Investigation of Solution Methodology for Resolution of Side of Body Flow Separation

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Outline

- Introduction
- Grid Details
- Results
- Conclusion

Introduction

Objective

- **Investigate solution method issues for high-lift prediction on reasonable grids using only workshop provided grid systems**

- **Investigate ability of RANS methods to predict side-of-body separation in high-lift flows and the role of the Horse-shoe vortex in wing-body junction flows.**

Scope of Work

Configuration 1
(Slat 30° Flap 25° Full Span)

Re = 4.63 Million, M = 0.20

Grids Used : CoarseTet, MediumTet, CoarseTetPrism, MediumTetPrism, FineTetPrism

Angle of Attack (α) : 15.067°, 19.194°, 21.236°, 22.261°, 25.338°

Simulation Details

Tools Used

- Metacomp Technologies CFD++
- CEI Ensight 9.2

Solver Settings

- Unstructured Cell Based Finite Volume Method
- Compressible Navier-Stokes Equations with and without Preconditioning
- Second Order Upwind Spatial Descretization
- Minmod Flux Limiter
- SA/SARC/KERT/SST Turbulence Model
- Multigrid Convergence Acceleration

Computational Platform

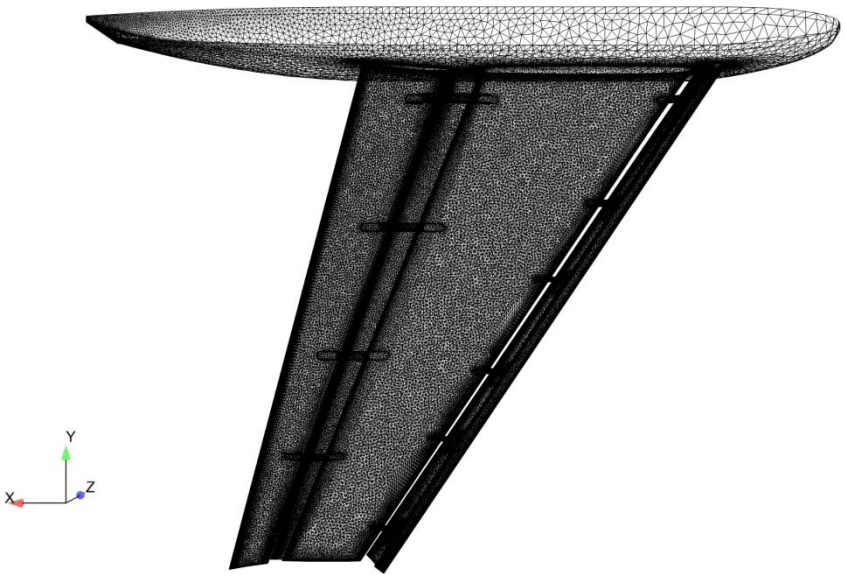
- **EKA** Supercomputing Cluster
- 1800 Compute Nodes
- Each node contains Dual Intel Xeon Quad Core E5365, 3.0 GHz Processors with 16GB Memory and 72 GB Hard Disk
- Peak Compute Capacity 180 Teraflops
- Attained Sustained Compute Capacity 132.8 Teraflops for Linpack Benchmark

Grid Details

Grid Details

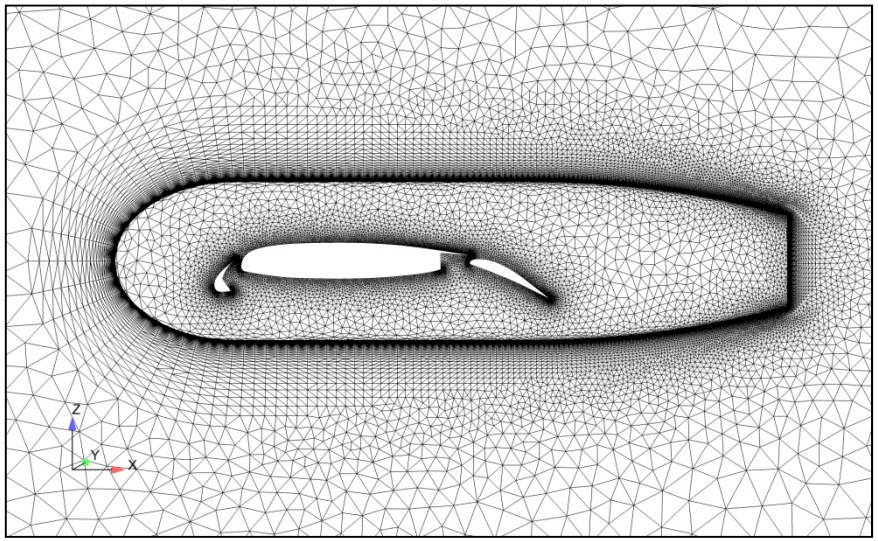
All the grids were availed from the AIAA HiLiftPW website and model brackets

Grid Type	Pyramids	Tetrahedra	Prisms	Total Cell Count	Total Point Count
Coarse Tets	N.A.	16406610	N.A.	16406610	2782000
Medium Tets	N.A.	48347976	N.A.	48347976	8146915
Coarse TetPrisms	113278	1570378	4869892	6553548	2782000
Medium TetPrisms	244863	3572175	14762025	18579063	8146915
Fine TetPrisms	386410	23493668	40063863	63943941	24232815

