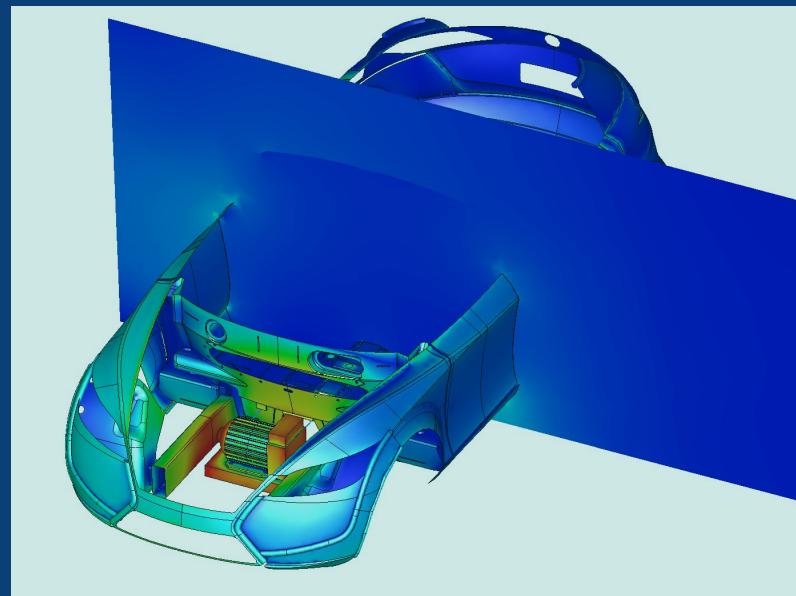




电传动系统的电磁仿真



新一代汽车

车身



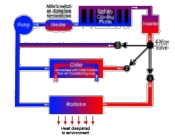
- High attention on weight management (light material) to counter balance battery

电气



- Dual tension cable technology in vehicle (high voltage & 12V)

HVA



- Clean cooling (no contact with engine emission, oil, gas)
- No front grid required

电池



- 800 kg batteries = 92 kWh energy (vs 75 liters of gasoline= 750 kWh of energy)
- Filling time is several hours (vs 3 minutes for traditional tank)

底盘



- Simplified dynamics with very low center of gravity
- High modularization capabilities (packaging simplified)

电机



- 89 to 95% of efficiency (vs 25% for ICE)
- Immediate torque (no transmission required)

概述

电磁仿真

电机设计和优化

电传动系统中的传导发射

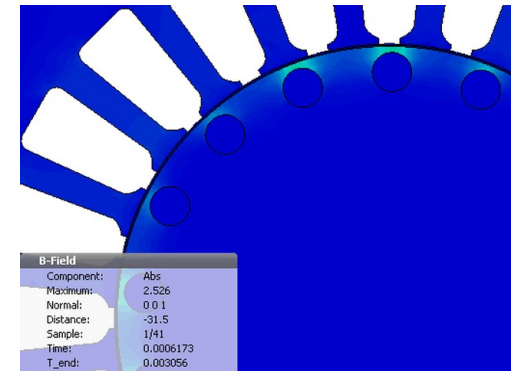
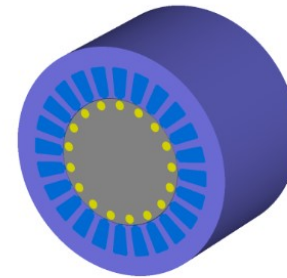
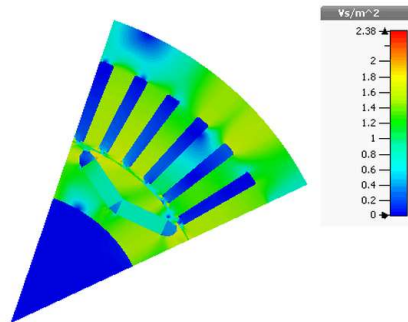
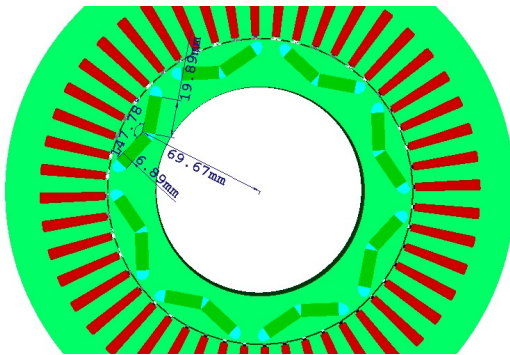
整车共模分析

人体安全

总结

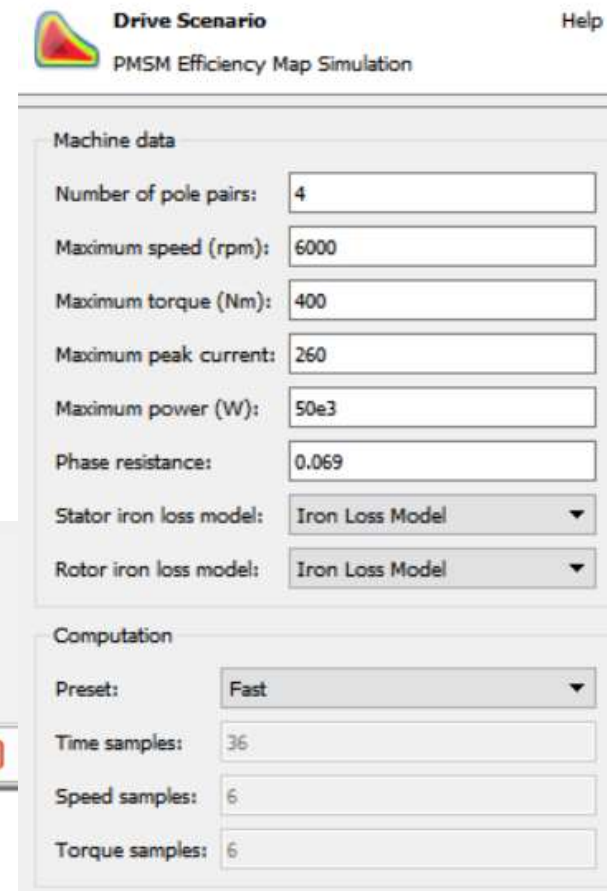
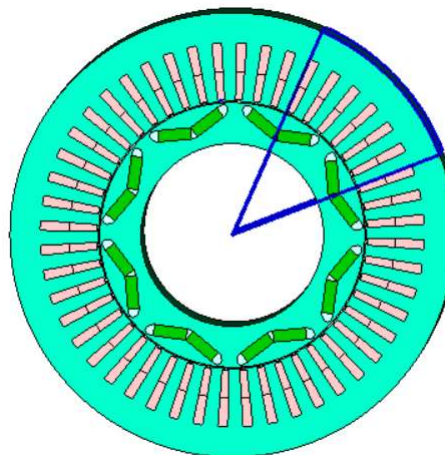
电机设计与优化

Permanent Magnet Synchronous Motor Optimization 4-Pole, 400Hz Induction Motor



电机

永磁同步电机的设计与优化



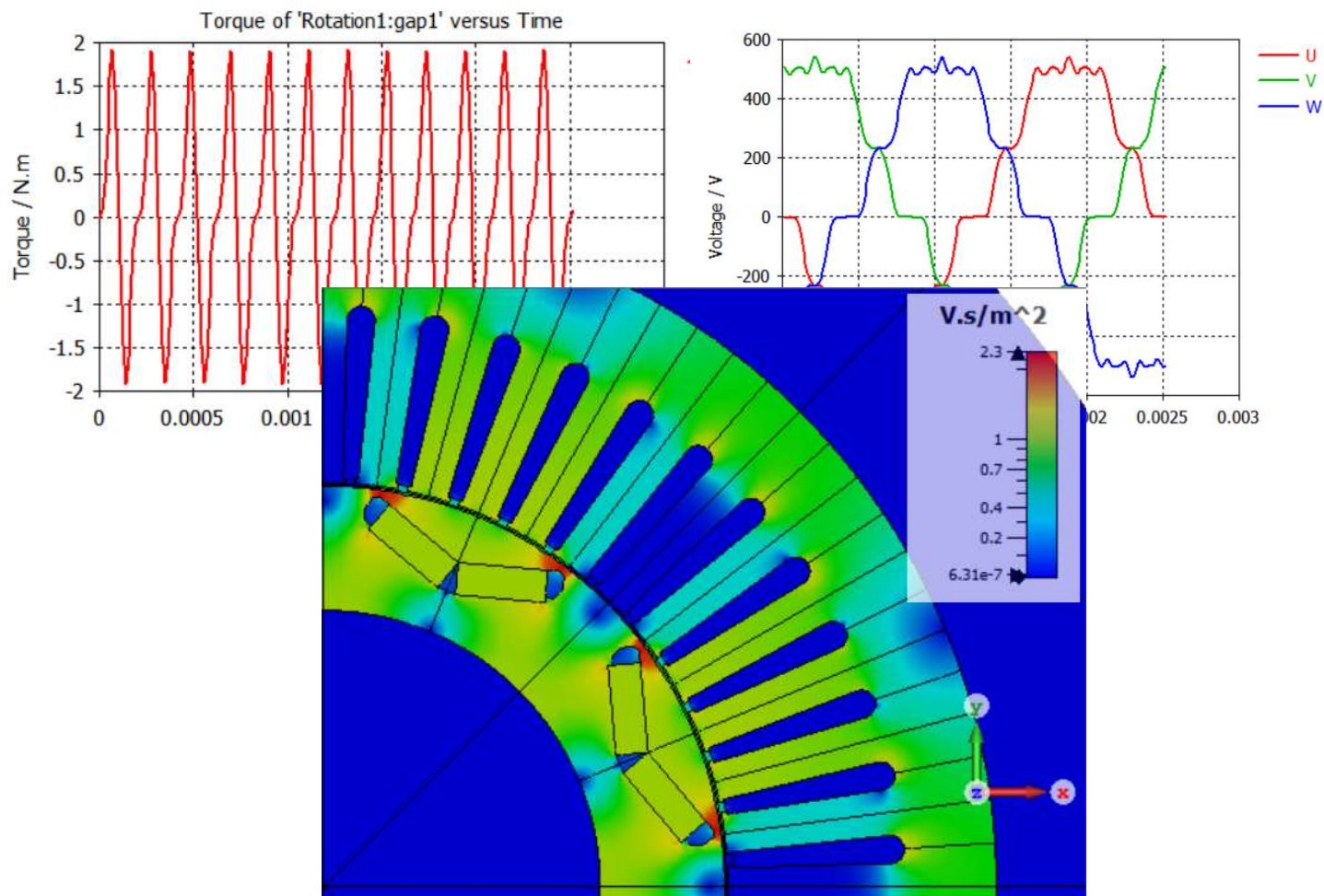
电机

υ 空载/零电流

ω 齿槽转矩

ω 反电动势

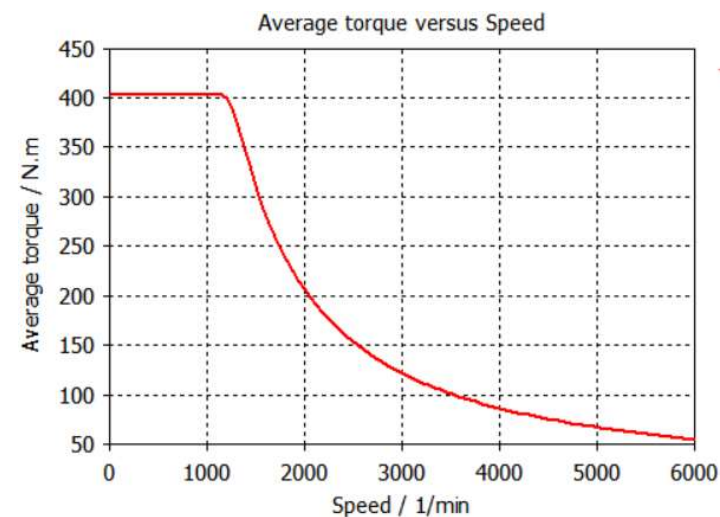
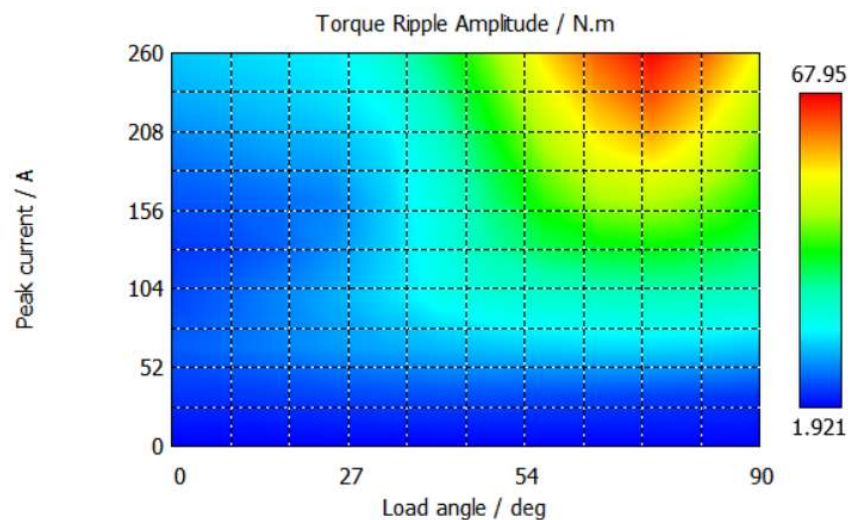
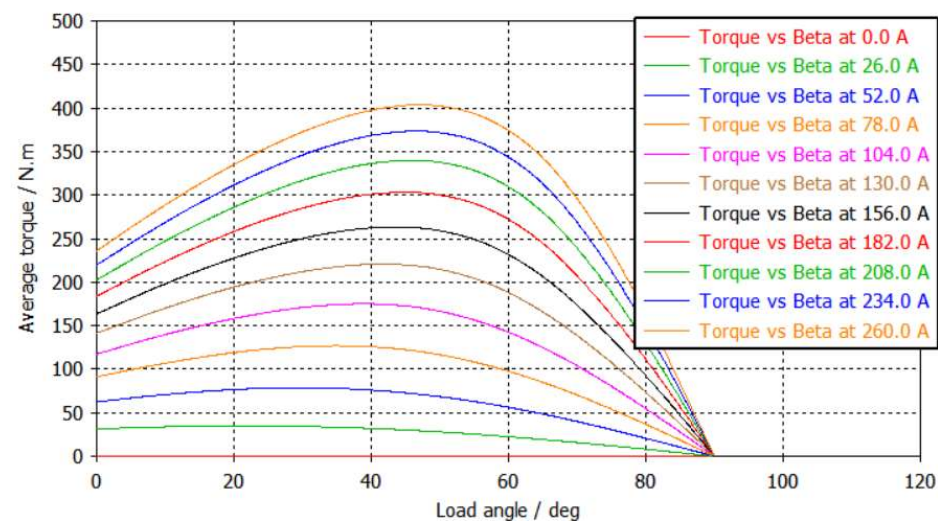
ω 磁通量密度



电机

负载操作

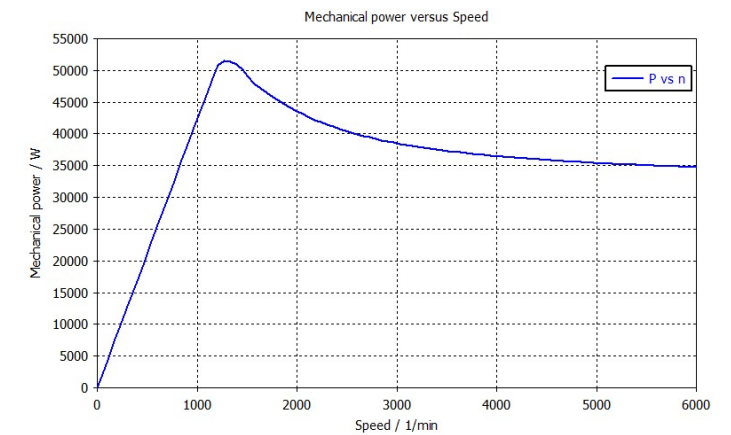
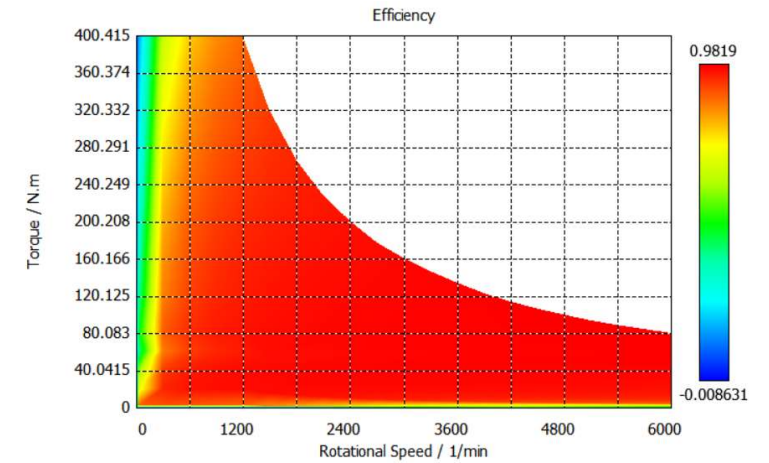
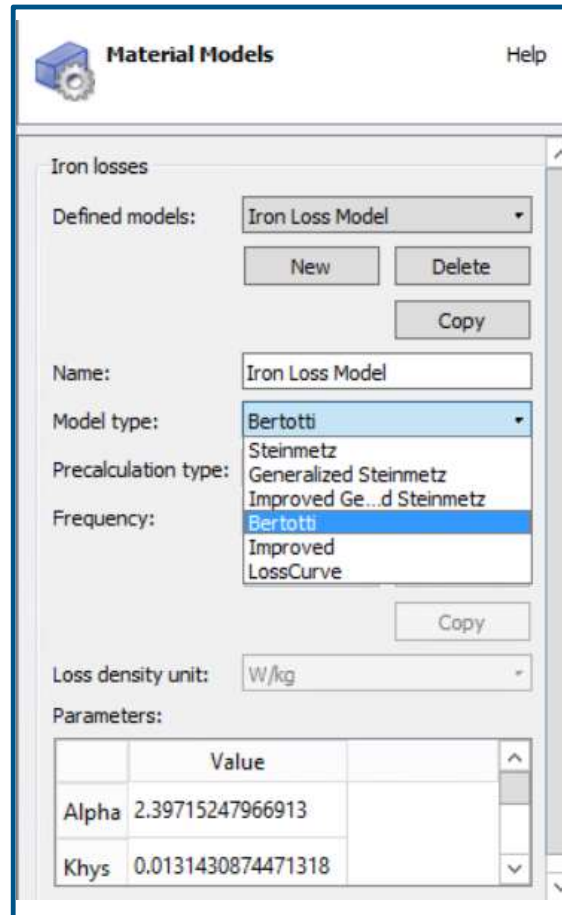
- 扭矩与电流
- 扭矩与速度曲线
- 扭矩波动



