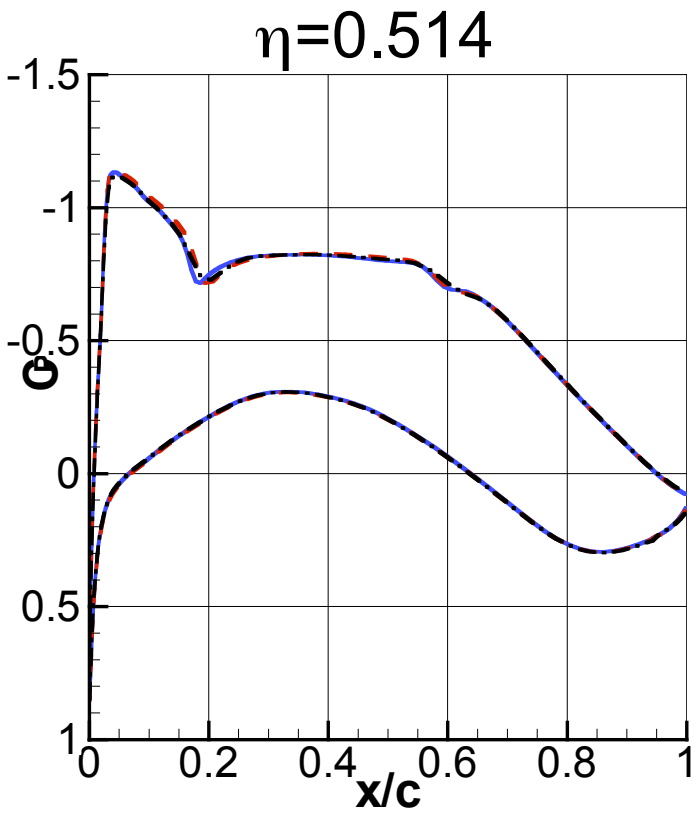
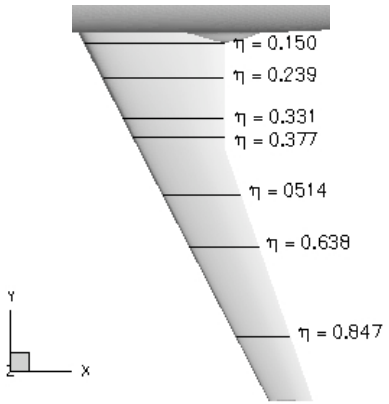
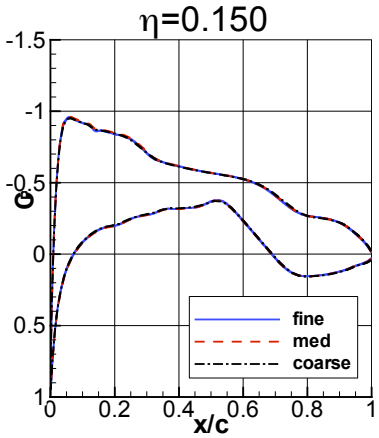
Grid density effect on Cp

