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IDAJ CAE
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比想象中更强大！
IDAJ-China联合ANSYS-China
共同开创中国CAE&CFD新未来

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VOLVO采用统一模型进行S80整车分析

ANSYS CHINA
朱祥德

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建模流程
案例分析
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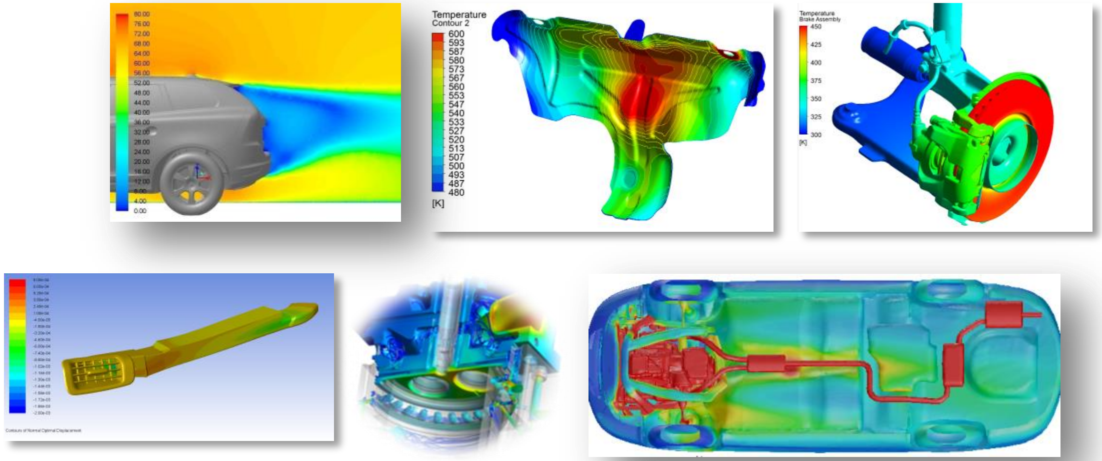
背景介绍

在汽车OEM厂商内，按照分析内容划分成不同的团队

- 空气动力学
- 机舱热管理
- 气动噪声
- 发动机共轭传热
- 刹车盘
- 排气及后处理
- 空调系统
- 车身污染(雪、尘、雨)
- …


Temperature
Contour 2
600
593
587
580
573
567
560
553
547
540
533
527
520
513
507
500
493
487
480
[K]
Temperature
Brake Assembly
450
425
400
375
350
325
300
[K]

这样可以让团队专注在各自的分析领域

然而，这样做的潜在影响是

- 重复的CAD处理工作
- 重复的网格生成工作
- 可能导致边界条件及材料属性的过度或不一致
- 可能会影响分析精度
- 不是最优的分析效率

背景介绍

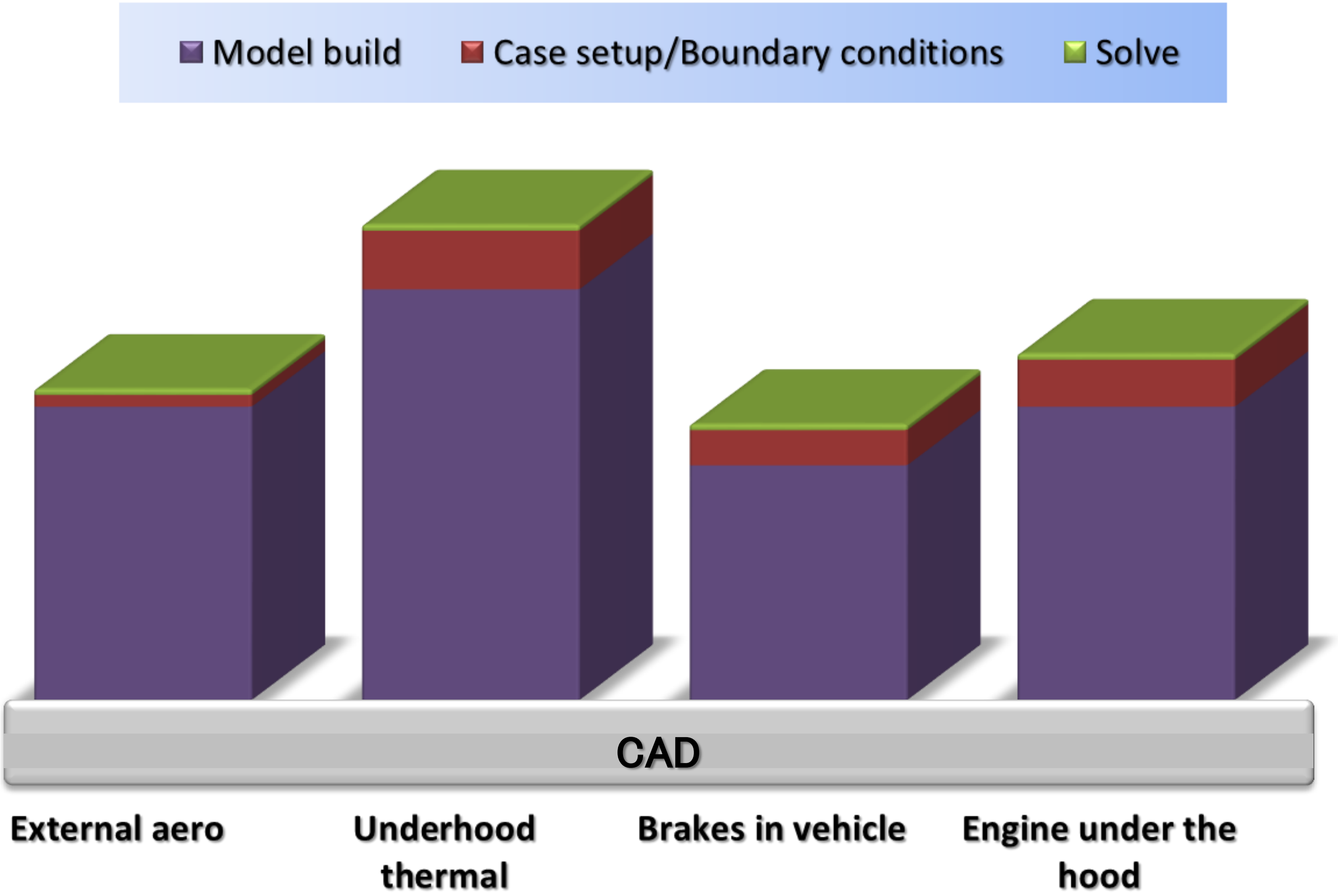
可用于多任务分析的统一模型

- 减少企业内花费在CAD处理上的时间
- 在一次分析内完成多个问题的求解
- 减少收集边界条件及材料属性的需求
    - E.g. 比如发动机共轭传热分析
- 采用统一的材料数据库用于所有的分析
- 采用一致的网格生成策略
- 更准确的反应真实世界的物理现象
- 采用统一的多学科优化模型

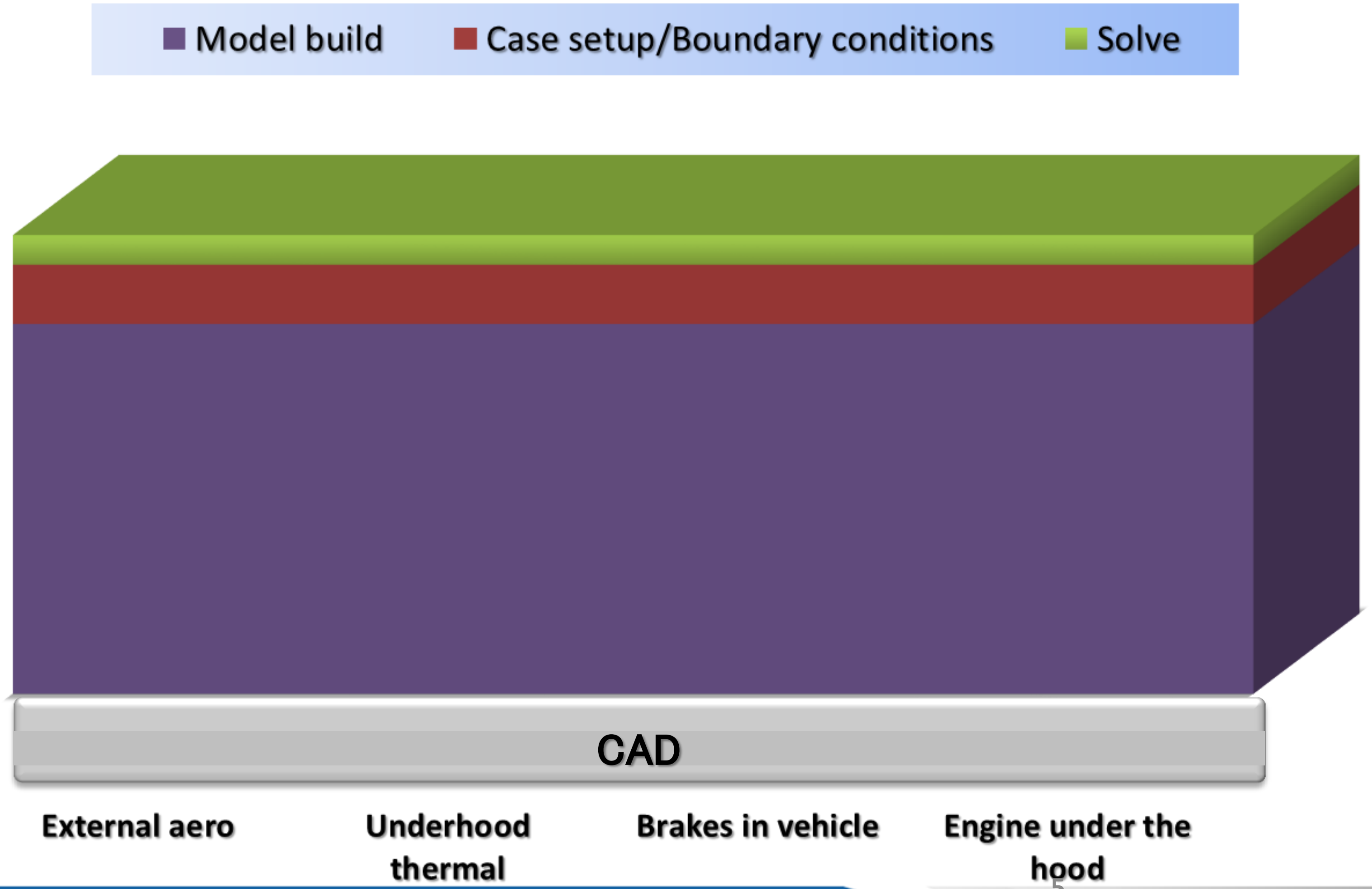
针对特定分析应用，只需要选择对应的分析内容，通过选择统一的CAD模型

- 分别设定表面网格的策略，比如局域网格加密/稀疏
- 分别设定体网格的生成策略，比如局部区域的网格加密及调整附面层网格

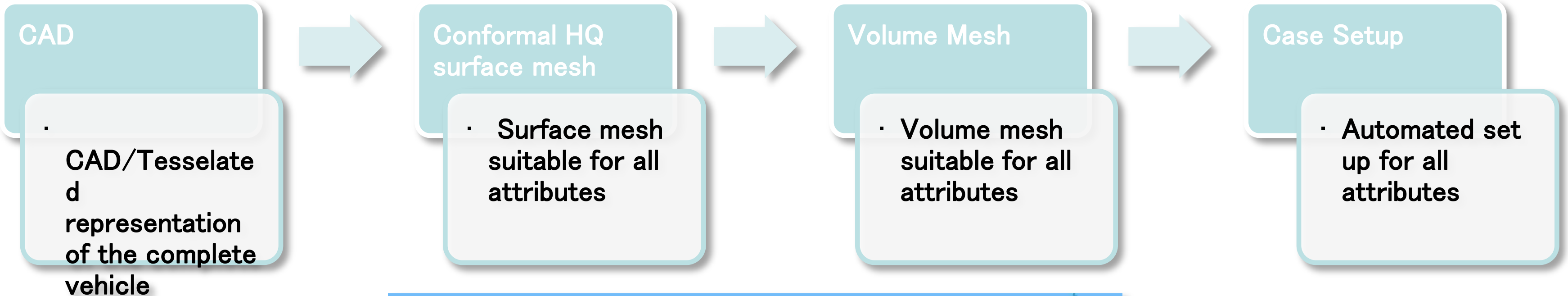
独立模型处理方式


Model build
Case setup/Boundary conditions
Solve
CAD
External aero
Underhood thermal
Brakes in vehicle
Engine under the hood

统一模型处理方式


🟪 Model build
🟥 Case setup/Boundary conditions
🟩 Solve
CAD
External aero
Underhood thermal
Brakes in vehicle
Engine under the hood

分析流程（当前）



CAD

- CAD/Tesselated representation of the complete vehicle

Conformal HQ surface mesh

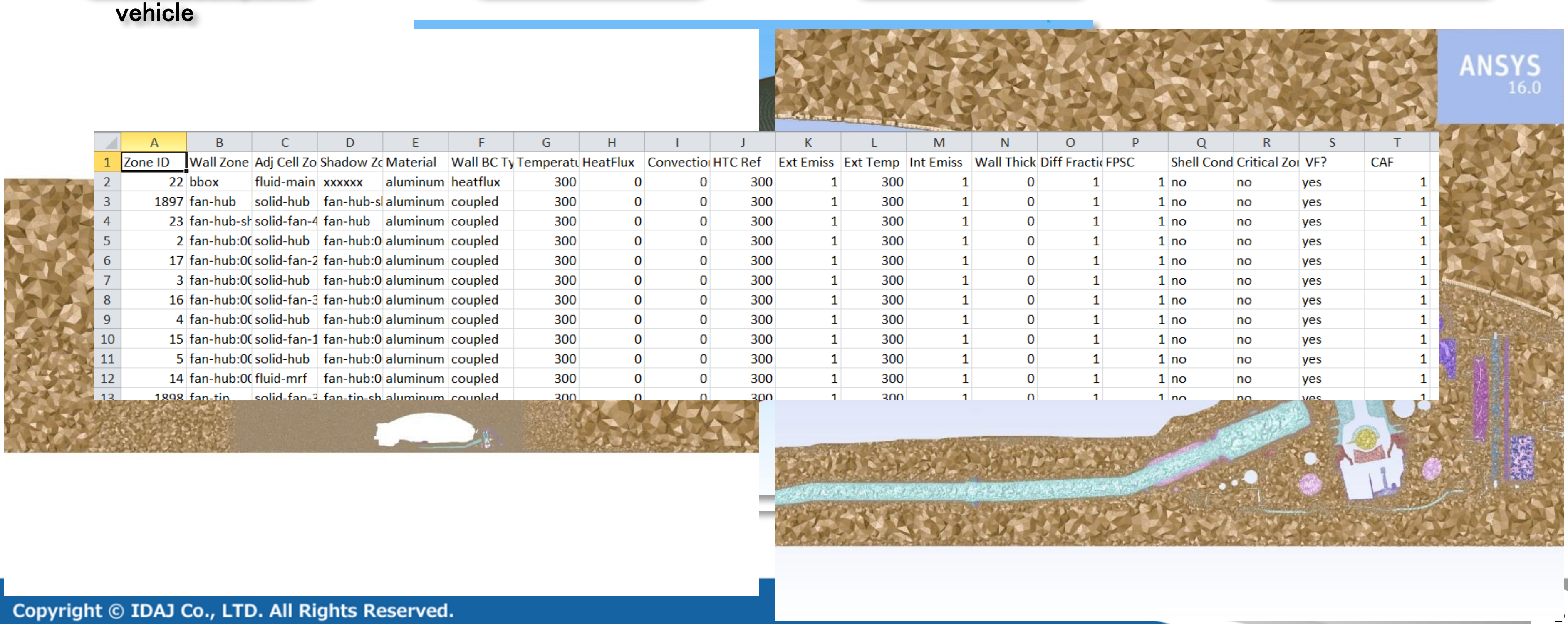
- Surface mesh suitable for all attributes

