

Ansys

INNOVATION

C O N F E R E N C E

2020

平面变压器设计与仿真

作者:李大勇

单位: 南京埃斯顿自动控制技术有限公司

职务: 研发工程师

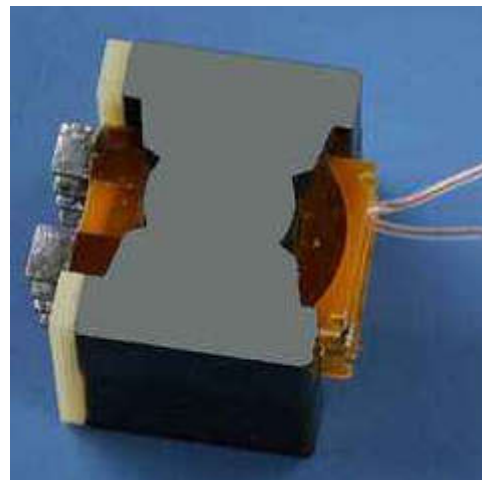
行业与产品概述

- 行业背景

通讯及伺服控制领域广泛使用模块电源，产品微型化设计对变压器提出了更严格的要求，如小尺寸、低剖面、大输出电流、小电磁辐射。传统变压器已经成为制约开关电源技术进一步发展的一个重要因素。

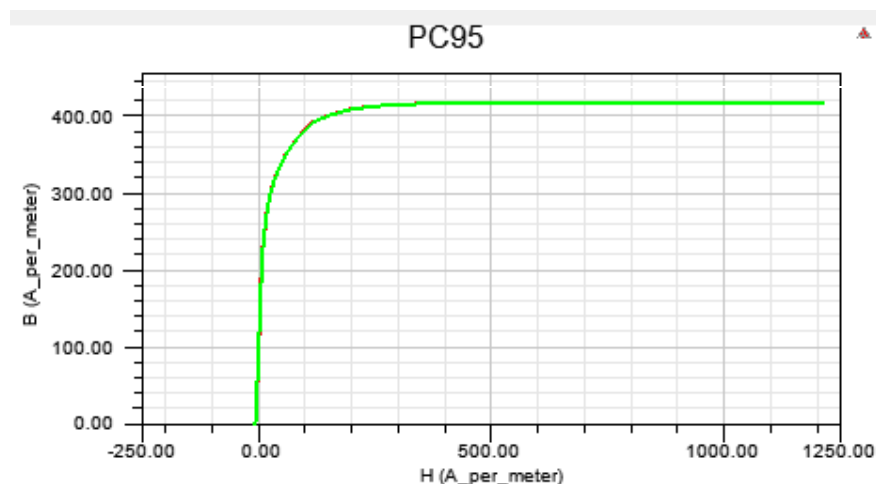
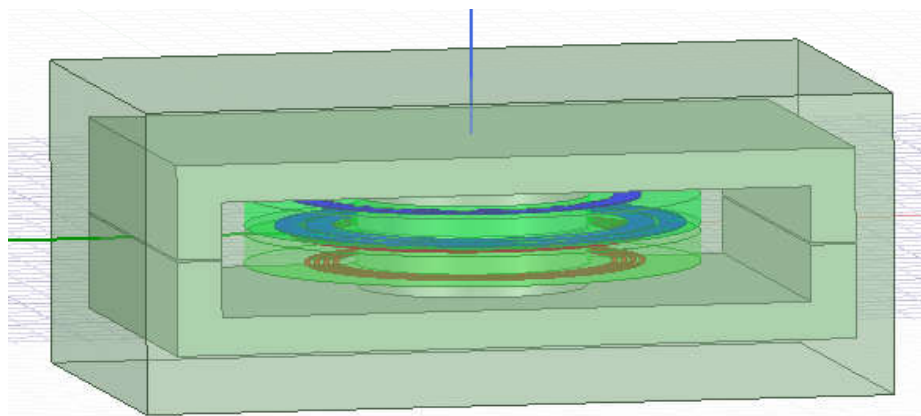
- 产品特点

平面变压器由于体积小，工作频率高，高频寄生参数得到了很大的降低，近年来在开关电源中得到了广泛应用。其中PCB型平面变压器可以省去绕组骨架，电流密度最高可达20A/mm，功率大、工艺简单。随着电子、信息技术向微型化发展的趋势，未来平面变压器必然成为变压器、变流器、电感器的首选。