FX2B case, CFL3D, full N-S





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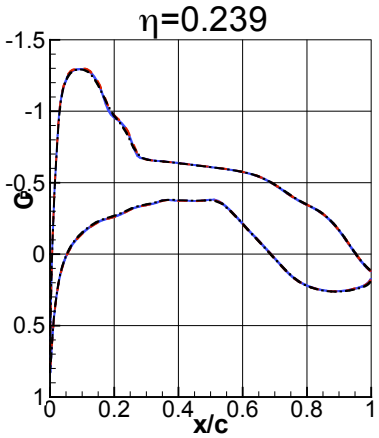
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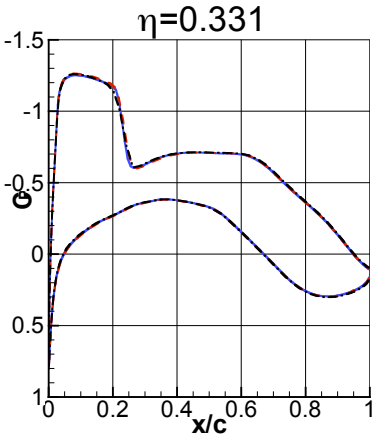
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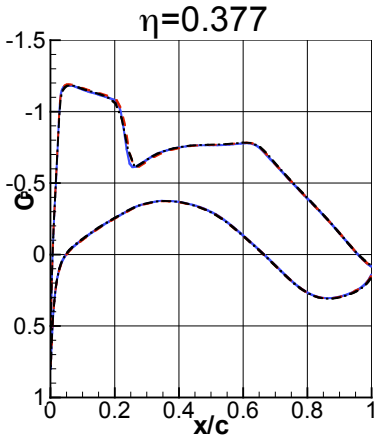
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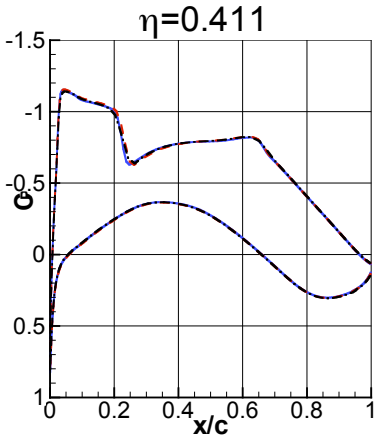
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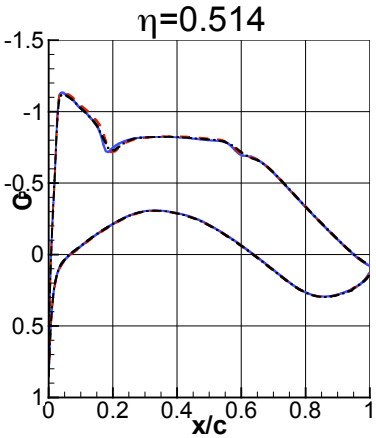
