微电机世界网

emotor. big-bit. com

Realize Your Product Promise®

ANSYS®

仿真驱动工业创新

Maxwell在电机行业的分析和高级应用

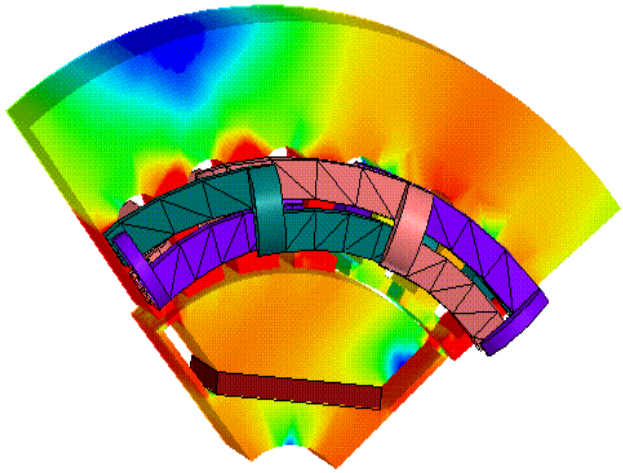
庄百兴

baixing.zhuang @ansys.com

18675506525

ANSYS 深圳

内容：



仿真：令工程师更强大

仿真软件公司介绍

ANSYS电机工业创新

- 电机专用工具包
- 电机电磁-系统仿真
- 电机电磁-热耦合仿真
- 电机电磁-振动耦合仿真

ANSYS 公司

- ANSYS成立于1970。
- ANSYS 致力于工程仿真软件的开发、销售和技术支持，通过仿真预测产品在真实环境下的行为模式和制造过程。
- 世界领先的电磁、结构、流体、芯片和嵌入式系统仿真软件供应商

公司大事记—ANSYS收购Ansoft

ANSYS

John Swanson 博士创建ANSYS的前身SAS公司 1970

SAS发布ANSYS/EMAG 3D软件 1983

SAS收购FLOTRAN和Compuflo公司1992

与TA Associates公司合并，正式更名为ANSYS Inc. 1994

ANSYS Inc. 在NASDAQ上市 1996

收购ICEM CFD 公司 2000

收购CADOE公司 2001

收购CFX公司 2003

收购AutoDYN 软件，Century Dynamics 公司 2005

收购Fluent 公司，设立ANSYS中国分公司 2006

收购Ansoft公司 2008

收购Apache DS 公司 2011

收购Esterel Technologies S.A 2012

收购Reaction Design公司 2014

收购 SpaceClaim公司 2014

Fluent

1979 英国谢菲尔德大学发布TEMPEST（FLUENT的原型）

1983 Creara开始销售FLUENT

1995 FLUENT Inc.成立

2004 成立FLUENT 中国分公司

Ansoft

1984 卡内基 梅隆大学教授Zoltan J Cendes创立Ansoft公司

1984 发布Maxwell 软件

1990 发布高频结构仿真软件HFSS，与HP 签署OEM协议

1996 收购Compact公司，在NASDAQ上市

1997 收购MSC 公司EBU分部，设立Ansoft 北京办事处

1999 收购Pacific Numrix 公司

2000 收购Aglient HFSS软件

Apache DS

2001 Apache 公司成立，提供芯片低功耗和PI 设计工具

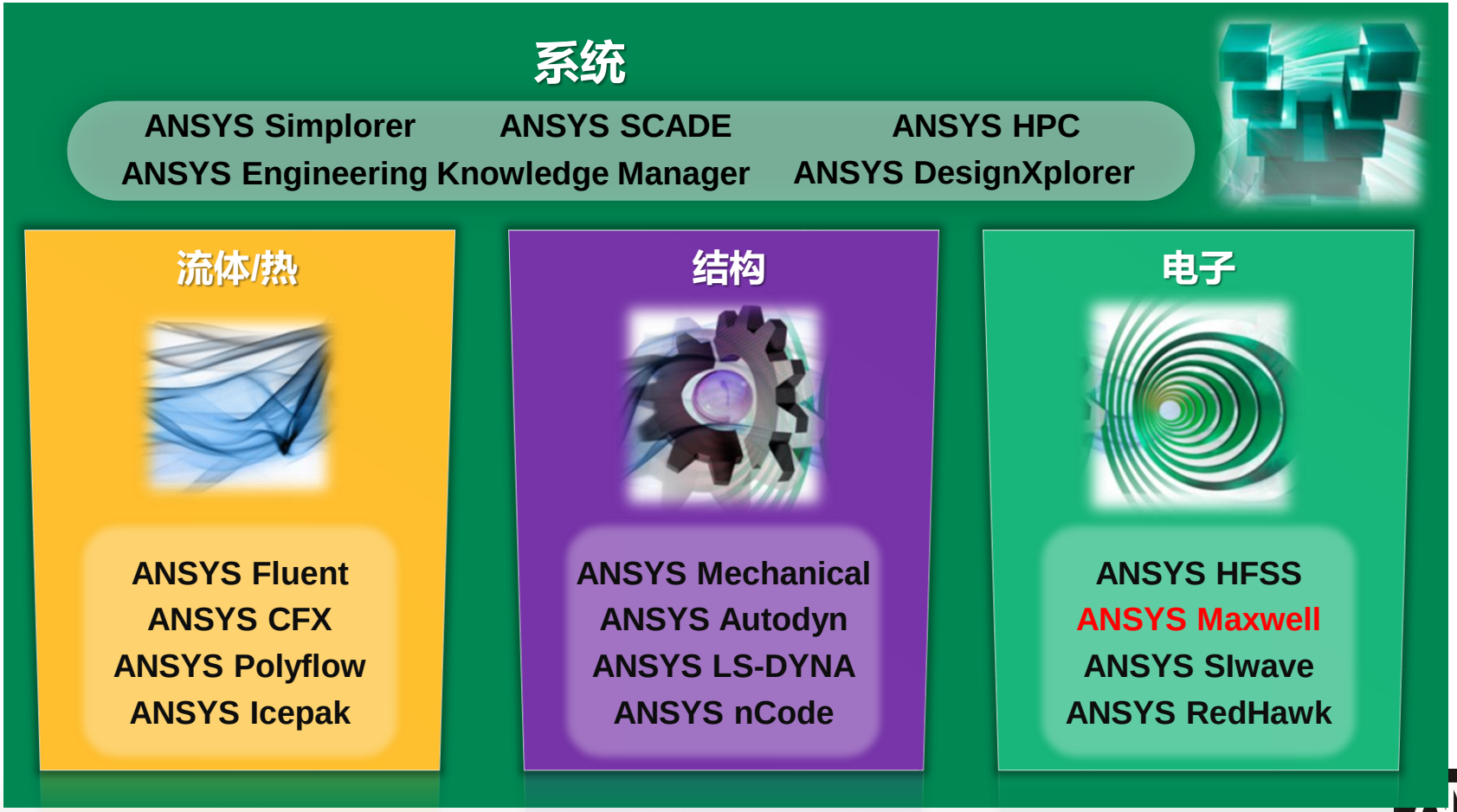
2006 成立成都工程研发中心

2007 收购Optimal Corporation

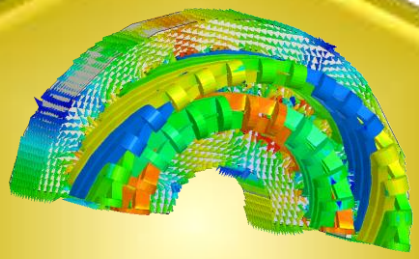
2009 收购Sequene Design

ANSYS 产品线

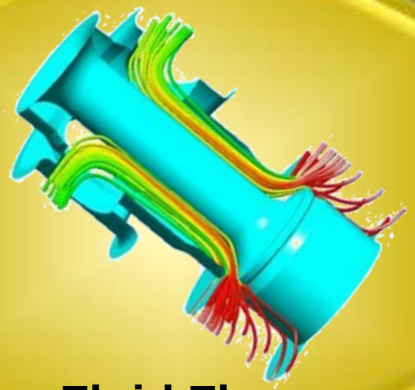
ANSYS在各个学科都拥有最先进的仿真技术，同时能实现跨越各个学科的集成化协同仿真。