Volume Mesh

- Volume mesh suitable for all attributes

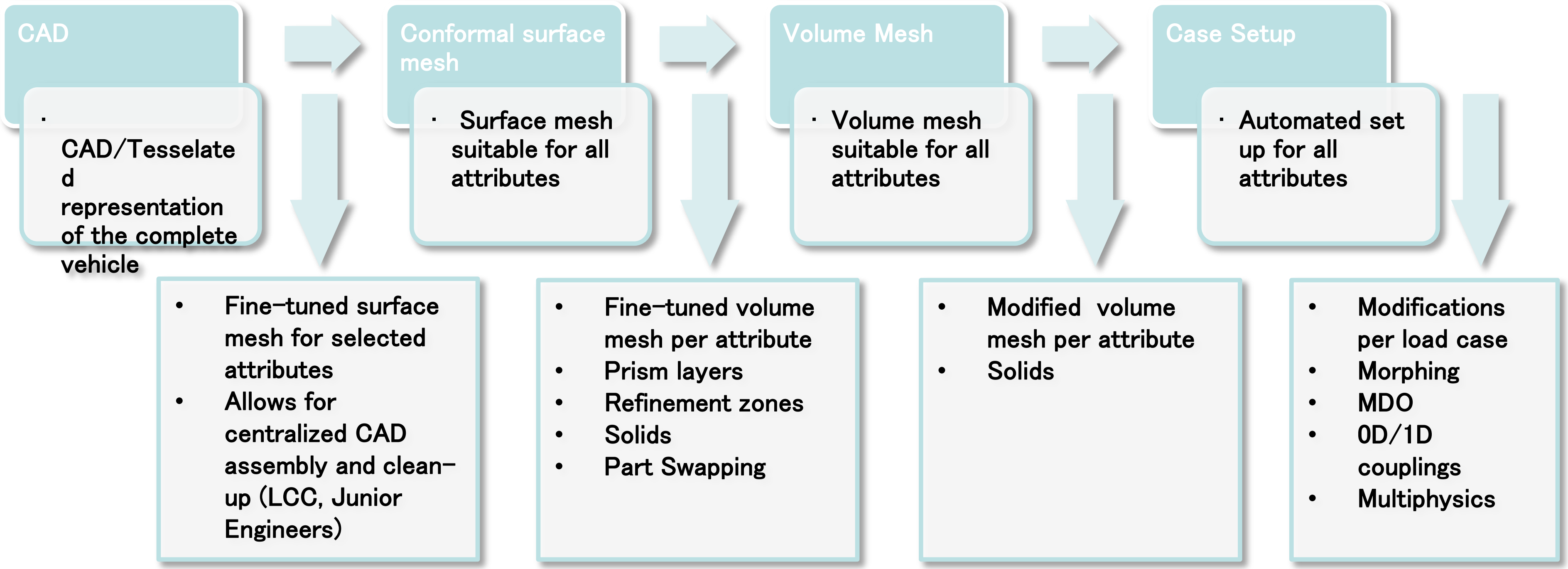
Case Setup

- Automated set up for all attributes



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Zone ID	Wall Zone	Adj Cell Zo	Shadow Zc	Material	Wall BC Ty	Temperatu	HeatFlux	Convectio	HTC Ref	Ext Emiss	Ext Temp	Int Emiss	Wall Thick	Diff Fractio	FPSC	Shell Cond	Critical Zo	VF?	CAF
2	22	bbox	fluid-main	xxxxxx	aluminum	heatflux	300	0	0	300	1	300	1	0	1	1	no	no	yes	1
3	1897	fan-hub	solid-hub	fan-hub-sl	aluminum	coupled	300	0	0	300	1	300	1	0	1	1	no	no	yes	1
4	23	fan-hub-sh	solid-fan-4	fan-hub	aluminum	coupled	300	0	0	300	1	300	1	0	1	1	no	no	yes	1
5	2	fan-hub:00	solid-hub	fan-hub:0	aluminum	coupled	300	0	0	300	1	300	1	0	1	1	no	no	yes	1
6	17	fan-hub:00	solid-fan-2	fan-hub:0	aluminum	coupled	300	0	0	300	1	300	1	0	1	1	no	no	yes	1
7	3	fan-hub:00	solid-hub	fan-hub:0	aluminum	coupled	300	0	0	300	1	300	1	0	1	1	no	no	yes	1
8	16	fan-hub:00	solid-fan-3	fan-hub:0	aluminum	coupled	300	0	0	300	1	300	1	0	1	1	no	no	yes	1
9	4	fan-hub:00	solid-hub	fan-hub:0	aluminum	coupled	300	0	0	300	1	300	1	0	1	1	no	no	yes	1
10	15	fan-hub:00	solid-fan-1	fan-hub:0	aluminum	coupled	300	0	0	300	1	300	1	0	1	1	no	no	yes	1
11	5	fan-hub:00	solid-hub	fan-hub:0	aluminum	coupled	300	0	0	300	1	300	1	0	1	1	no	no	yes	1
12	14	fan-hub:00	fluid-mrf	fan-hub:0	aluminum	coupled	300	0	0	300	1	300	1	0	1	1	no	no	yes	1
13	1898	fan-tip	solid-fan-3	fan-tip-sh	aluminum	coupled	300	0	0	300	1	300	1	0	1	1	no	no	yes	1

分析流程(进一步)



CAD

- CAD/Tesselated representation of the complete vehicle

- Fine-tuned surface mesh for selected attributes
- Allows for centralized CAD assembly and clean-up (LCC, Junior Engineers)

Conformal surface mesh

- Surface mesh suitable for all attributes

- Fine-tuned volume mesh per attribute
- Prism layers
- Refinement zones
- Solids
- Part Swapping

Volume Mesh

- Volume mesh suitable for all attributes

- Modified volume mesh per attribute
- Solids

Case Setup

- Automated set up for all attributes

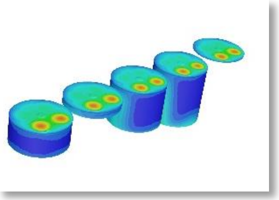
- Modifications per load case
- Morphing
- MDO
- 0D/1D couplings
- Multiphysics

统一模型

3
4
5
6
1
0
110
km/h
10°c
19:55

Volvo S80 D5 MY2012

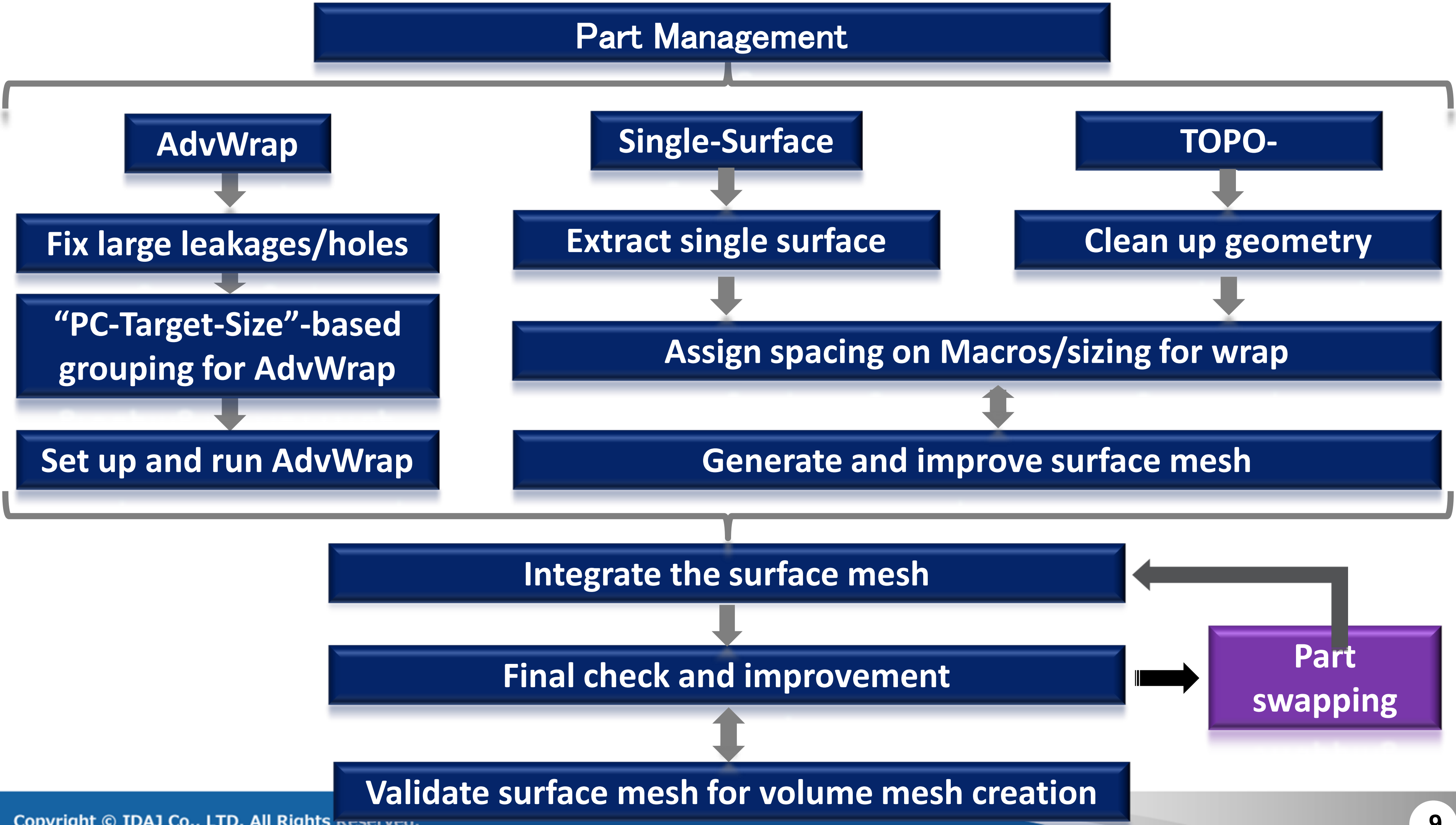
2.4升，5缸，双涡轮增压汽油机，功率215 hp，扭矩 440 Nm



- 分析内容
  - 空气动力学
  - 热管理
  - 发动机共轭传热
  - 冷却系统
  - 制动系统
  - 进气系统
  - 排气系统
- **~400** 多个固体部件
- **~50** 多个壳体部件(可至**1000**多)

- 分析工况
  - 车速**110kph**
  - 发动机转速**2050**
  - 热源:
    - 缸内燃烧
    - 高温排气
    - 刹车盘摩擦
  - 考虑刹车盘
  - 涡轮增压
  - 冷却模块
    - 风扇及换热器

建模流程



Part Management

AdvWrap

Fix large leakages/holes

"PC-Target-Size"-based grouping for AdvWrap

Set up and run AdvWrap

Single-Surface

Extract single surface

TOPO-

Clean up geometry

Assign spacing on Macros/sizing for wrap

Generate and improve surface mesh

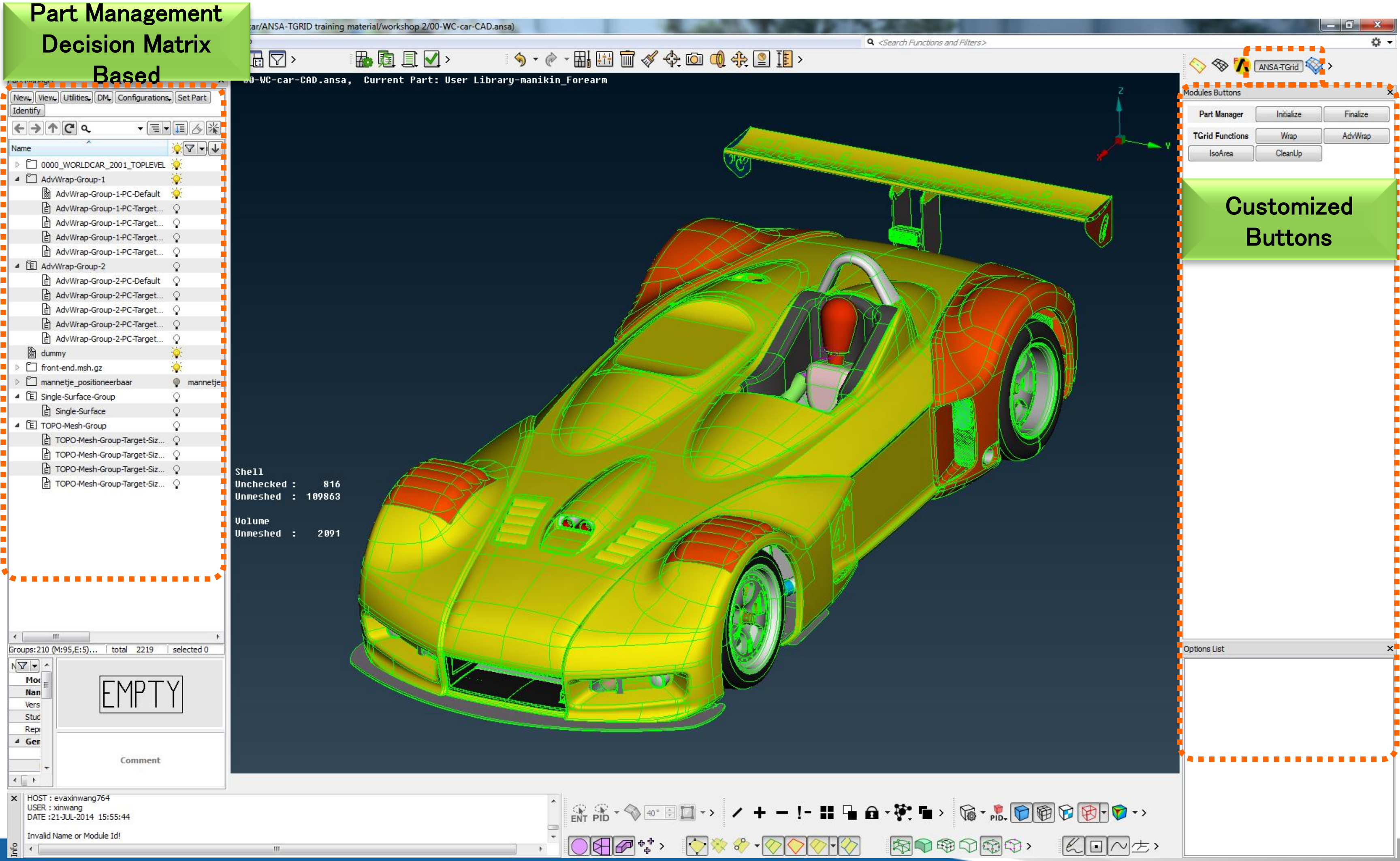
Integrate the surface mesh

Final check and improvement

Part swapping

Validate surface mesh for volume mesh creation

ANSA-TGRID(当前)



Part Management Decision Matrix Based

Customized Buttons

ar/ANSA-TGRID training material/workshop 2/00-WC-car-CAD.ansa)
<Search Functions and Filters>
00-WC-car-CAD.ansa, Current Part: User Library-manikin_Forearm
New
View
Utilities
DM
Configurations
Set Part
Identify
Name
ANSA-TGrid
Modules Buttons
Part Manager
Initialize
Finalize
TGrid Functions
Wrap
AdvWrap
IsoArea
CleanUp
Options List
EMPTY
Comment
Info
ENT
PID

- 0000_WORLDCAR_2001_TOPLEVEL
- AdvWrap-Group-1
  - AdvWrap-Group-1-PC-Default
  - AdvWrap-Group-1-PC-Target...
  - AdvWrap-Group-1-PC-Target...
  - AdvWrap-Group-1-PC-Target...
  - AdvWrap-Group-1-PC-Target...
- AdvWrap-Group-2
  - AdvWrap-Group-2-PC-Default
  - AdvWrap-Group-2-PC-Target...
  - AdvWrap-Group-2-PC-Target...
  - AdvWrap-Group-2-PC-Target...
  - AdvWrap-Group-2-PC-Target...
- dummy
- front-end.msh.gz
- mannetje_positioneerbaar mannetje
- Single-Surface-Group
  - Single-Surface
- TOPO-Mesh-Group
  - TOPO-Mesh-Group-Target-Siz...
  - TOPO-Mesh-Group-Target-Siz...
  - TOPO-Mesh-Group-Target-Siz...
  - TOPO-Mesh-Group-Target-Siz...