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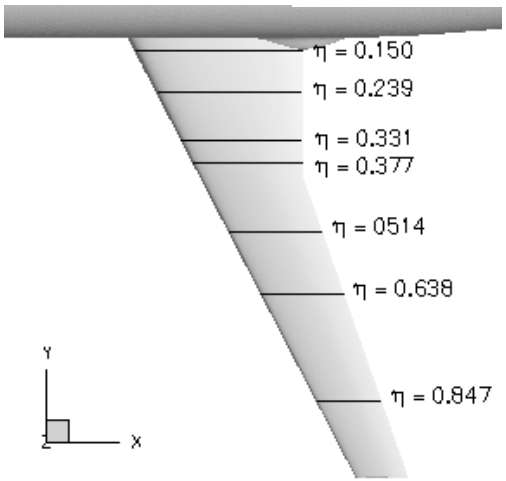
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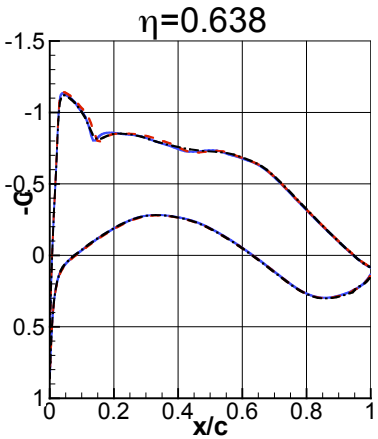
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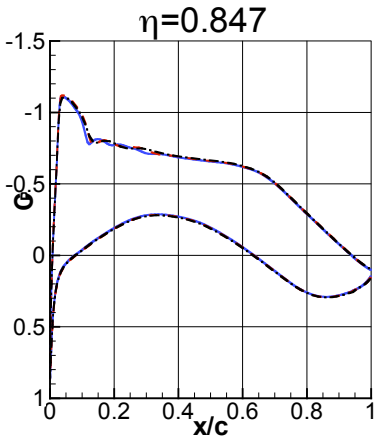
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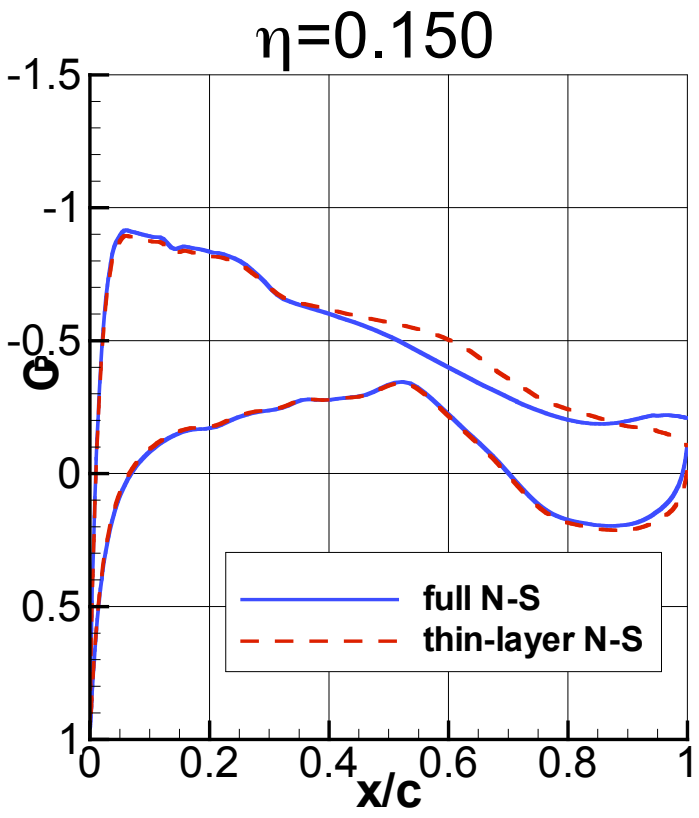
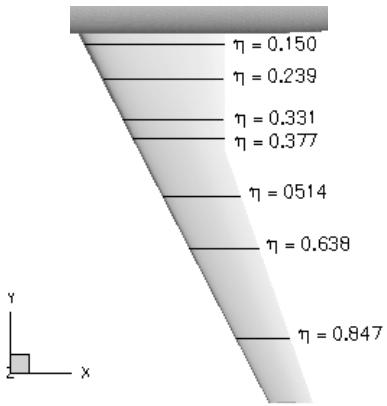
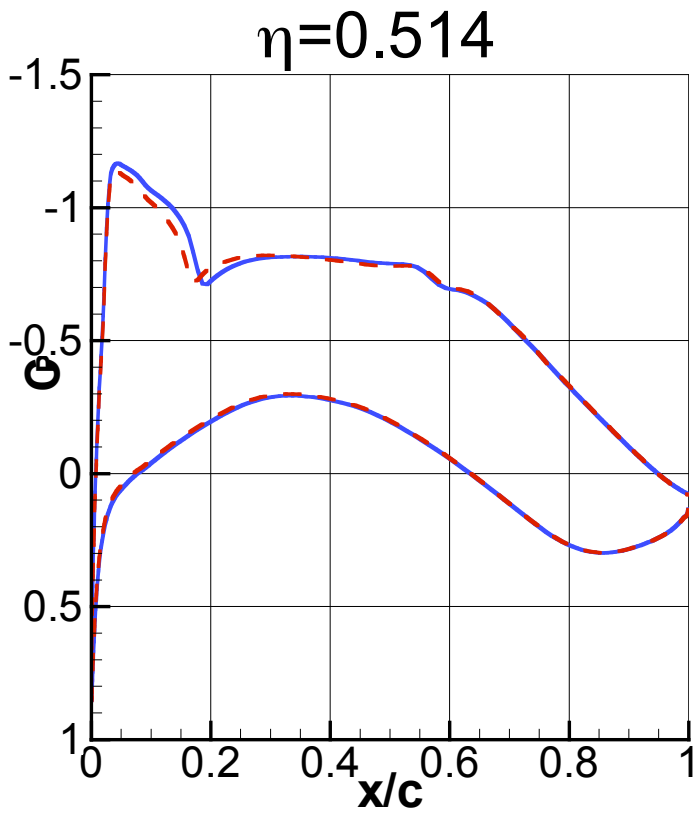
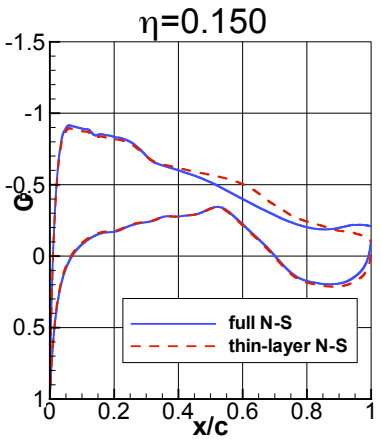
Viscous model effect on Cp