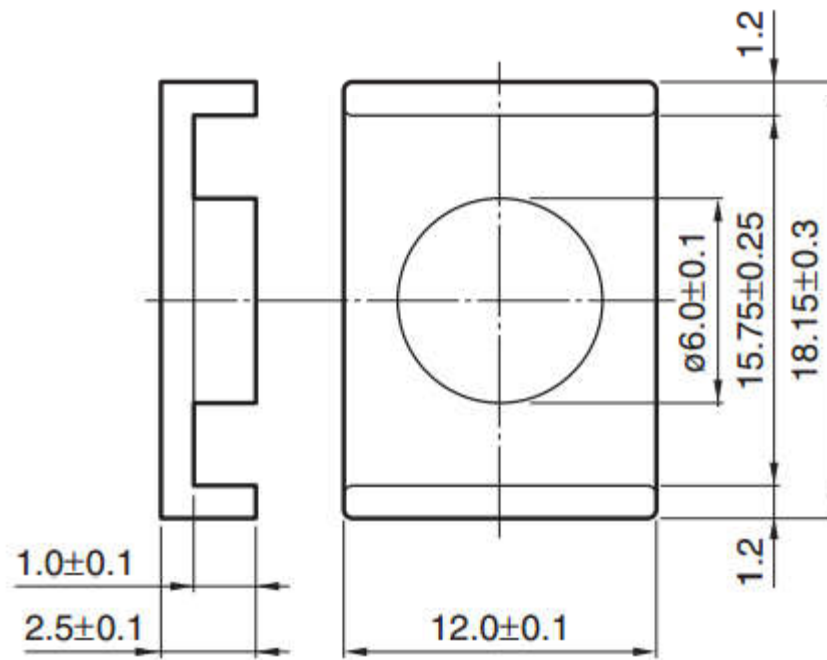
仿真需求分析

- 设计中的关键问题
 - PCB绕组有不同的简化方式，不同模型简化方式对等效漏感及温升计算精度有较大的影响。不合理的简化方式影响PCB绕组的布铜及对PCB及磁芯温升的评估并影响变压器设计的合理性。
- 仿真需求分析
 - 利用Maxwell计算各个绕组的欧姆损耗，铁心损耗，初级等效漏感及各绕组等效电阻，评估PCB布铜的合理性
 - 利用Fluent或Icepak计算绕组的温升及磁芯的运行温度，根据温度分布及最高温升点评估温度安全裕度。