多物理场仿真

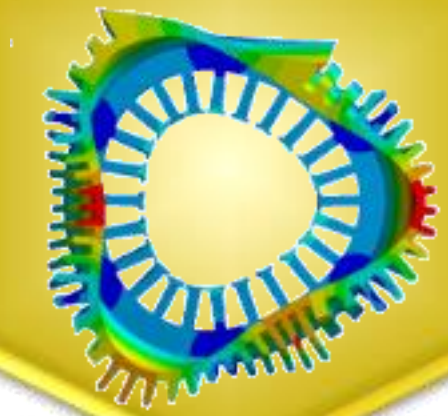


Electromagnetic

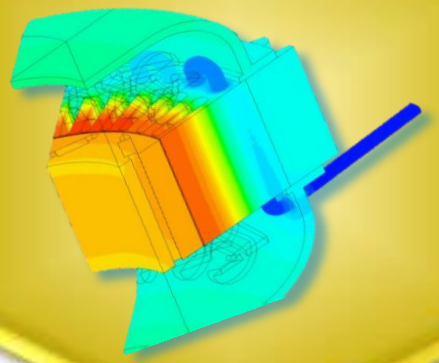


Fluid Flow

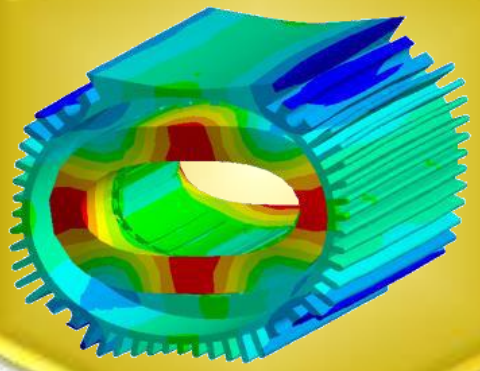
Structural



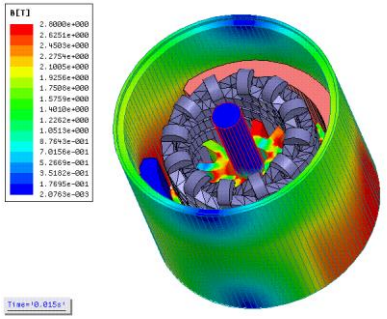
Thermal



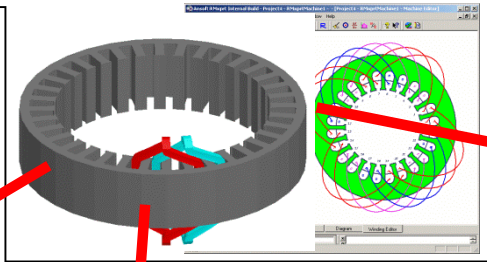
Noise



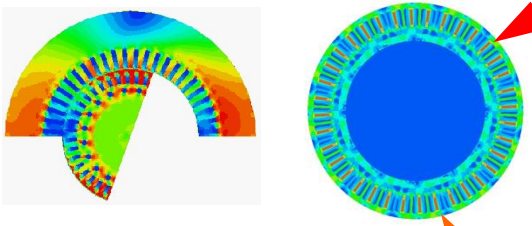
ANSYS电机设计流程



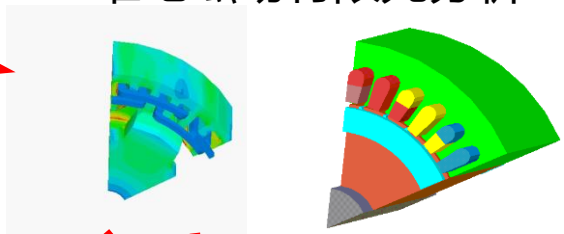
RMxprt
电机磁路法设计工具



Maxwell 2D
二维电磁场有限元分析

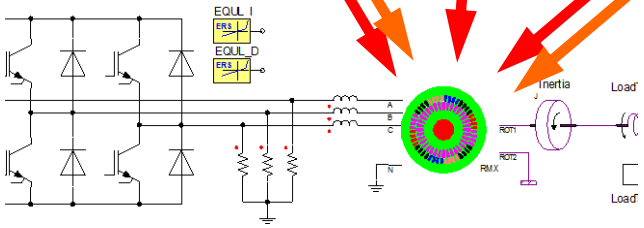


Maxwell 3D
三维电磁场有限元分析

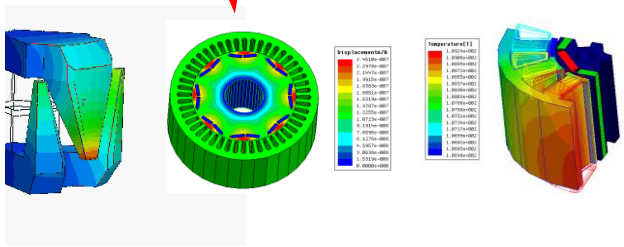


OPT
参数化、优化

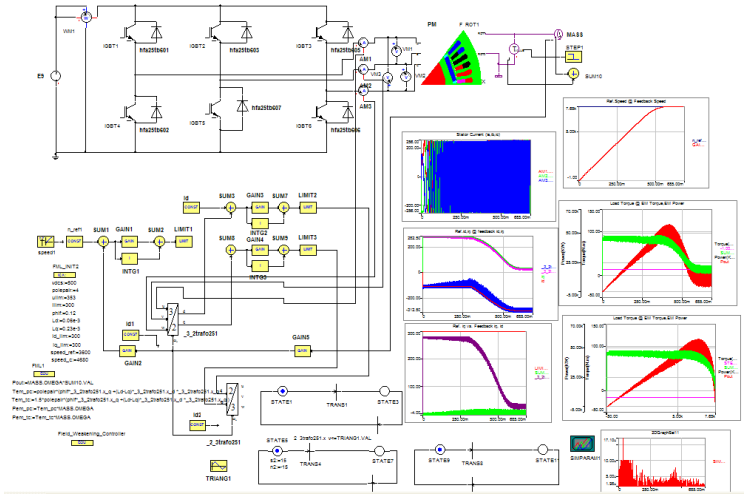
Simplorer
电路和多域系统仿真工具



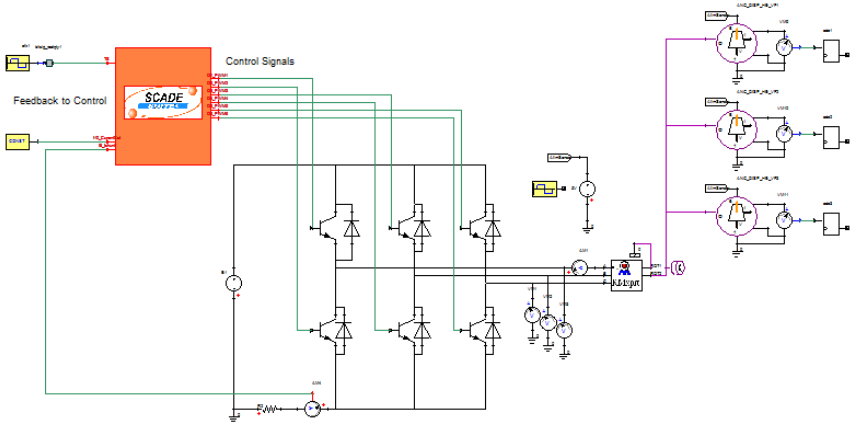
ANSYS WB、FLUENT等
结构场、流体场和温度场分析



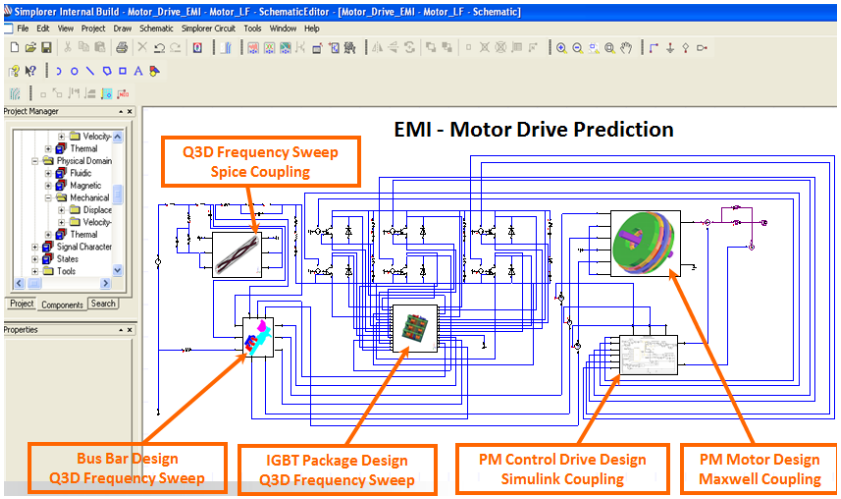
电机控制及其机电系统仿真



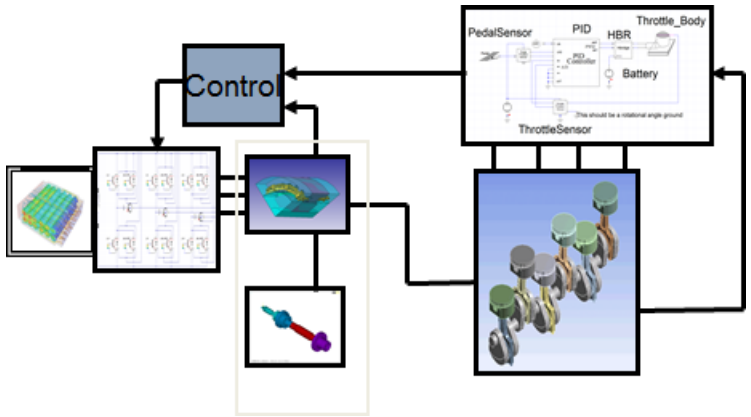
IPM电机弱磁控制



电机控制系统嵌入式代码生成

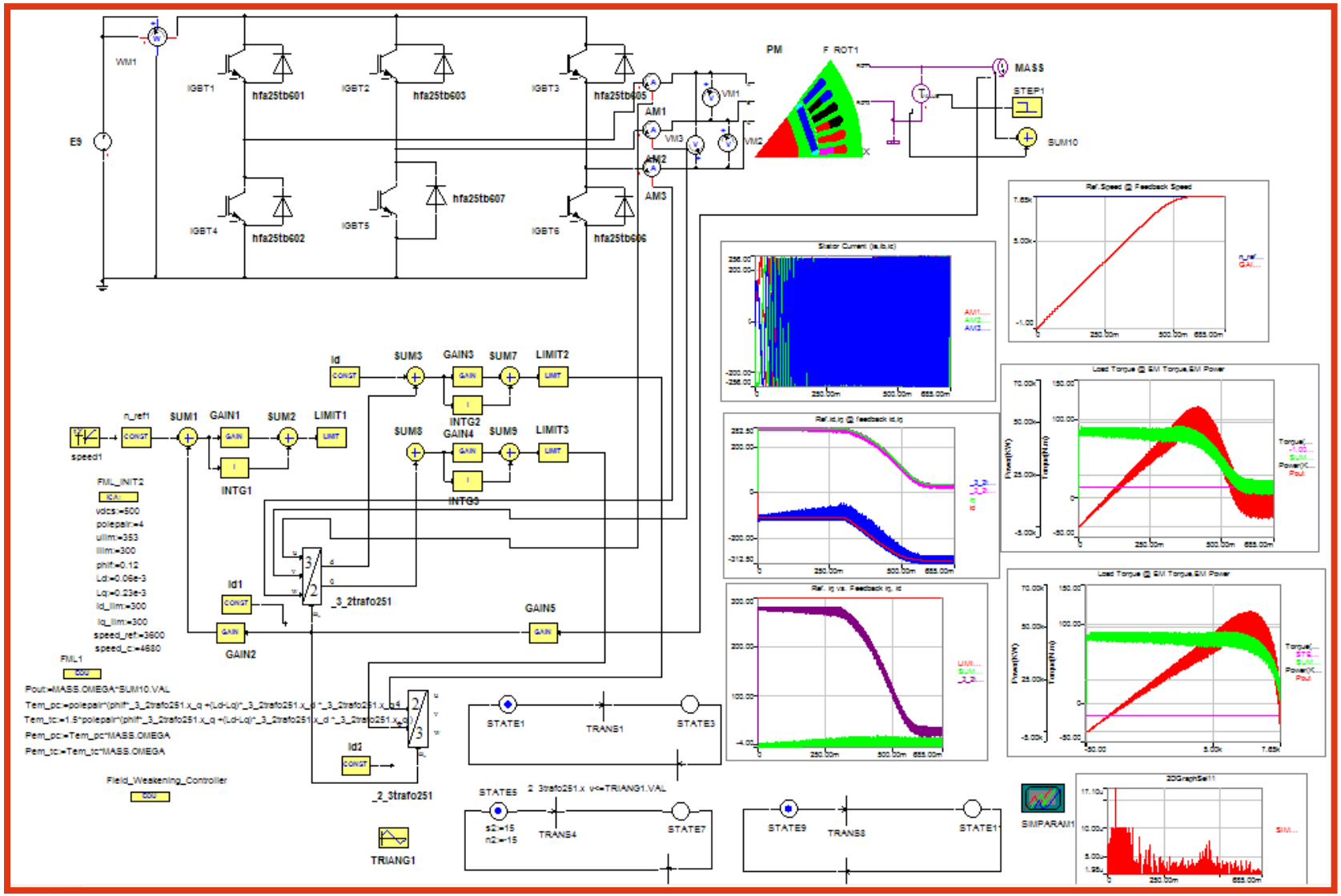


电机控制系统传导干扰分析

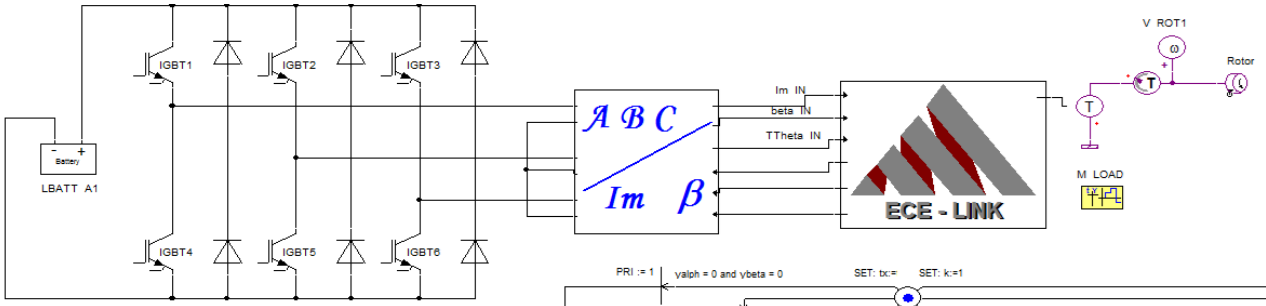


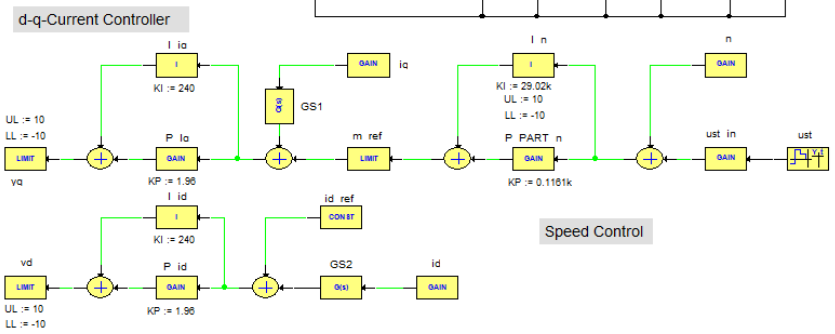
多域系统仿真

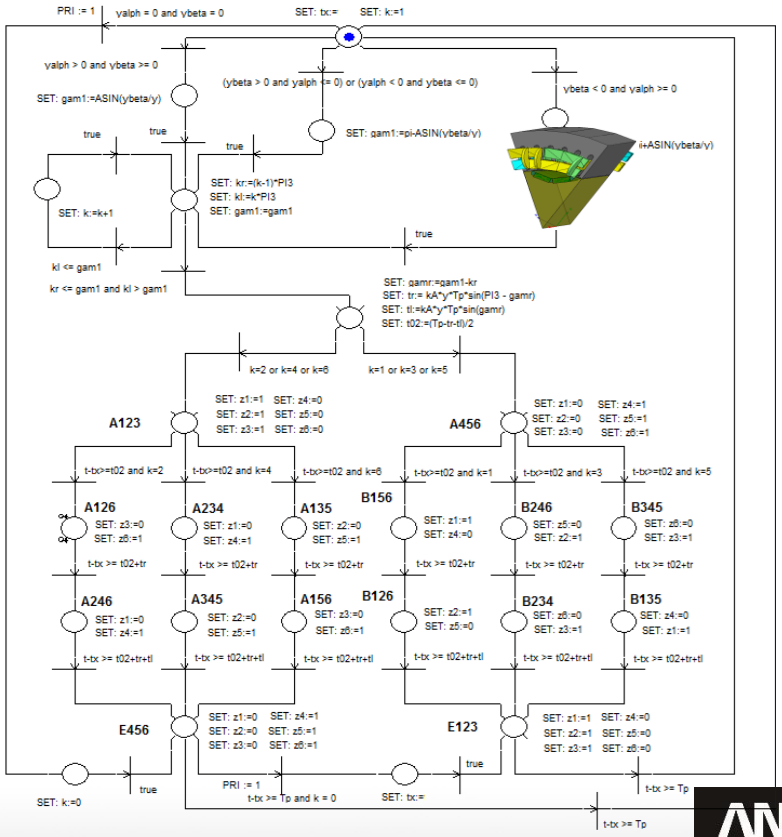
IPM弱磁控制调速



SVPWM 电机控制







Phase Transformation / Control Signal Generation by Space Vector Modulation

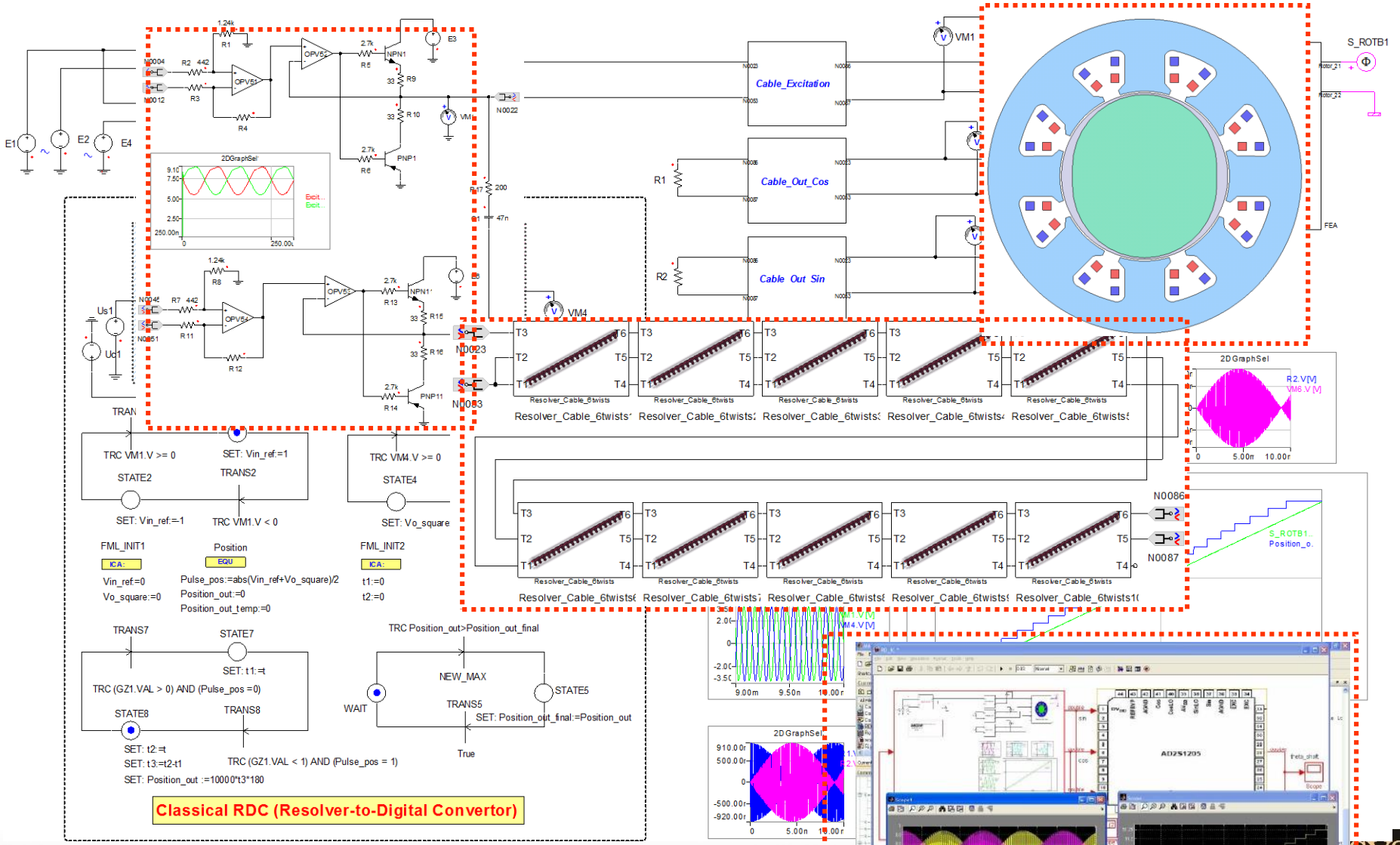
ICA:

```
fp:=10k
Tp:=1./fp
tx:=0
wu3:=sqrt(3.)
wu32:=sqrt(3.) / 2.
P18:=pi / 180.
PI3:=pi / 3.
gam1:=0.
kA:=0.1
```

EQU

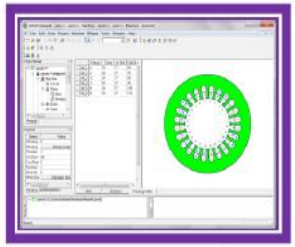
