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OpenCAE

OpenCAEシンポジウム2011
ESI によるOpenFOAM 事例

2011/12/2

日本ESI 株式会社
三邉 考志

www.esi-group.com

アジェンダ

- ESI　CFDのご紹介
- 背景
- 事例紹介
  - 商用CFDコードとの比較
  - SanpyHexa vs. VisCART
  - 最適化ツールとの連携事例

ESI Group CFD

- 1973 航空宇宙、原子力産業のコンサルタント会社として設立
- 1985 PAM-CRASHを開発
- 1997 Framatome(SYSTUS, SYSEWLD)を買収
- 2000/7/6 Nouveau Marche に上場
- 2000-2003
  - STRACO, VASCi, ProCASTを獲得
- 2004 CFDRCよりソフトウェアプロダクト部門(CFD-ace)を獲得
- 2006
  - IPS International から人体モデルの部門を買収
  - 中国のAET Technology Internationalを統合
- 2008-2009
  - Vdot (PLM ツール) を獲得
  - イタリアとブラジルに子会社を設立
  - CFD /CAEコンサルティング会社 Mindware Engineering を買収


San Diego (CA, USA)


Huntsville (AL, USA)


Bloomfield Hills (MI, USA)


Oxford (United Kingdom)
Lausanne (Swiss)
Pilzen (Czech Republic)
Rungis (France)
Eschborn (Germany)


Seoul (Korea)
Tokyo (Japan)
Bangalore (India)
Beijing (China)

- 12 subsidiaries
- 30カ国以上
- 15の支社
- 従業員数 約780

ESI CFD Experience

- ✓Fire Dynamics Simulator
- ✓National Institute of Standards and Technology (NIST), USA.
- ✓Open-source software
- ✓CFD model of fire-driven fluid flow

背景

- CFDに掛るコストの削減
- 最もボリュームのあるアプリケーション(設計者の範疇)には汎用ソフトは高機能すぎる
- 汎用ソフト価格の変化
  - 商用コードを切り替える?
  - OpenFOAMでも良いのでは？

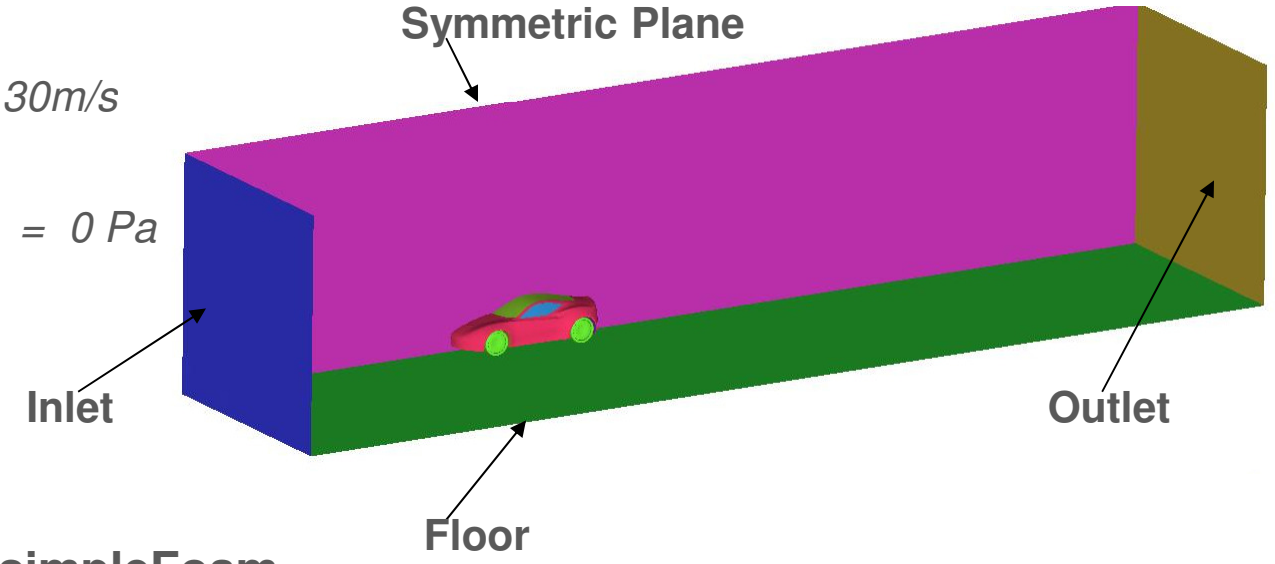
商用コードとの比較事例

External Aerodynamics

事例(コード比較) : External Aerodynamics
(Incompressible Turbulent Flow: Sample Car)

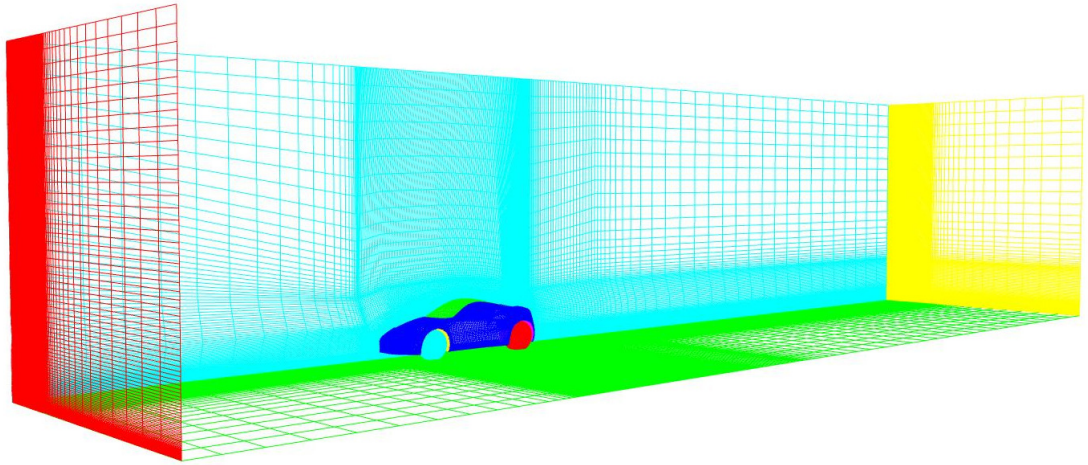
- Comparison is made between the results of OpenFOAM, Fluent and Star-CCM+.

- Boundary Conditions
  - Inflow:
    - *Velocity Inlet = 30m/s*
  - Outflow:
    - *pressure outlet = 0 Pa*

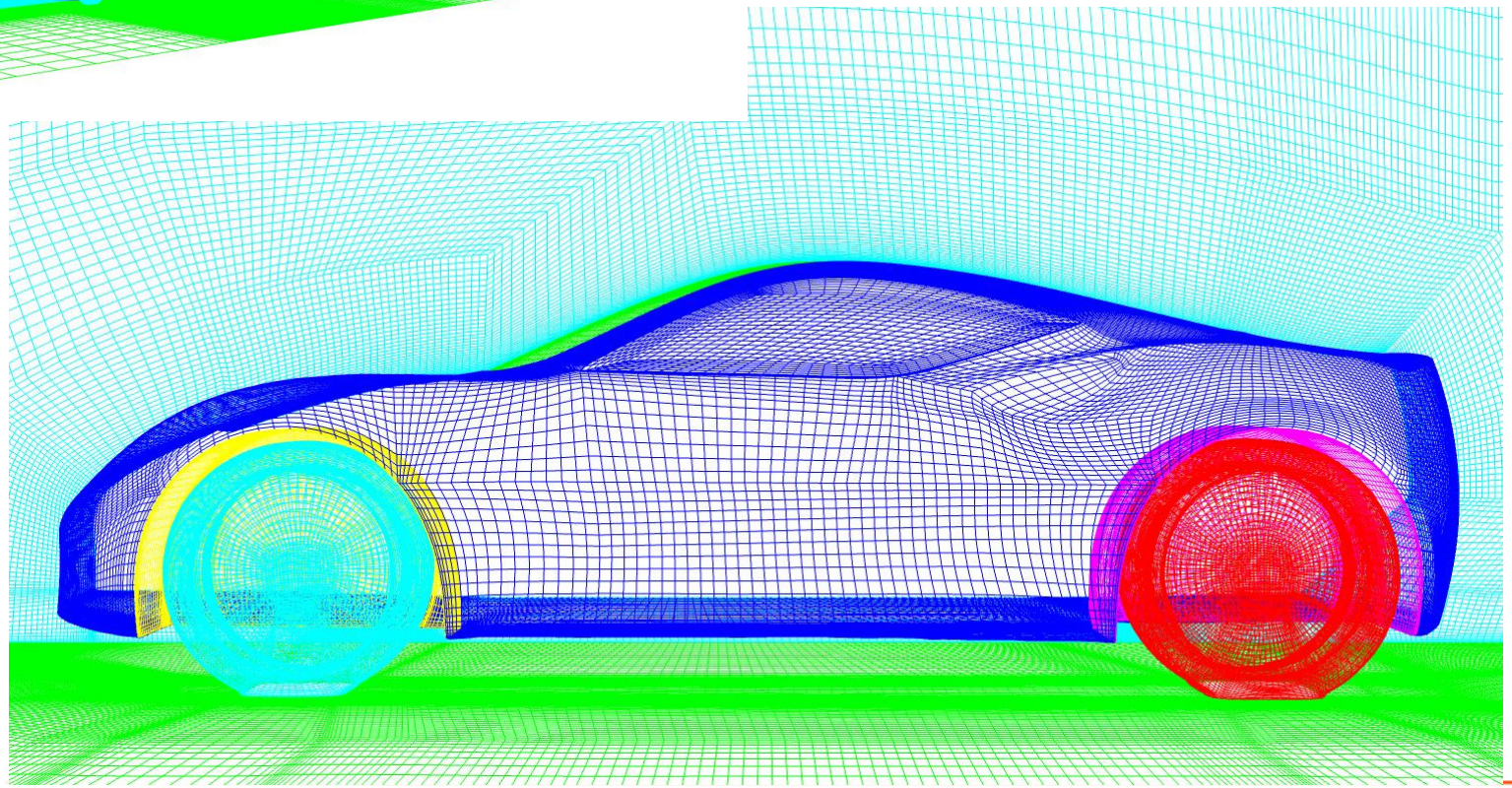


- **OpenFOAM Solver: simpleFoam**

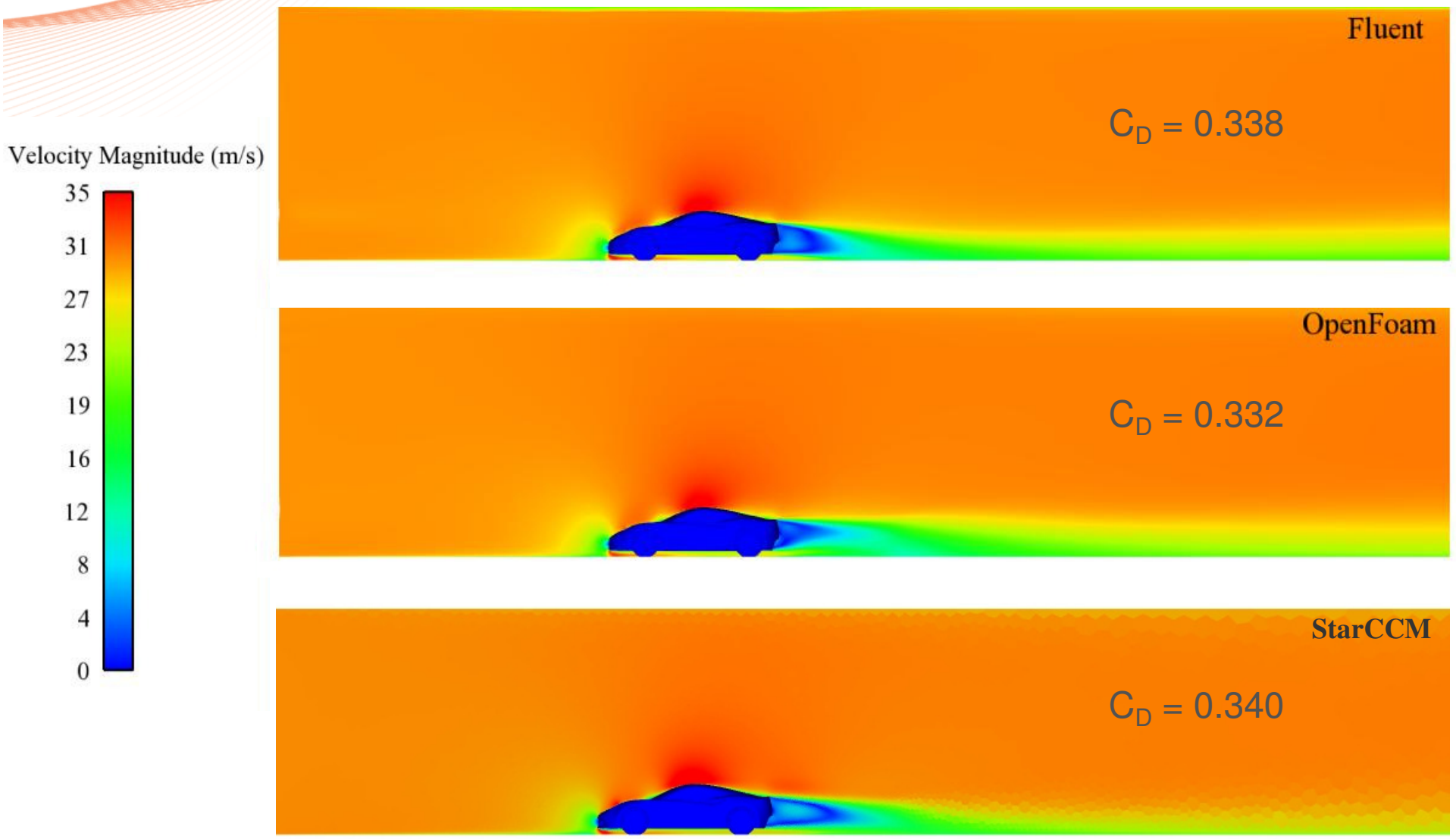
事例(コード比較) : External Aerodynamics
(Mesh Details)



