

ANSYS



仿真
新时代

2017 ANSYS用户技术大会

中国·烟台

新能源与智能汽车分会场

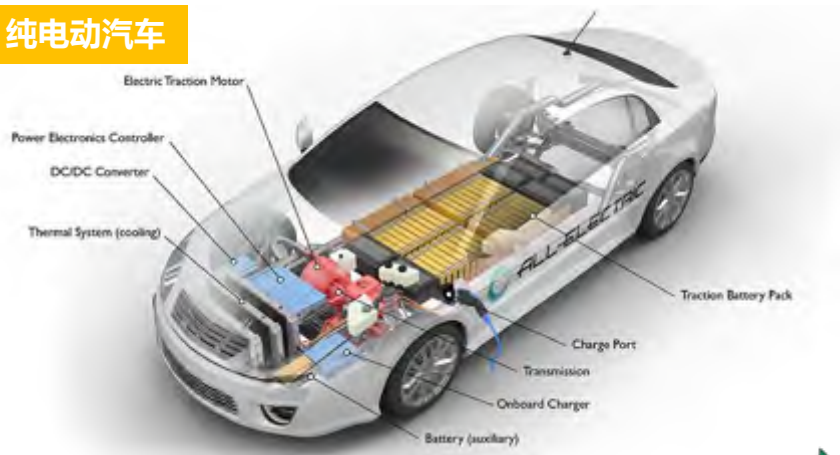
新能源汽车 电机/电池/电驱动 综合仿真与最佳实践

庄百兴/ 华南区技术经理

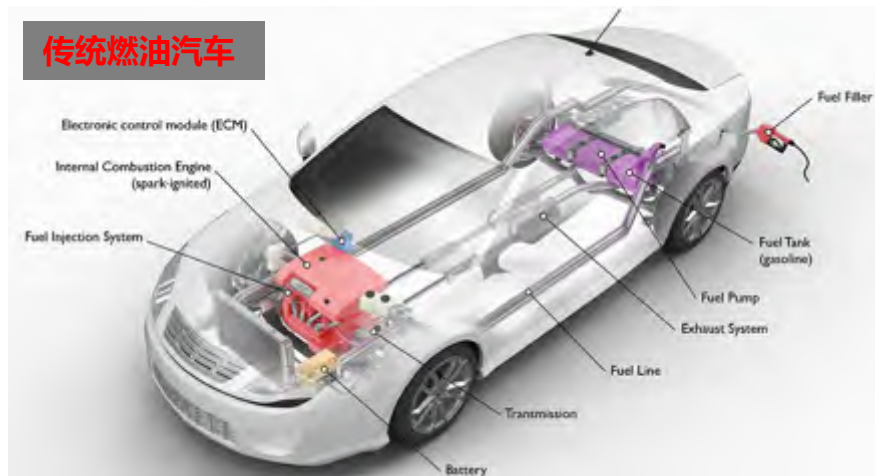
ANSYS深圳

现代汽车发展趋势

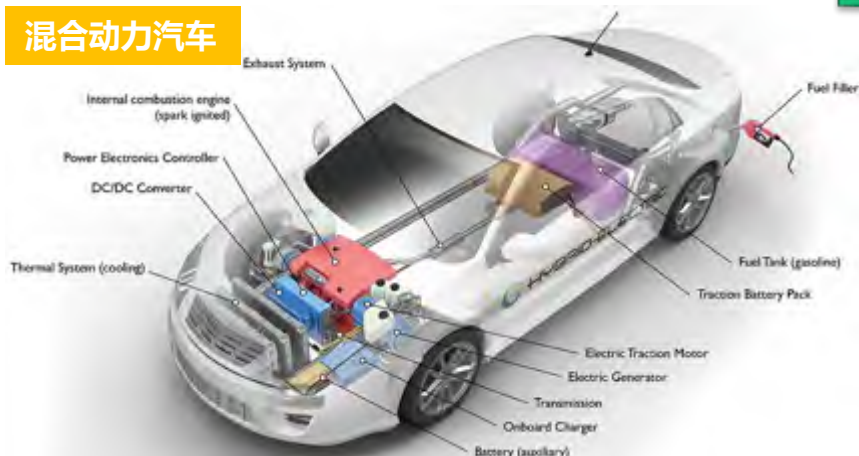
纯电动汽车



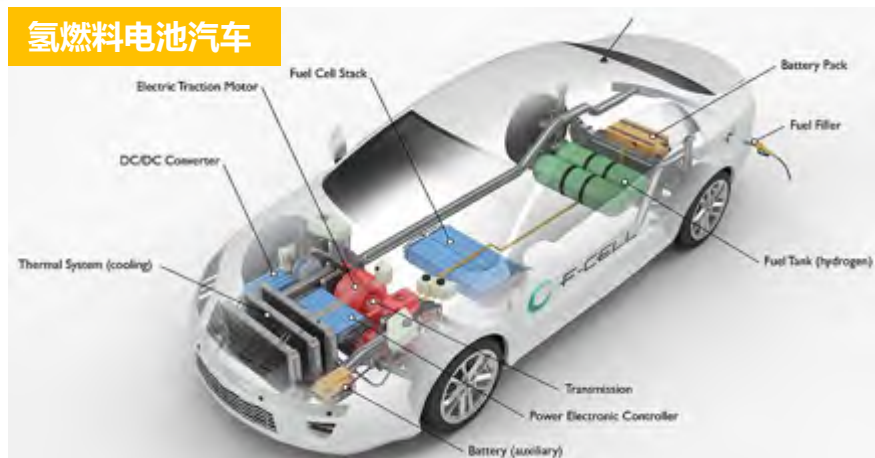
传统燃油汽车



混合动力汽车



氢燃料电池汽车



新能源 + 智能 = 现代汽车必然趋势

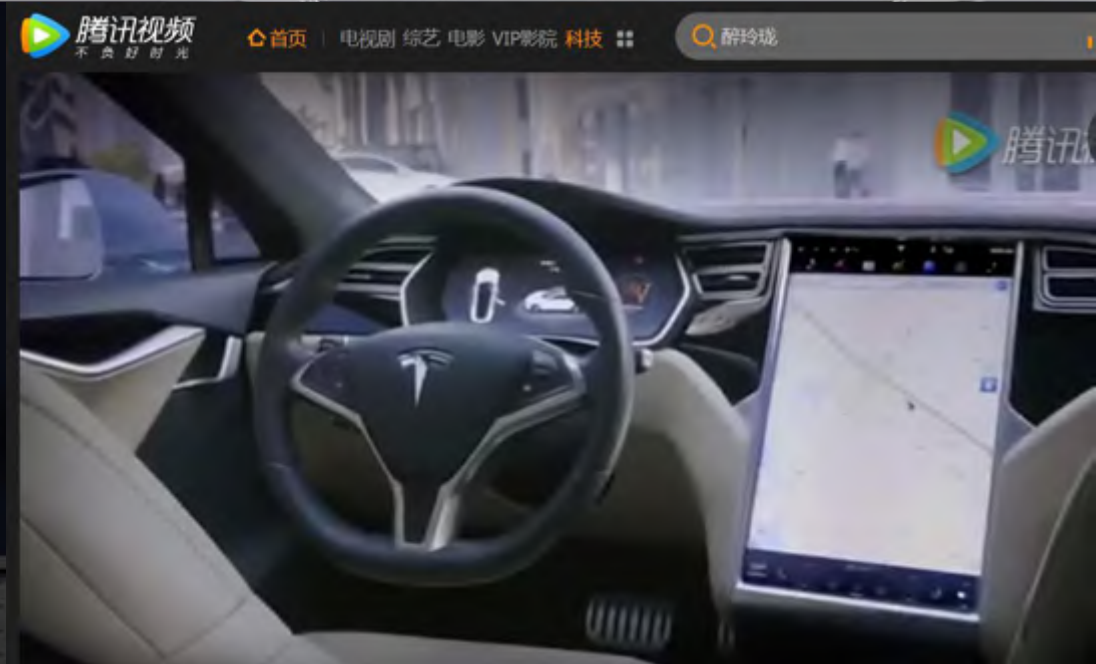
全电气化

百公里加速3.1 秒

轻量化铝制车身

5 星碰撞测试评分

17" 高清触屏



TESLA

新能源汽车的关键技术



动力电池



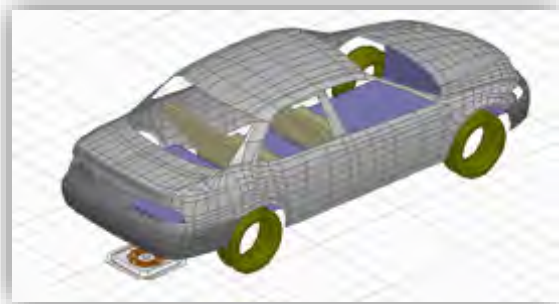
控制器



软件



牵引电机



无线充电

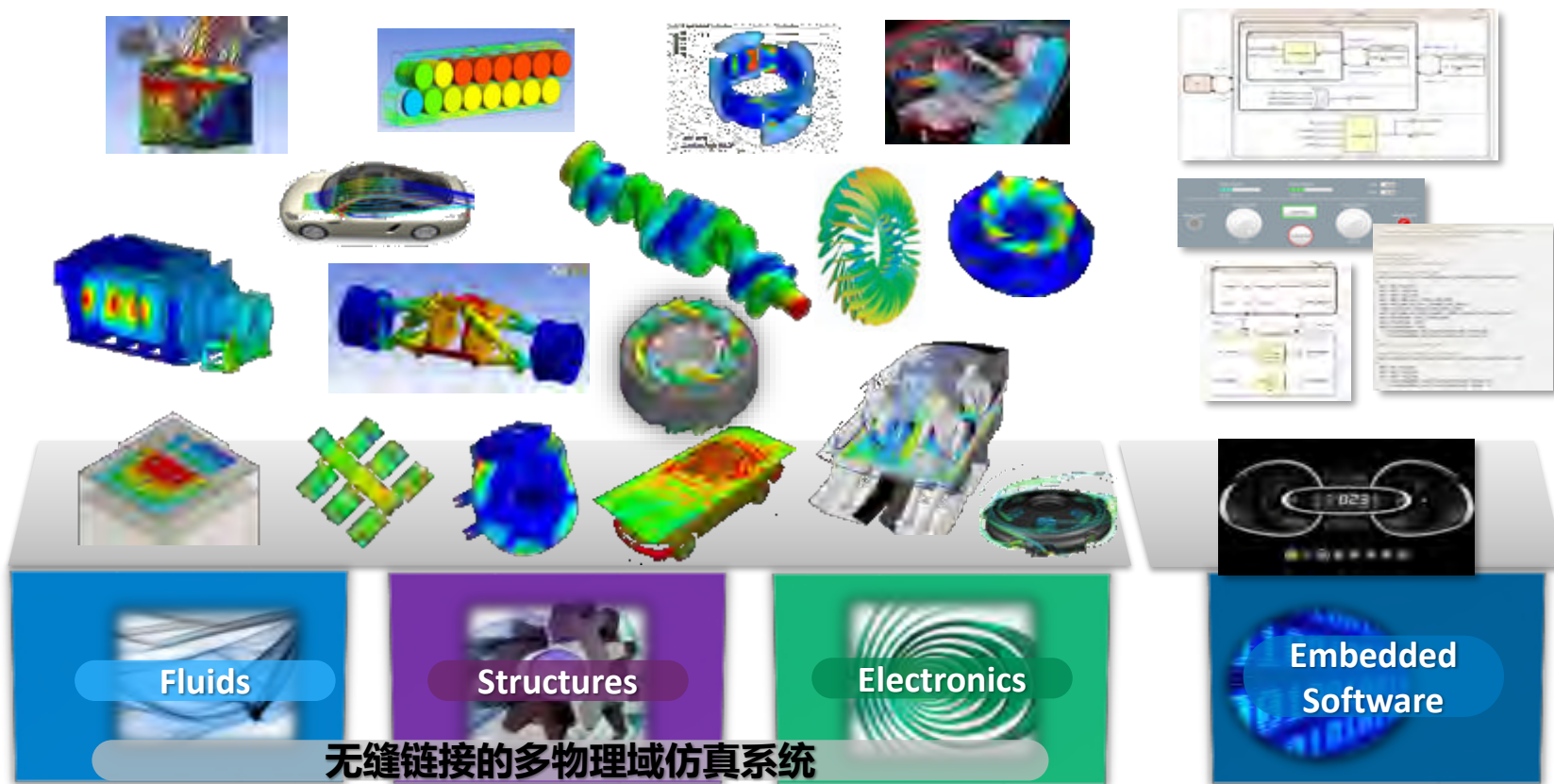


智能驾驶



传动机构

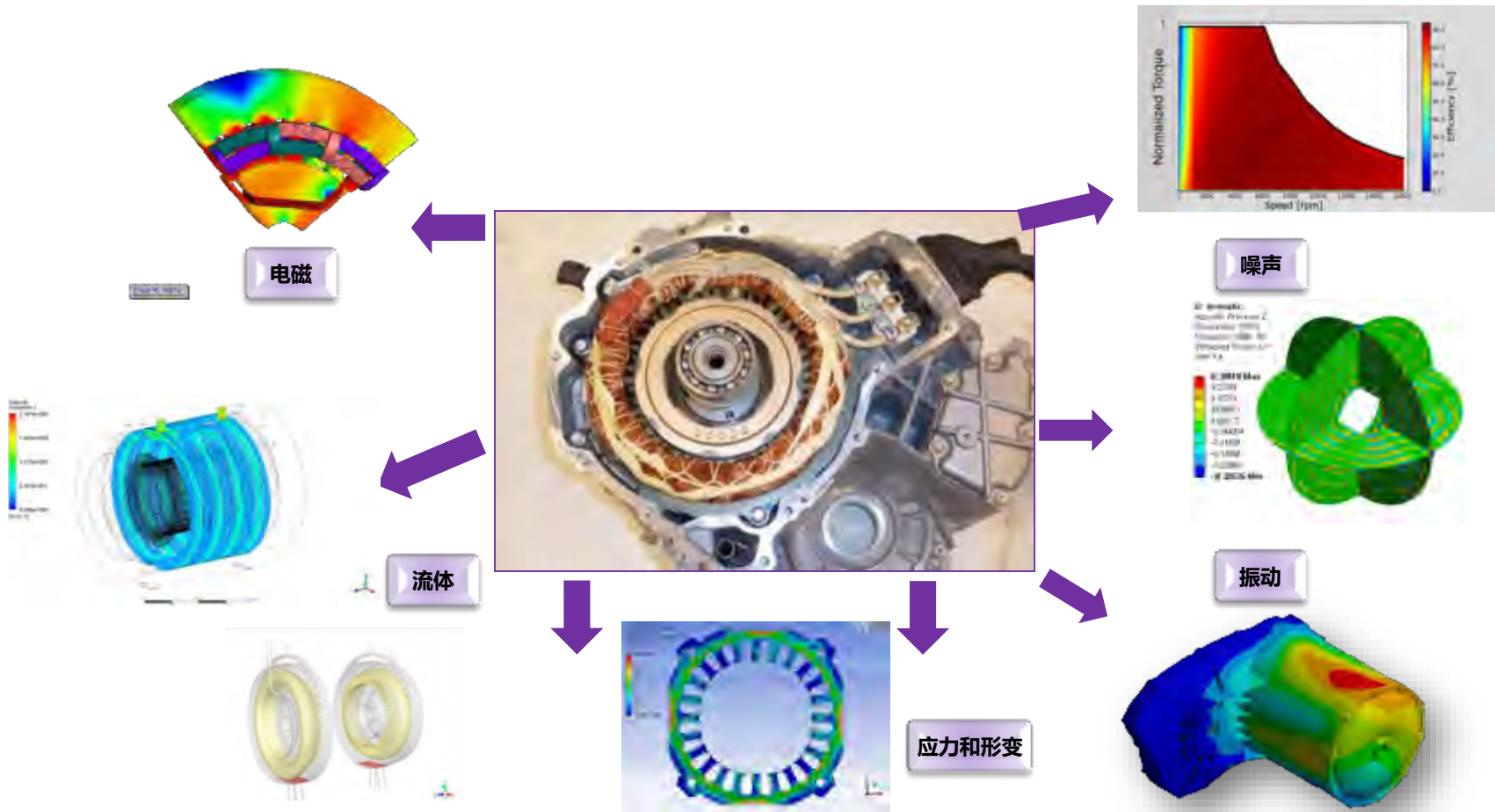
ANSYS 集成化+系统级的零部件+整车仿真系统



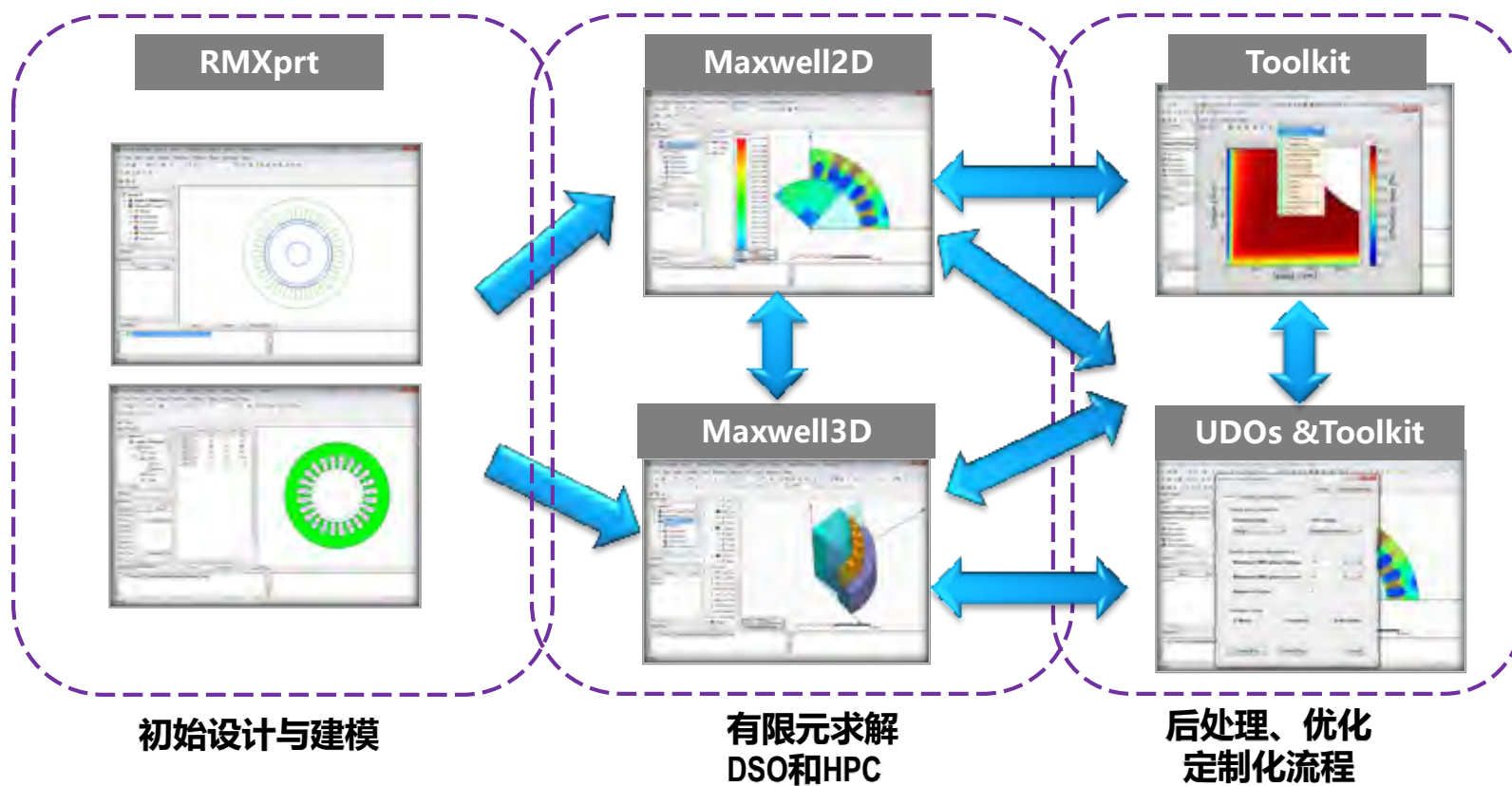
电机

综合仿真与最佳实践

新能源汽车电机本体

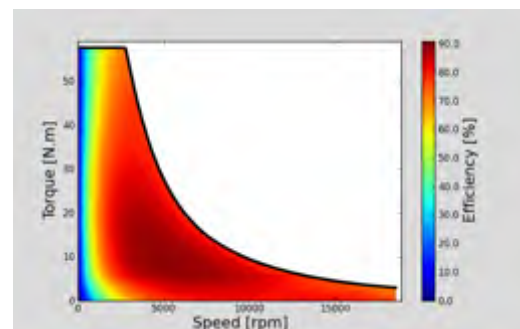
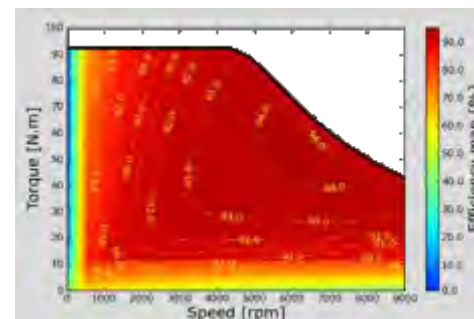
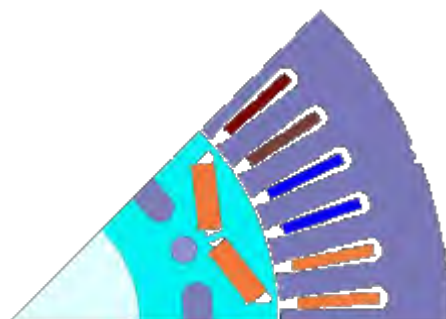