```
theta_el:=SYMPOD1.PHIDEG * P18
sinthe:=sin(theta_el)
costhe:=cos(theta_el)
yalph:=costhe * yd.VAL - sinthe * yq.VAL
ybeta:=sinthe * yd.VAL + costhe * yq.VAL
y:=SQRT(SQU(yalph)+SQU(ybeta))
if (y>10.) {y:=10.}
i1alph:=SYMPOD1.I1A
i1beta:=(SYMPOD1.I1A + 2 * SYMPOD1.I1B) / wu3
i1d:=i1alph * costhe + i1beta * sinthe
i1q:=i1beta * costhe - i1alph * sinthe
theta_m:=theta_el / 3.
```

旋转变压器及其控制器仿真

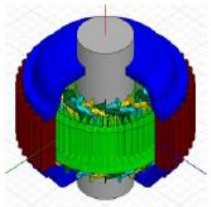


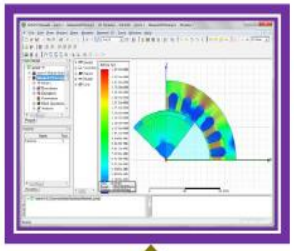
详见IEEE VPPC2008论文

高效的电机电磁自动化设计流程

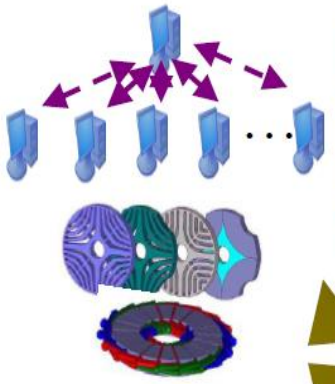


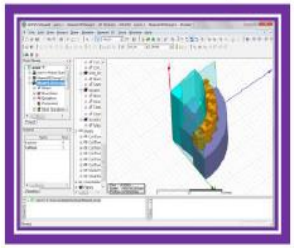
RMXprt



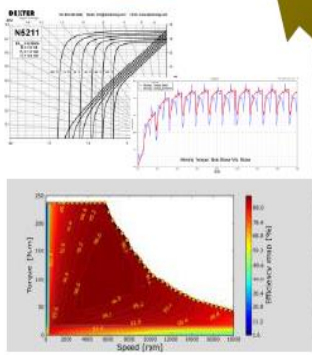


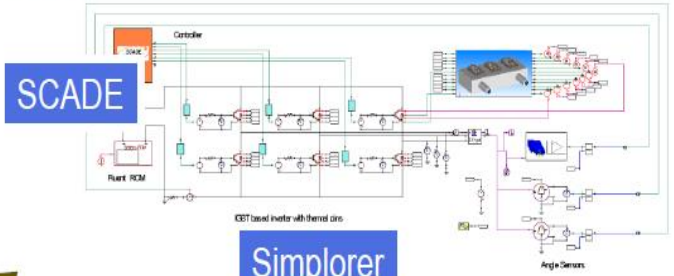
Maxwell2D

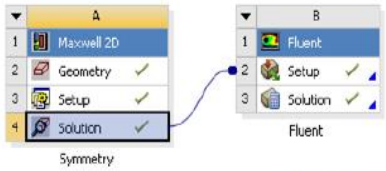


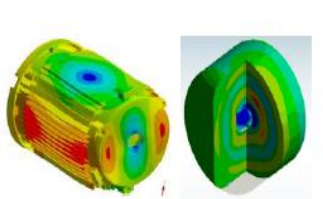


Maxwell3D

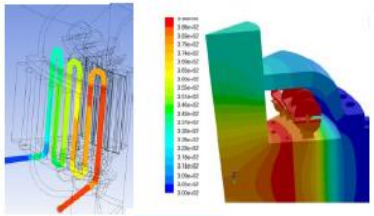








Mechanical



CFD

初始设计与建模

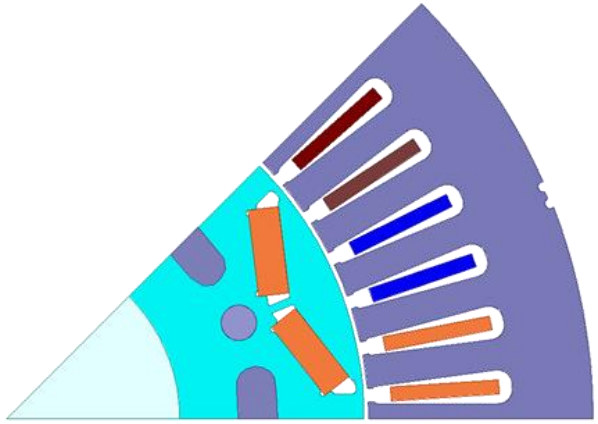
有限元求解
DSO和HPC

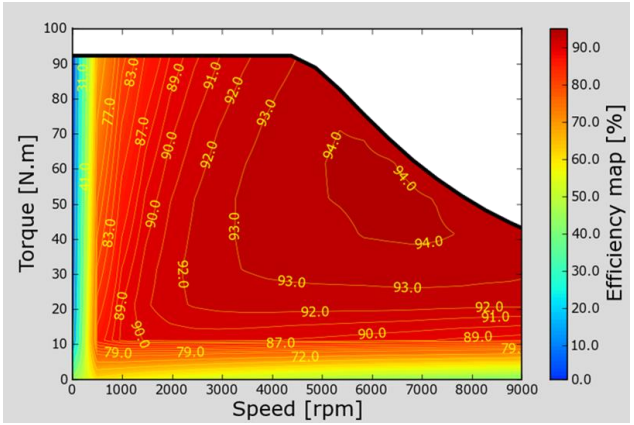
后处理
优化
定制化流程

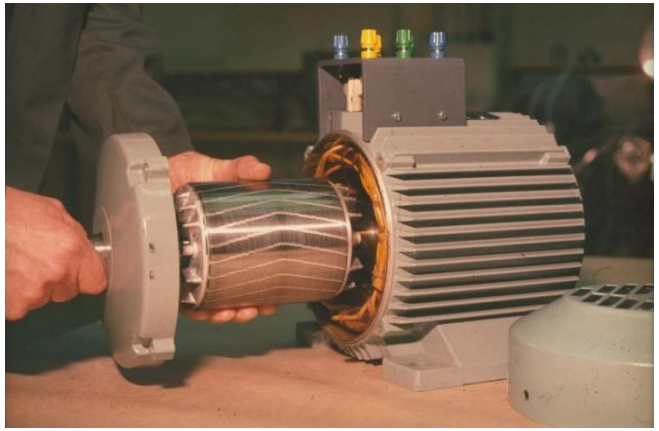
系统及多物理域仿真

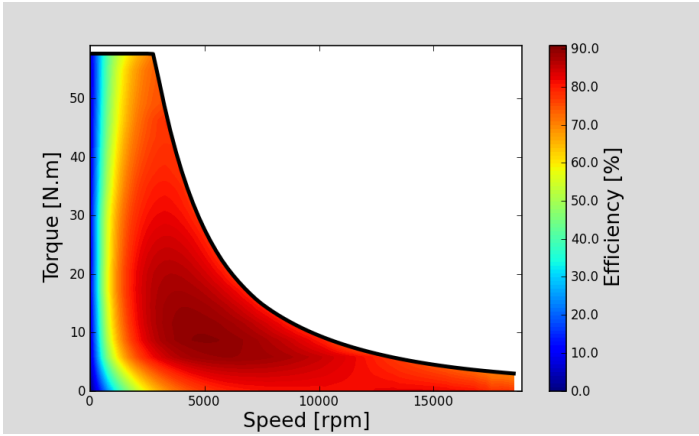
电机设计工具包（UDO/Toolkits）

- InputPower
- OutputPower
- Torque
- Speed
- PowerFactor
- SupplyCurrent
- PhaseVoltage
- CoreLoss
- SolidLoss
- StrandedLossR
- 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)