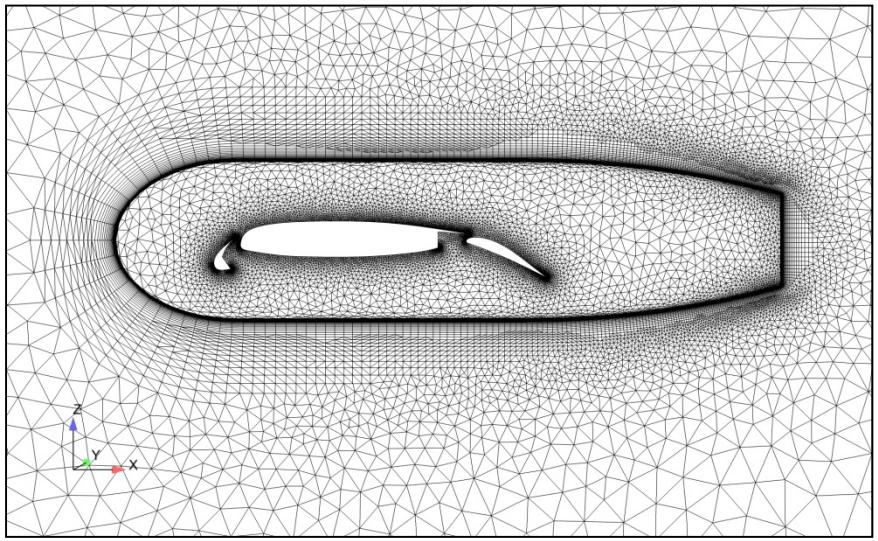


Grid Details

Tetrahedral Grids were obtained by splitting the prism elements.



