Presented by :

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Airbus

Drag Prediction Workshop 4

Airbus results

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Method

- **elsA** solver:
  - ‣ Developed by ONERA
  - ‣ Centred scheme
  - ‣ Dissipation : Jameson type scalar scheme
  - ‣ Implicit time integration : LU-SSOR method

- **Turbulence models used :**
  - ‣ Spalart-Allmaras (SA) 1-equation model
  - ‣ Menter k-ω Shear Stress Transport (SST) 2-equations model

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Grids characteristics

- Structured, multiblock grids

- In compliance with DPW commitee gridding guidelines

- C-topology around fuselage, wing and tail
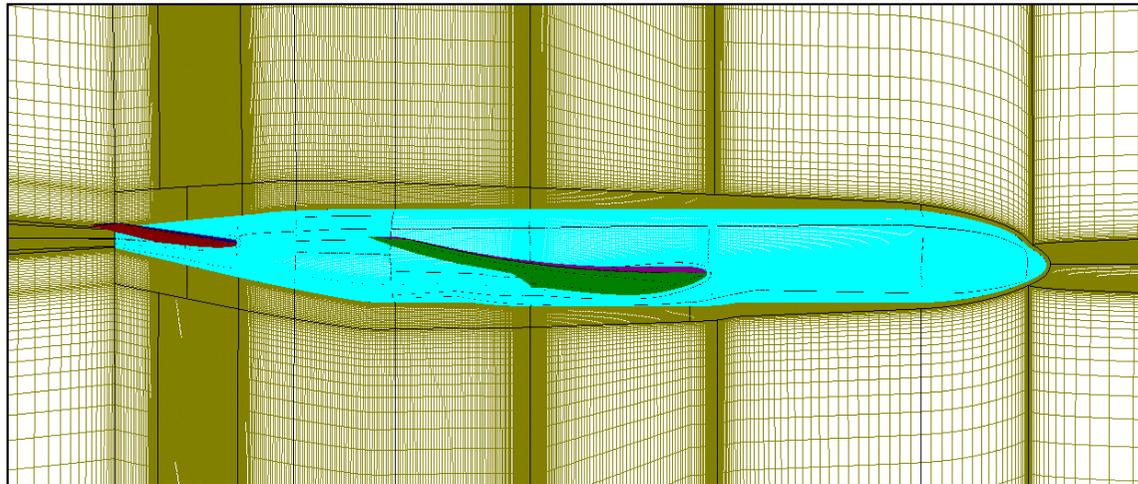
- 7 grids generated :

    - Coarse, Medium, Fine, Extra fine at iH=0°

    - Medium at iH=-2°, +2°, No Tail

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Grids characteristics

- Grids dimensions :

| Grid level	Nodes	Zones	y+	Cells across trailing edge
Coarse	4.6 millions	146	1	18
Medium (no tail)	8.9 millions	128	0.666	24
Medium (tail)	13.5 millions	167	0.666	24
Fine	37.2 millions	228	0.444	32
Extra fine	108.3 millions	334	0.296	48
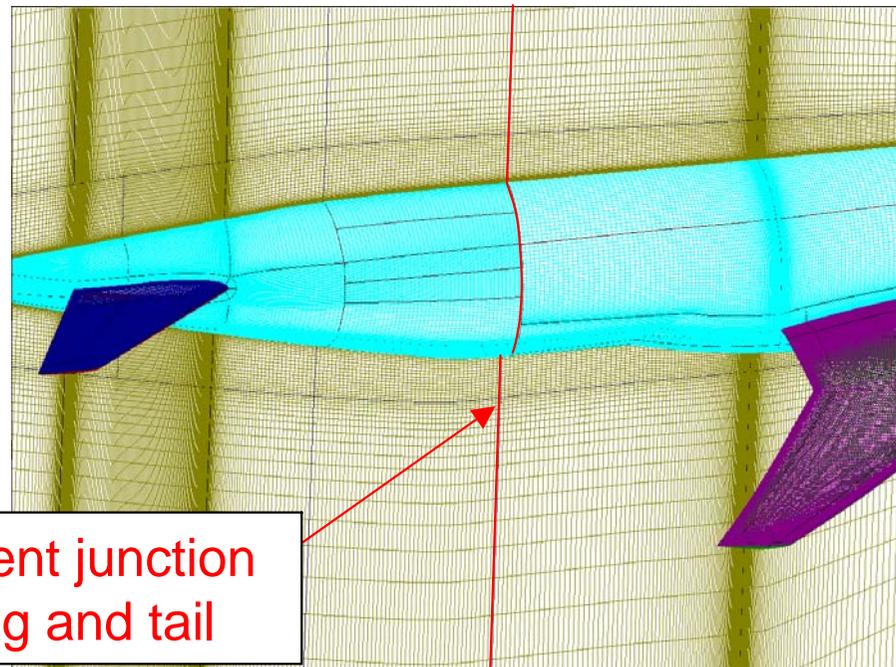
Non-coincident junction between wing and tail
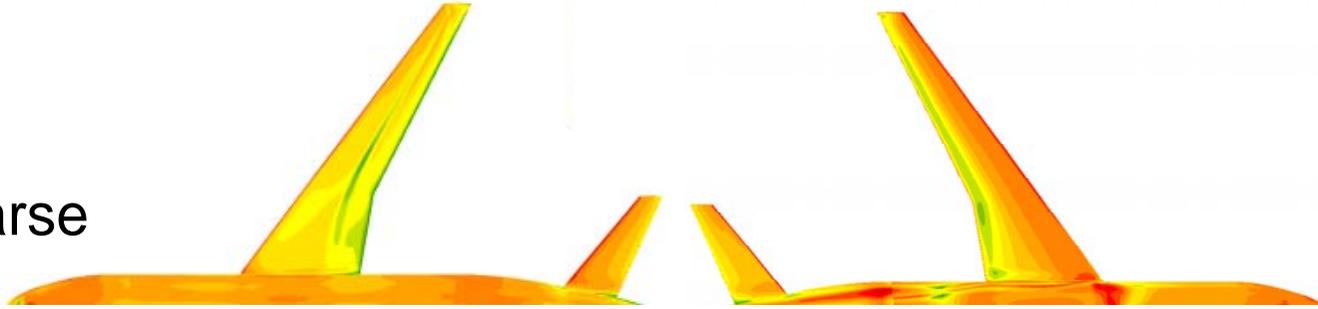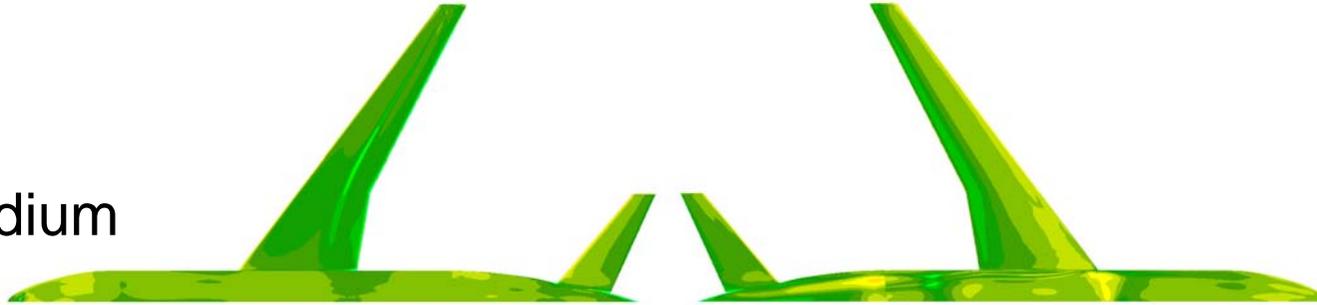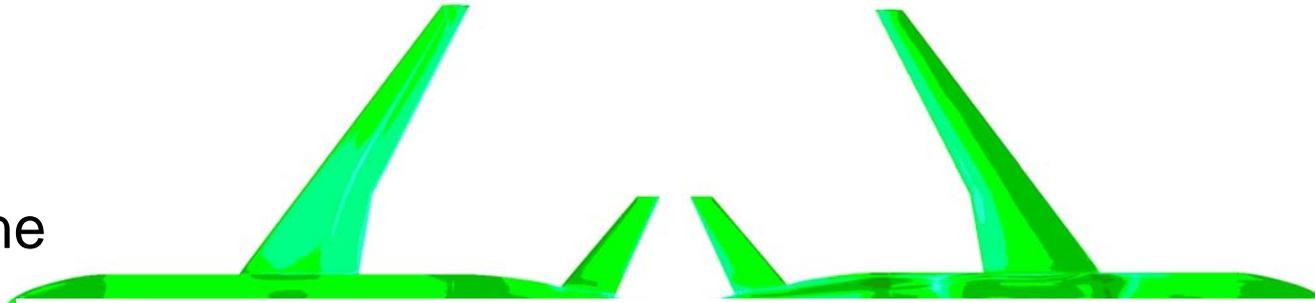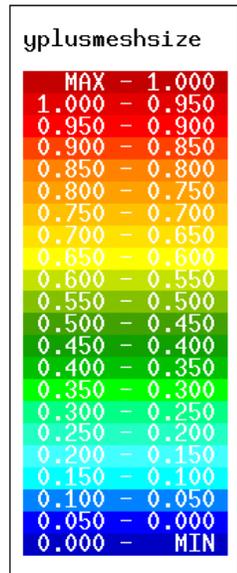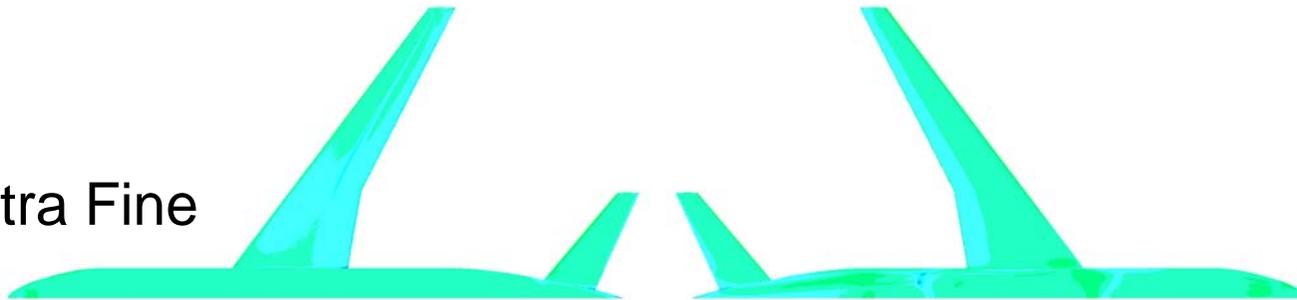
Coarse