Maxwell高效电机电磁自动化设计流程



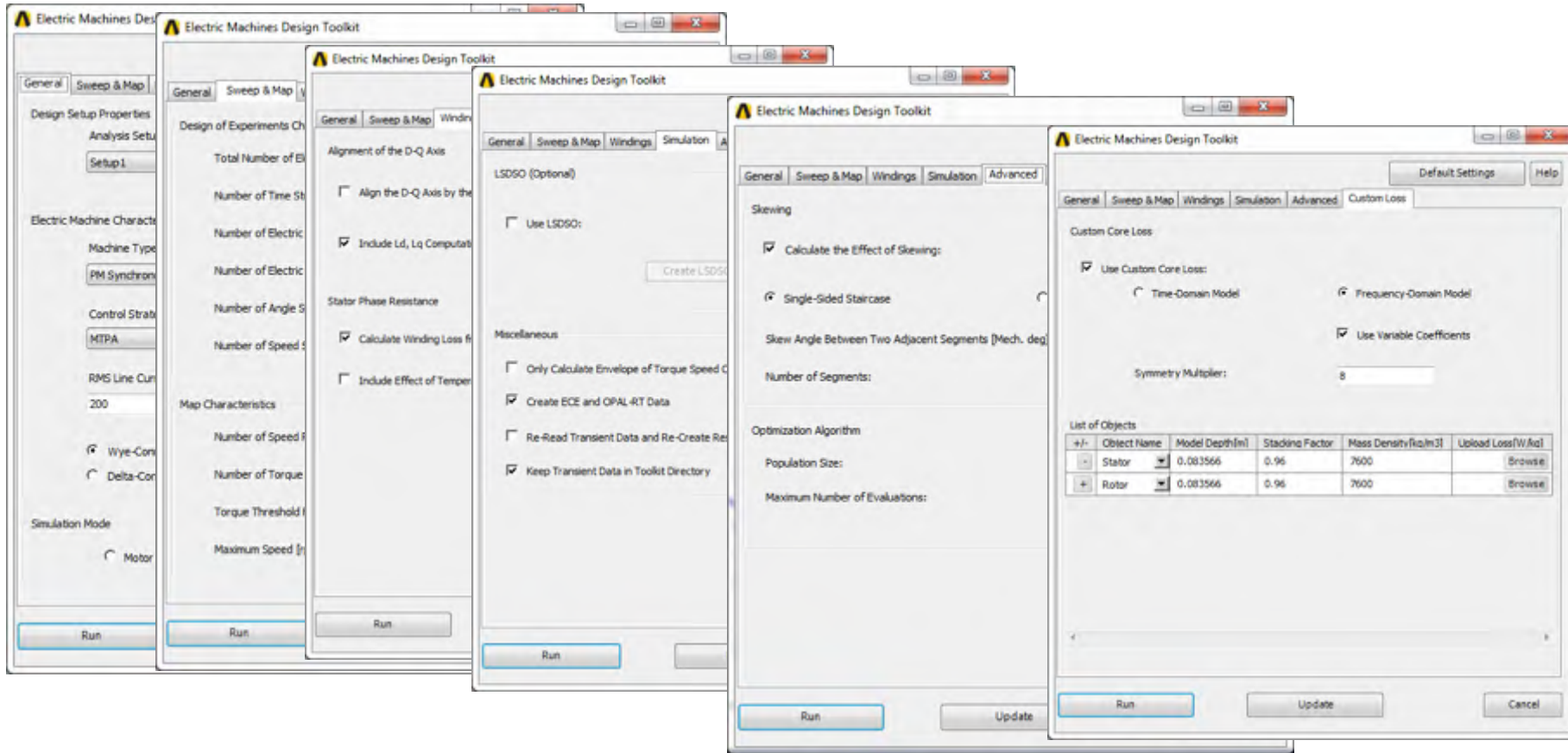
电机设计工具包 (UDO/Toolkits)

- OutputPower
- OutputPower
- Torque
- Speed
- PowerFactor
- SupplyCurrent
- PhaseVoltage
- CoreLoss
- SolidLoss
- StrandedLoss
- MechanicalLoss
- TotalLoss
- Efficiency
- TorqueRipple
- PowerBalance
- V(d-axis)
- V(q-axis)
- I(d-axis)
- I(q-axis)
- L(d-axis)
- L(q-axis)
- FluxLinkage(d-axis)
- FluxLinkage(q-axis)

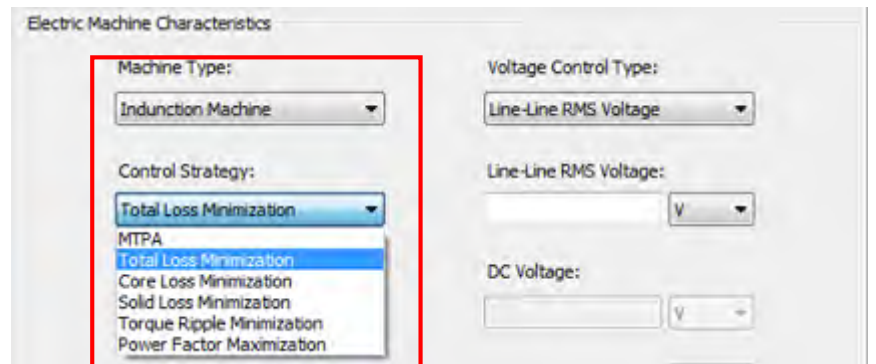
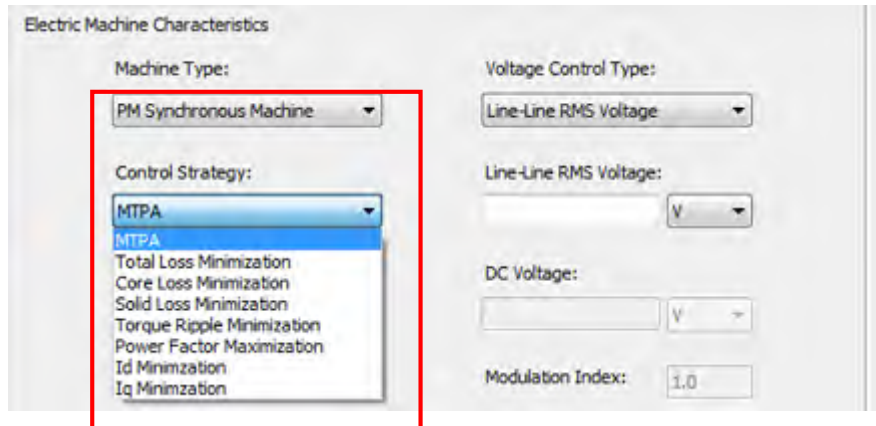
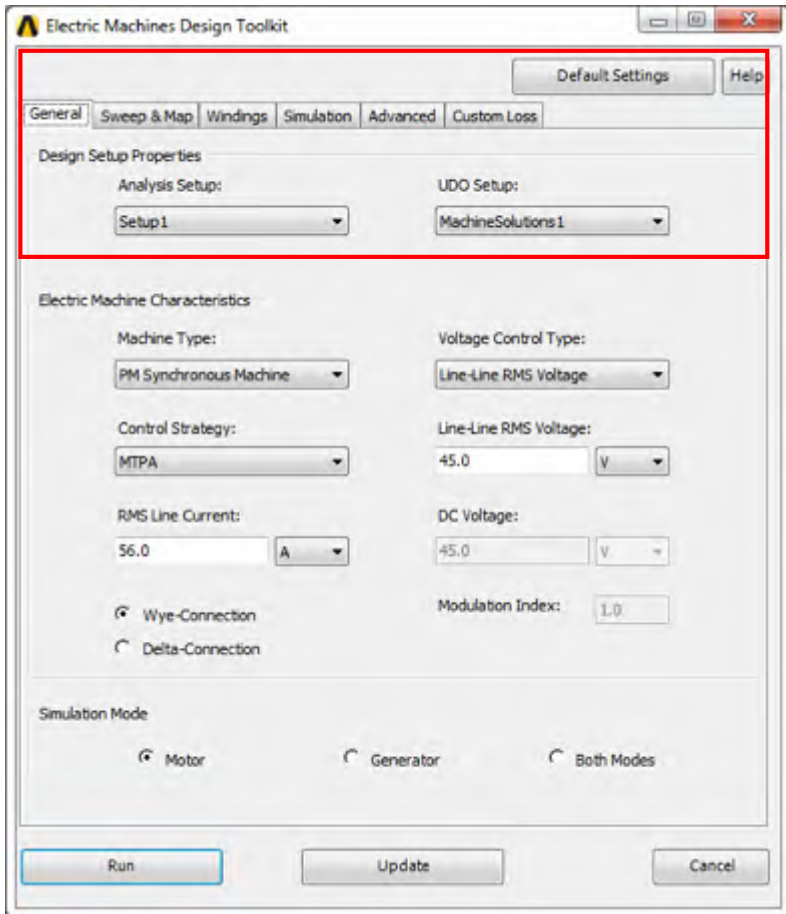


- UDO和Toolkits是针对客户需求定制化开发的电机设计工具包，可直接输出电机电磁性能数据，自动化计算转矩转速特性、效率Map图等，在电机设计领域应用广泛。

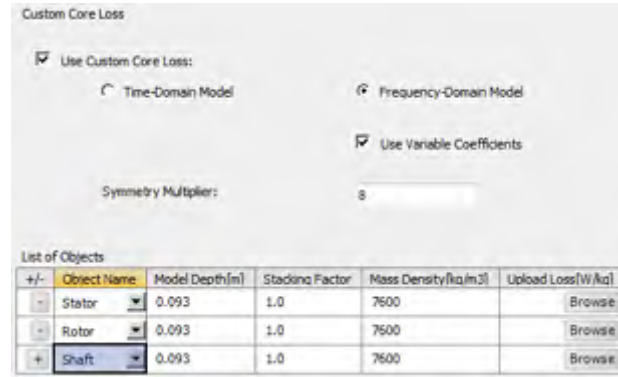
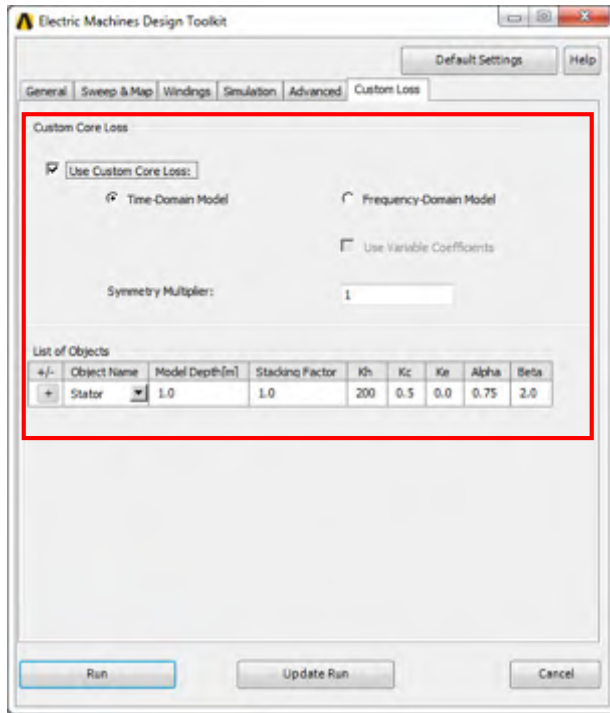
ToolKits案例：IPM效率Map图计算



选择多种控制算法和电压控制方式



集成了自定义铁耗算法

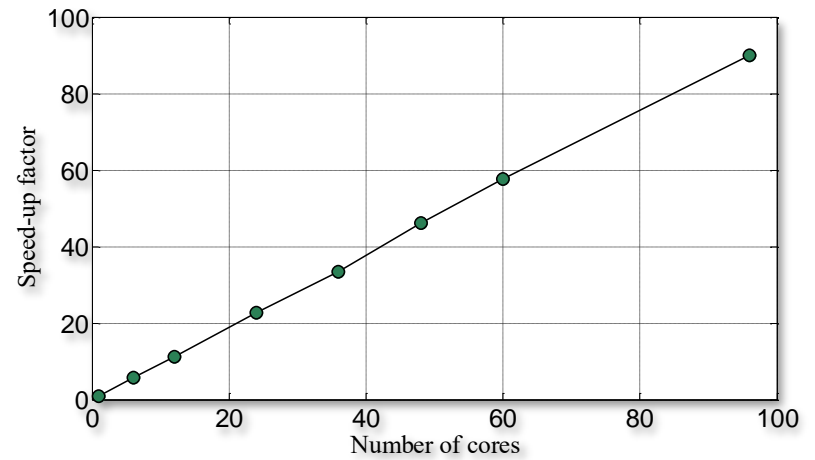
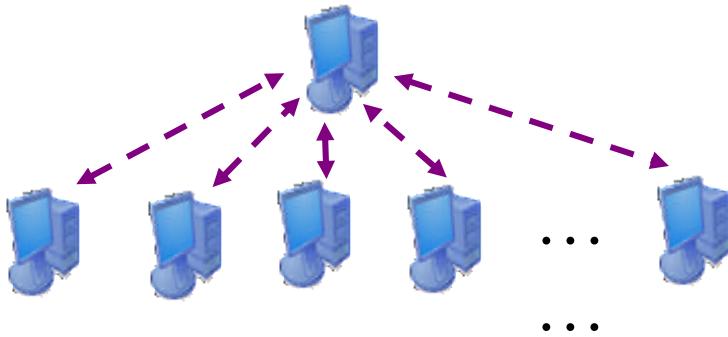


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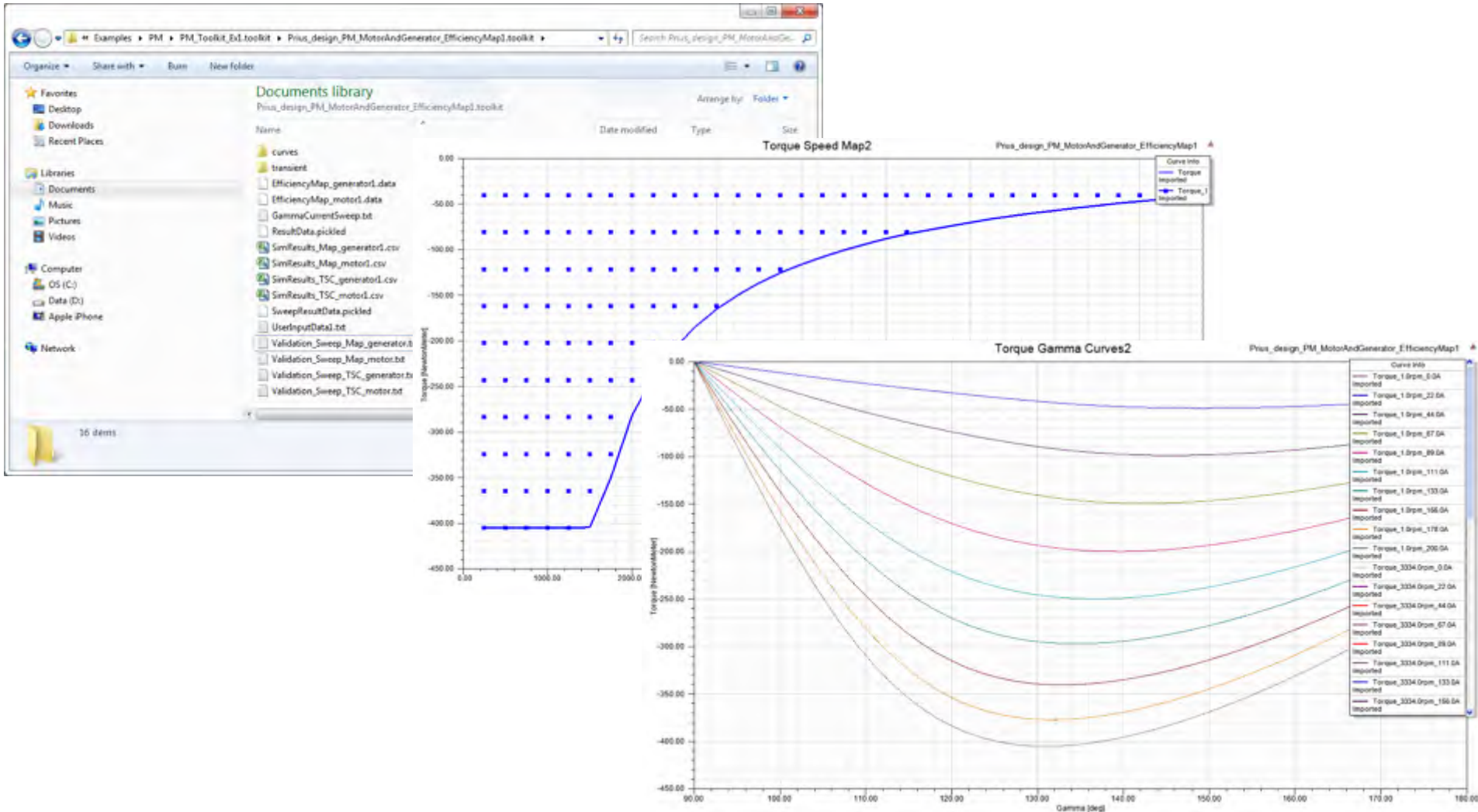
***ERROR***
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...

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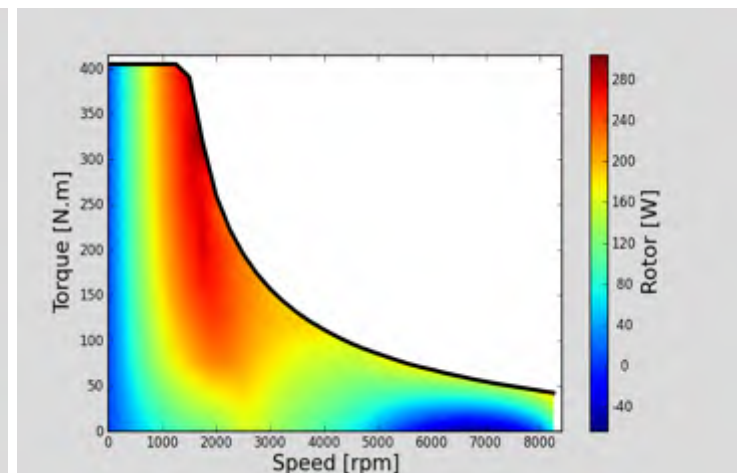
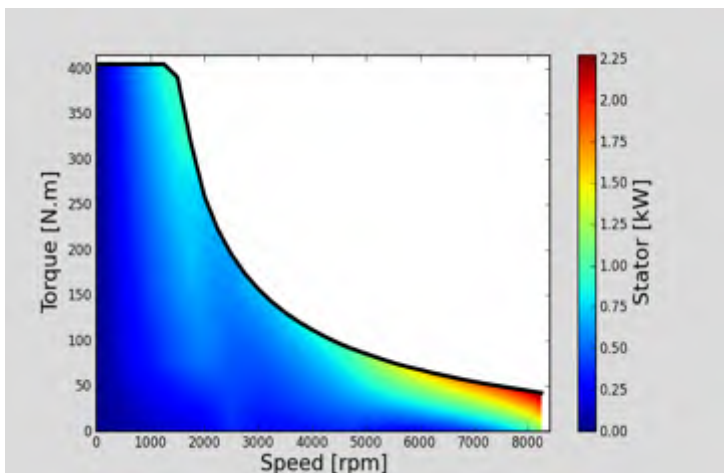
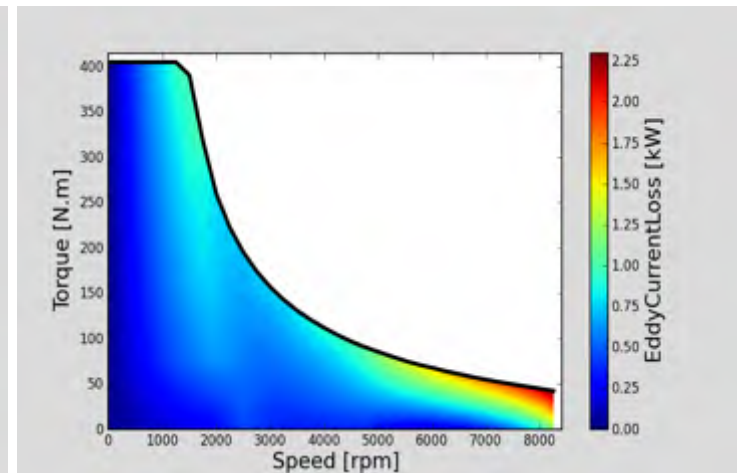
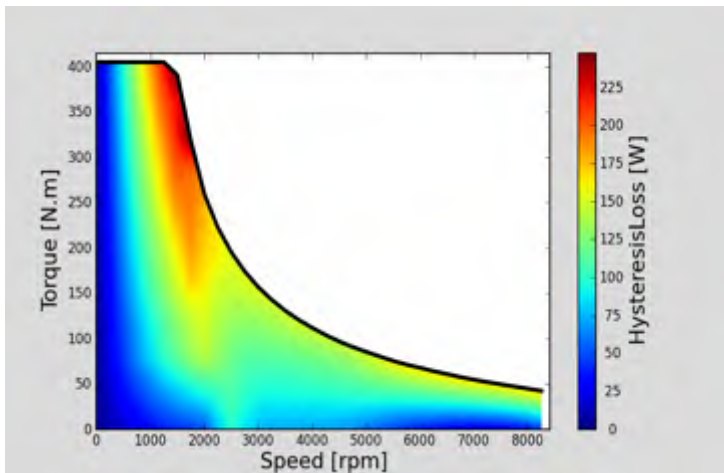
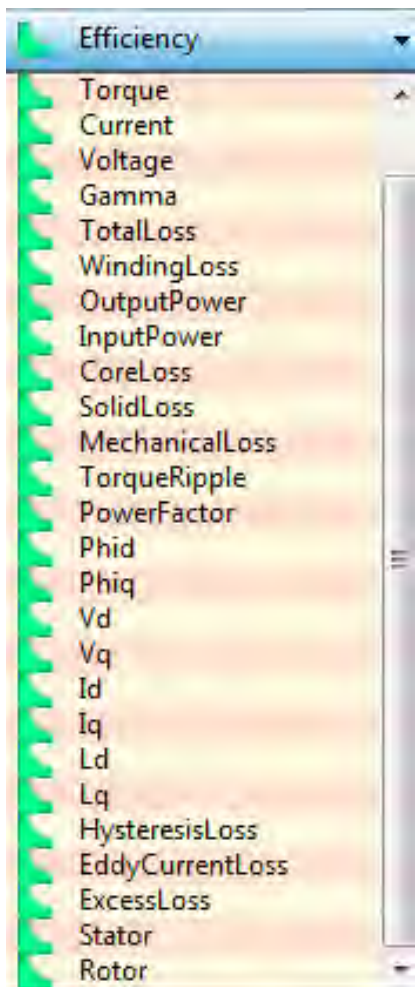
大规模分布式计算加速分析