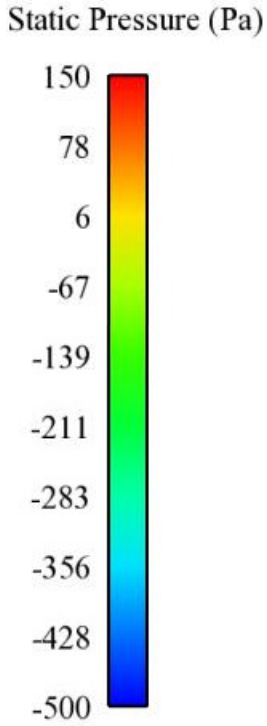
Hexa Mesh = 2.8 Millions

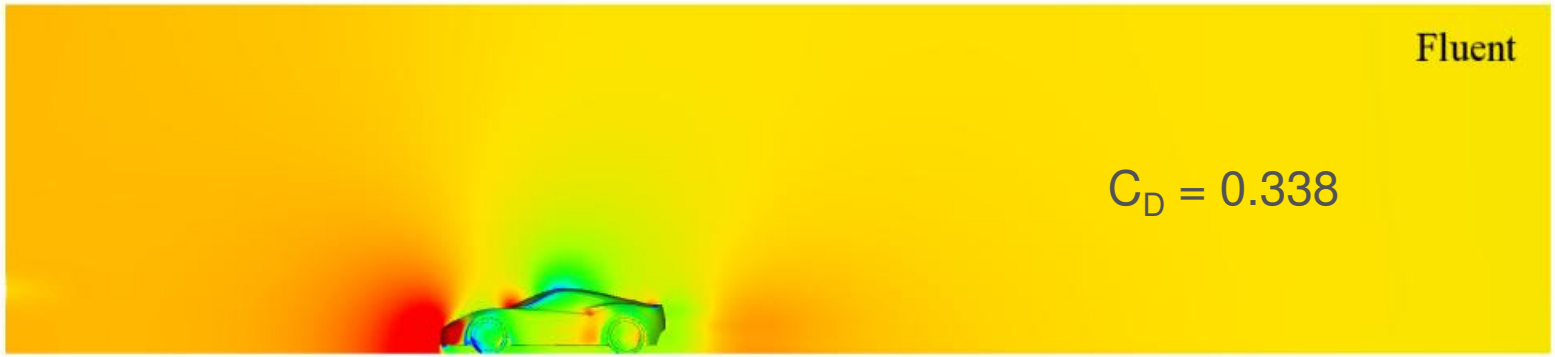


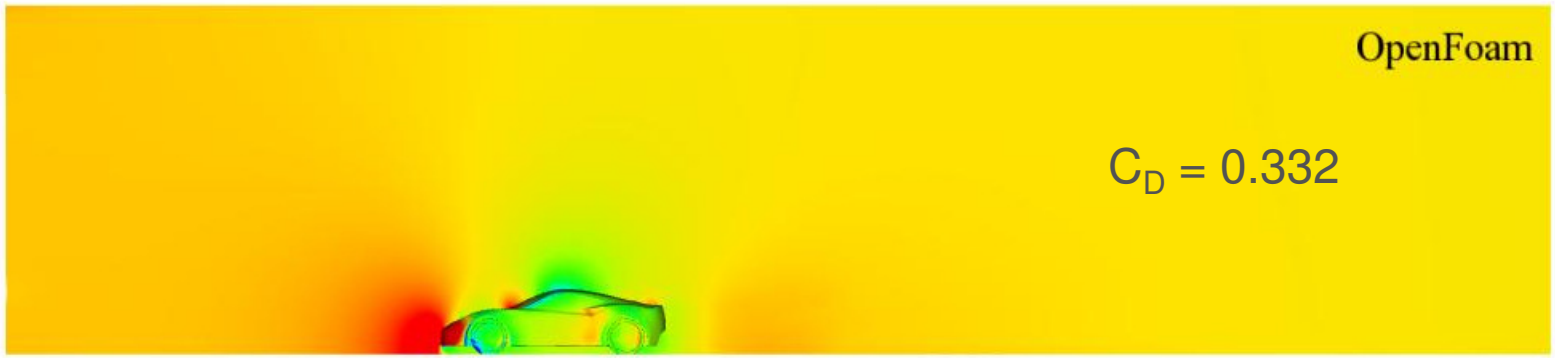
事例(コード比較) : External Aerodynamics
(Velocity Distribution at Symmetry Plane)

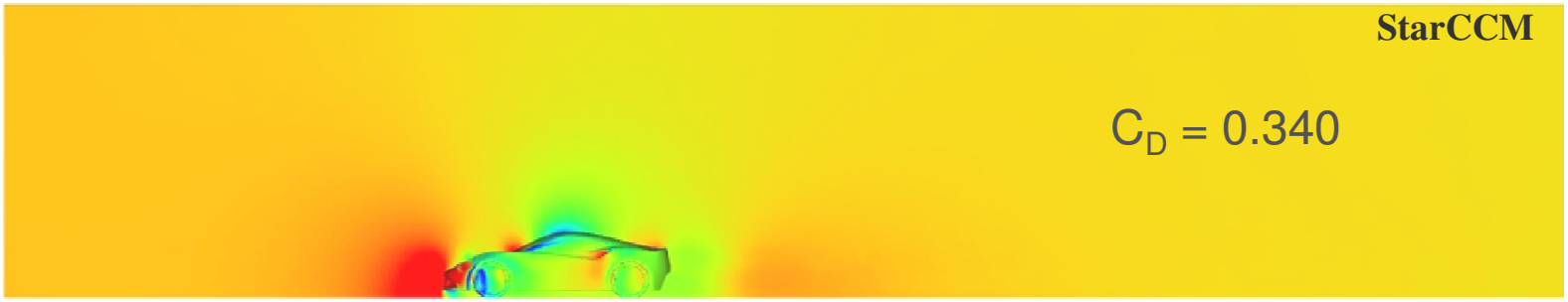


事例(コード比較) : External Aerodynamics
(Static Pressure Distribution at Symmetry Plane)









商用コードとの比較事例

実形状データでの比較

External Aerodynamics

事例(コード比較) :Aerodynamic
(Incompressible Turbulent Flow: Real Car)

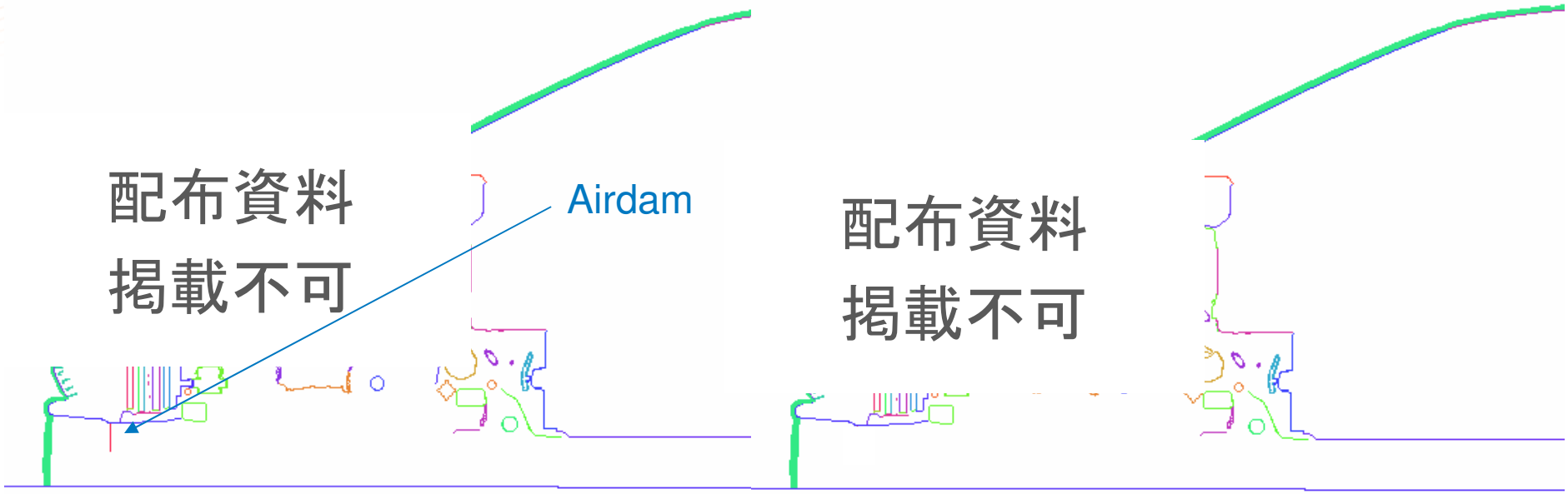
- **Objective:** To Analyze the different effects caused by the air dam on the following attributes:
  1. Drag
  2. Frontend cooling
  3. Comparisons with another commercial code and Test data

- **Boundary Conditions:**
  - Inflow:
    - *Velocity Inlet = 50km/hr and 110km/hr*
  - Outflow:
    - *pressure outlet = 0 Pa*
  - Fan at 12 Volt
  - Heat Exchangers

- **OpenFOAM Solver:** porousSimpleFoam (1.5)

配布資料掲載不可

事例(コード比較) :Aerodynamics
Two cases: With and Without Airdam

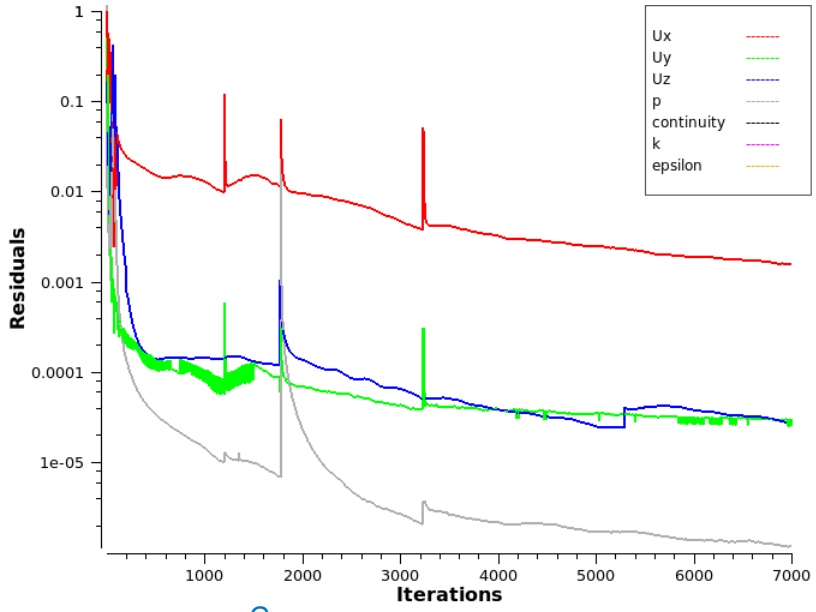


With Airdam

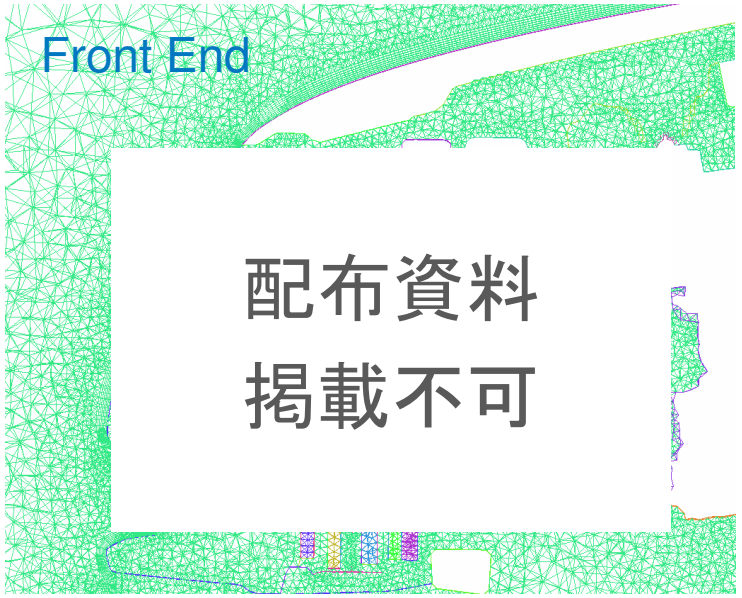
Without Airdam

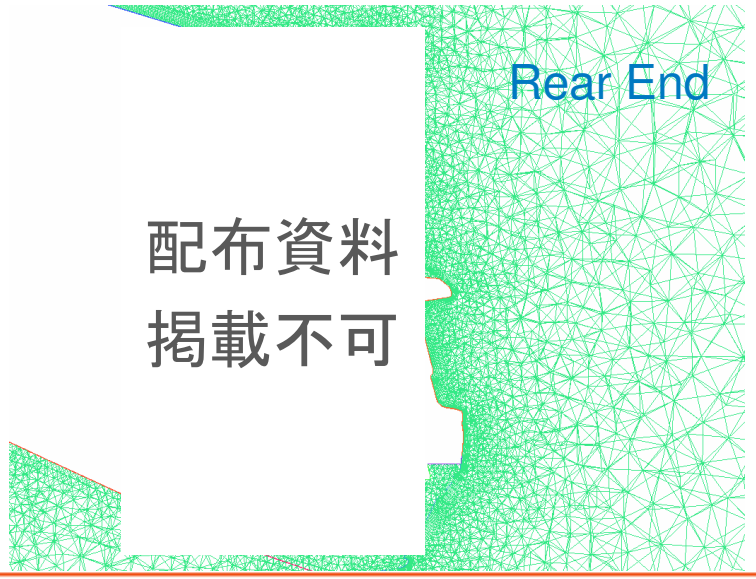
事例(コード比較) :Aerodynamic (Incompressible Turbulent Flow: Real Car)

- Meshing done in 6.5 days using ICEMCFD and ANSA
- 10 prism layers with first cell height 1mm
- 29M cell count