Groups:210 (M:95,E:5)... total 2219 selected 0

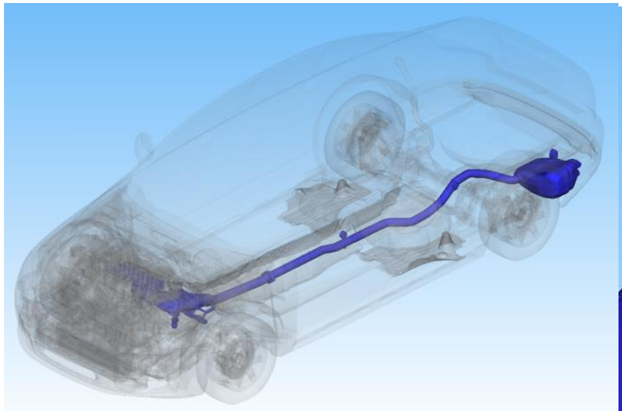
```
Shell
Unchecked :     816
Unmeshed  :  109863

Volume
Unmeshed  :    2091
```

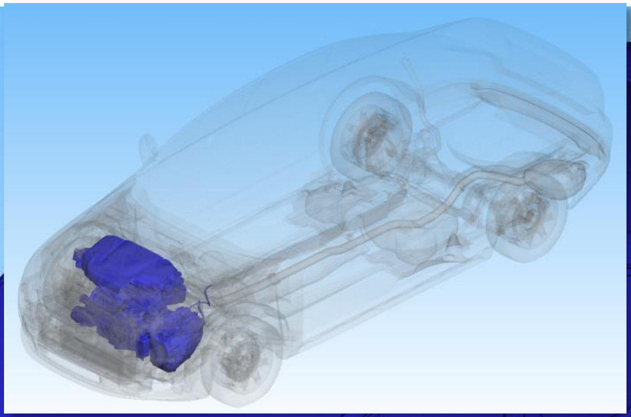
```
HOST : evaxinwang764
USER : xinwang
DATE :21-JUL-2014  15:55:44

Invalid Name or Module Id!
```

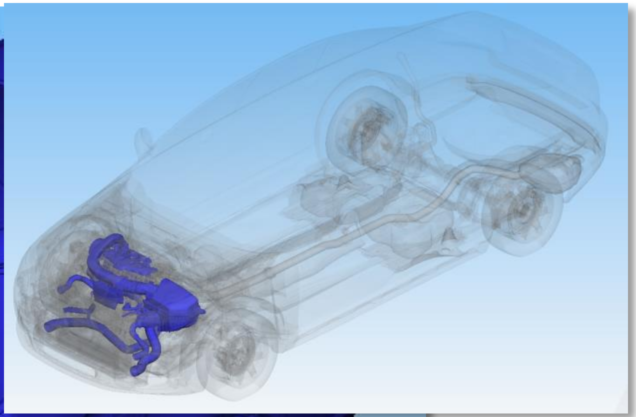
子系统



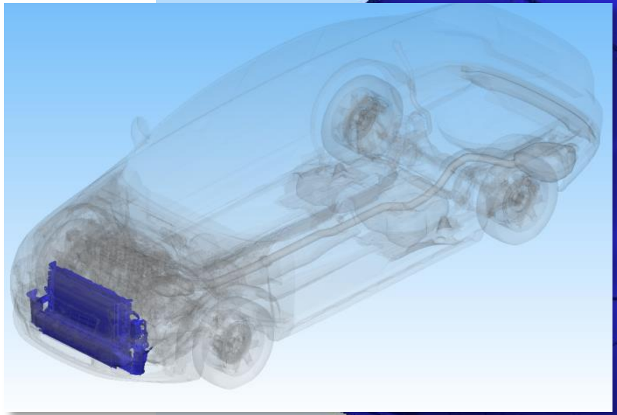
Exhaust System



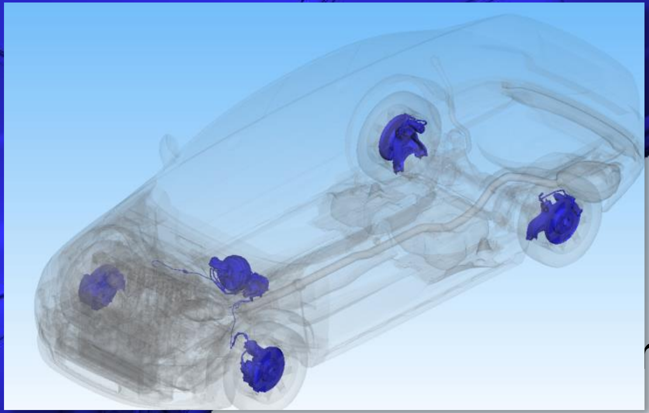
Engine



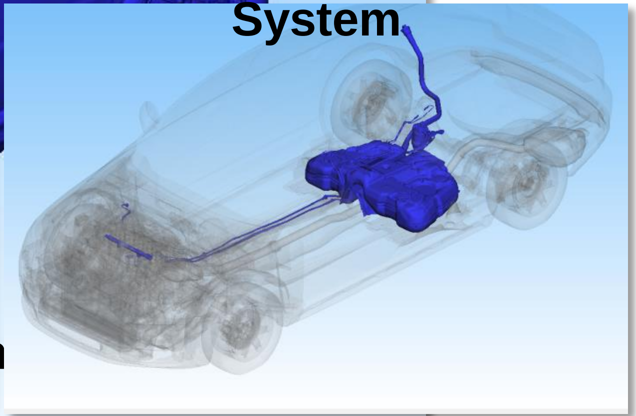
Air Intake System



Cooling System



Brake System



Fuel System

分析细节

一次分析

R-k-ε 湍流模型、壁面增强函数

耦合求解器、二阶迎风格式

辐射模型S2S

次级流动

- 排气
- 进气
- 冷却液

EGR混合

理想气体

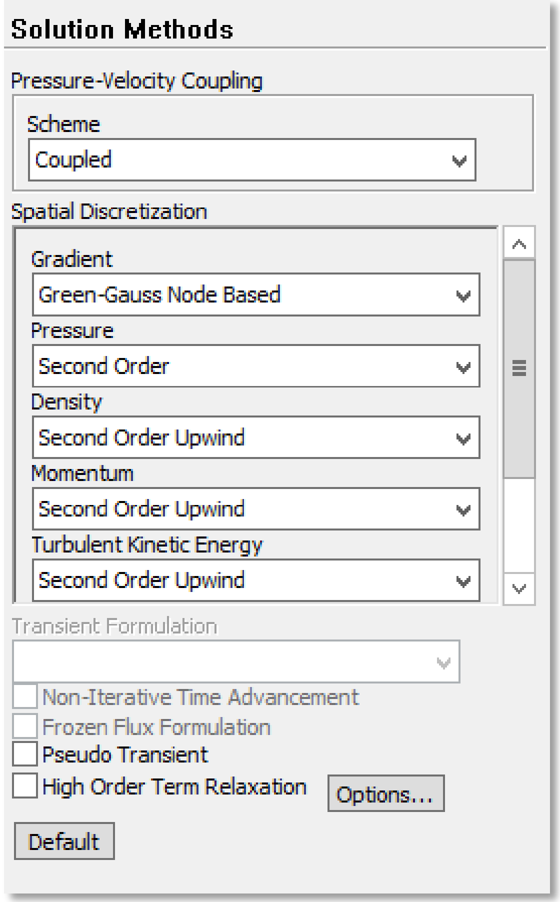
涡轮增压采用MRF模拟，转速140K rpm

车速110 kph, 空气温度35° C

风扇数据由厂商提供

水泵采用MRF模型，转速2050 rpm

迭代步数3000



Solution Methods

Pressure-Velocity Coupling

Scheme: Coupled

Spatial Discretization

Gradient: Green-Gauss Node Based

Pressure: Second Order

Density: Second Order Upwind

Momentum: Second Order Upwind

Turbulent Kinetic Energy: Second Order Upwind

Transient Formulation

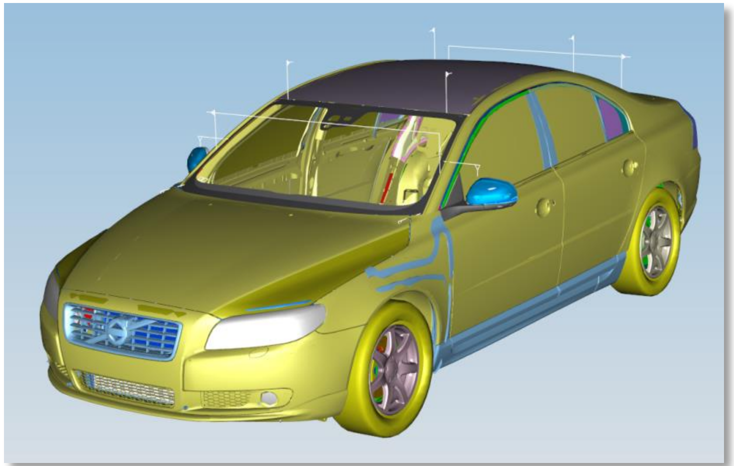
☐ Non-Iterative Time Advancement

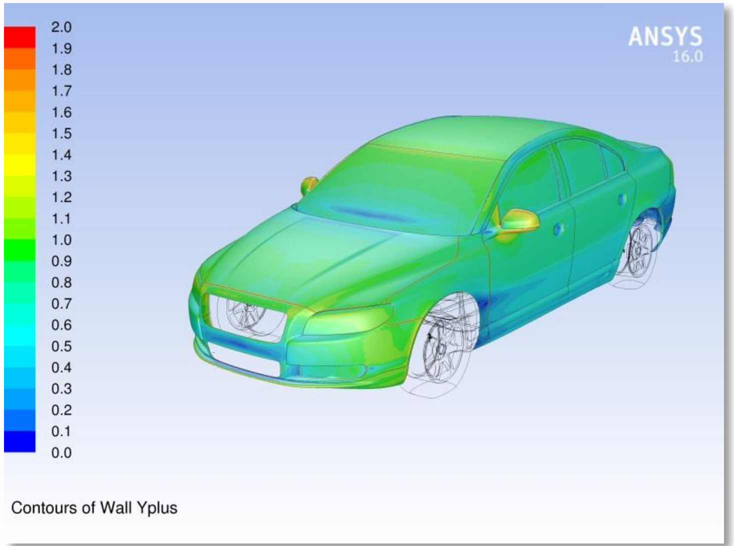
☐ Frozen Flux Formulation

☐ Pseudo Transient

☐ High Order Term Relaxation

空气动力学分析

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1.5
1.4
1.3
1.2
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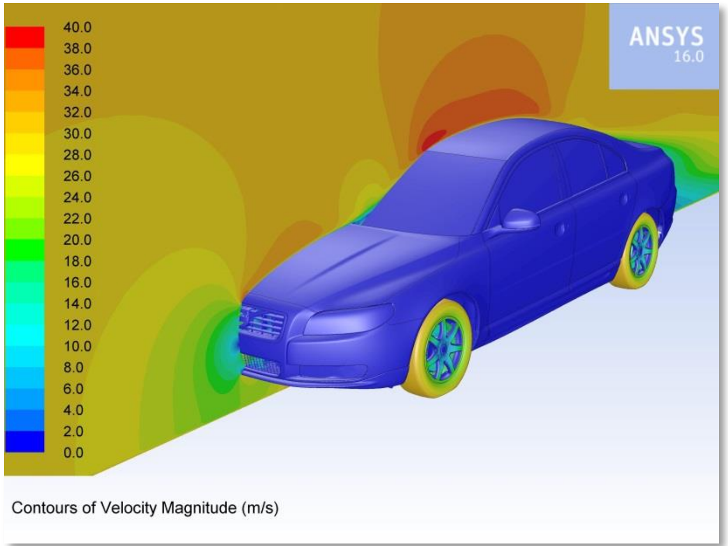
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
ANSYS
16.0

Contours of Wall Yplus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34.0
32.0
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26.0
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22.0
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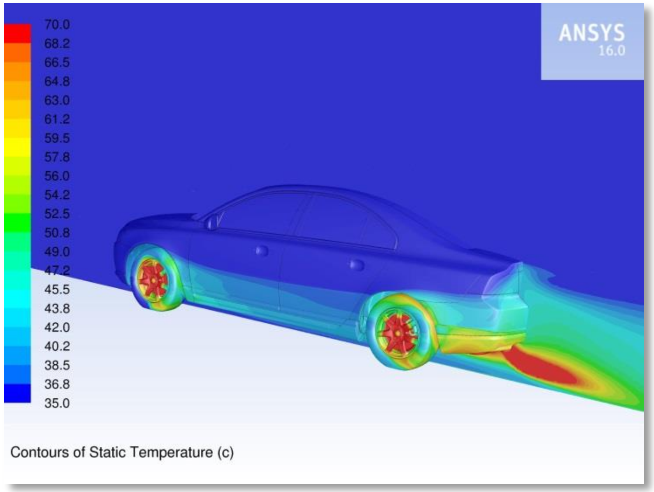
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
ANSYS
16.0

Contours of Velocity Magnitude (m/s)

- 细致的捕捉了所有的造型面，包括内外表面
- **12**层三棱柱附面层网格，第一层高度**0.02mm**
- 旋转坐标系 **(MRF)**
- 地面移动
- 尾迹区及分离区进行网格加密

空气动力学分析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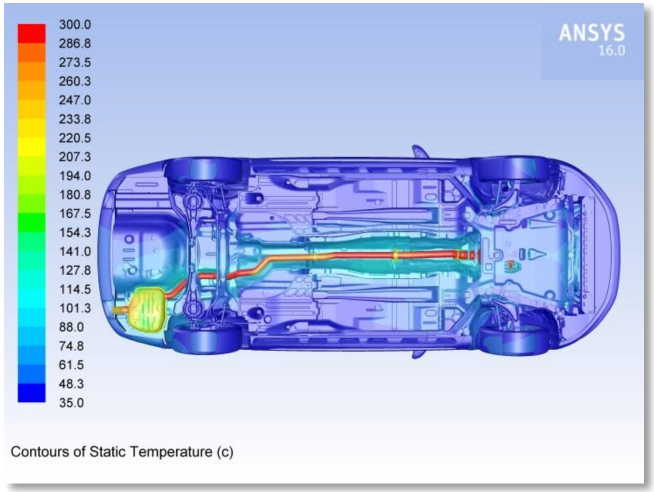
52.5
50.8
49.0
47.2
45.5
43.8
42.0
40.2
38.5
36.8
35.0