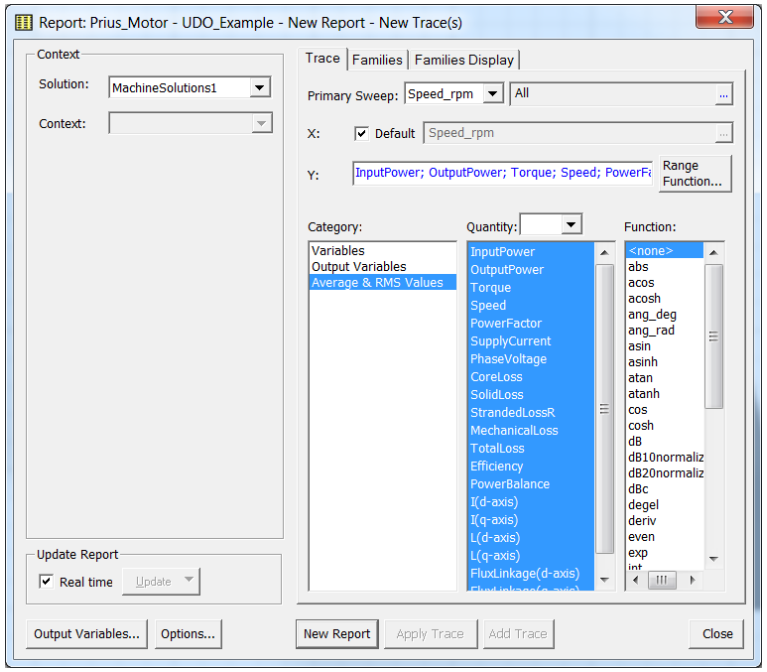


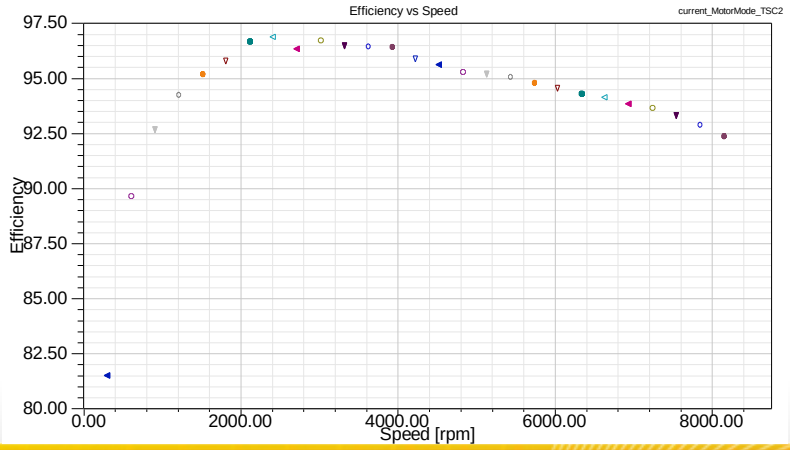




- UDO和Toolkits是针对客户需求定制化开发的电机设计工具包，可直接输出电机电磁性能数据，自动化计算转矩转速特性、效率Map图等，在电机设计领域应用广泛。

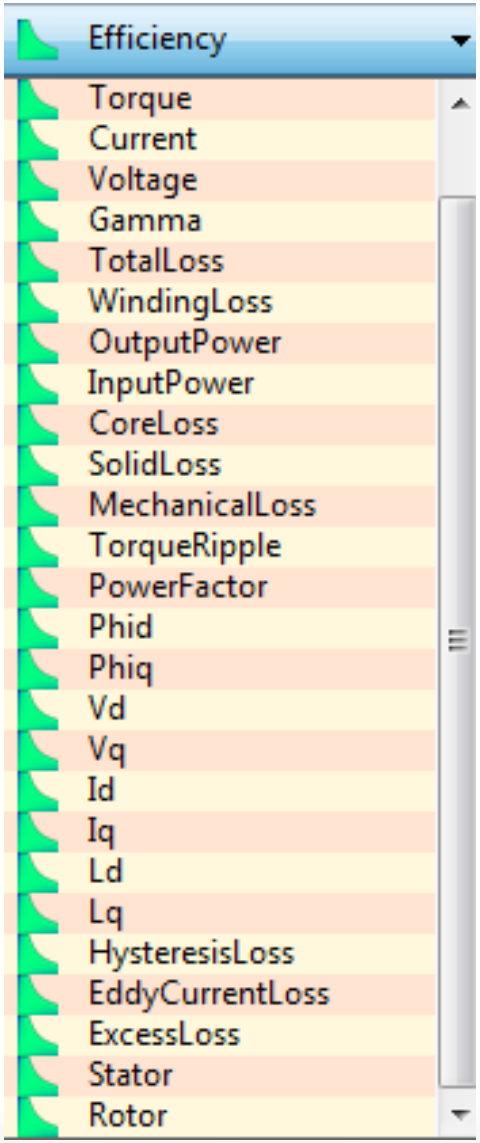
IPM电机UDO

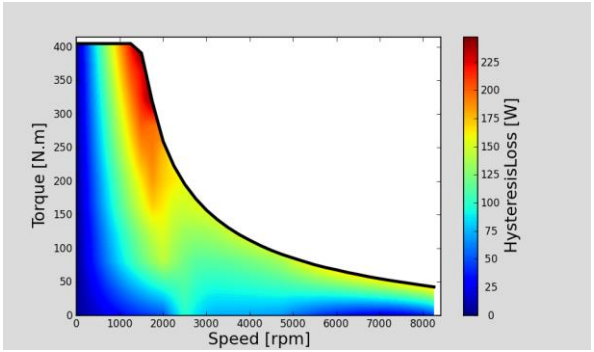


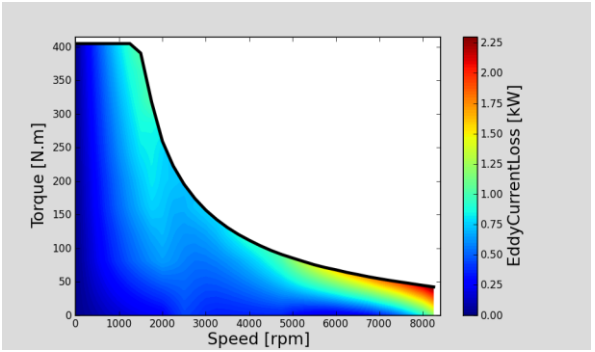


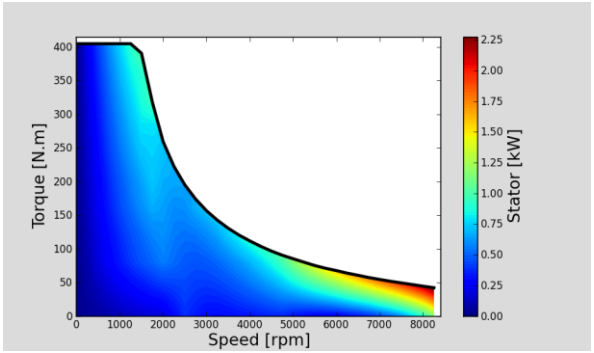
	1
Im [A]	200.000000
InputPower [kW]	71.008314
OutputPower [kW]	64.920012
Torque [NewtonMeter]	309.970223
Speed [rpm]	2000.000000
PowerFactor	0.776497
SupplyCurrent [A]	141.421356
PhaseVoltage [V]	215.542488
LineVoltage [V]	373.331140
CoreLoss [W]	223.290671
SolidLoss [W]	32.057088
StrandedLossR [kW]	2.400000
MechanicalLoss [W]	282.841720
TotalLoss [kW]	2.938189
Efficiency	95.670104
TorqueRipple [NewtonMeter]	59.431130
PowerBalance	5.329158
V(d-axis) [V]	-253.708552
V(q-axis) [V]	151.061294
I(d-axis) [A]	-68.374006
I(q-axis) [A]	187.949448
L(d-axis) [mH]	2.640212
L(q-axis) [mH]	2.707216
FluxLinkage(d-axis) [Wb]	0.157904
FluxLinkage(q-axis) [Wb]	0.321646