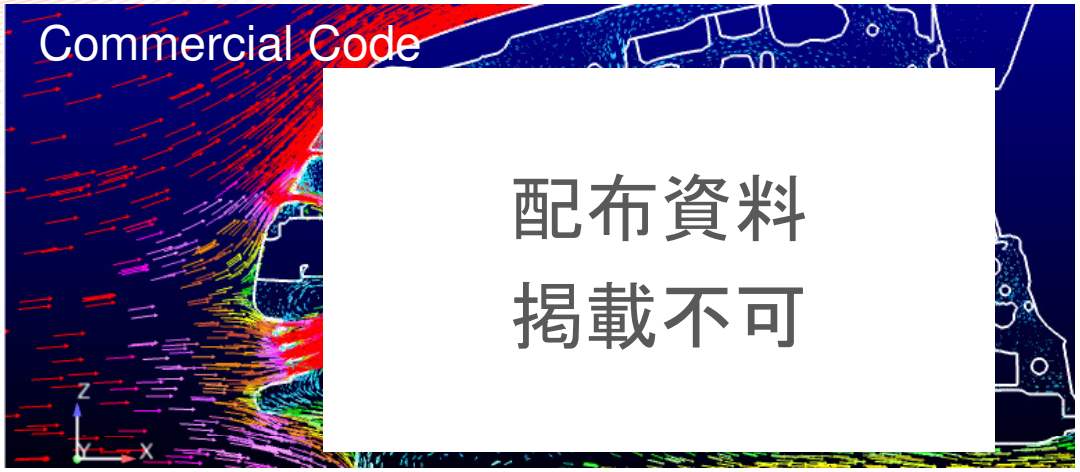


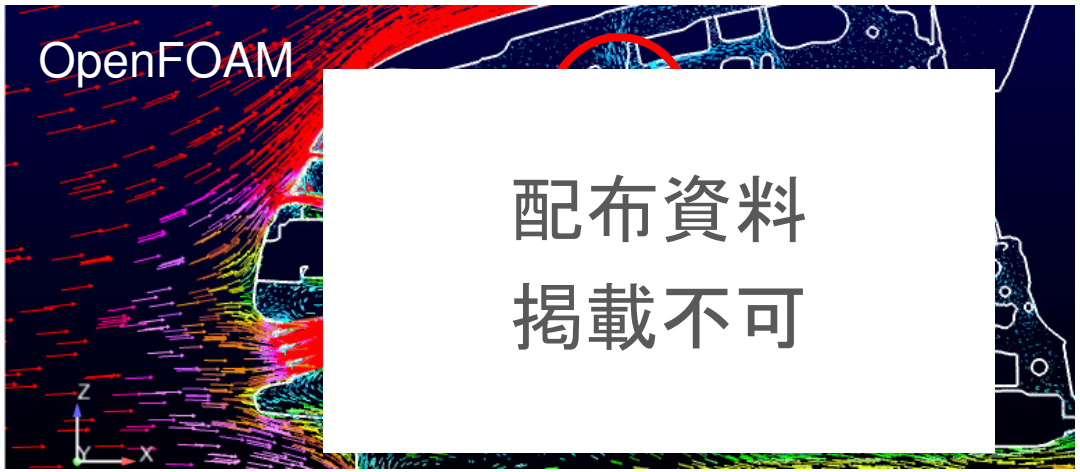
Convergence





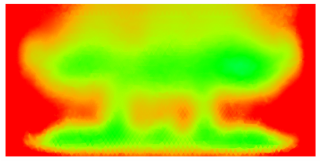
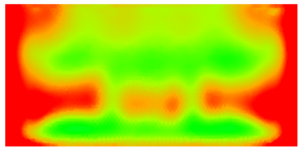
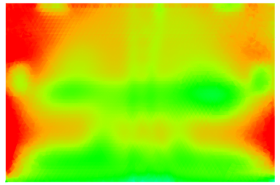
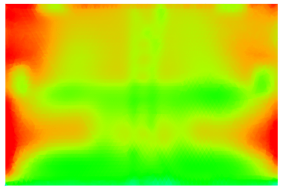
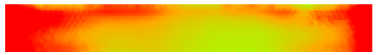
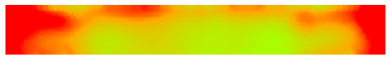
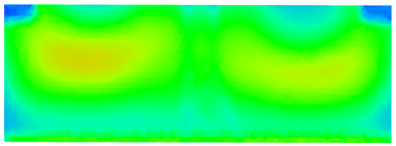
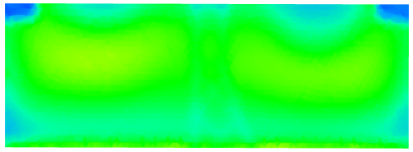
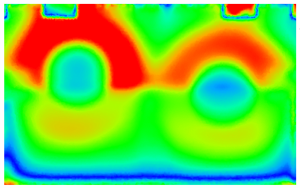
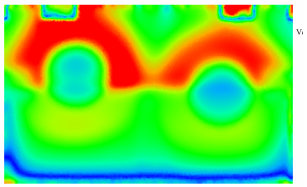
事例(コード比較) :Aerodynamic (Incompressible Turbulent Flow: Real Car)

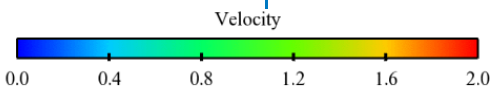




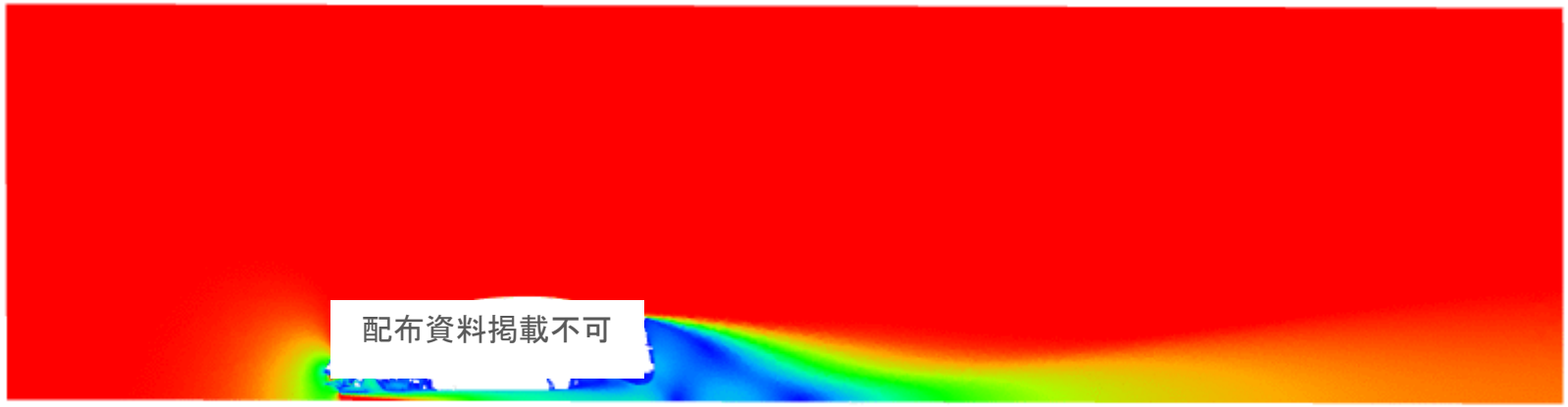
- Flow field comparisons where made between the commercial code and OpenFOAM
- OpenFOAM solution looks comparable
- Slight differences in the solution are a result of differences in the mesh used.

事例(コード比較) : Aerodynamic
(HX Flow Rates for 50km/hr Vehicle Speed – No Airdam)

Flow through Heat Exchangers	OpenFOAM		Other Commercial Code	
	Flow Rate (m^3/min)	Plot	Flow Rate (m^3/min)	Plot
BAT	21.87		21.12	
CNDSR	23.39		22.58	
PE	6.35		6.11	
ATOC	8.57		8.09	
RAD	18.08		17.63	

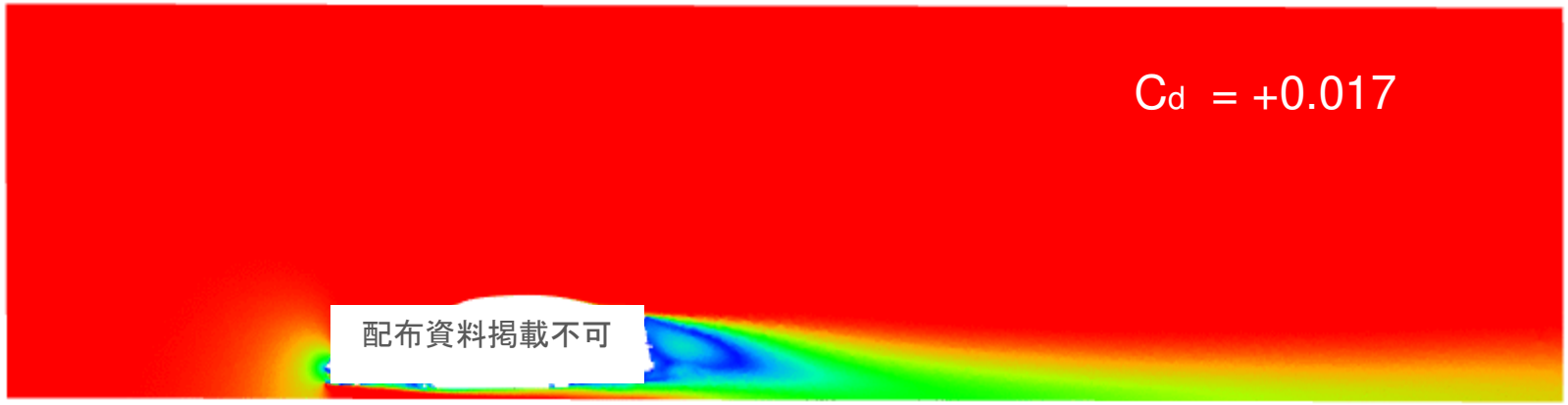


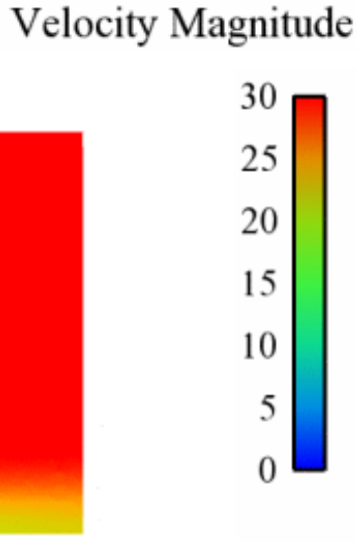
事例(コード比較) : Aerodynamic
(Incompressible Turbulent Flow)



With Airdam

Results were close to Test and Other Commercial Code data



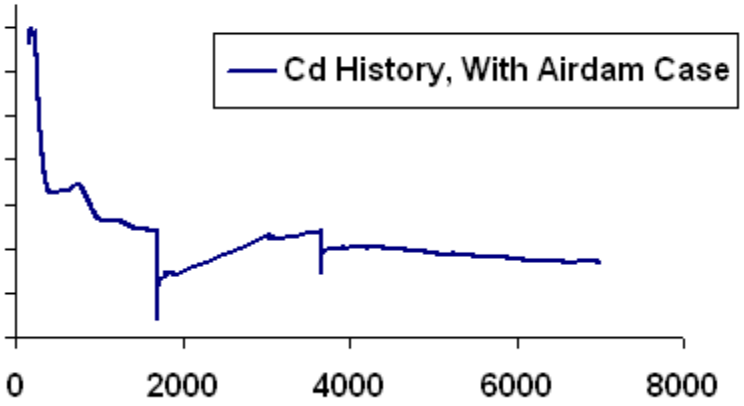


Without Airdam

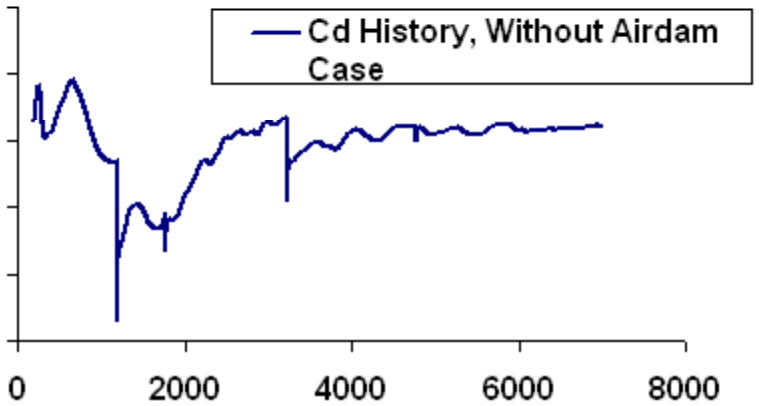
事例(コード比較) :Aerodynamic
(Incompressible Turbulent Flow: Real Car)