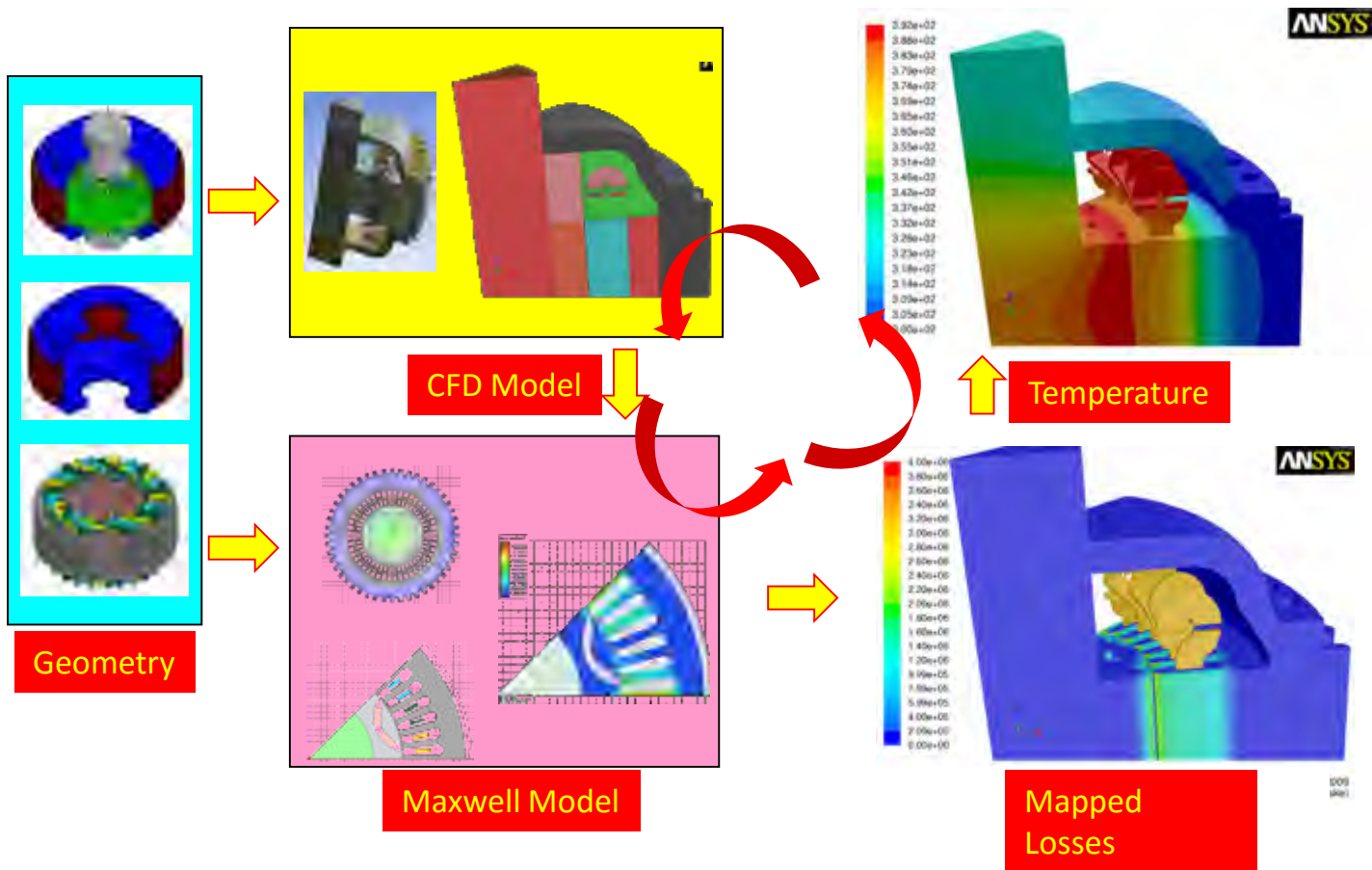
ToolKits : IPM效率Map图



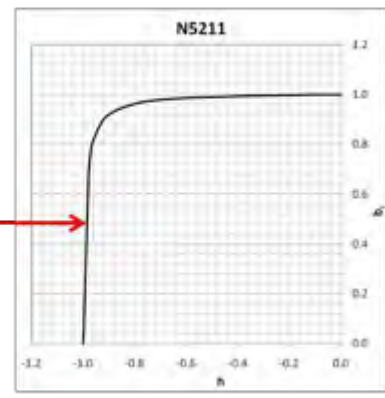
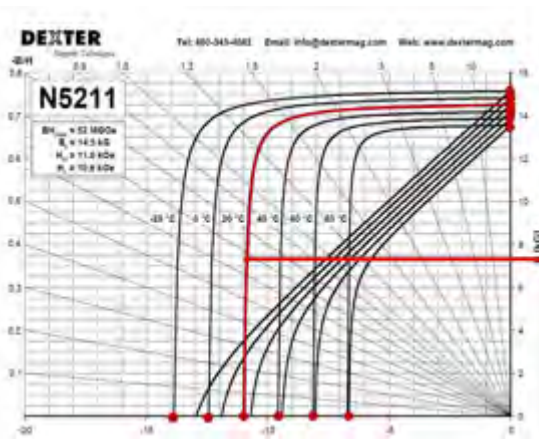
ToolKits : IPM效率Map图



电机温升、散热分析流程



考虑磁钢温度特性的电机特性仿真

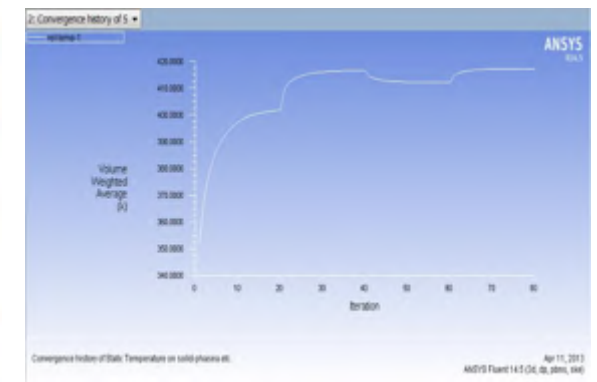
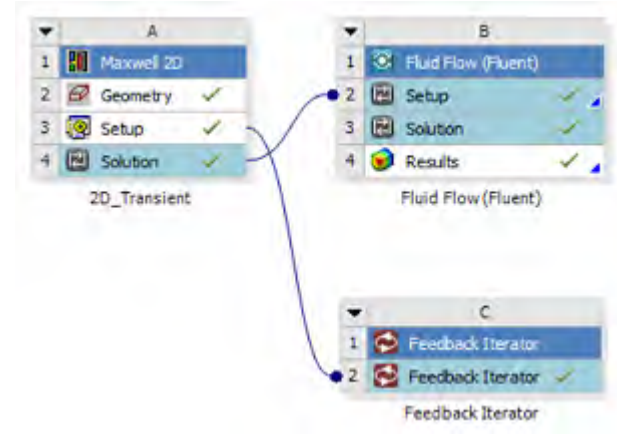
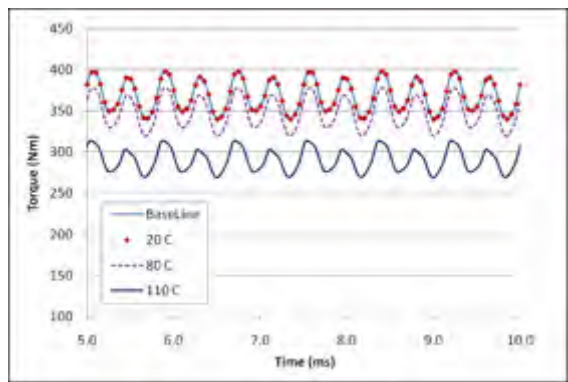


View / Edit Material

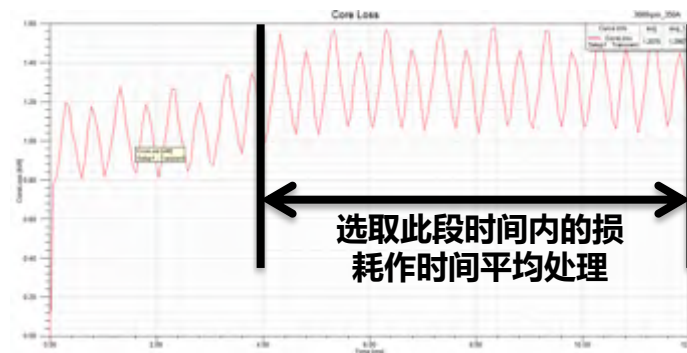
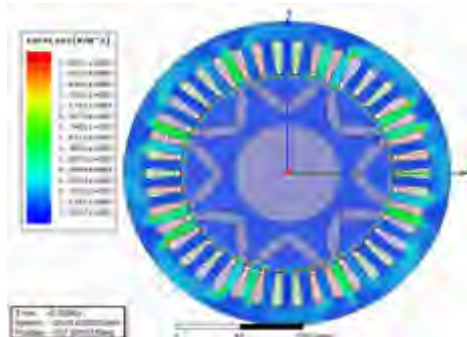
Material Name: N5211

Material Coordinate System Type: Cartesian

Name	Type	Value	Unit	Thermal Modifier
B-H Curve	Table	B-H Curve		1.0000000000000000
Bulk Conductivity	Simple	625000	siem	None
Magnetic Field	Vector			
Magnitude	Vect	-11.01518919	kOe	1.000651752*(Tc - T)
-X Component	Unit V	1		
-Y Component	Unit V	0		
-Z Component	Unit V	0		
Core Loss Model	None		w/m ³	
Mass Density	Simple	0	kg/m ³	None
Composition	Solid			

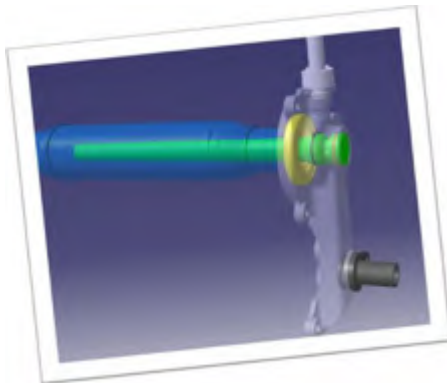
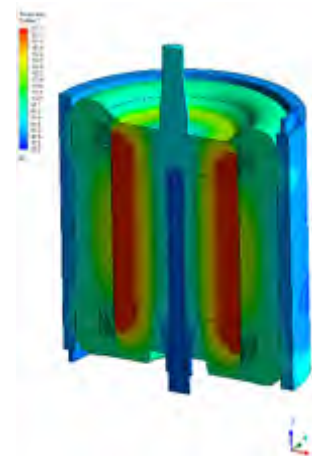
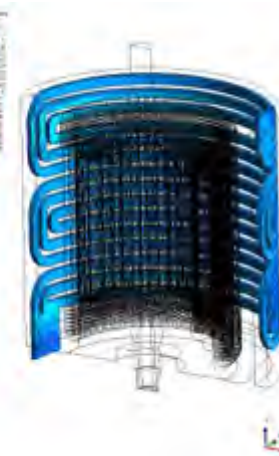
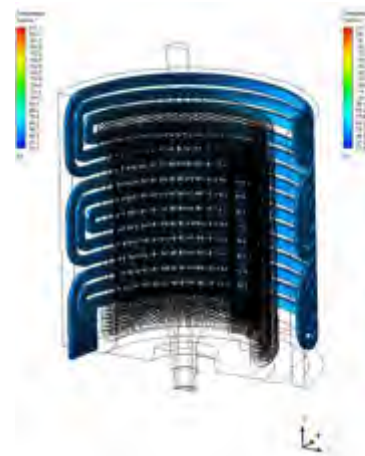
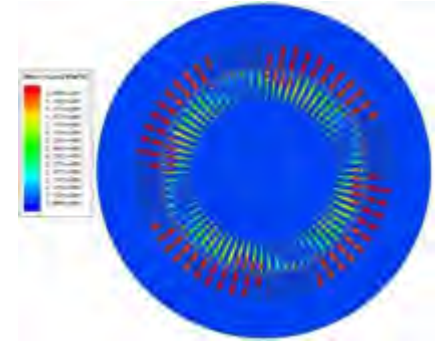
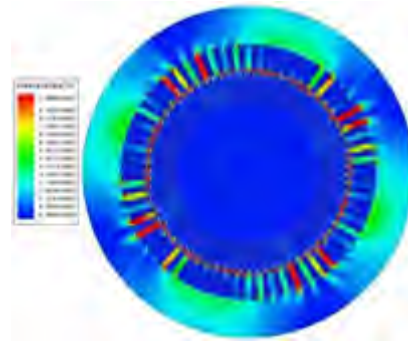


永磁电机定子水冷仿真

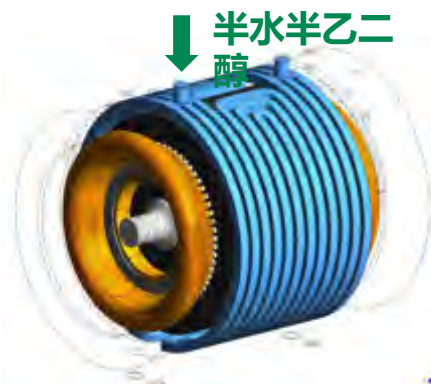


	实验值 °C	计算值 °C
进水口和出水口温升	2.4	2.58
绕组温度	137	132.5
机壳点201温度	46.5	48.7
机壳点201温度	48	53
机壳点201温度	45.9	47.2
机壳点201温度	45.8	47.7

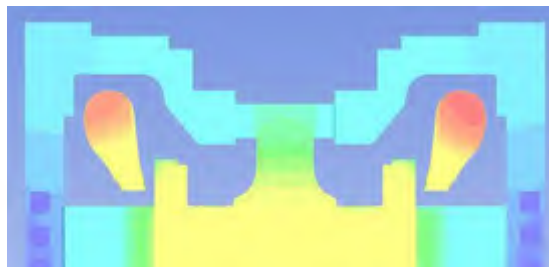
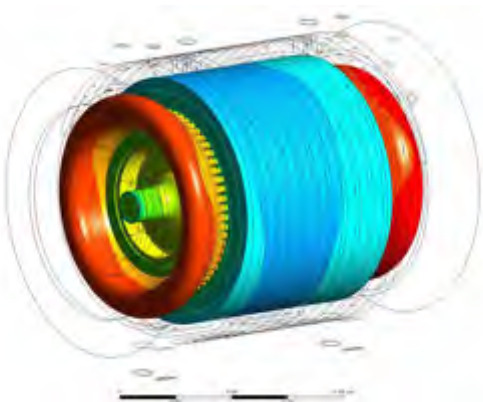
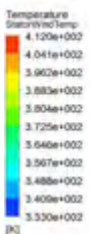
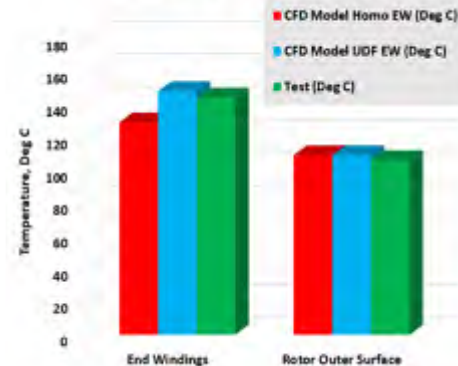
三相感应电机液冷仿真