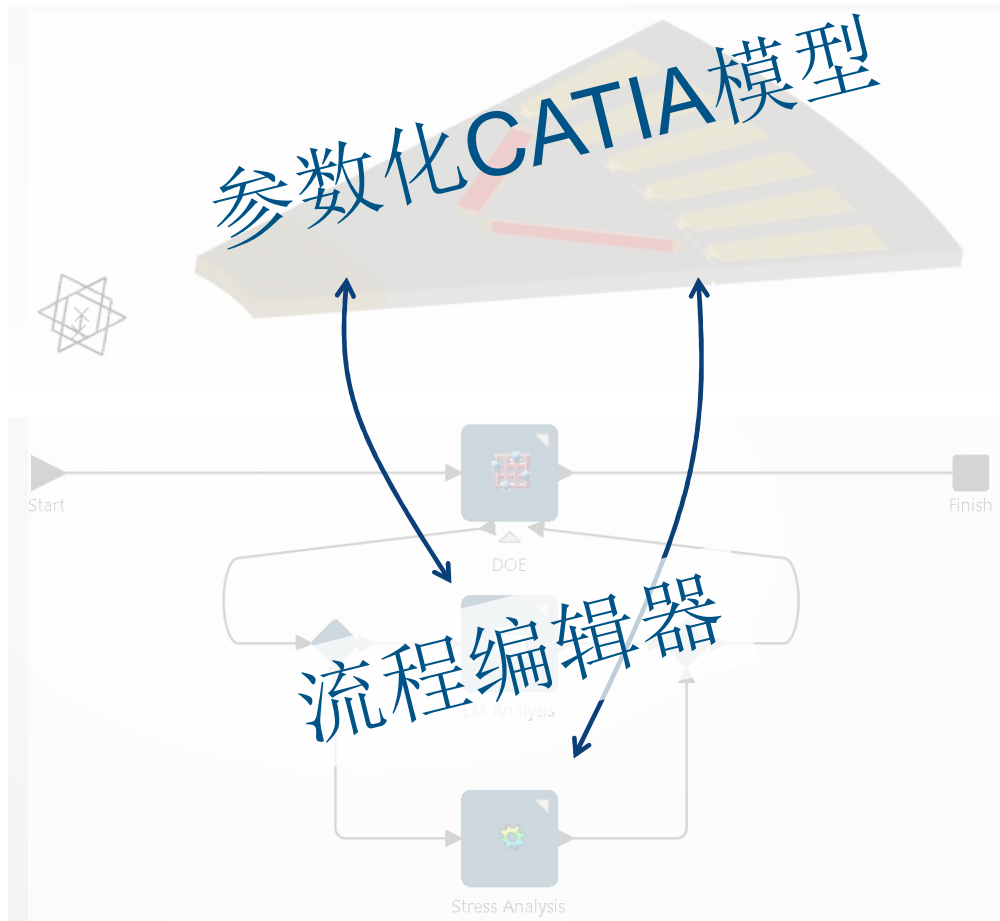
电机

效率

- ⌚ 非线性材料
- ⌚ 铁损耗
- ⌚ 效率图



组合优化-多物理场

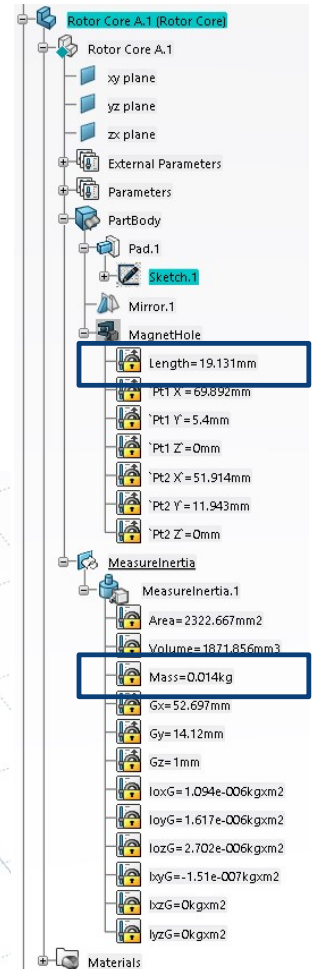
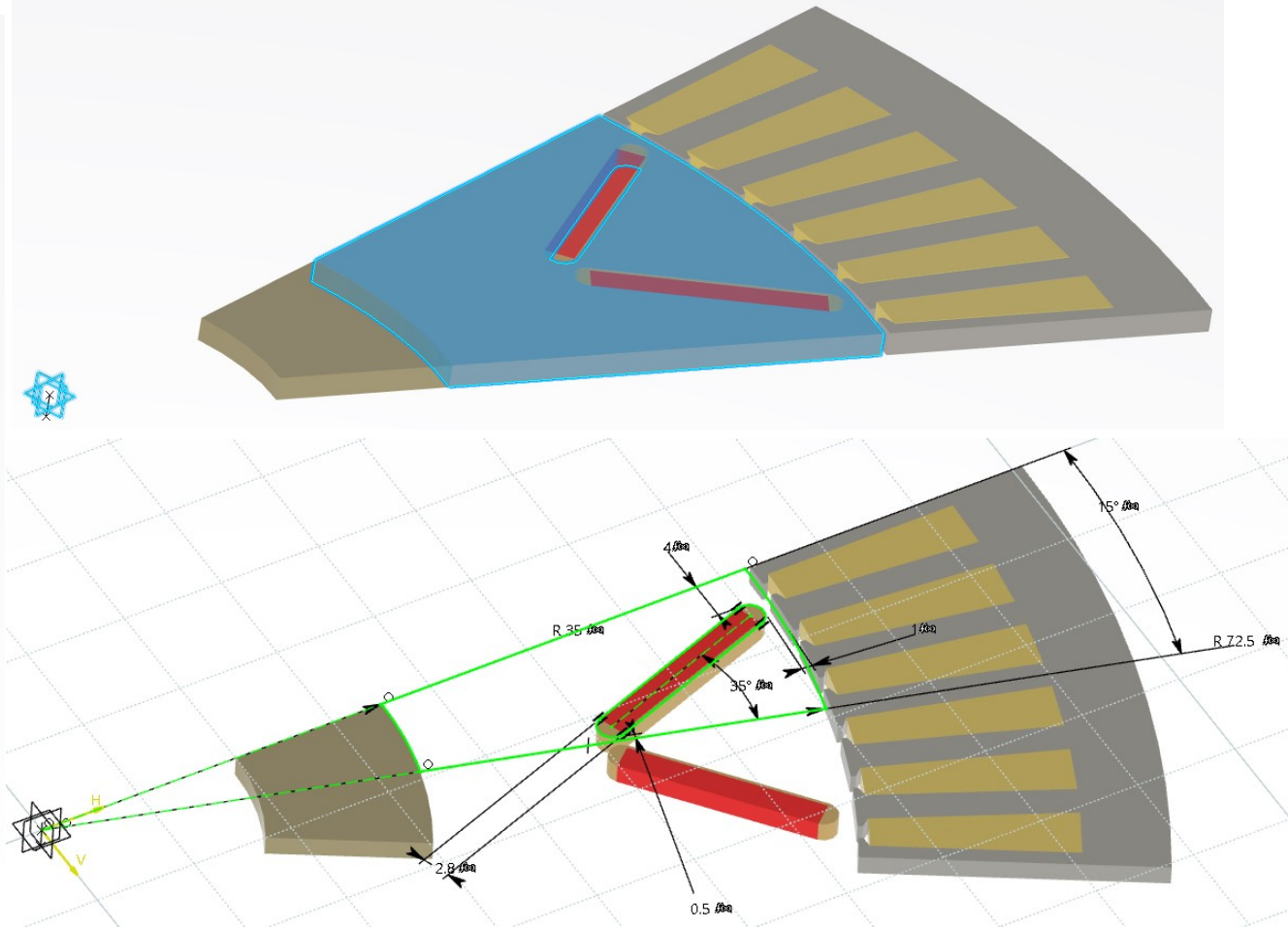
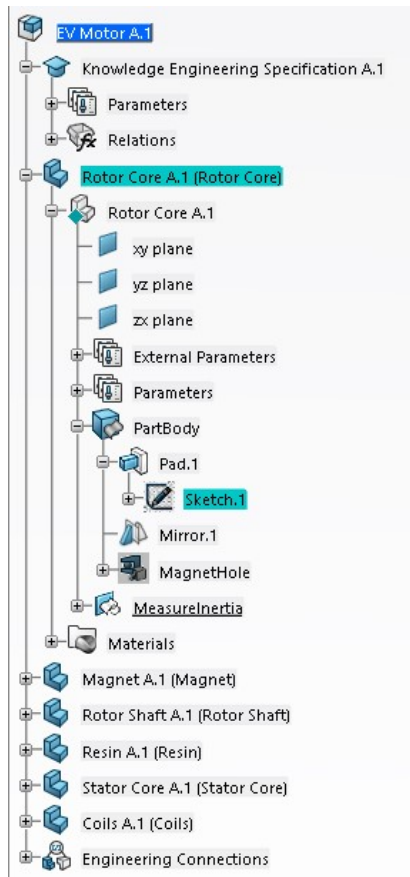


 SIMULIA

- 电磁KPI(CST Studio Suite Power ' by)
 - 最大扭矩
 - 最大化功率
 - 最小化扭矩波动
 - 尽量减少损失
 - 在故障条件下，尽量减少PM的退磁
- 应力KPI(3DX/Abaqus上的Physics Simulation应用程序)
 - 给定阈值下的离心载荷(20000 rpm)和/或热载荷的 Von mises 应力值

 DASSAULT SYSTEMES

创建结构→参数化



EM Analysis : 电磁场景

CST PowerBy Execution Editor

EM Analysis

Pre-Execute | Pre CST Param | Execute | Post CST Param | Post-Execute

Content: EV Motor CST A.1

Mapping direction: FROM 3DX Parameters TO activity

EV Motor CST A.1

- EV Motor A.1 (EV Motor.CATProduct.Instance)
 - Rotor Core A.1 (Rotor Core)
 - Magnet A.1 (Magnet)
 - Rotor Shaft A.1 (Rotor Shaft)
 - Resin A.1 (Resin)
 - Stator Core A.1 (Stator Core)
 - Coils A.1 (Coils)
 - Knowledge Engineering Specification A.1
 - Finite Element Model A.1
 - EV Motor CST [file tree] A.1

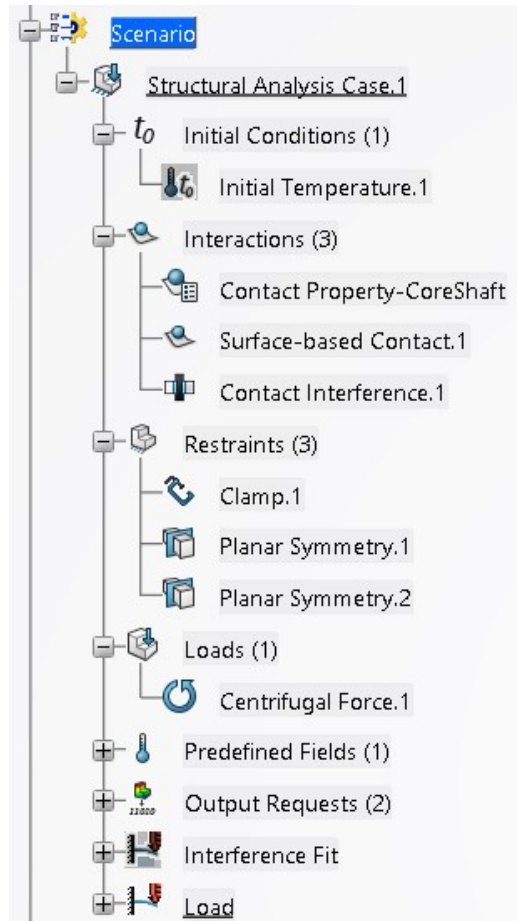
Filters

☒ 3DX parameters ☒ Publications

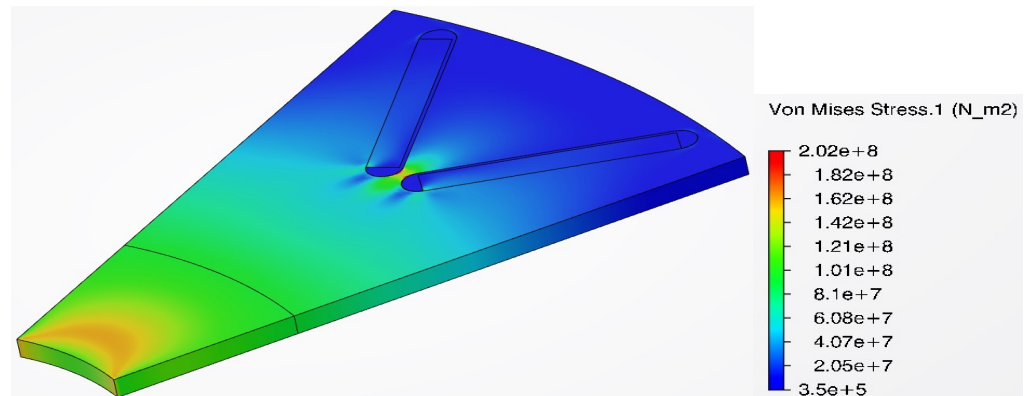
Name: Type: All

Select	Name	Type	Value	Activity Parameter
☒	EV Motor A.1\Knowledge...ation A.1\Motor_Volume	Real	5.127...06mm ³	Motor_Volume
☒	EV Motor A.1\Knowledge ...lication A.1\Max_Current	Real	152.803A	MAX_COIL_CURRENT
☒	EV Motor A.1\Knowledge ...ification A.1\Gap_Radius	Real	72.75mm	GAP_RADIUS
☒	EV Motor A.1\Knowledge ...ion A.1\Coil_Resistance	Real	0.005...543Ohm	COIL_RESISTANCE
☒	EV Motor A.1\Knowledge...fication A.1\Motor_Mass	Real	33.8257kg	Motor_Mass
☒	EV Motor A.1\Knowled...A.1\Motor_Magnet_Mass	Real	1.35909kg	Motor_Mass_Magnets
☒	EV Motor A.1\Knowledge...A.1\Stator_Outer_Radius	Real	101mm	STATOR_OUTER_RADIUS