WB case, CFL3D, fine grid





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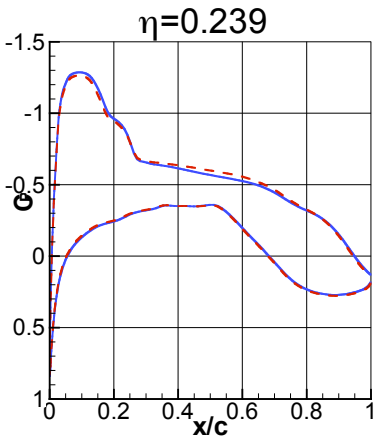
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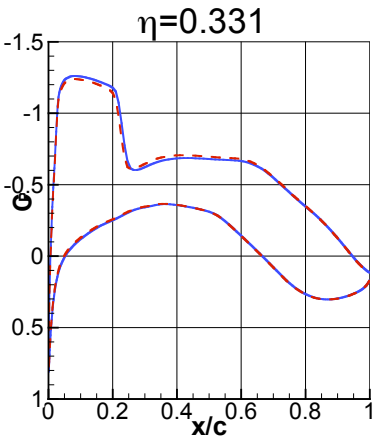
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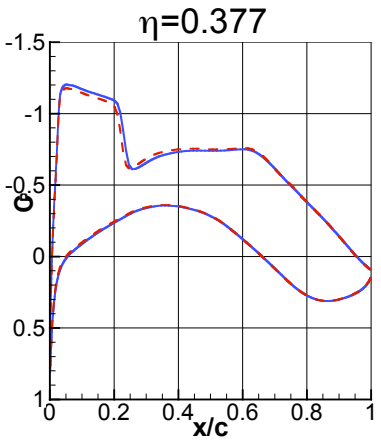
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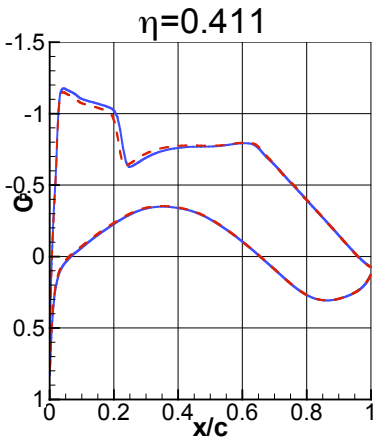
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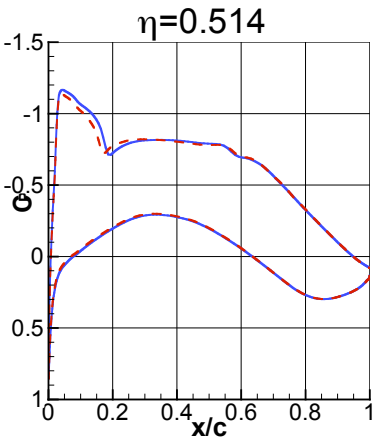
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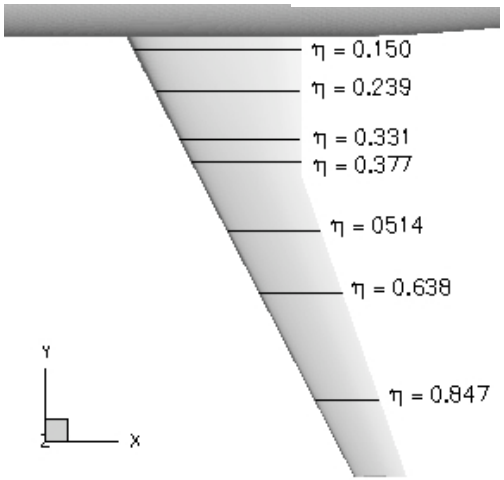
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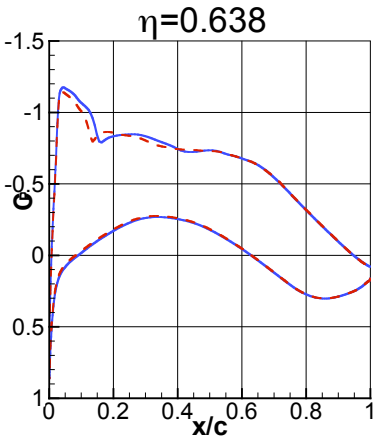
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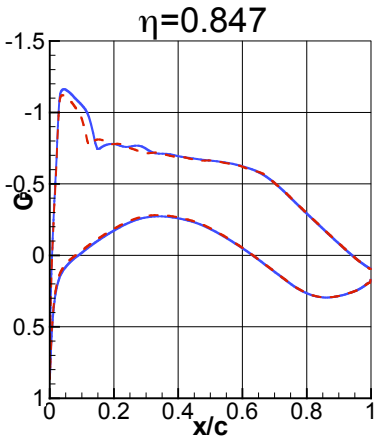
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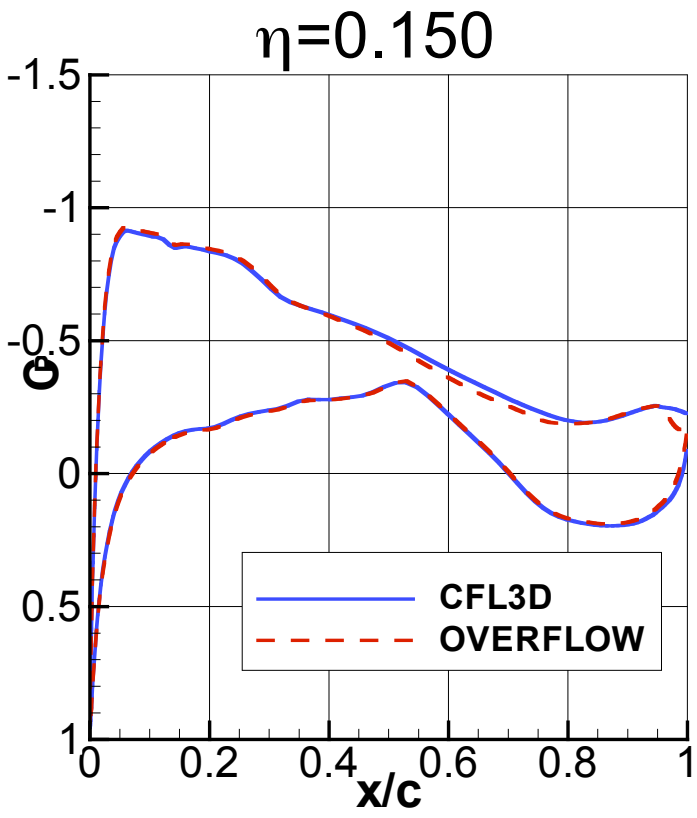
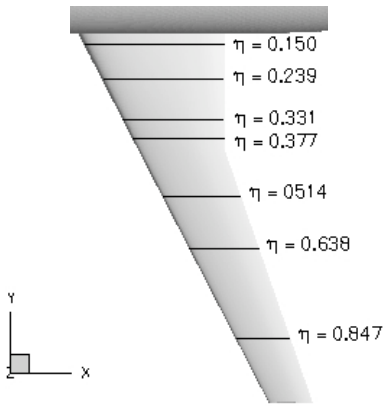
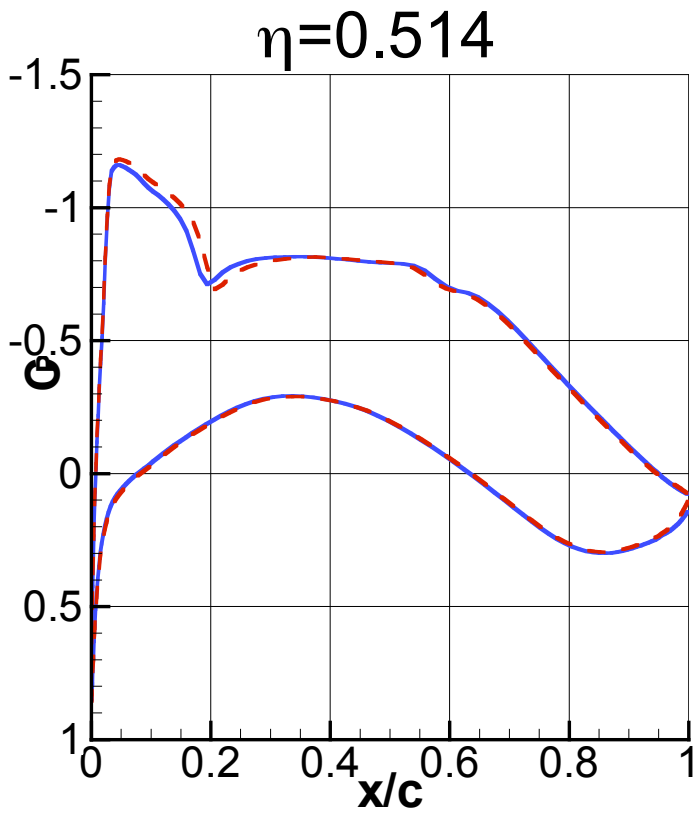
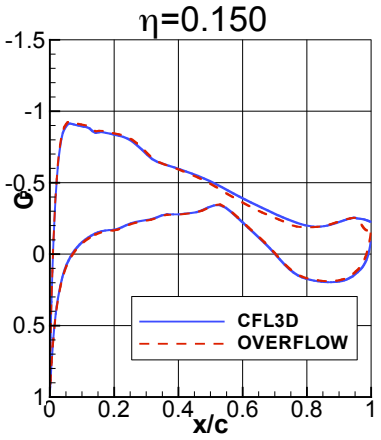
Code effect on Cp