Contours of Static Temperature (c)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220.5
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194.0
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167.5
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127.8
114.5
101.3
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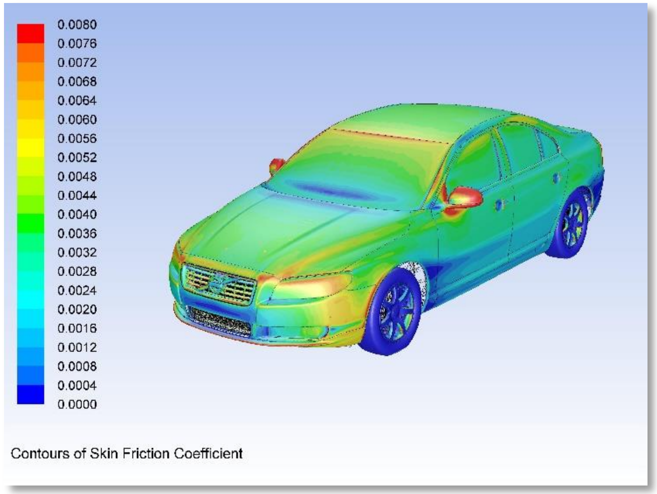
74.8
61.5
48.3
35.0

Contours of Static Temperature (c)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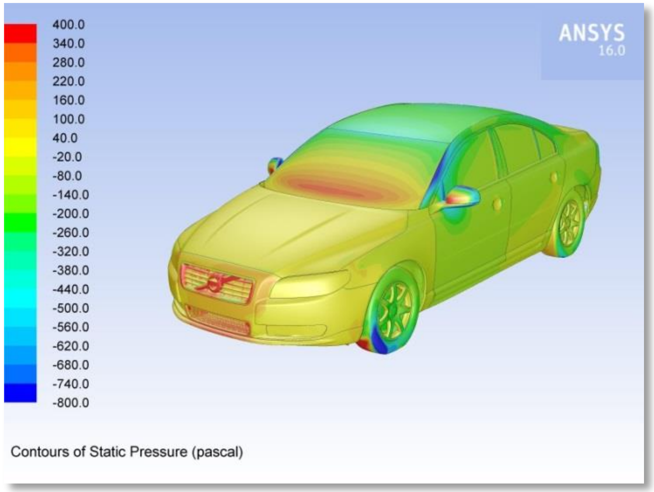
0.0016
0.0012
0.0008
0.0004
0.0000

Contours of Skin Friction Coefficient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16.0
400.0
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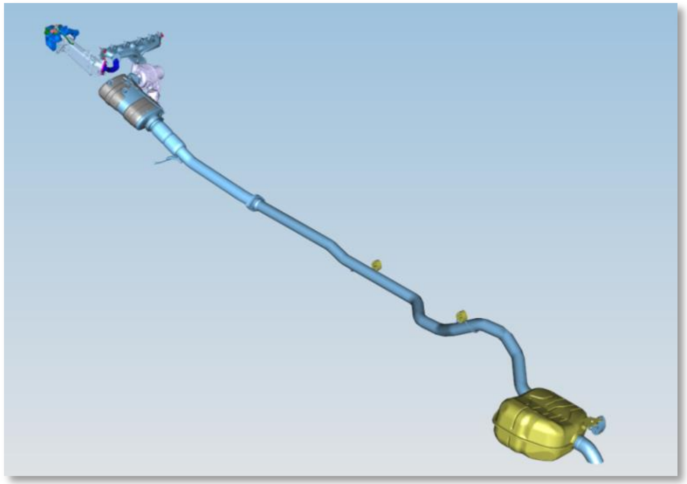
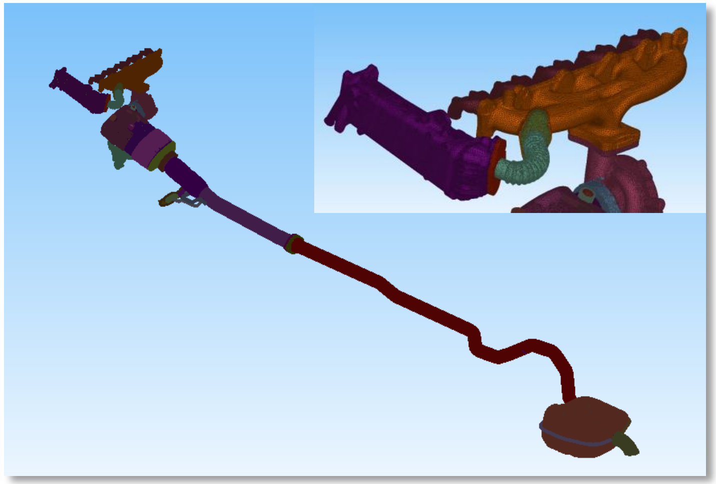
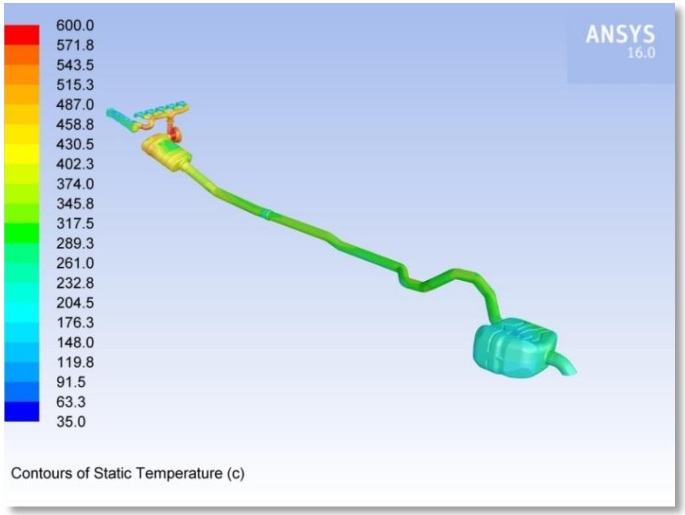
-20.0
-80.0
-140.0
-200.0
-260.0
-320.0
-380.0
-440.0
-500.0
-560.0
-620.0
-680.0
-740.0
-800.0

Contours of Static Pressure (pascal)

排气系统



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487.0
458.8
430.5
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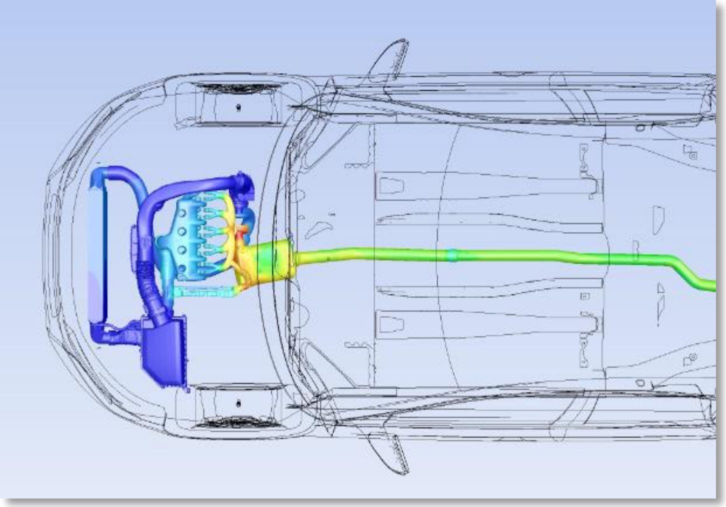
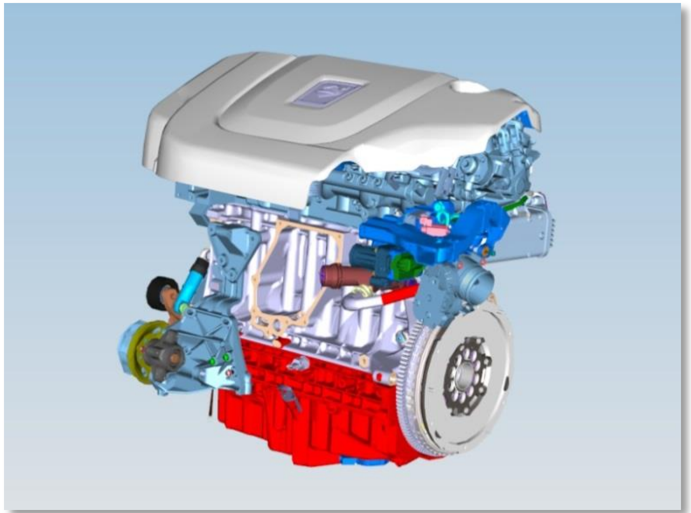
345.8
317.5
289.3
261.0
232.8
204.5
176.3
148.0
119.8
91.5
63.3
35.0
ANSYS
16.0

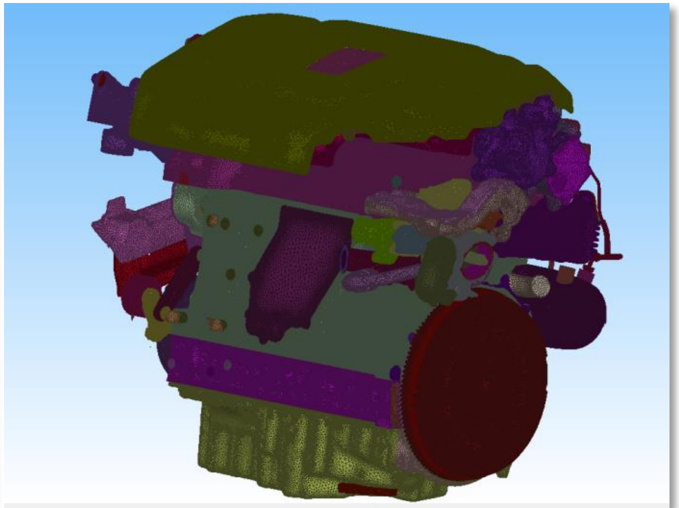
Contours of Static Temperature (c)

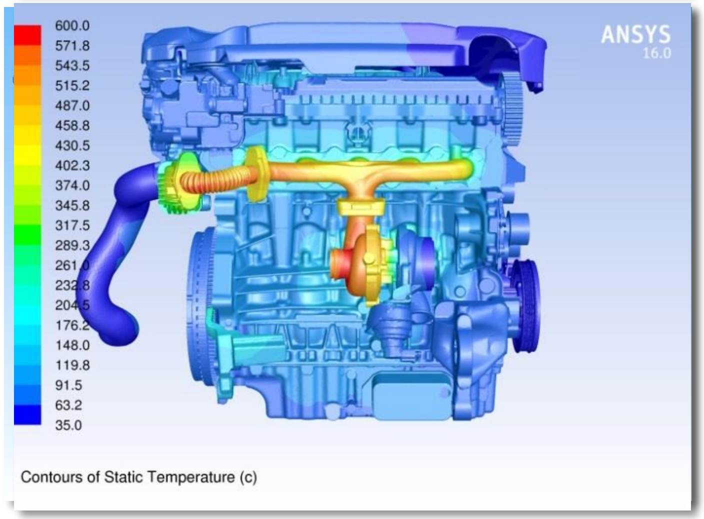


- 从气门到环境的完整排气系统，包括歧管、涡轮、EGR
- 气流在EGR同进气气流混合
- 包括100多个固体区域

发动机



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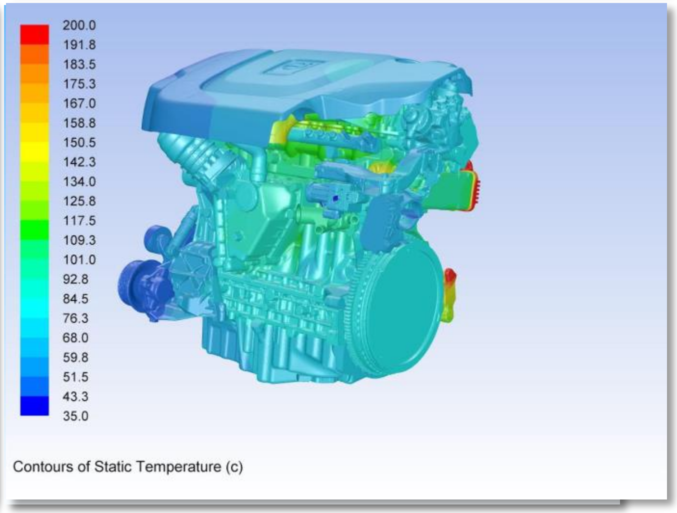
345.8
317.5
289.3
261.0
232.8
204.5
176.2
148.0
119.8
91.5
63.2
35.0
ANSYS
16.0
Contours of Static Temperature (c)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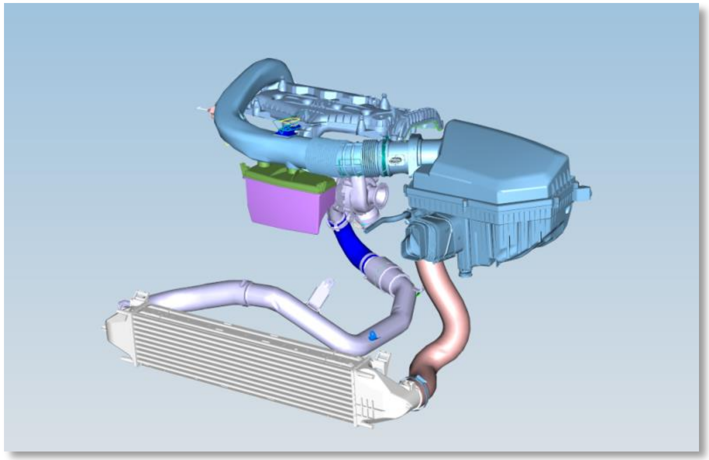
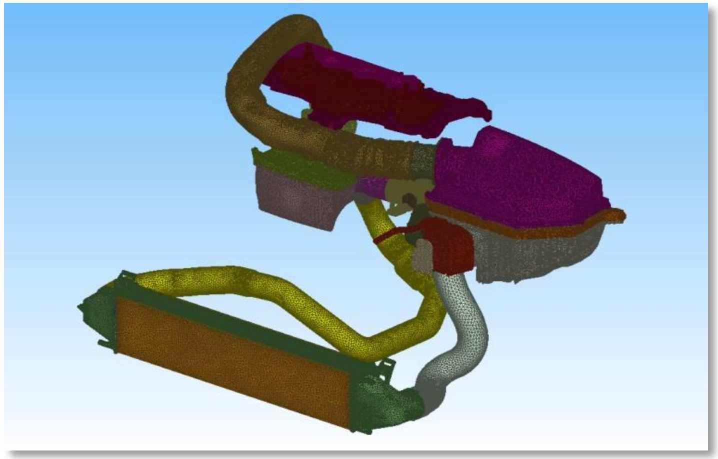
125.8
117.5
109.3
101.0
92.8
84.5
76.3
68.0
59.8
51.5
43.3
35.0
Contours of Static Temperature (c)

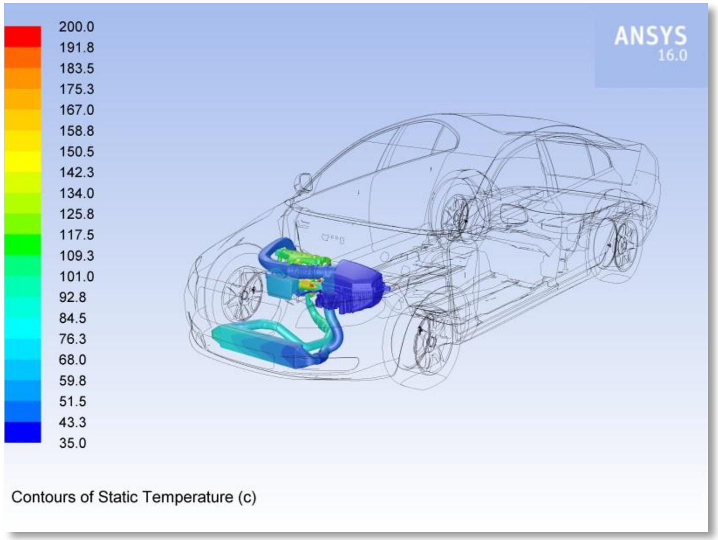
- **包括部件:缸套、缸体、曲轴及连杆、凸轮轴、气门、活塞、连杆盖、皮带轮、齿轮、油泵、分离器、减震系统等**
- **歧管隔热是层压钢/陶瓷**
- **包括100多个固体区域**