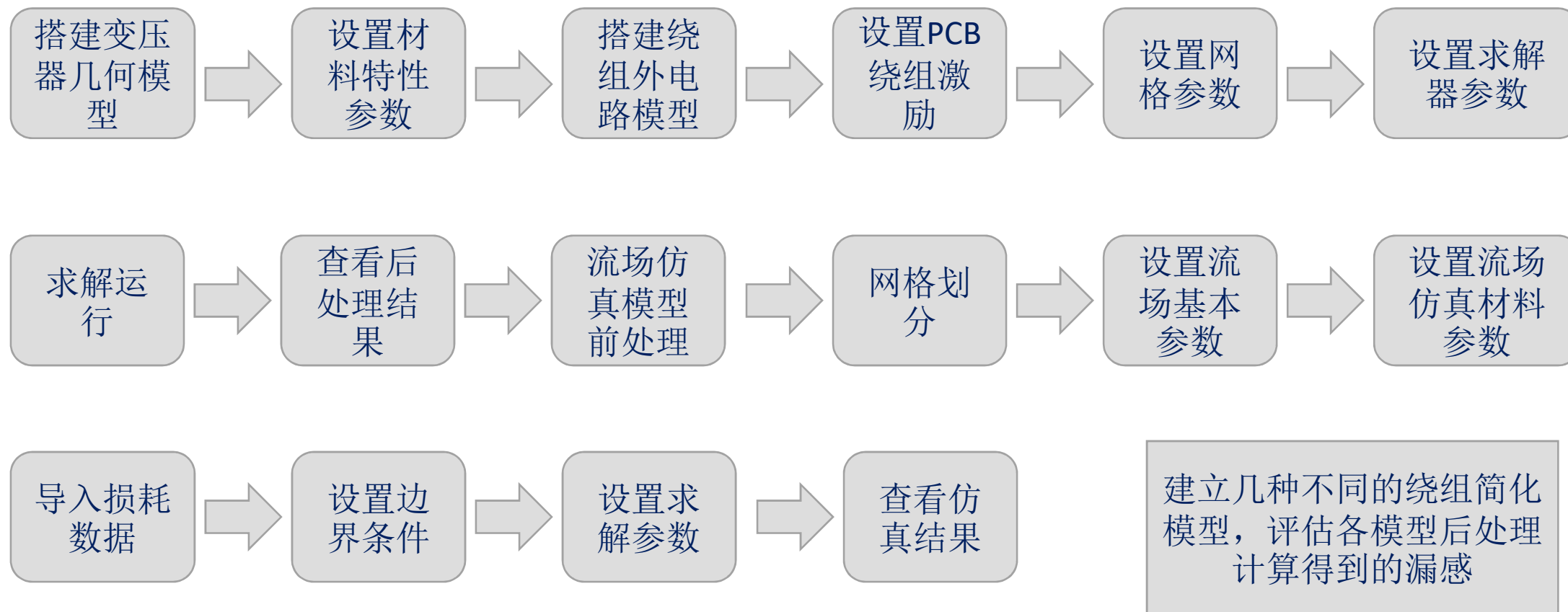


仿真需要具备的条件

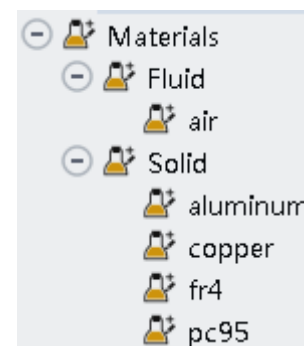
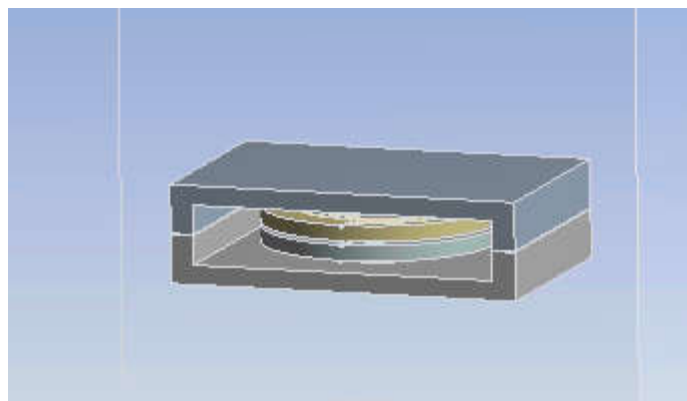
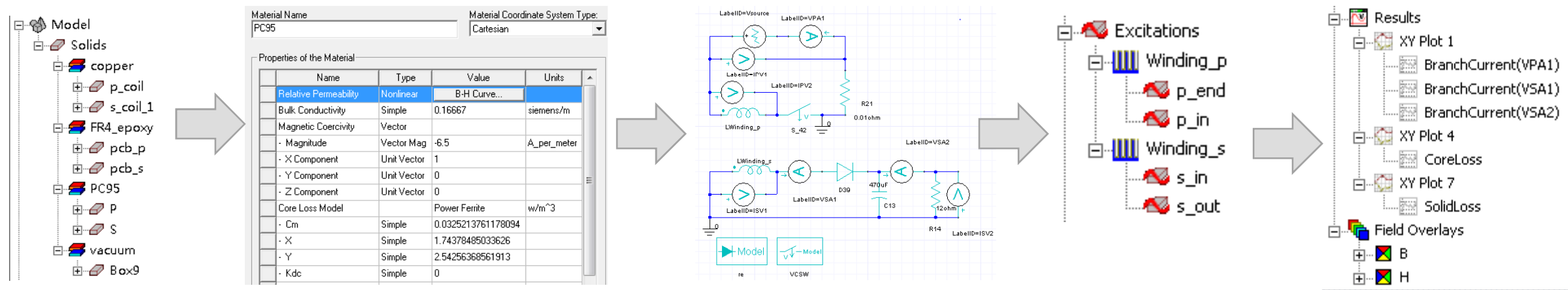
- 模型或数据
 - 磁芯尺寸及PCB绕组匝数、布铜位置及覆铜厚度等模型尺寸数据
- 参数与条件
 - 反激电路参数
 - 磁芯的材料性能数据，包括BH曲线、BP曲线、导热系数
- 软件与硬件
 - Ansys Maxwell及Fluent或Icepak、32核、64G内存图形工作站
- 其他准备
 - 印制电路板生产商为设计提供可制造性方面的评估