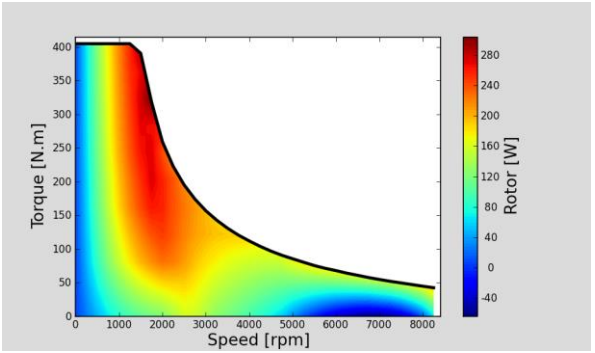
IPM效率Map图



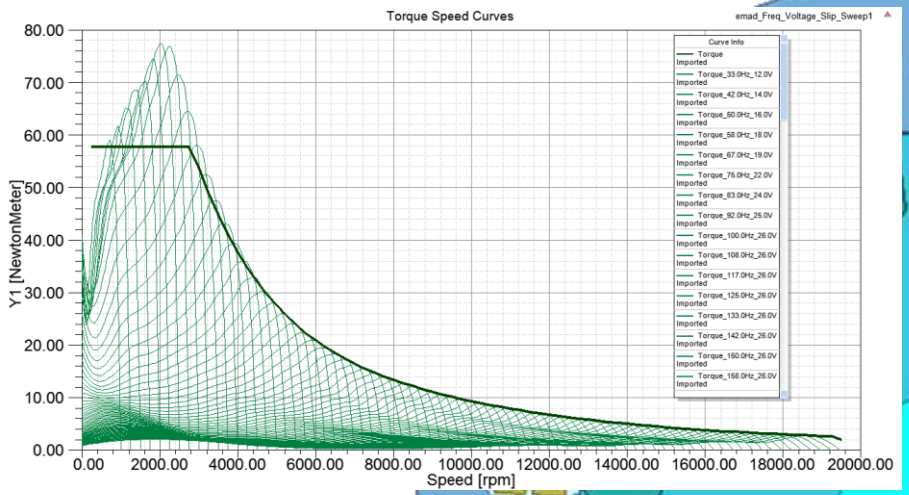


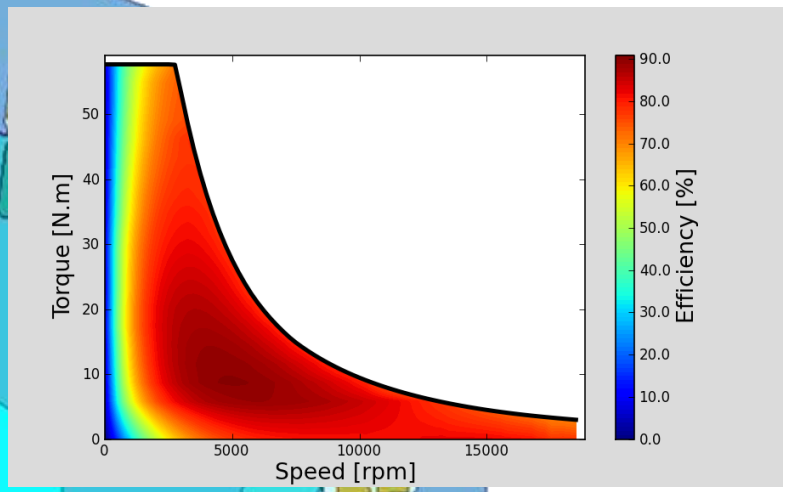


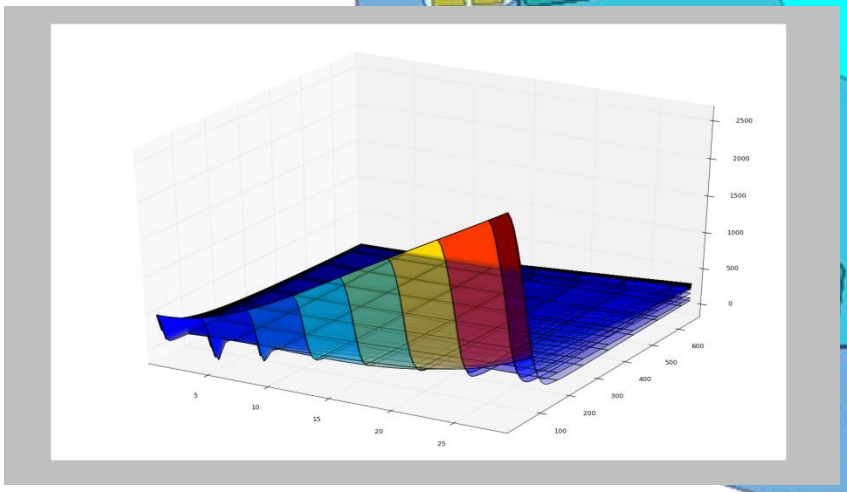


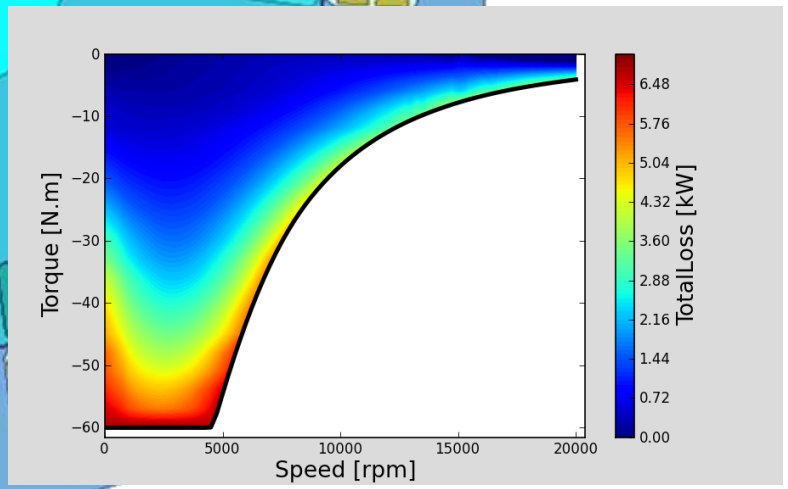


三相感应电动机



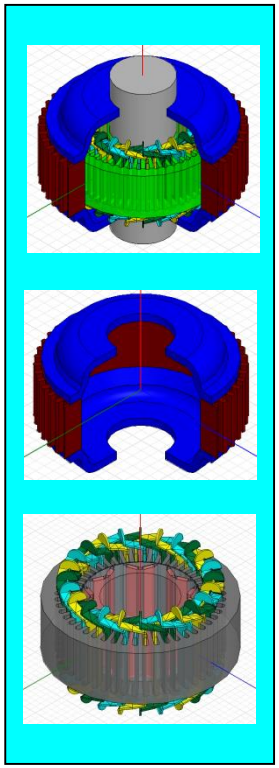




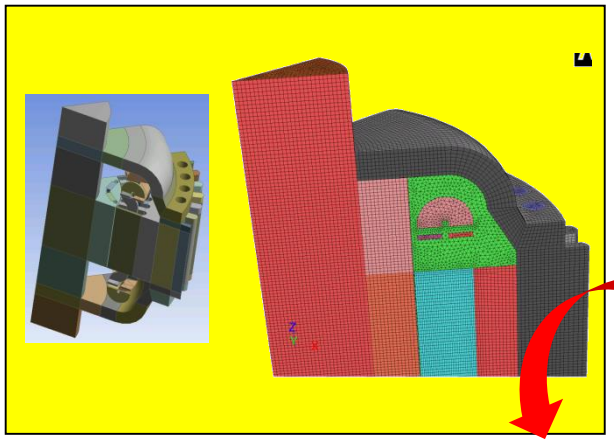


电机设计平台

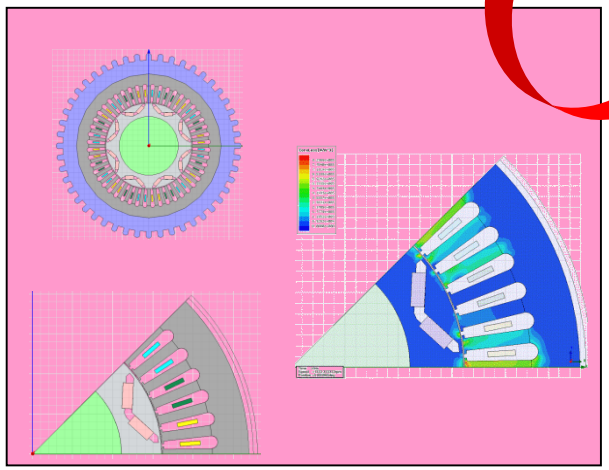
电机温升、散热分析流程



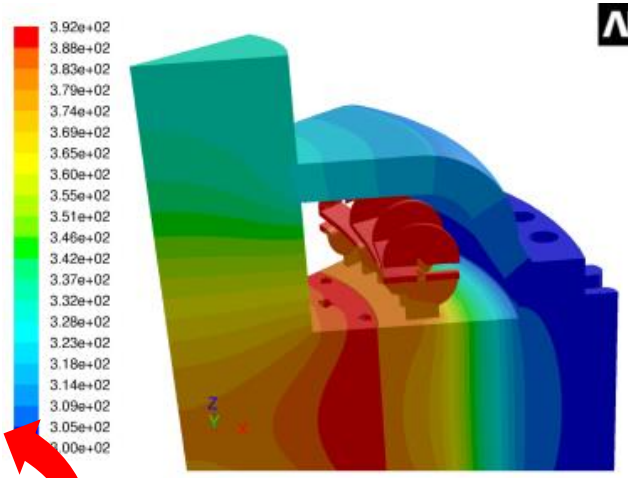
Geometry



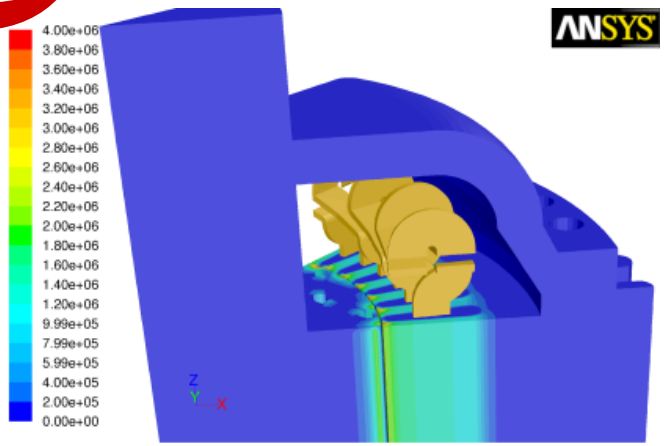
CFD Model



Maxwell Model



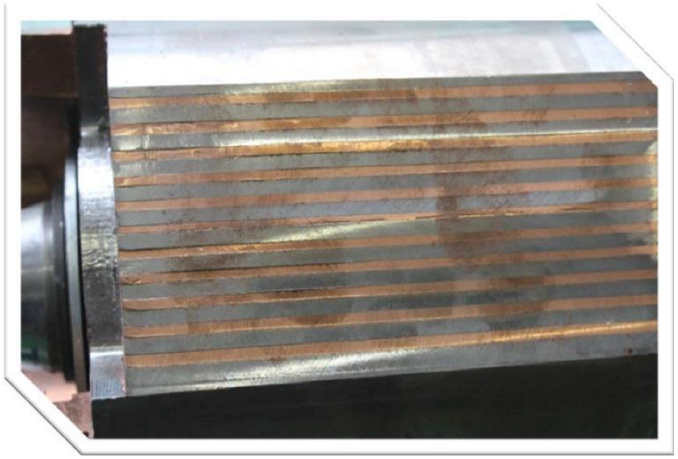
Temperature

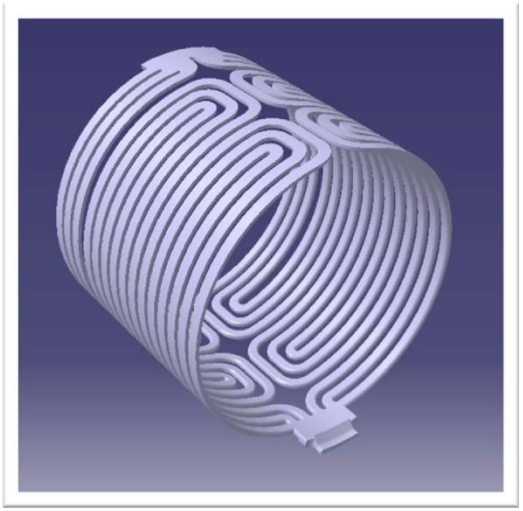


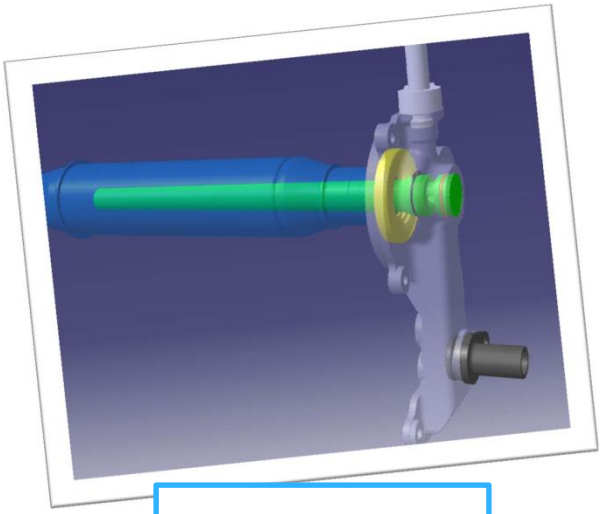
Mapped Losses

电机原型

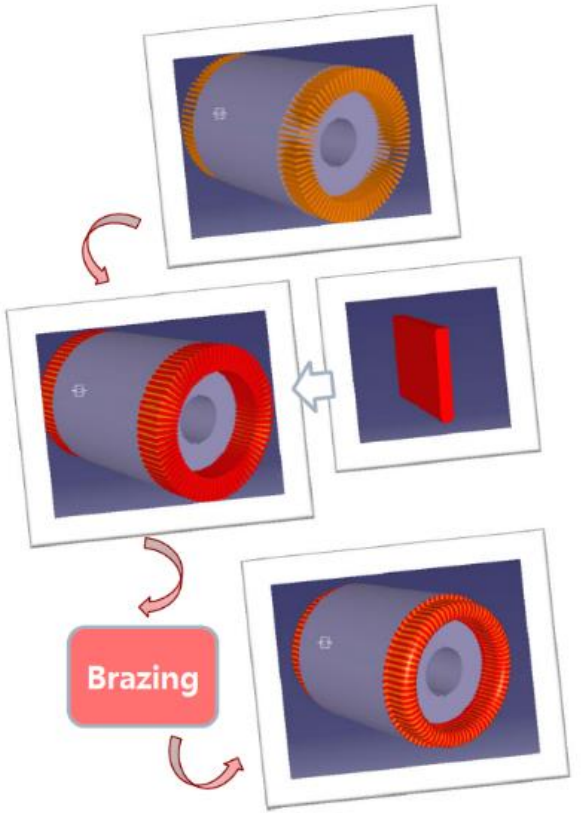
转子导条





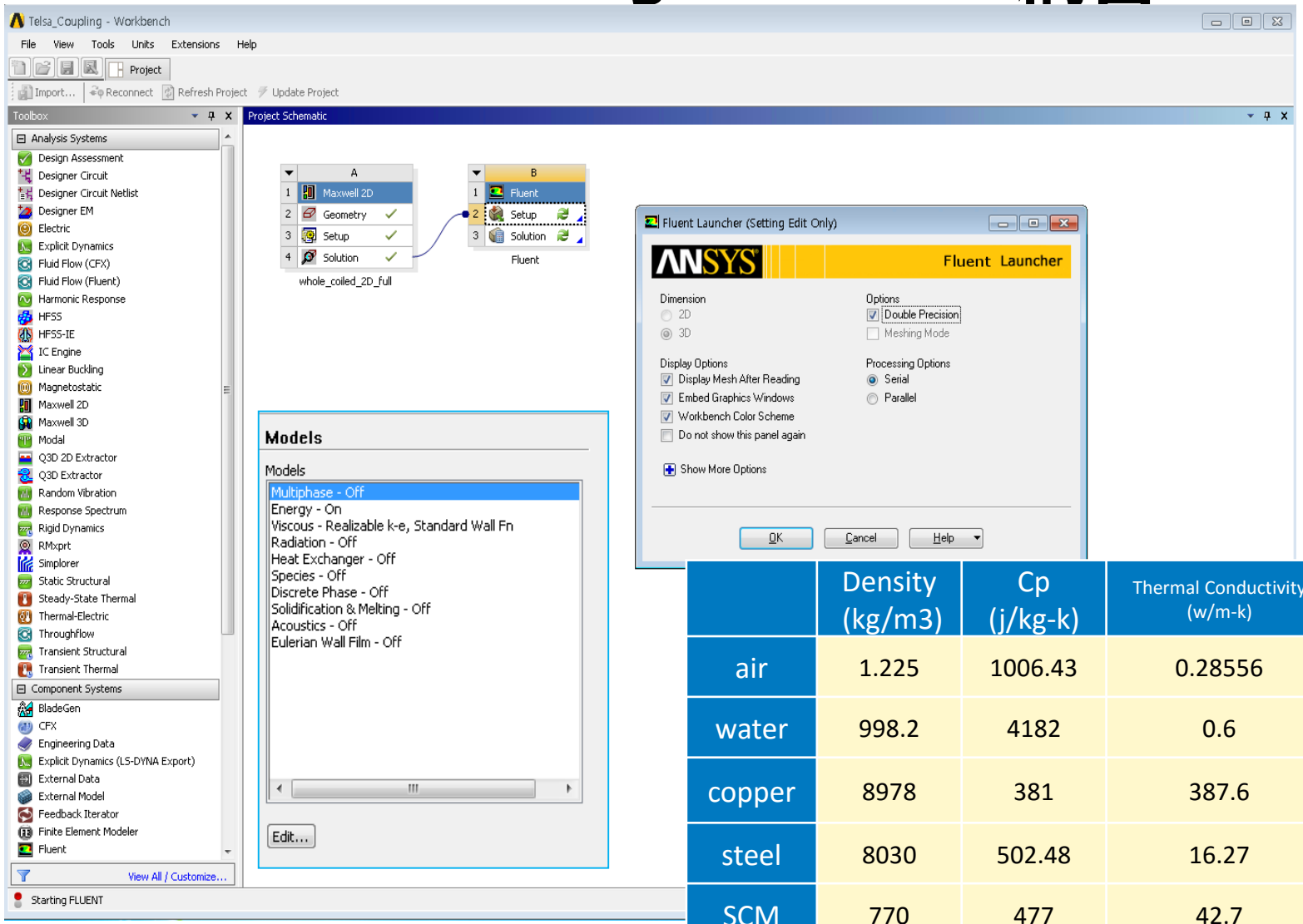


冷却系统



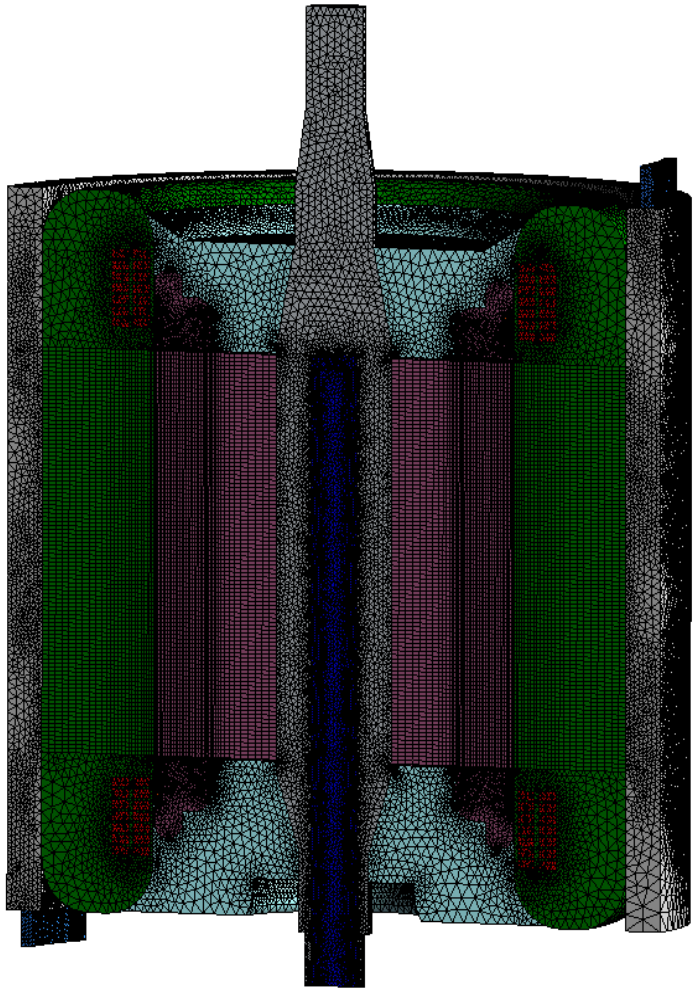
转子端环

Maxwell 2D 与FLUENT 3D耦合

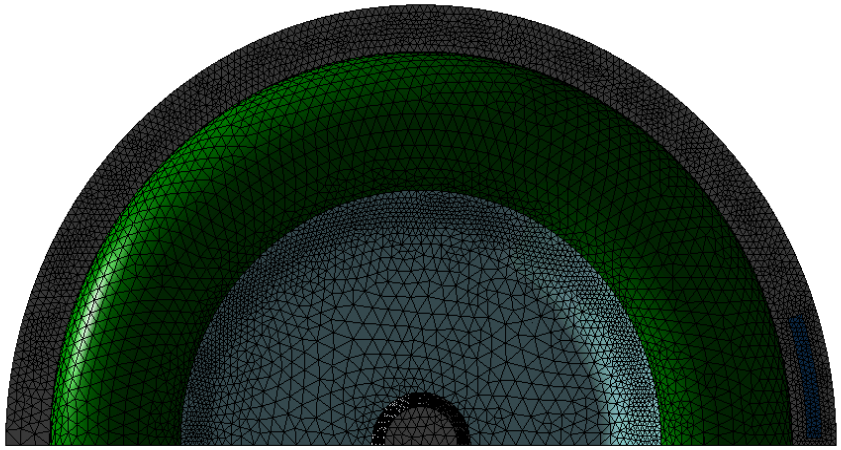