OpenFOAM results were in-line with Test results

With Air dam



Without Air dam

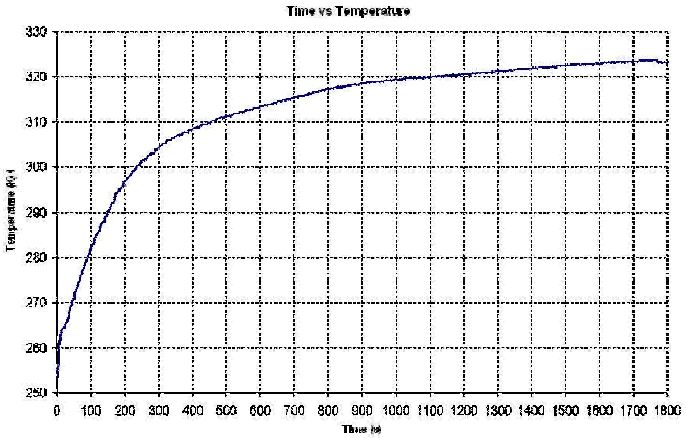


商用コードとの比較事例

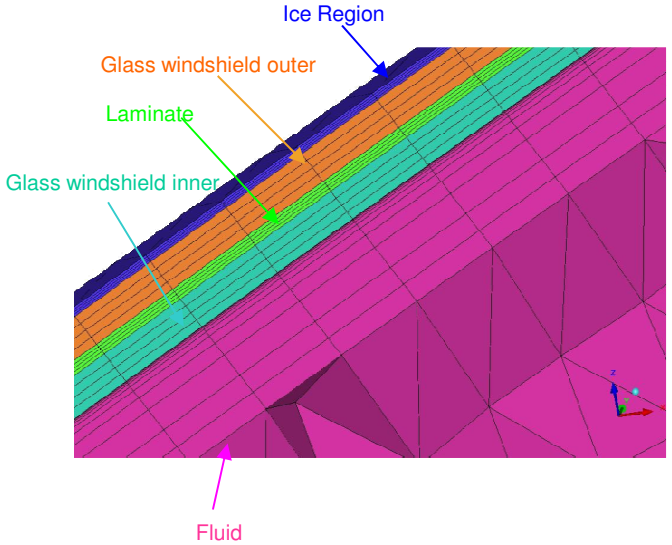
Defrost

事例 (コード比較) : Defrost

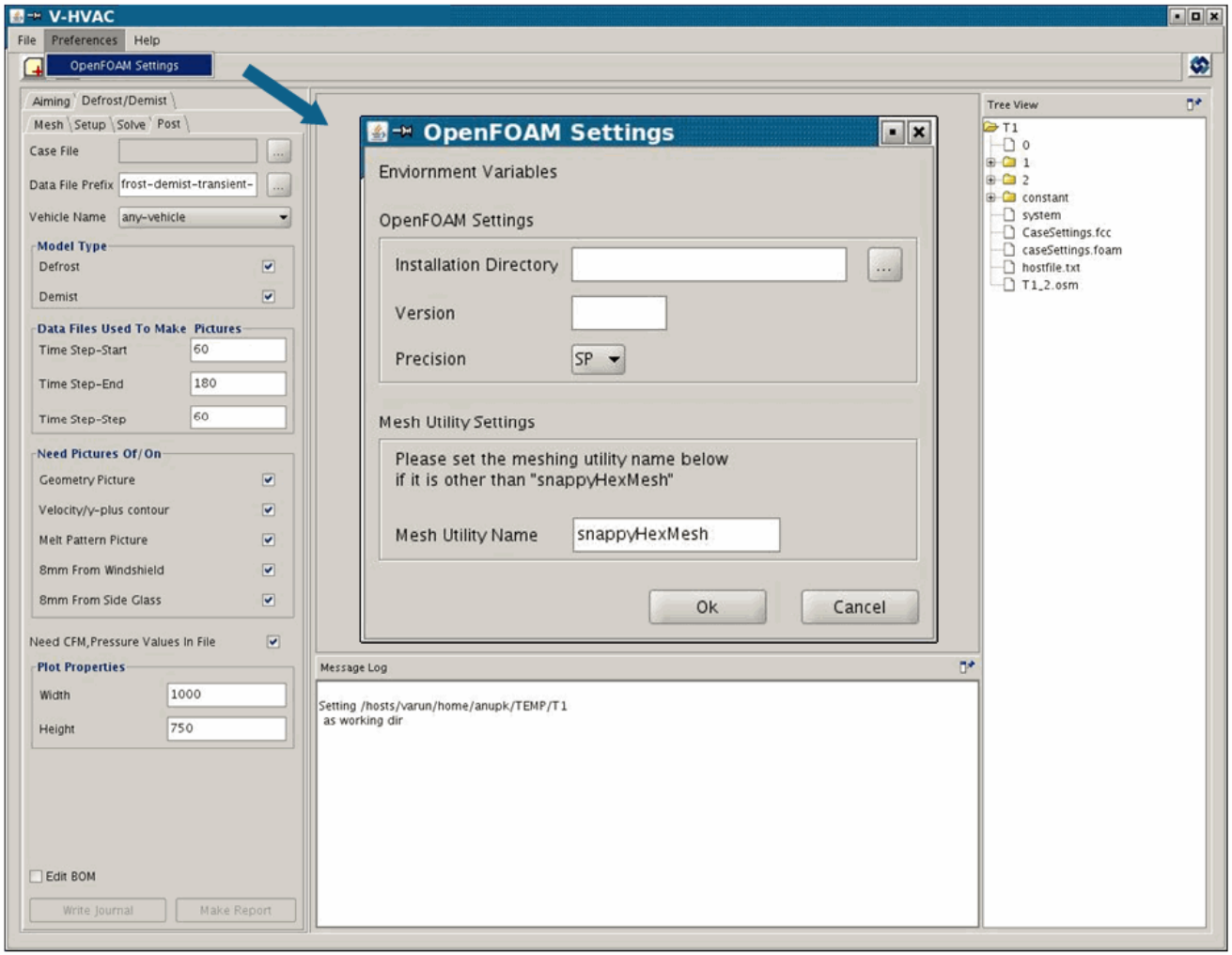
- Melting of ICE
- Tetra/Prism Mesh (about 10.3M Cells)
- Velocity Inlet at Duct (3.776 m/s) and Pressure Outlet at back
- Turbulence Model: Realizable k-epsilon is used in Fluent and k-omega SST in OpenFoam
- Time Step size for Ice melting simulation = 5 sec.



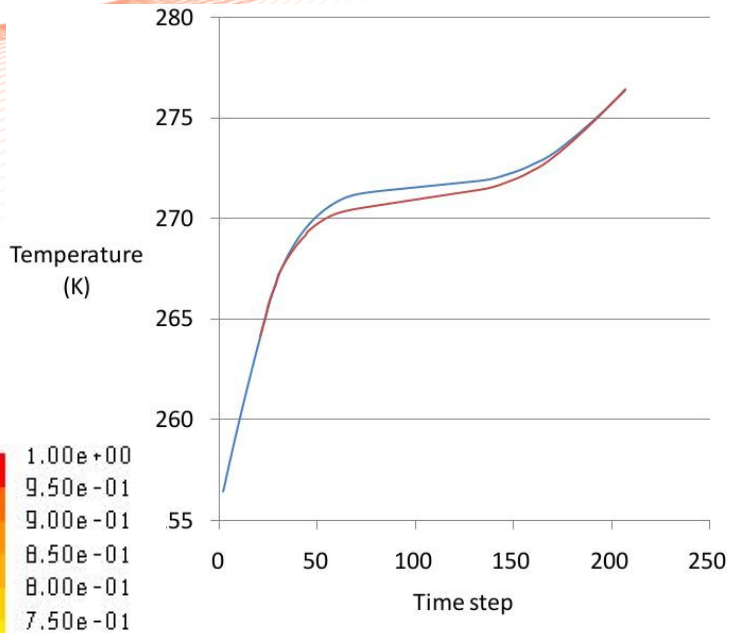
Inlet Temperature

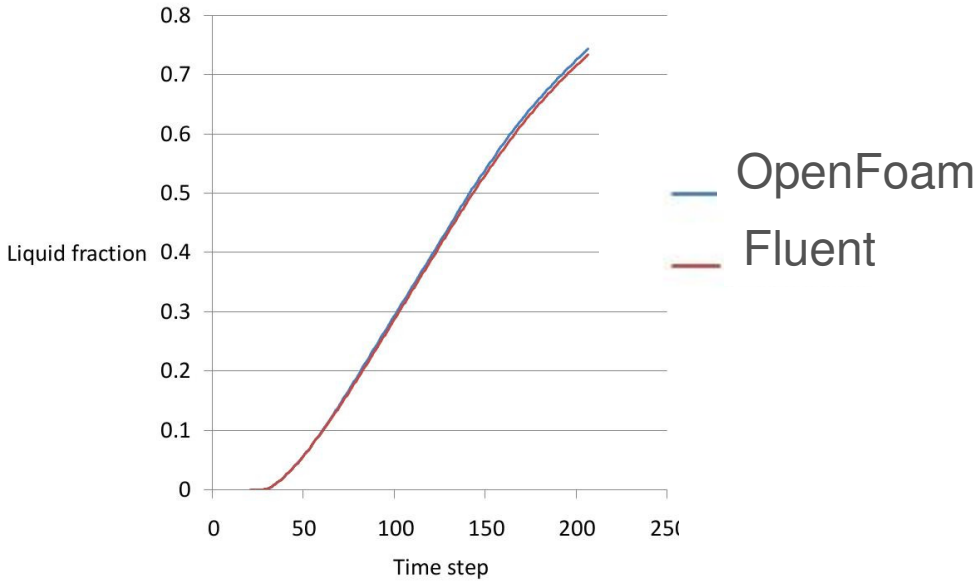


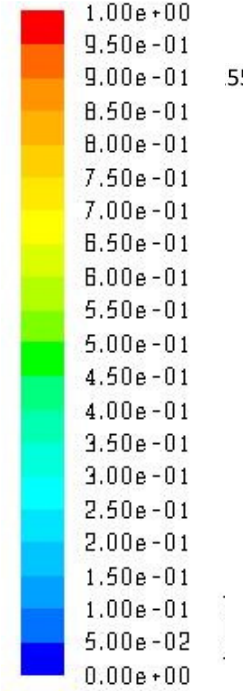
Climate Control

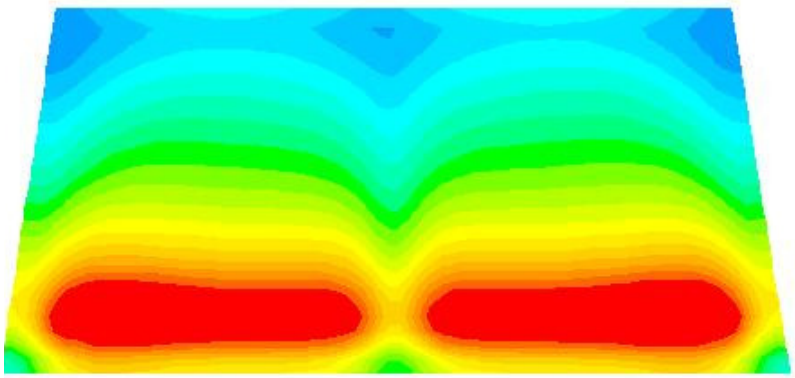


事例 (コード比較) : Defrost

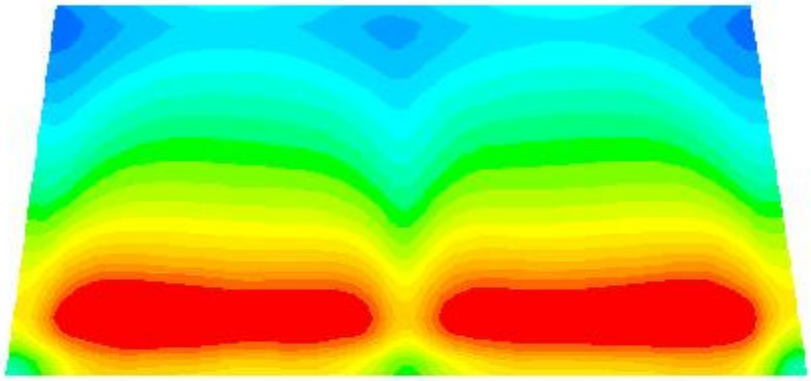








OpenFoam

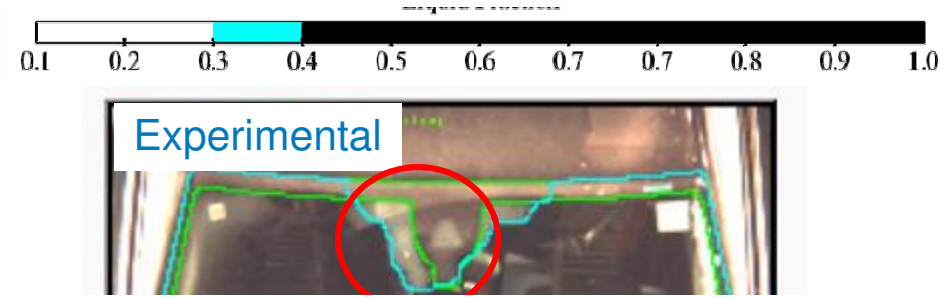


Fluent

事例 (コード比較) : Defrost
Contours on Ice region top layer

Time = 18 min

配布資料掲載不可

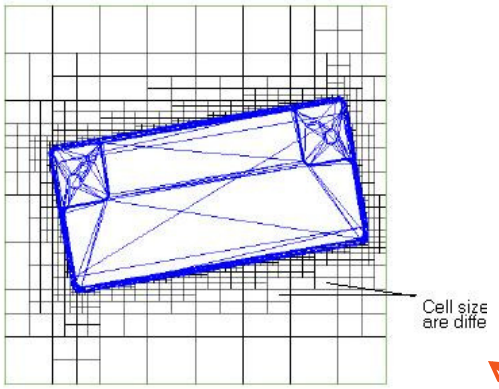


配布資料掲載不可

snappyHex vs. CFD-VisCART

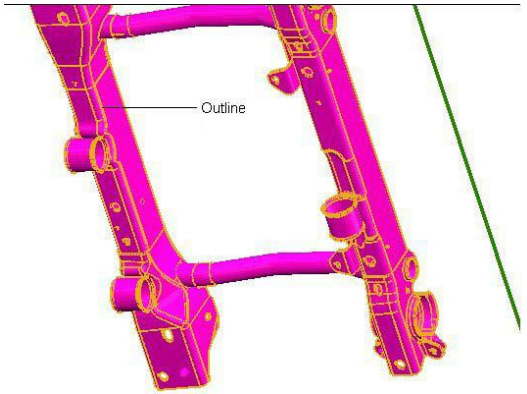
ESI's PreProcessor

CFD-VisCART
Overview of Features



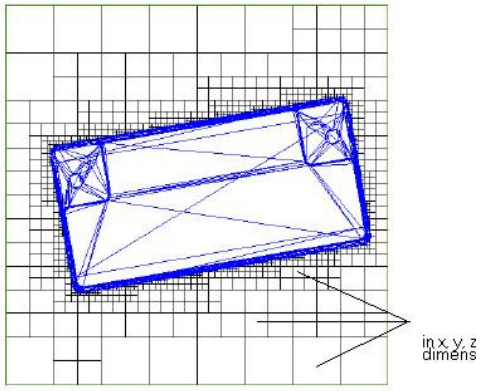
Omnitree Meshing

Leak Detection



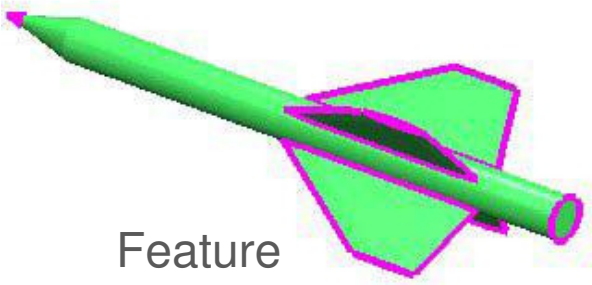
Outline detection

CFD-VisCART



Octree Meshing

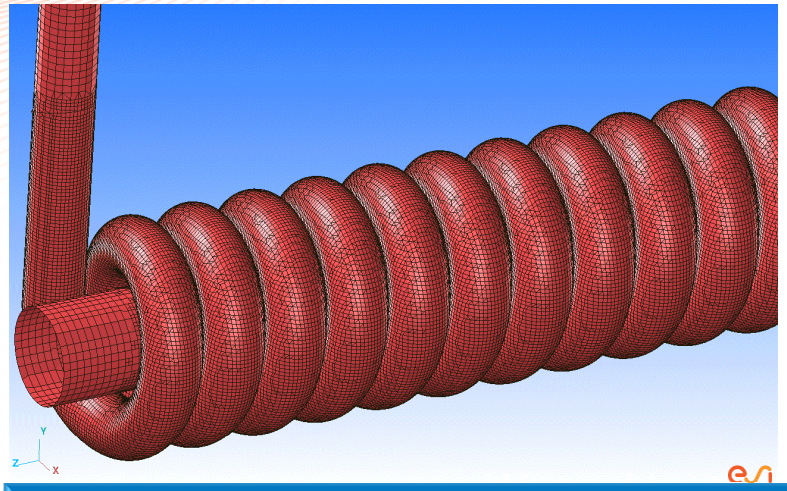
Mesh Generation
- Stair-case
- Single Domain
- Multi-Domain
- Shrink Wrap