WB case, full N-S, med grid





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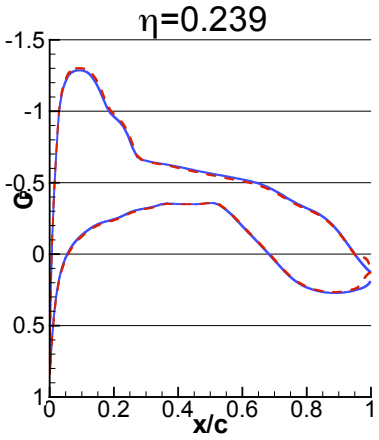
Cp
x/c
CFL3D
OVERFLOW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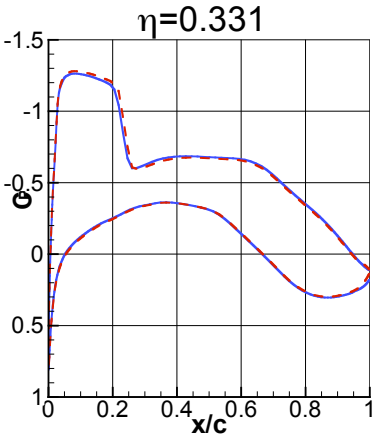
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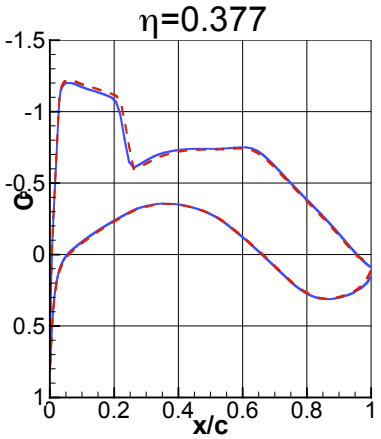
x/c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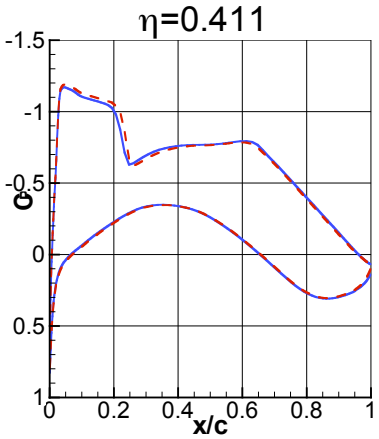
x/c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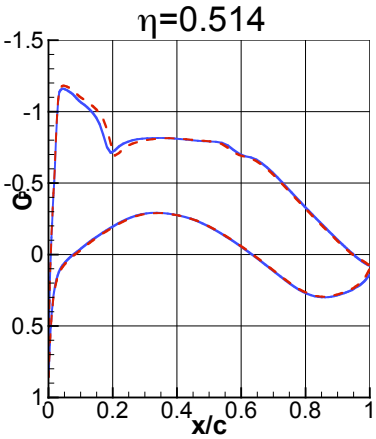
x/c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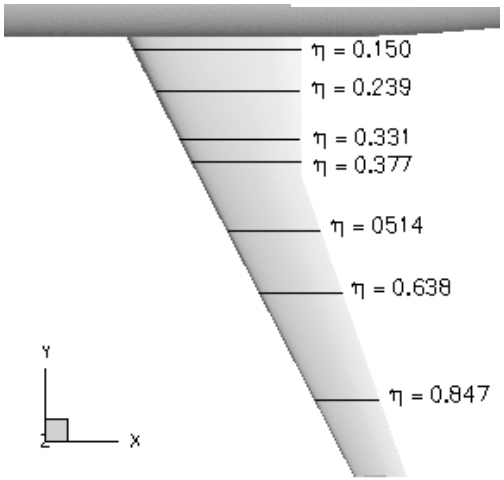
x/c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η = 0.377
η = 0514
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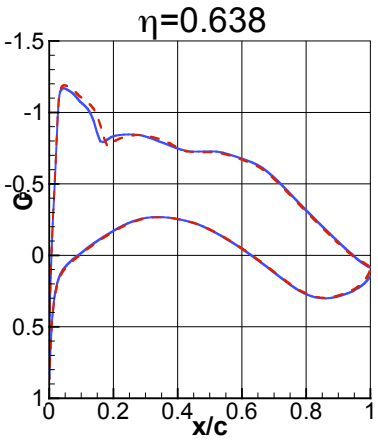
Y
Z
X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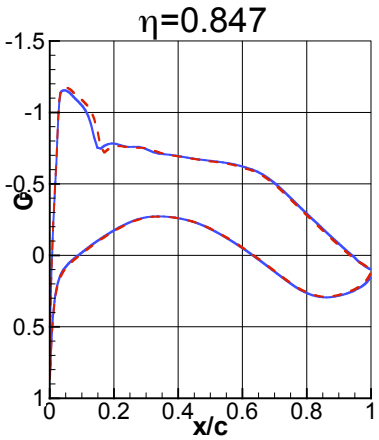
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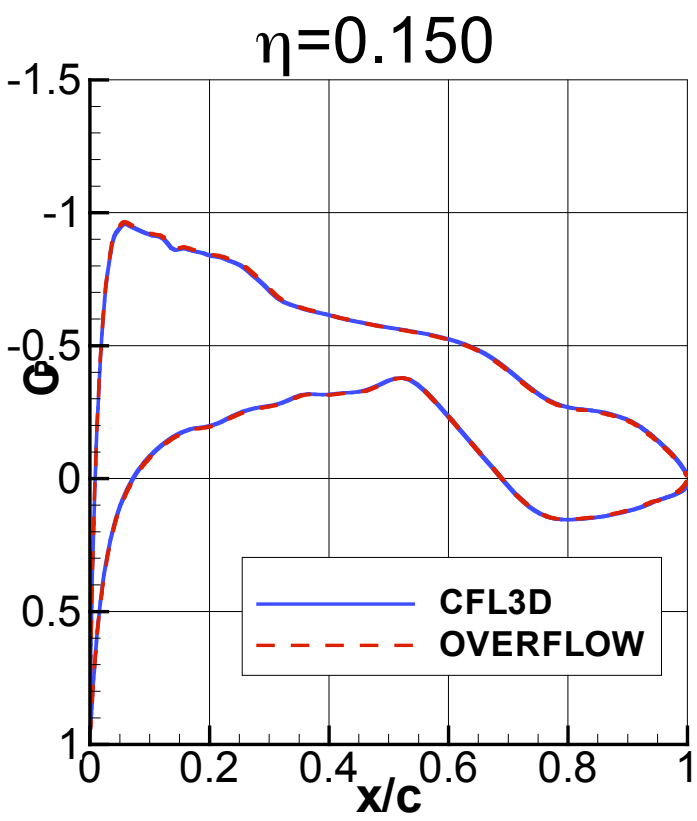
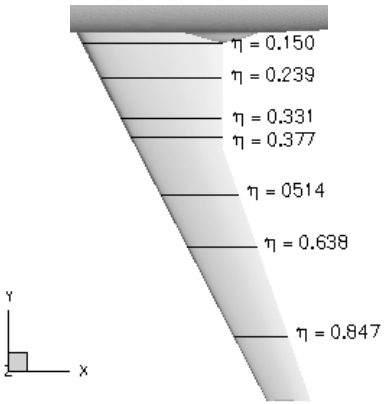
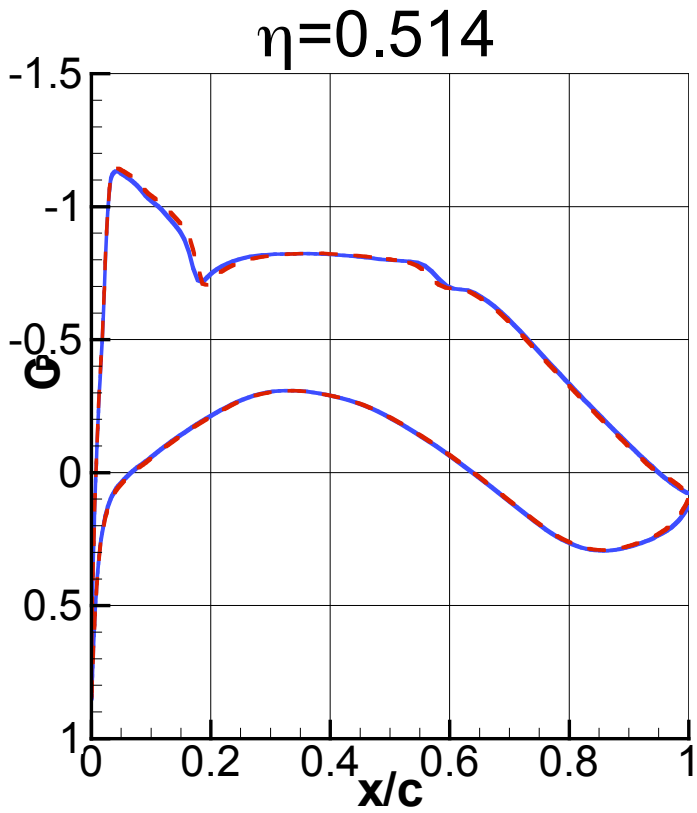
Cp
x/c