	Density (kg/m3)	Cp (j/kg-k)	Thermal Conductivity (w/m-k)	Part
air	1.225	1006.43	0.28556	Air gap
water	998.2	4182	0.6	Two cooling line
copper	8978	381	387.6	coil, rotor bar, rotor coil ring
steel	8030	502.48	16.27	rotor, stator
SCM	770	477	42.7	Shaft

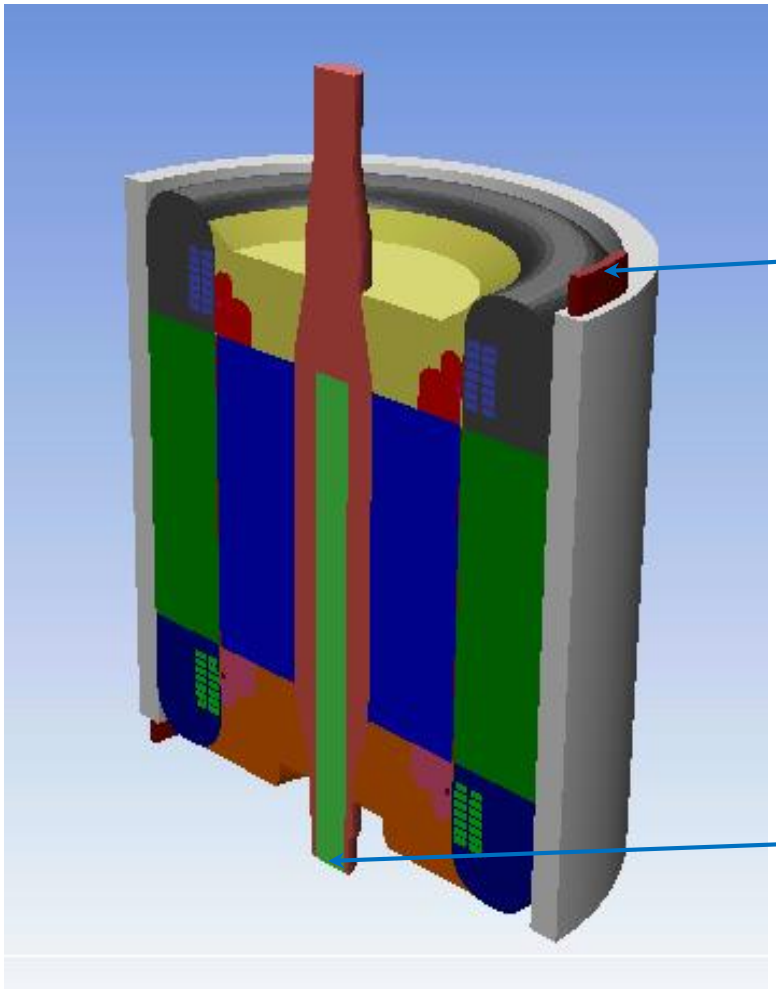
流体网格

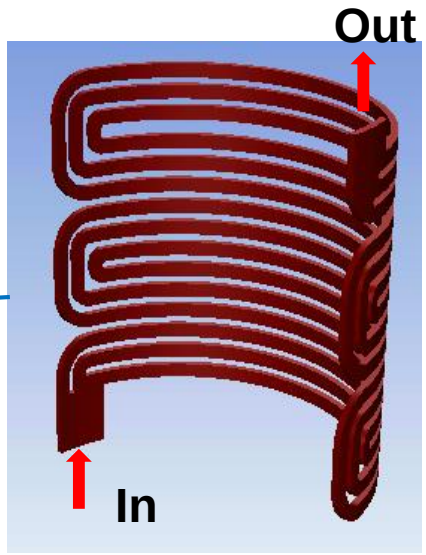


Cells : 28,489,022



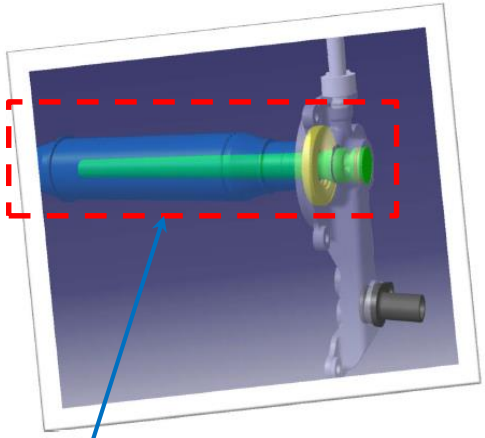
冷却系统

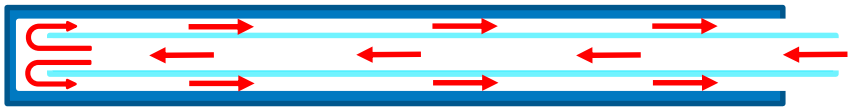




Water Jacket Cooling Line

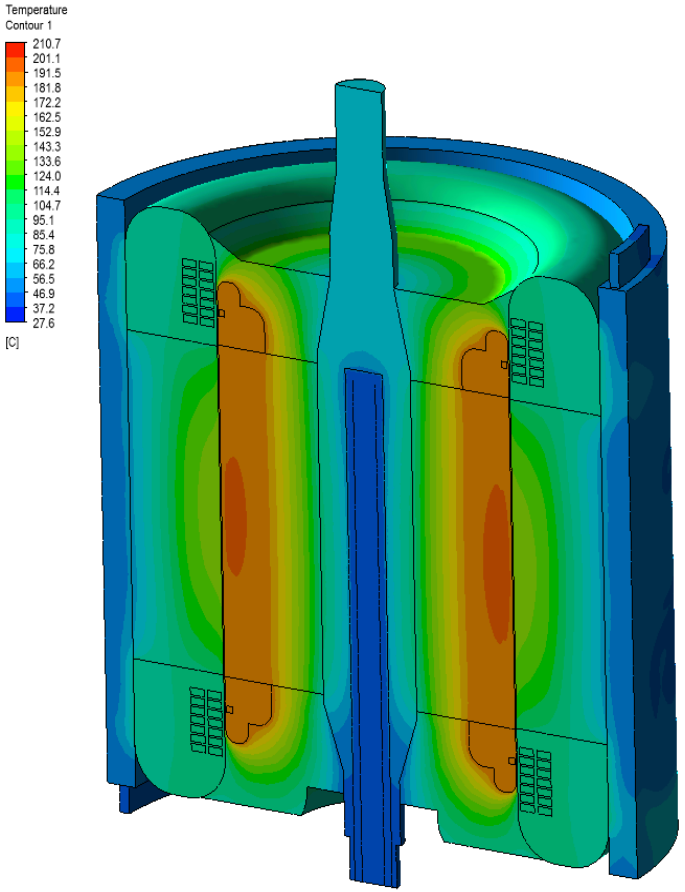
Coolant : Water
Coolant Tem. : 45℃
Water Jacket In : 0.4 kg/s
Shaft cooling in : 0.28 kg/s



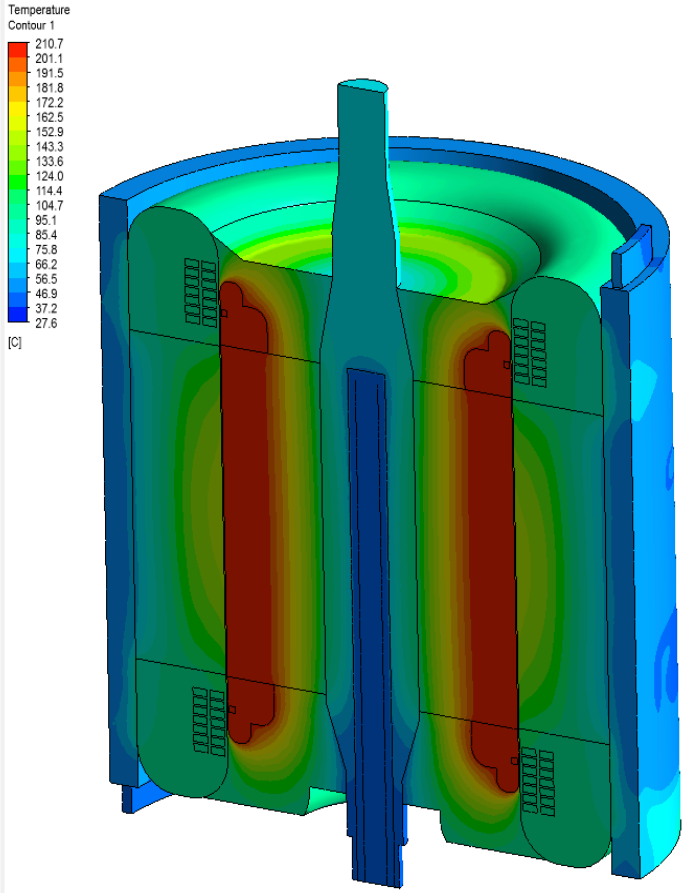


Shaft Cooling Line

结果-温度



Case1： 理想电压源

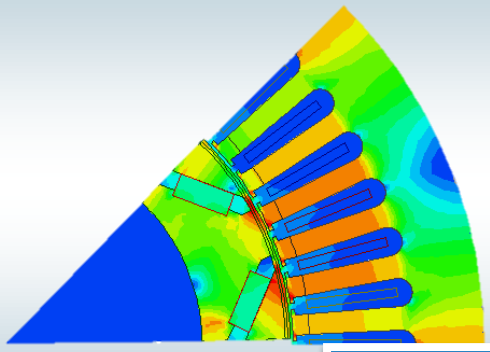


Case2 : PWM 电流源

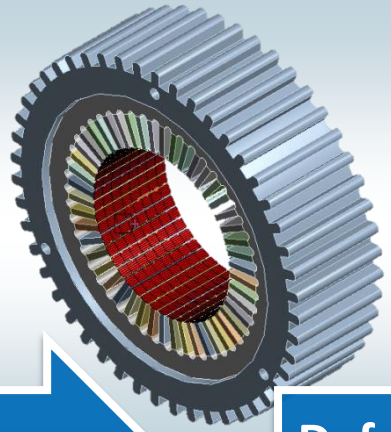
ANSYS 振动和噪声仿真

- **功能强大的振动和噪声求解技术**
  - 高度集成化的仿真流程
  - 分布式求解、HPC与GPU共同加速计算
  - 内嵌于Workbench的噪声计算模块