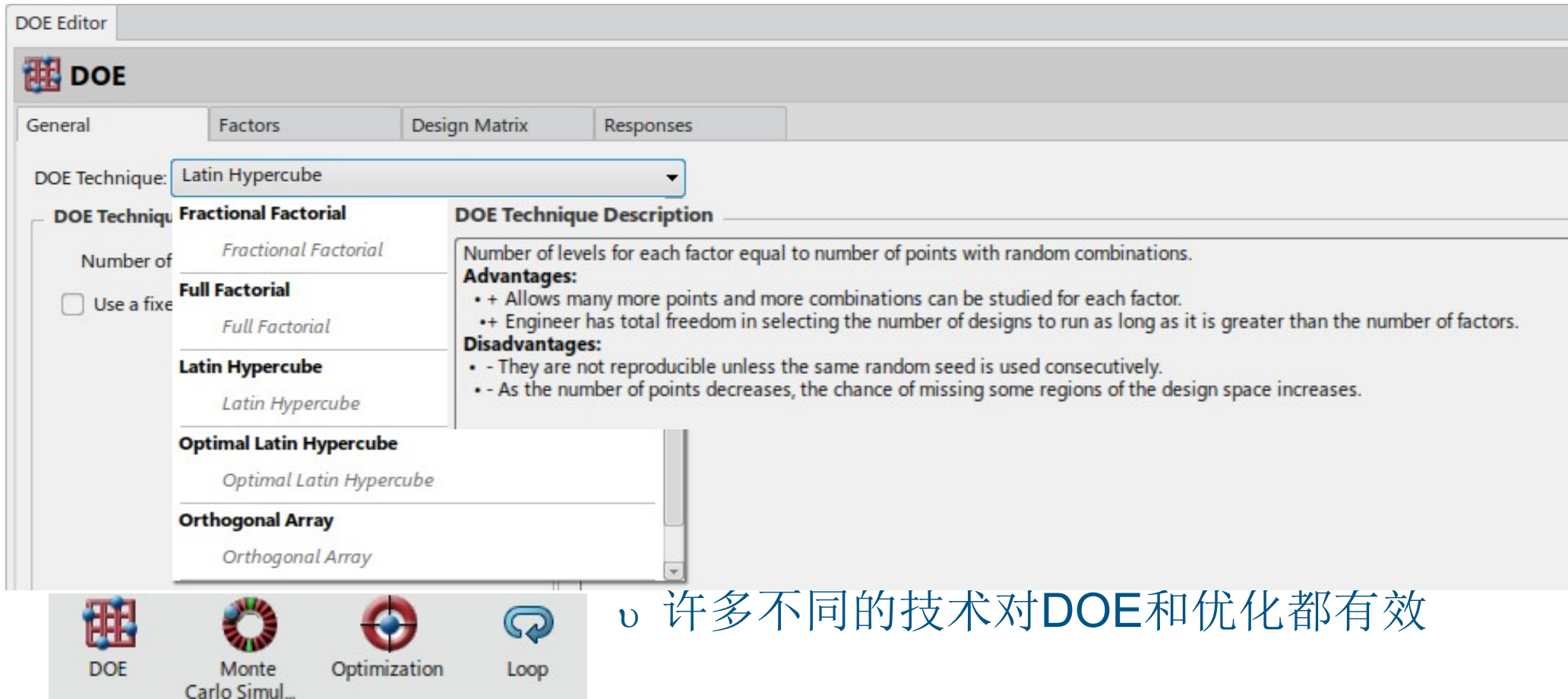
Stress Analysis : 力学场景



Feature Manager							
	..	Name	Type	Category	Definition	Interference Fit	Load
☒	☒	Clamp.1	Clamp	Restraints			
☒		Contact Interference.1	Contact Interference	Interactions	-0.03 mm		
☒		Output.1	Field	Output Requests	Field		
☒		Output.2	History	Output Requests	History		
☒	☒	Planar Symmetry.1	Planar Symmetry	Restraints			
☒	☒	Planar Symmetry.2	Planar Symmetry	Restraints			
☒	☒	Surface-based Contact.1	Surface-based Contact	Interactions	COF=0		
☒	☒	Centrifugal Force.1	Centrifugal Force	Loads	20000 turn_mn		
☐	☒	Prescribed Temperature.1	Prescribed Temperature	Predefined Fields	193 Kdeg		
		Contact Property-CoreShaft	Contact Property	Interactions			
		Global Element Types	Global Element Map	Element Type Assignments			
☒	☒	Initial Temperature.1	Initial Temperature	Initial Conditions	293 Kdeg		



Process Composer : DOE / 优化



许多不同的技术对DOE和优化都有效

Process Composer : DOE / 优化

DOE Editor

DOE

General Factors Design Matrix Responses

☒

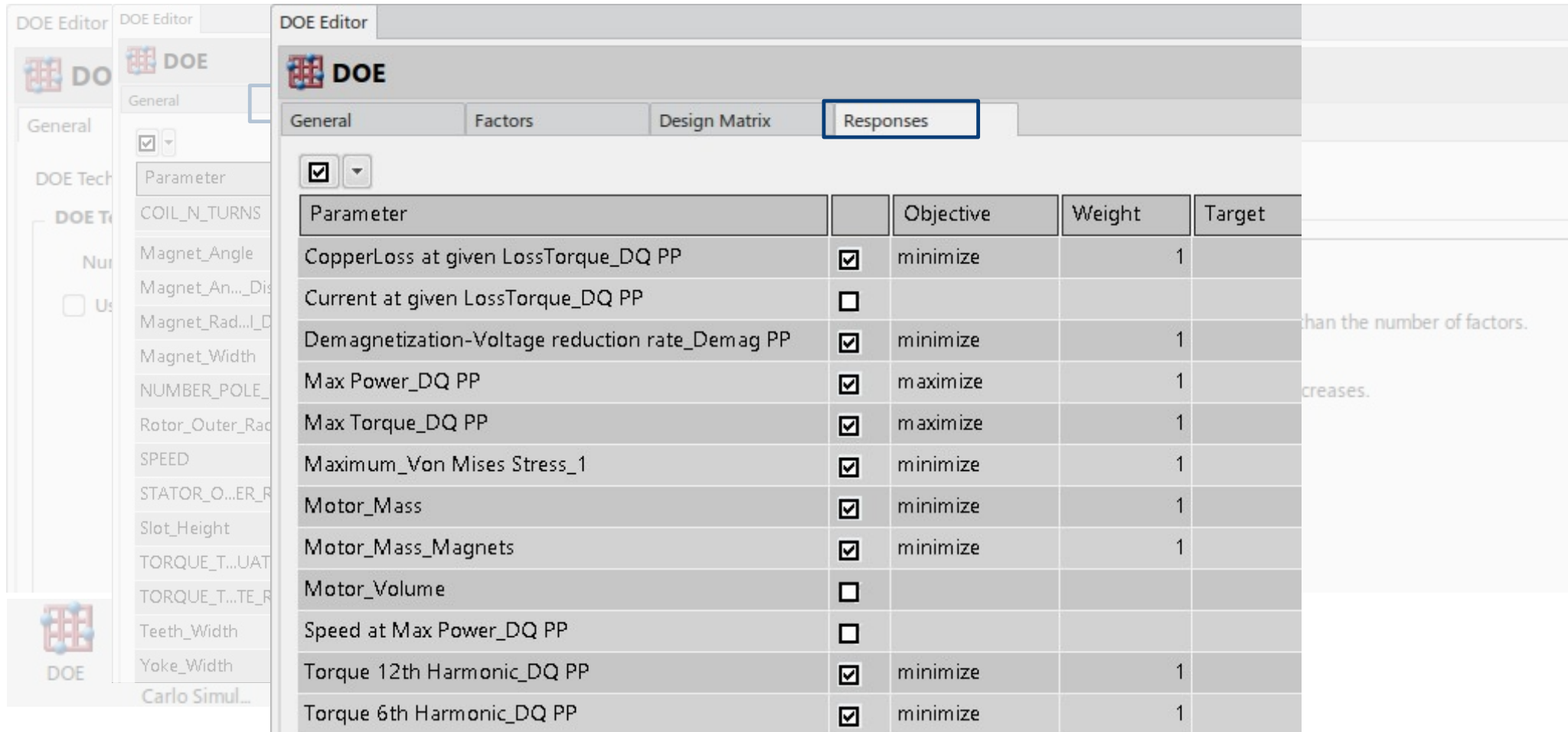
Parameter		Lower	Upper	Relation	Baseline	Values
COIL_N_TURNS	☒	6	8	values	8	6 6 6 6 6 6 ... 8 8 8 8 8 8
Magnet_Angle	☒	60	100	values	70	60 60.04 60...99 99.96 100
Magnet_An..._Distance	☒	1	4	values	2	1 1.003 1.0...9399 3.997 4
Magnet_Rad..._Distance	☒	0.5	3	values	1	0.5 0.50250...99 2.9975 3
Magnet_Width	☒	2	5	values	2.5	2 2.003 2.0...9399 4.997 5
NUMBER_POLE_PAIRS	☐					
Rotor_Outer_Radius	☒	-10	10	%	72.5	65.25 65.26...9.7355 79.75
SPEED	☐					
STATOR_O...ER_RADIUS	☐					
Slot_Height	☒	15	20	values	18	15 15.005 1...99 19.995 20
TORQUE_T...UATE_LOSS	☐					
TORQUE_T...TE_RIPPLE	☐					
Teeth_Width	☒	-10	10	%	3	2.7 2.7006 ...8 3.2994 3.3
Yoke_Width	☒	-10	10	%	8	7.2 7.2016 ...8 8.7984 8.8

DOE

Carl

the number of factors.

Process Composer : DOE / 优化



The screenshot displays the DOE Editor software interface. The 'Responses' tab is selected, showing a table of parameters to be optimized. The table has columns for 'Parameter', a selection checkbox, 'Objective', 'Weight', and 'Target'.

Parameter		Objective	Weight	Target
CopperLoss at given LossTorque_DQ PP	☒	minimize	1	
Current at given LossTorque_DQ PP	☐			
Demagnetization-Voltage reduction rate_Demag PP	☒	minimize	1	
Max Power_DQ PP	☒	maximize	1	
Max Torque_DQ PP	☒	maximize	1	
Maximum_Von Mises Stress_1	☒	minimize	1	
Motor_Mass	☒	minimize	1	
Motor_Mass_Magnets	☒	minimize	1	
Motor_Volume	☐			
Speed at Max Power_DQ PP	☐			
Torque 12th Harmonic_DQ PP	☒	minimize	1	
Torque 6th Harmonic_DQ PP	☒	minimize	1	

On the left sidebar, a list of parameters is visible, including COIL_N_TURNS, Magnet_Angle, Magnet_An..._Dis, Magnet_Rad..._D, Magnet_Width, NUMBER_POLE_, Rotor_Outer_Rad, SPEED, STATOR_O...ER_R, Slot_Height, TORQUE_T...UAT, TORQUE_T...TE_R, Teeth_Width, and Yoke_Width. The 'DOE' icon is also present in the sidebar.

使用Result Analytics进行数据研究

The screenshot displays the 3DEXPERIENCE 3DDashboard interface for a project named "EV Motor DOE". The top navigation bar includes "Getting Started", "Simulation", and "Result Analytics". The "Result Analytics" section is active, showing a workflow diagram with a central "DOE" block connected to "Data Sources" and "Methods".

EV Motor DOE

Project: Honda
Revision Number:
Group: Christian Kremers
Owner: Christian Kremers
Originated: 3/25/2019 9:10:31 AM
Last Modified: 3/26/2019 4:49:23 PM
Due Date:
Status: In Process

Background

Data Sources

Methods

Parameter Summary

Parameter Name	Units	Mode	Alias	Min	Max	Comments
COIL_N_TURNS		INPUT	COIL_N_TURNS		6	8
Magnet_Angle		INPUT	Magnet_Angle		60	100
Magnet_Angular_Distance		INPUT	Magnet_Angular_Distance		1	4
Magnet_Radial_Distance		INPUT	Magnet_Radial_Distance		0.5	3
Magnet_Width		INPUT	Magnet_Width		2	5
Rotor_Outer_Radius		INPUT	Rotor_Outer_Radius		65.25	79.75
Slot_Height		INPUT	Slot_Height		15	20
Teeth_Width		INPUT	Teeth_Width		2.7	3.3
Yoke_Width		INPUT	Yoke_Width		7.2	8.8
CopperLoss at given LossTorque_DQ PP		OUTPUT	CopperLoss at given LossTorque_DQ PP		91.445	485.37
Demagnetization-Voltage reduction rate_Demag PP		OUTPUT	Demagnetization-Voltage reduction rate_Demag PP		-48.55	-7.580e-2
Max Power P0 PP		OUTPUT	Max Power P0 PP		6.014	1.915e-5

1 Preview 2 Define 3 Explore 4 Predict 5 Compare 6 Collaborate 7 Recommend

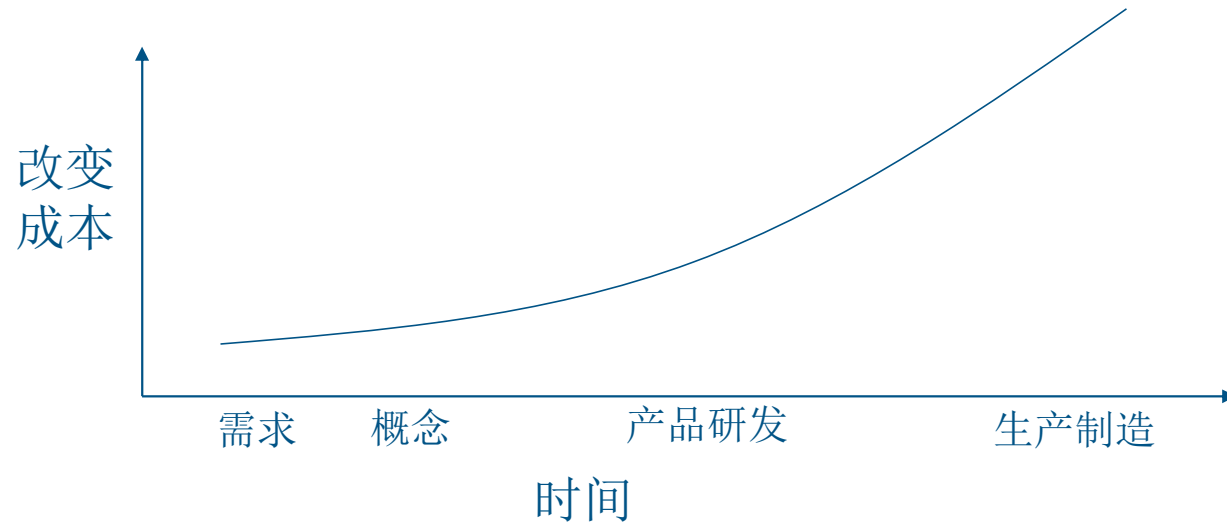
EMC/EMI

EMC/EMI范围

- u 电气系统工作的能力
 - o 在电磁环境中
 - o 不影响周围设备(发射)
 - o 或不受到周围设备的影响(敏感度)
- u 对所有产品**EMC**合规都至关重要！
 - o 发射和抗扰度是一个监管良好的领域
 - o 汽车**OEM**对零部件实施严格的标准

仿真的动机

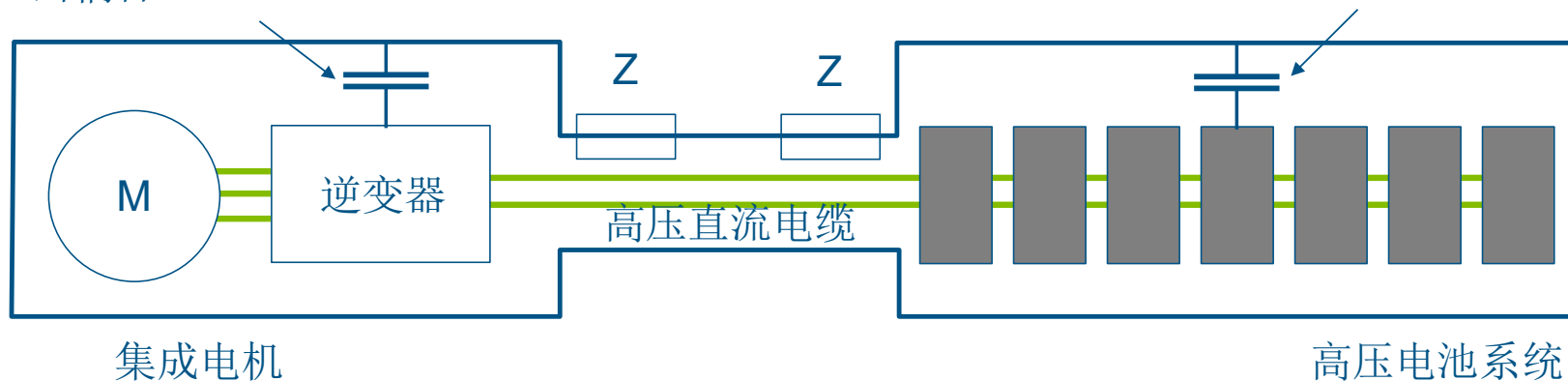
- EMC作为设计流程的一部分，有助于避免：
 - 多次troubleshooting迭代
 - 更正的高工作量和成本
 - 上市时间延迟