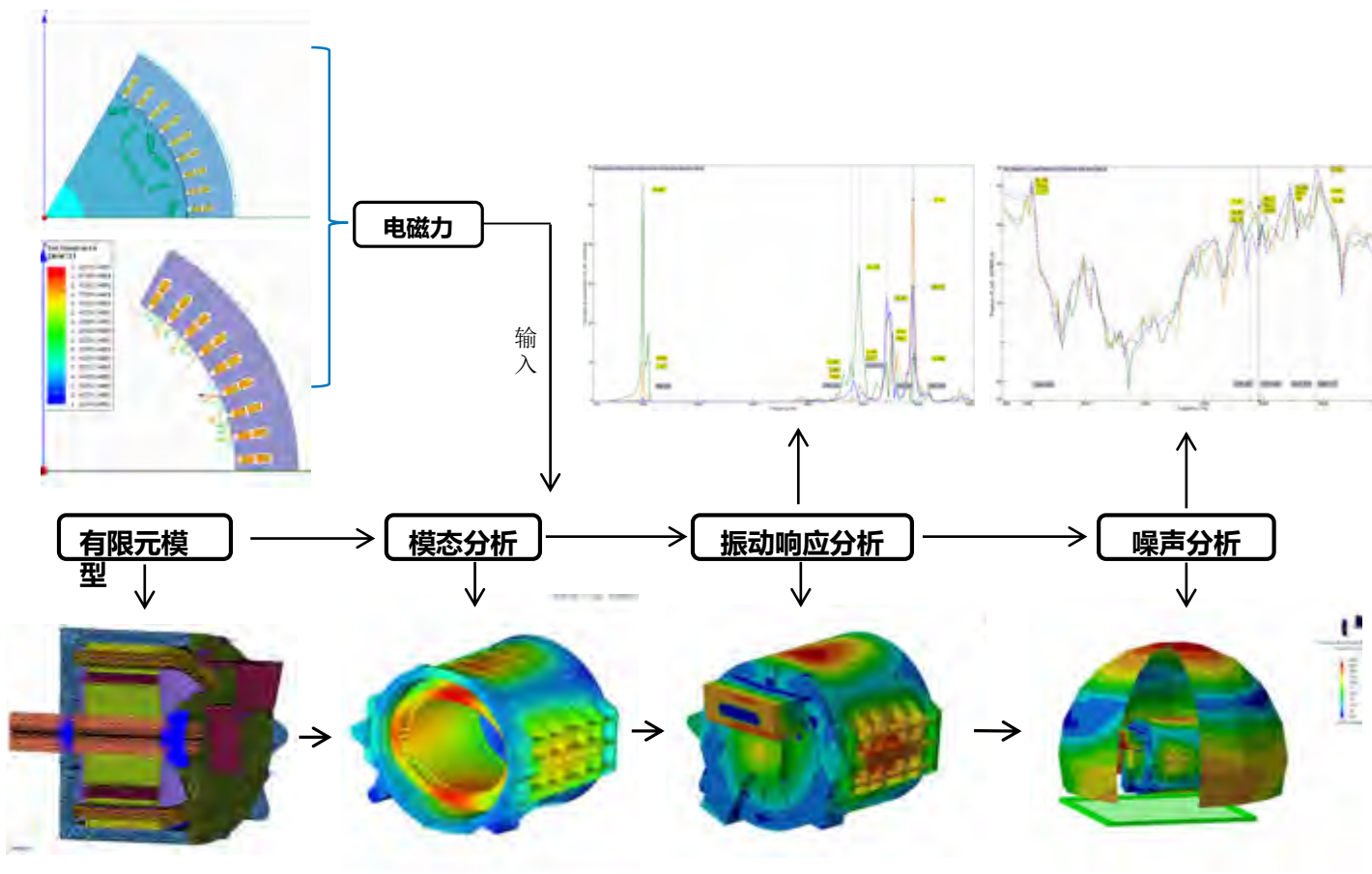
三相感应电机喷油及液冷仿真



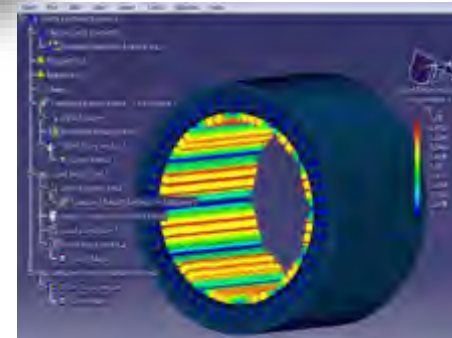
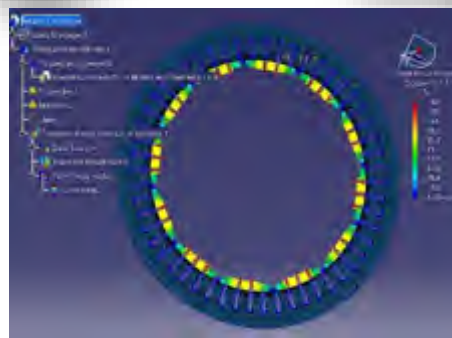
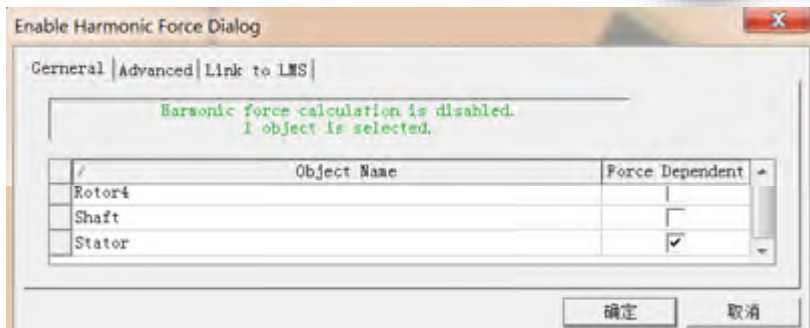
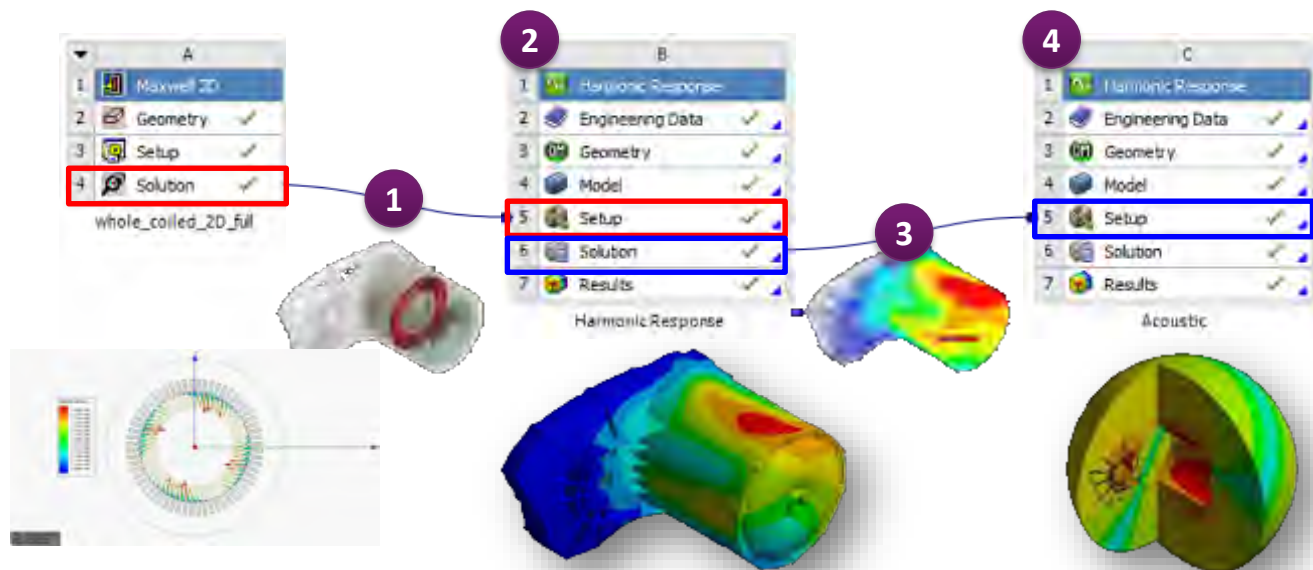
CFD Thermal Model - Iteration # 5



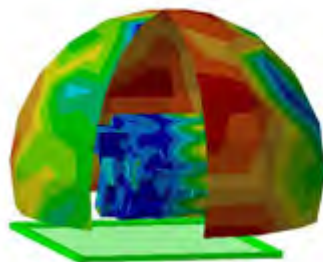
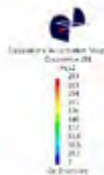
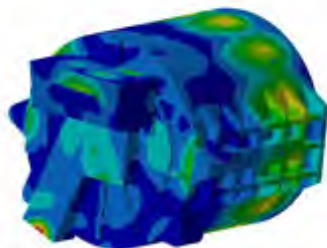
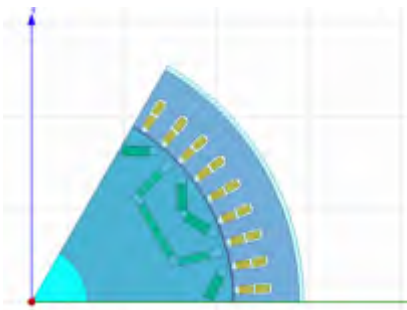
电机电磁振动噪声耦合分析流程



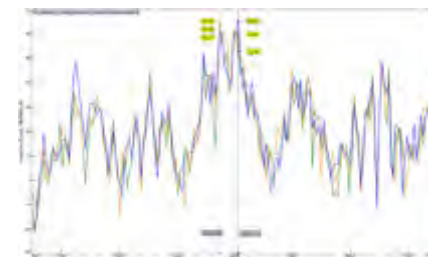
电磁力与振动分析的两种耦合流程



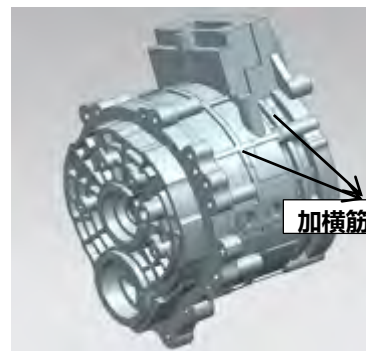
振动噪声分析案例



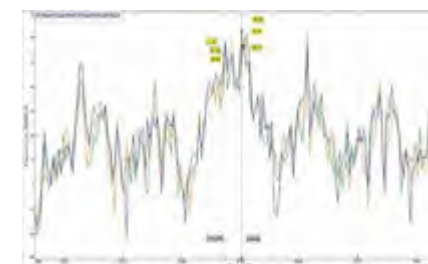
优化前



优化前：电机在3740Hz和4060Hz处存在共振，噪声分别为65.09和65.03dB (A)。



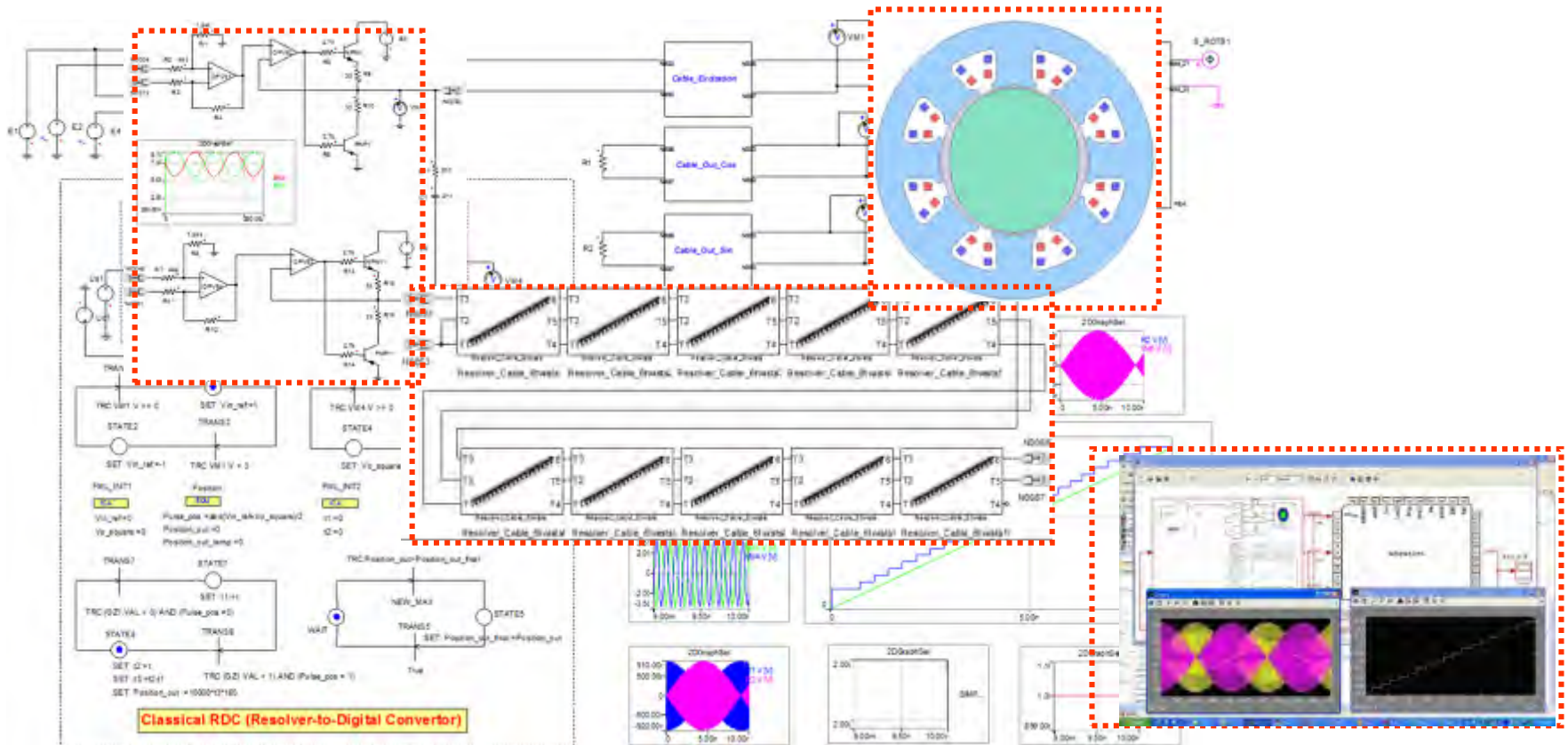
优化后



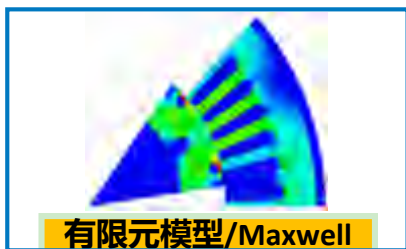
优化后：电机在3739Hz和4024Hz处存在共振，噪声分别为57.83和62.59dB (A)。

旋转变压器及其控制器仿真

详见IEEE VPPC2008论文

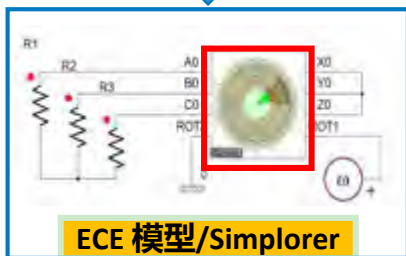


电机ECE模型抽取

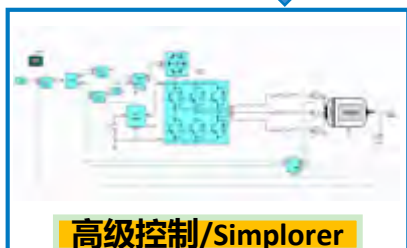


有限元模型/Maxwell

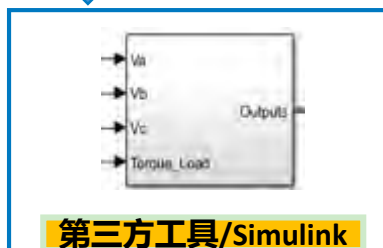
↓ Extraction



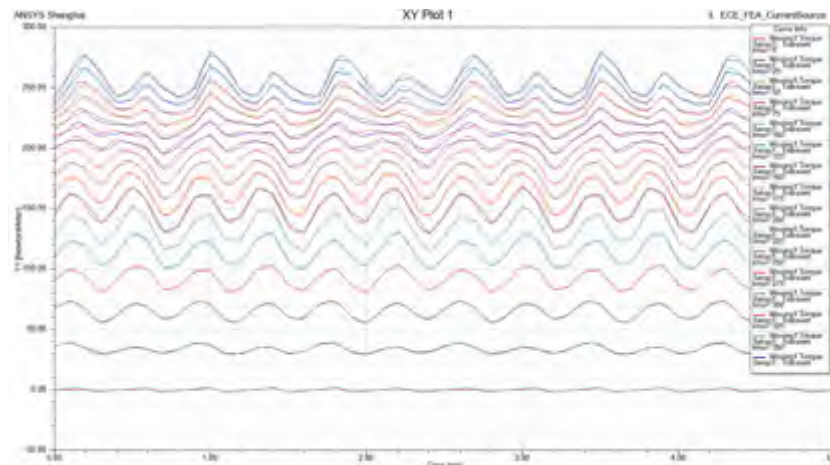
ECE 模型/Simplorer



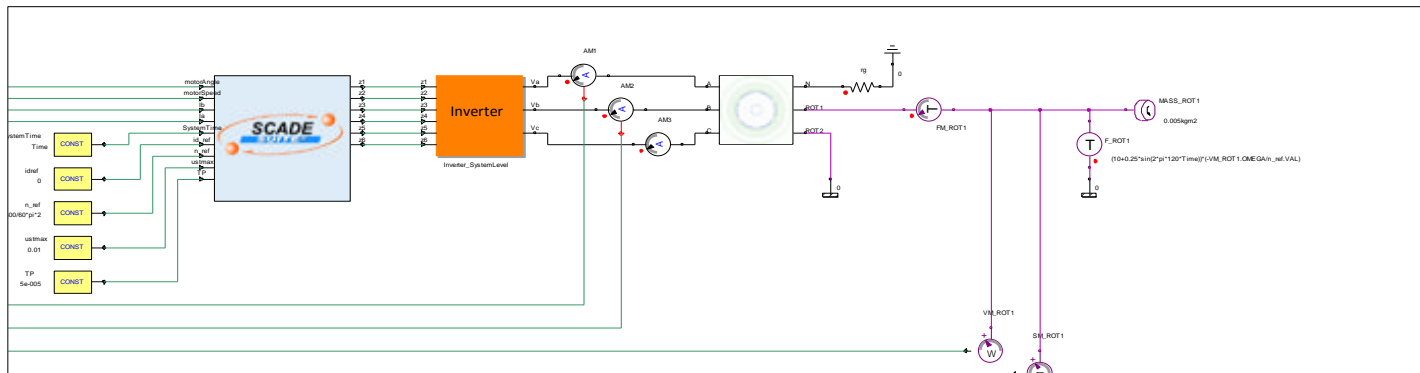
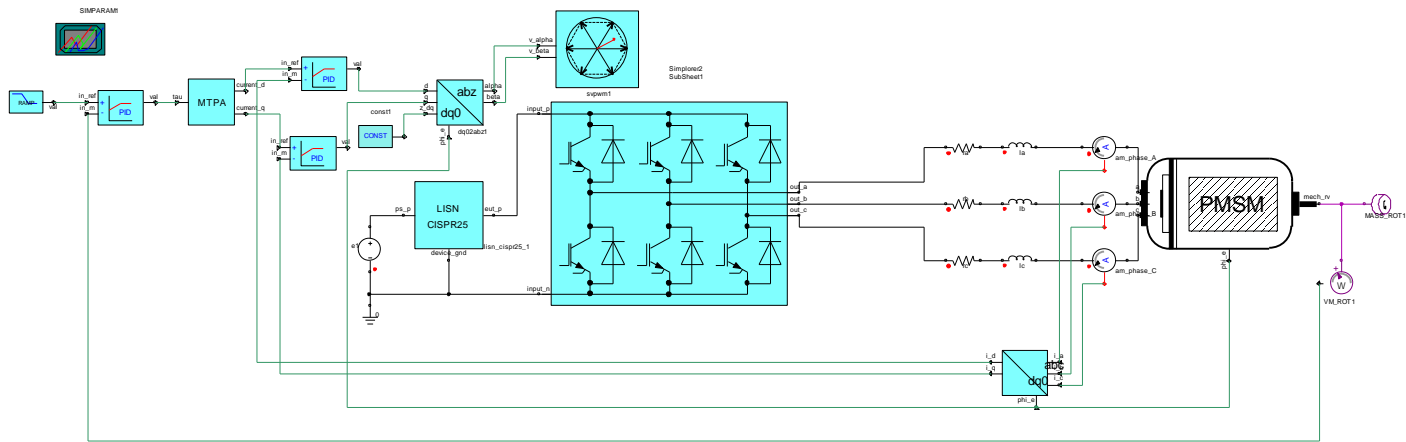
高级控制/Simplorer