Medium

Fine

Extra Fine

Coarse

Extra Fine

delta_cell_count

MAX	60.000
60.000	58.500
58.500	57.000
57.000	55.500
55.500	54.000
54.000	52.500
52.500	51.000
51.000	49.500
49.500	48.000
48.000	46.500
46.500	45.000
45.000	43.500
43.500	42.000
42.000	40.500
40.500	39.000
39.000	37.500
37.500	36.000
36.000	34.500
34.500	33.000
33.000	31.500
31.500	30.000
30.000	MIN

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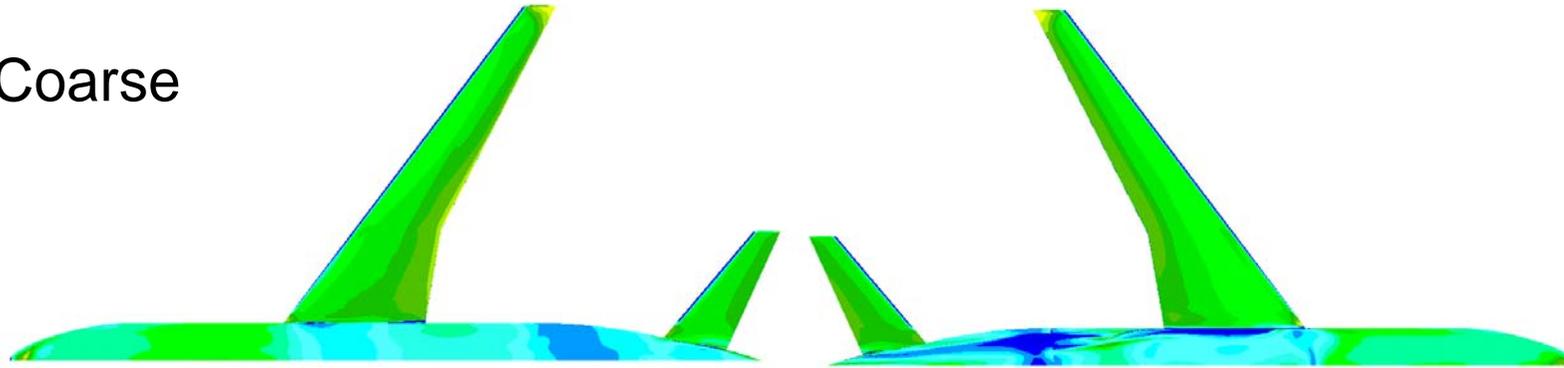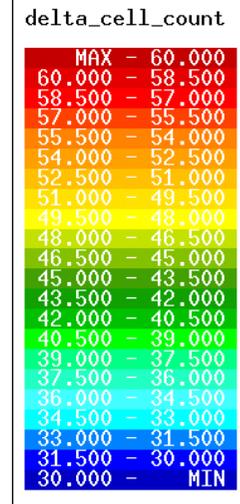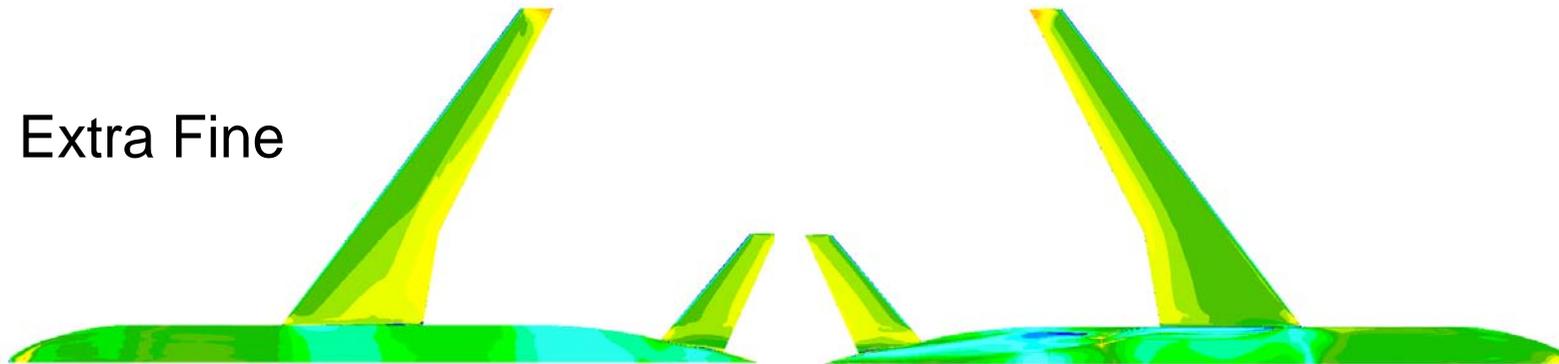
Grid convergence at C_L=0.5