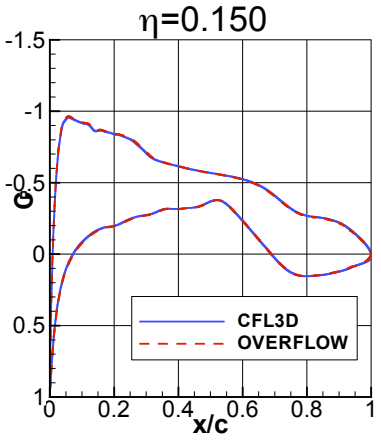
Code effect on Cp

FX2B case, full N-S, fine grid





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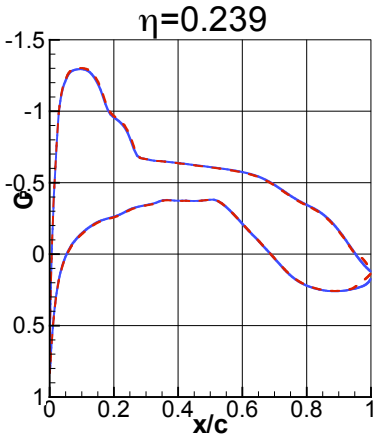
0.4
0.6
0.8
1
x/c
CFL3D
OVERFLOW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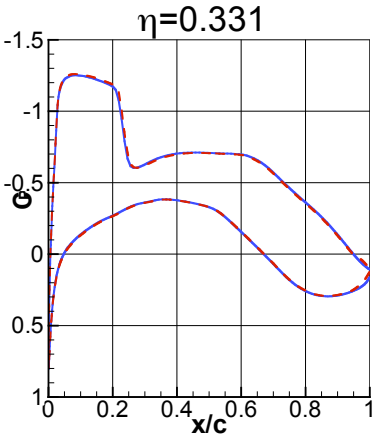
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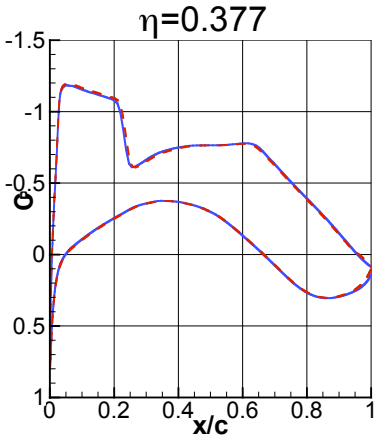
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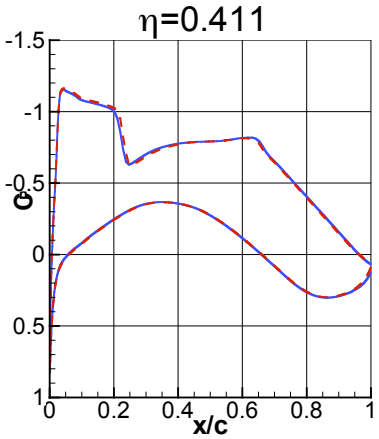