第三方工具/Simulink

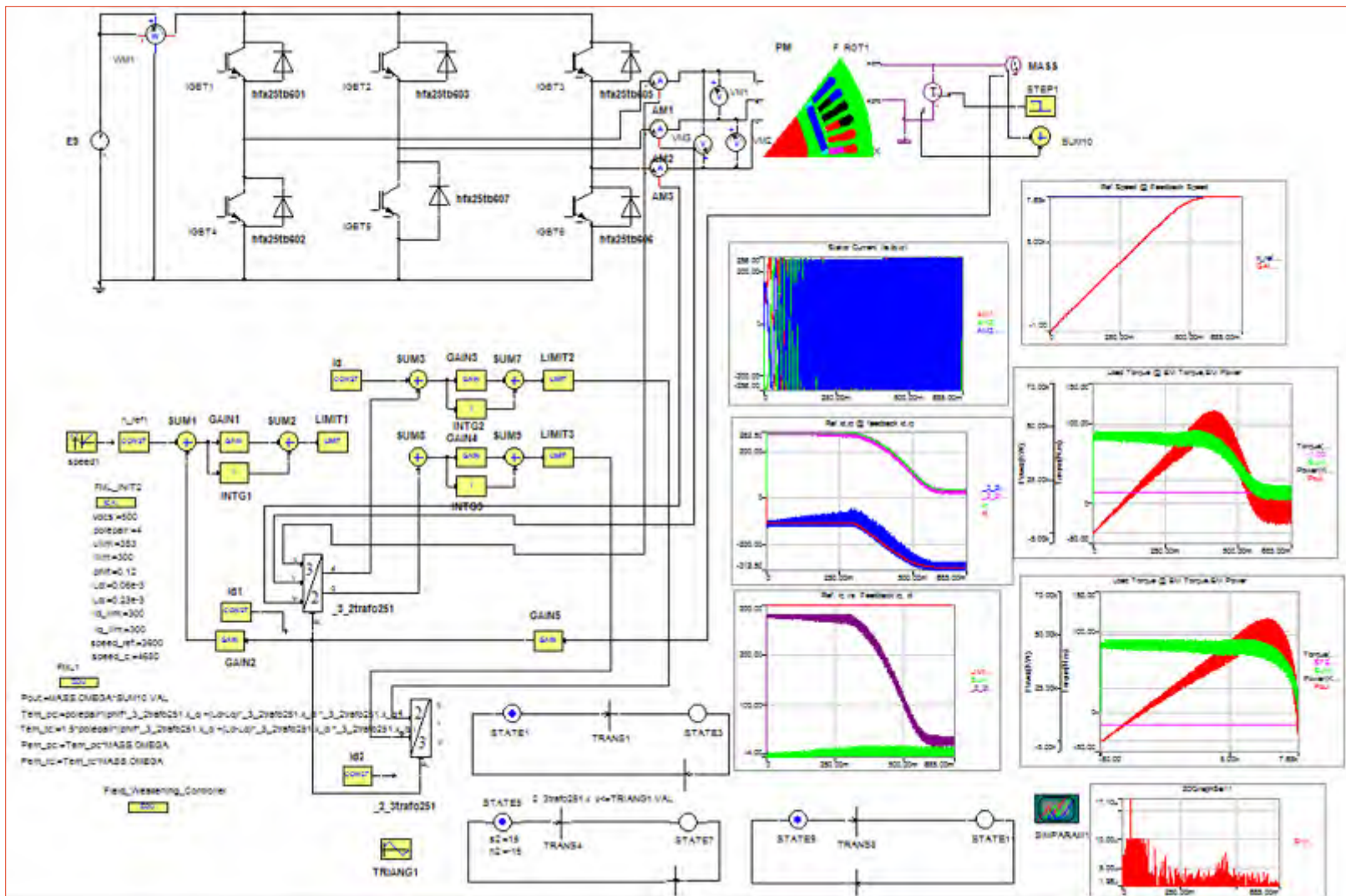


PMSM 高级控制仿真

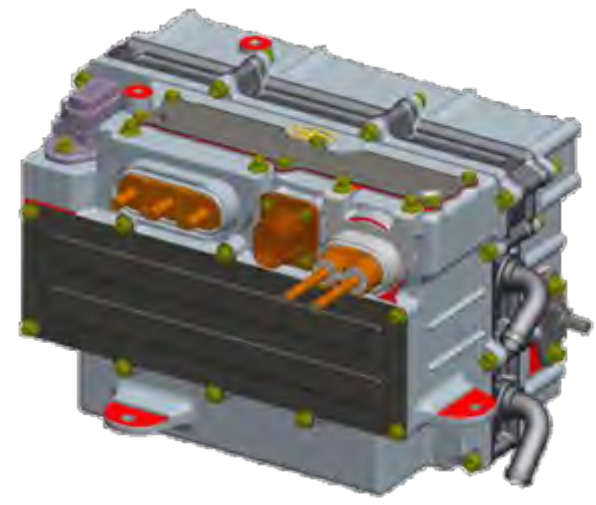
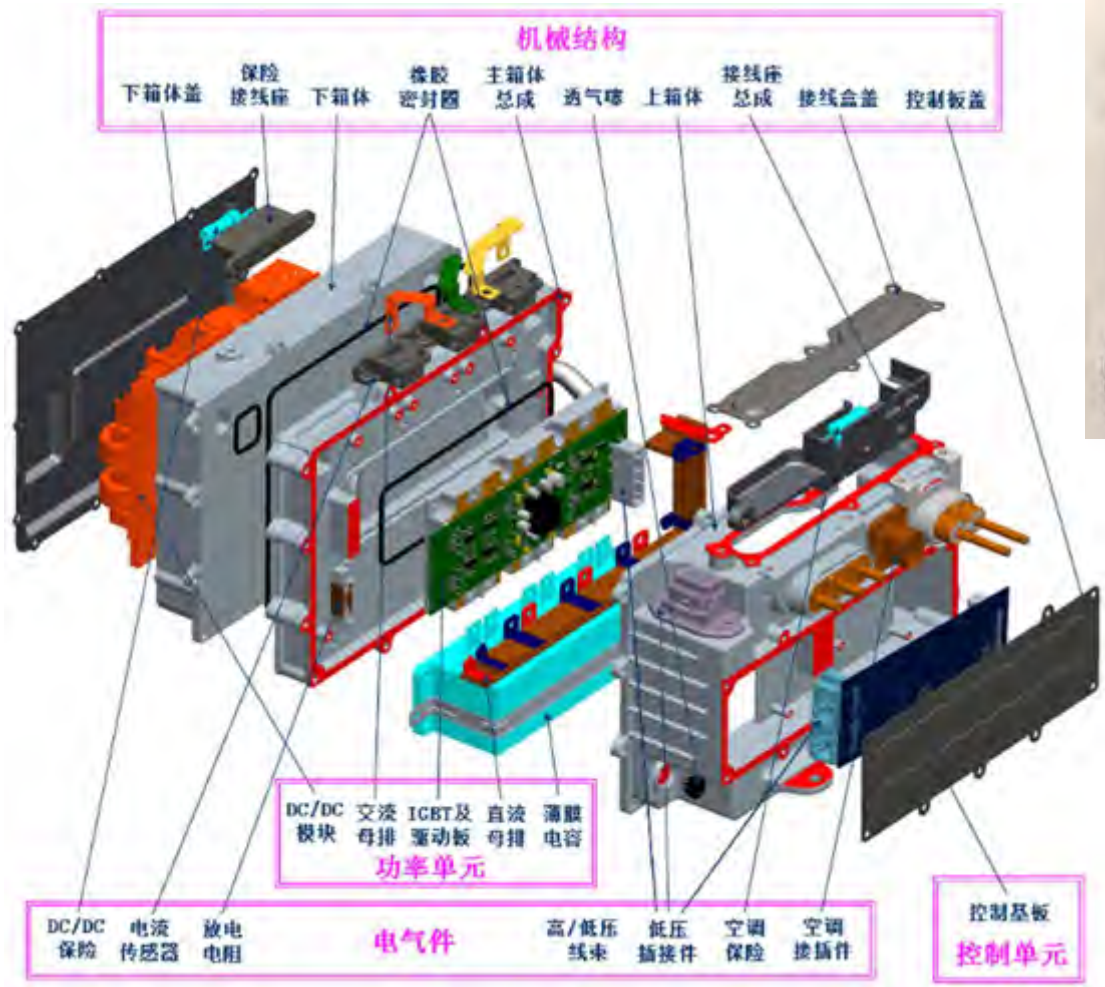


电驱动/逆变器 综合仿真与最佳实践

IPM弱磁控制调速



1. 结构复杂

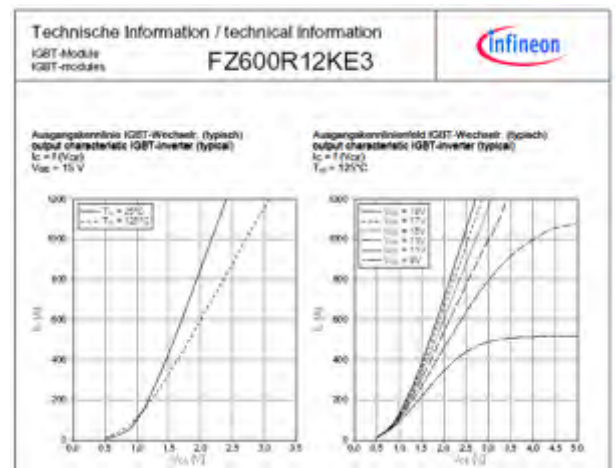


开关器件物理原型建模

专业IGBT开关器件物理原型建模工具，可生成包含MC特性的IGBT模型



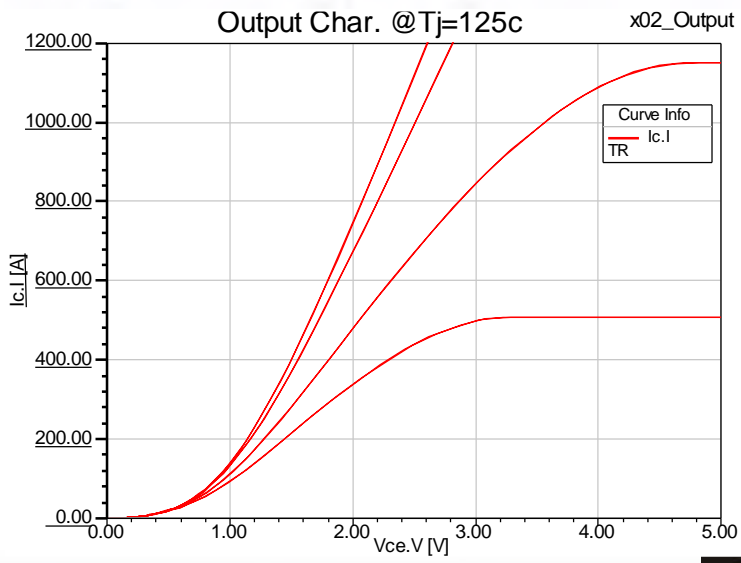
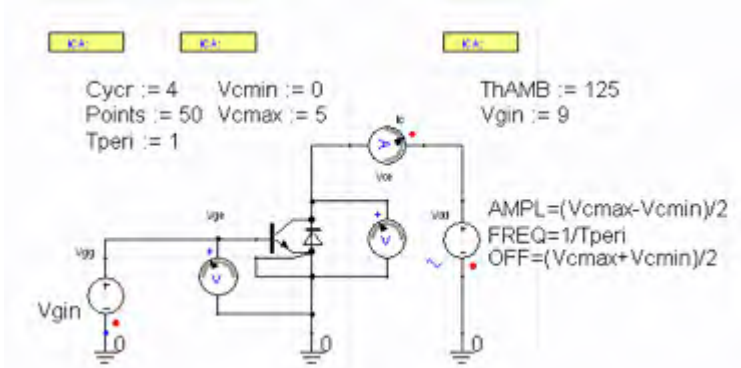
Infineon : FZ600R12KE3



数据手册



参数提取工具

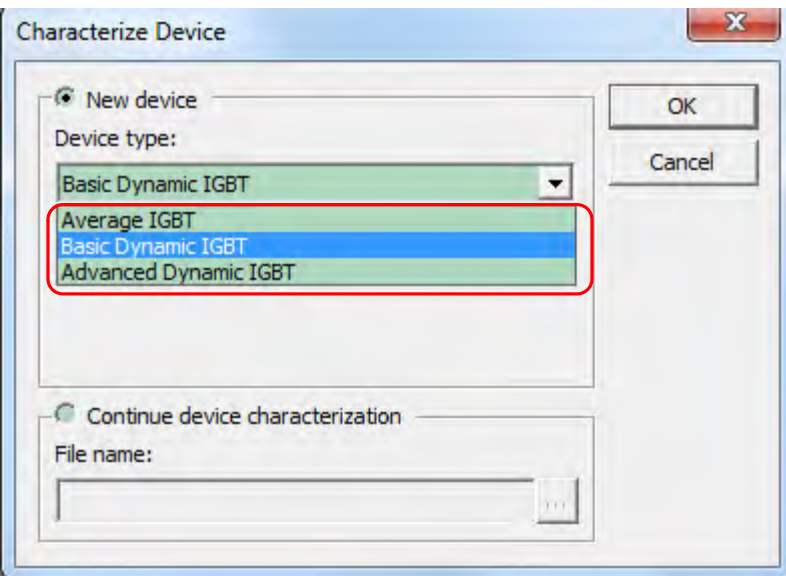
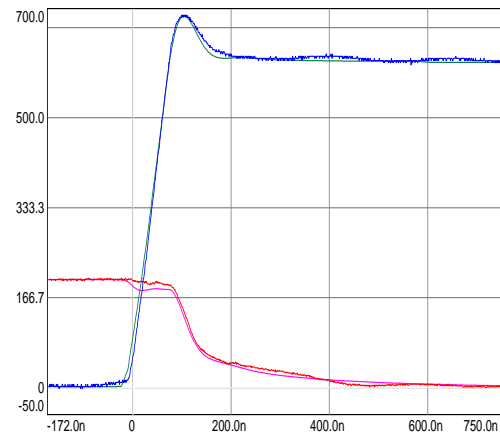
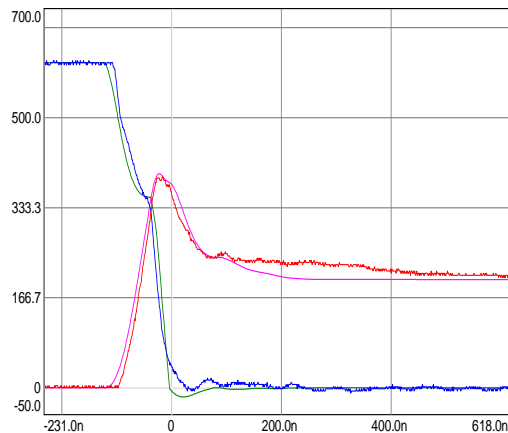


输出特性曲线 Vce-Ic

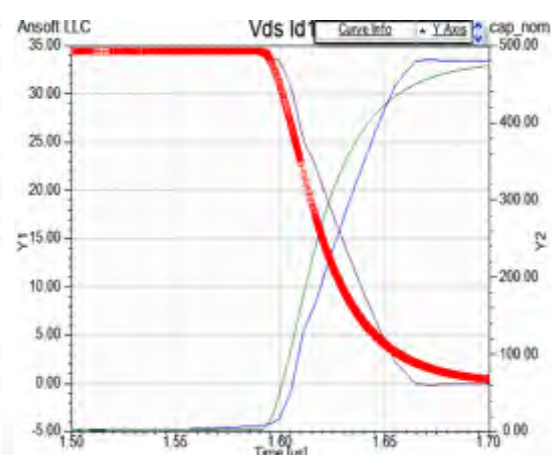
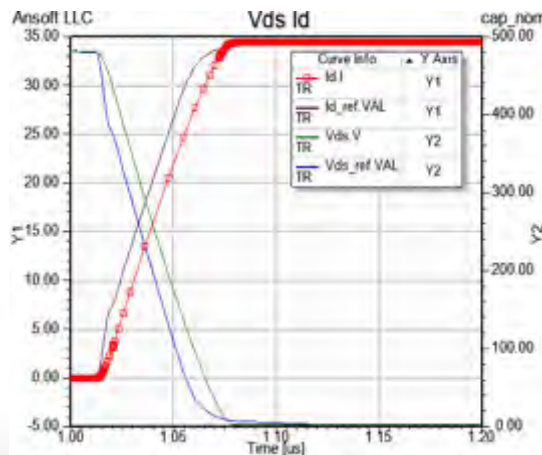


示例：不同精度模型仿真结果差异

高级动态模型



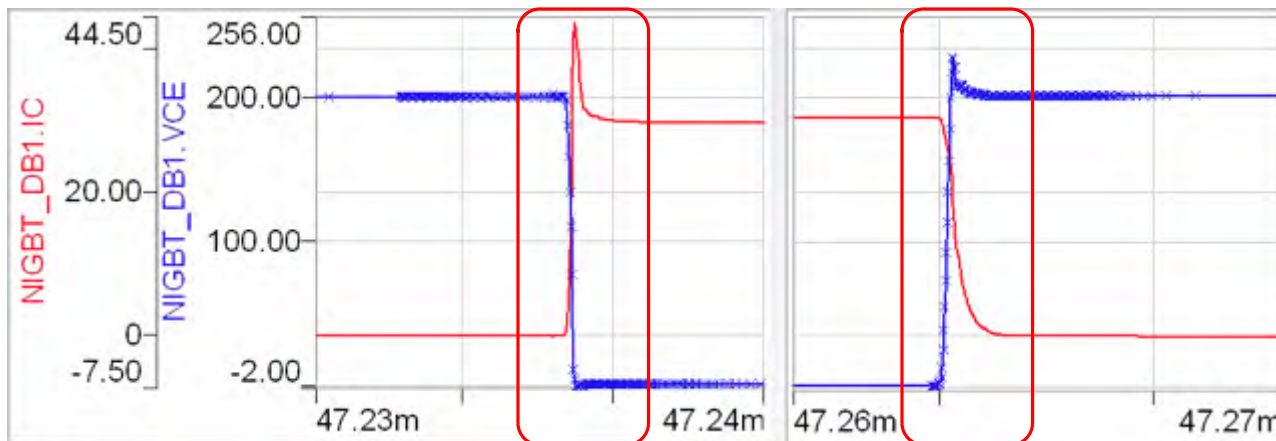
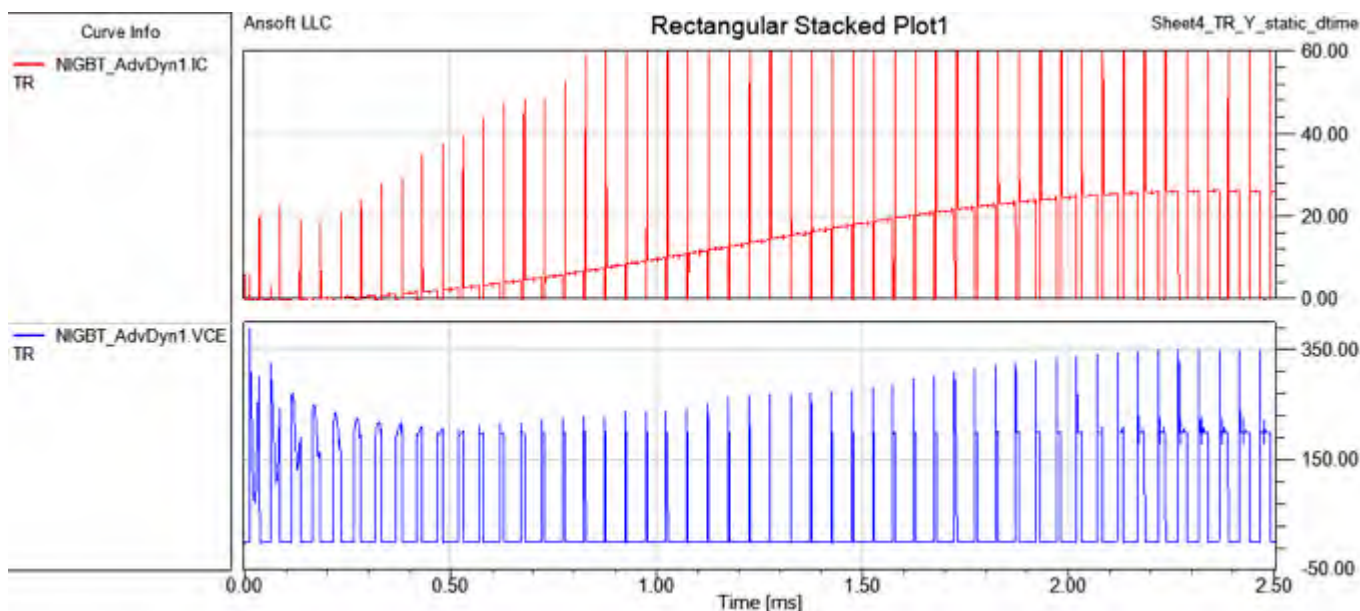
基本动态模型



开通

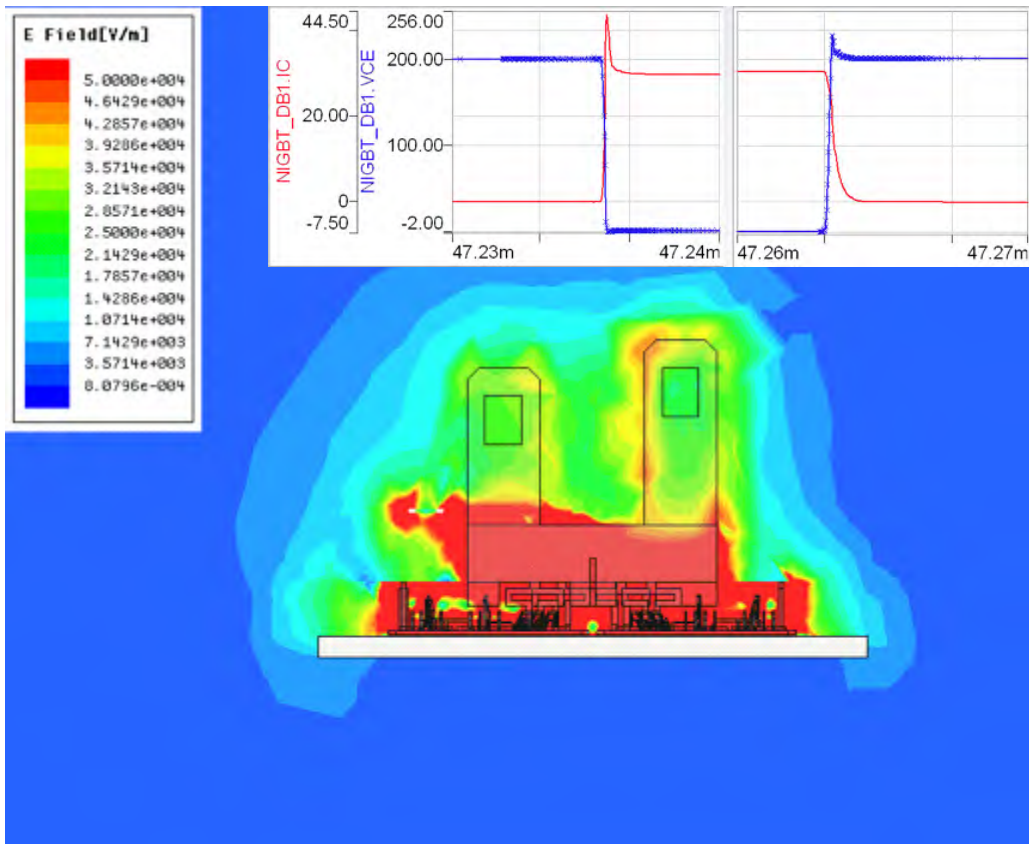
关断

示例结论：器件精度影响EMC仿真



高级动态模型+封装寄生参数提取：开通/关断特性

示例：开关器件开关过程电磁辐射



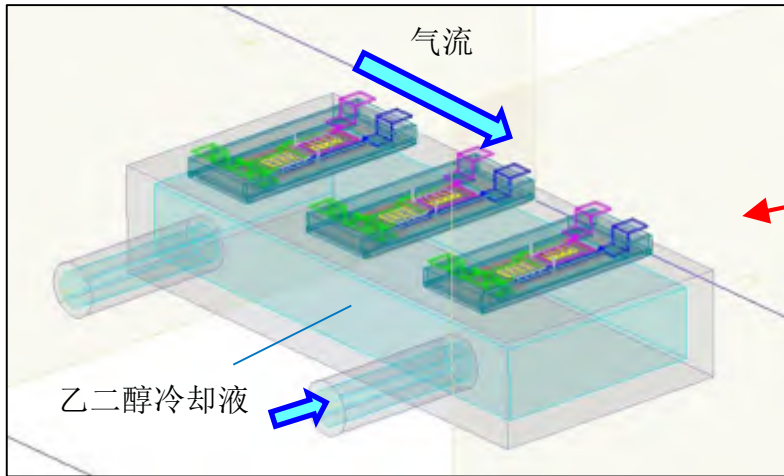
- 即使器件工作在100MHz，电场也主要分布在器件周围；
- 器件功率较高，由此造成了距离器件很远的地方电场强度依然很高；
- 经过优化设计和分析，当前模型在110MHz工况下，工作情况良好。