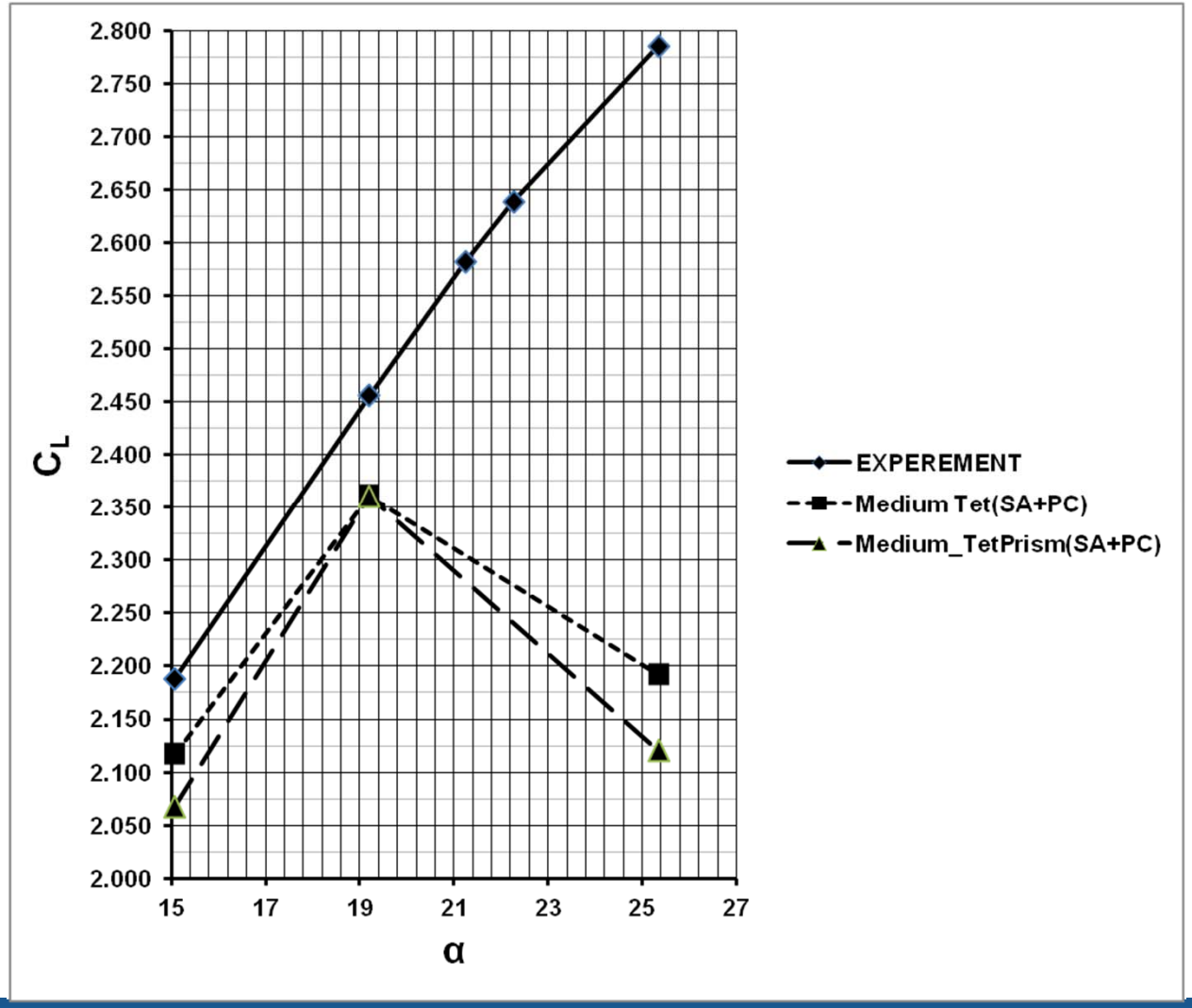
Tetrahedral Grid

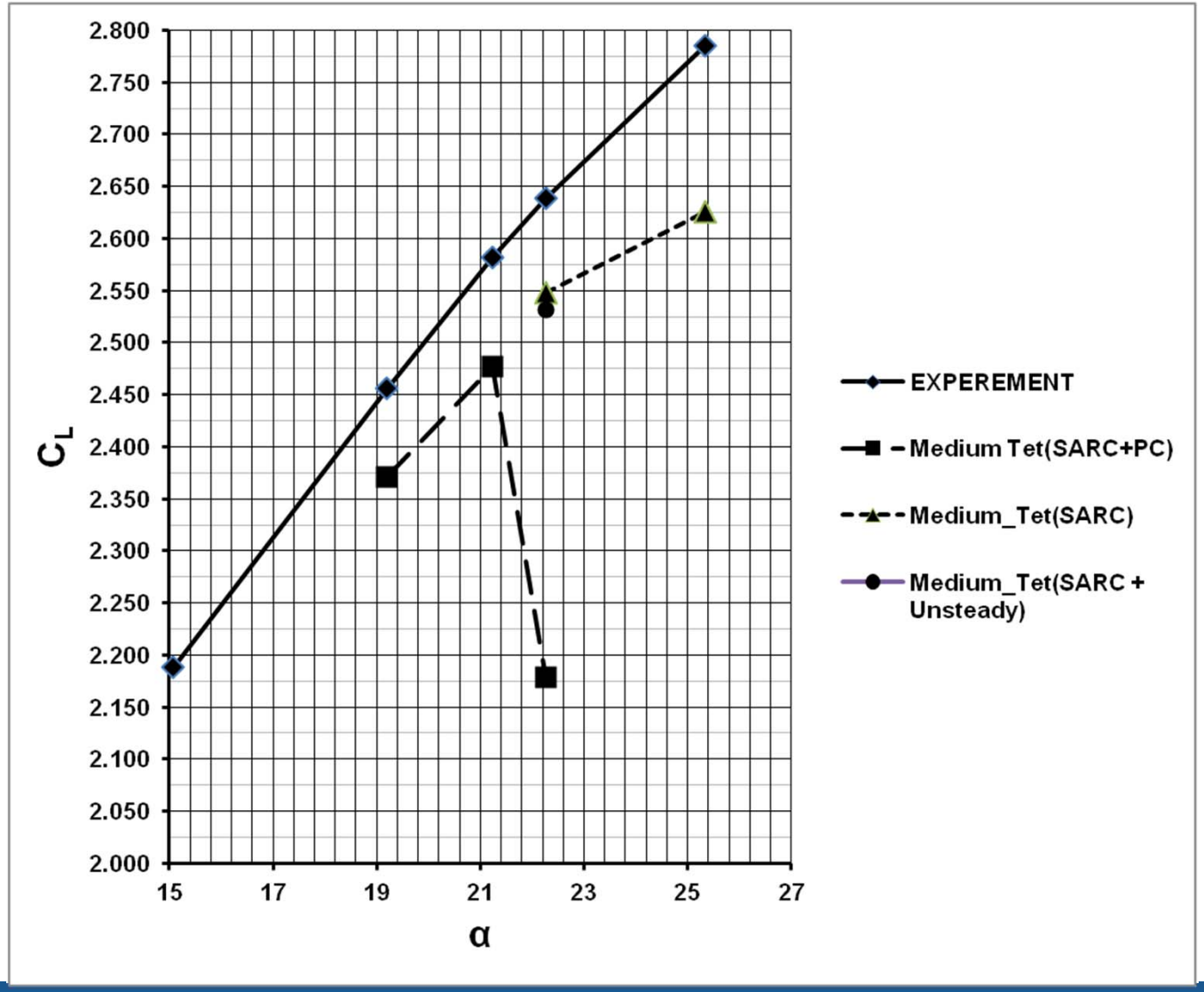


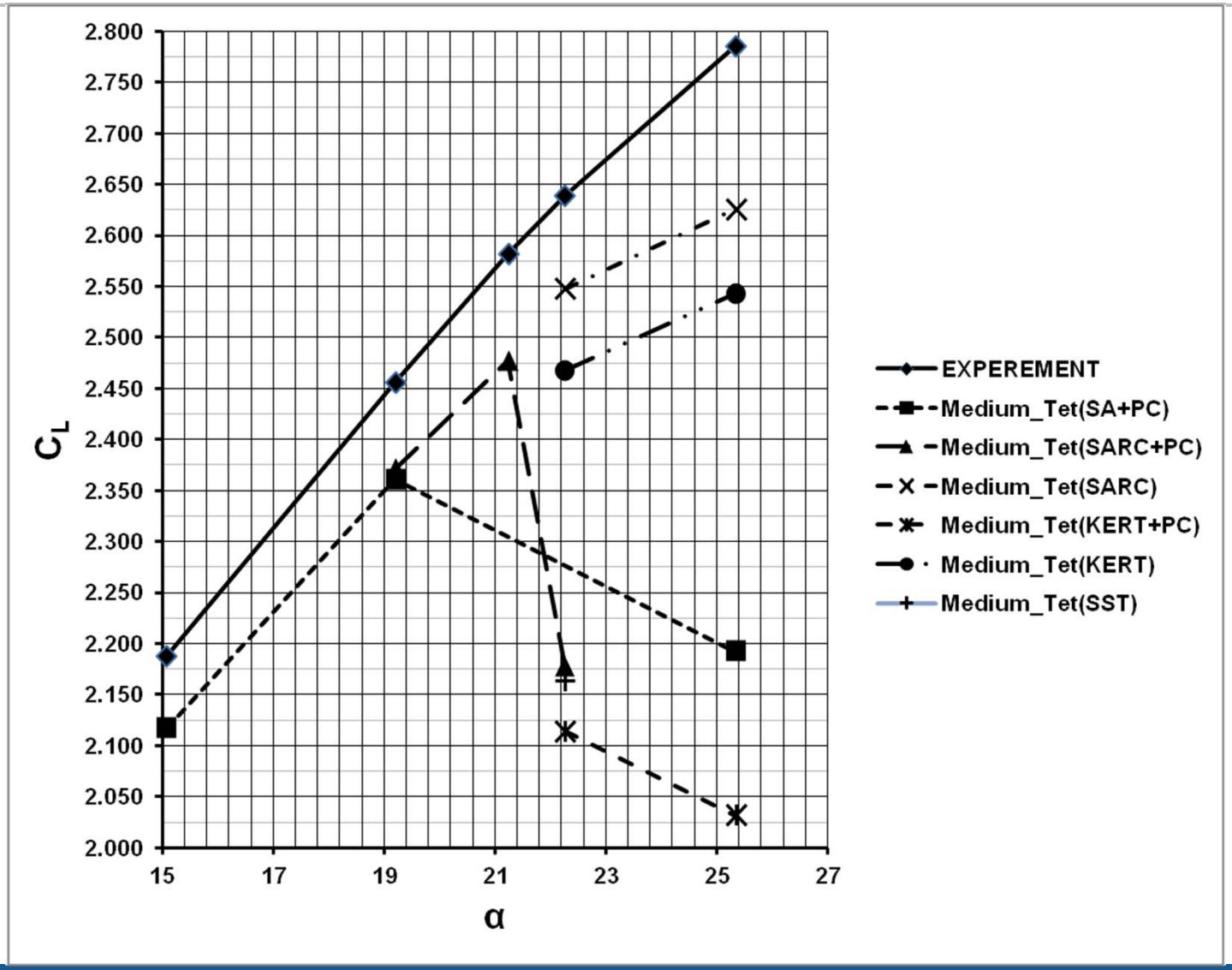
TetPrism Grid

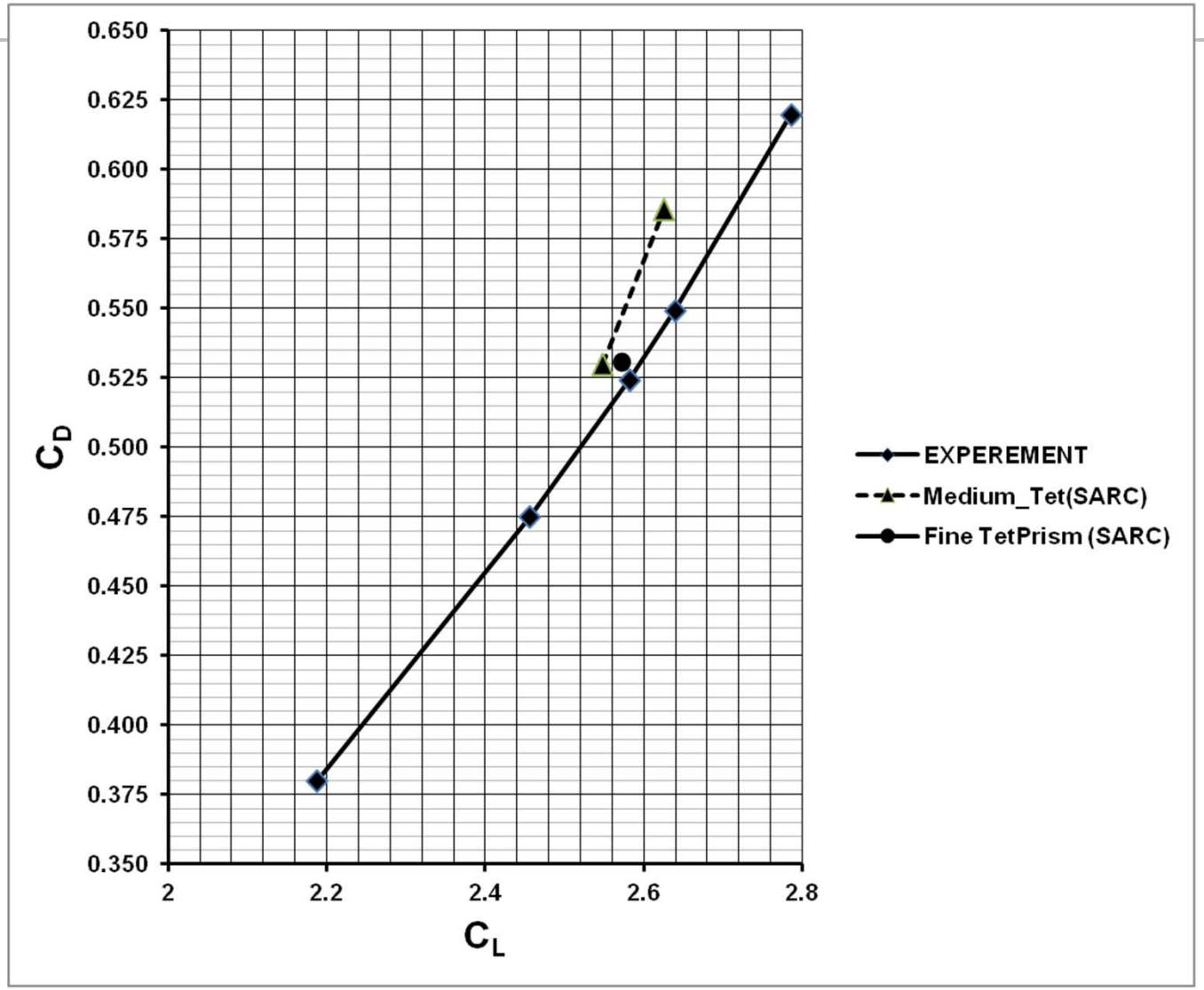
Results

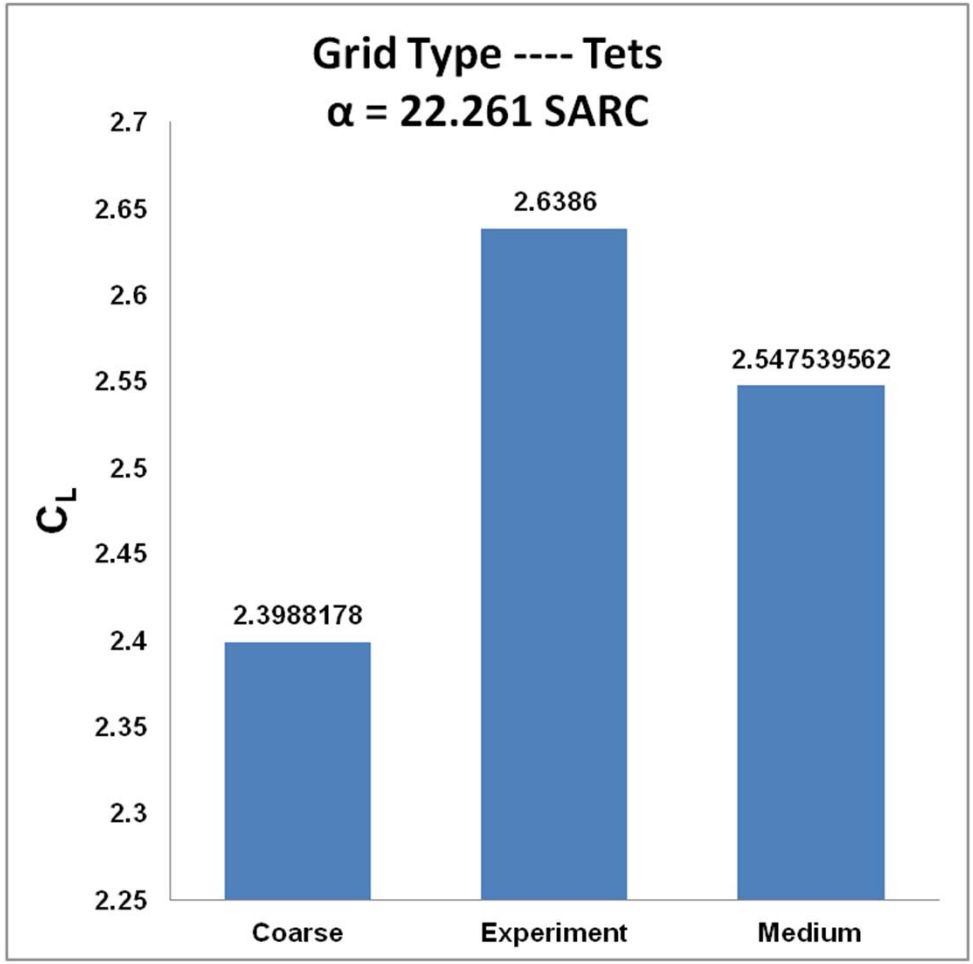
Solution Procedure

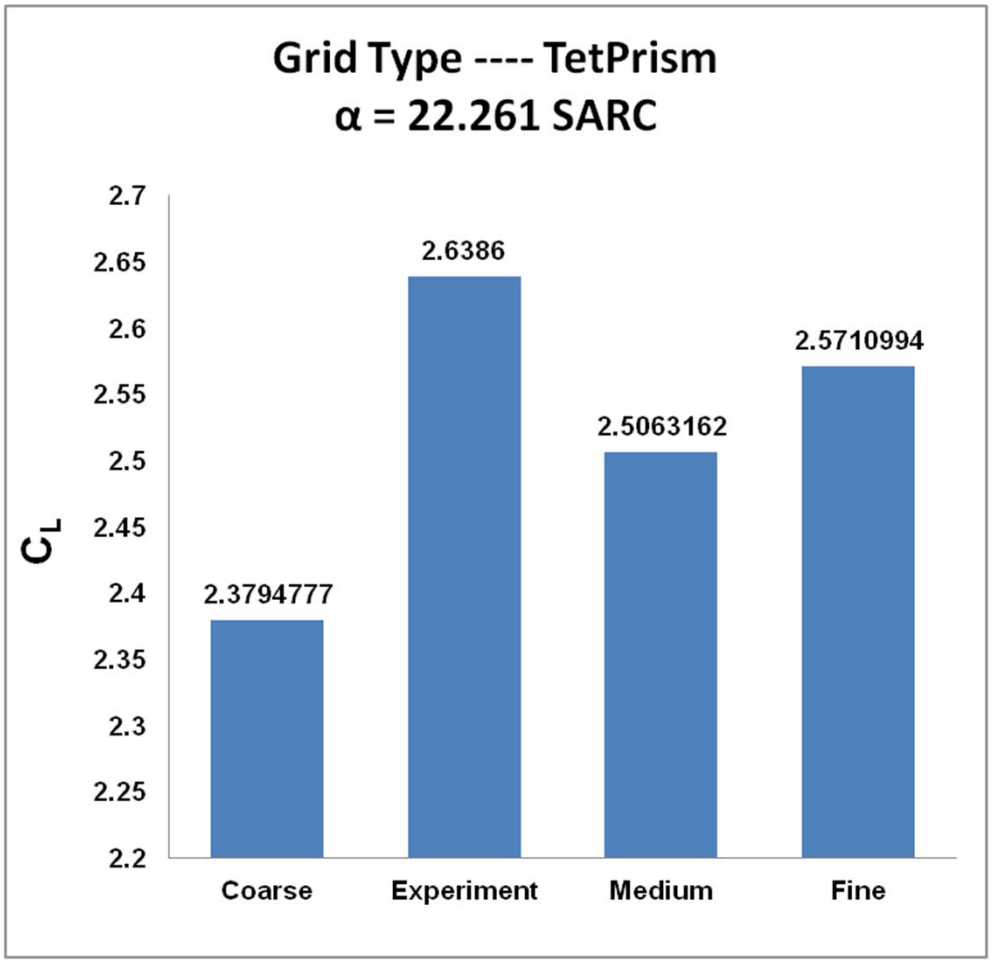

2.800
2.750
2.700