仿真设计过程简述



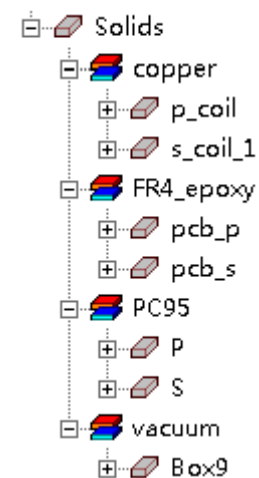
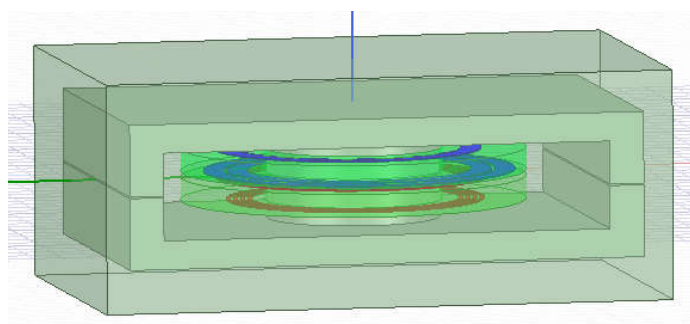
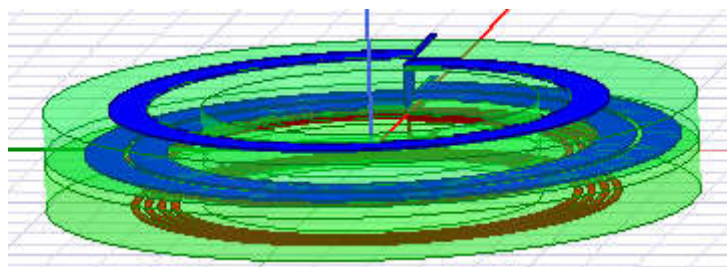
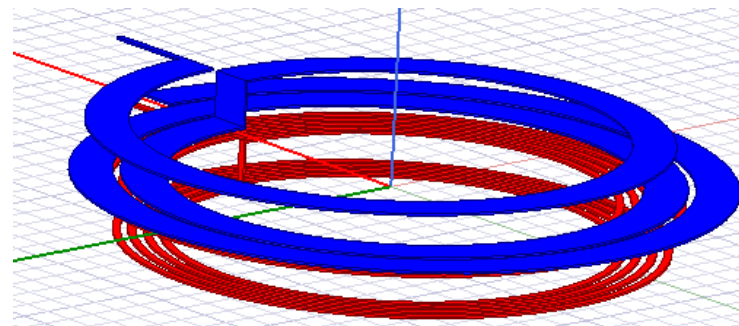
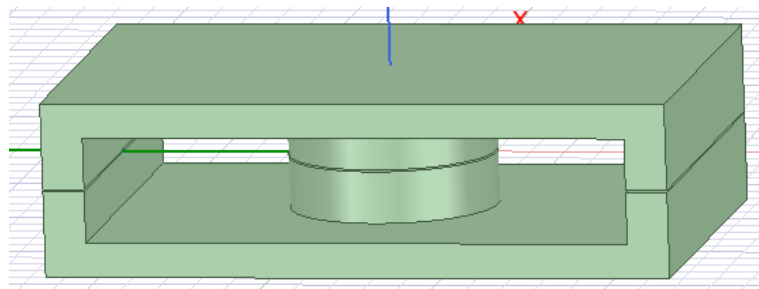
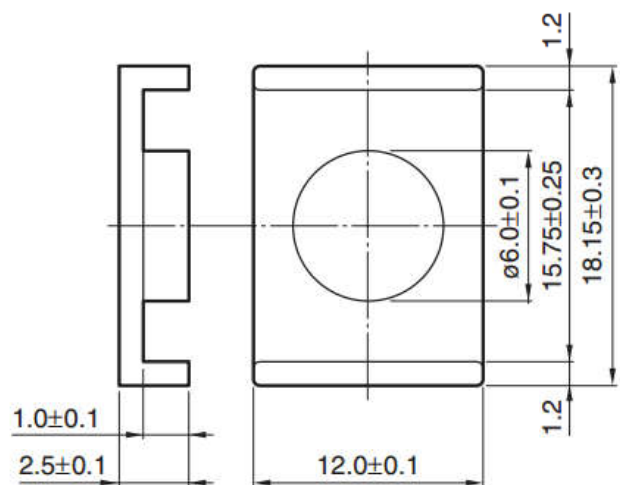
仿真设计过程简述