Spectrum (MHz)	Power (W)	E field at 1m (V/m)
115.7024793	2308.359536	10.35553171

电场强度在100MHz



外部热设计

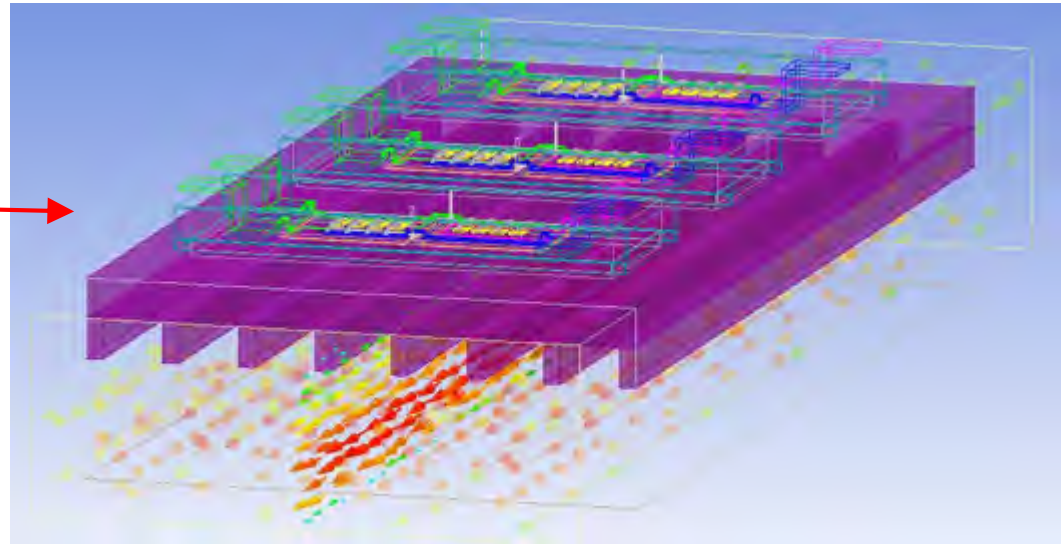


冷却液 (冷板) 设计

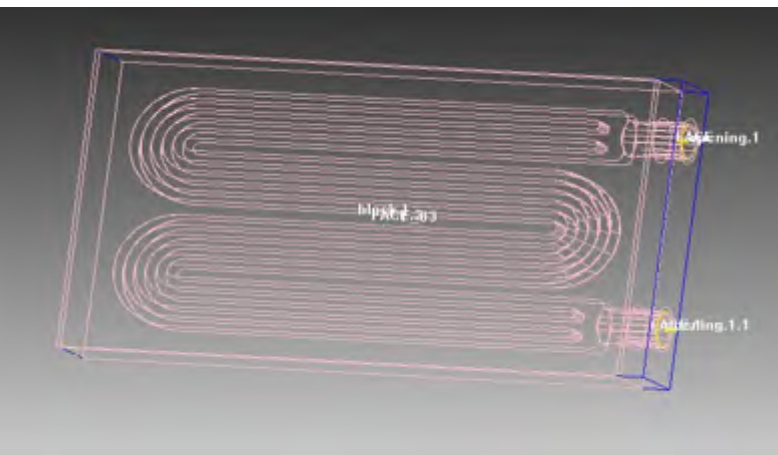
- 冷却液：乙二醇
- 温度：45 °C
- 外部气流通过冷板表面
- 效果较好但昂贵

风冷散热设计

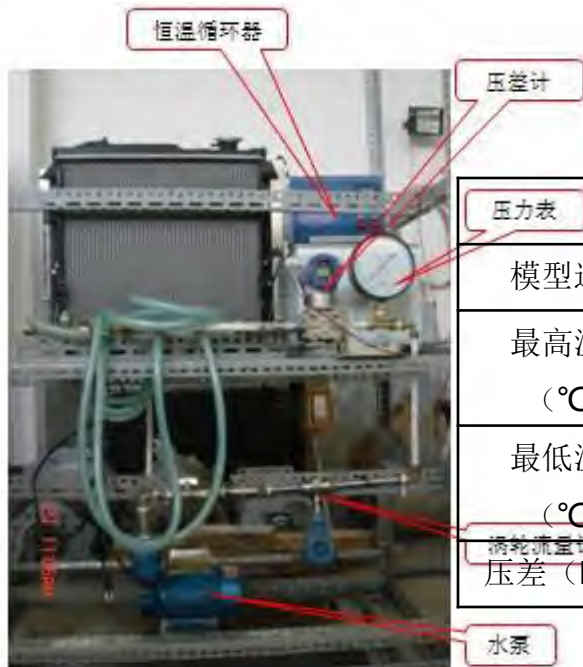
- 成本较低
- 温度变化区域较大
- 需要进一步进行优化设计



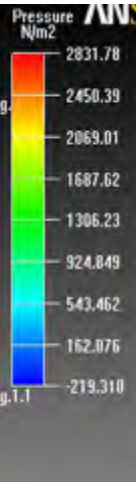
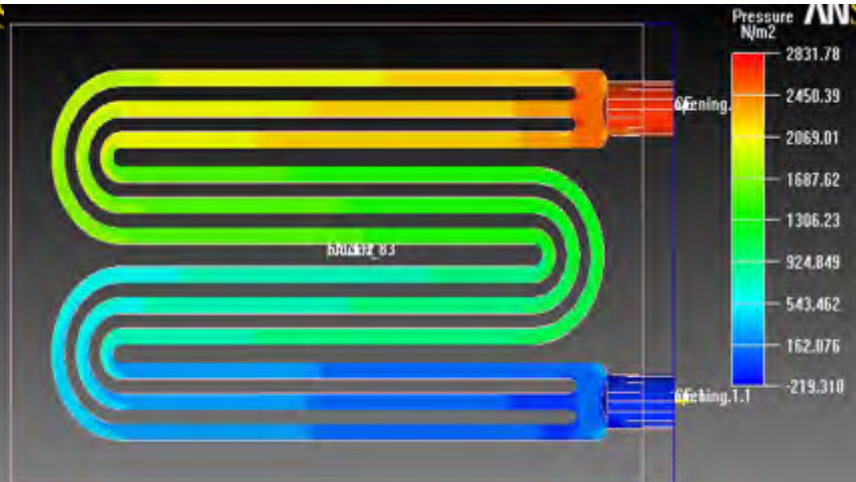
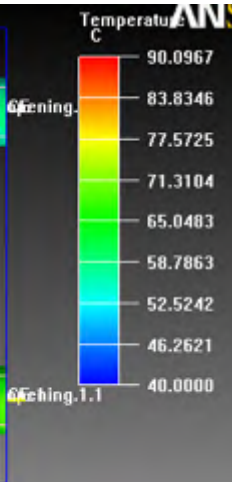
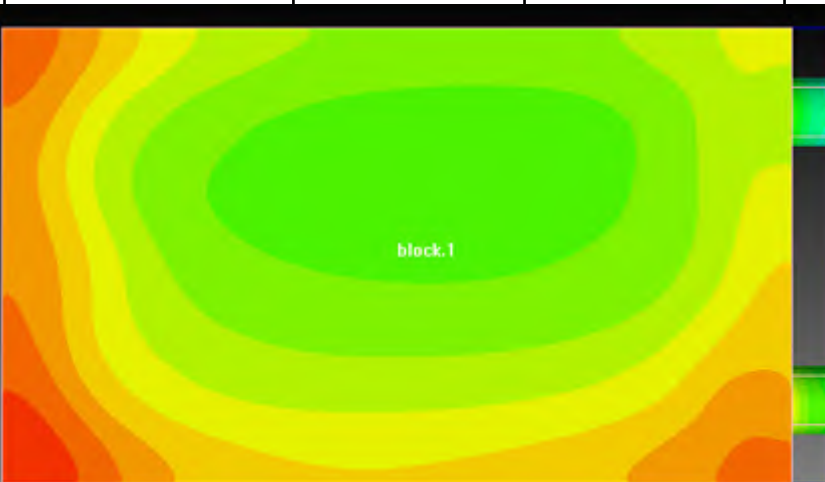
车用控制器散热底板分析----中科院电工所



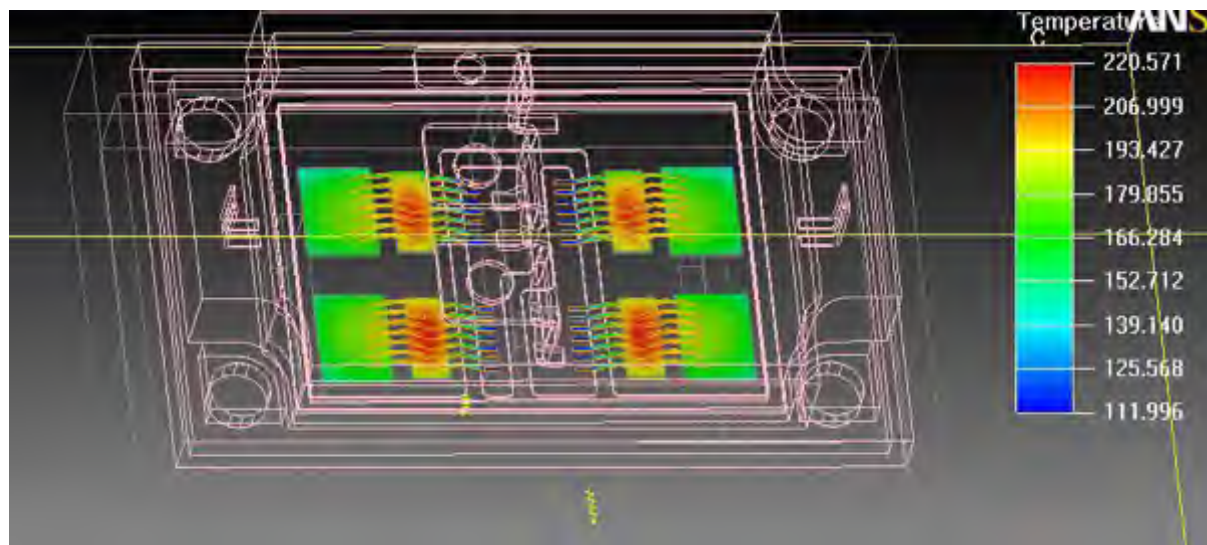
边界条件		
水流量L/mi (m/s)	进水口温度°C	热源功率W



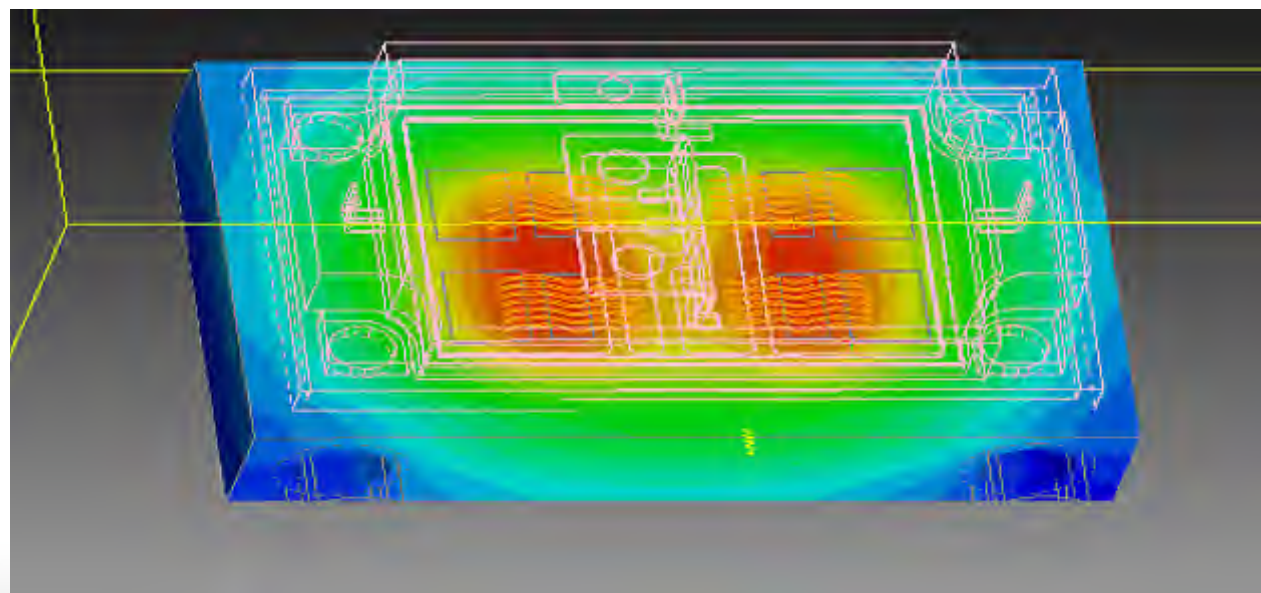
	Icepak	实验值
模型选择	面热源	
最高温度 (°C)	95.3	99.2
最低温度 (°C)	68.9	71.4
涡轮流量计 压差 (kpa)	2.8	2.2



IGBT封装热特性仿真分析：温度场

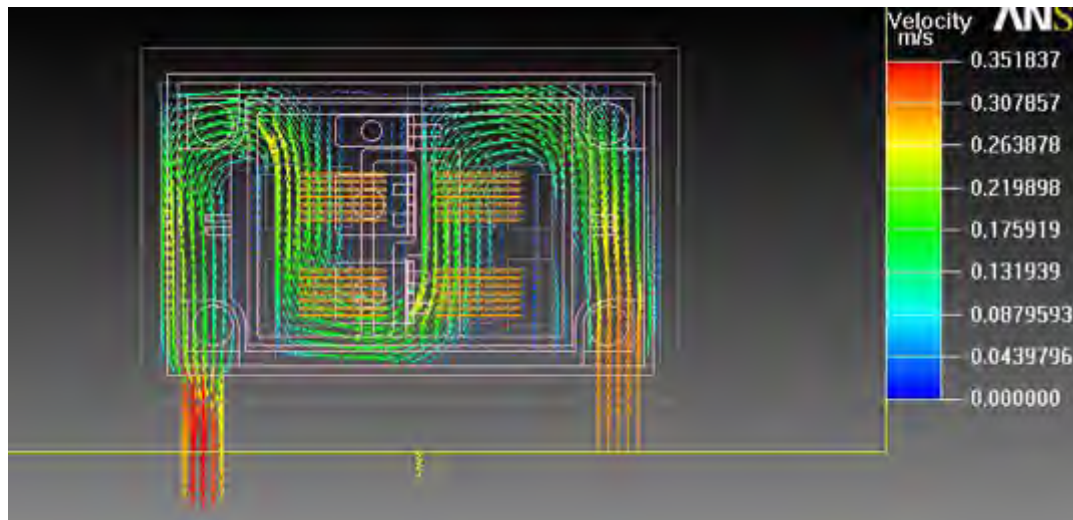


- 热源及引脚温度，最高温的二极管220度



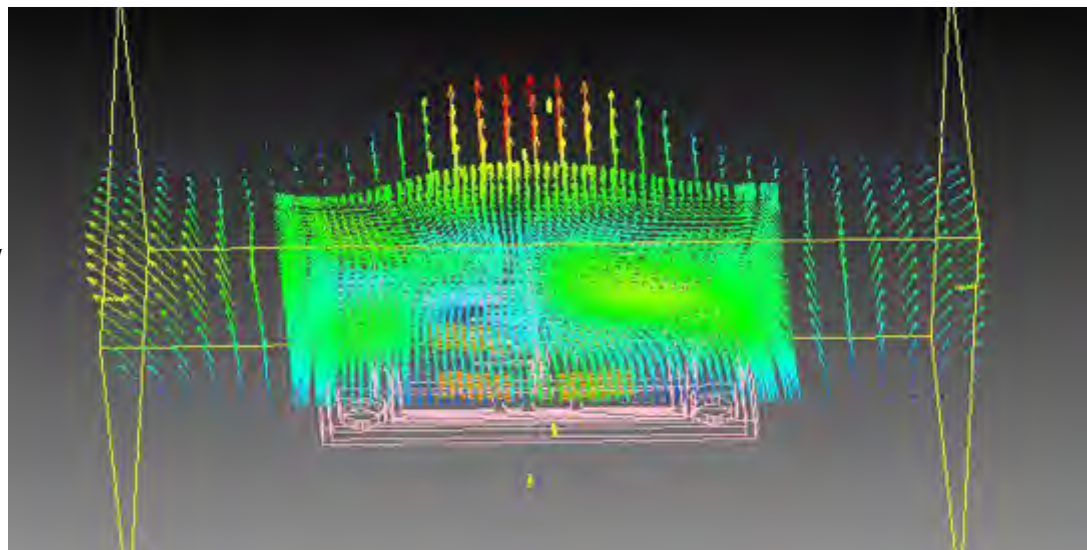
- 冷板温度，最高处126度

IGBT封装热特性仿真分析：流速分析



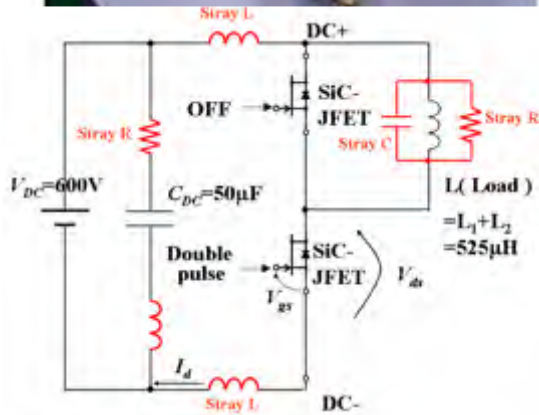
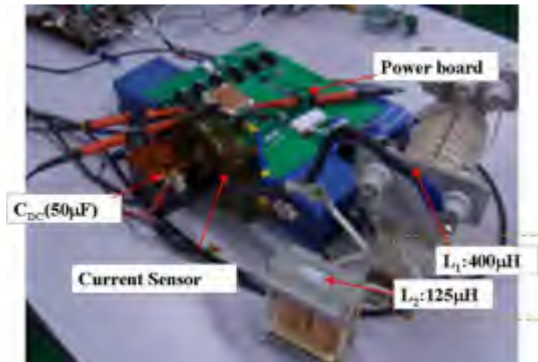
■ 冷板中面上水流速度矢量分布图

- 模组上方的空气流动矢量图，因主要是水冷散热，自然对流带走的热量少，流动不强

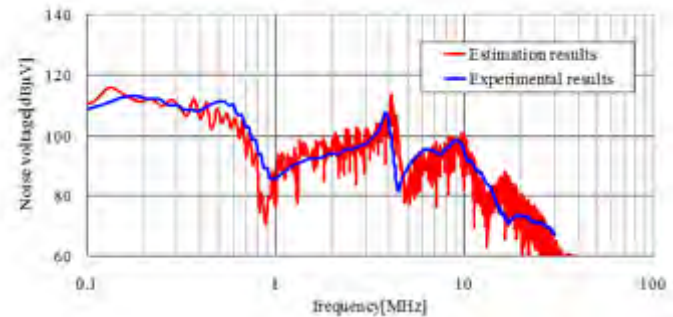
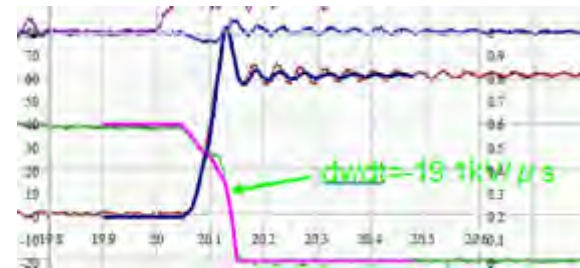
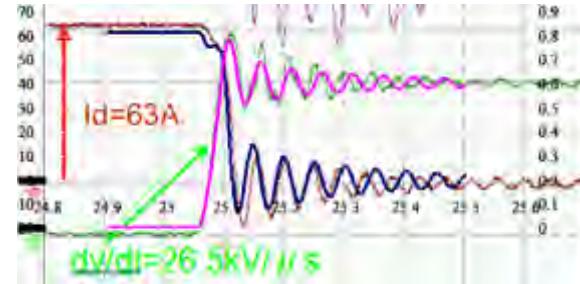