- Total drag
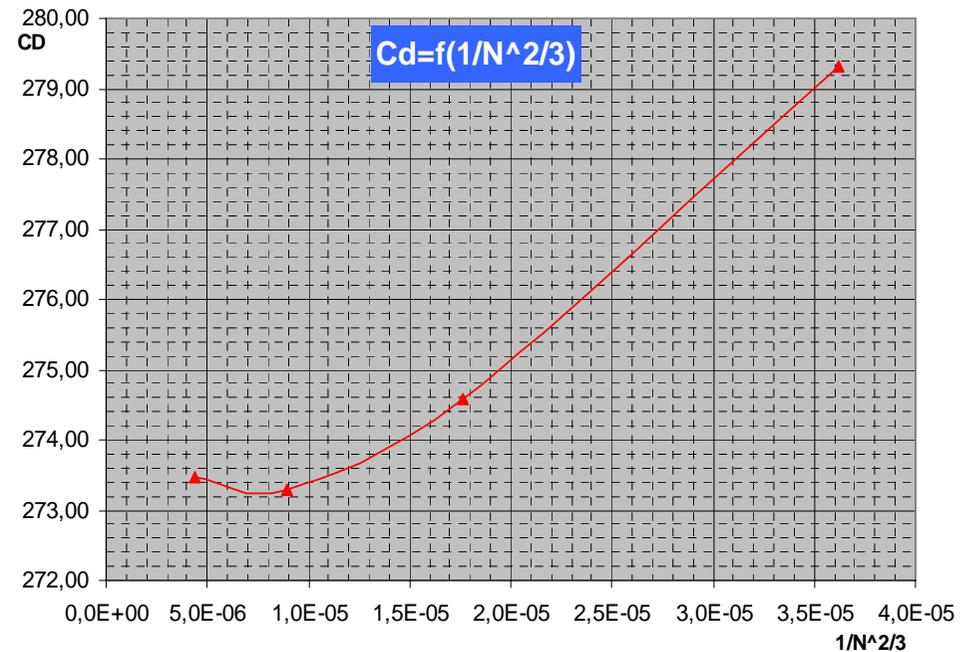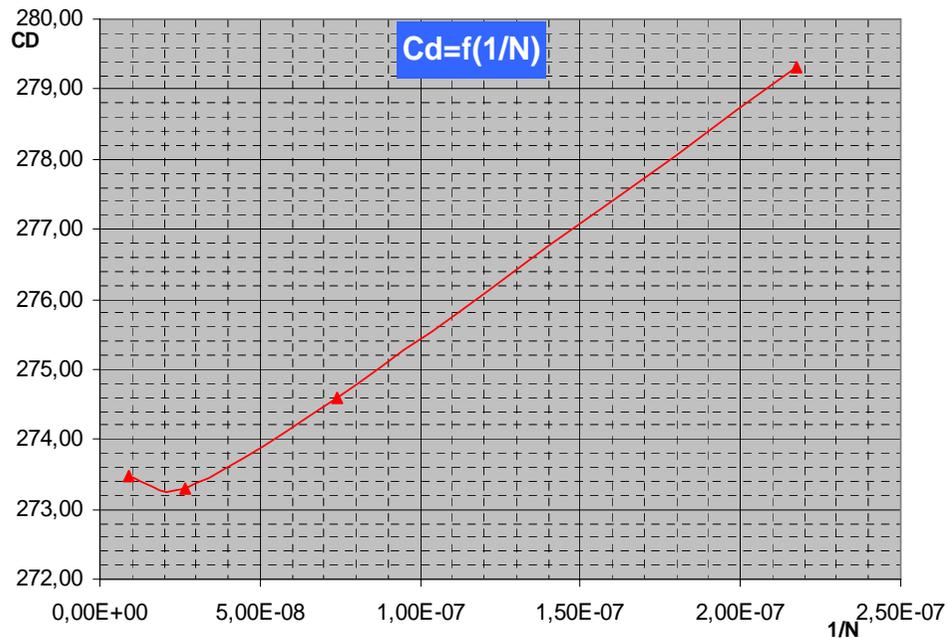
N = number of grid nodes

C_L=0.5

M=0.85

k-ω SST model

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- Pressure and friction drag
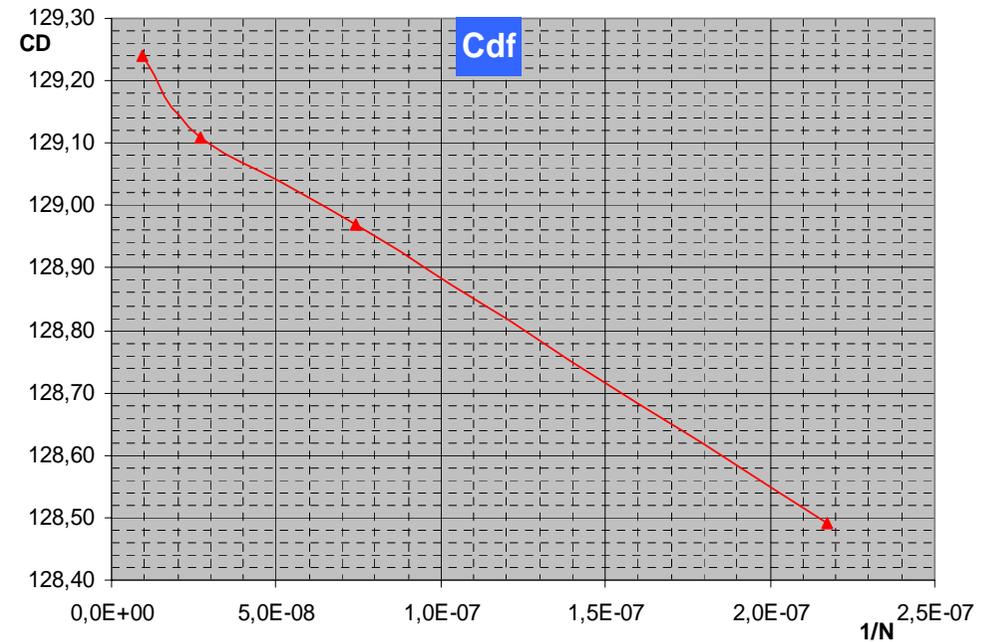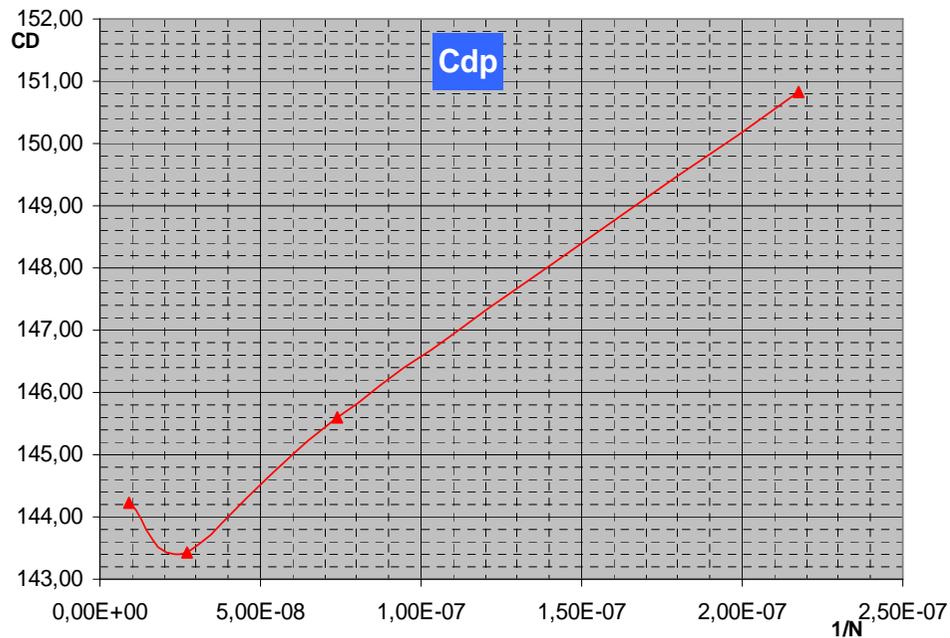
C_L=0.5, fine grid