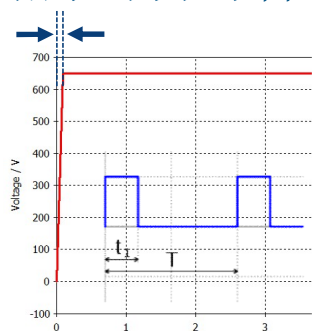
传动系统传导发射

IGBTs的容性输出耦合

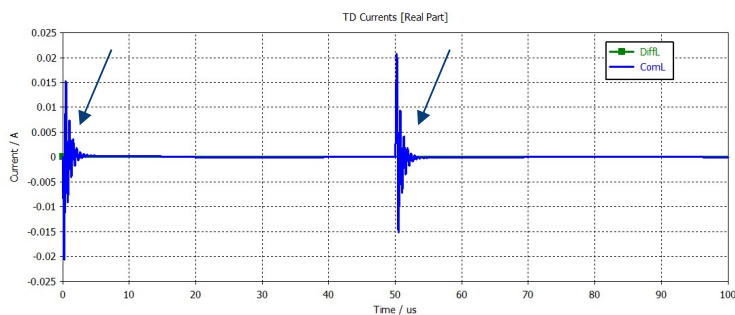
模块的容性输出耦合



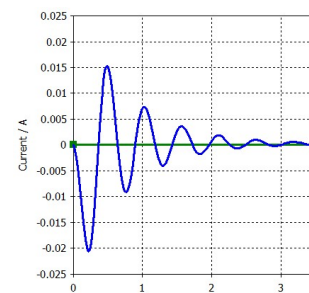
陡峭的上升和下降沿



双绞线对的串扰影响



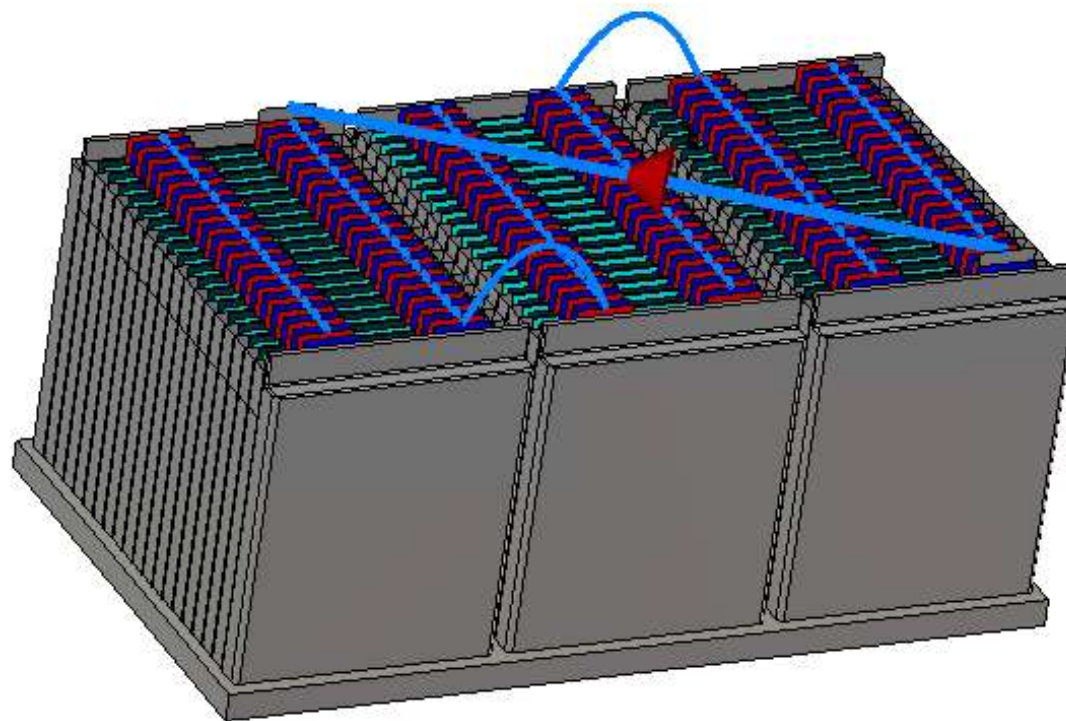
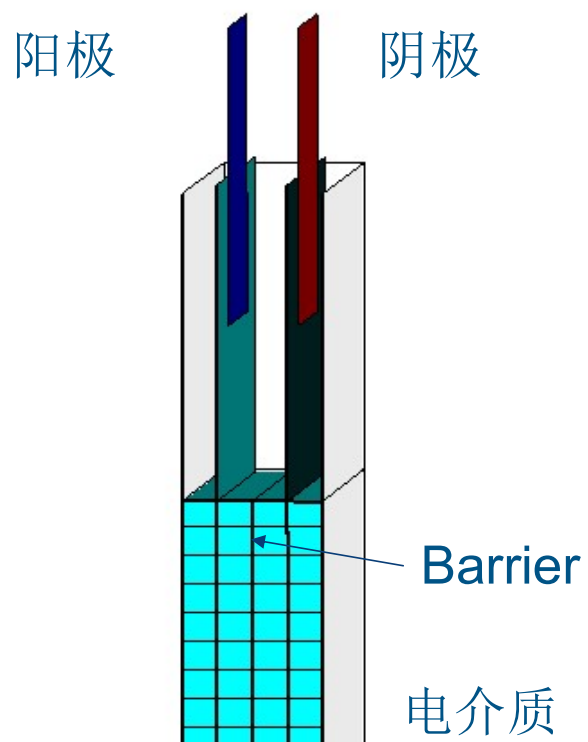
反射导致的振铃



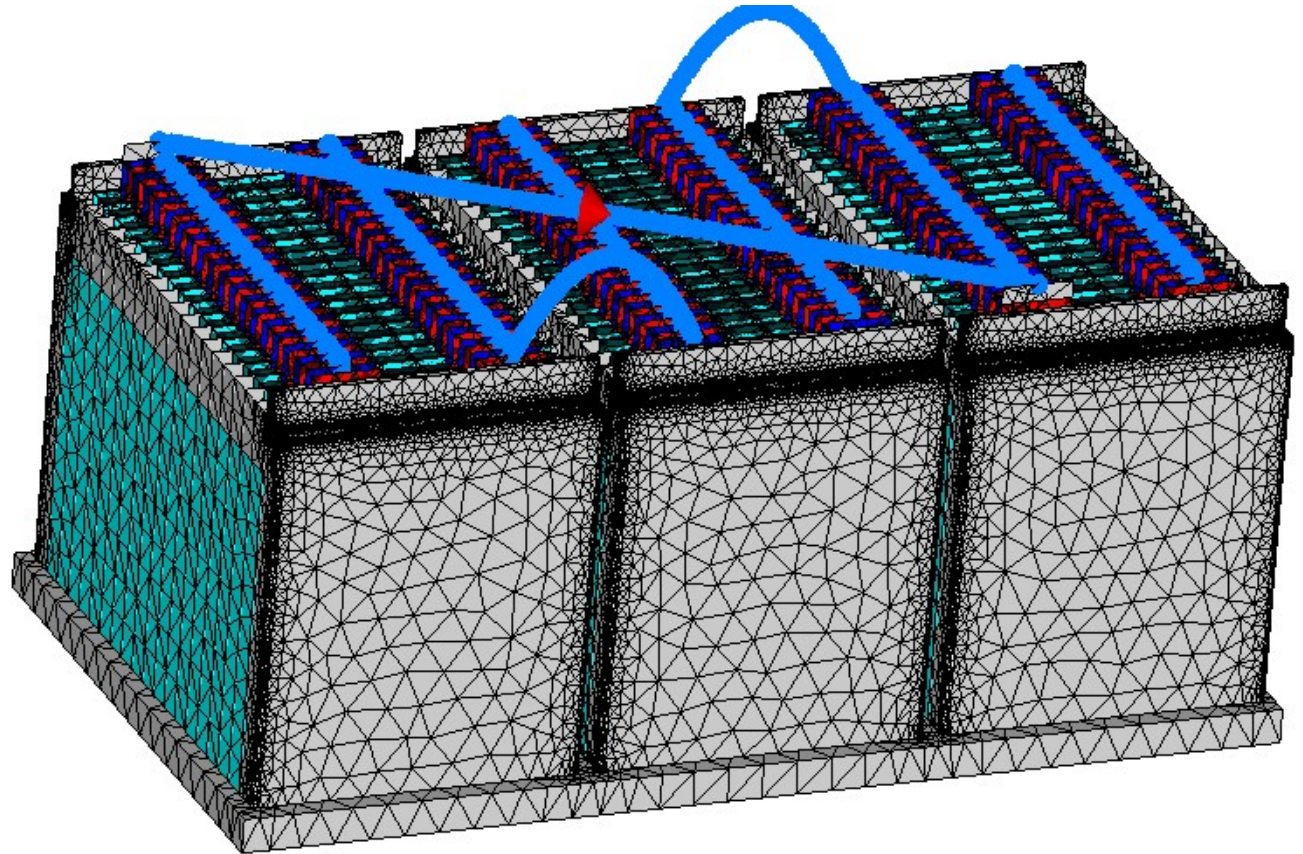
器件仿真

特征阻抗提取

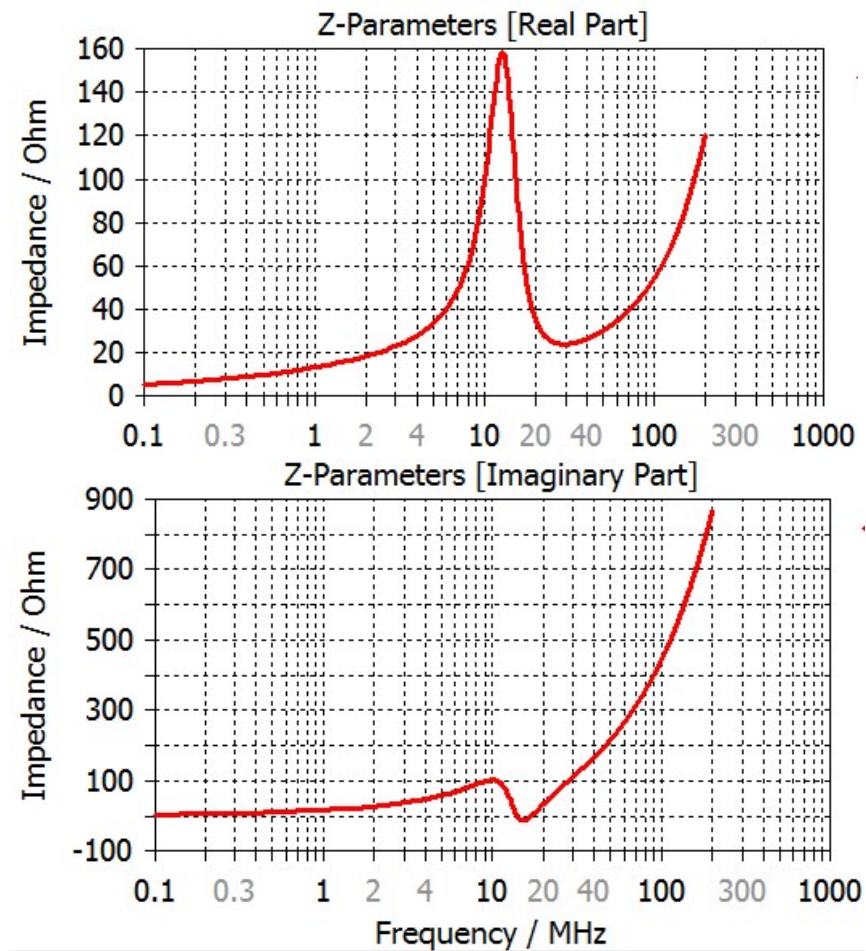
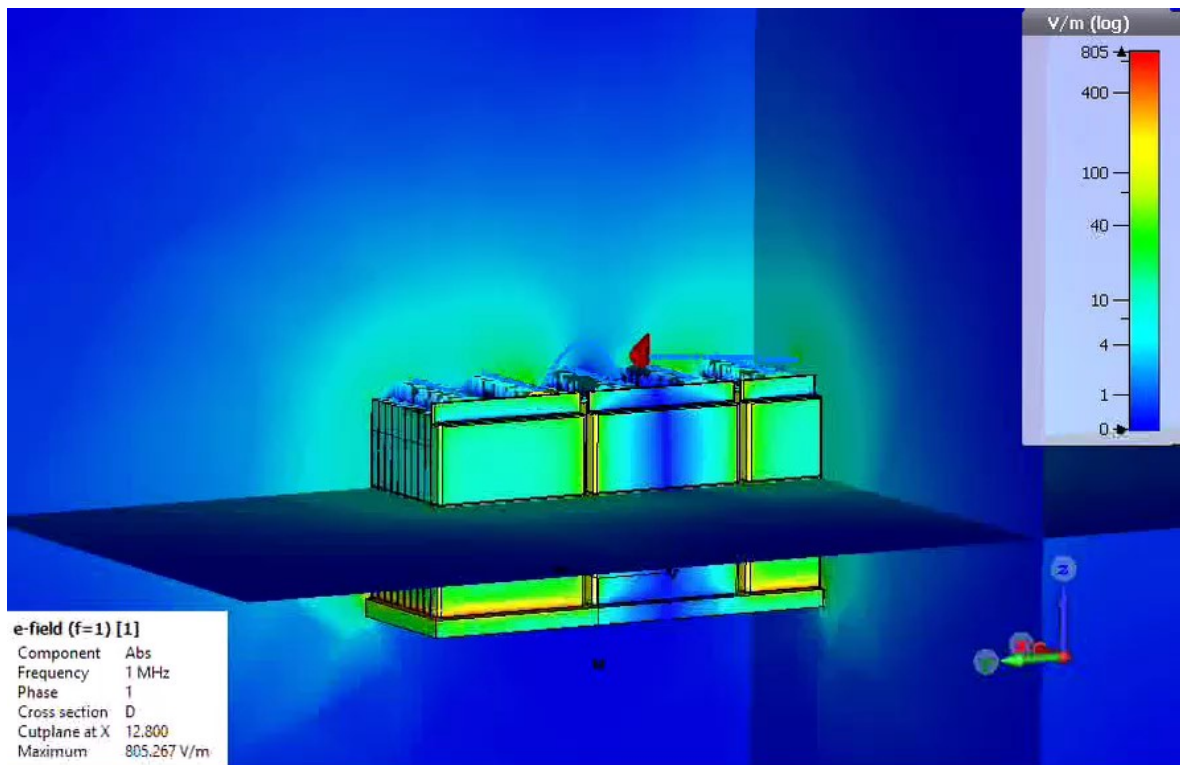
电池建模



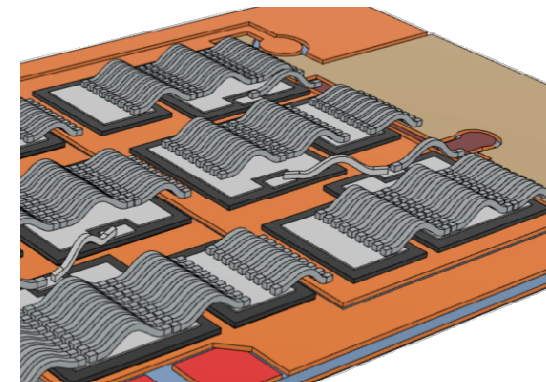
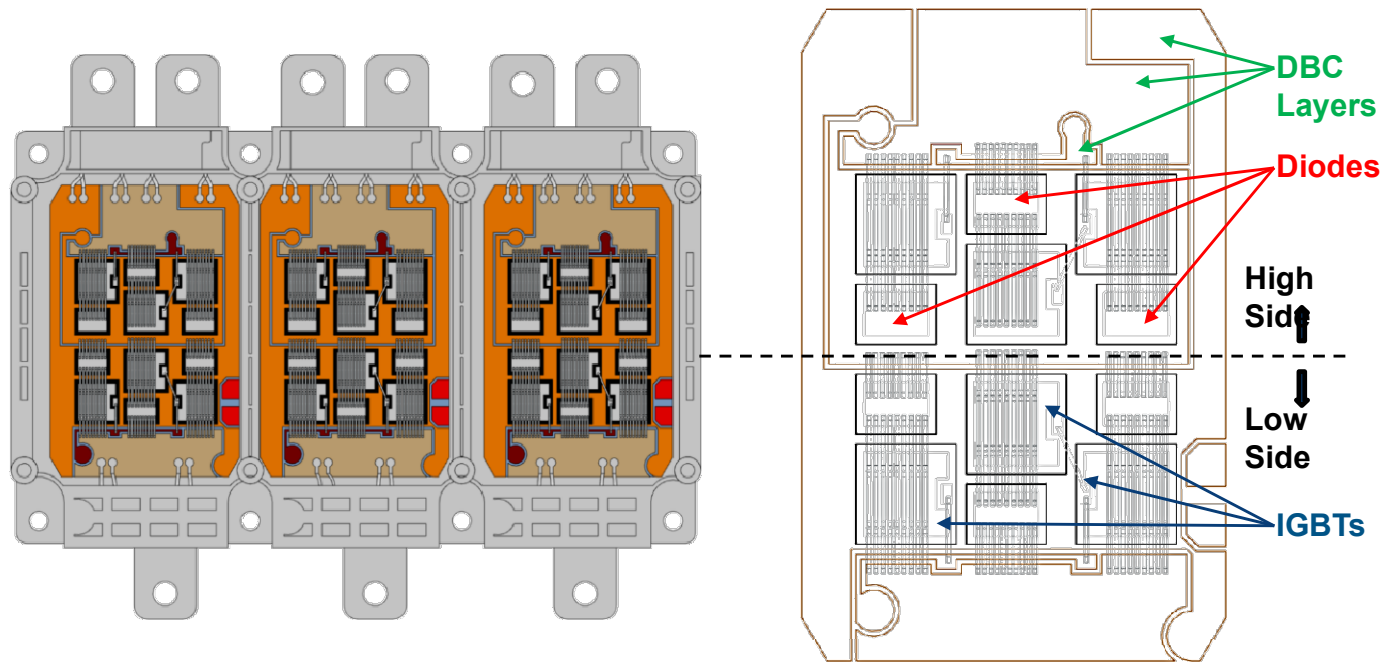
电池建模-网格