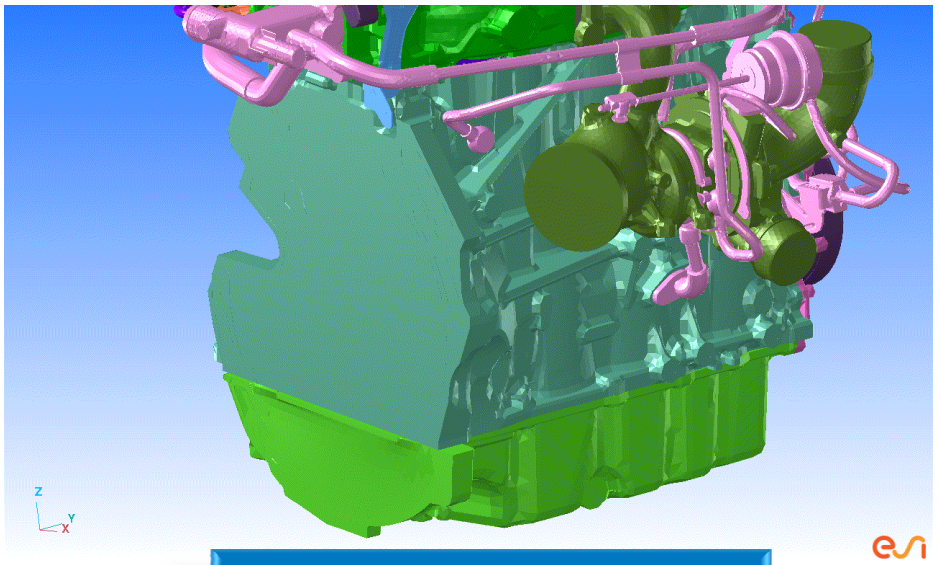


Feature extraction

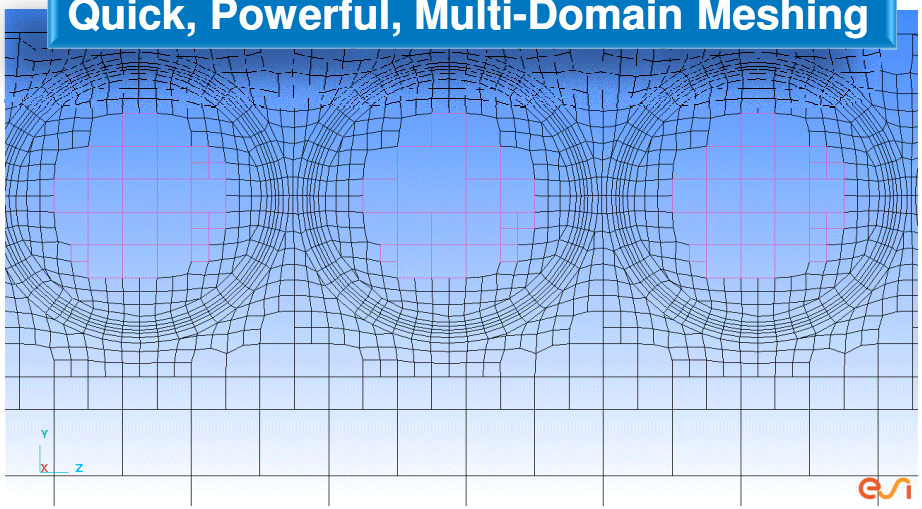
CFD-VisCART

Quick, yet powerful meshing

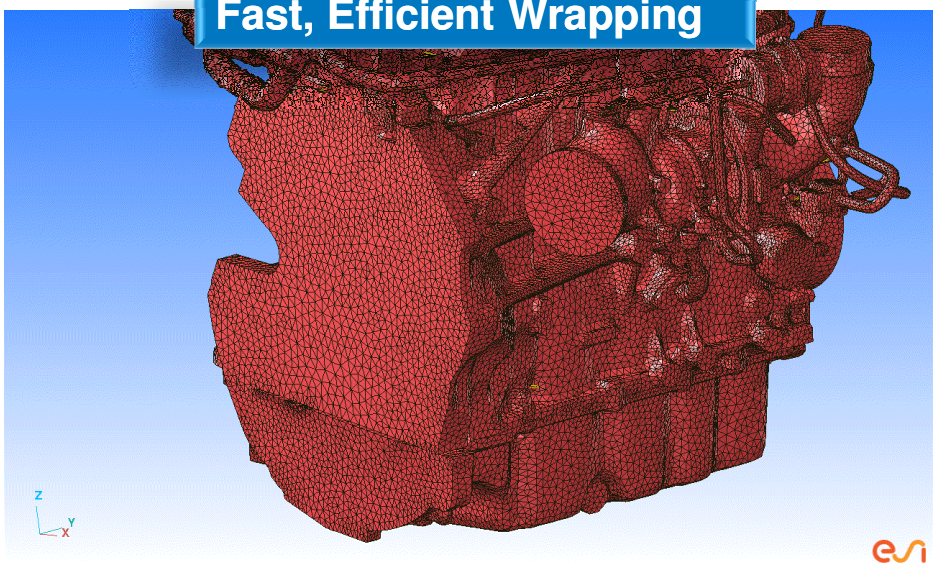




Quick, Powerful, Multi-Domain Meshing



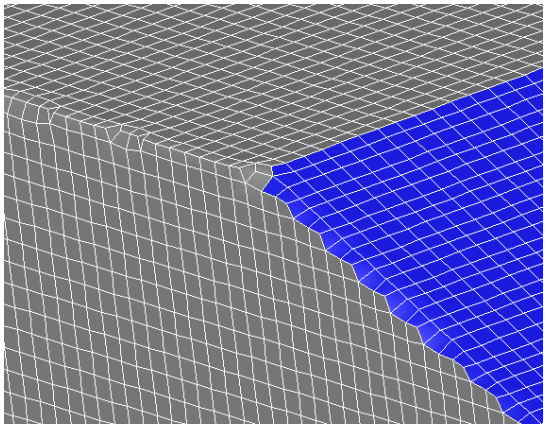
Fast, Efficient Wrapping



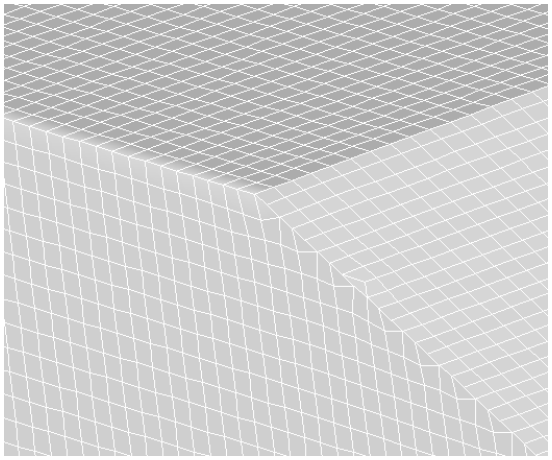
•Courtesy: Bissell Inc.

VisCART vs snappyHex
(Comparison for Ahmed Body: Feature Resolution, BL)

- SnappyHex does not resolve sharp feature angles (latest version does somewhat but not completely.

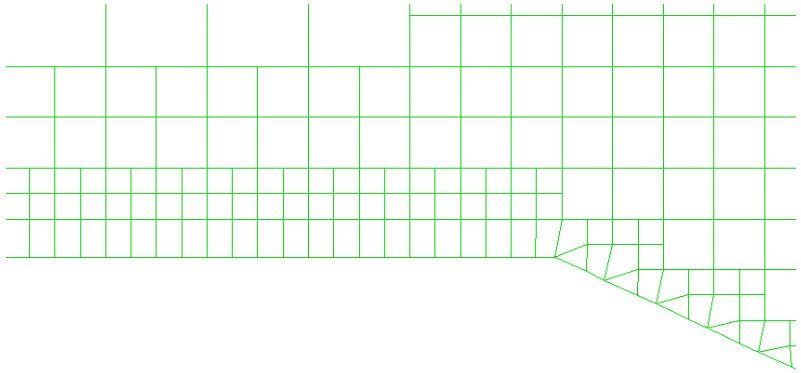


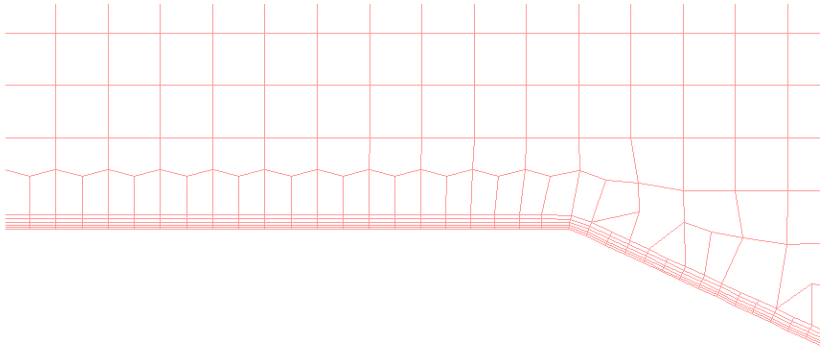
snappyHex



VisCART

- SnappyHex cannot show prism layers on symmetry plane.

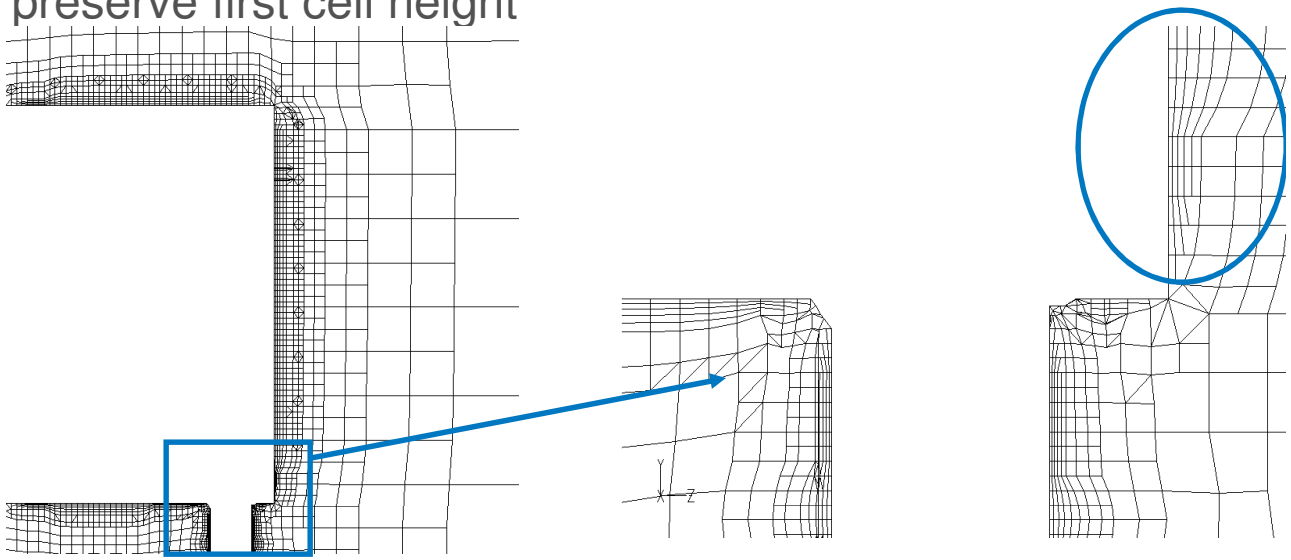




VisCART vs snappyHex
(Comparison for Ahmed Body: Boundary Layer)

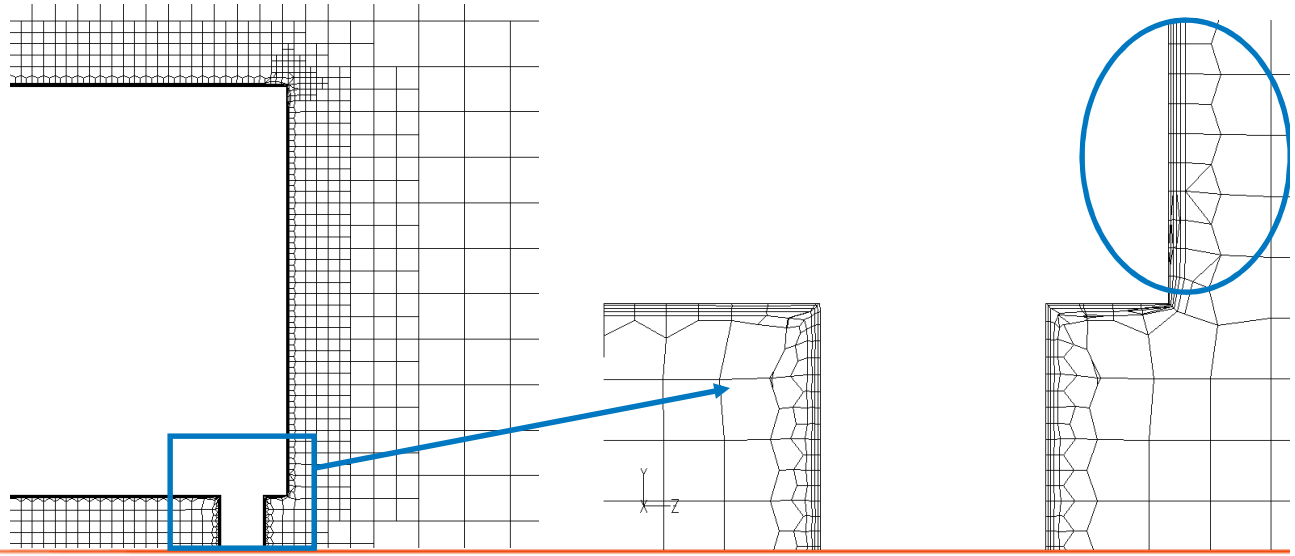
- SnappyHex does not preserve first cell height

snappyHex



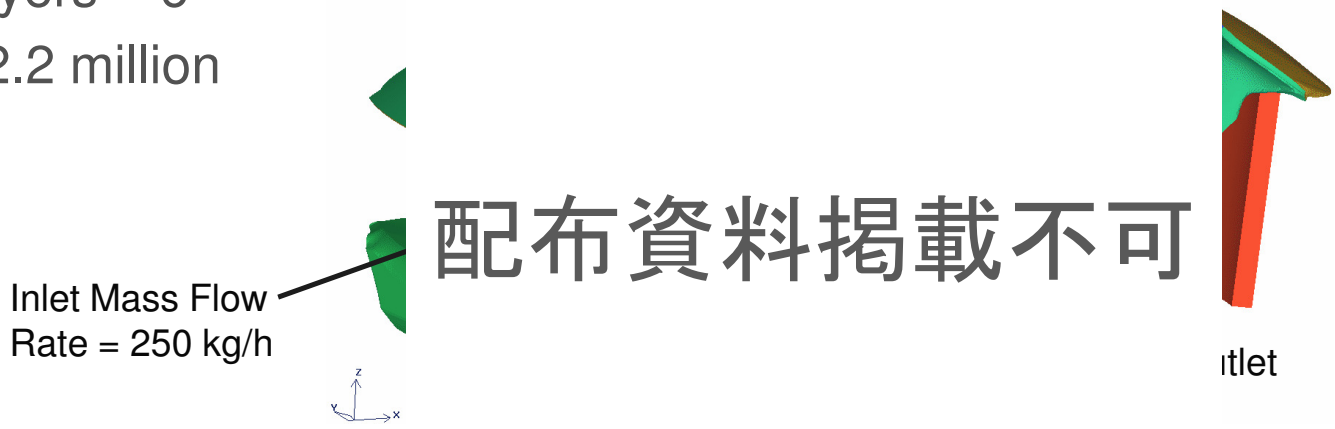
- VisCART gives option to choose between Expanding or Fixed height.