2.650
2.600
2.550
2.500
2.450
2.400
2.350
2.300
2.250
2.200
2.150
2.100
2.050
2.000
C_L
15
17
19
21
23
25
27
α
EXPEREMENT
Medium Tet(SA+PC)
Medium_TetPrism(SA+PC)


2.800
2.750
2.700
2.650
2.600
2.550
2.500
2.450
2.400
2.350
2.300
2.250
2.200
2.150
2.100
2.050
2.000
C_L
15
17
19
21
23
25
27
α
EXPEREMENT
Medium Tet(SARC+PC)
Medium_Tet(SARC)
Medium_Tet(SARC + Unsteady)

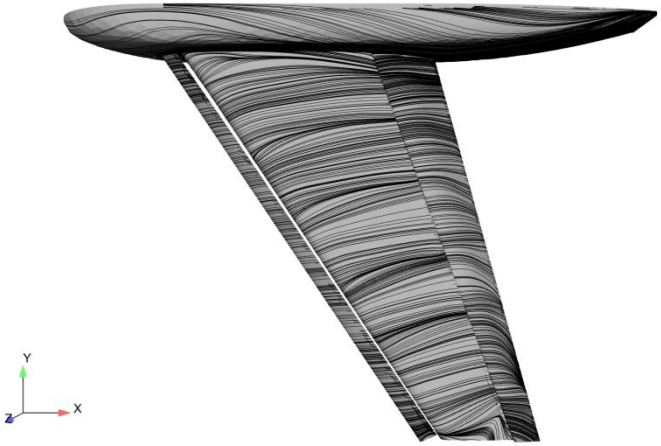

2.800
2.750
2.700
2.650
2.600
2.550
2.500
2.450
2.400
2.350
2.300
2.250
2.200
2.150
2.100
2.050
2.000
C_L
15
17
19
21
23
25
27
α
EXPEREMENT
Medium_Tet(SA+PC)
Medium_Tet(SARC+PC)
Medium_Tet(SARC)
Medium_Tet(KERT+PC)
Medium_Tet(KERT)
Medium_Tet(SST)