进气系统





- 从环境到气门，包括涡轮、中冷、EGR
- 在EGR处同排气气体混合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101.0
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76.3
68.0
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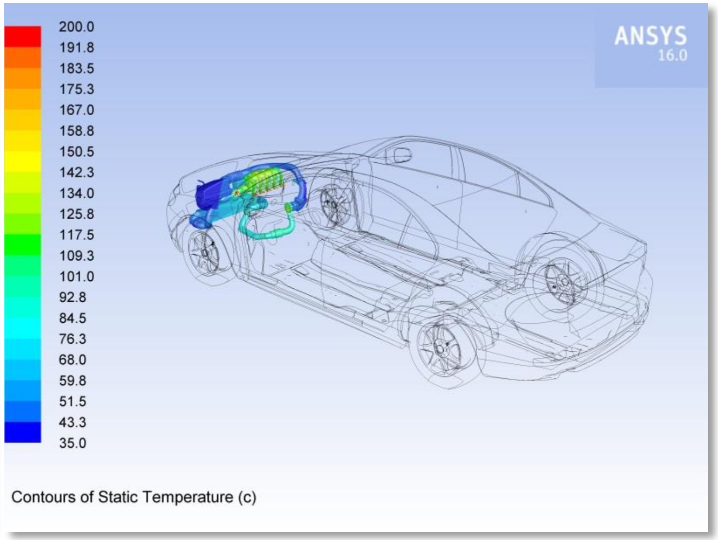
43.3
35.0
ANSYS
16.0

Contours of Static Temperature (c)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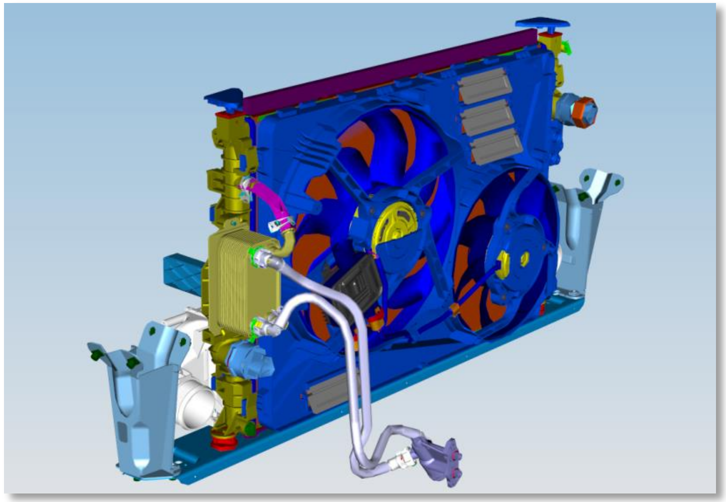
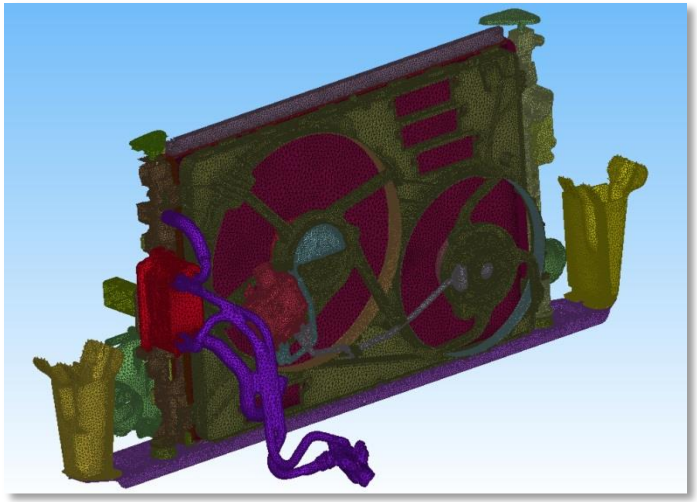
101.0
92.8
84.5
76.3
68.0
59.8
51.5
43.3
35.0
ANSYS
16.0

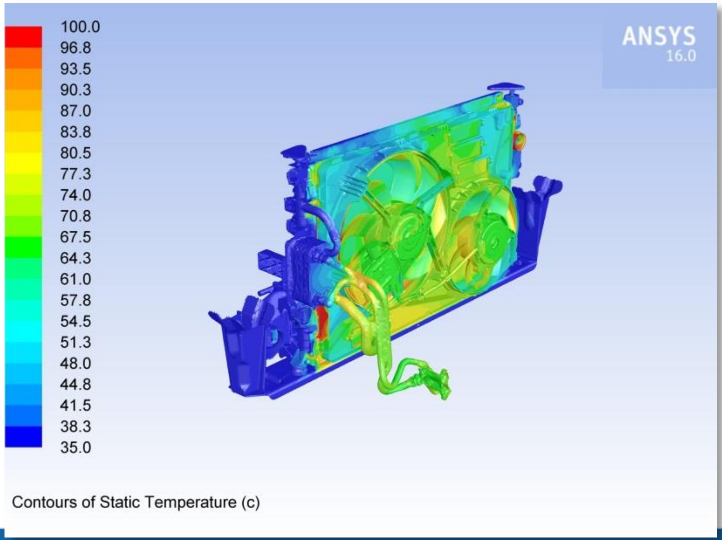
Contours of Static Temperature (c)

冷却模块





- 双风扇
- 风扇模型MRF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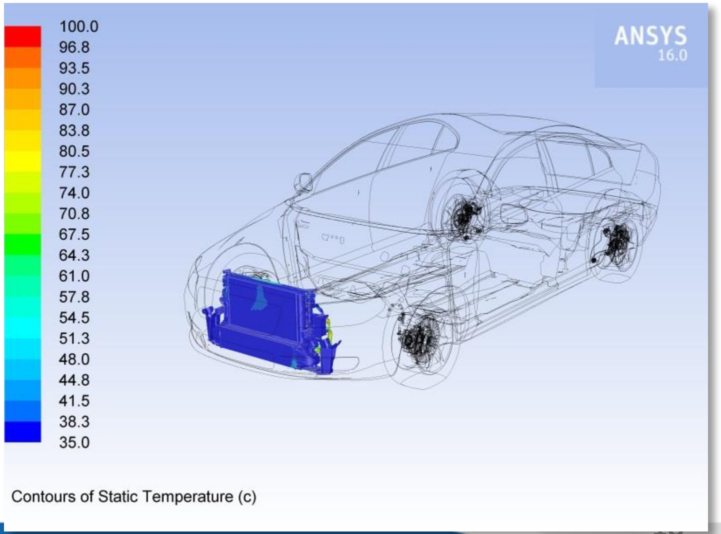
ANSYS
16.0
Contours of Static Temperature (c)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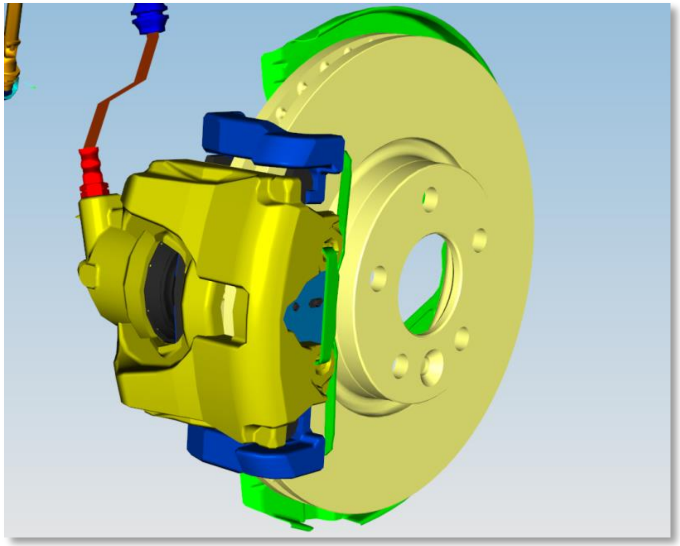
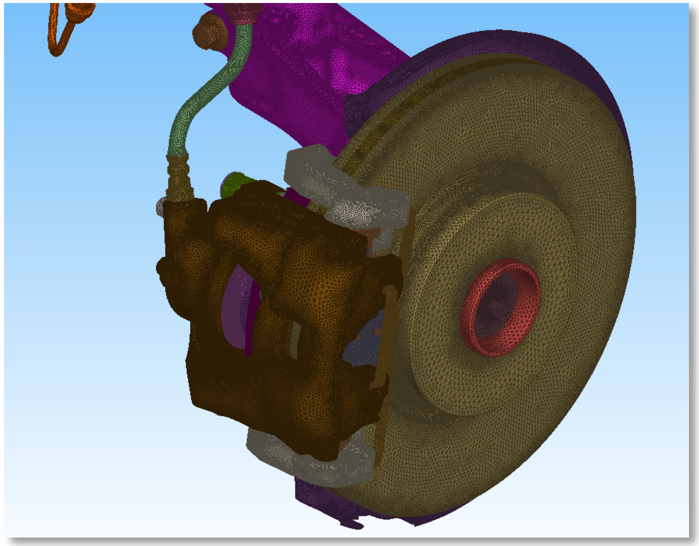
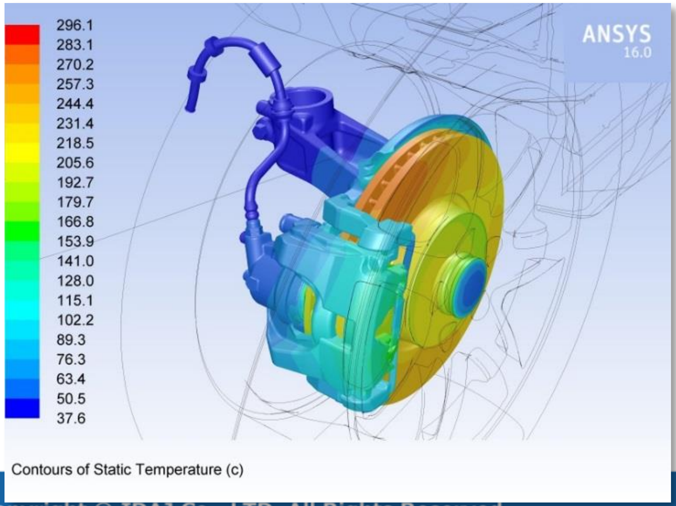
44.8
41.5
38.3
35.0
ANSYS
16.0
Contours of Static Temperature (c)

刹车系统



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283.1
270.2
257.3
244.4
231.4
218.5
205.6
192.7
179.7
166.8
153.9
141.0
128.0
115.1
102.2
89.3
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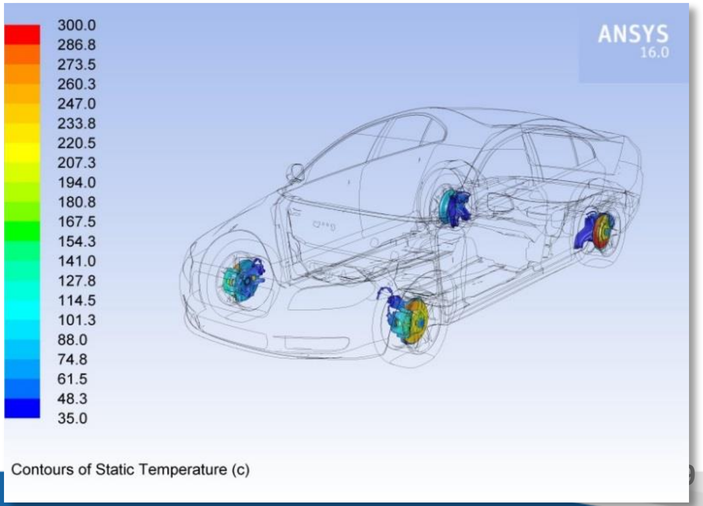
63.4
50.5
37.6
ANSYS
16.0
Contours of Static Temperature (c)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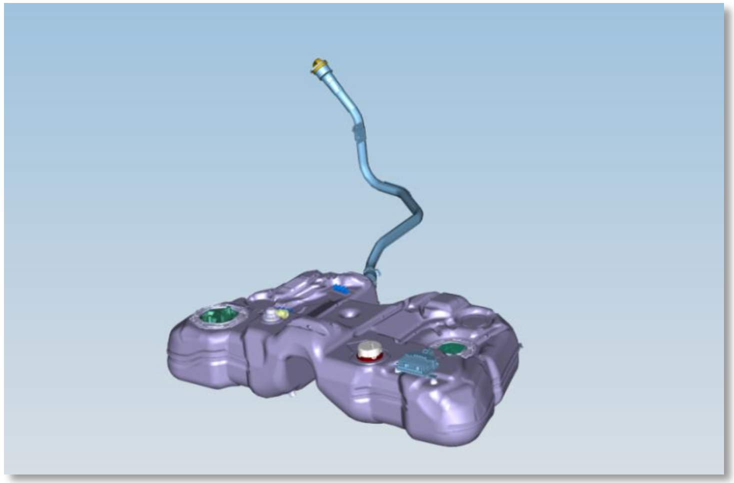
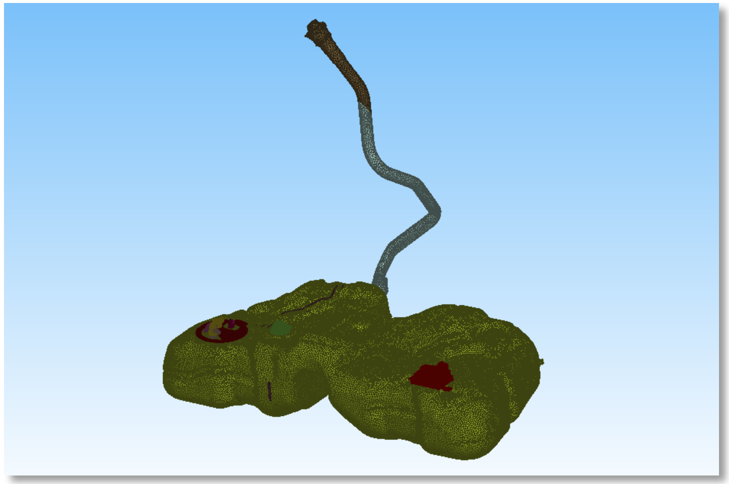
141.0
127.8
114.5
101.3
88.0
74.8
61.5
48.3
35.0
ANSYS
16.0
Contours of Static Temperature (c)

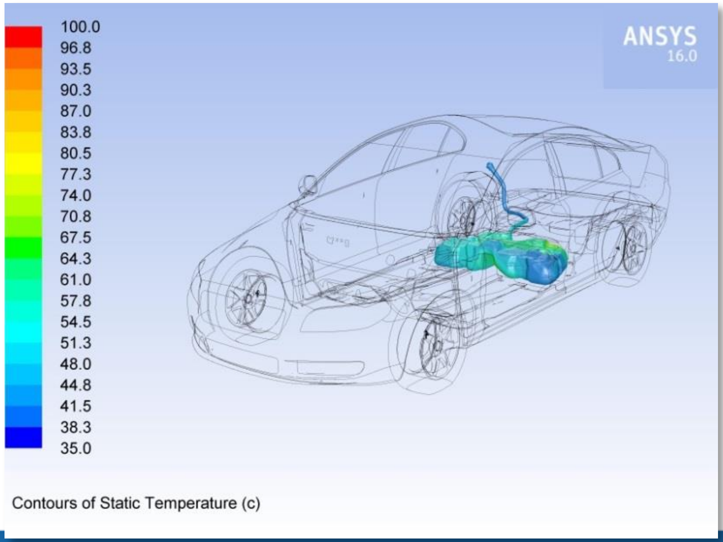
- 200多个固体区域
- 考虑了所有零件
- 冷却槽采用MRF模型 (2x40)
- 刹车盘转子有摩擦热源