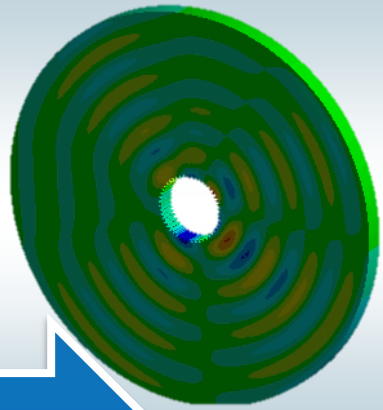
Magnetic Field
ANSYS Maxwell



Structural Dynamics
ANSYS Mechanical



Acoustic Field
ANSYS Mechanical



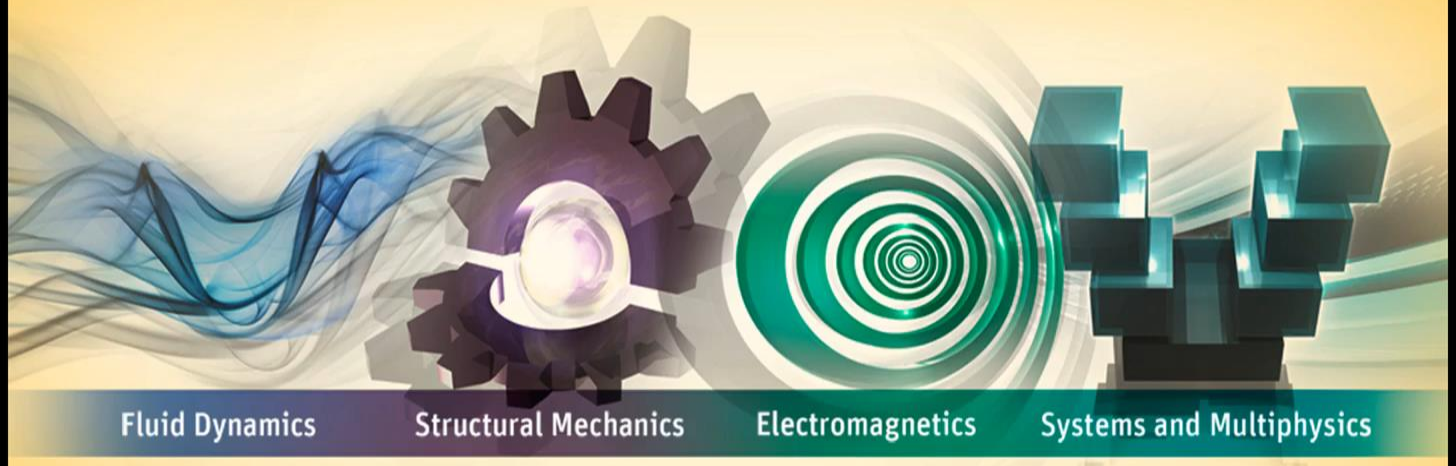
Magnetic Forces

Deformation

ANSYS

Realize Your Product Promise™

Full multiphysic simulation of an Induction motor
From analytical sizing to thermal and vibro-acoustic