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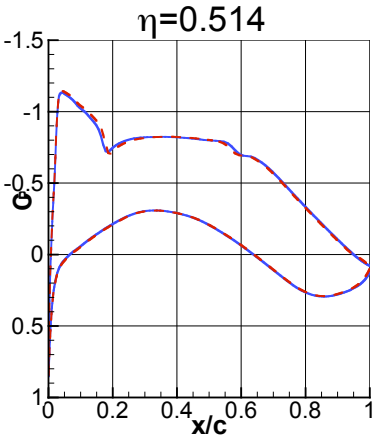
x/c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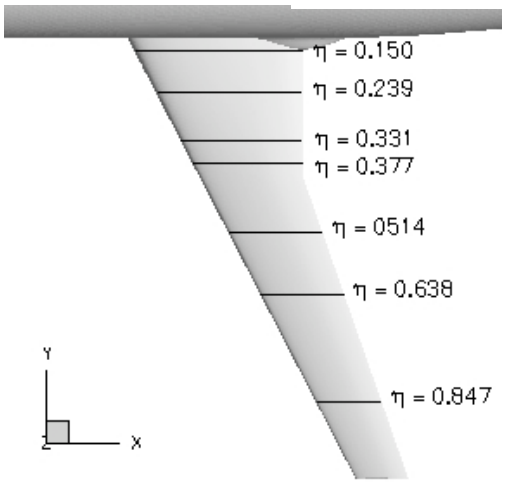
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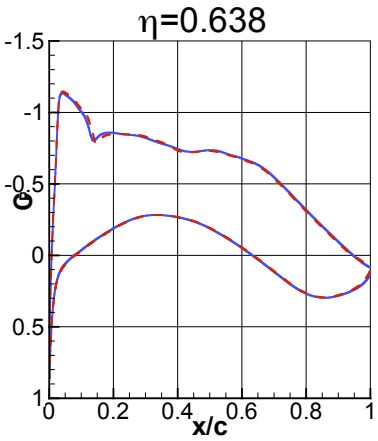
Z
X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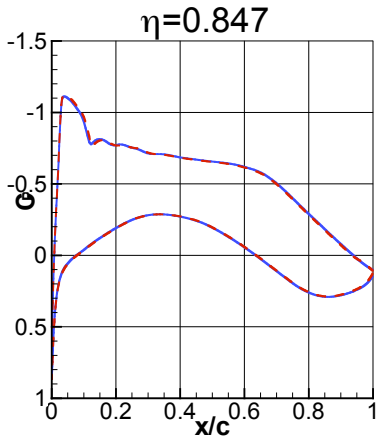
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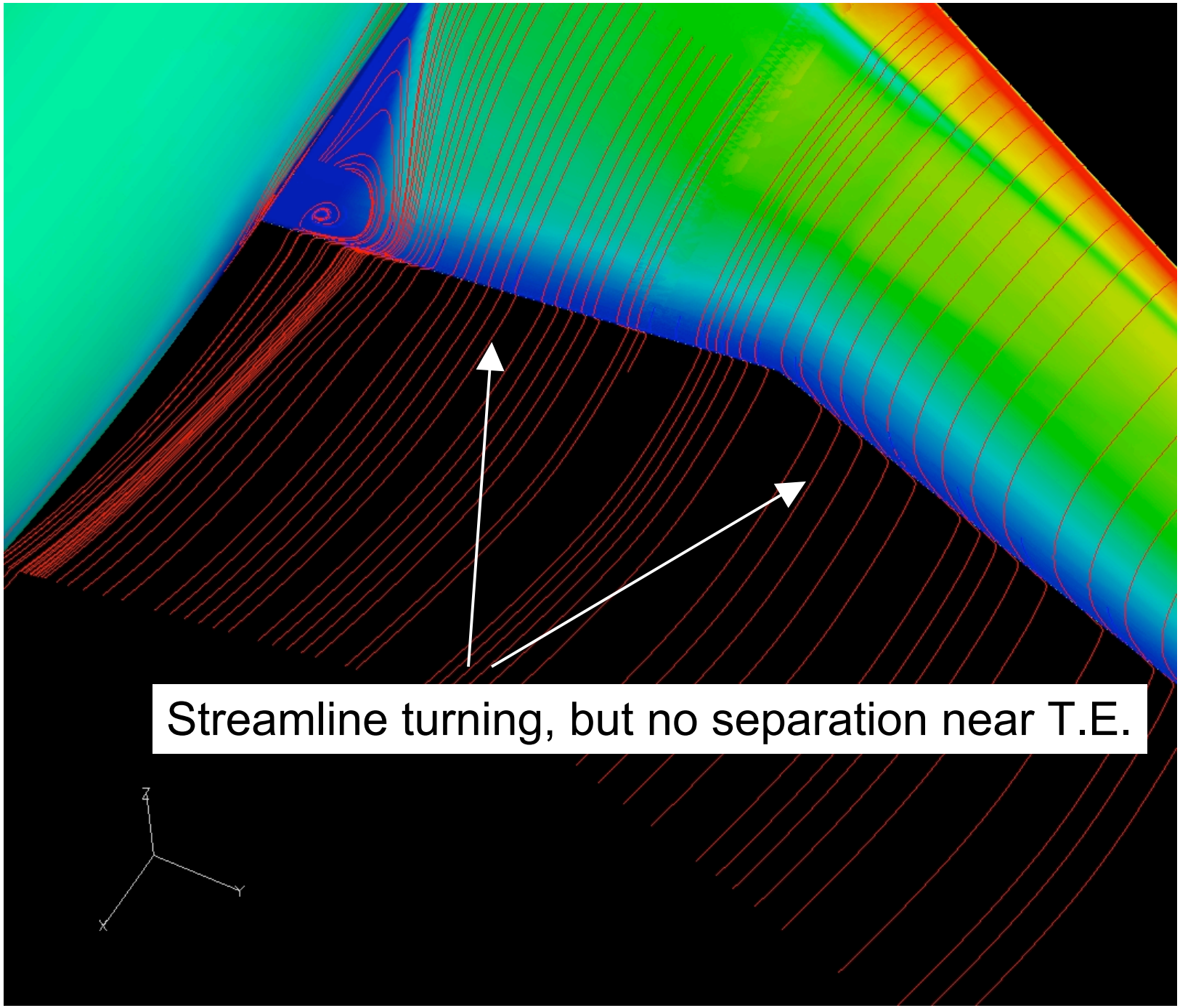
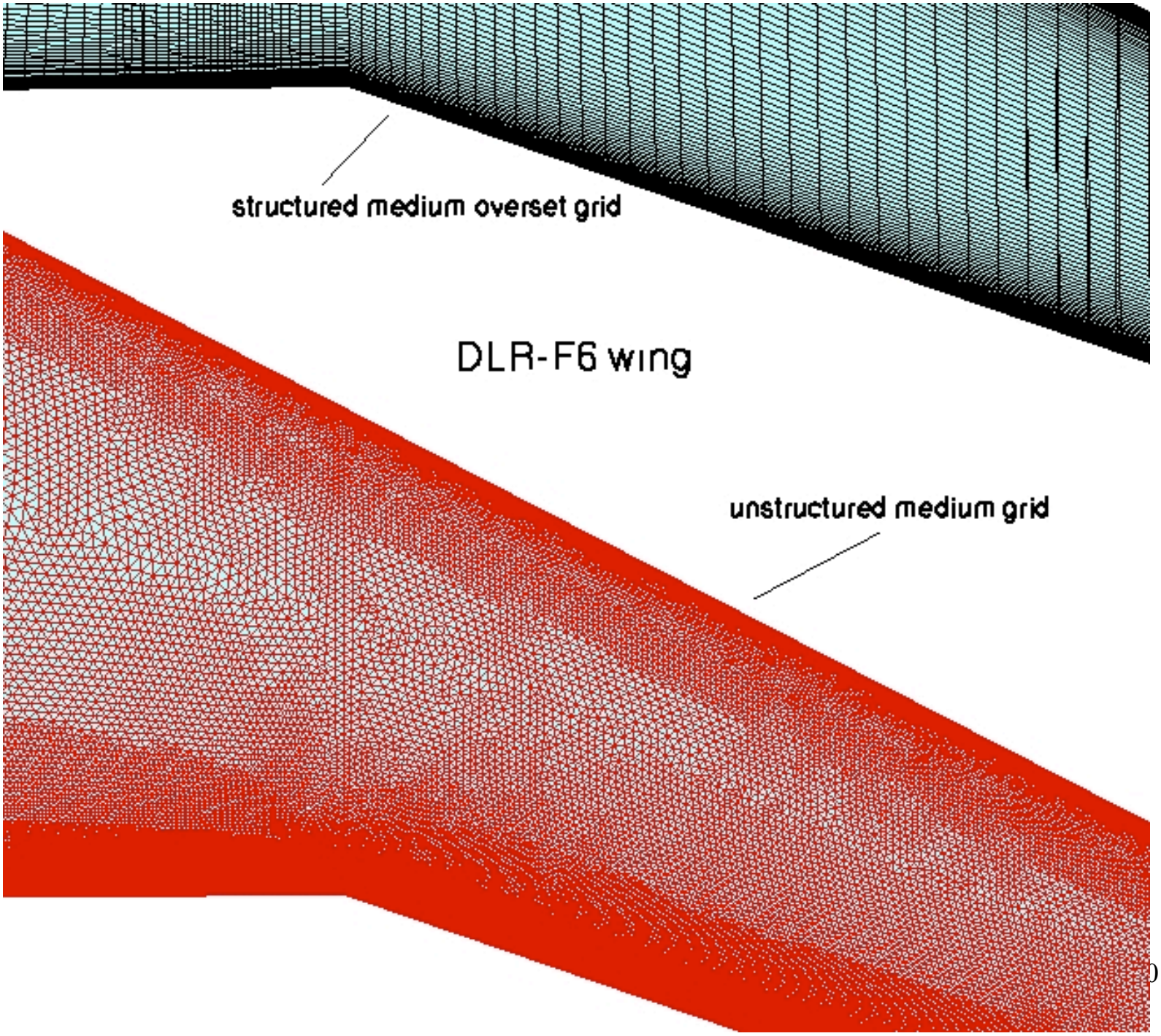
x/c


Streamline turning, but no separation near T.E.

