CFD computations for Common Research Model using the code HIFUN

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Outline

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Introduction

Tools employed

- Grid generation for Common Research Model (CRM) is carried out using GAMBIT and TGRID, commercial softwares from Fluent available at Supercomputer Education and Research Centre (SERC), IISc.
- Flow computations for CRM are performed using the code HIFUN, a commercial software from Simulation and Innovation Engineering Solutions (SandI) available at CAd Lab, Department of Aerospace Engineering, IISc.
- Postprocessing is carried out using TECPLOT available at SERC, IISc.

Features of code HIFUN

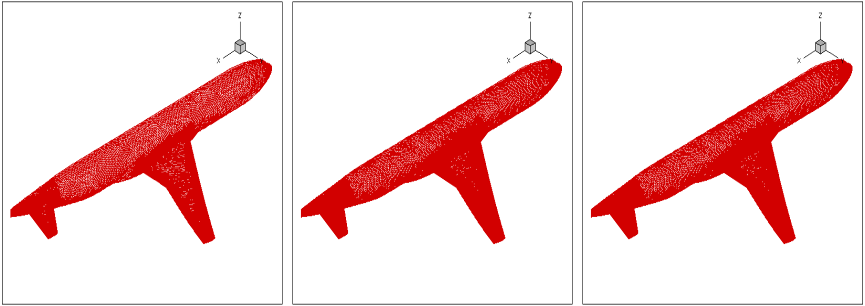
HIFUN: **HI**gh Resolution **F**low Solver on **UN**structured Meshes

Algorithmic features

- Unstructured cell centre finite volume methodology.
- Higher order accuracy: linear reconstruction procedure.
- Flux limiting: Venkatakrishnan Limiter.
- Inviscid flux computation: Roe scheme.
- Convergence acceleration: matrix free symmetric Gauss Seidel relaxation procedure.
- The viscous flux discretization: Green–Gauss theorem based diamond path reconstruction.
- Eddy viscosity computation: Spalart Allmaras TM.
- Parallelization: MPI.

Outline

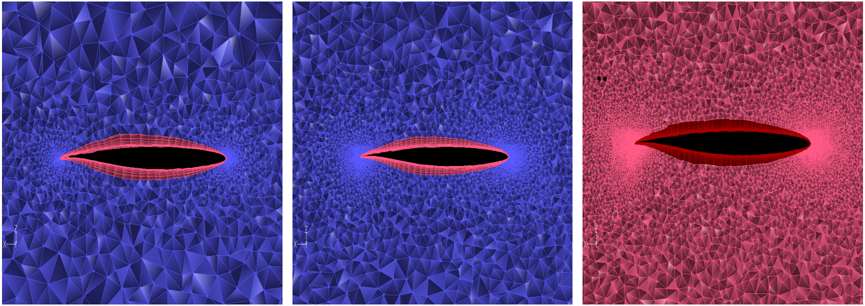
Tail 0 configuration: Surface grids



	Coarse	Medium	Fine
Field cells:	6244147	21288317	58076968
TE cells:	2	4	8

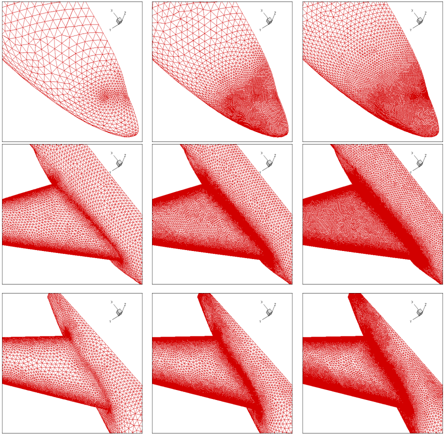
Tail 0 configuration: Cut section

Cut section at 40 % of wing span



	Coarse	Medium	Fine
BL Cells:	21	31	41
Average y^+:	0.50	0.40	0.27
Max y^+:	0.89	0.74	0.52

Tail 0 configuration: Surface grids



← Nose

← Wing fuselage junction

← Tail fuselage junction

Coarse Medium Fine

Tail 0 configuration: Grid details

Grid details

Grid Type	Coarse	Medium	Fine
Field Nodes	2152435	7442279	19028150
Field Cells	6244147	21288317	58076968
Boundary Nodes	89994	213560	390969
Boundary Faces	171374	407710	748150
BL 1^{st}–Cell (in)	0.001478	0.000985	0.000657
BL Max-Growth	1.5	1.32	1.24
BL Cells	21	31	41

Note

Boundary layer is grown using aspect ratio based algorithm.