Small separated areas exist at wing and tail roots leading edge and trailing edge
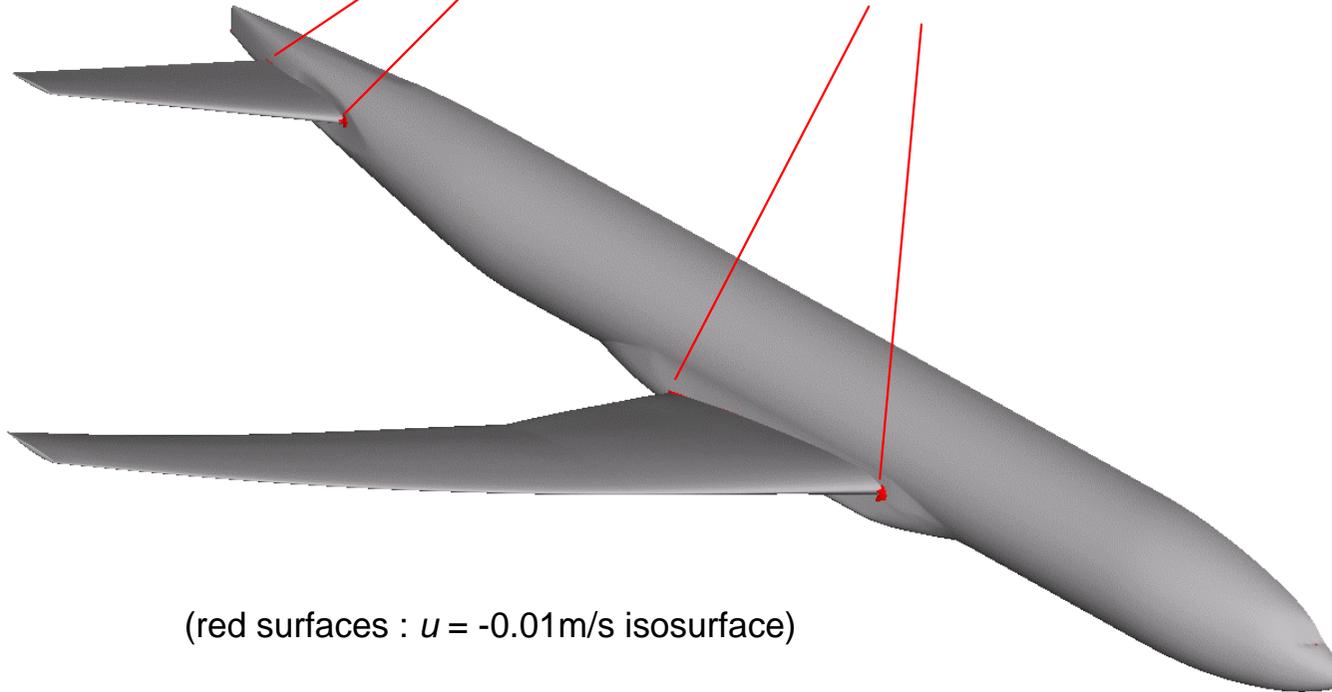
(red surfaces : u = -0.01m/s isosurface)

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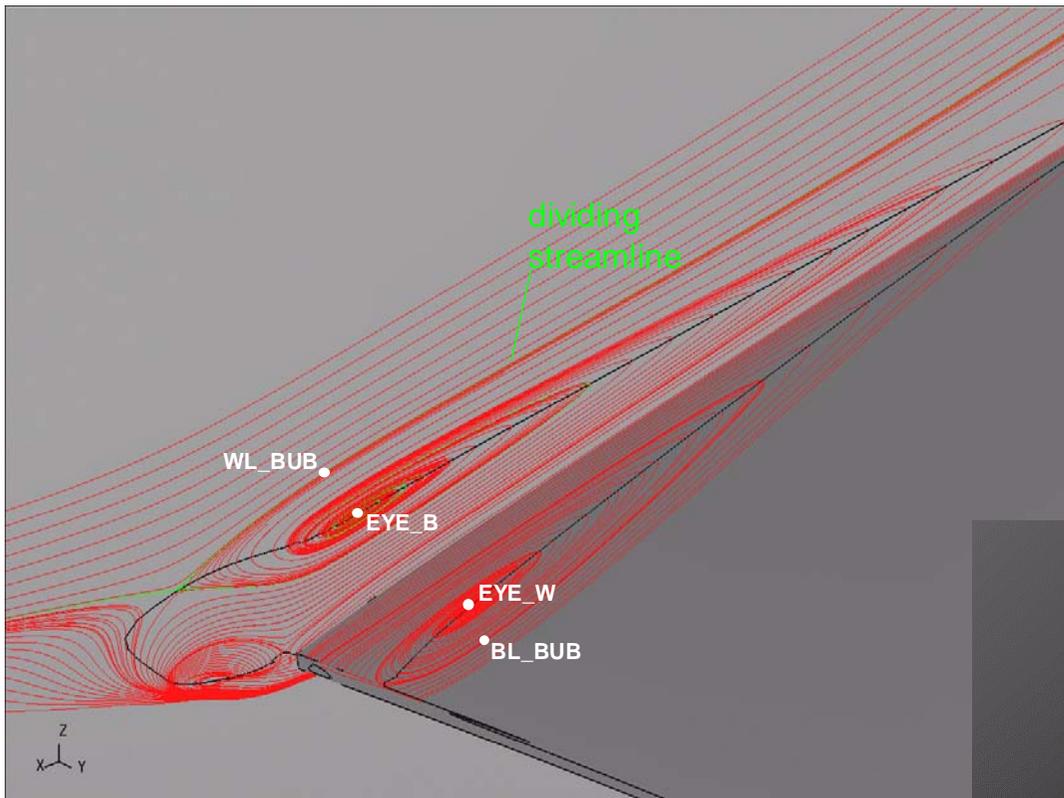
Small region (not more than 5 mm wide) of negative c_{fx} starting at a quite upstream location : FS_BUB abscissa is low
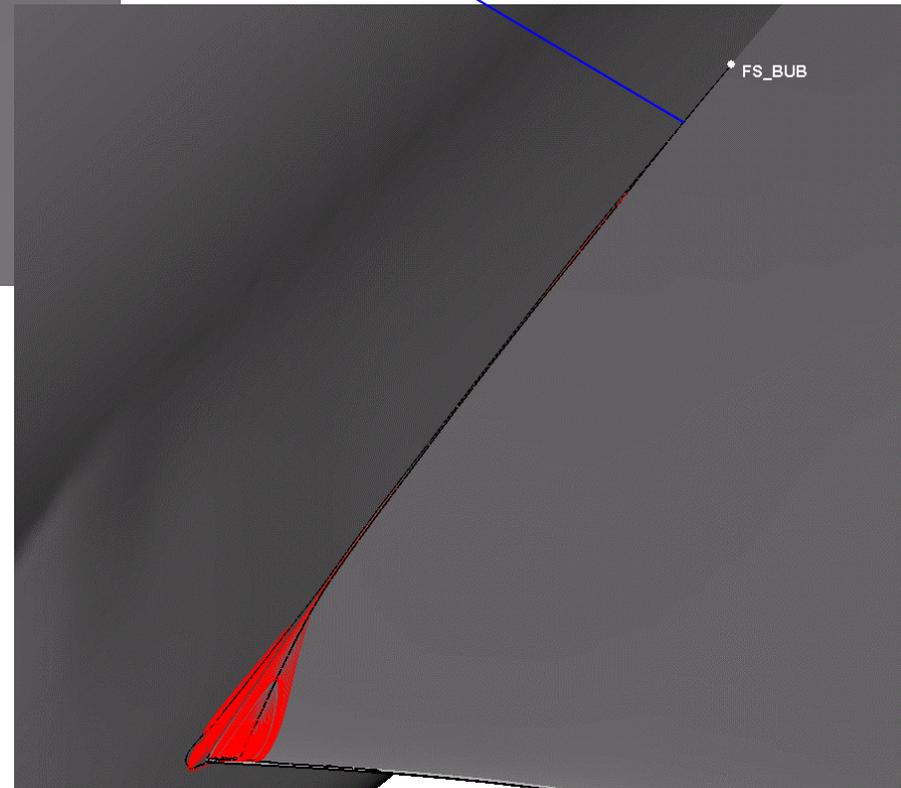
C_L=0.5, fine grid