油箱





- 考虑油箱内流体
- 简化内部部件
- 考虑油箱内的传热加速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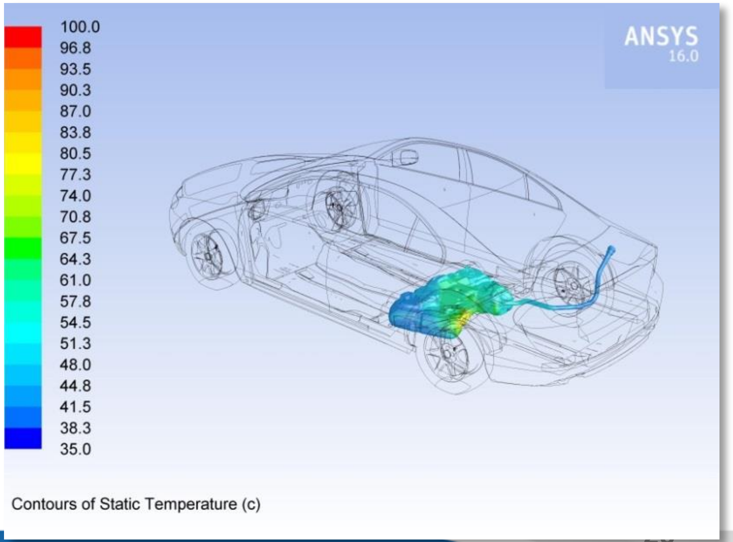
38.3
35.0
ANSYS
16.0

Contours of Static Temperature (c)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57.8
54.5
51.3
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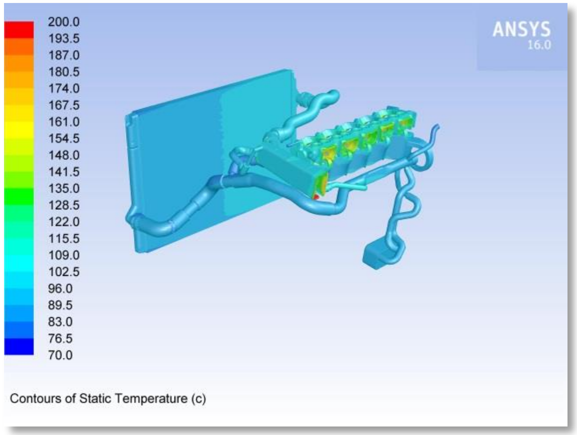
41.5
38.3
35.0
ANSYS
16.0

Contours of Static Temperature (c)

其它部件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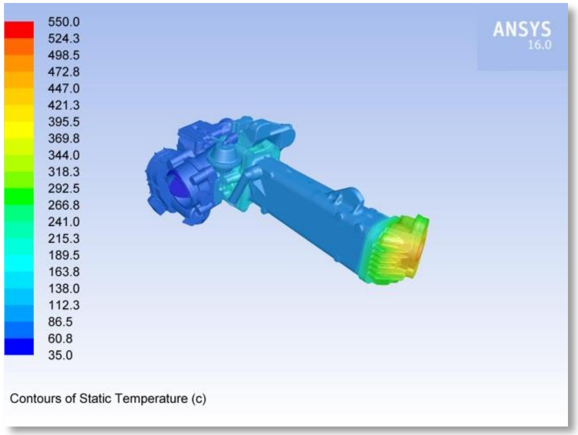
122.0
115.5
109.0
102.5
96.0
89.5
83.0
76.5
70.0
ANSYS
16.0
Contours of Static Temperature (c)

冷却液流动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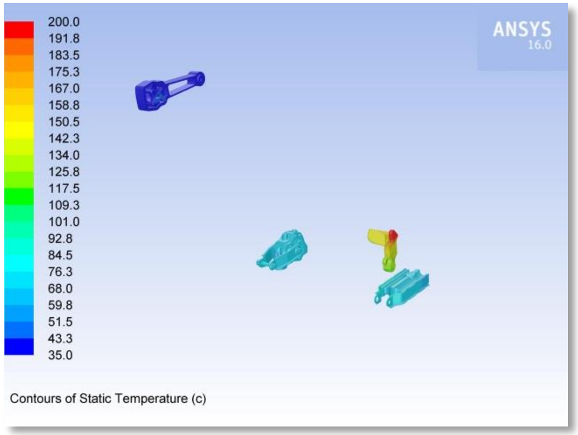
318.3
292.5
266.8
241.0
215.3
189.5
163.8
138.0
112.3
86.5
60.8
35.0
ANSYS
16.0
Contours of Static Temperature (c)

EGR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101.0
92.8
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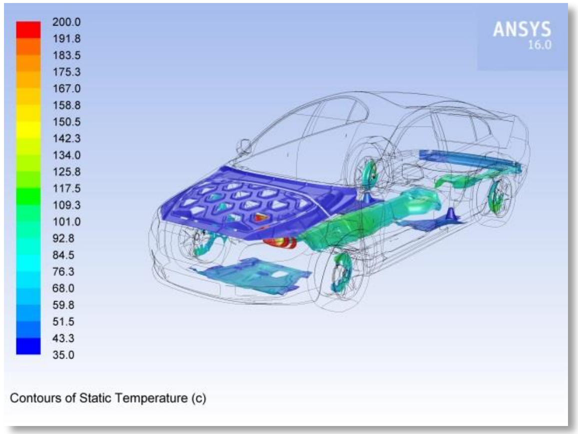
76.3
68.0
59.8
51.5
43.3
35.0
ANSYS
16.0
Contours of Static Temperature (c)

悬置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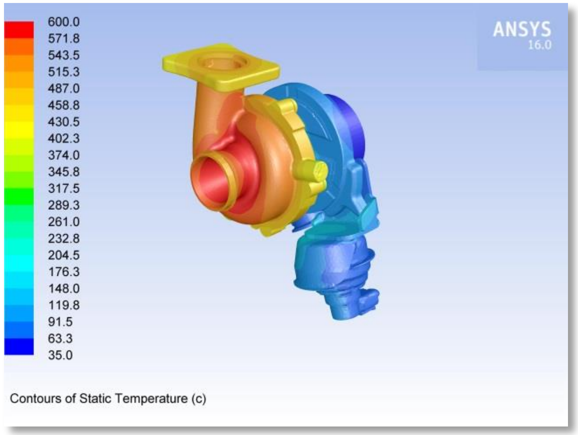
101.0
92.8
84.5
76.3
68.0
59.8
51.5
43.3
35.0
ANSYS
16.0
Contours of Static Temperature (c)

盖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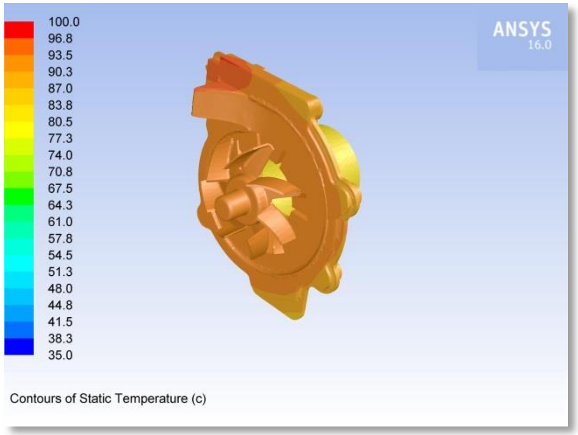
261.0
232.8
204.5
176.3
148.0
119.8
91.5
63.3
35.0
ANSYS
16.0
Contours of Static Temperature (c)

涡轮增压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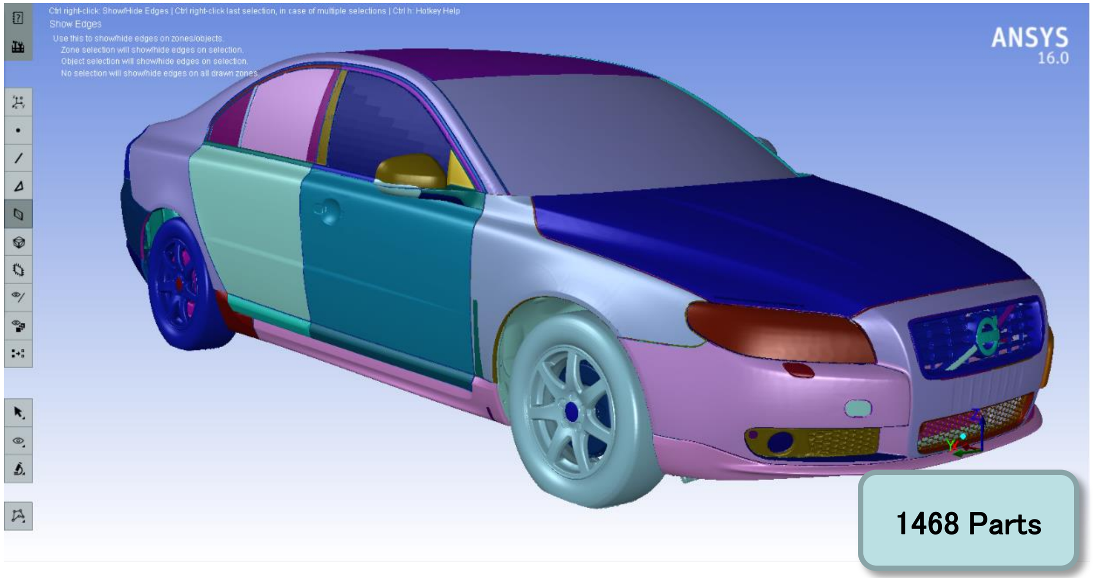
61.0
57.8
54.5
51.3
48.0
44.8
41.5
38.3
35.0
ANSYS
16.0
Contours of Static Temperature (c)

水泵

FLUENT MESHING自动化网格生成

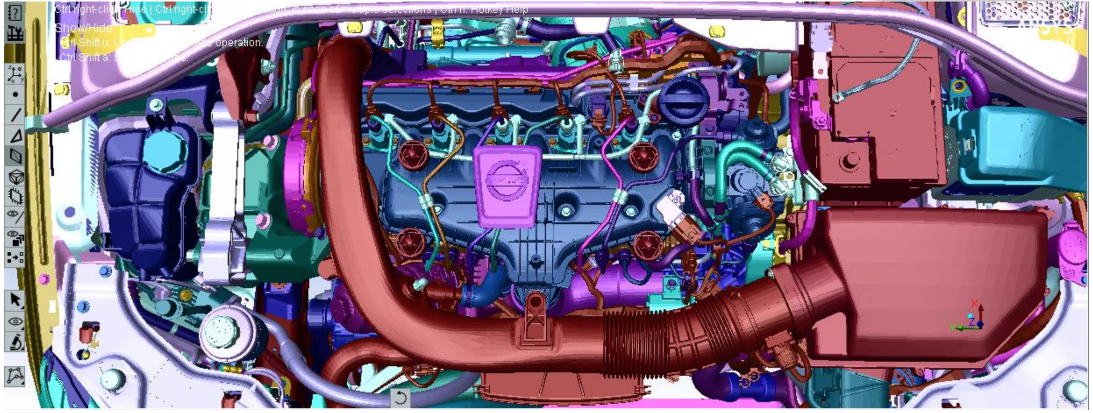


Ctrl right-click: Show/Hide Edges | Ctrl right-click last selection, in case of multiple selections | Ctrl h: Hotkey Help

Show Edges

Use this to show/hide edges on zones/objects.
Zone selection will show/hide edges on selection.
Object selection will show/hide edges on selection.
No selection will show/hide edges on all drawn zones.

1468 Parts



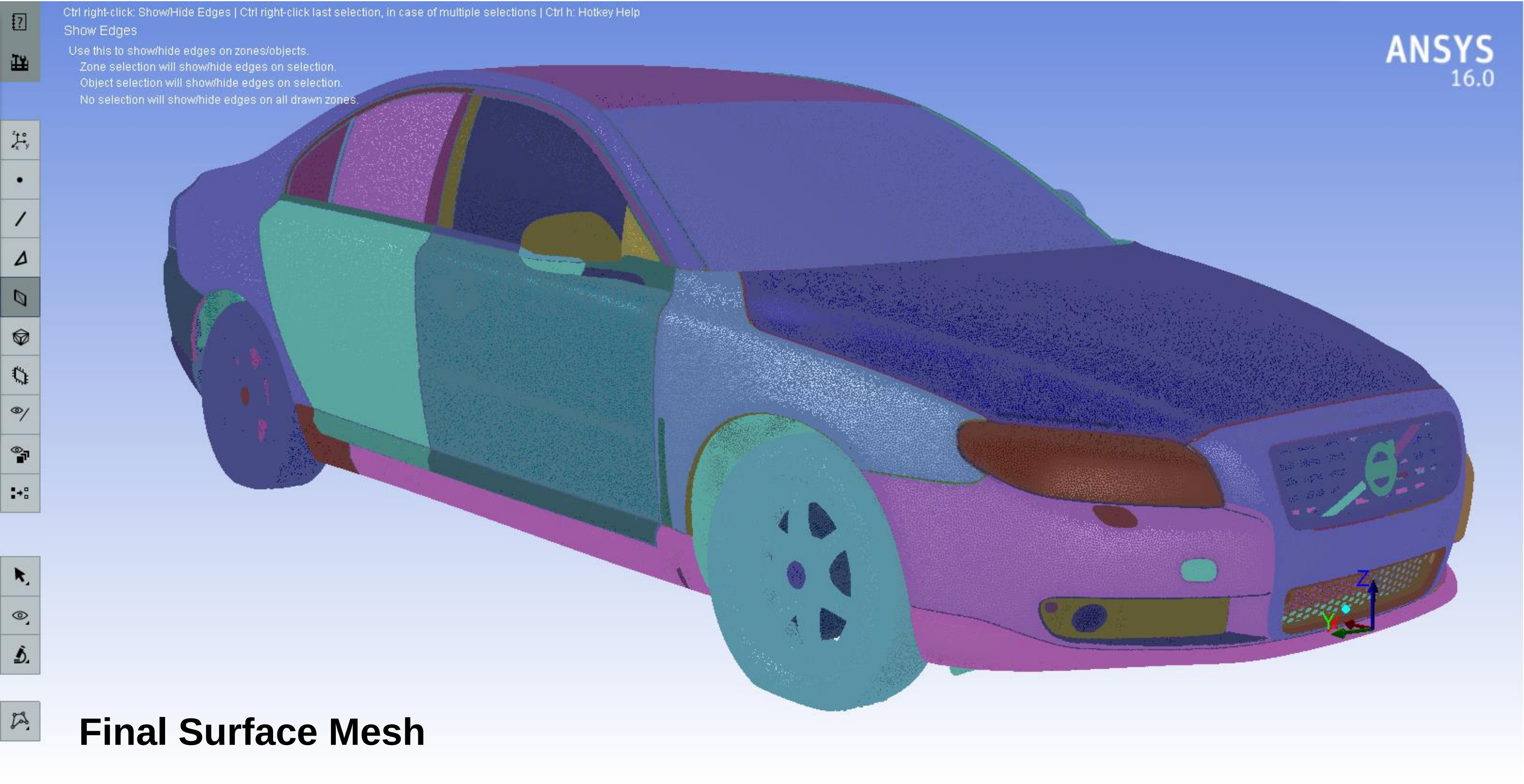
Geom (JT Faceting)

- Import Geometry
- Define/Modify Objects
- Define / Modify Features
- Define Material Points
- Apply Prism Settings
- Assign Sizes (Size Functions)
- Edit User Input
- Run Script

FLUENT MESHING自动化网格生成

Final Surface Mesh

Produced Acceptable Mesh in 1st Trial!