Computational details

Tail 0 configuration: Fine grid with about 58 million field cells

Resource details

- Computer Platform: IBM Blue Gene
- Number of processors: 1024
- Operating system: Unix
- Compiler: XL FORTRAN 90
- Run time Wall clock: 38 hours
- Memory requirement of HIFUN: 51 MB per processor (Approximately)

Outline

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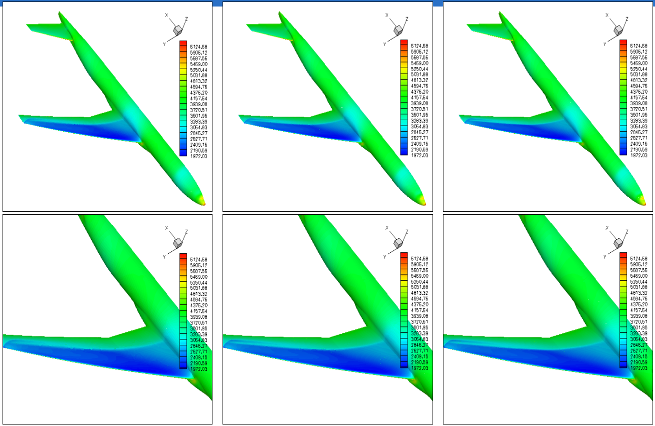
3 Results
- Case 1.1: Grid convergence
- Case 1.2: Downwash study
- Case 3 (optional): Reynolds number study

Tail 0 configuration: Pressure distribution

$M_\infty = 0.85$, $Re_\infty = 5.00$ *million*, $CL = 0.5 \pm 0.001$



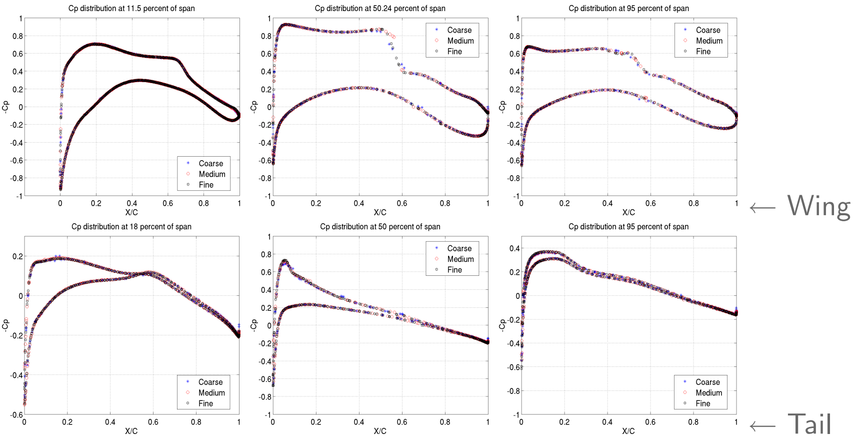
← Overall

← Wing

Coarse	Medium	Fine
$\alpha = 2.34^o$	$\alpha = 2.31^o$	$\alpha = 2.3^o$

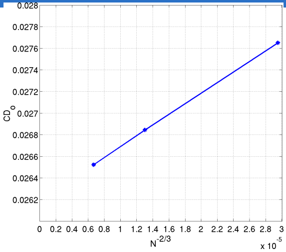
Tail 0 configuration: Cp distribution

$M_\infty = 0.85$, $Re_\infty = 5.00$ *million*, $CL = 0.5 \pm 0.001$

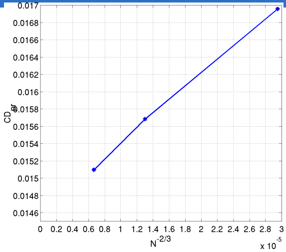


Tail 0 configuration: Drag convergence

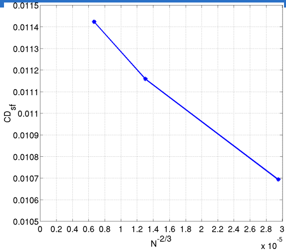
$M_\infty = 0.85$, $Re_\infty = 5.00$ *million*, $CL = 0.5 \pm 0.001$



CD_o



CD_{pr}



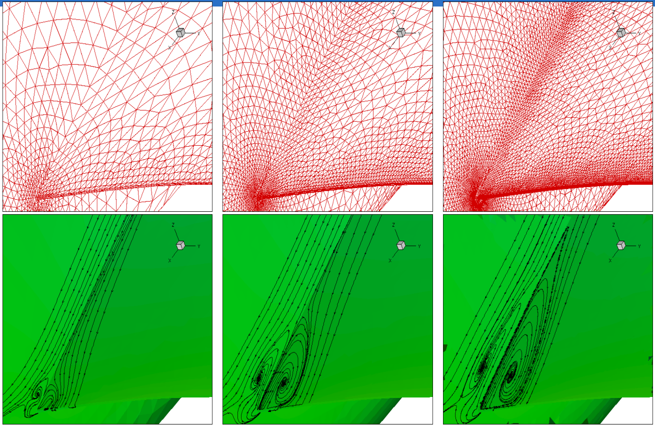
CD_{fr}

Comments

- For CD_o and CD_{pr}, $\Delta y = 2$ drag counts and for CD_{fr}, $\Delta y = 1$ drag count.
- Drag curves do not asymptote on fine grid.