仿真设计过程详解

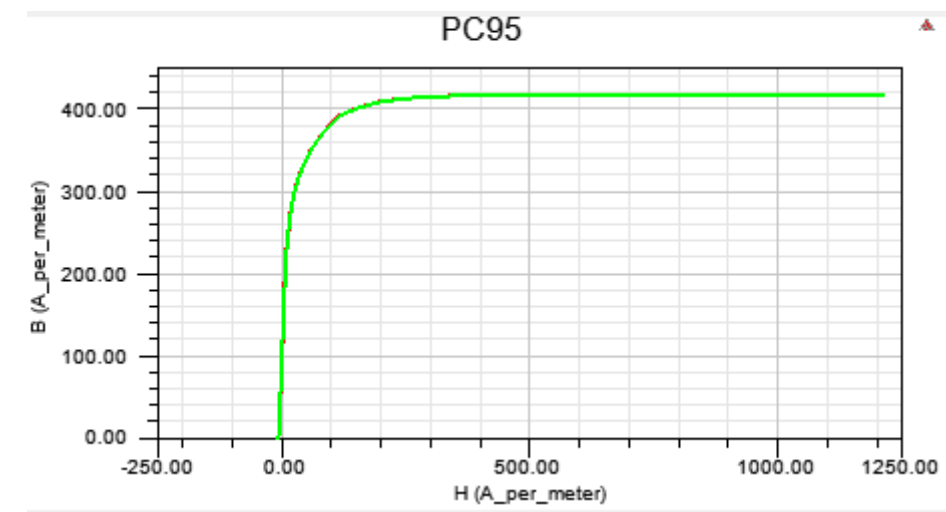
- 根据磁芯选型及实际PCB布板空间搭建模型，建立PCB详细模型，尽量还原实物模型。

布板空间搭建模



仿真设计过程详解

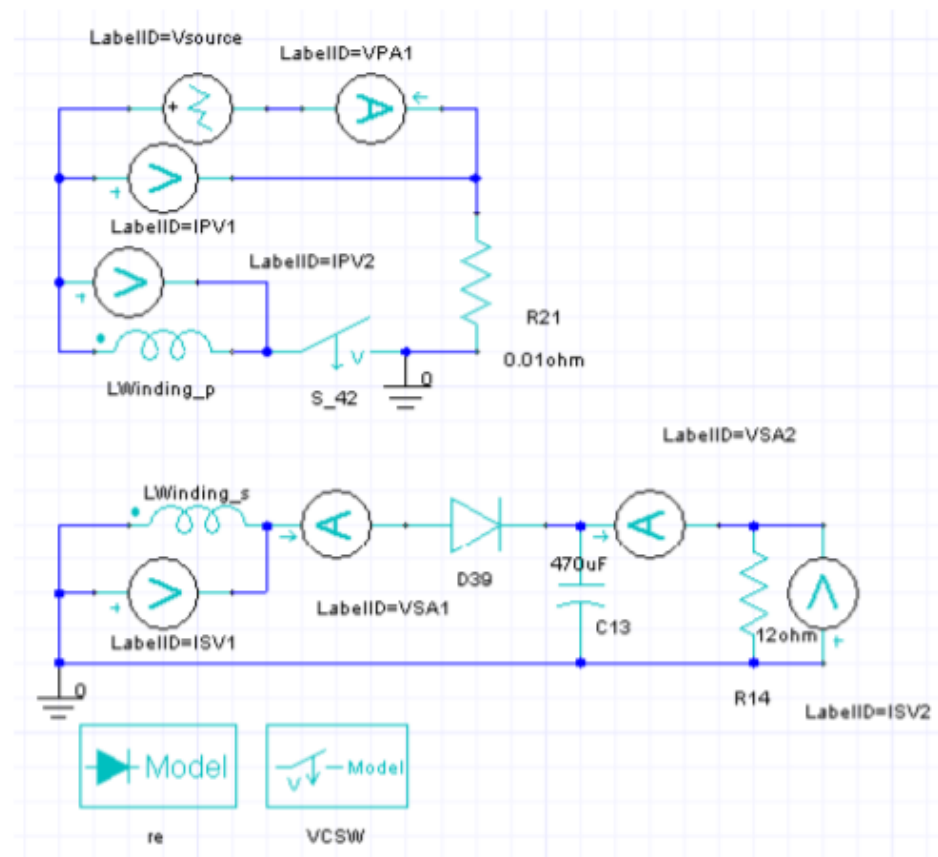
- 设置材料参数，包括BH、BP曲线。



Core Loss Model		Power Ferrite	w/m^3
- Cm	Simple	0.0325213761178094	
- X	Simple	1.74378485033626	
- Y	Simple	2.54256368561913	
- Kdc	Simple	0	
- Equiv. Cut Depth	Simple	0.001	meter