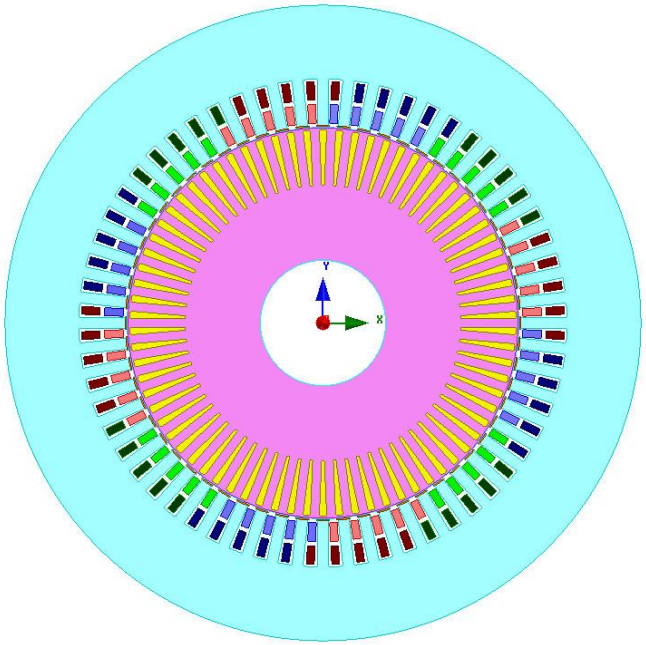


Olivier Roll
Emad Dlala
Eric Lin

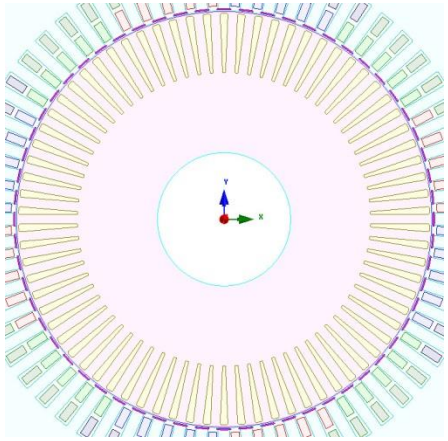
ANSYS

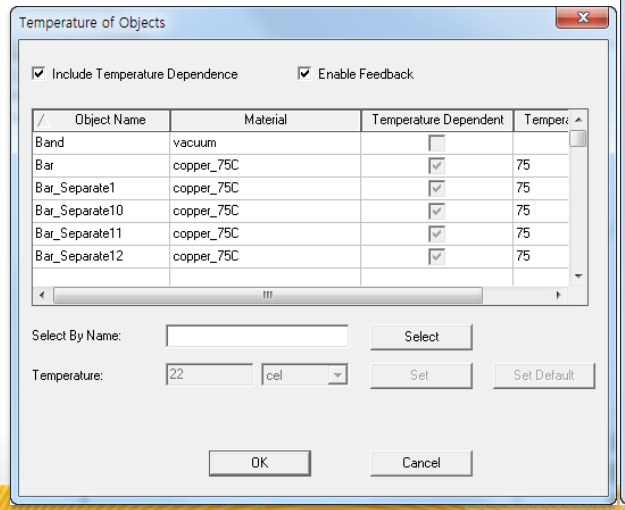
Maxwell 2D 模型

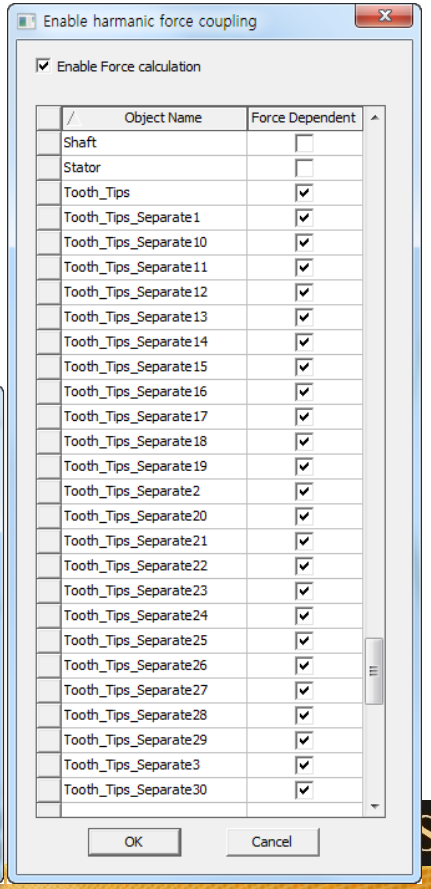
EM Model from RMxprt



ToothTips for Vibration Analysis



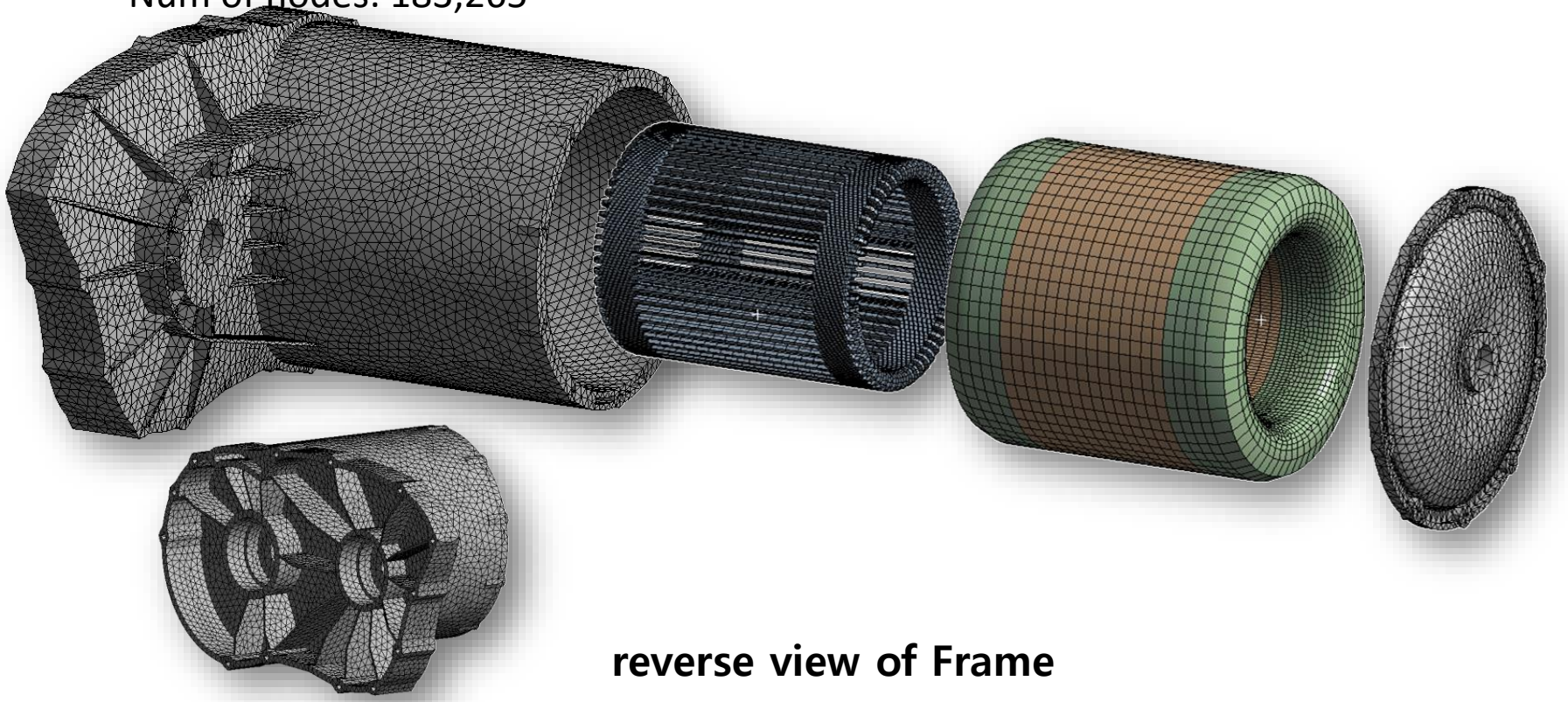




振动分析有限元模型

for Structure Harmonic Analysis

- Element Type: SOLID185
- Num of nodes: 183,265

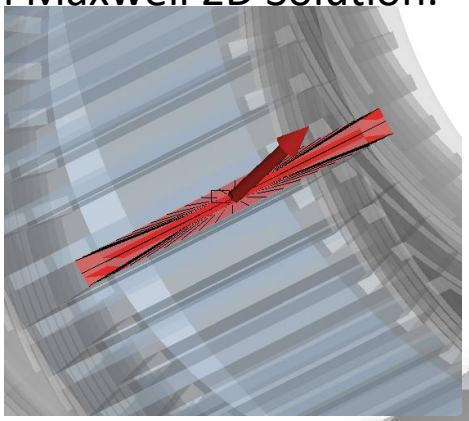


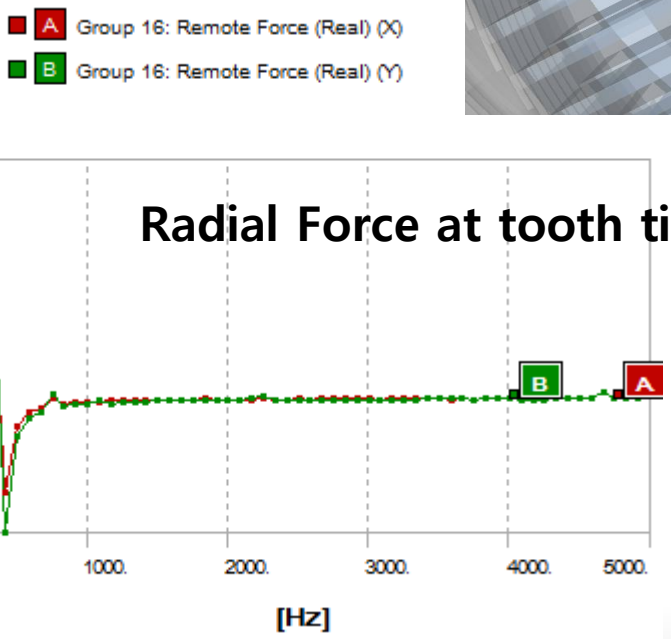
reverse view of Frame

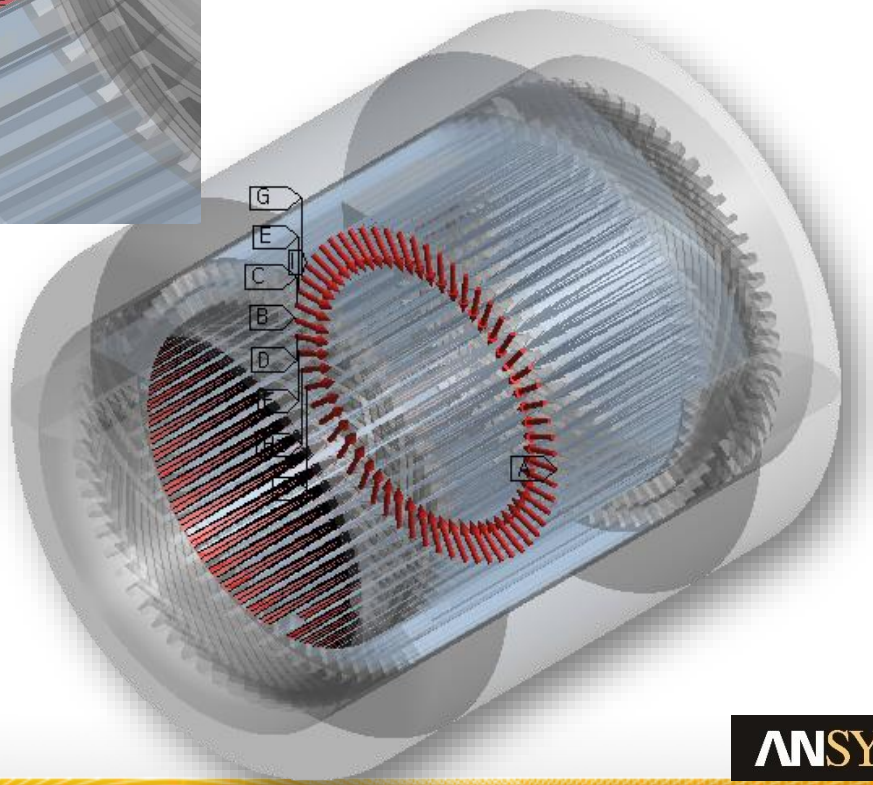
机械振动分析

…Boundary Conditions

- magnetic force Import from Maxwell 2D Solution.

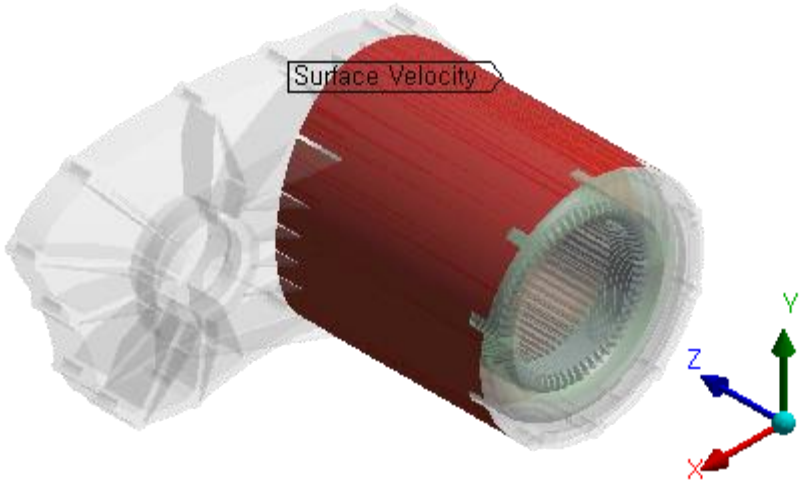


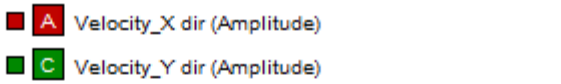


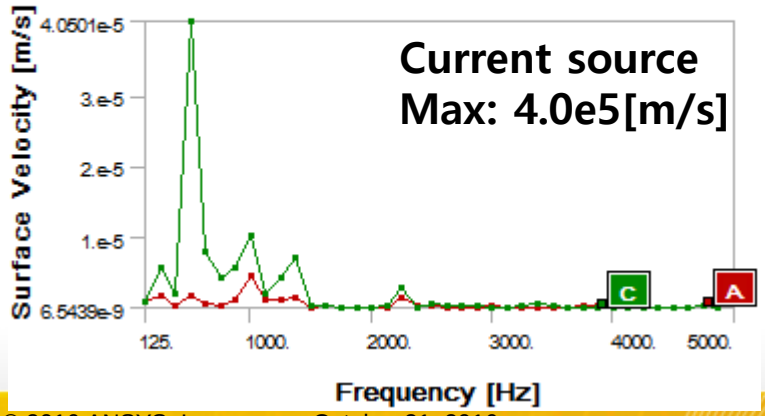


机械分析结果

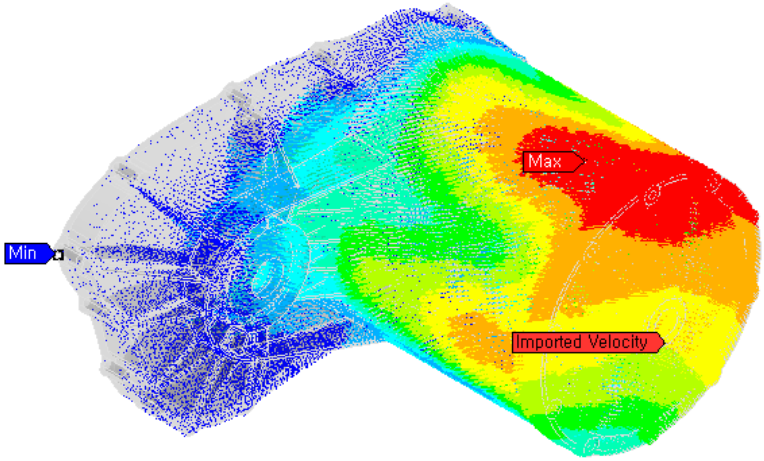
Extract of Surface Velocity

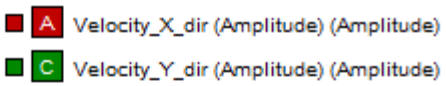


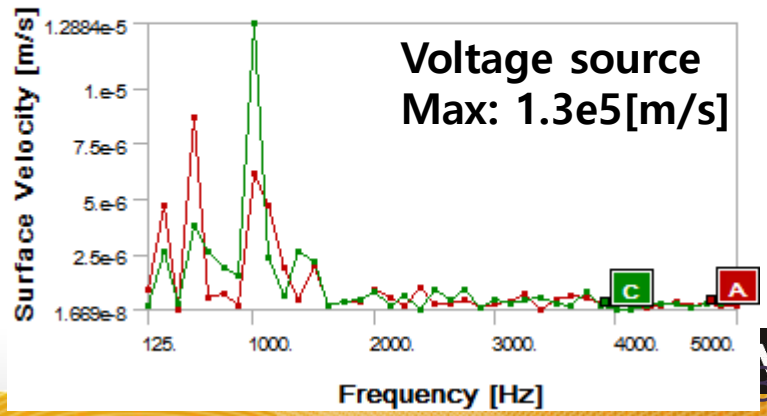




Surface Velocity Vector at 250Hz

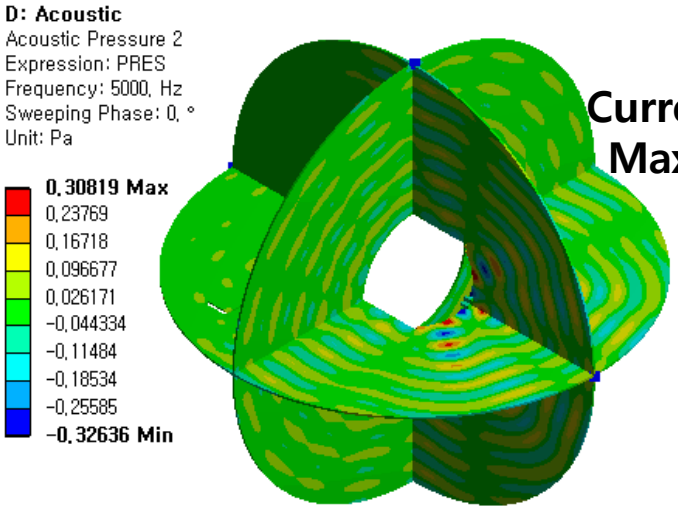




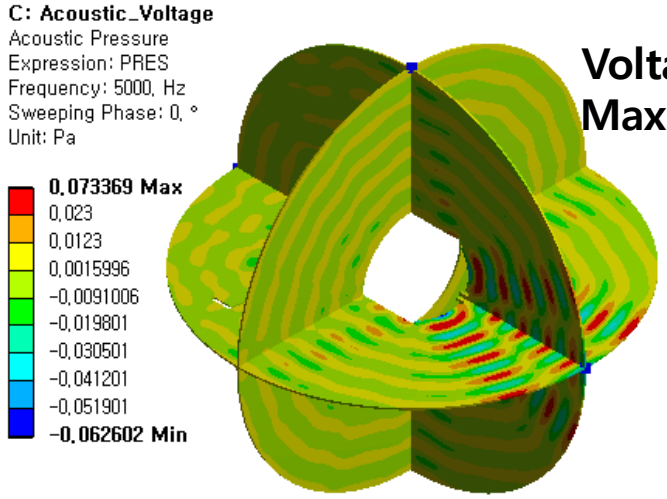


噪声计算结果

Acoustic Pressure(Pa) at 5,000Hz

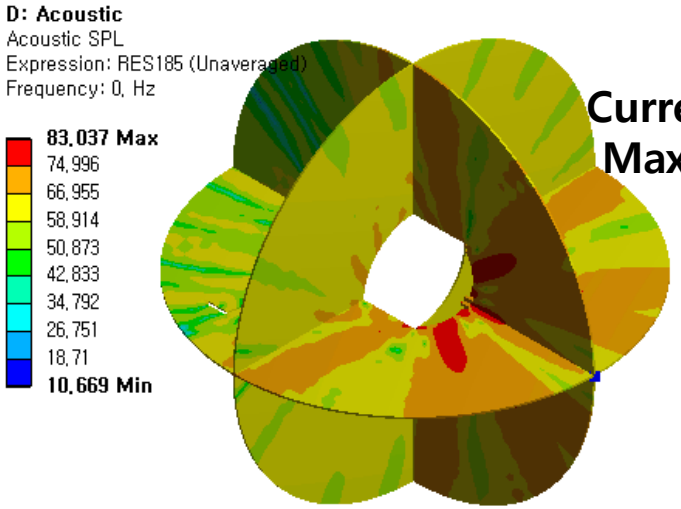


Current source
Max: 0.30[Pa]

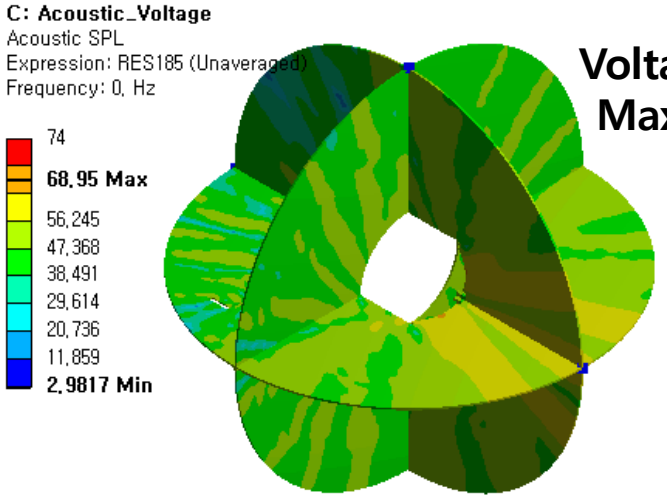


Voltage source
Max: 0.073[Pa]

Sound Pressure Level(dB)



Current source
Max: 83.0[dB]



Voltage source
Max: 68.9[dB]

培训信息：深圳市民中心

ANSYS 系列高级培训

ANSYS 新型永磁电机电磁、振动、噪音耦合分析高级培训班

【2016 年 12.01-02】

课程介绍：

电机的振动和噪声研究十分复杂，它涉及了电磁、能量转换、机械振动、特殊物理声学、电子学和数学等许多学科。电机噪声主要包括电磁噪声、和机械噪声，产生机理复杂，是电机研发中的关键技术。

联系方式

- 庄百兴
- baixing.zhuang @ansys.com
- 18675506525
- ANSYS 深圳

ANSYS 中国官方微信

ANSYS 中国官方微博