0.650
0.625
0.600
0.575
0.550
0.525
0.500
0.475
0.450
0.425
0.400
0.375
0.350
C_D
2
2.2
2.4
2.6
2.8
C_L
EXPEREMENT
Medium_Tet(SARC)
Fine TetPrism (SARC)

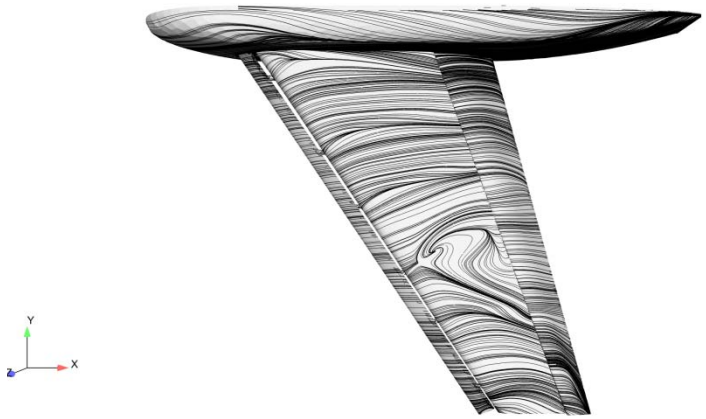

Grid Type ---- Tets
α = 22.261 SARC
2.7
2.65
2.6
2.55
2.5
2.45
2.4
2.35
2.3
2.25
C_L
2.3988178
2.6386
2.547539562
Coarse
Experiment
Medium


Grid Type ---- TetPrism
α = 22.261 SARC
C_L
2.7
2.65
2.6
2.55
2.5
2.45
2.4
2.35
2.3
2.25
2.2
2.3794777
2.6386
2.5063162
2.5710994
Coarse
Experiment
Medium
Fine