(black lines : c_{fx} = 0 contour)

Wing-fuselage separation bubble geometry

Coarse

Medium

Fine

Extra-fine

frictionvectorx

MAX	0.0030
0.0030	0.0029
0.0029	0.0027
0.0027	0.0026
0.0026	0.0024
0.0024	0.0023
0.0023	0.0021
0.0021	0.0020
0.0020	0.0018
0.0018	0.0016
0.0016	0.0015
0.0015	0.0014
0.0014	0.0012
0.0012	0.0010
0.0010	0.0009
0.0009	0.0008
0.0008	0.0006
0.0006	0.0004
0.0004	0.0003
0.0003	0.0002
0.0002	0.0000
0.0000	MIN
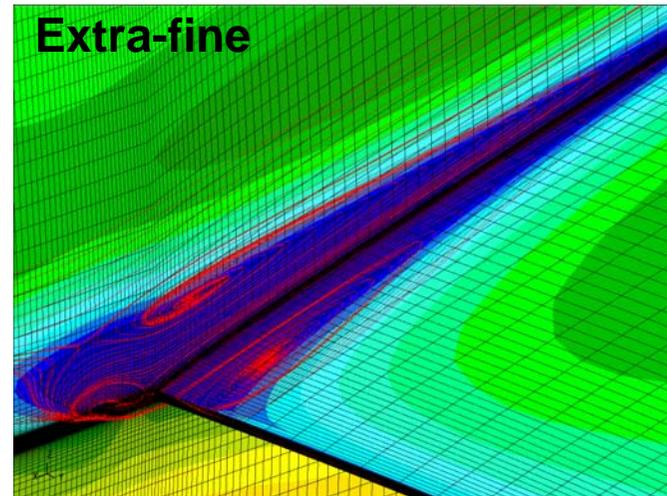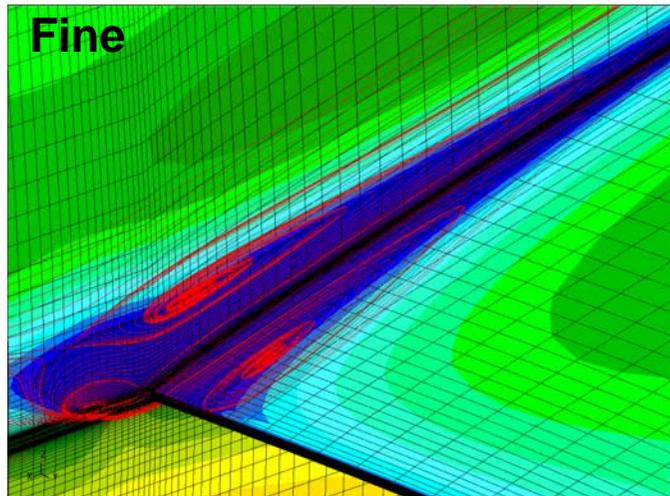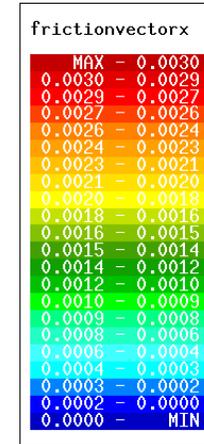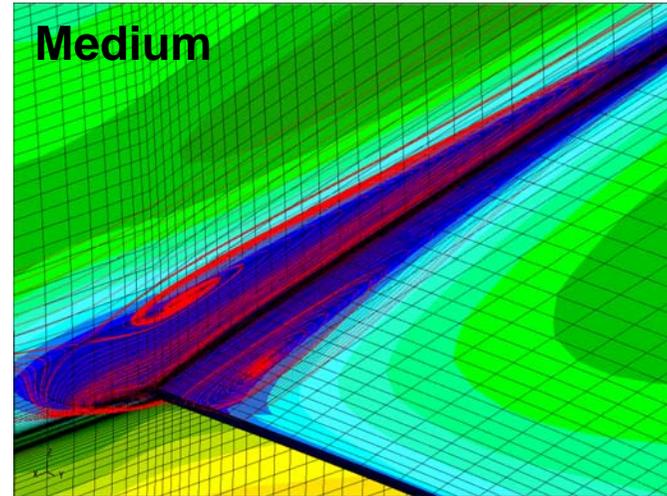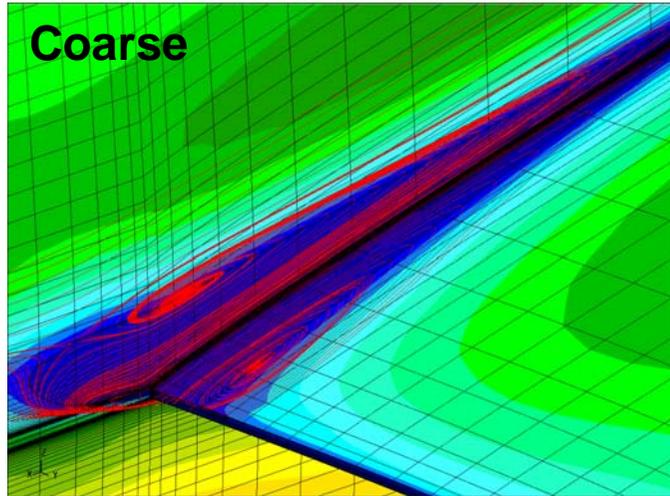
$C_L = 0.5$