Separation bubble: wing fuselage junction

$M_\infty = 0.85$, $Re_\infty = 5.0$ *million*, $CL = 0.5 \pm 0.001$



← Grids

← Bubbles

Coarse	Medium	Fine
$\alpha = 2.34^o$	$\alpha = 2.31^o$	$\alpha = 2.3^o$

Separation bubble location in inches

$M_\infty = 0.85$, $Re_\infty = 5.0$ *million*, $CL = 0.5 \pm 0.001$

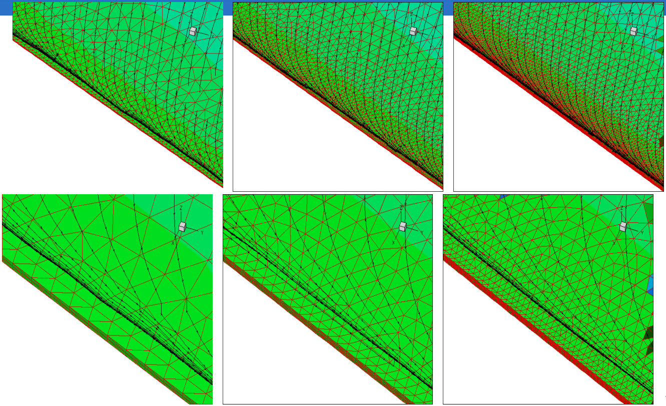
GRID	FS_BUB	BL_BUB	WL_BUB
Coarse	1451.82	125.608	144.788
Medium	1433.68	130.730	148.378
Fine	1410.47	132.632	149.274

GRID	FS_EYE_W	BL_EYE_W	WL_EYE_W
Coarse	1457.52	123.633	141.705
Medium	1453.34	125.337	143.211
Fine	1451.59	126.387	143.868

GRID	FS_EYE_B	BL_EYE_B	WL_EYE_B
Coarse	1456.81	120.308	143.101
Medium	1454.67	120.297	145.377
Fine	1452.47	120.267	146.384

Separation line near wing trailing edge

$M_\infty = 0.85$, $Re_\infty = 5.0$ *million*, $CL = 0.5 \pm 0.001$



← Close view

← Closer view

Coarse Medium Fine

Separation line extends between the stations that are 39.71% and 84.56% of wing span.

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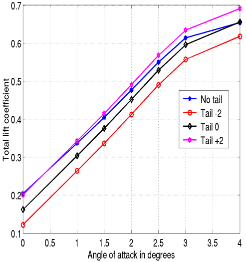
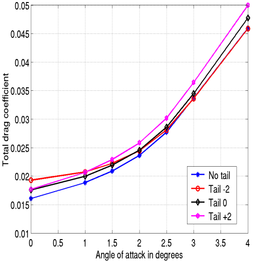
- Case 1.2: Downwash study
- Case 3 (optional): Reynolds number study

Comparison of integrated coefficients

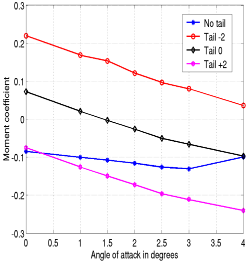
$M_\infty = 0.85$, $Re_\infty = 5.0$ *million*