电池阻抗提取



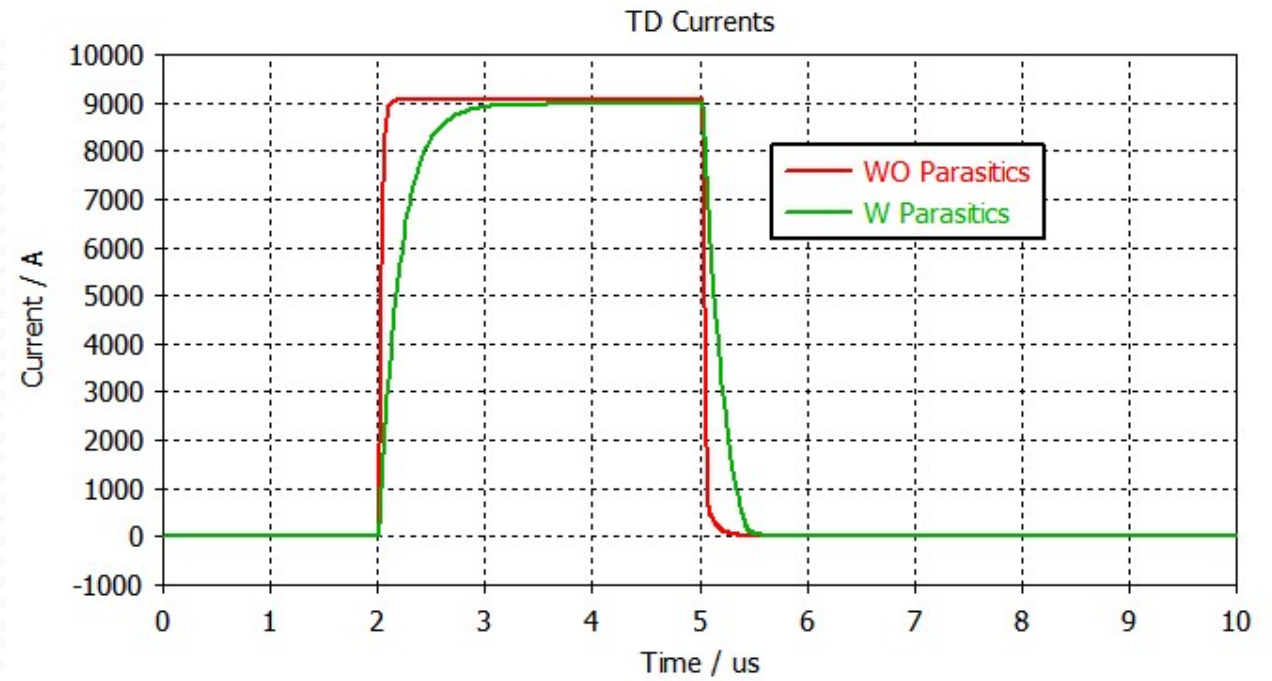
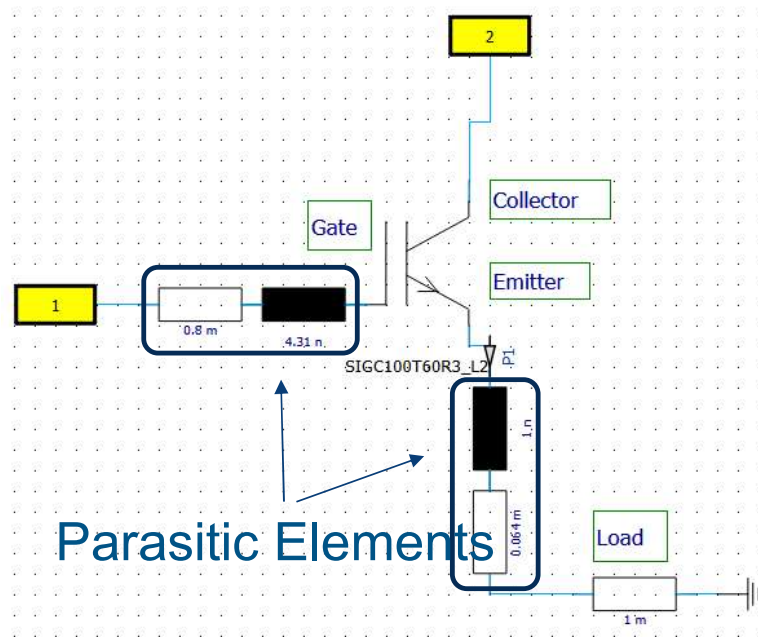
逆变器



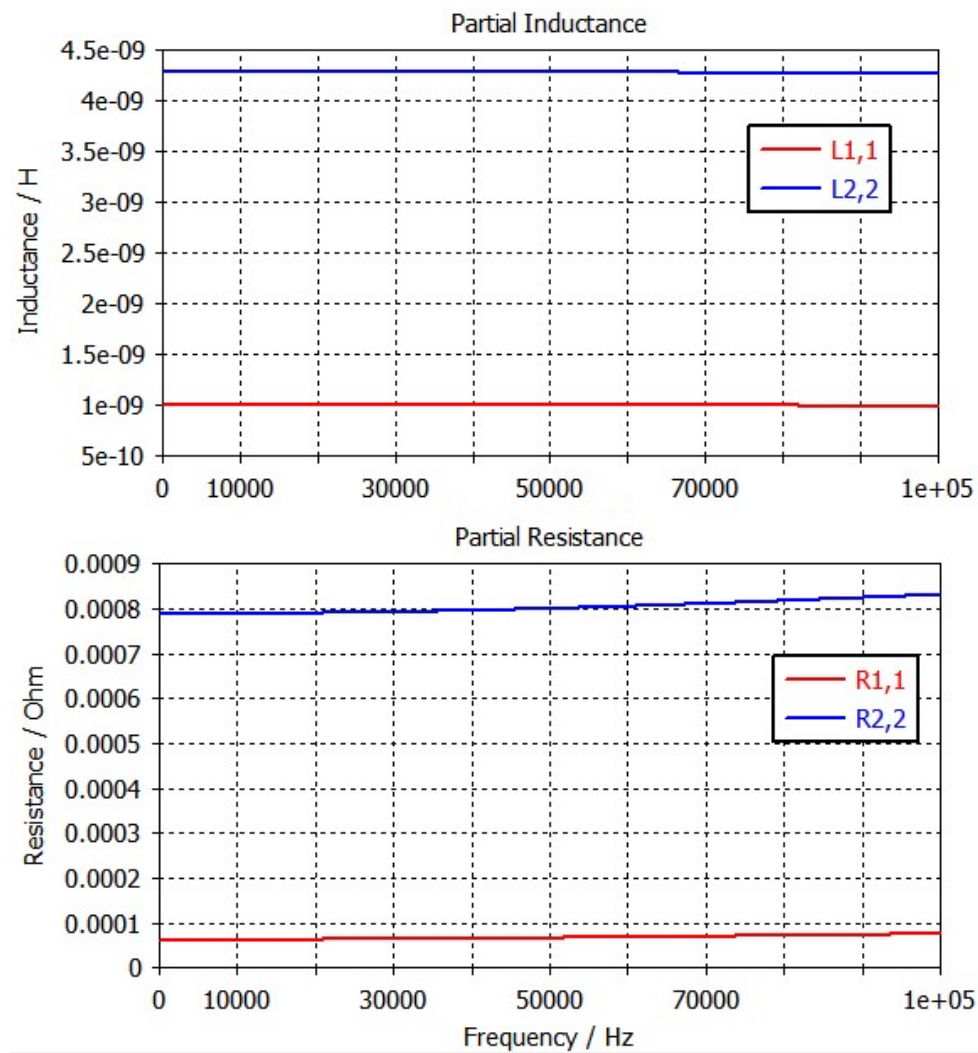
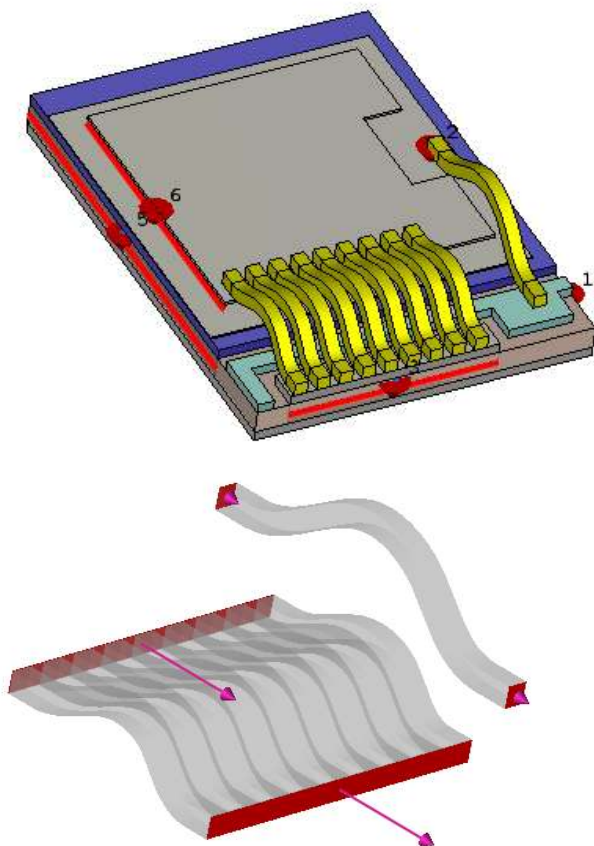
Wirebonds connecting IGBTs, Diodes and DBC Layers

Wirebonds connecting IGBTs, Diodes and DBC Layers

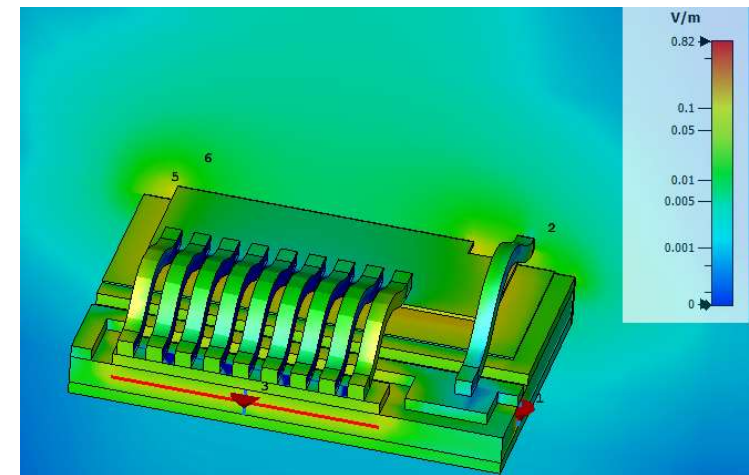
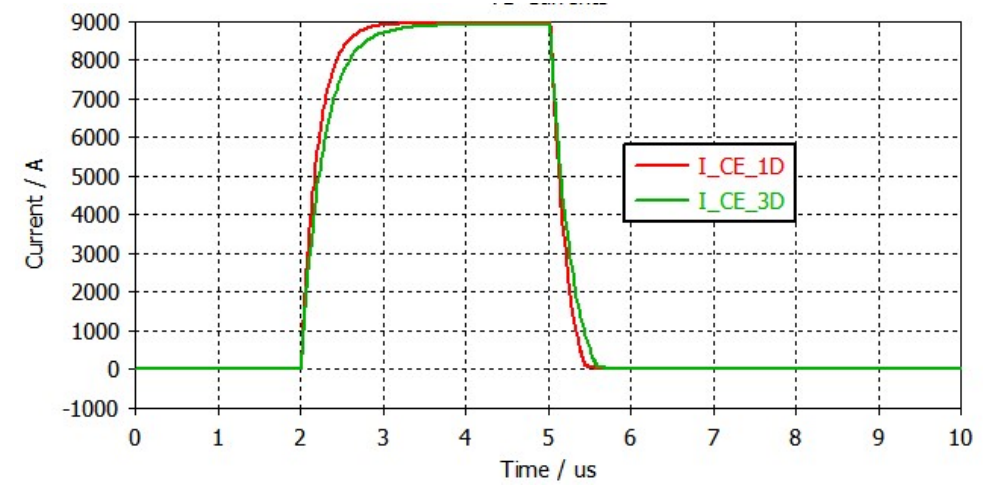
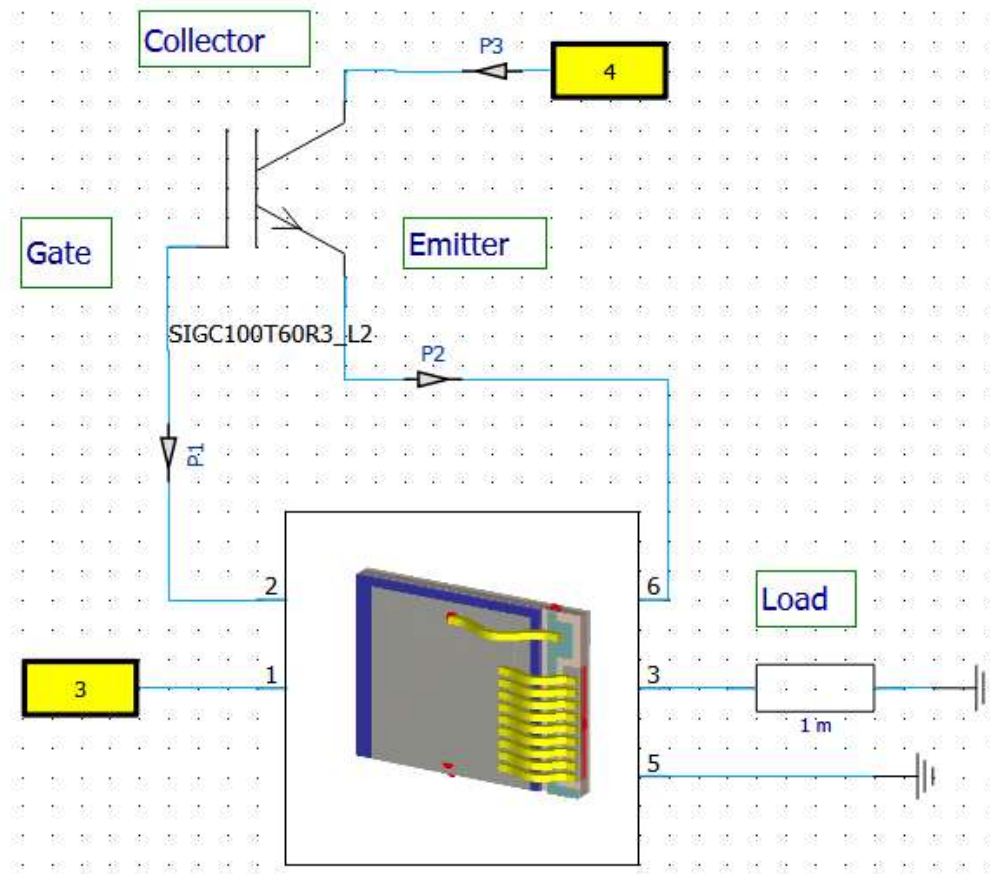
寄生参数