No strong influence of mesh refinement on separation bubble geometry

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LE separation bubble geometry

friction vector x

MAX	– 0.0030
0.0030	– 0.0029
0.0029	– 0.0027
0.0027	– 0.0026
0.0026	– 0.0024
0.0024	– 0.0023
0.0023	– 0.0021
0.0021	– 0.0020
0.0020	– 0.0018
0.0018	– 0.0016
0.0016	– 0.0015
0.0015	– 0.0014
0.0014	– 0.0012
0.0012	– 0.0010
0.0010	– 0.0009
0.0009	– 0.0008
0.0008	– 0.0006
0.0006	– 0.0004
0.0004	– 0.0003
0.0003	– 0.0002
0.0002	– 0.0000
0.0000	– MIN

C_L=0.5, fine grid

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Trailing edge separation

frictionvectorx

MAX	0.0030
0.0030	0.0029
0.0029	0.0027
0.0027	0.0026
0.0026	0.0024
0.0024	0.0023
0.0023	0.0021
0.0021	0.0020
0.0020	0.0018
0.0018	0.0016
0.0016	0.0015
0.0015	0.0014
0.0014	0.0012
0.0012	0.0010
0.0010	0.0009
0.0009	0.0008
0.0008	0.0006
0.0006	0.0004
0.0004	0.0003
0.0003	0.0002
0.0002	0.0000
0.0000	MIN