Surface streamlines, α = 25 degrees



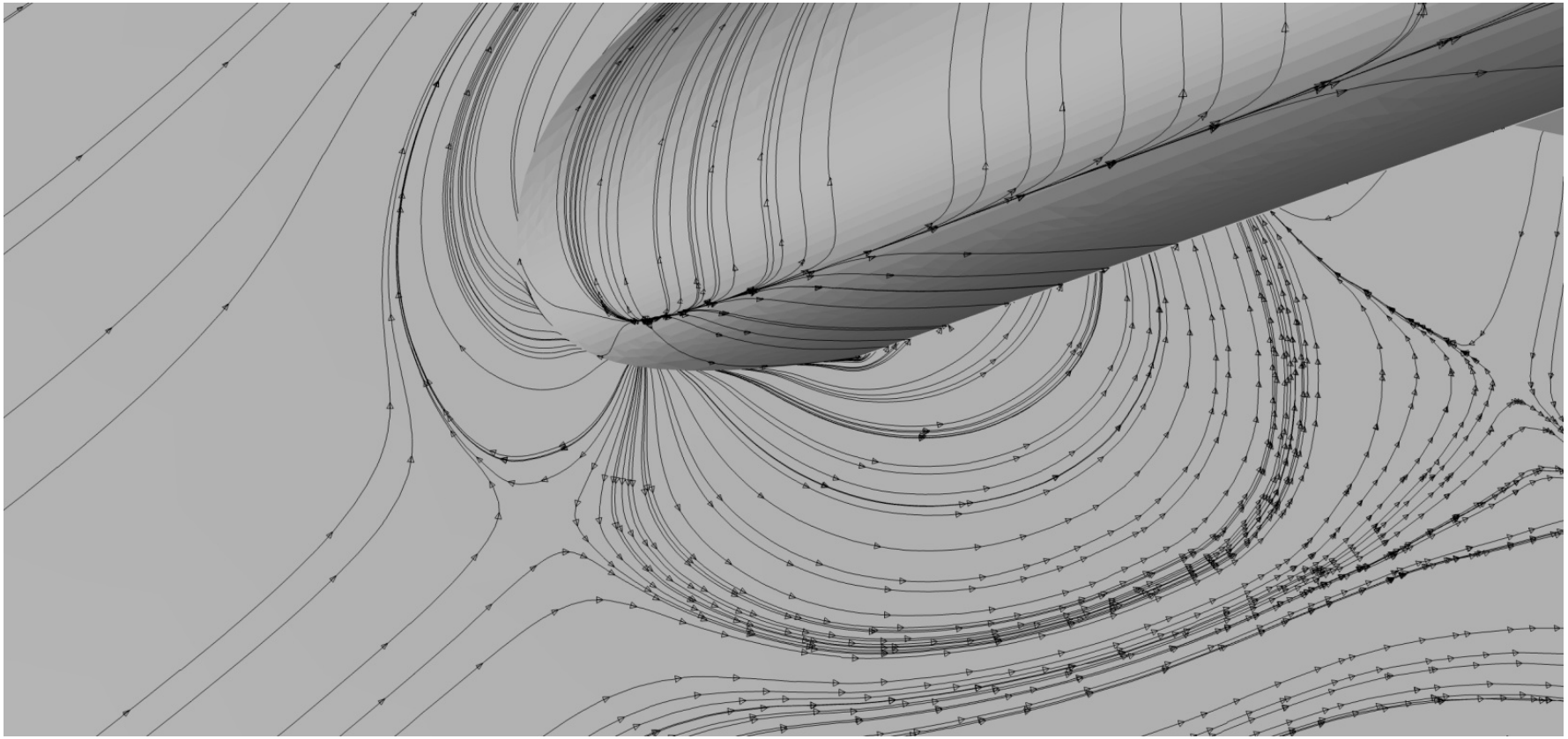
SARC turbulence model



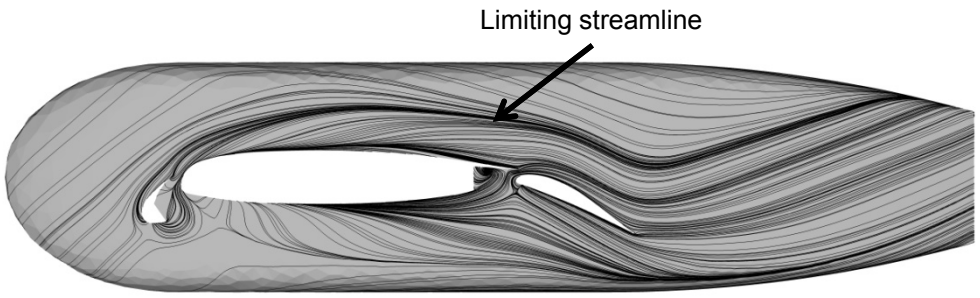
SA turbulence model

Side of Body Separation

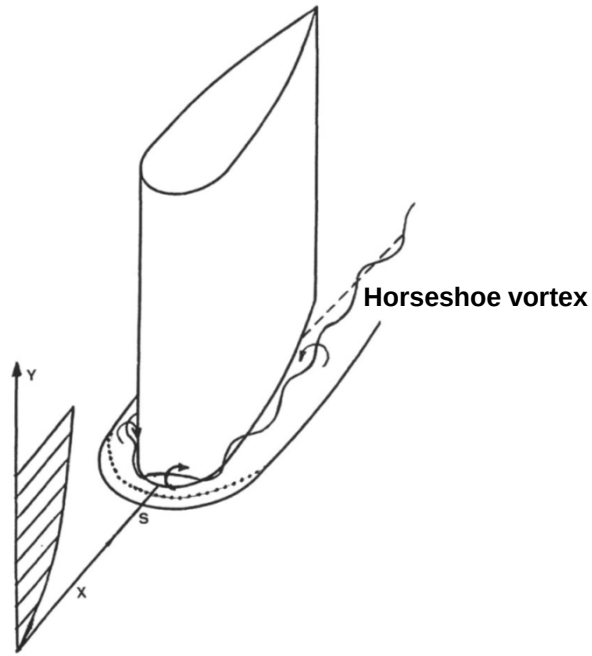
Wing-body Junction Flowfield



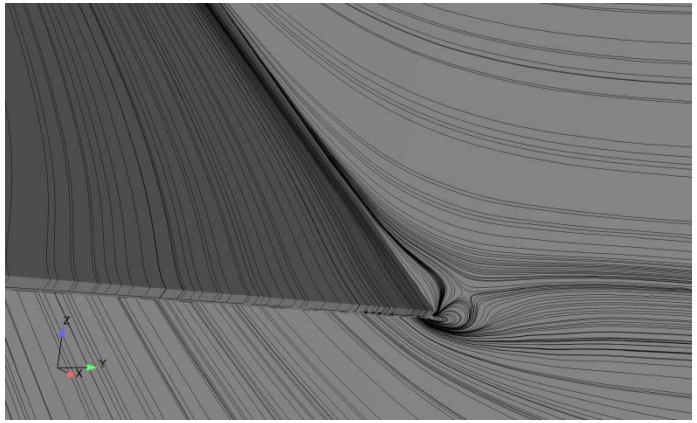
Wing-body Junction Flow



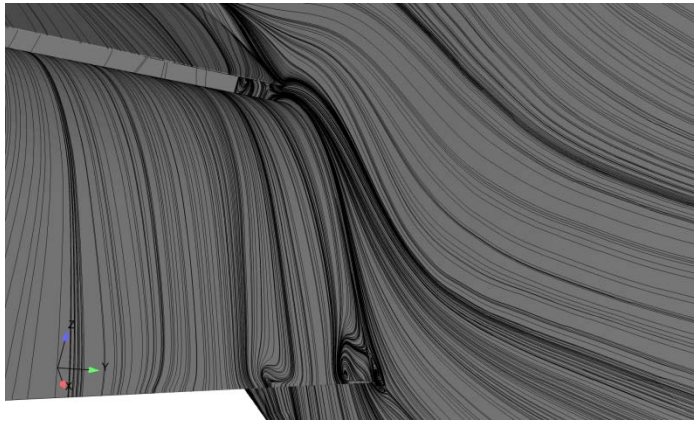
Streamlines on body



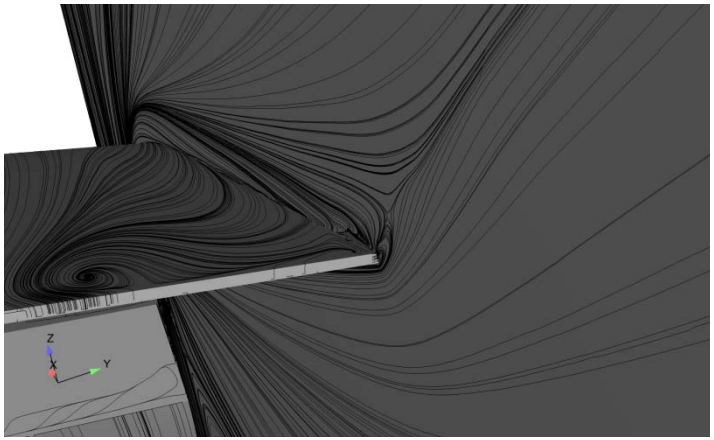
Side of body separation on flap



Medium tet grid



Medium tet-prism grid



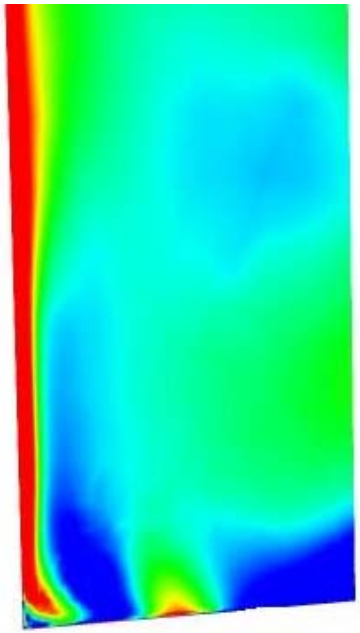
Fine tet-prism grid

Characteristic features of Horse-shoe vortex (HSV)