VisCART



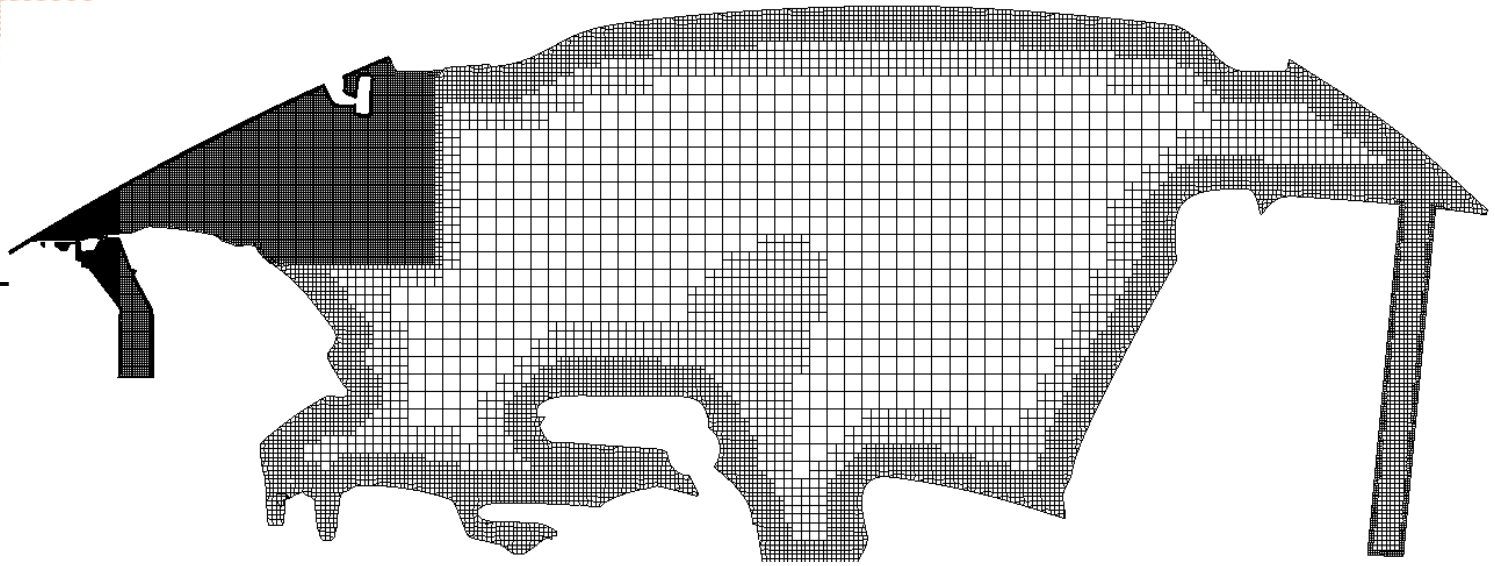
事例:(VisCART メッシュ適応)
(Industrial Test Case: Automotive Defrost/Demist)

- Mesh has been created in CFD-VisCART (as well in Snappy)
- Surface sizes, Refinements, Boundary Layer Parameters kept exactly same as in snappyHexMesh
- Prism layer information
  - First Cell Height – 0.2 mm
  - Expansion Ratio – 1.3
  - Total No. of Layers - 6
- Total Mesh size 12.2 million

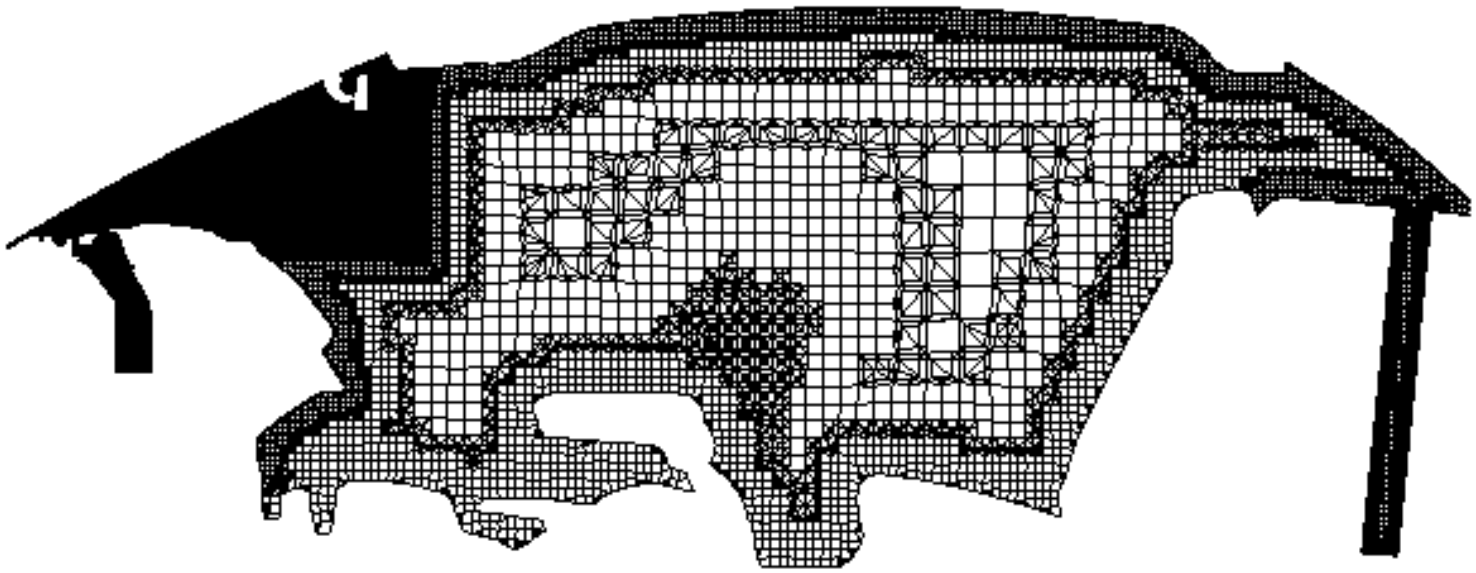


事例:(VisCART メッシュ適応)
メッシュの比較

CFD-VisCART

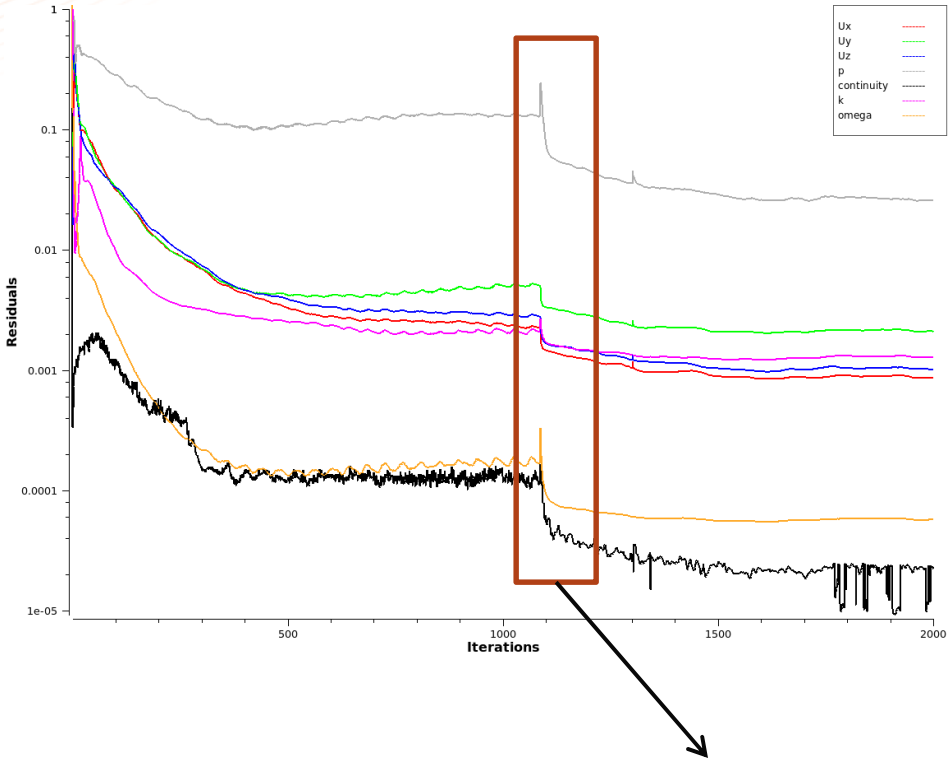


snappyHexMesh

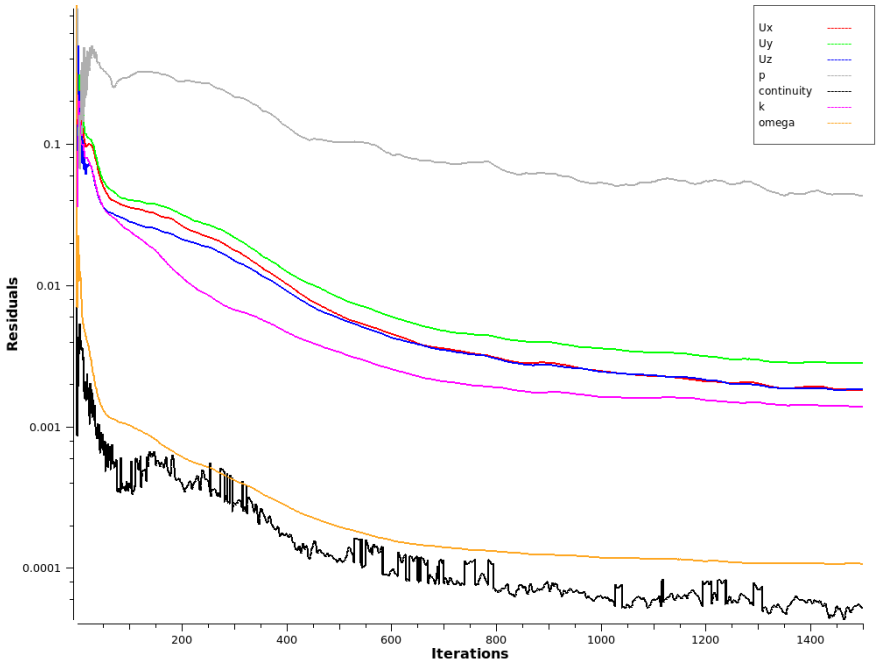


Results - Residual

CFD-VisCART



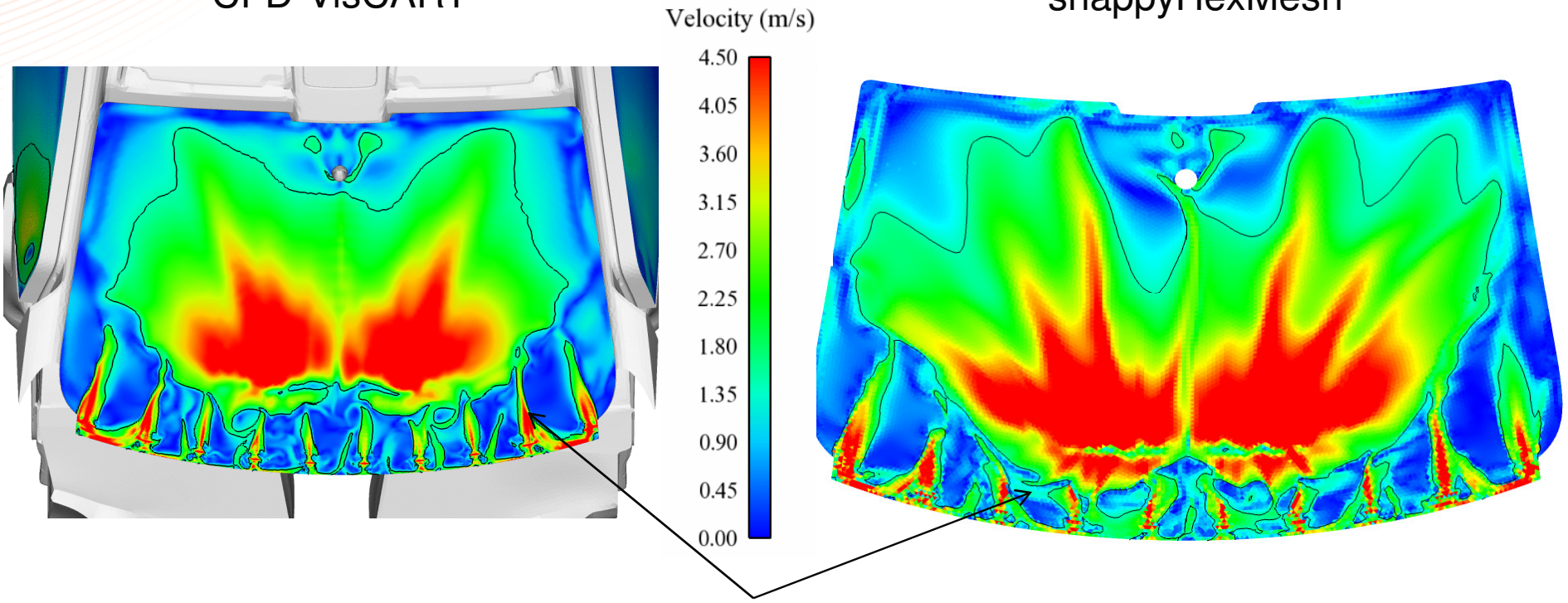
snappyHexMesh



This is because of reduction in relaxation parameters.