CL



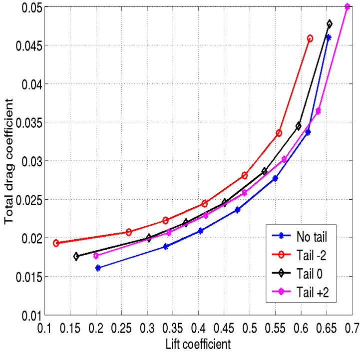
CD



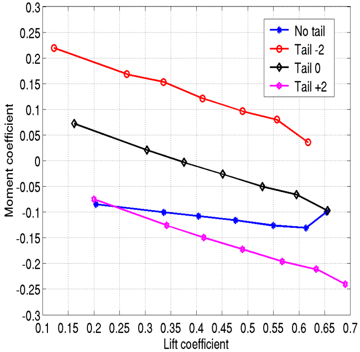
CM

Comparison of integrated coefficients

$M_\infty = 0.85$, $Re_\infty = 5.0$ *million*



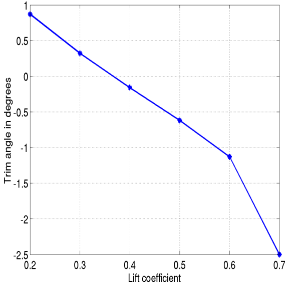
Drag polar



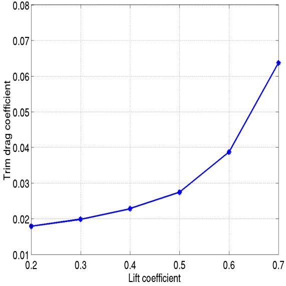
CL v/s CM

Trim drag and downwash calculations

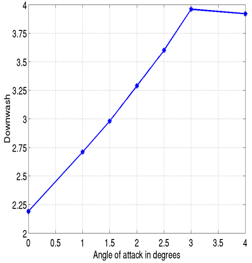
$M_\infty = 0.85, Re_\infty = 5.0$ *million*



Trim angle



Trim drag



Downwash

Outline

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- Case 1.1: Grid convergence
- Case 1.2: Downwash study
- Case 3 (optional): Reynolds number study

Reynolds number study

Tail 0, CL $= 0.5 \pm 0.001$, Mach $= 0.85$, Medium grid

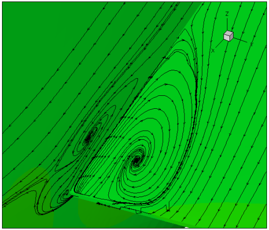
Re	Field cells	BL–first spacing (in)	Average y^+
5.0E6	21288317	0.000985	0.40
20.0E6	22802687	0.000273	0.29

Re	α	CL_T	CD_T	CM_T
5.0E6	2.31	0.4997	0.02765	-0.04141
20.0E6	2.07	0.4991	0.02264	-0.04592

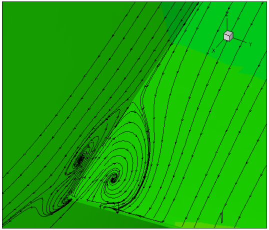
Re	CD_P	CD_{SF}	$CD - \frac{CL^2}{PA}$
5.0E6	0.01695	0.01069	0.018818
20.0E6	0.01434	0.00829	0.013829

Comparison of separation bubbles

Tail 0, $CL = 0.5 \pm 0.001$, $Mach = 0.85$, Medium grid



$Re = 5.0E6$



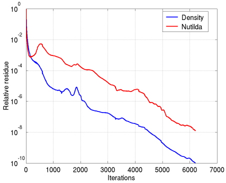
$Re = 20.0E6$

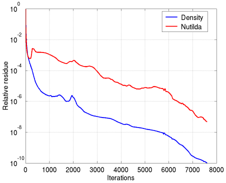
Note

- Smaller separation bubble at Wing Body junction for $Re = 20.0E6$.
- No separation near wing trailing edge for $Re = 20.0E6$.

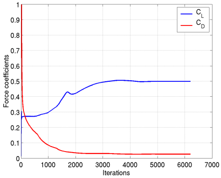
Comparison of convergence histories

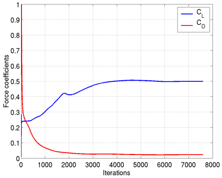
Tail 0, $CL = 0.5 \pm 0.001$, $Mach = 0.85$





← Residue convergence





← Coefficients evolution

$Re = 5.0E6$
Fine grid

$Re = 20.0E6$
Medium grid

Outline

Concluding remarks

Conclusions

- In the present work, results of RANS computations for Common Research Model using the code HIFUN are presented.
- Unstructured hybrid grids for various configurations are generated using GAMBIT and TGRID.
- During grid generation, except for the number of field cells and number of trailing edge points, the guidelines provided by DPW4 committee are followed.

Concluding remarks

Conclusions continued

- With grid refinement, total drag shows reduction by 4–8 drag counts. However, the drag curves do not asymptote on fine grid. Hence any conclusion about the grid convergence of drag can be drawn only after obtaining results on extra–fine grid.
- Separation bubble is seen at wing–fuselage junction and with grid refinement it becomes more pronounced.
- Separation line is seen near the trailing edge on the wing upper surface. The location and spanwise extent of the separation line does not change with grid refinement.
- For all the grids, no separation is observed on the tail.

Concluding remarks

Conclusions continued

- We await the experimental results for validation of downwash and trim drag calculations.
- For $Re = 20.0E6$, separation bubble seen at the wing–fuselage junction is smaller in size compared to the one seen for $Re = 5.0E6$.
- For $Re = 20.0E6$, no separation is observed near wing trailing edge.

Acknowledgments

Authors wish to thank Prof. Govindarajan, Chairman, Supercomputer Education and Research Centre (SERC), IISc for permitting them to use IBM Blue Gene facility on a preferential queue and Mr. Kiran, System Administrator, IBM Blue Gene, for his help in the execution; but for this support these computations wouldn't have been possible.

Thank you

Thank you

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