部分电感



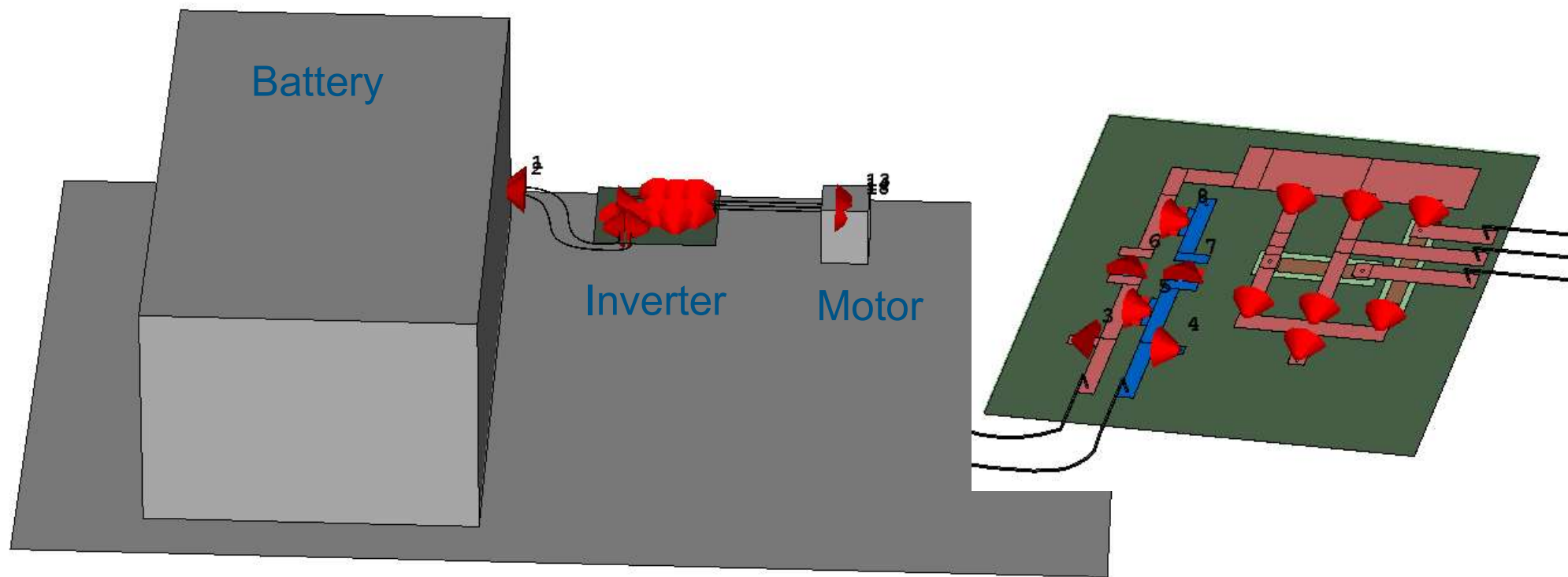
全三维协同仿真



台架测试

传导发射

传动系统EMC台架测试

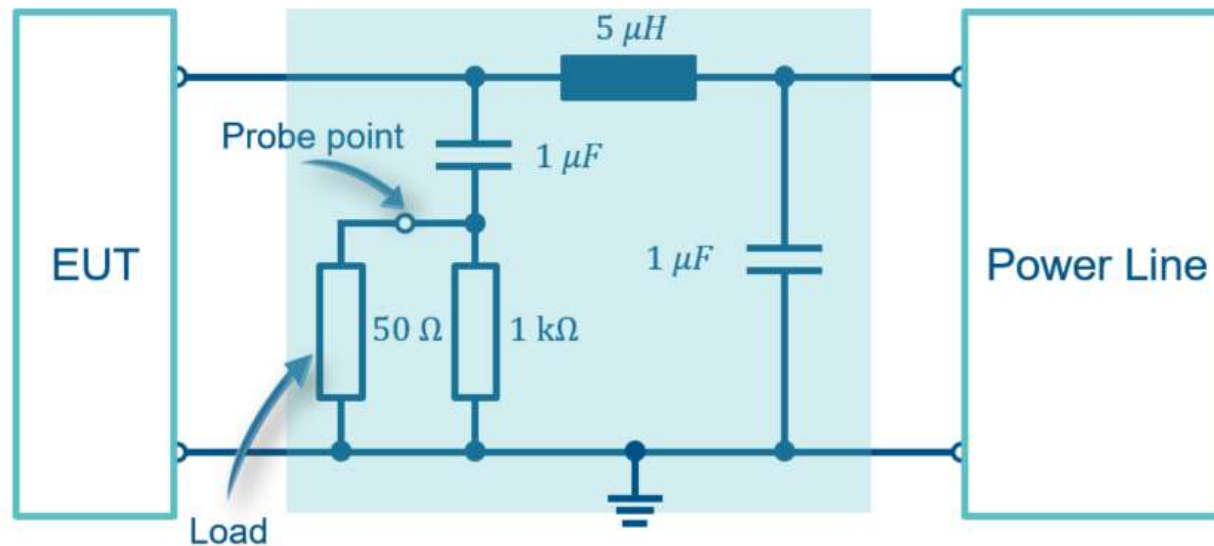


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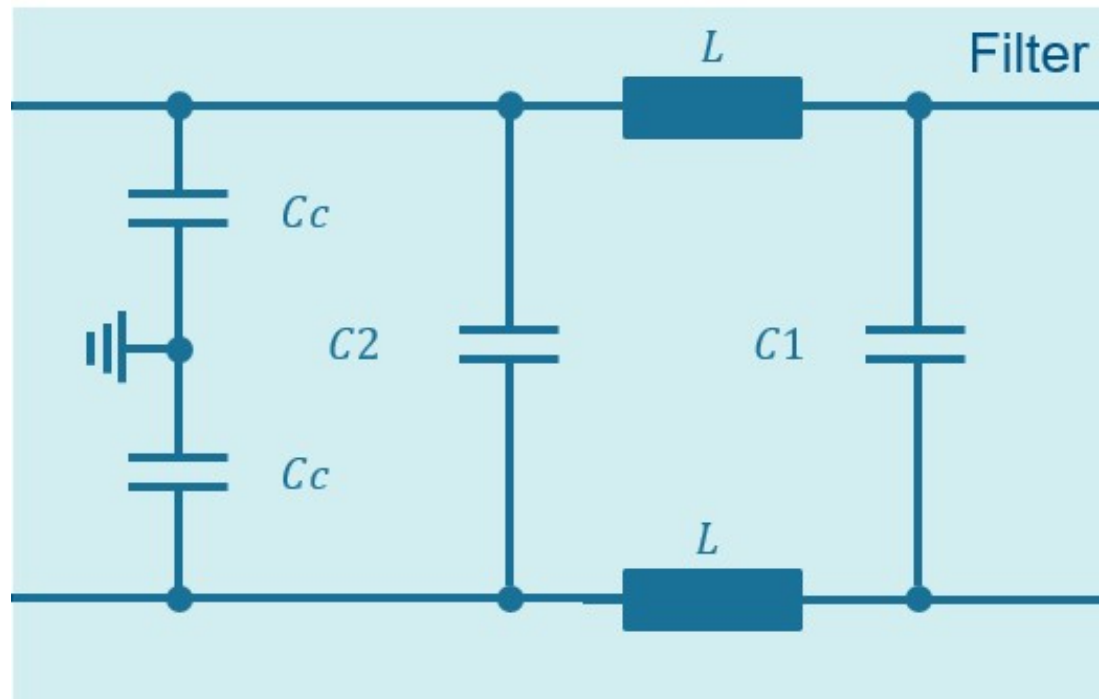
线路阻抗稳定网络(LISN)

- 测量传导发射，LISN(线路阻抗稳定网络)是必要的。
- 根据CISPR 25，LISN应该使用5 uH电感。
- 电路如下图。



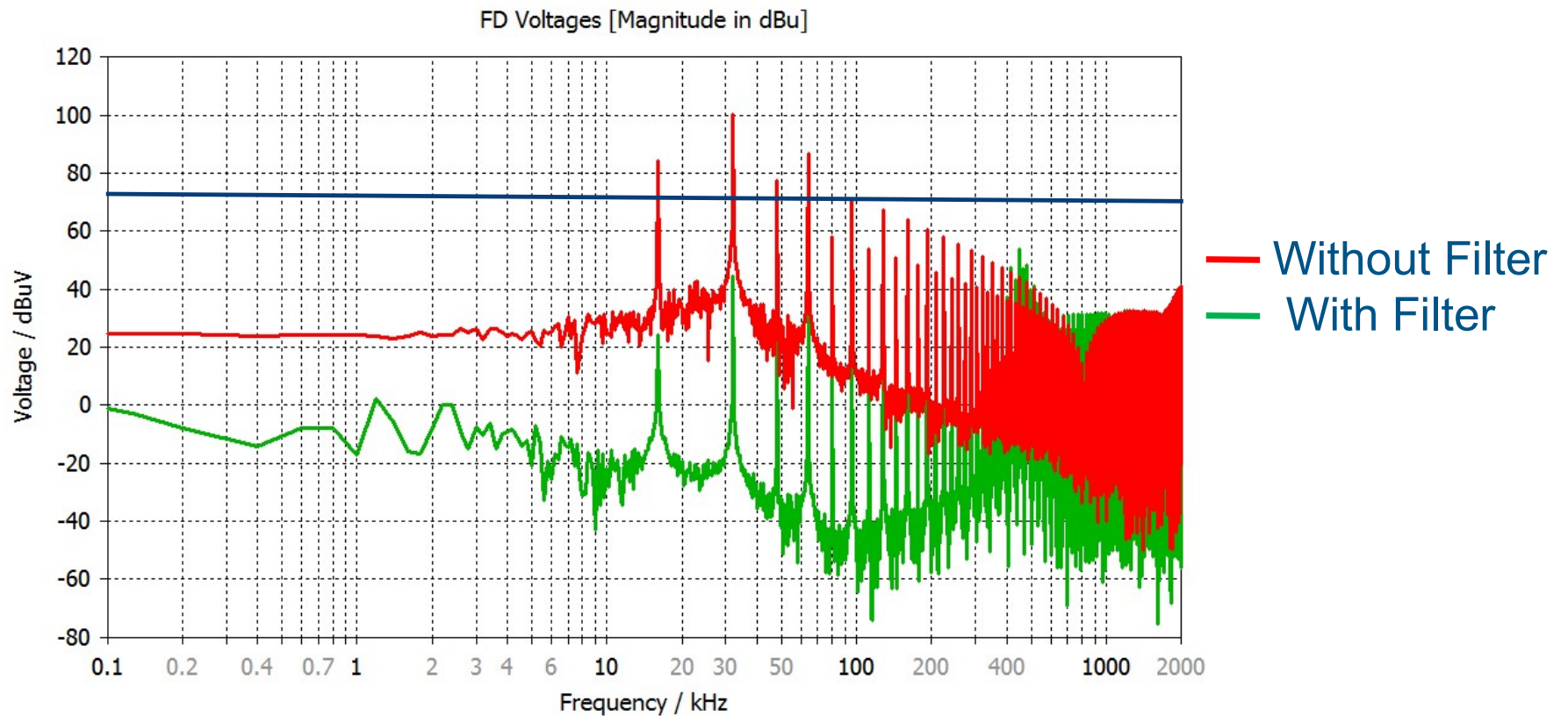
带滤波器的传导发射

所提出的滤波器设计用于去耦差模和共模电流噪声。

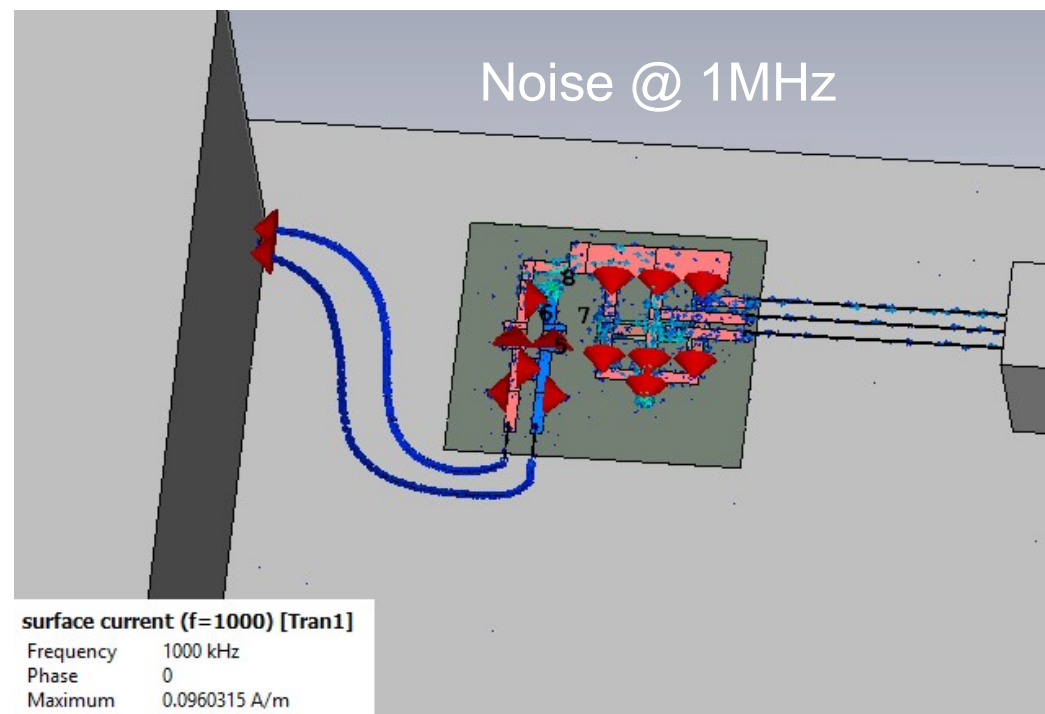
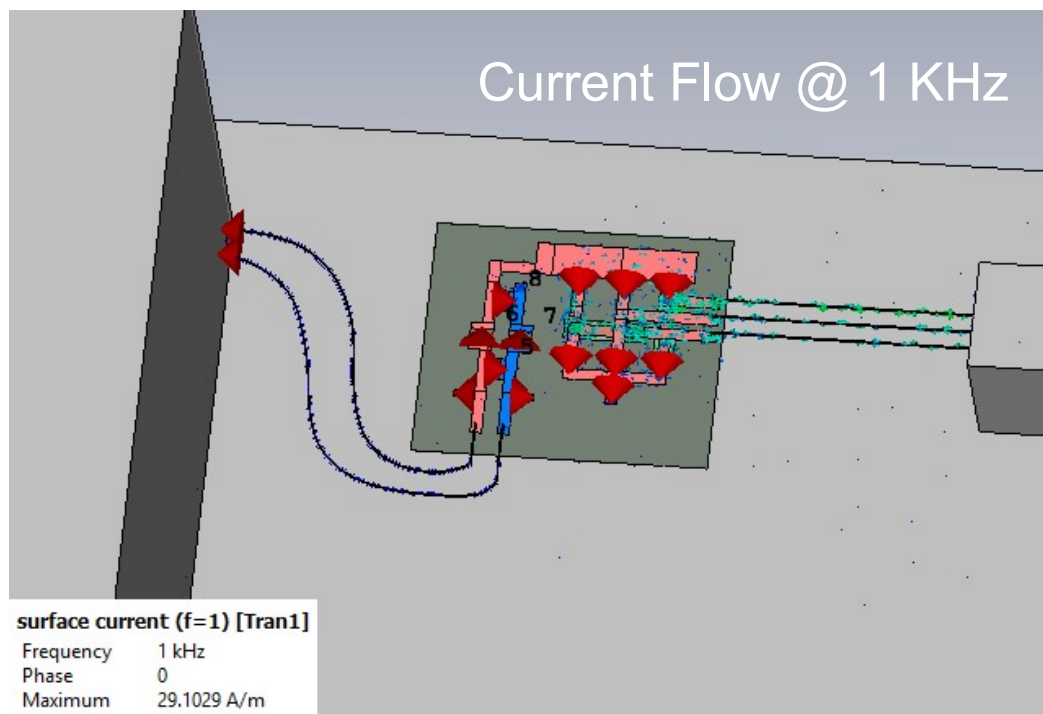