Ctrl right-click: Show/Hide Edges | Ctrl right-click last selection, in case of multiple selections | Ctrl h: Hotkey Help

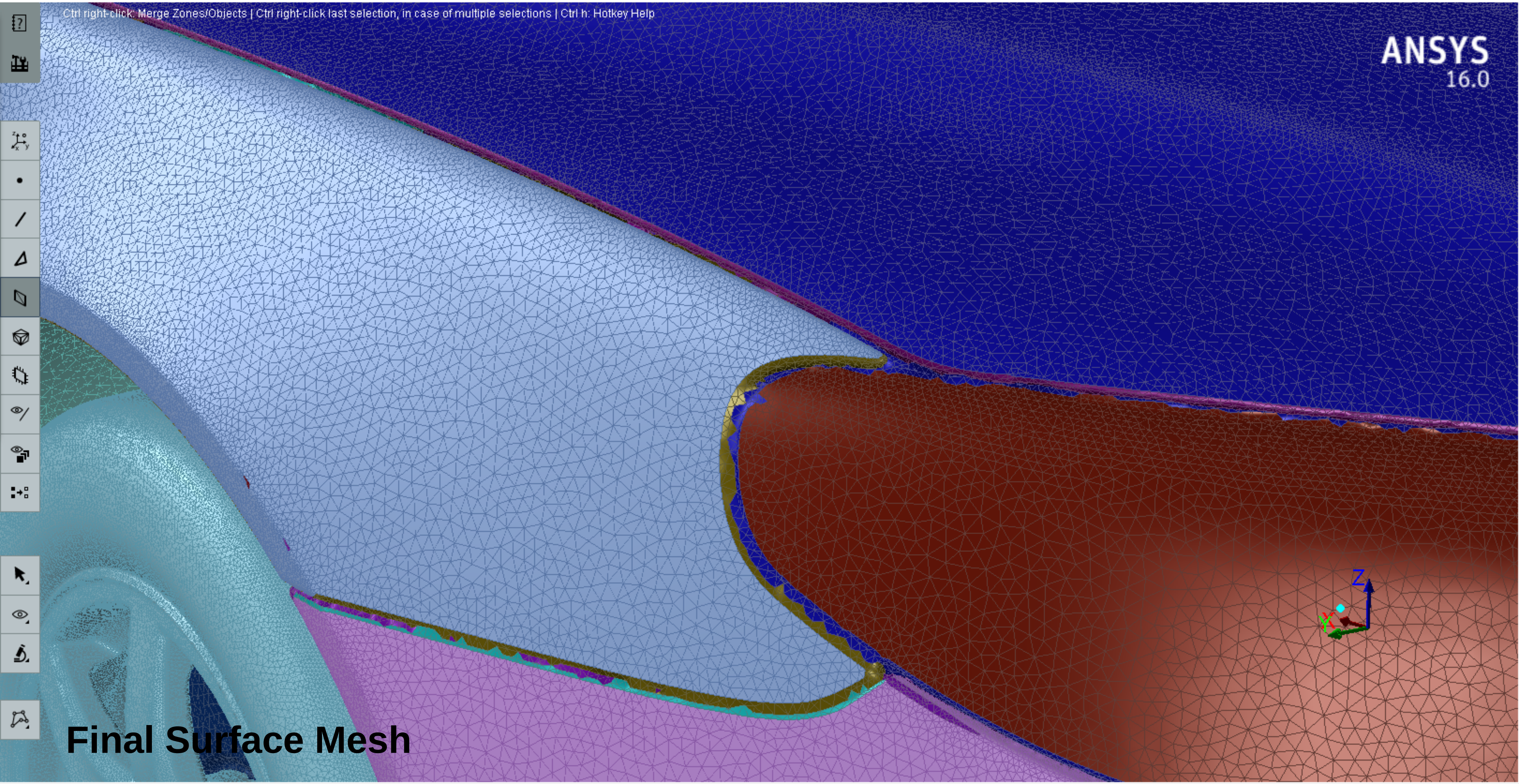
Show Edges

Use this to show/hide edges on zones/objects.
Zone selection will show/hide edges on selection.
Object selection will show/hide edges on selection.
No selection will show/hide edges on all drawn zones.

Final Surface Mesh

FLUENT MESHING自动化网格生成

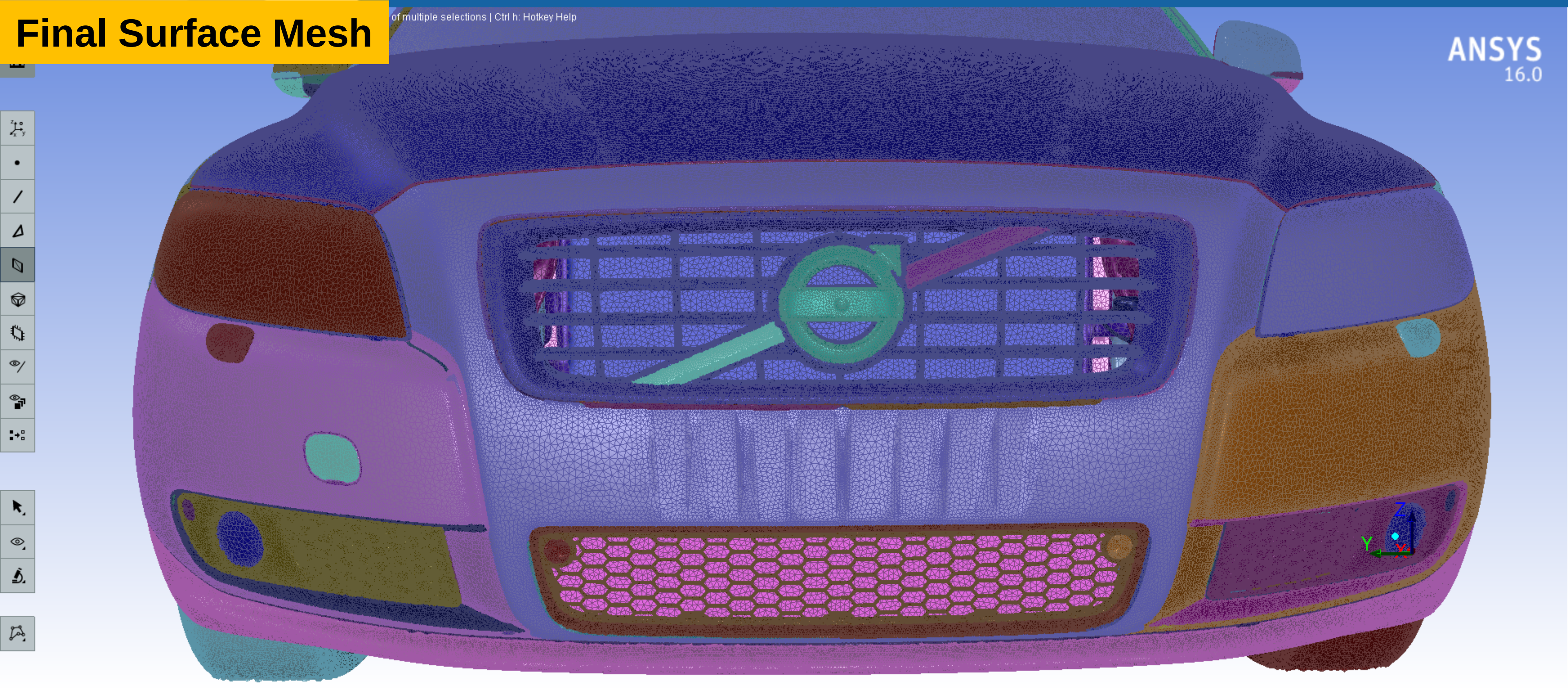
Final Surface Mesh



Ctrl right-click: Merge Zones/Objects | Ctrl right-click last selection, in case of multiple selections | Ctrl h: Hotkey Help

Final Surface Mesh

Final Surface Mesh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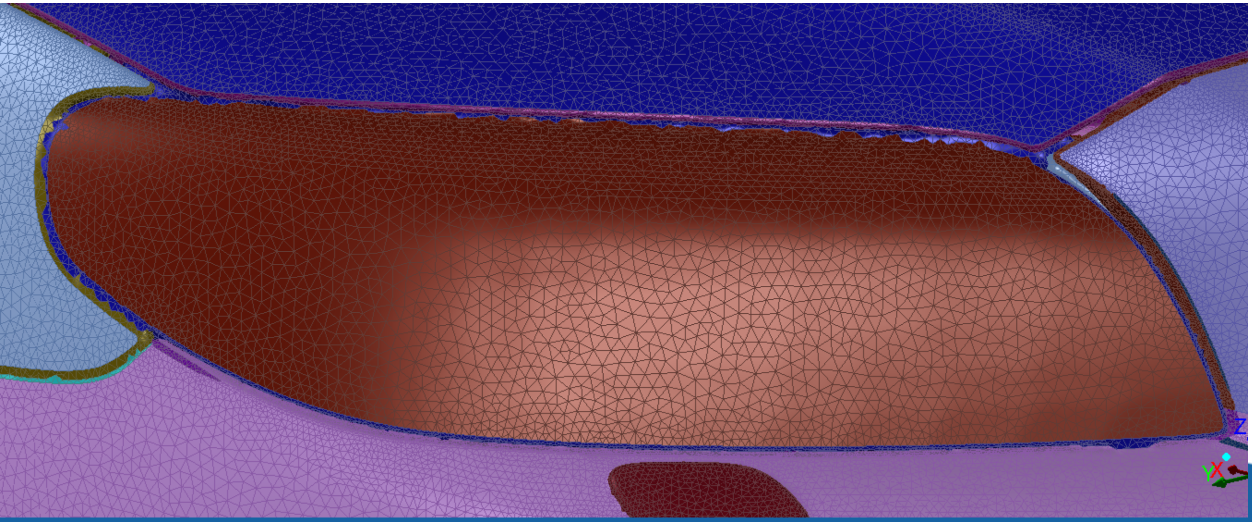
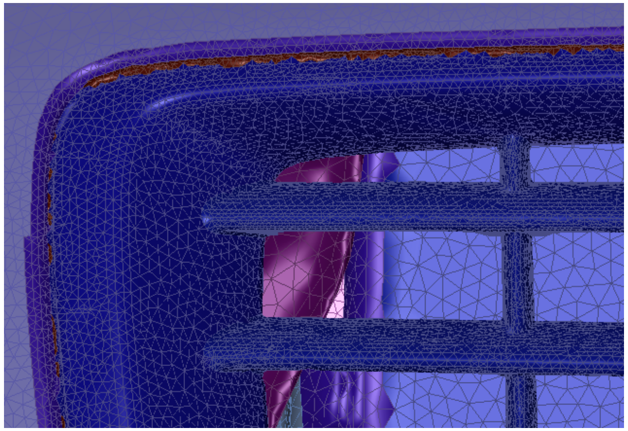
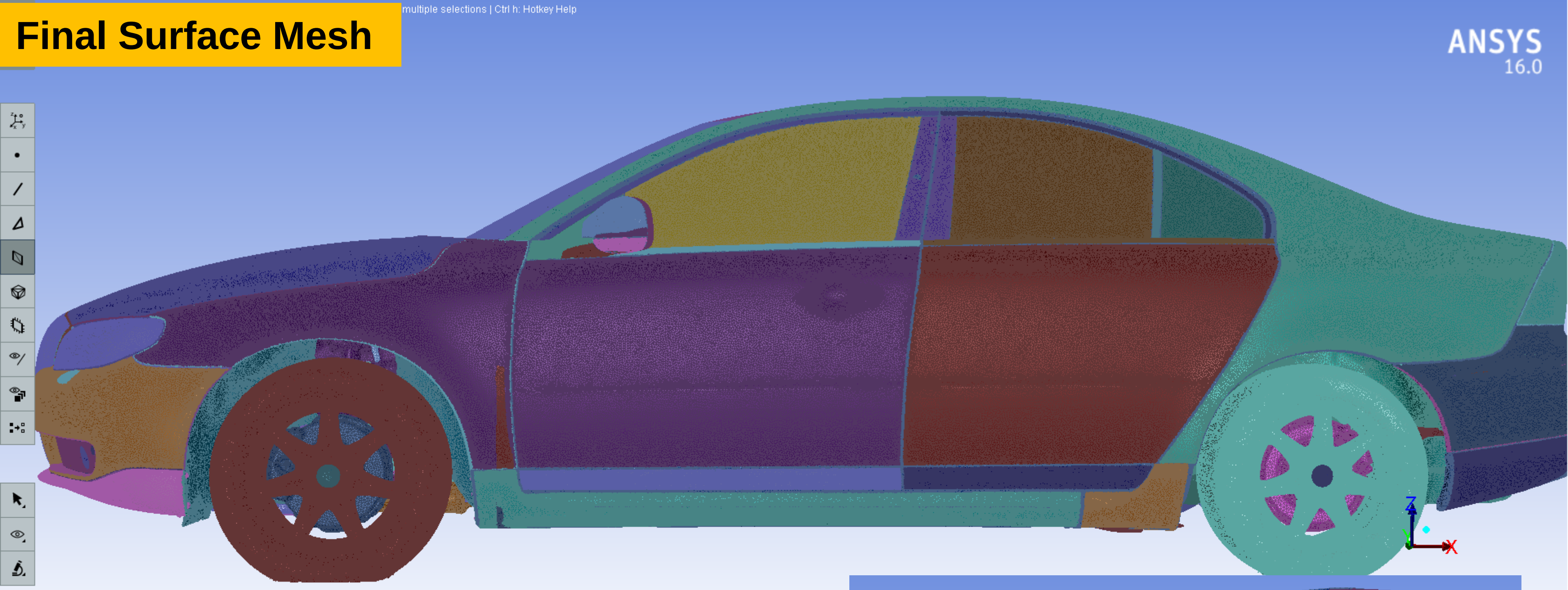
ANSYS
16.0
Z
Y
X