仿真设计过程详解

- 搭建PCB线圈的驱动电路外电路模型并设置绕组参数



Excitations

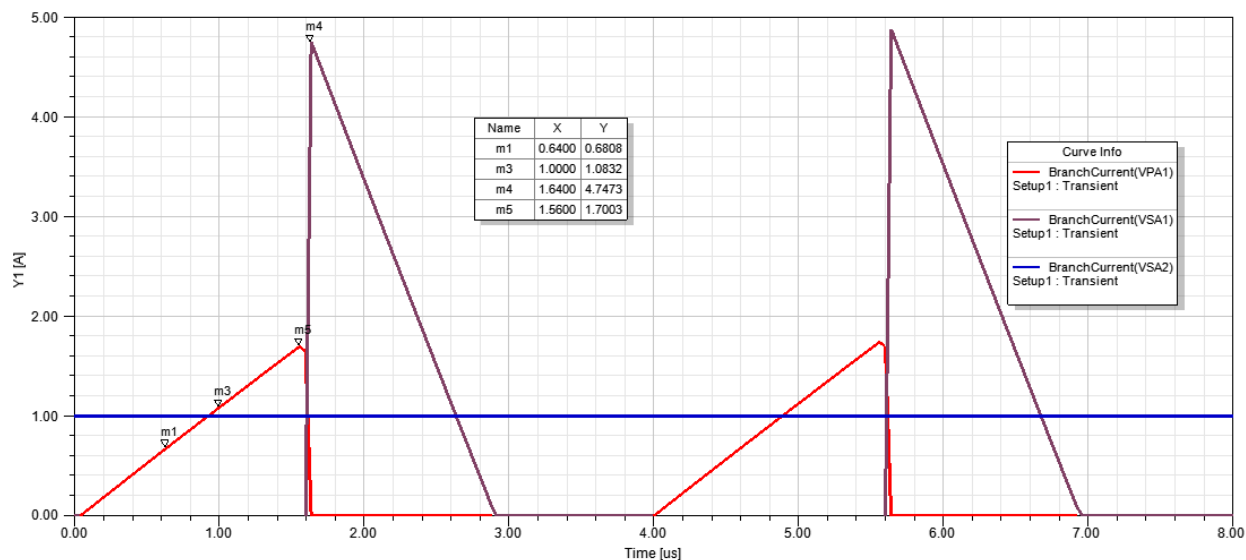
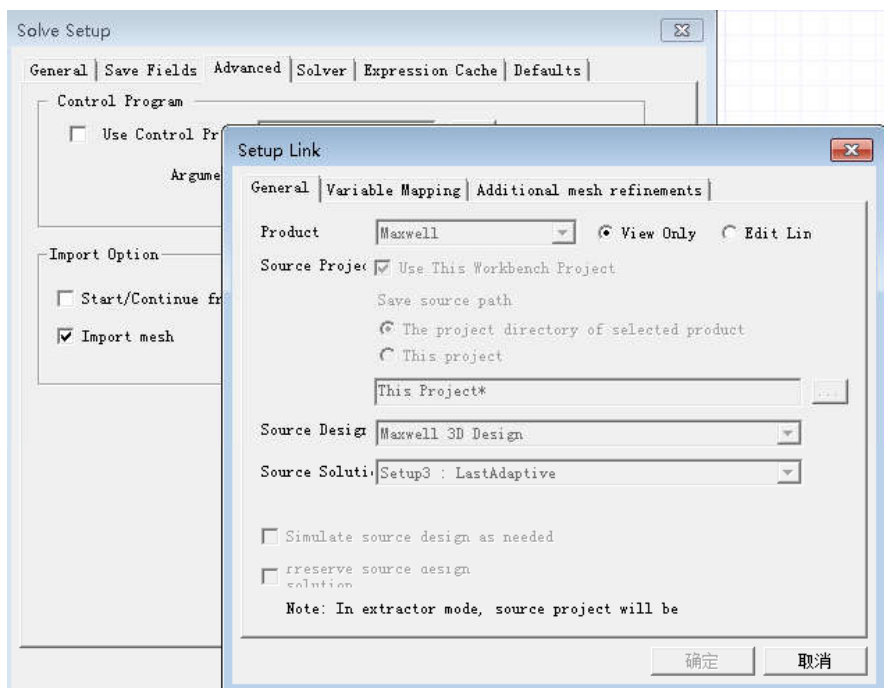
Name:

Parameters

Number of Conductors:

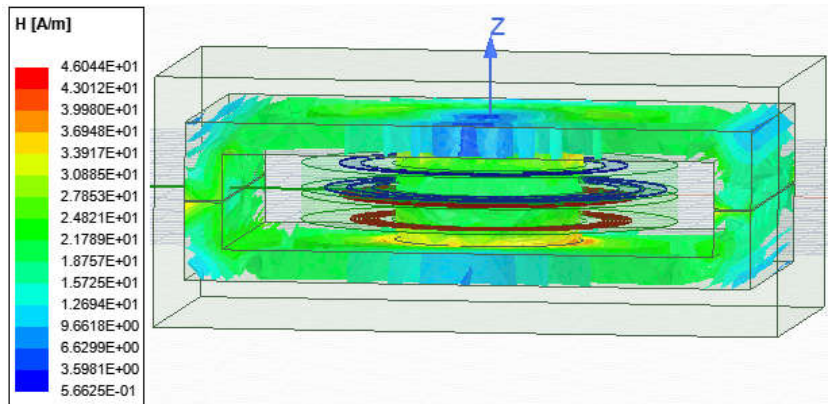
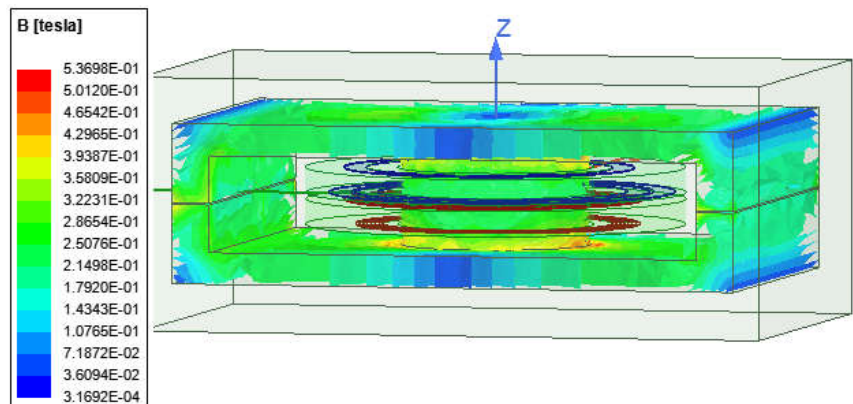
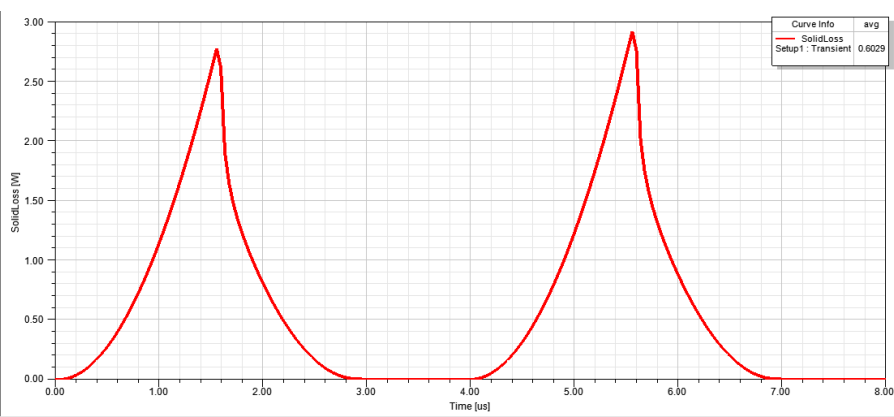
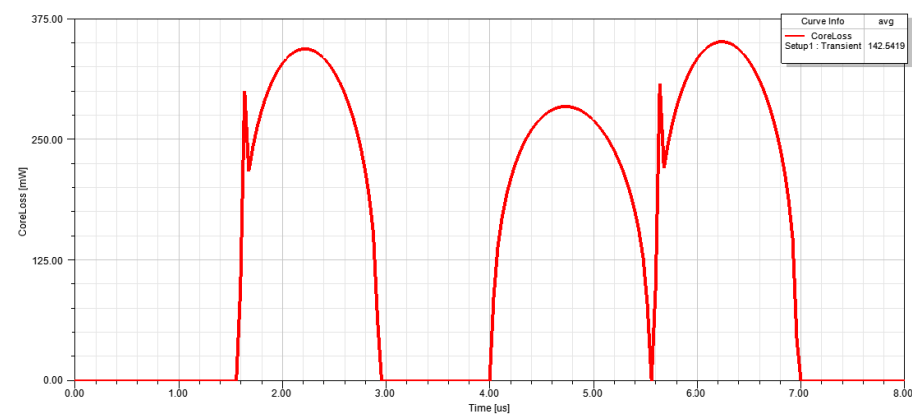
仿真设计过程详解