Small
trailing edge
separation in the
outer part of the wing

C_L=0.5, fine grid

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Polars

M=0.85

Medium grids
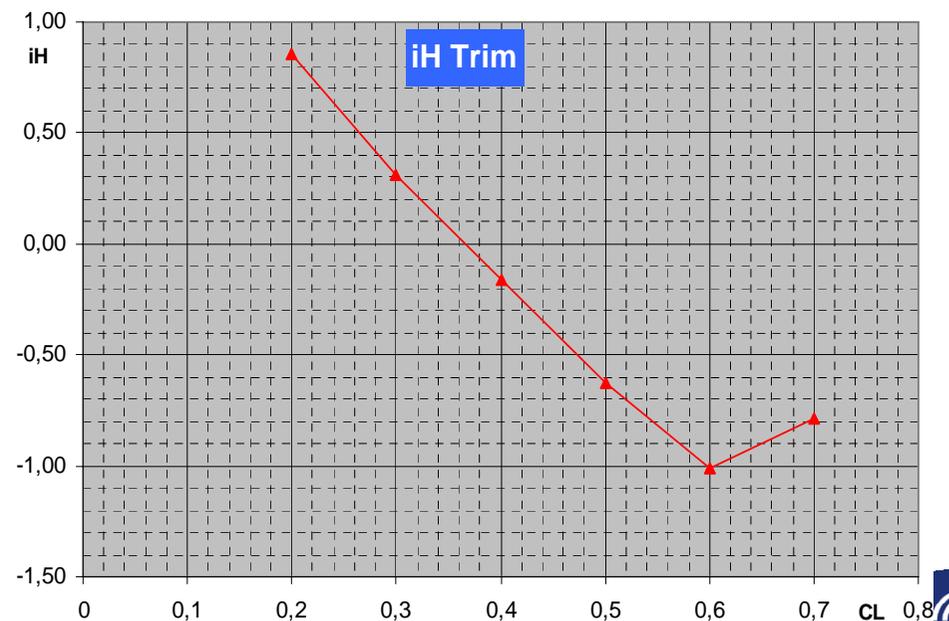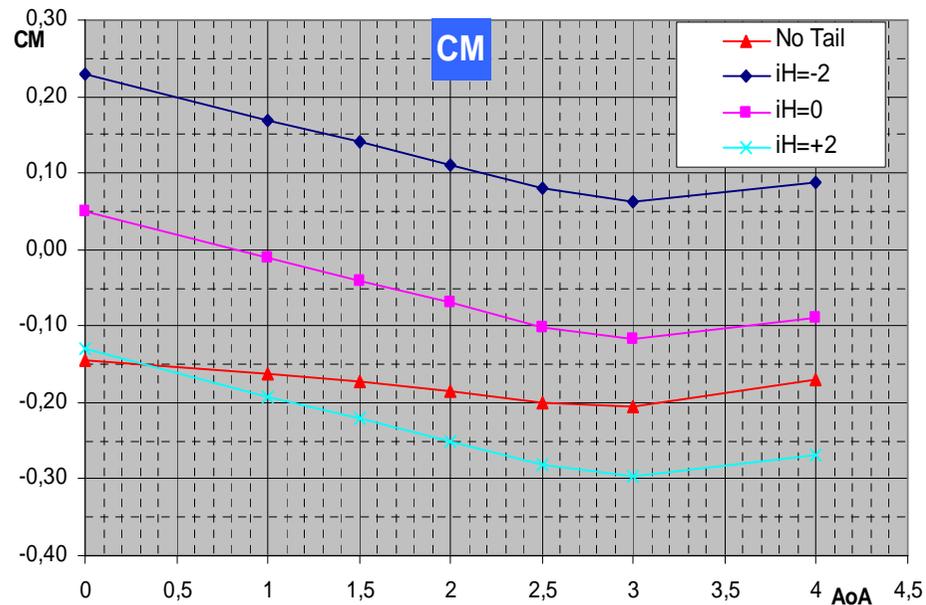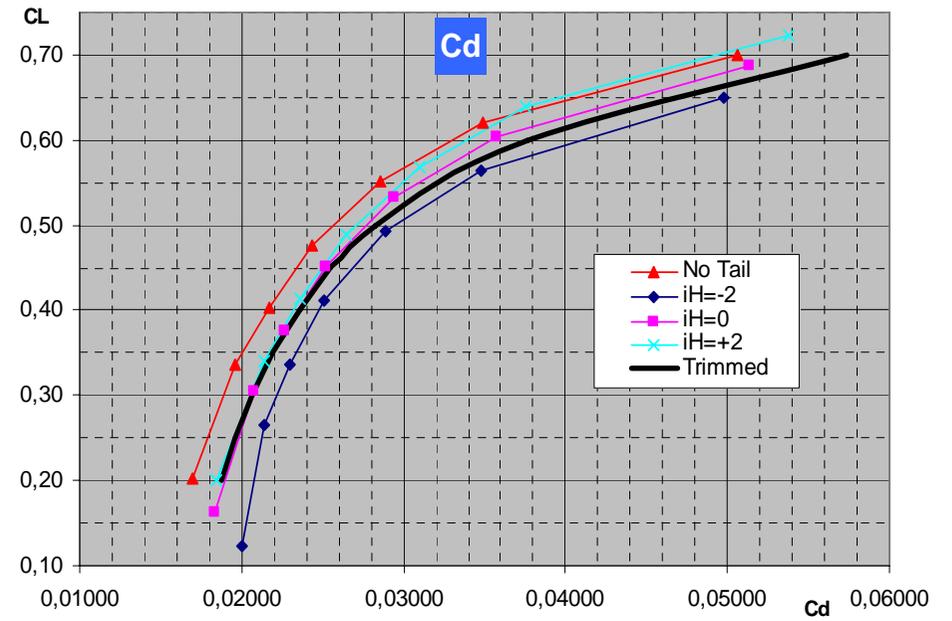
Turbulence model effect
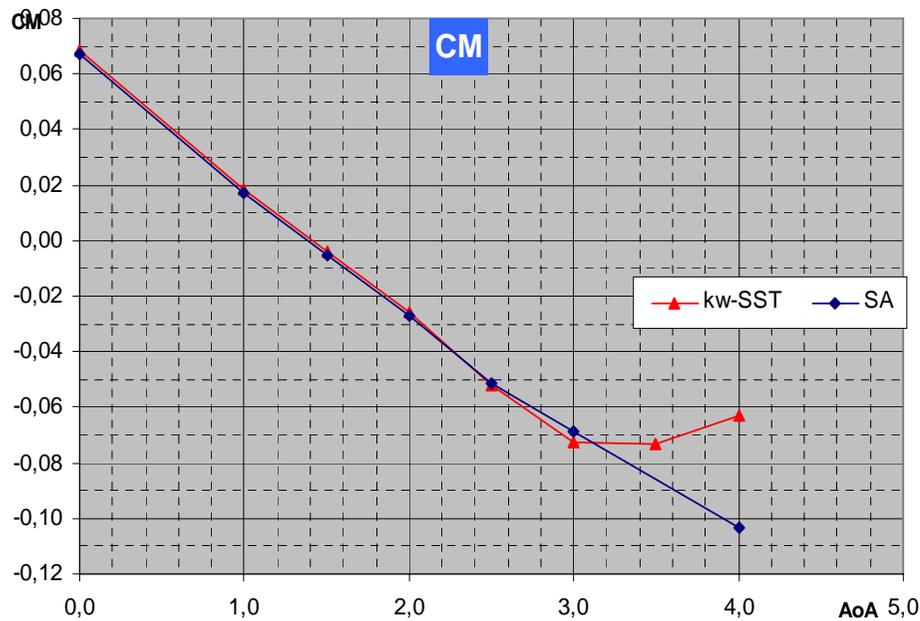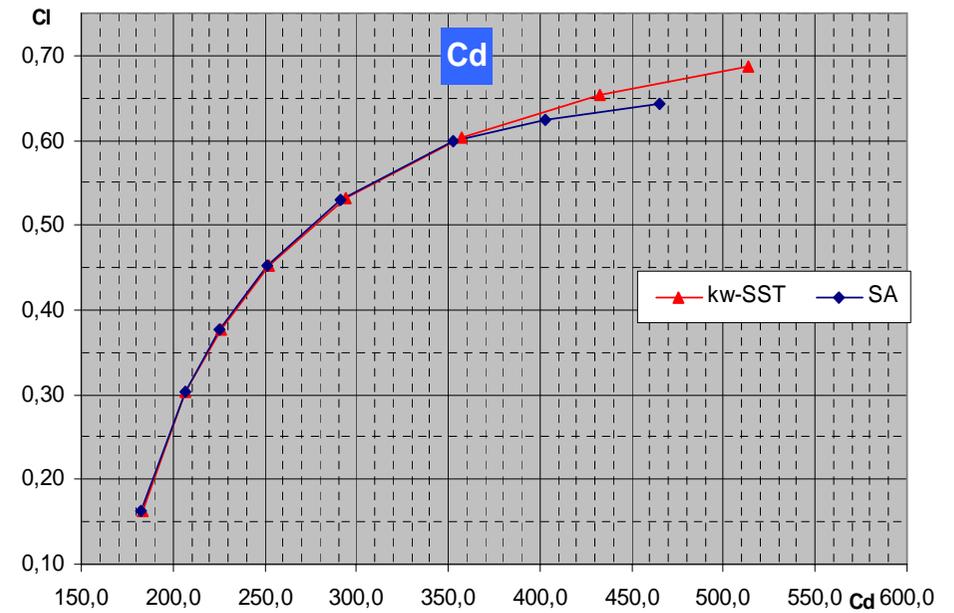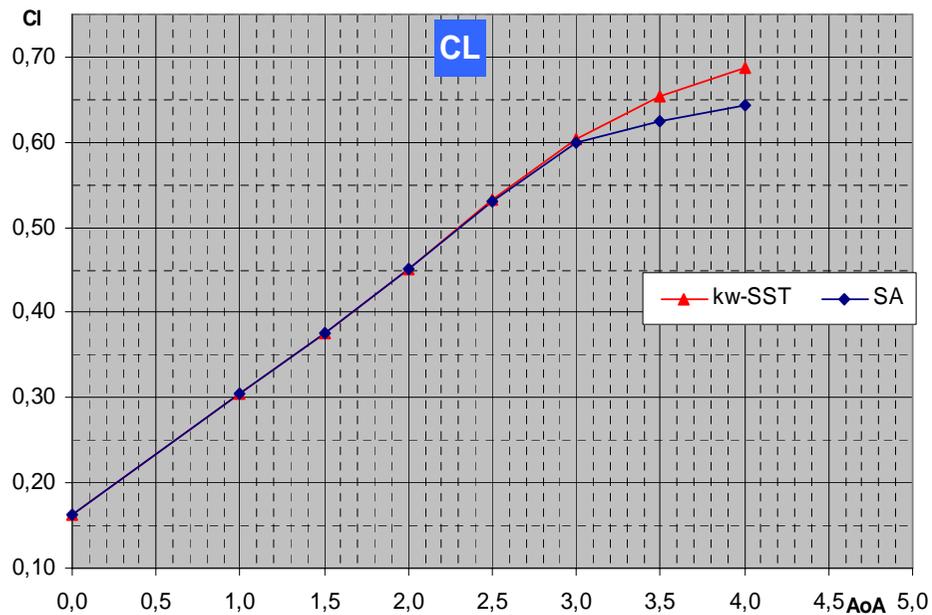
SA and SST models diverge
on C_L, C_D and C_M for $\alpha > 3°$

Turbulence model effect
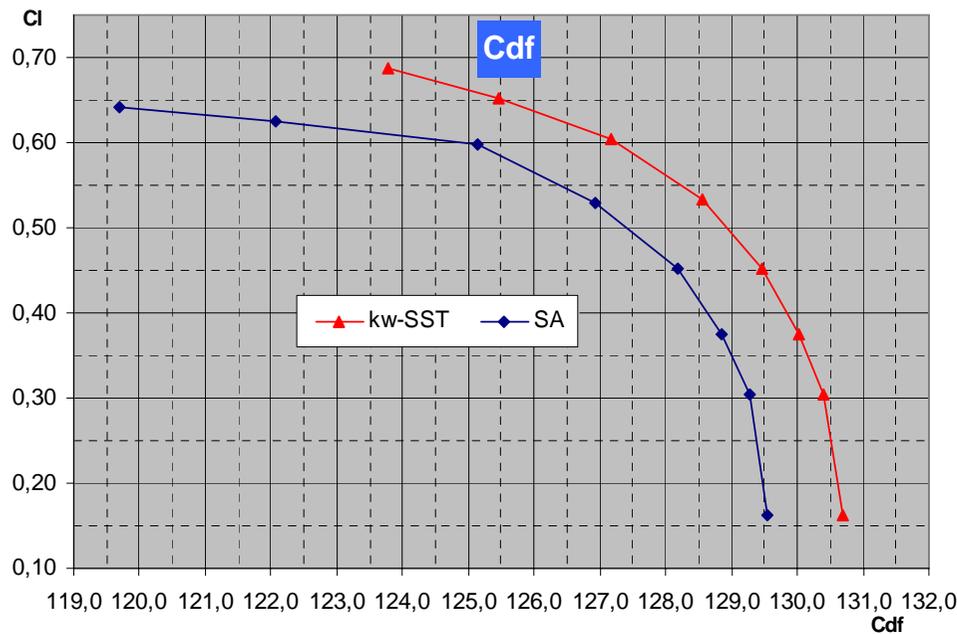
- **Linear range (α=0 to 2.5°) :**