Final Surface Mesh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ANSYS
16.0
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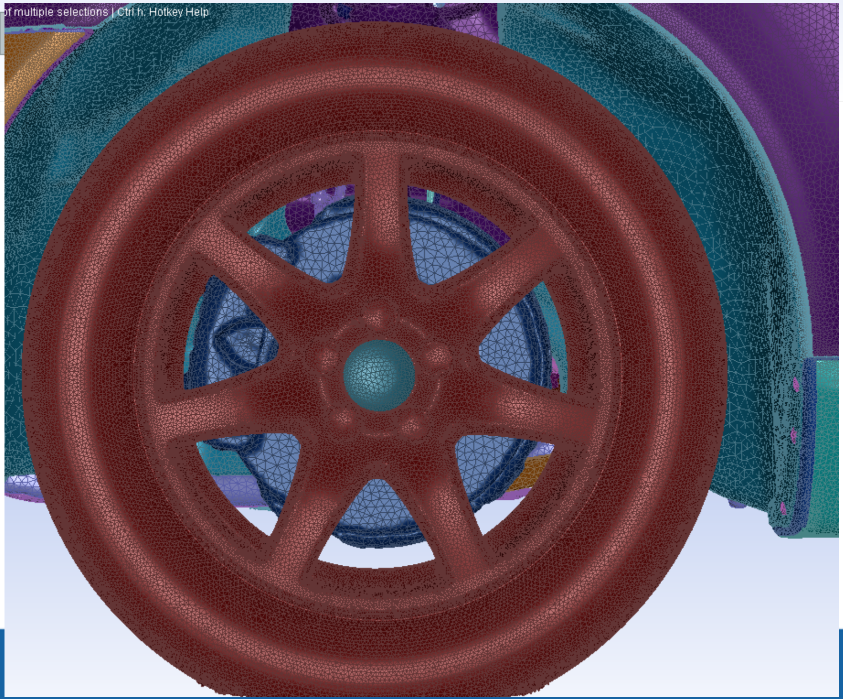
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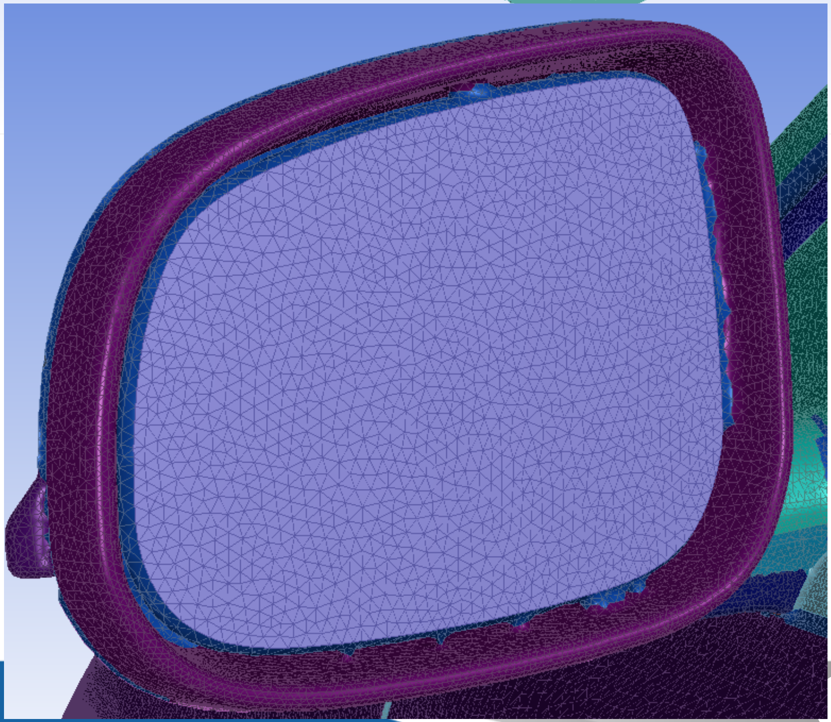
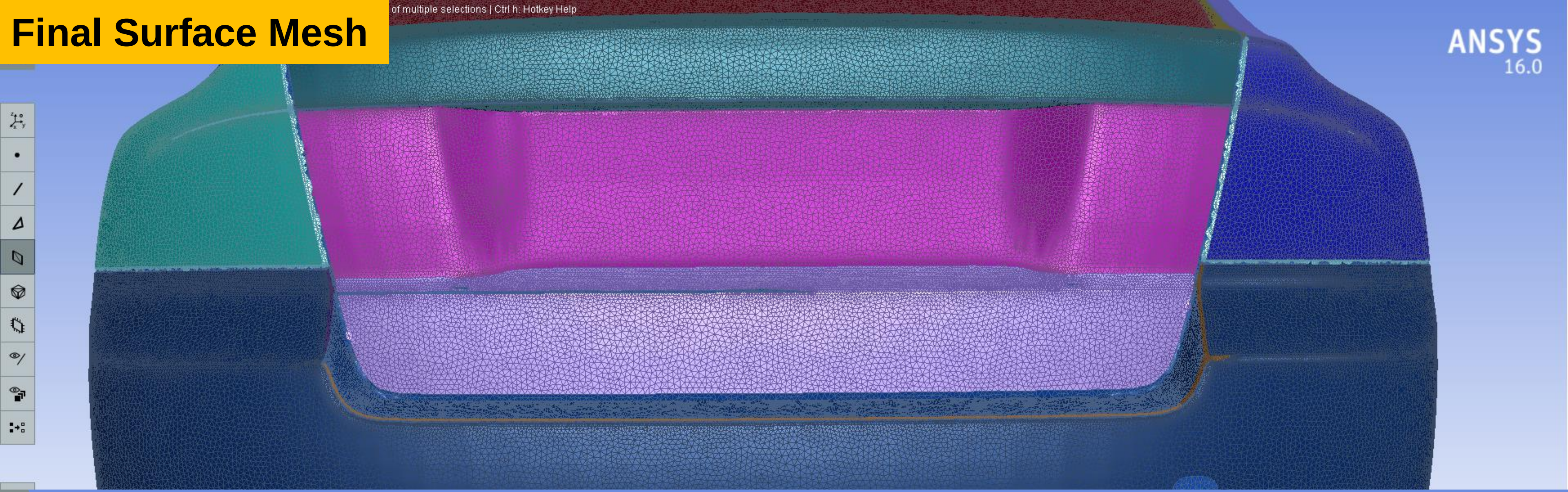


Final Surface Mesh



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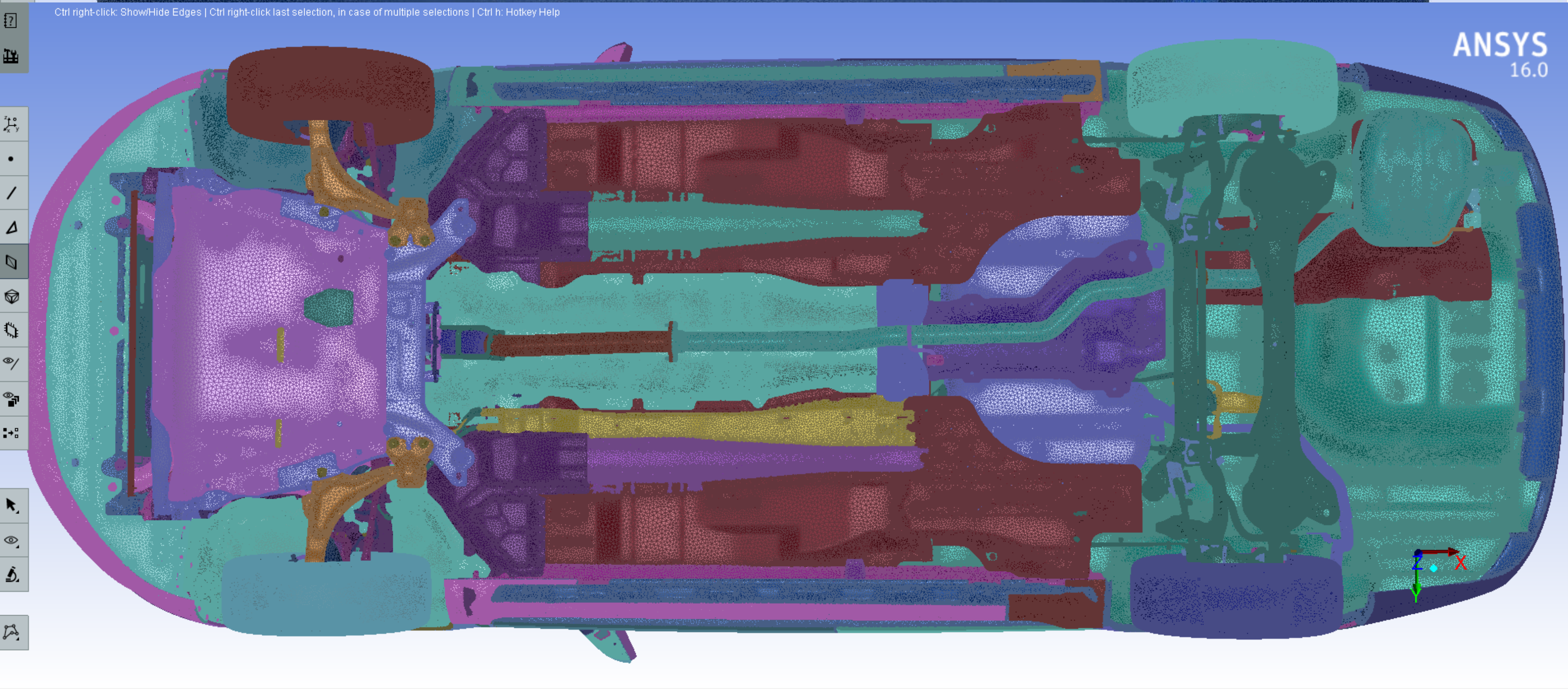

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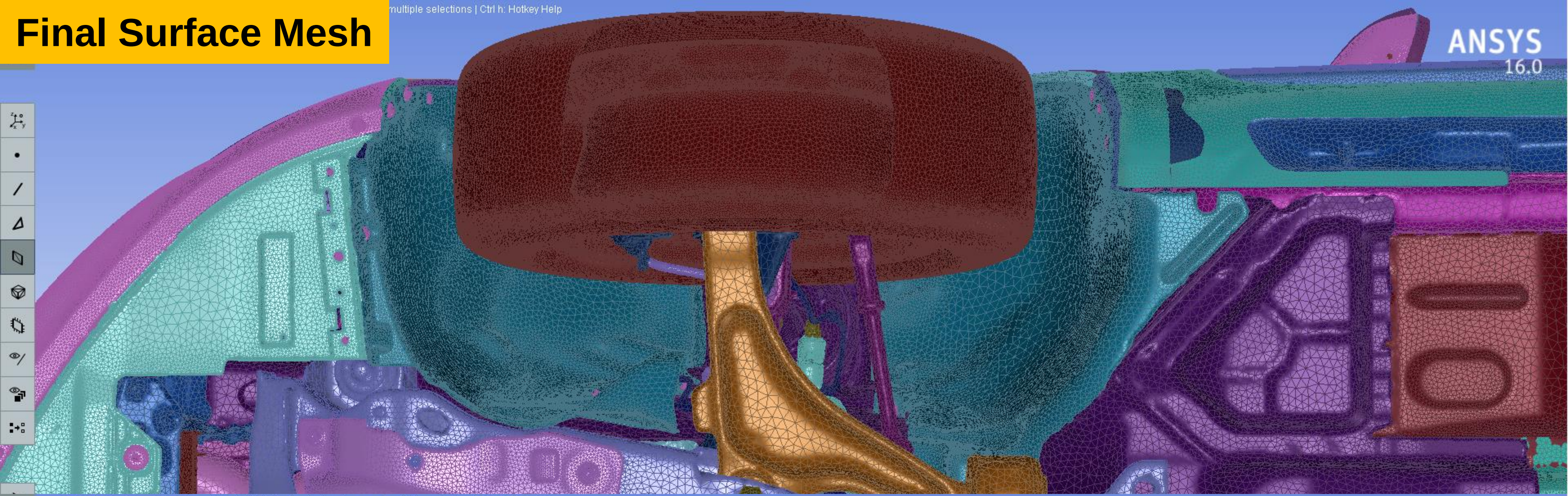
ANSYS
16.0
Z
X
Y

Final Surface Mesh



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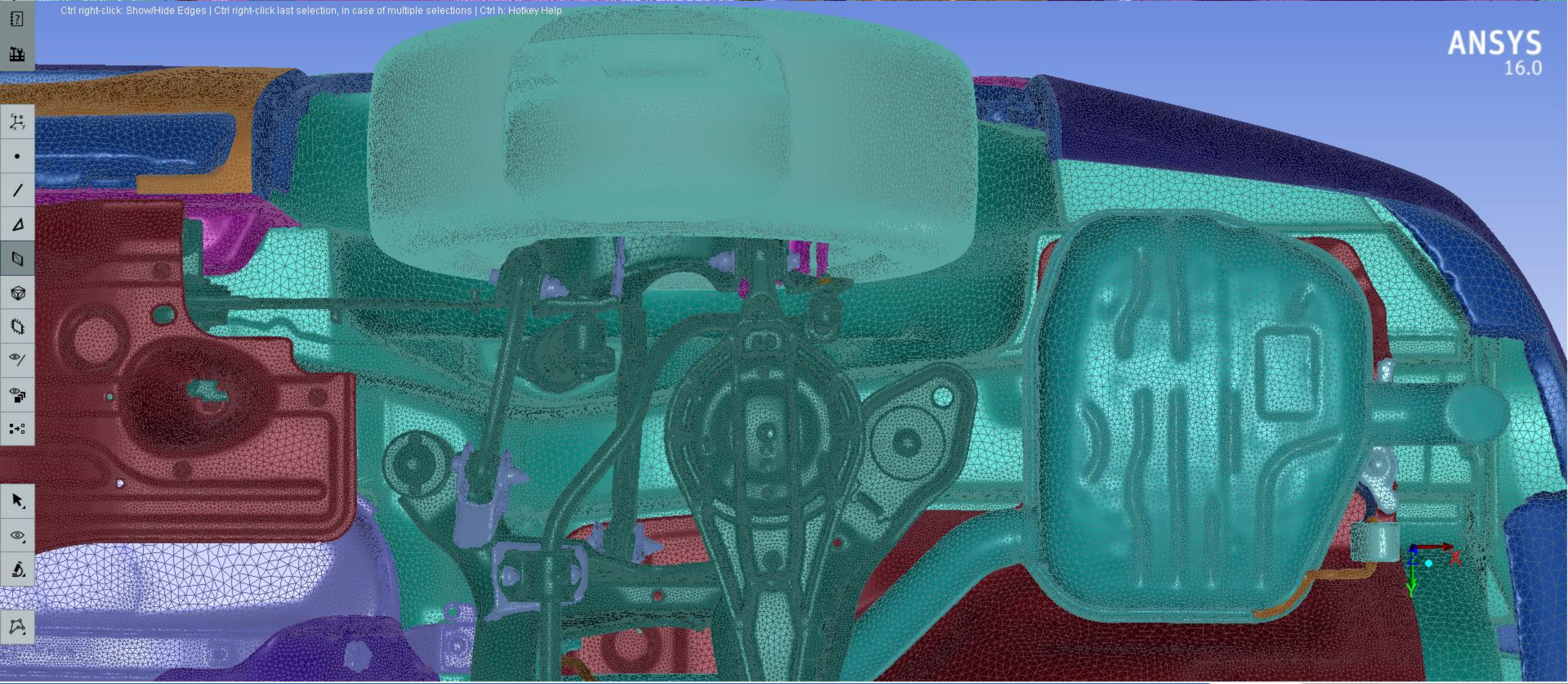

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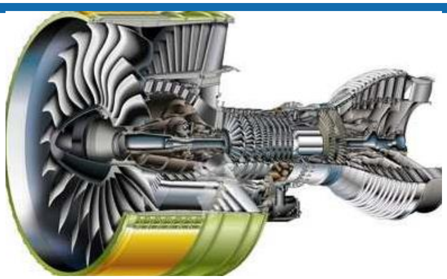
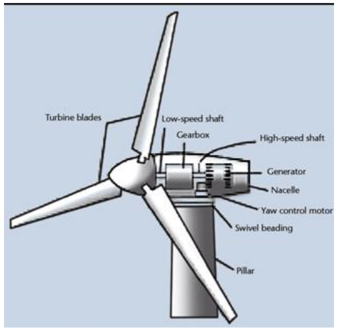
ANSYS
16.0
Z
X

网格效率




Turbine blades
Low-speed shaft
Gearbox
High-speed shaft
Generator
Nacelle
Yaw control motor
Swivel beading
Pillar

Application	Objective	Cell Count	Peak RAM (GB)	Effort
Loader Machine	FEAF	28 million tet (2 layers)		1 day
Small Truck	FEAF	46 million tet (2 layers)		1 day
Oven	Flow Rate	55 million tet (3 layers)		1.5 days
1/8th Scale Truck and Trailer	External Aero + FEA	40 million hexcore	24	1 day
Full-Scale Truck and Trailer	Aero	95 million hexcore (3 layers)	??	1 day
Wind-Turbine	Aero	46 million (10 layers)	21	0.5 day
Combustor (1 sector)	Aero	54 million (6 layers)	24	0.5 day
Nacelle	Aero	45 million (4 layers)	20	1 day
Oil Refinery	Aero	40 million (10 prism layers)	19.8	0.5 day
Passenger Car	Aero	80 million (2 layers) → 170 million (21 max layers – all adapted)		2-3 days
Volvo S80	Aero	95 million (2 layers)		2-3 days
Motorcycle	UTM	10 million (2 layers)		< 0.5 day

进一步工作

集成、统一的多学科优化模型

方法可以用于流固耦合分析

- 气动弹性
- 热-结构-寿命分析(耦合系统分析工具)

集成缸内燃烧分析

瞬态分析

- 气动噪声
- 热冲击
- 驾驶循环
- 润滑系统
- 考虑热效应的溅水/涉水

排气进入乘员舱

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