开关模块建模

TOSHIBA
Leading Innovation >>>



ANSYS Simplorer + Q3D



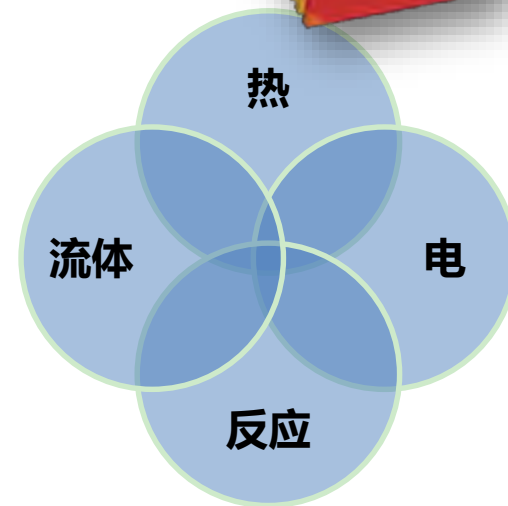
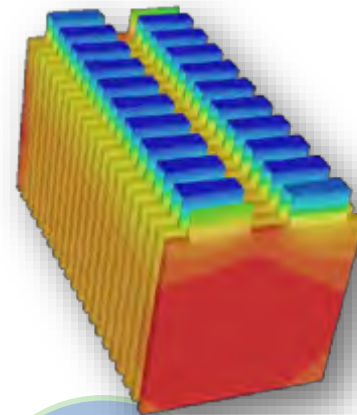
电池包

综合仿真与最佳实践

电池开发中面临的主要挑战

- 性能（能量密度及功率密度）
- 耐用性和使用寿命（考虑在不同环境和使用周期）
- 安全性（考虑恶劣环境）

- 复杂的多尺度、多物理场系统
- 快速发展的材料和设计理念
- 现有软件工具不专业针对电池



热管理至关重要



Molecular



Particle



Electrode



Cell



Pack



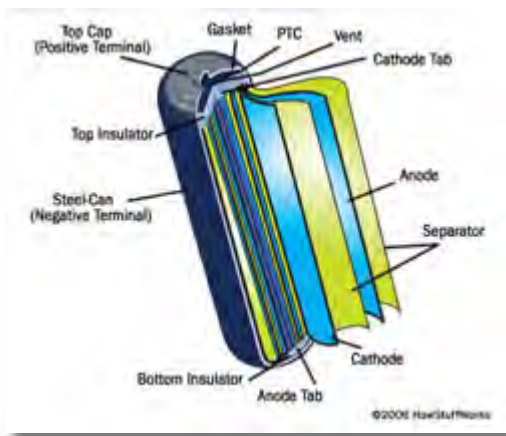
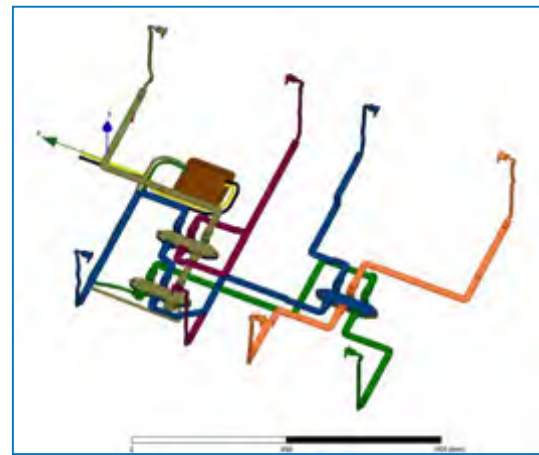
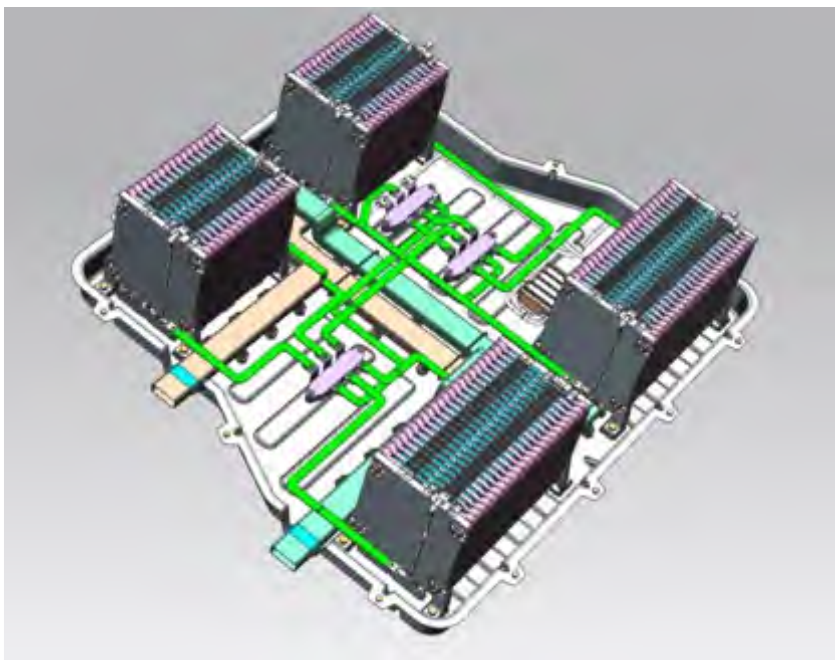
Vehicle

锂离子电池全面仿真解决方案

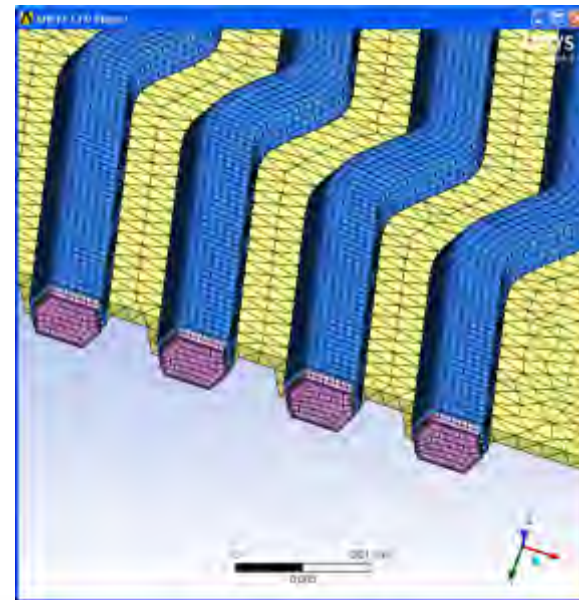
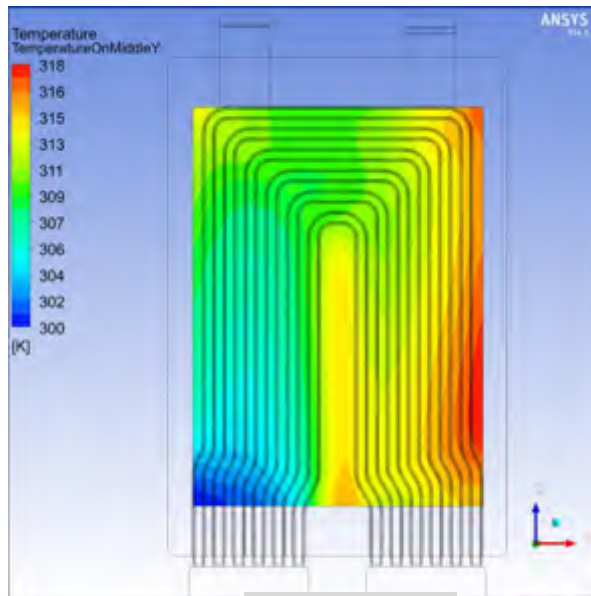
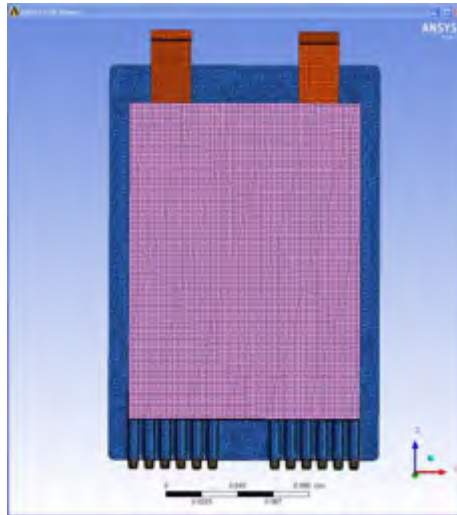


		→						
		分子	电极	电池单体	模块/封装	汽车		
Small Scale	材料		Layout Process Life SEI	充电 放电 发热 安全性	热管理 耐久性 NVH EMI/EMC	系统集成	Large Scale	
			电化学	等效电路模型 CFD FEA	等效电路模型 CFD ROM FEA	等效电路模型 ROM		

锂离子电池全面仿真解决方案

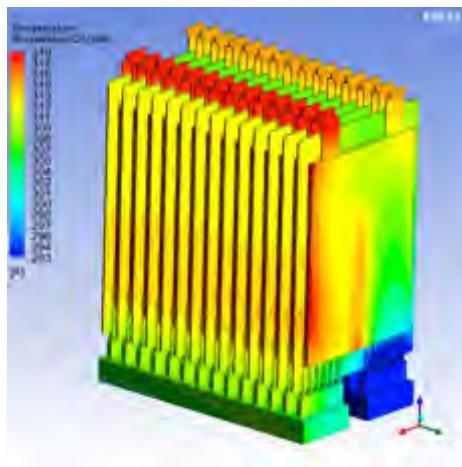
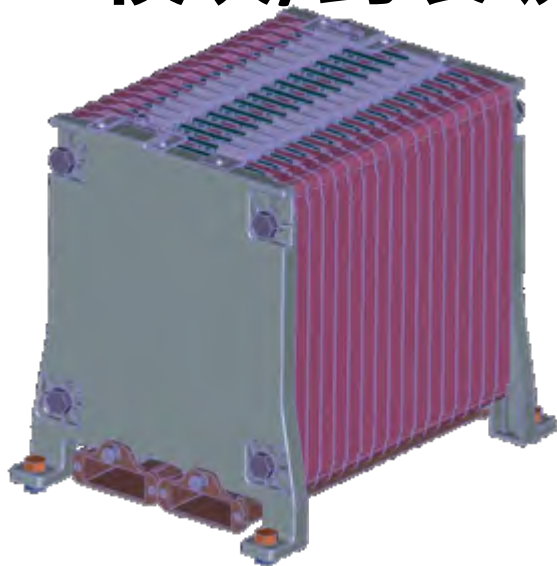


单元级- CFD 热仿真

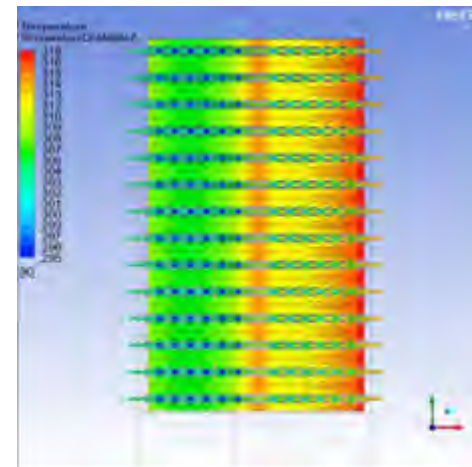


温度分布

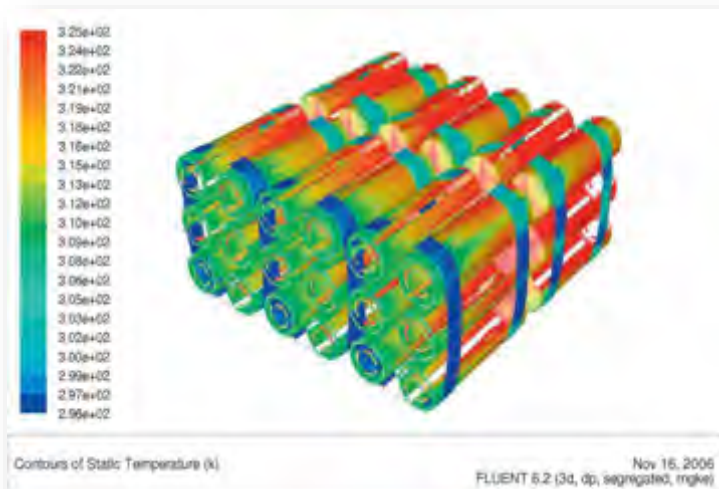
模块/封装级- CFD 热分析



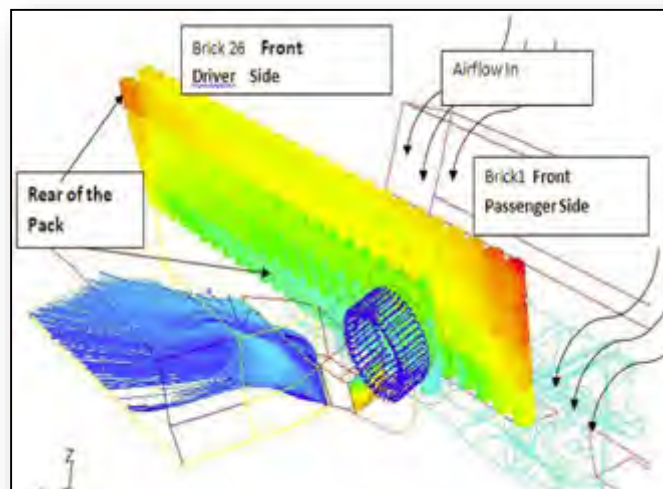
温度分布



温度分布



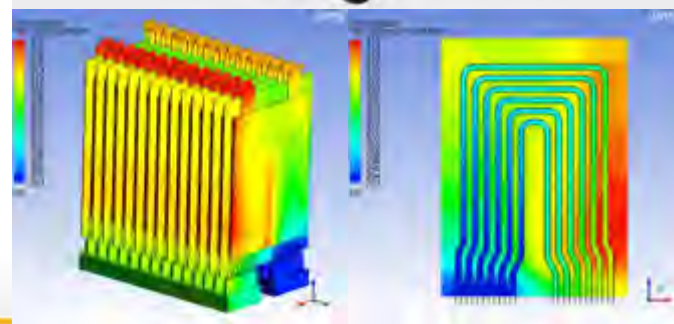
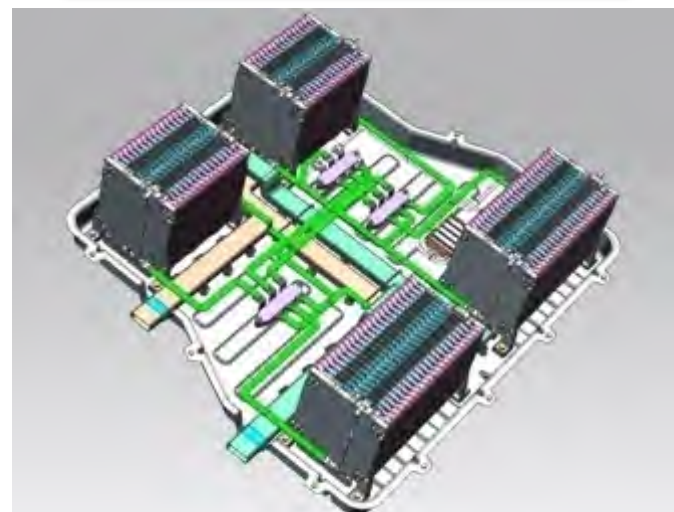
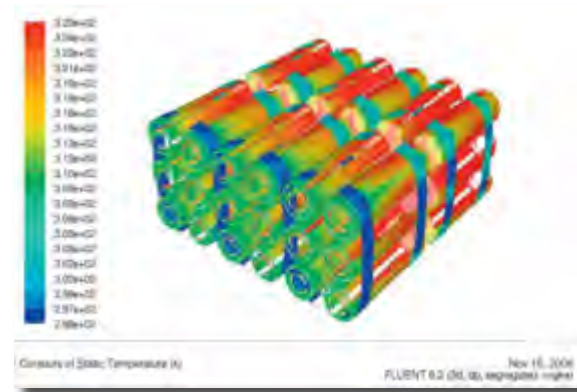
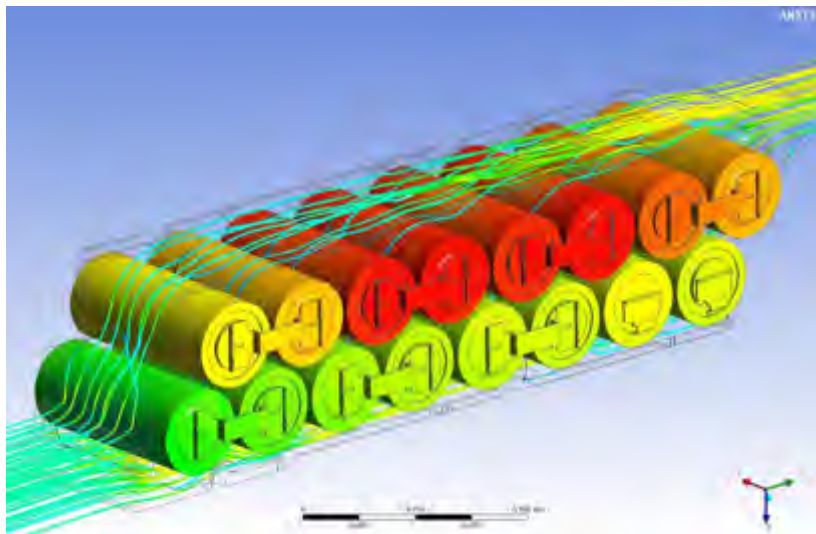
温度分布



温度和迹线

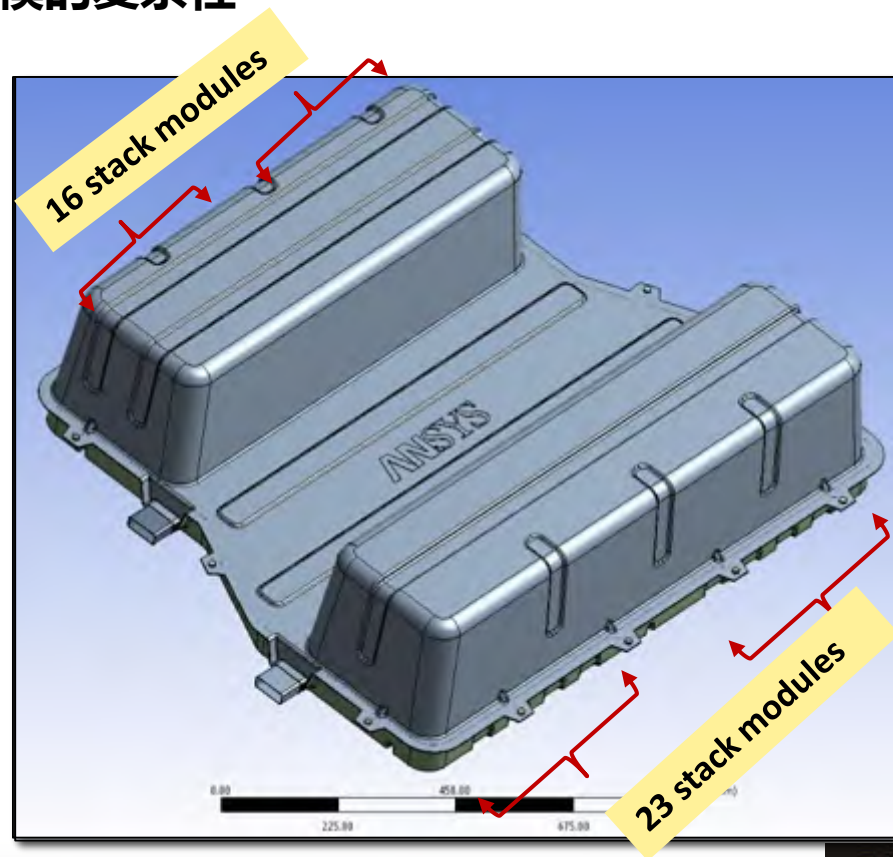
降阶模型(ROM)分析

- 作为一种通用的热分析方法，CFD是准确的
 - 但对大规模系统级瞬态分析来说计算代价太大
- ROM可以显著降低模型规模和模拟时间
- ROM是系统级模拟的重要工具



电池结构分析

- 在Workbench下导入UG的模型
- 电池包内部包含超过2000的零件
- 电池包内的很多零部件是一样
- ANSYS可以利用该一致性来降低建模的复杂性



自重分析

- **目标:**

- 分析电池自身重量

- **载荷:**

- 重力

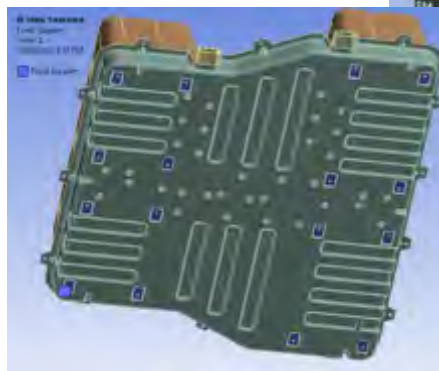
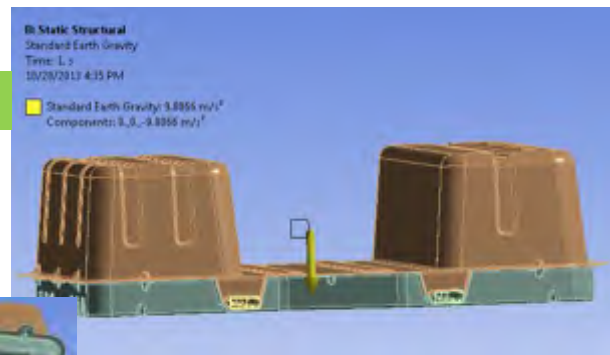
- **约束:**