Good agreement for C_{dp}, drag difference between SA and SST is due to skin friction (1 to 1.5 drag counts)
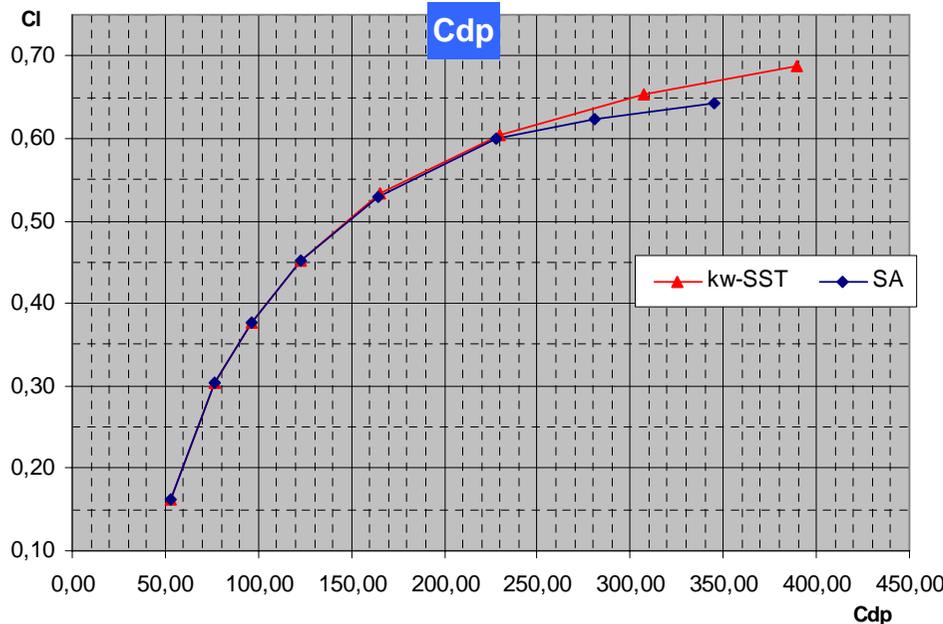
- **High angles of attack (α > 3°) :**

Divergence of pressure drag

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Turbulence model effect

- Spalart-Allmaras model overestimates the wing-fuselage separation at high angles of attack (>3°)

Spalart-Allmaras, α=4°
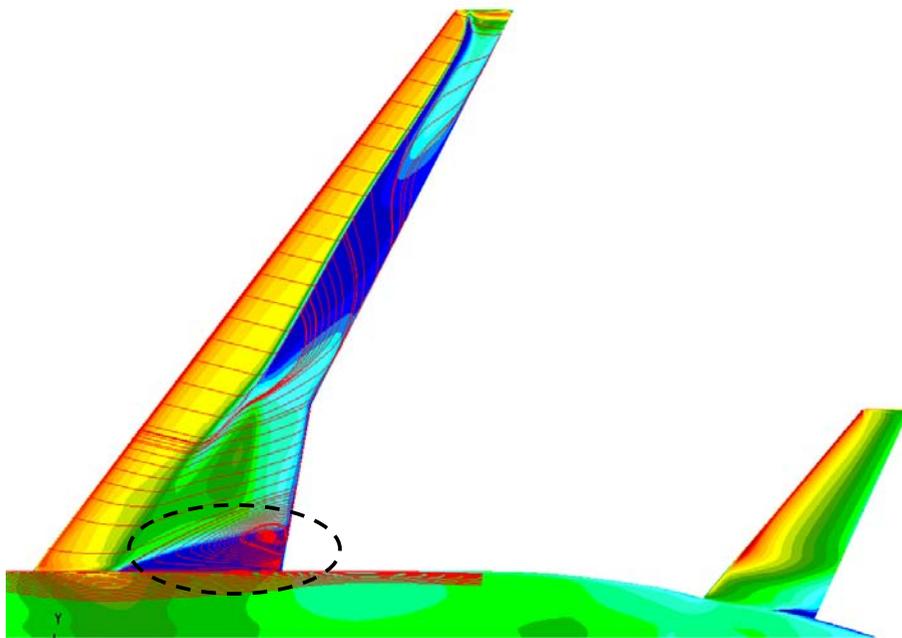
kω-SST, α=4°
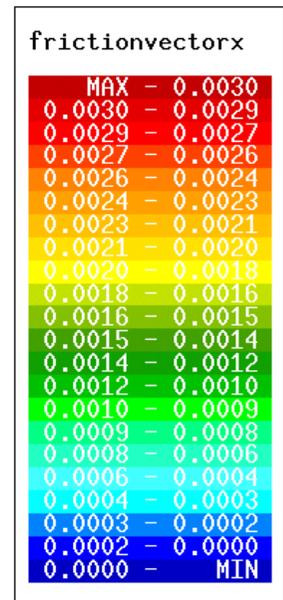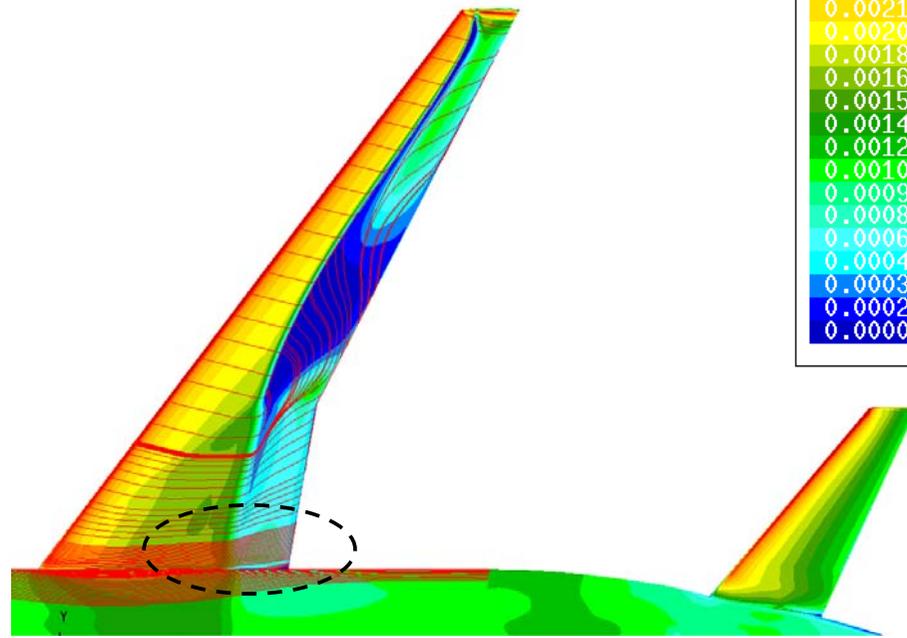
Conclusions

- 4 grid levels used, from 4.6 to 108.3 millions nodes

- No clear grid convergence achieved for extra-fine grids

- Separated areas observed at wing root (leading edge and trailing edge), independent of grid level

- kω-SST model retained for submitted results because of better robustness at high angles of attack

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WITH BAE SYSTEMS