事例:(VisCART メッシュ適応)
Velocity Contour on 2.5 mm away from Windshield Glass Wall

CFD-VisCART

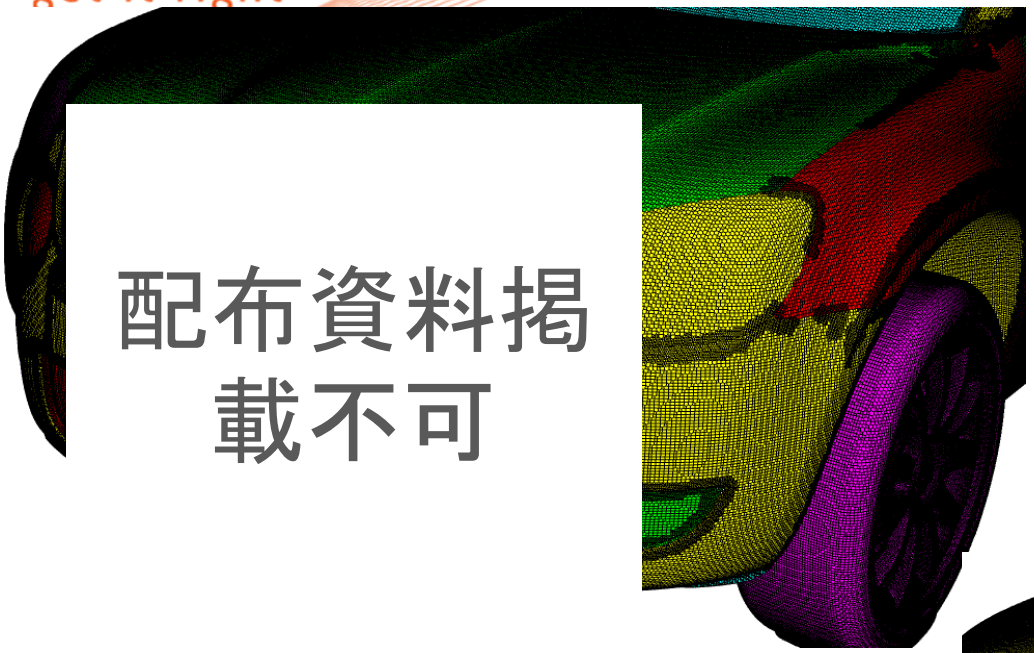


snappyHexMesh

Isoline at 1.5 m/s

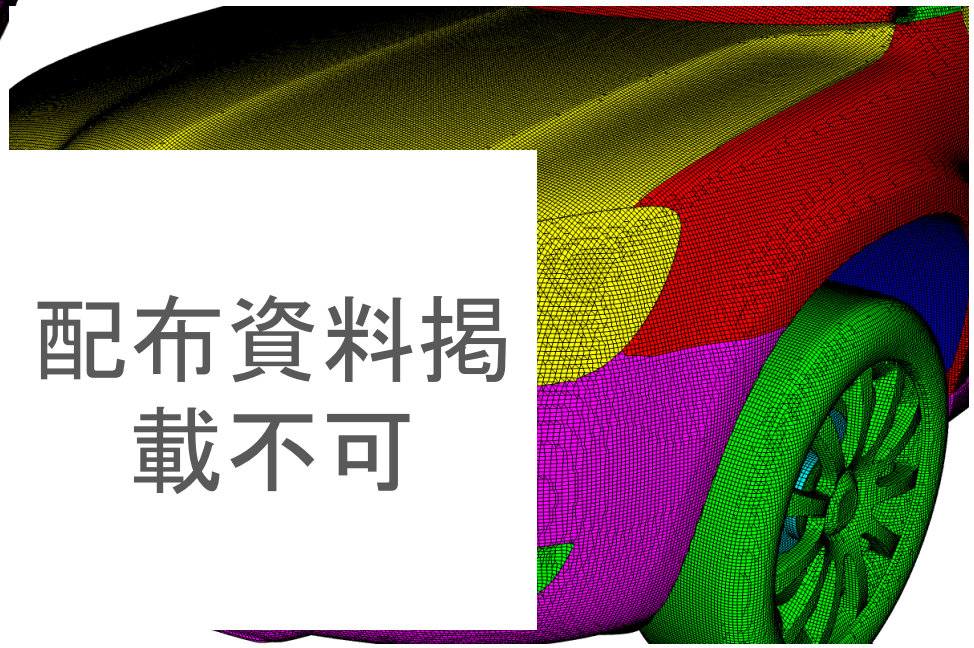
The spike in Velocity Contour on the RHS is not physical.

事例:(VisCART メッシュ適応)
(Mesh Comparison)



snappyHexMesh

OEM's own version of snappyHex
Mesh size: 45.4 Million



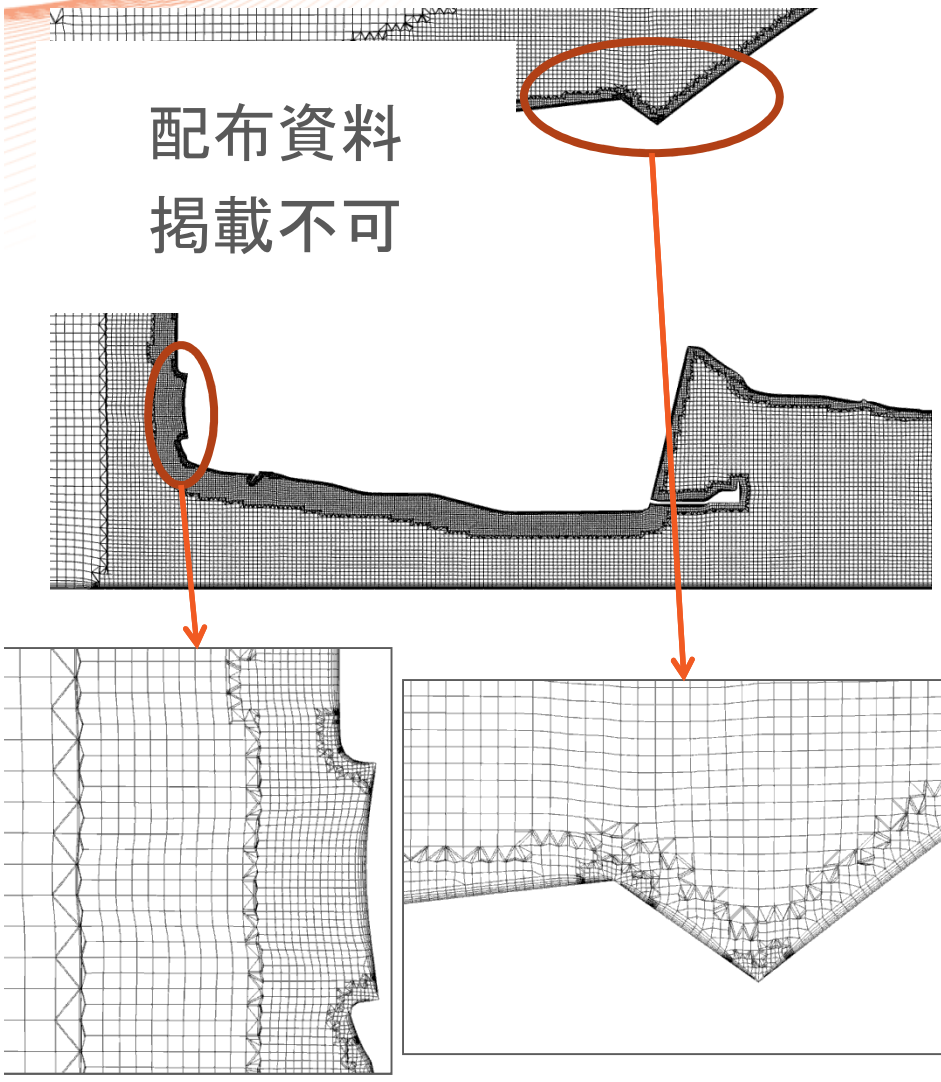
CFD-VisCART

ESI's preprocessor
Mesh size: 30.7 Million

事例:(VisCART メッシュ適応)
(Mesh Comparison)

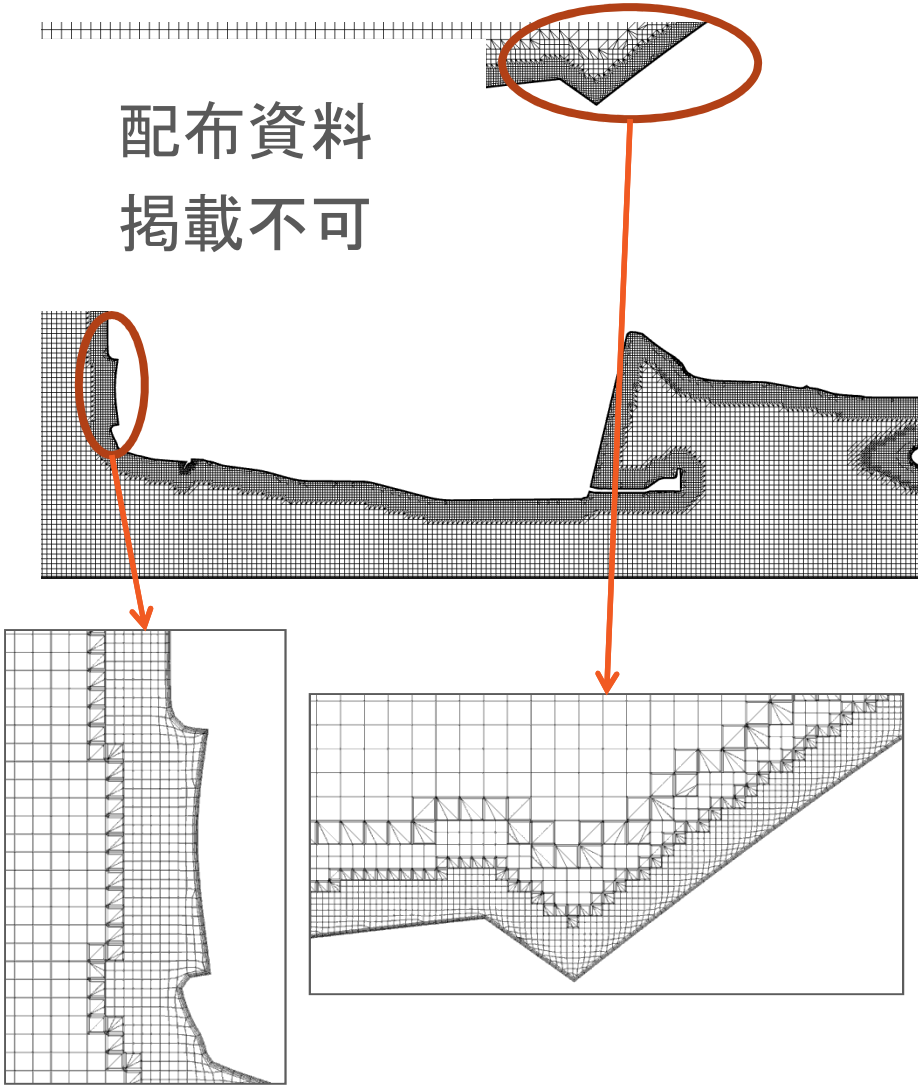
snappyHexMesh

配布資料
掲載不可



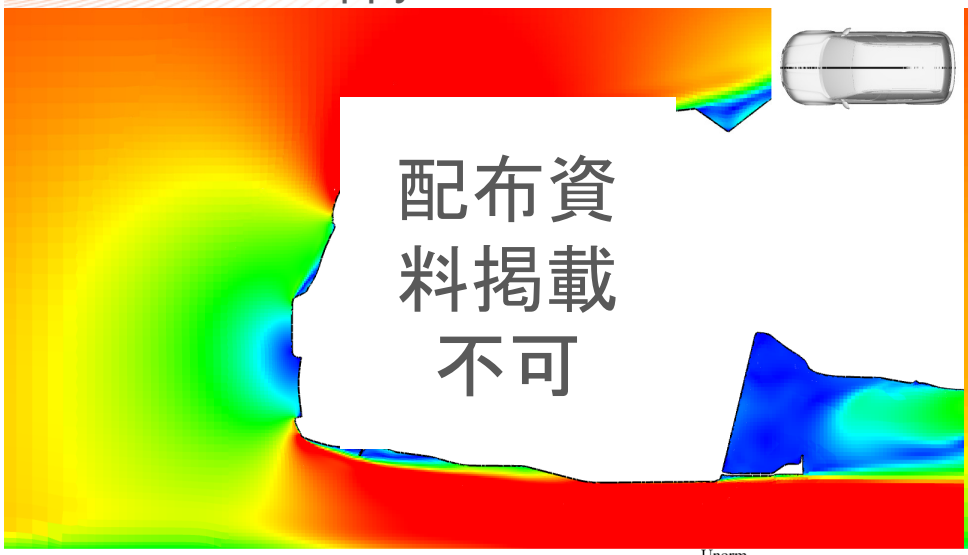
CFD-VisCART

配布資料
掲載不可

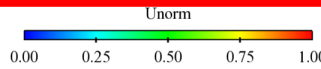


事例:(VisCART メッシュ適応)
Domain Plots　Velocity (normalized)

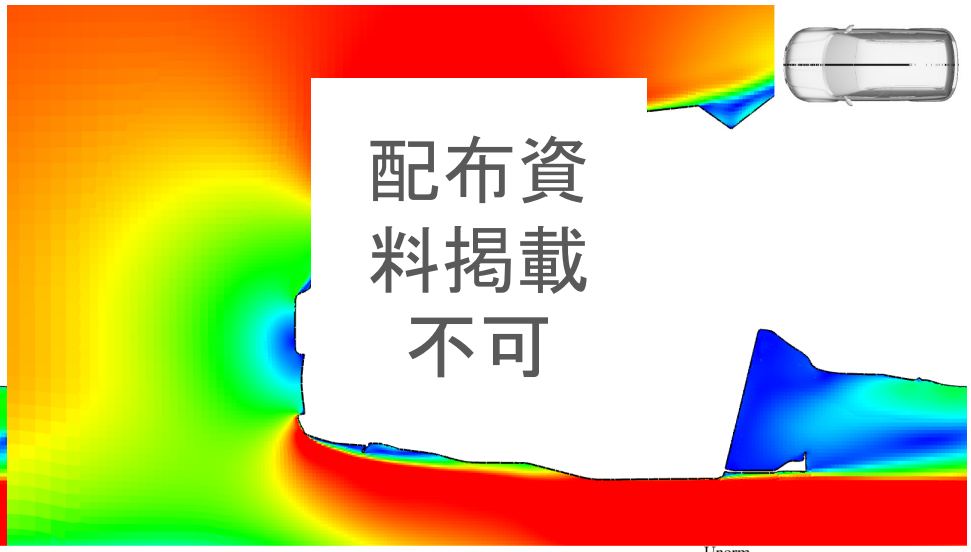
snappyHexMesh



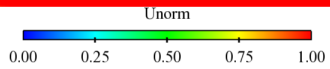
Normalised Velocity (ref. = 33.330002 m/s) at y = 0.000000 [m]
Skoda-Results-



CFD-VisCART



Normalised Velocity (ref. = 33.330002 m/s) at y = 0.000000 [m]
ESI-MW-OpenFoam-1.5-Skoda-Settings



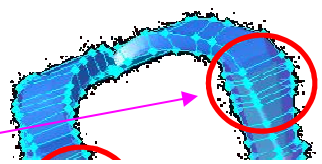
Customer quite satisfied, next phase to start!