- 固定电池底座的安装位置

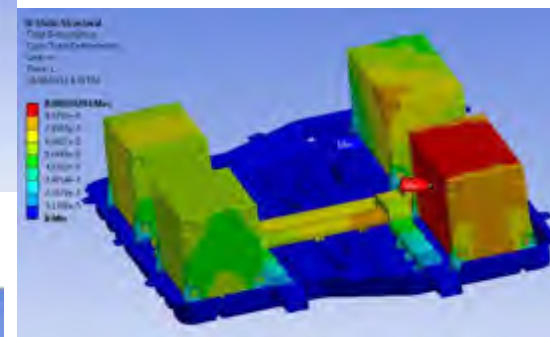
- **结果:**

- 电池顶部有较大的位移
- 应力在许可范围内，最大应力出现在最大应变位置相对的支撑位置

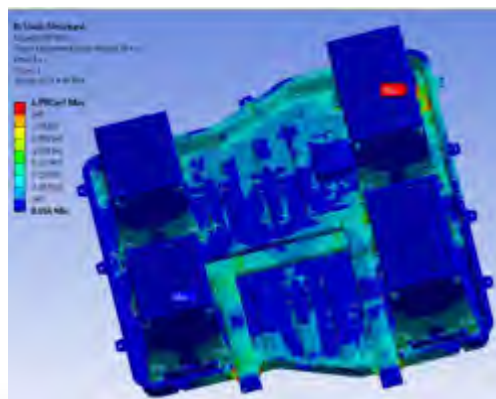
Gravity load



Fixed support



Total Deformation

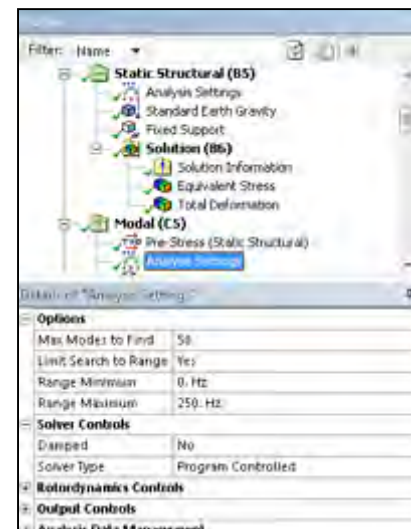


Equivalent Von Mises Stress

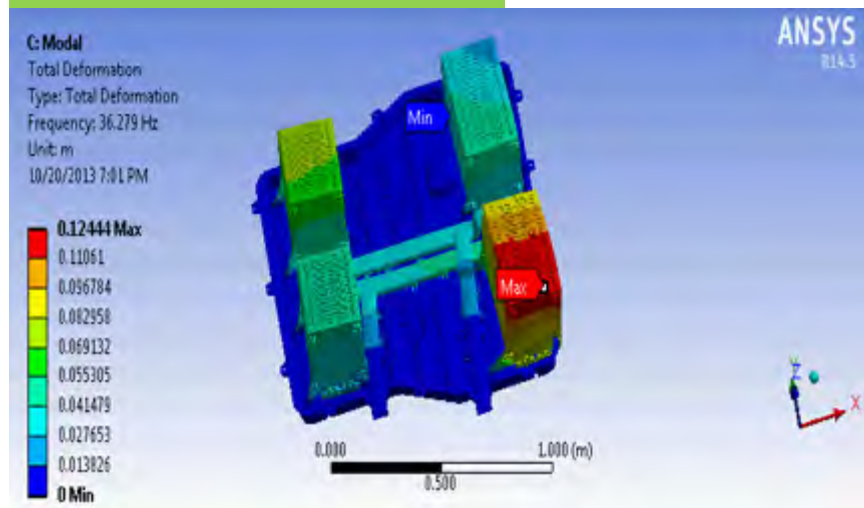
预紧力作用下的振动模态分析

- **目标:**
 - 分析电池部件在预紧力下的振动模态
- **分析设置:**
 - 由于随机振动载荷高达190 Hz，分析中需要考虑1.5倍范围，因此分析频率高达250Hz
- **约束:**
 - 由于分析预紧力下的工况，因此约束是由静力学分析获得
- **结果:**
 - 提取了32阶模态
 - 80%的质量分布在三个方向，随机振动模拟的精度足够

Analysis setting



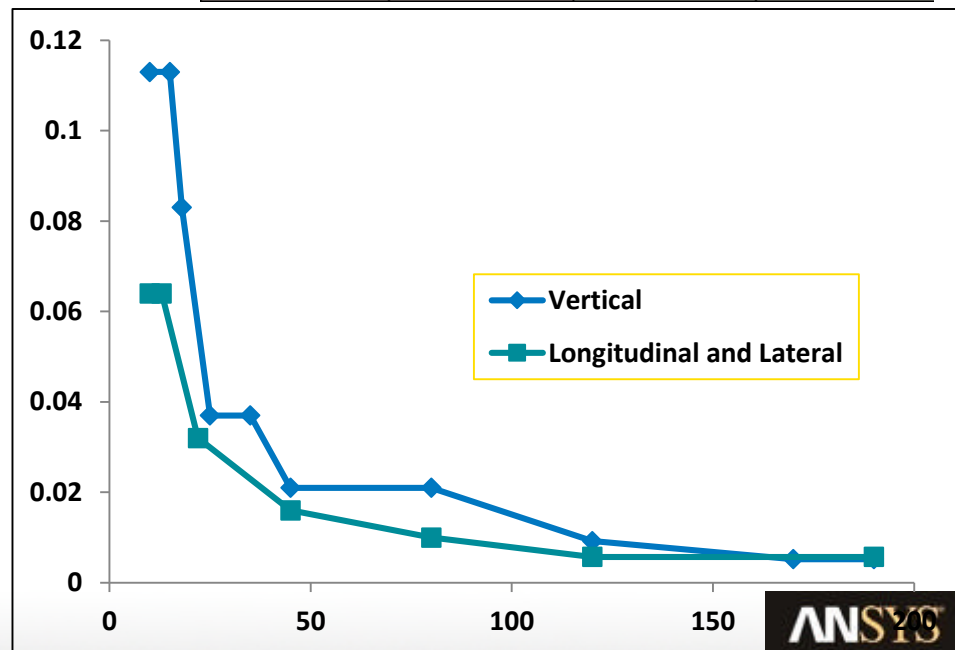
Mode shape 1st mode = 36Hz



随机振动分析

- **目标:**
 - 在预紧力作用下，对纵向、侧向和垂直三个方向进行随机振动分析
- **载荷:**
 - 载荷按照SAE J2380中的标准
 - 纵向和侧向施加相同的振动载荷
- **约束:**
 - 约束是由静力学分析获得

Vertical		Longitudinal and Lateral	
Frequency (Hz)	1.9 grms Amplitude (G^2/Hz)	Frequency (Hz)	1.9 grms Amplitude (G^2/Hz)
10	0.113	10	0.064
15	0.113	13	0.064
18	0.083	22	0.032
25	0.037	45	0.016
35	0.037	80	0.01
45	0.021	120	0.0057
80	0.021	190	0.0057
120	0.0092		
170	0.0052		
190	0.0052		

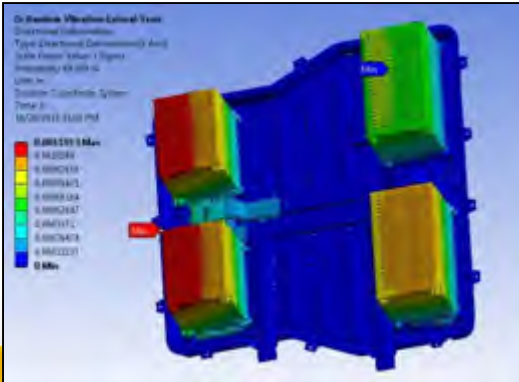
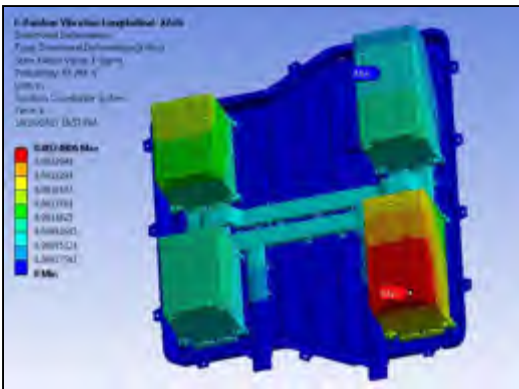
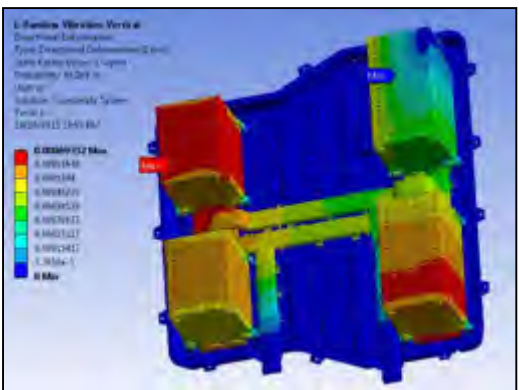


随机振动分析

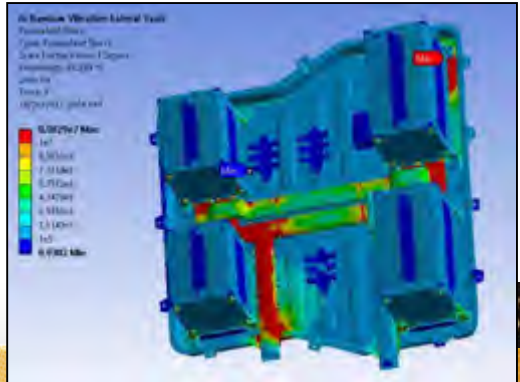
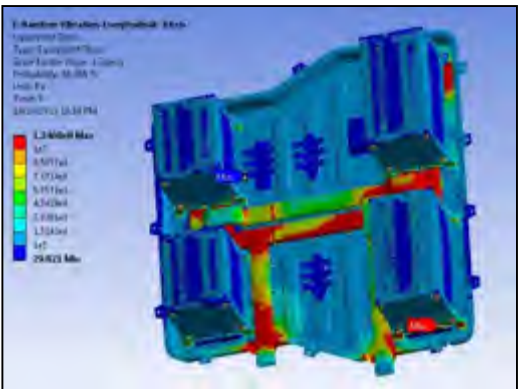
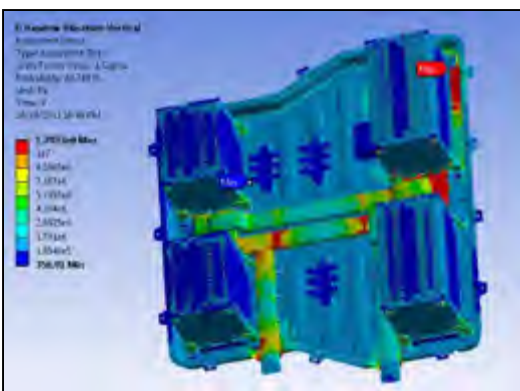
结果:

- 无量纲应力在三个方向都是安全的，最大值发生在垂直方向
- 变形同样很小，最大值发生在纵向
- 尽管纵向和侧向激励一致，但结果差别明显

Directional deformation



1 sigma equivalent stress



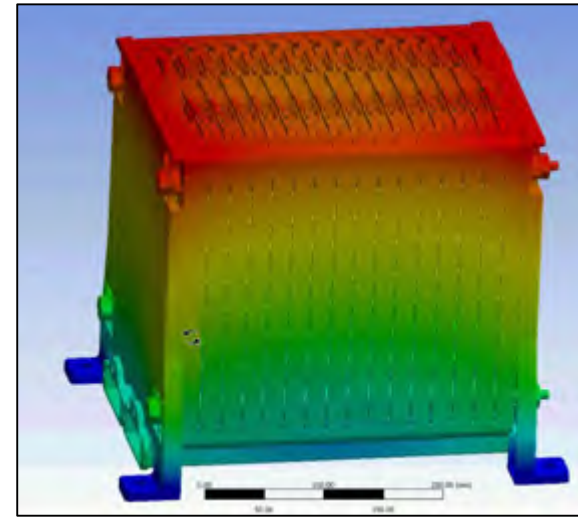
Direction	Deformation (m)	Equivalent Stress (Pa)
Vertical	6.93e-4	1.78e8
Longitudinal	2.4e-3	1.24e8
Lateral	1.19e-3	8.58e7

热应力分析

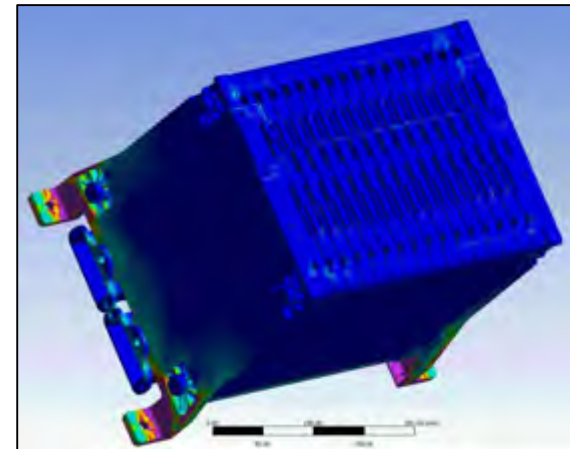
- **目标:**
 - 对电池模块进行热应力分析
- **载荷**
 - 热载荷由MAXWELL进行电磁场分析获得
 - 电池模块固定在底面上
- **结果:**
 - 分析热应力和变形是否导致部件的失效



Electromagnetic FEA Analysis for Busbar
RLC Network Extraction



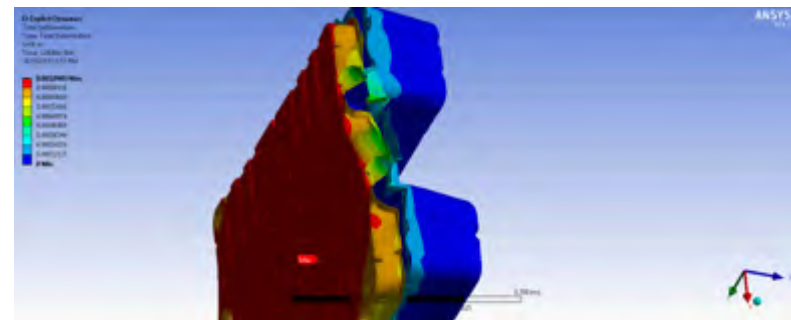
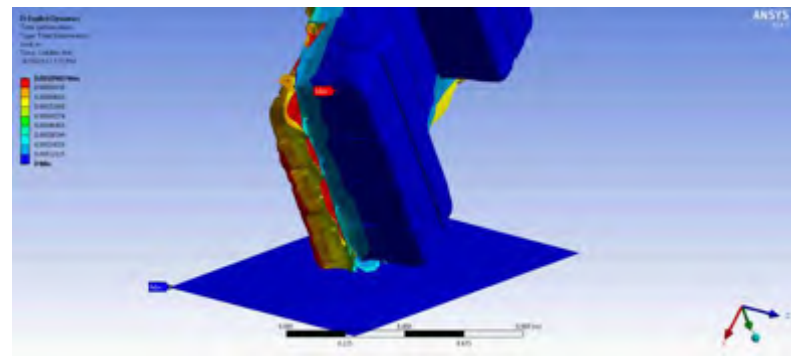
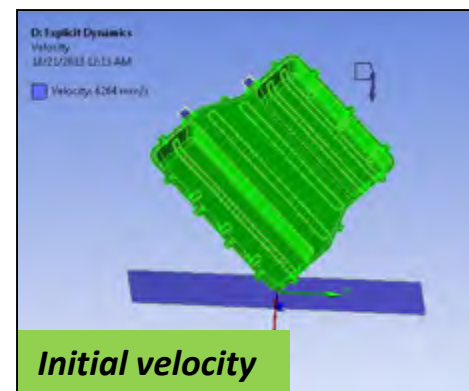
Structural FEA: Total Deformation



Structural FEA: Equivalent Stress

跌落分析

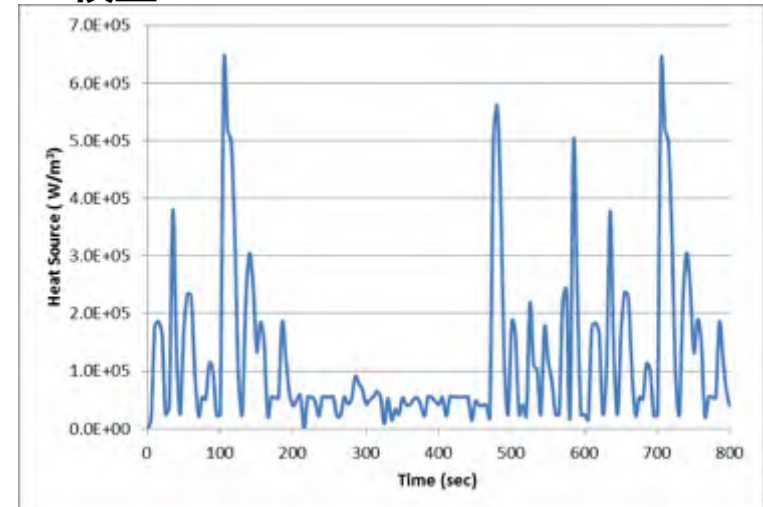
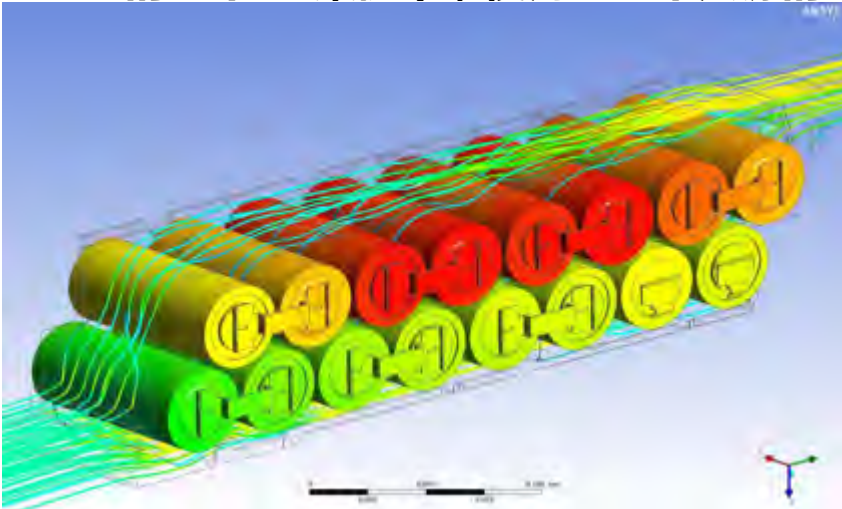
- **目标:**
 - 按照SAE J2464标准进行电池电池组的跌落分析
- **工具:**
 - 显式动力学模块
- **网格 & 接触:**
 - 避免使用金字塔网格，保证网格可以用于所有类型的分析
 - 可能破坏的接触位置定义为超过150MPa后自动分离
- **载荷 & 边界条件:**
 - 电池从2米高以45度角跌落
 - 为节省分析时间，定义接触前的跌落速度作为初始载荷
- **结果:**
 - 套件的上下位置分离



Total deformation after 15% solve time

最佳实践 : SVD ROM : GM 16 Cell Test Case

- SVD ROM technology allows for quick temperature distribution calculation in addition to average temperature calculation.
- SVD (奇异值分解法) ROM技术能够在以往计算平均温度的基础上, 快速的计算温度场的分布
- Using a heat source from GM, SVD ROM is applied to the GM 16 cell case.
- GM的16个cell案例中, 使用了一个热源的SVD ROM 模型



Heat source used

S. Asgari, X. Hu, M. Tsuk, S. Kaushik, "Application of POD plus LTI ROM to Battery Thermal Modeling: SISO Case," SAE 2014.-01-1843
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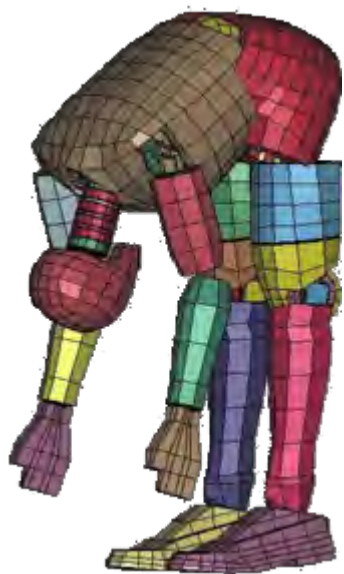
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