传导发射

CISPR 25: <76 dBuV for frequency lower than 300 kHz



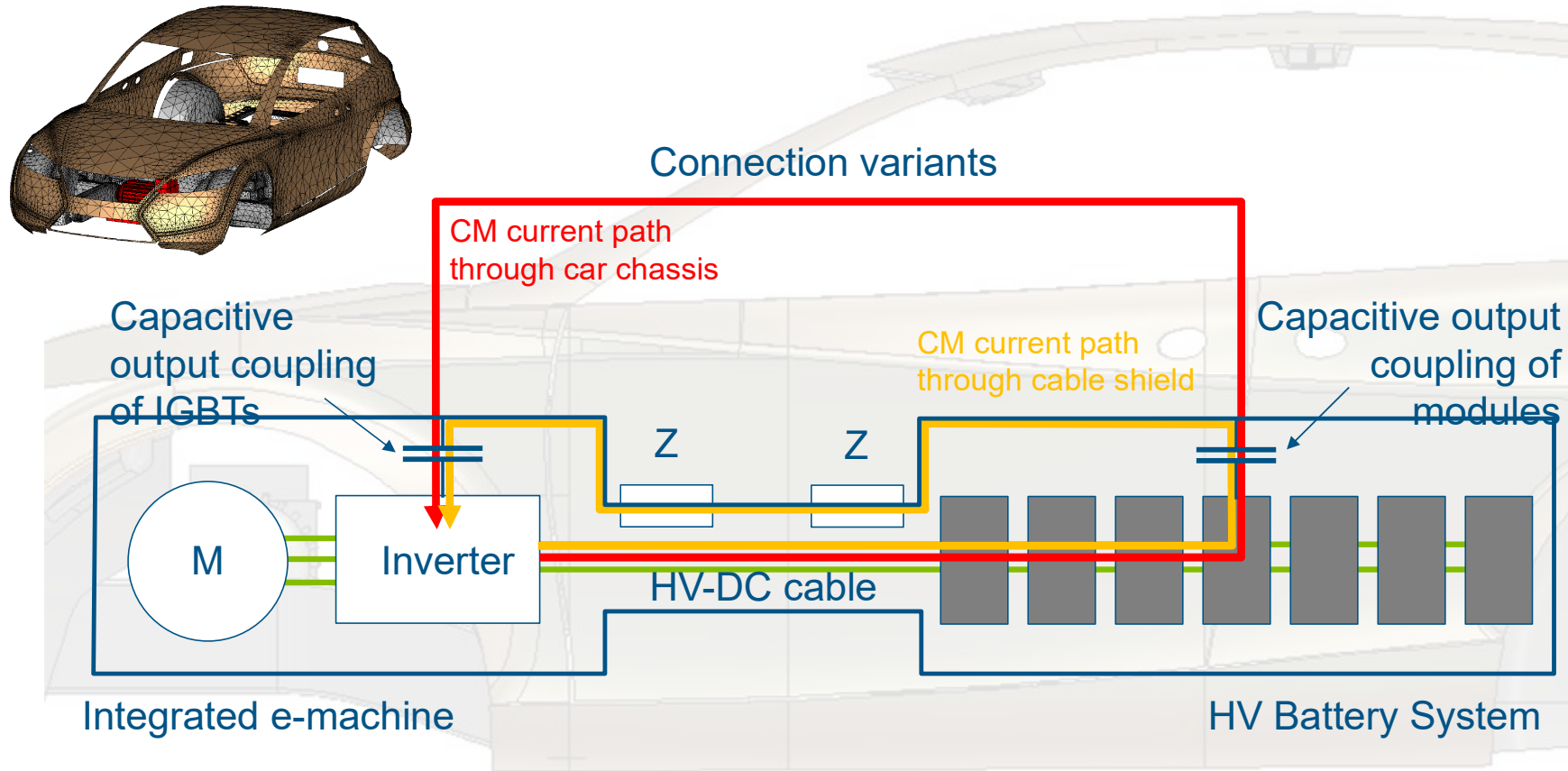
电流分布



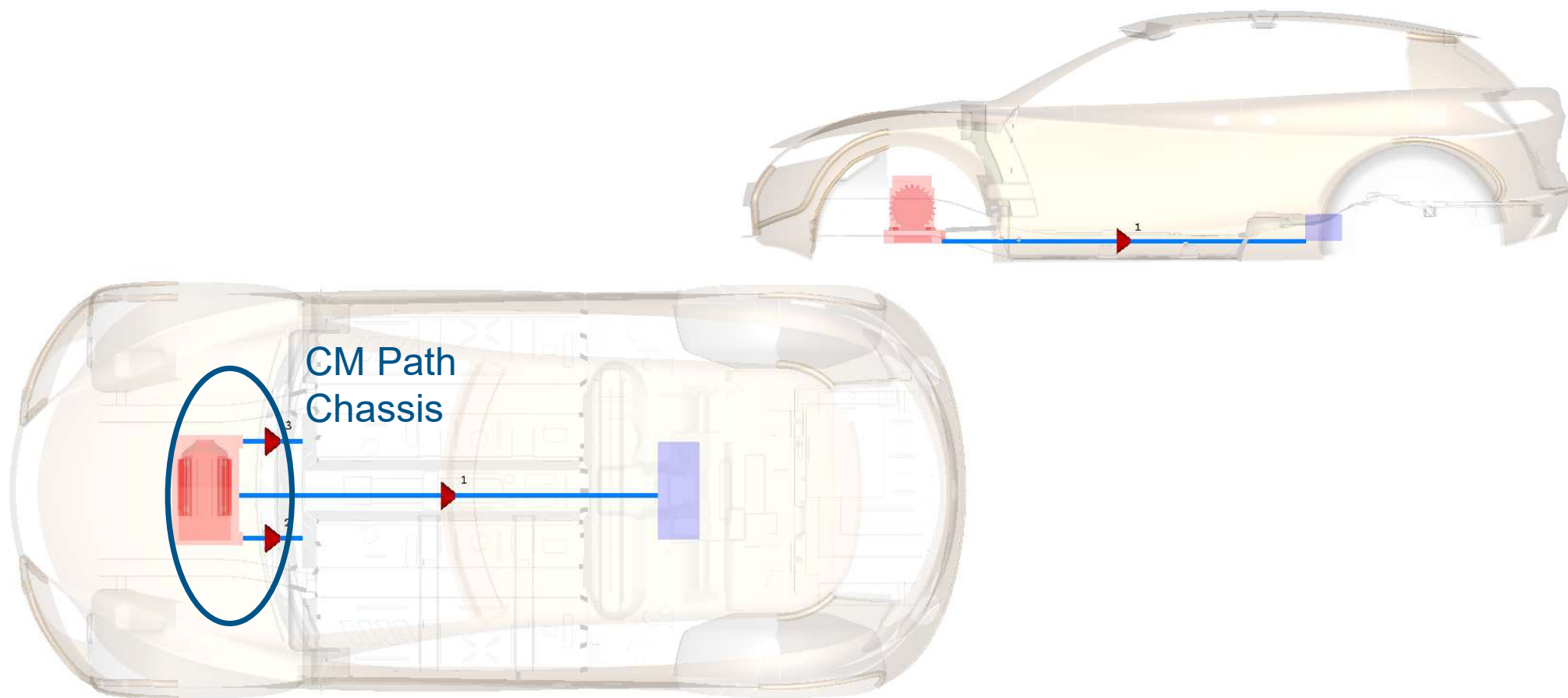
整车级仿真

共模分析

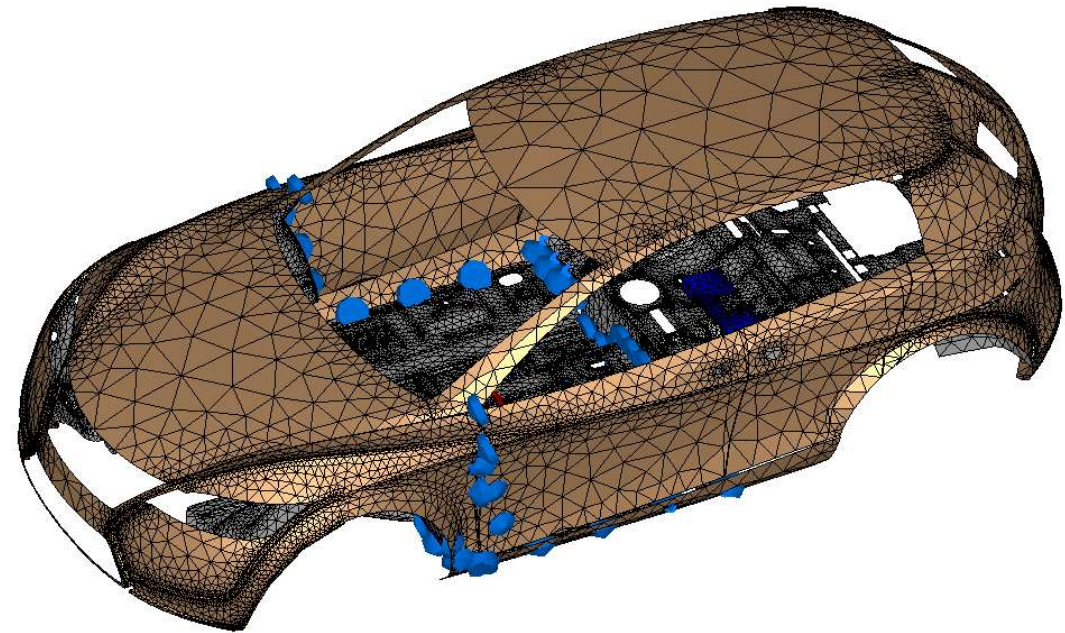
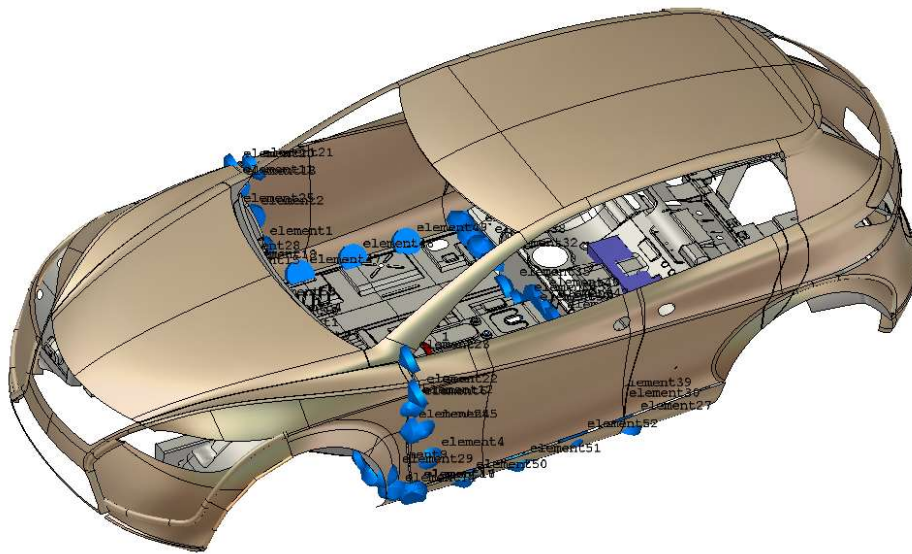
电动汽车中的共模电流路径



电动汽车中的共模电流路径

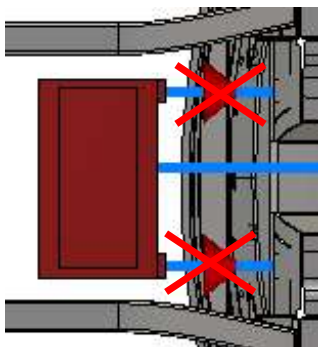


模型准备

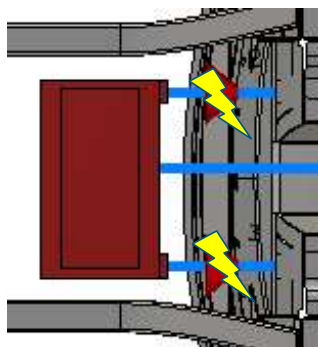


辐射电场

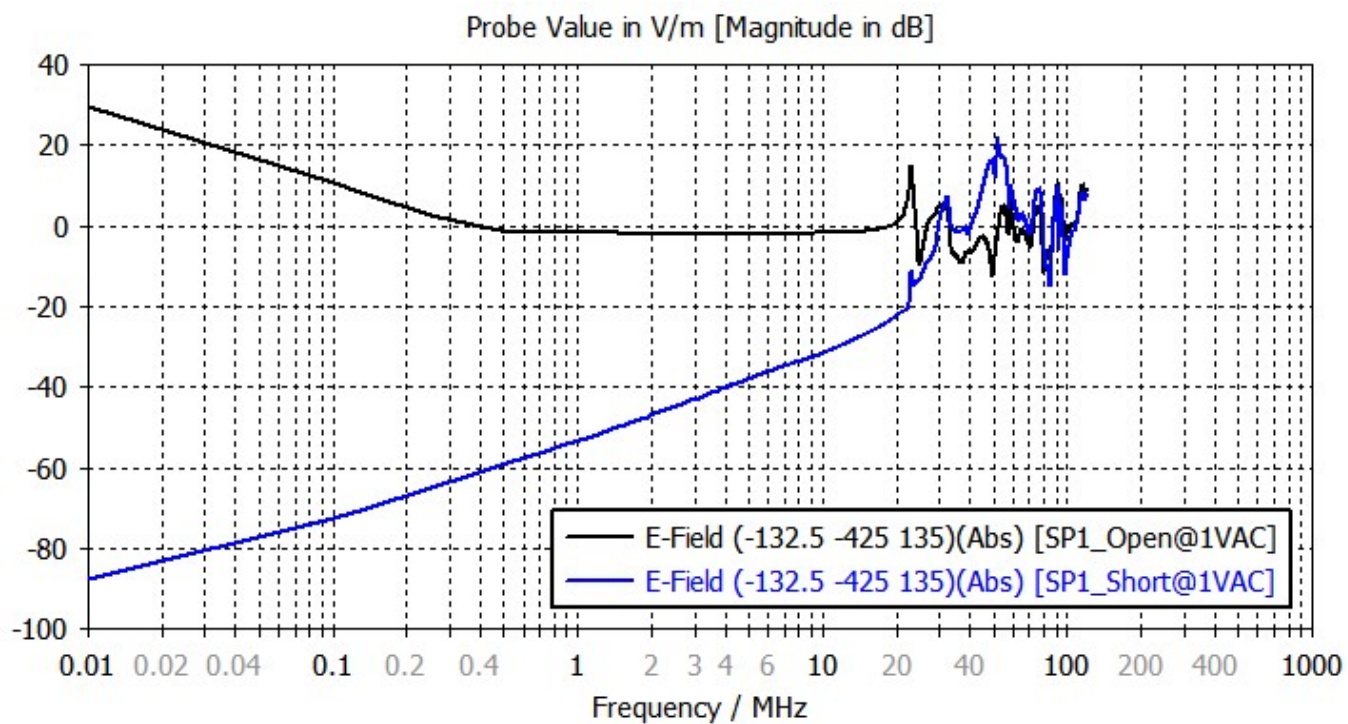
Open



Short



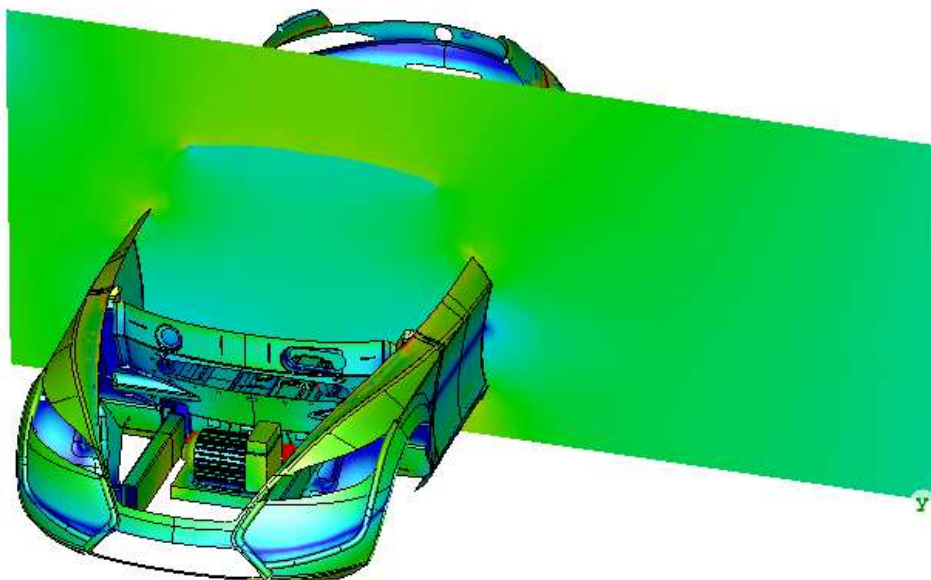
E-Field



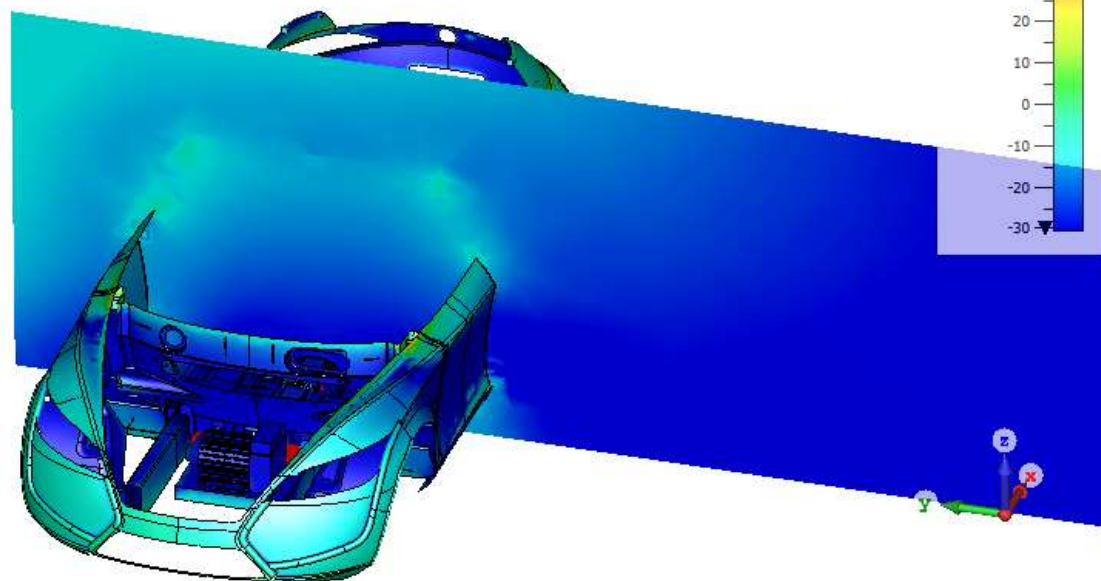
电场分布

12 MHz

Open



Short

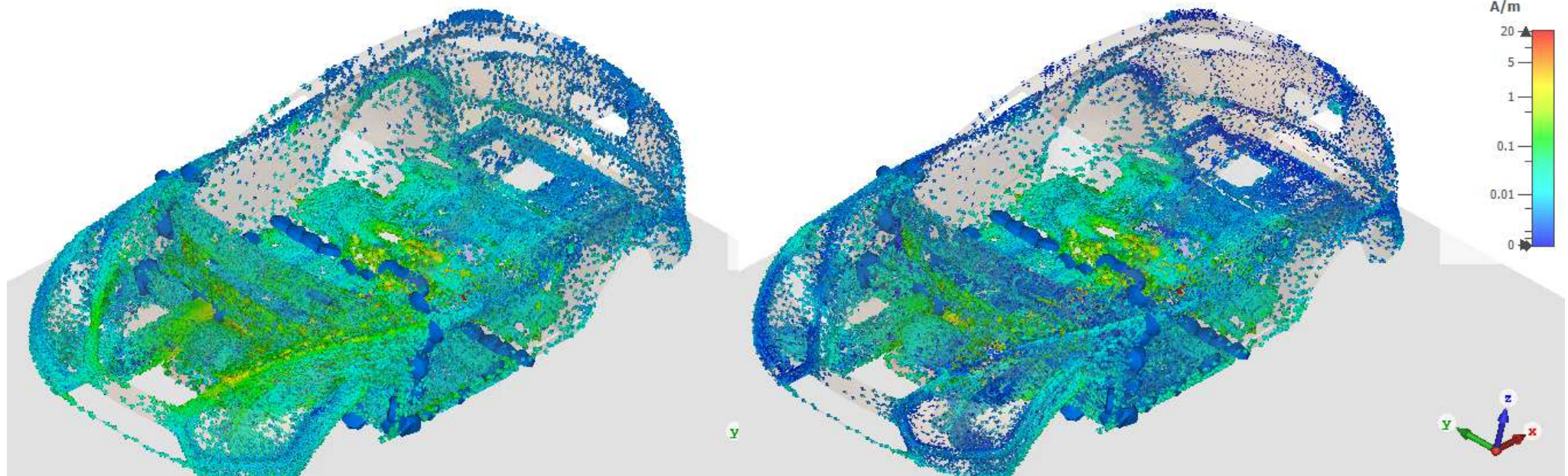


电流分布

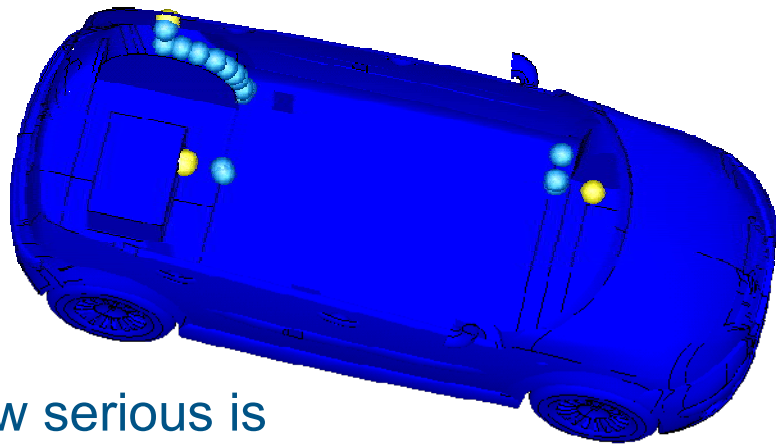
υ 12 MHz

Open

Short



有关布线和电缆线束的问题



“How serious is the electromag emission?”