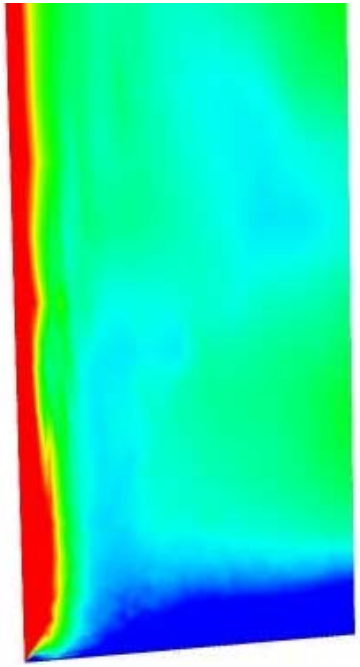
- **HSV contains vortex cores of opposite signs**
- **Vortex core close to wing surface decays downstream due to skewing by span-wise flow at wing-body junction**
- **Appearance of vorticity "fingers" characterize vortex-boundary layer interaction leading to SOB separation**

Vorticity at Flap-Body Junction

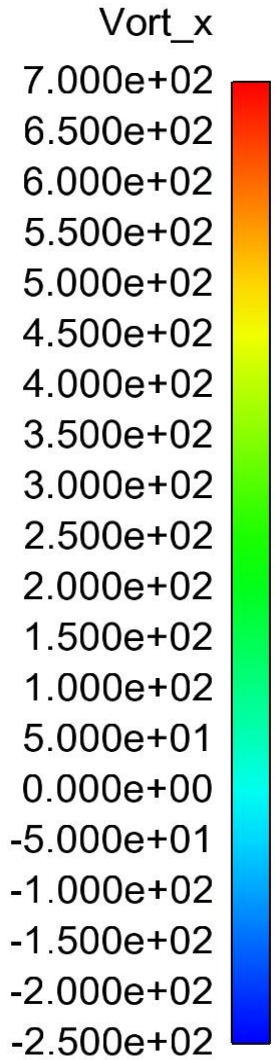
Medium TetPrism

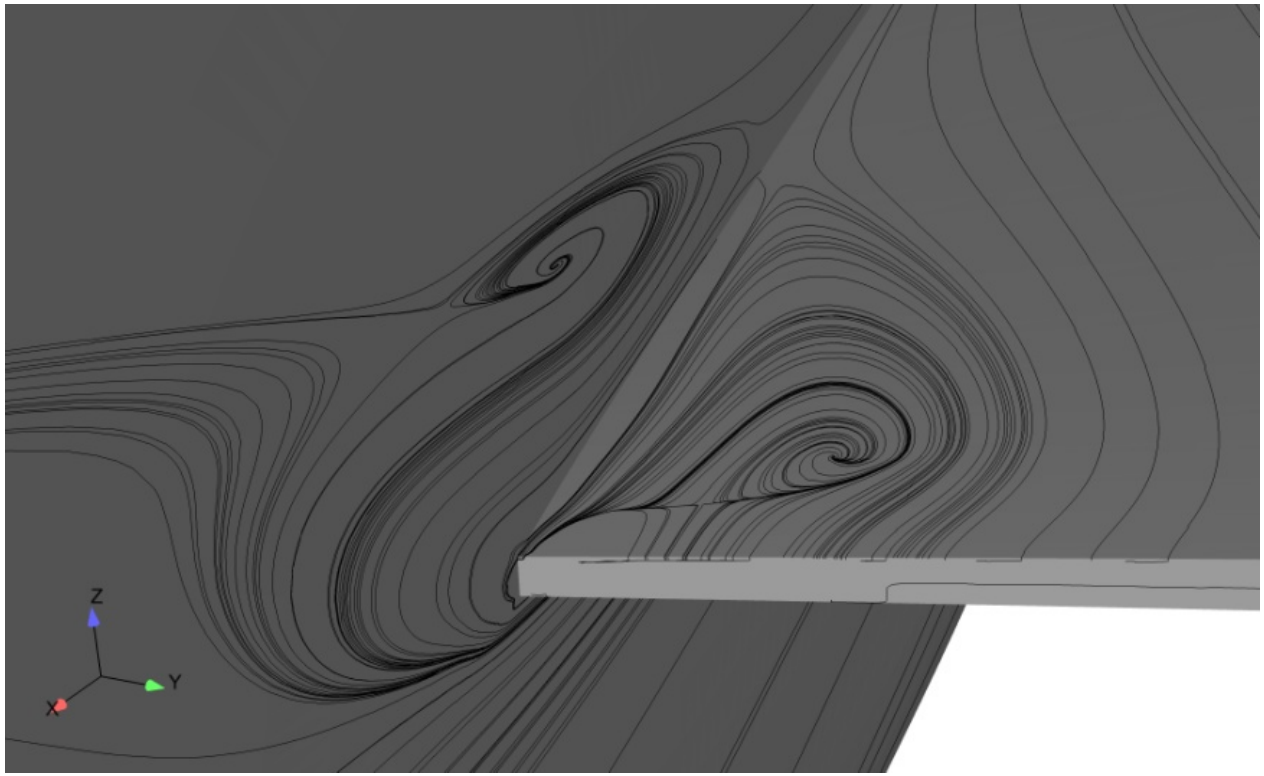


Medium Tet



X/C = 0.[redacted]





Side of body separation on flap – CRM in high-speed flow

Concluding remarks

•Tetrathedral-prism hybrid grids have made qualitatively correct predictions of SOB separation and largescale time-averaged behavior of the Horse-Shoe Vortex

•Tetrahedral grids constructed from tertrahedral-prism grids by subdividing the prisms do not capture SOB flow separation due to excessive dissipation of HSV vortex systems

•. Higher order tutbulence treatments, e.g., LES or DES techniques are necessary for analyzing microscale instabilities and unsteady vortex phenomena characterizing the HSV.

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Thank You

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