OF Version	Mesh Tool	Cd	CSF (3%)	Cl (total)	Cl front	KFU (0.040)	Cl rear	CSF (0.010)	Remarks
Experiment	-	0.353	0.011	0.085	-0.049	0.040	0.134	0.010	OEM Measurement
OEM (1.5-1)	snappyHexMesh	0.351	0.002	0.091	-0.043	0.006	0.134	0.000	OEM Result
ESI-OF-1.5	**ESI-VisCART**	**0.353**	**0.000**	**0.087**	**-0.047**	**0.002**	**0.135**	**0.001**	**Ran on ESI Cluster**

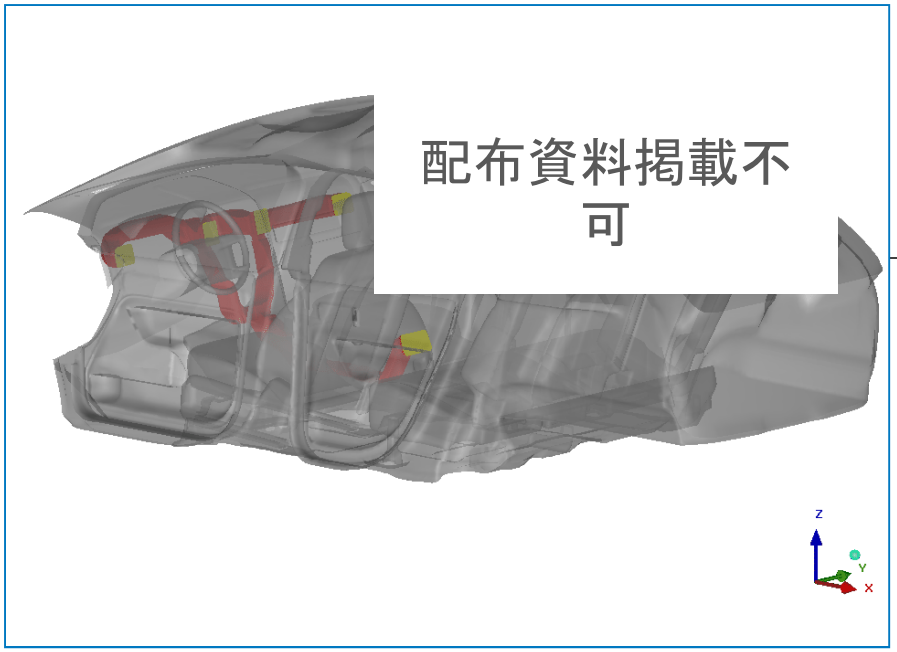
他ツールとの連携

最適化ソフト

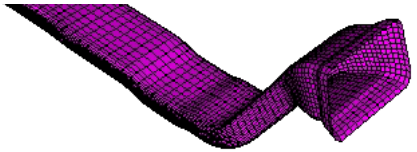
事例:Duct Optimization
Morphing using Sculptor



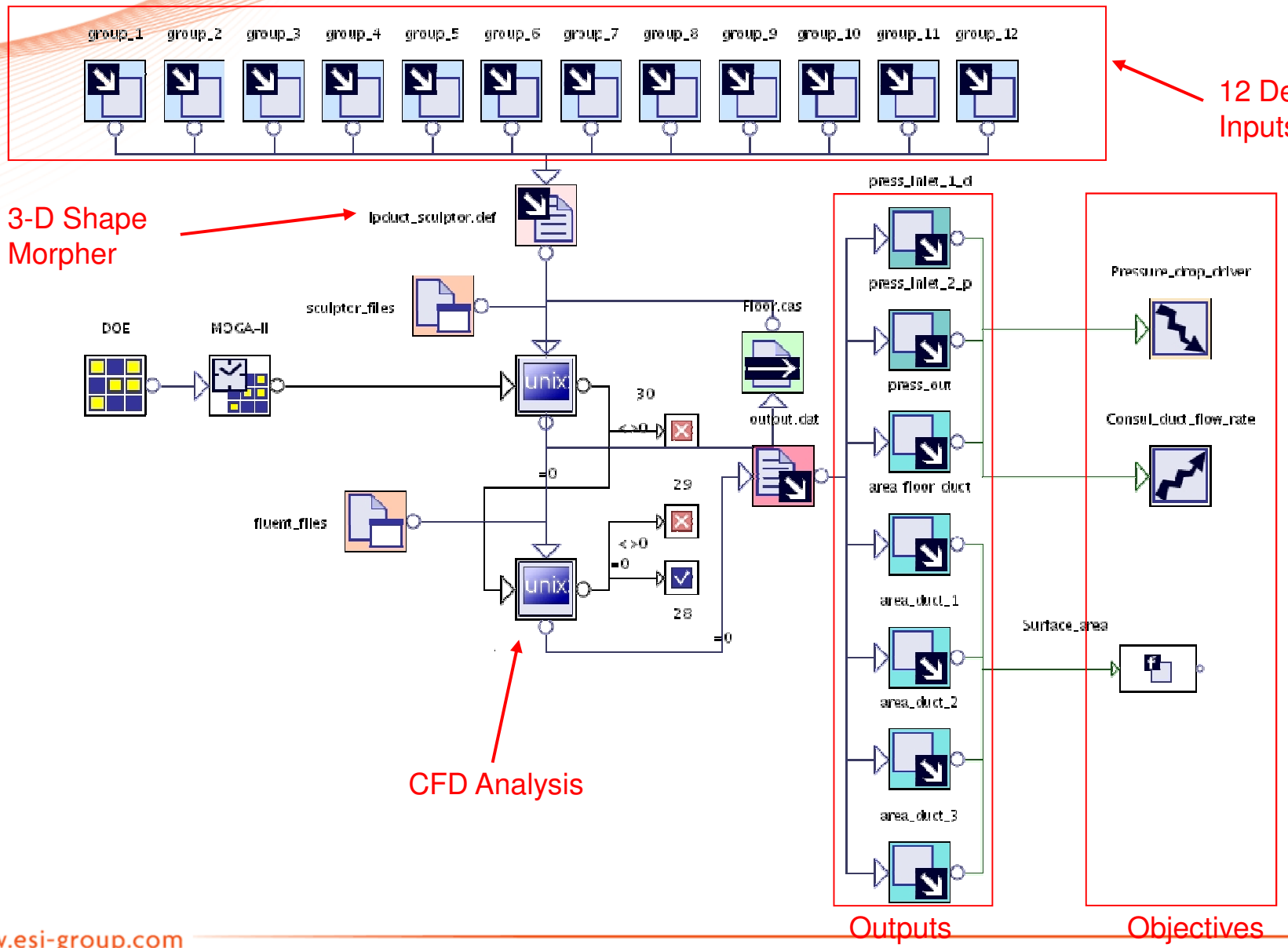
Control Group Locations for mesh morphing



配布資料掲載不可



Optimization Process

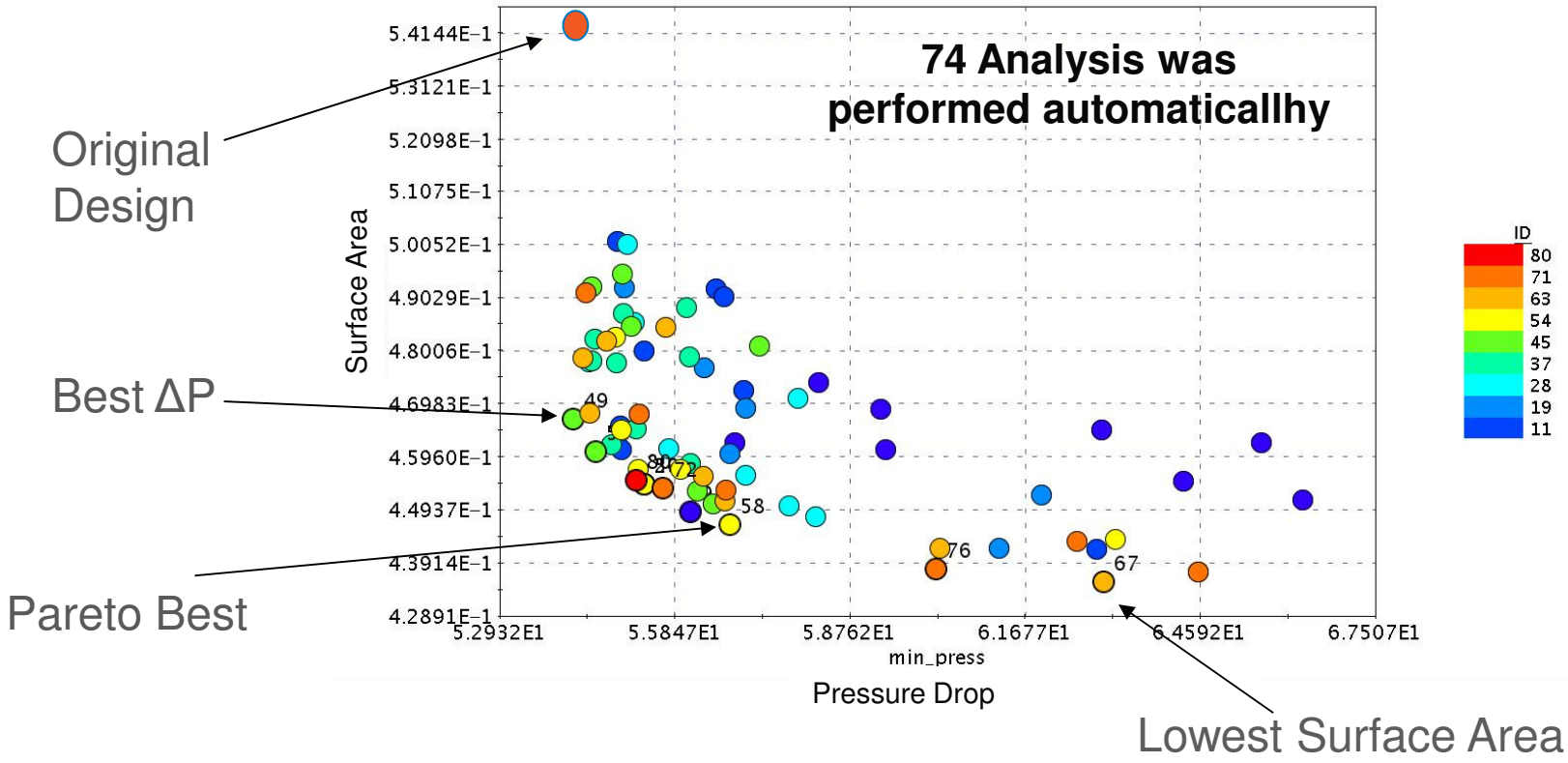


事例:Duct Optimization
Perato Chart with Interaction between the Objectives

Plot of Pressure Drop (Horizontal axis)

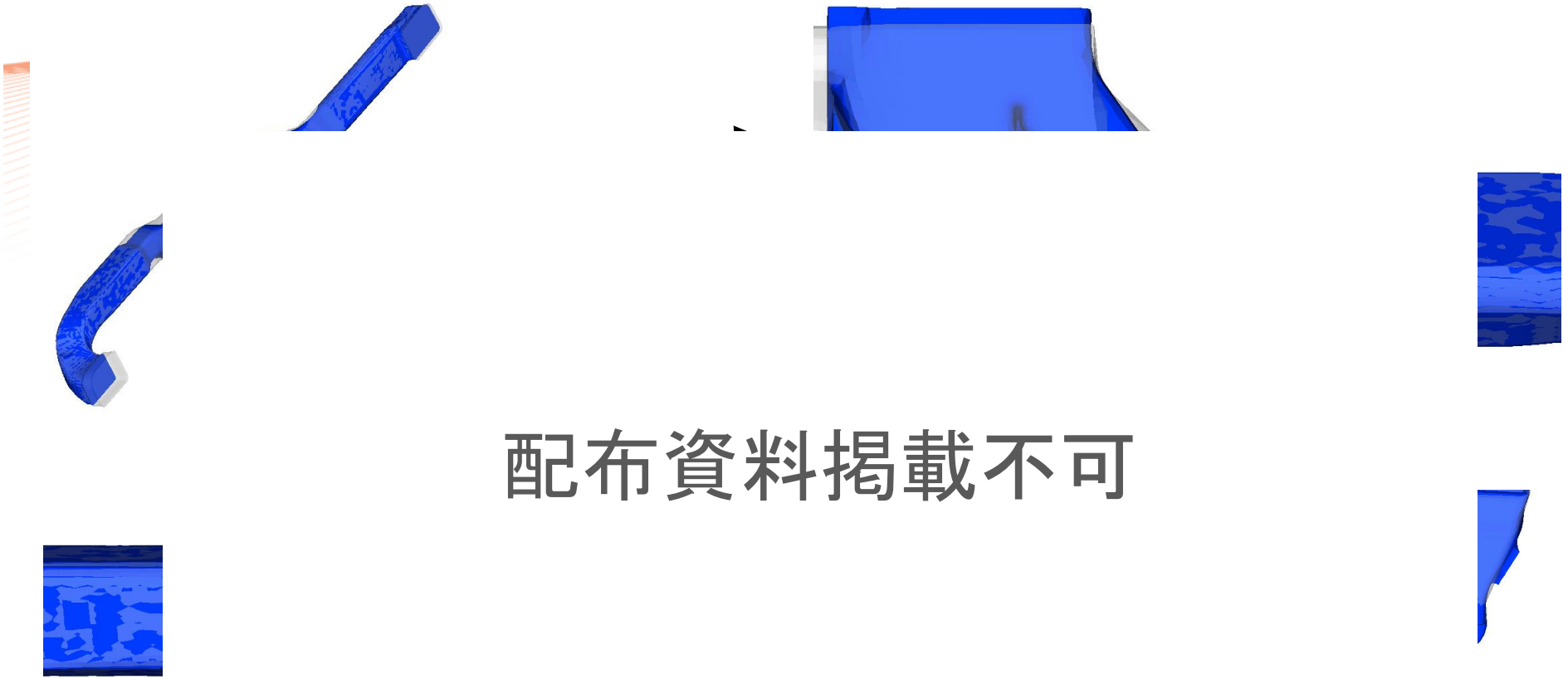
vs.

Surface Area (Vertical Axis)



事例:Duct Optimization

Optimized Geometry



配布資料掲載不可

Grey: Baseline

Blue: Optimized

事例:Duct Optimization

Comparison of Baseline Vs Optimized Design

- Reduced testing and elimination of prototype tooling costs
- $150,000 Savings/Vehicle Program
- ~$750,000 / Year

配布資料掲載不可

	Outlet Driver Side	Outlet Panel Driver Side	Outlet Panel Passenger Side	Outlet Passenger Side	Outlet Console
Mass Flow (%) (Baseline)	23.7	20.9	24.6	23.2	7.6
Mass Flow (%) (Optimized Shape)	21.4	21.2	20.1	20.2	17.1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