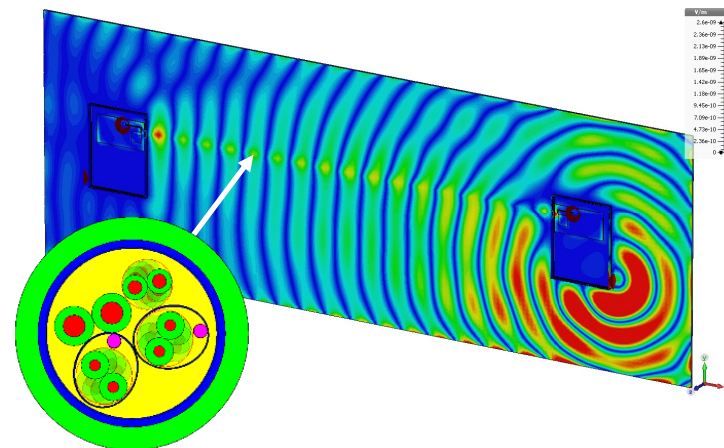
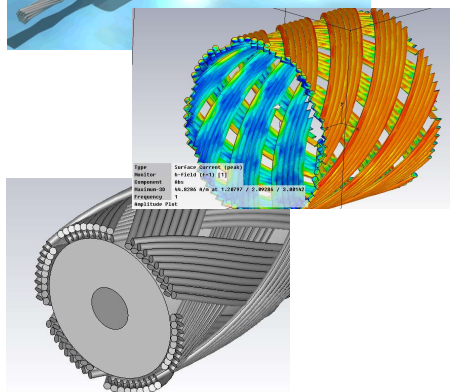
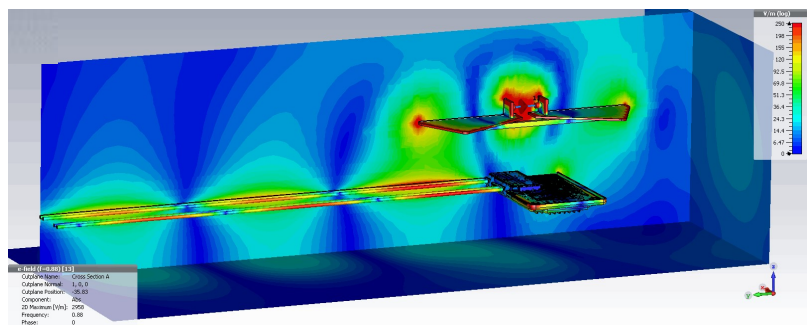
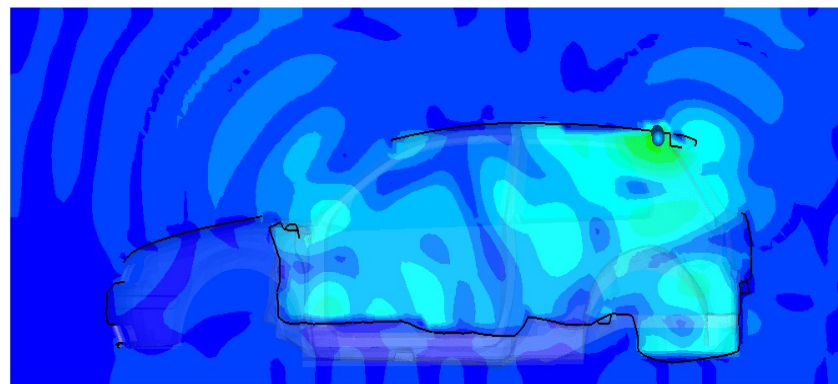
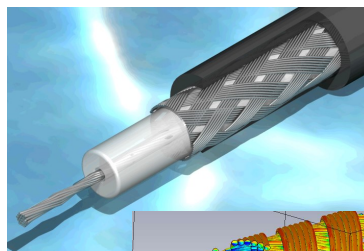
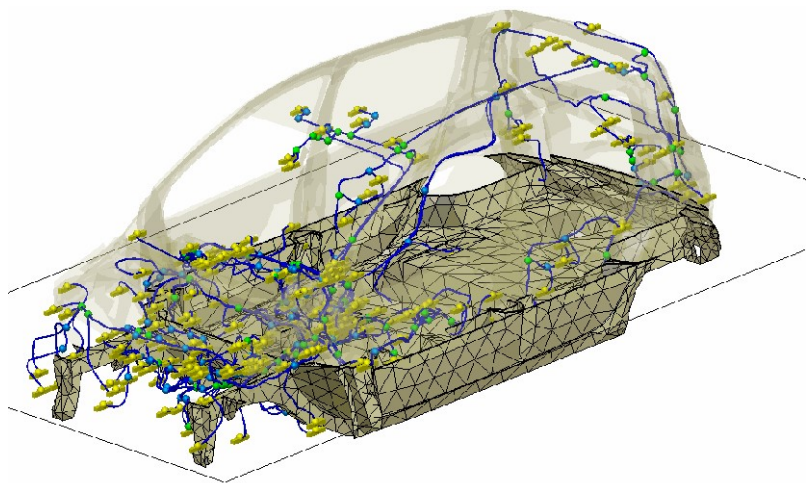
“Do we need shielded cables?”



“How can we reduce vehicle weight and labor cost?”

辐射发射/抗扰度

器件级 & 系统级
分析



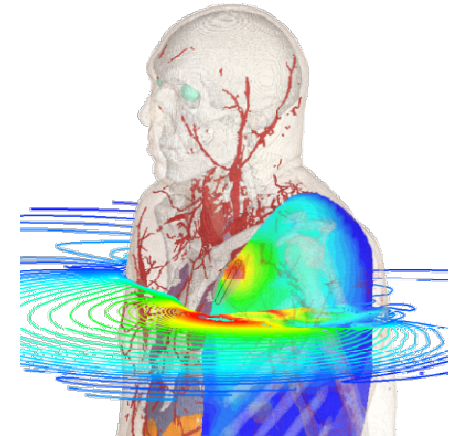
安全性:与高压相关的潜在风险

各种组织参与标准化和规范，为测量和仿真设置提供指导，并定义限值

国际非电离辐射防护委员会（ICNIRP）

IEC、IEEE、当地标准化机构

当地法规，例如欧洲指令**2013-35 EU**“关于工人暴露于物理因素(电磁场)风险的最低健康和安全要求”



Potential risks are:

- Electric energy
- Accidental arcs
- Electric current flowing through the body (electric shock)
- Electromagnetic fields affecting e.g. pacemakers
- Interactions between electric energy and other media

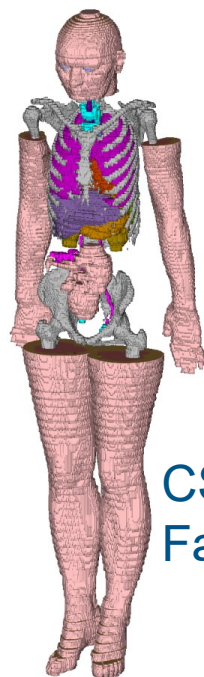
人体仿真模型

正确选择生物模型对于生物电磁仿真的可靠性至关重要

解剖细节:



Homogeneous
models



CST Voxel
Family

Heterogeneous
CAD models



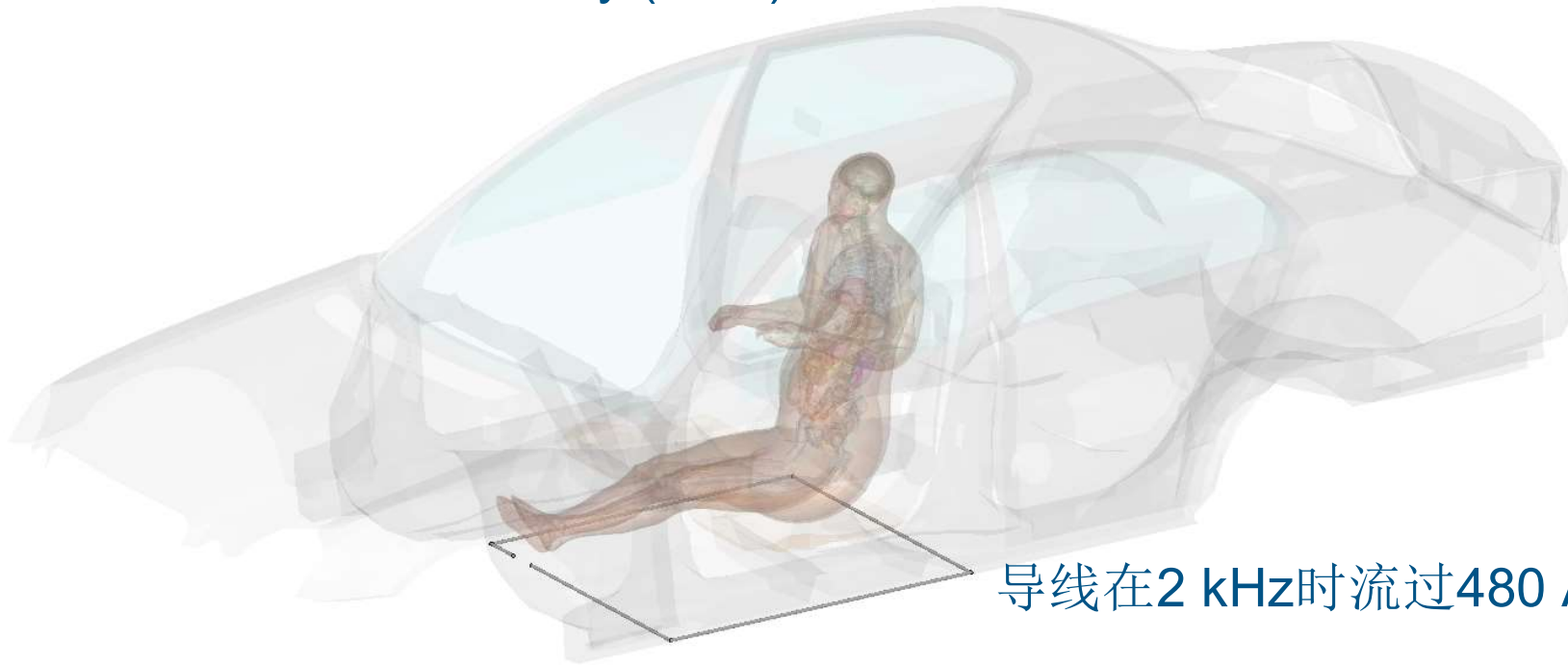
材料属性:

- 频率相关的电磁特性 (4Cole-Cole模型)
- 温度相关的电磁特性
- 依赖于温度的热特性

高牵引电流下的驾驶员安全

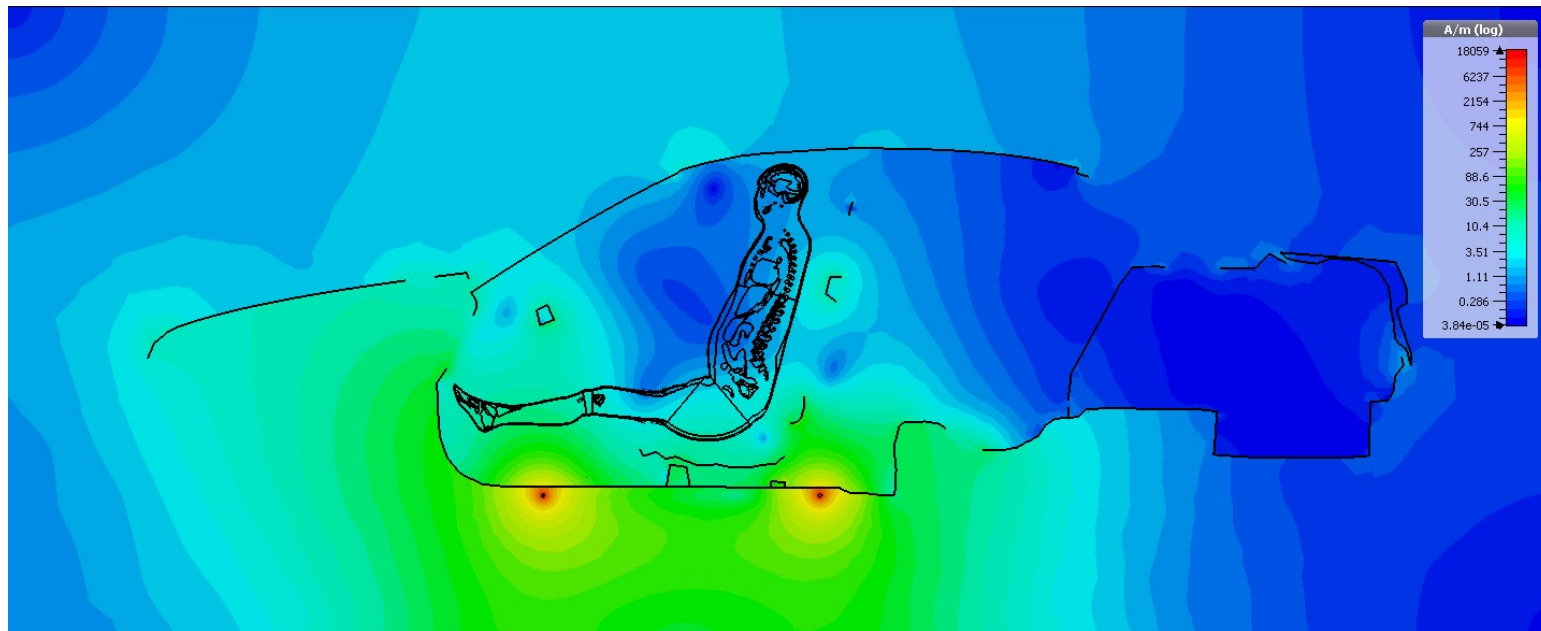
用透明阻抗片建模汽车底盘

基于异构CAD的人体模型Nelly (VHP)



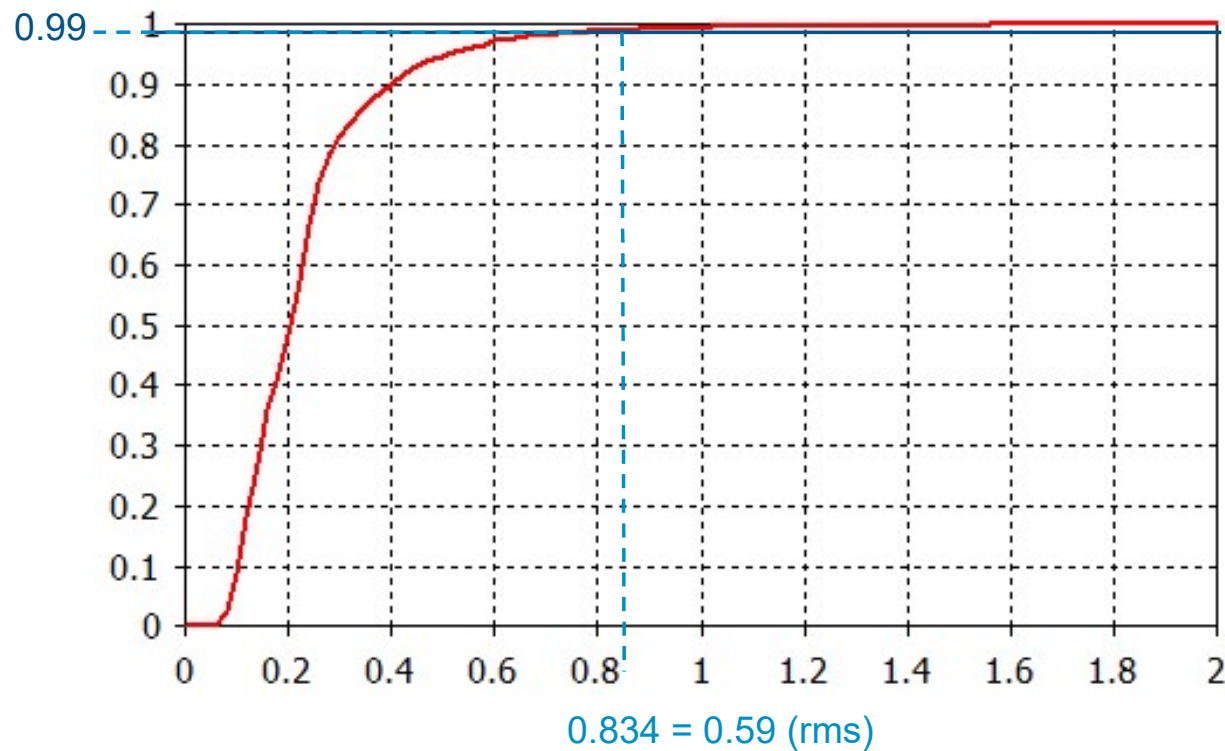
导线在2 kHz时流过480 A的牵引电流

高牵引电流下的驾驶员安全



牵引电流的合规

E-Field Cumulative Histogram in V/m (peak)



人体暴露基本
限制在2 kHz (ICNIRP)

- 职业暴露: 0.8 V/m
- 一般公共暴露: 0.4 V/m

第99百分位为0.59 V/m
(均方根)，高于一般接
触限值。但是：峰值电流
高，需要考虑平均值！

总结

- 仿真对于电动汽车的创新起着至关重要的作用。
- 仿真可以在不同的层次上进行
 - 部件、电机设计、电池和逆变器
 - **EMC/EMI**台架测试
 - 整车仿真
- 仿真可以深入了解与发射有关的问题。
- **SIMULIA**提供标准解决方案和定制工程服务