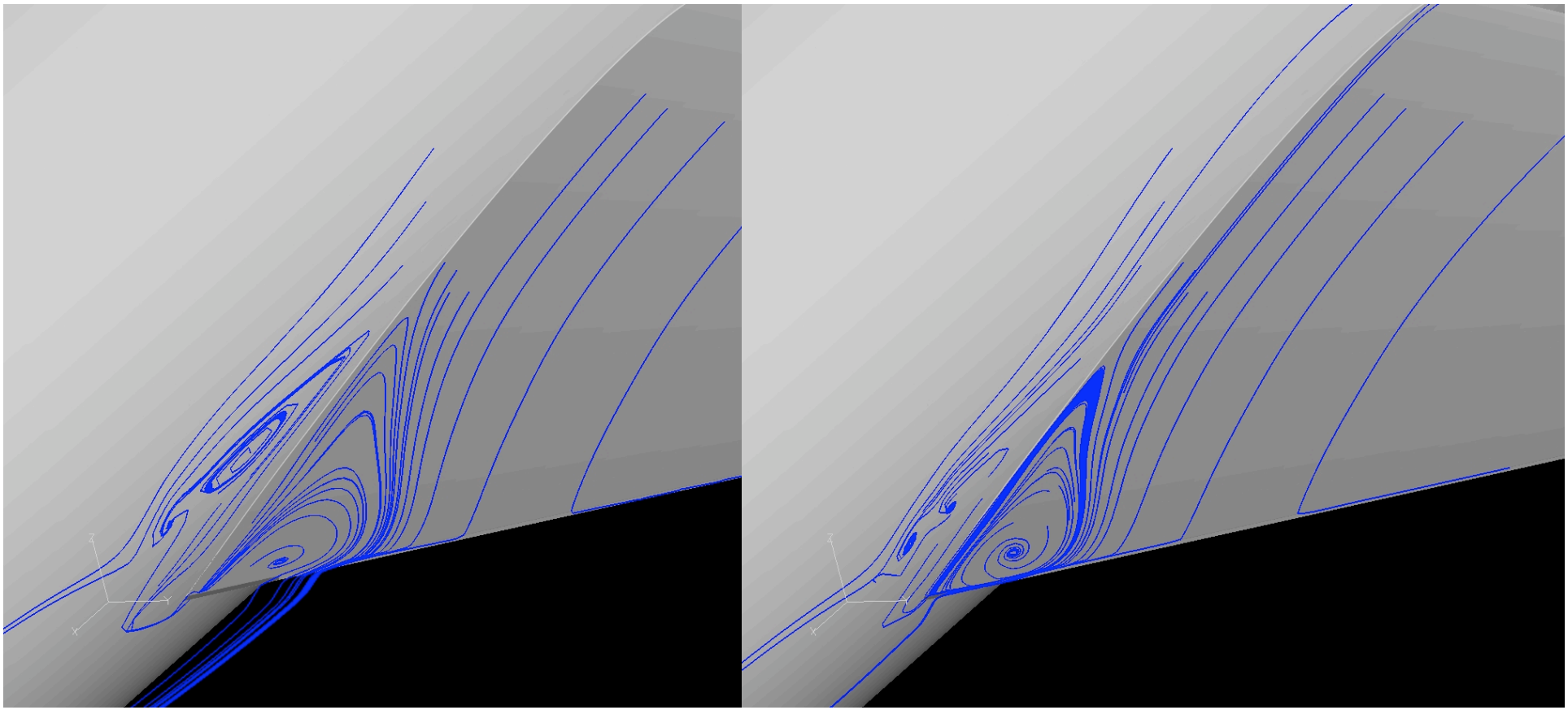

structured medium overset grid
DLR-F6 wing
unstructured medium grid

Viscous model effect on separation bubble

WB case, CFL3D, fine grid

full N-S

thin-layer N-S



Some conclusions from our DPW-II study (revisited)

- Grid density studies inconclusive

N/A – 1-to-1 grids were poor quality and inconsistently refined

? – Overset grids indicated likelihood that medium-level grids still not in asymptotic region (finer grid needed to confirm – 90M?)

? – Estimate: medium grids in error by ~10 counts from infinitely-refined grid (based on CFL3D alone, it may be less… finer grid needed to confirm)

- Effect of viscous model

 – Full N-S predicted larger wing-root separation bubble than thin-layer

 – Other than this, no major global effect of t1 vs. t3 vs. full: max 5 drag counts difference

Some conclusions from our DPW-II study (revisited)

- Effect of code

X – CFL3D predicted consistently lower C_L levels than OVERFLOW (by at most 0.036) (different turbulence model - SST)

 – At C_L=0.5, C_D was different by 5 counts (WB) between the two codes on med or fine grid levels

Additional conclusions

- Full N-S important when separation present
  - Affects prediction of bubble size
  - For FX2B (no separation) only 1 drag count difference between thin-layer and full
- Structured grids do not predict T.E. separation
  - Possibly due to insufficient spanwise grid resolution

Additional conclusions

- Problems with OVERFLOW using SST model (likely coding issue)
  - When it runs, OVERFLOW and CFL3D are generally very close:
    - within 5 drag counts at C_L=0.5
    - within 6 drag counts over entire drag polar
    - within 0.005 in C_M over entire drag polar
    - C_L very close at low alphas; max difference of 0.034 at high alphas

Typical CPU timings

for the DPW-III fine overset grid (27M nodes)

- Typically at least 2000-5000 cycles needed per case
- OVERFLOW on PC Linux cluster (15 processors)
  - 27 hrs wall-clock for 2000 MG cycles
- CFL3D on PC Linux cluster (10 processors)
  - 150 hrs wall-clock for 2000 MG cycles
  - Slower (in part) because cannot do mesh sequencing on overset grids

Note on “fully turbulent”

- When “fully turbulent”, models transition on their own
- For SA and SST, this location can be inconsistent!
  - often MOVES DOWNSTREAM as grid is refined
- See AIAA 2006-3906