- 创建静态仿真模型并生成自适应网格，瞬态仿真导入静态仿真模型的自适应网格，查看电流波形，确保外电路的正确性。



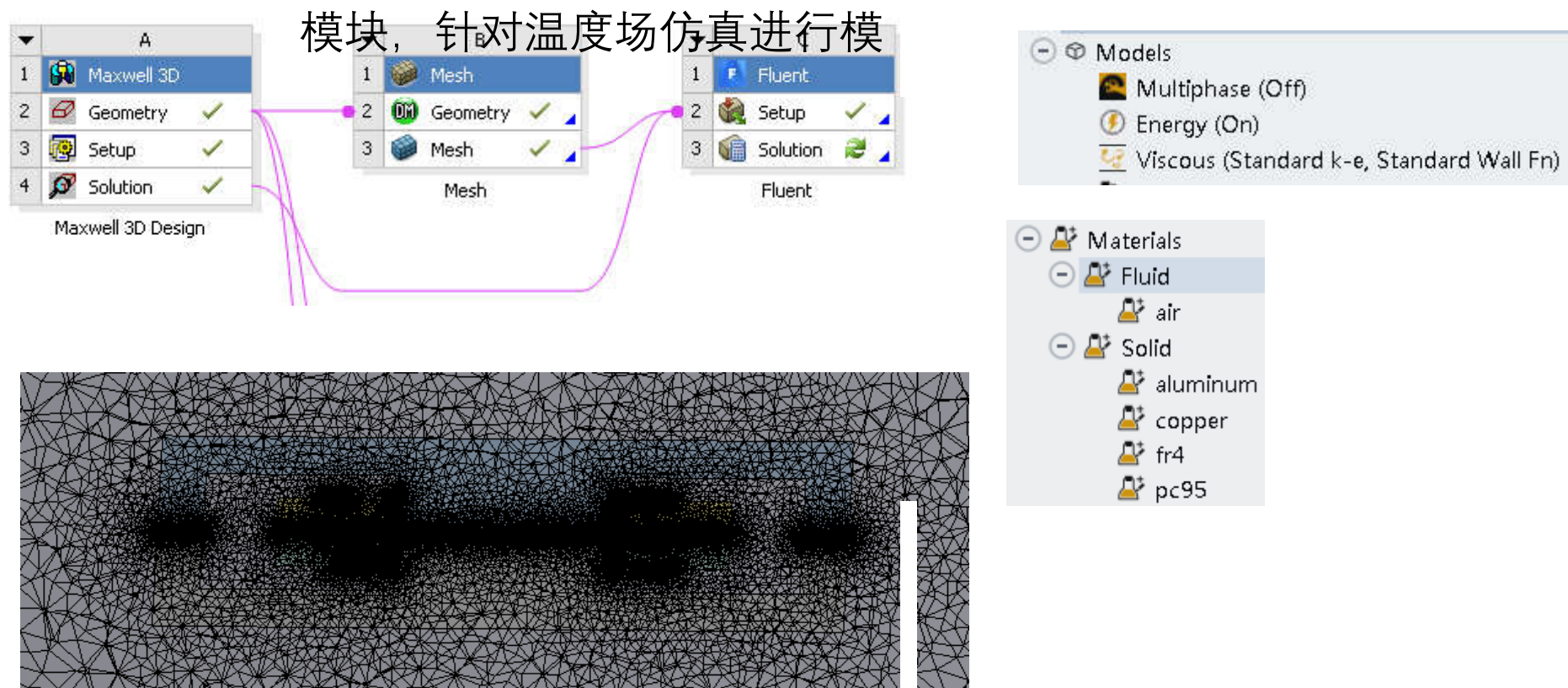
仿真设计结果

- 查看铁损曲线及铜损曲线并计算平均值、B及H云图



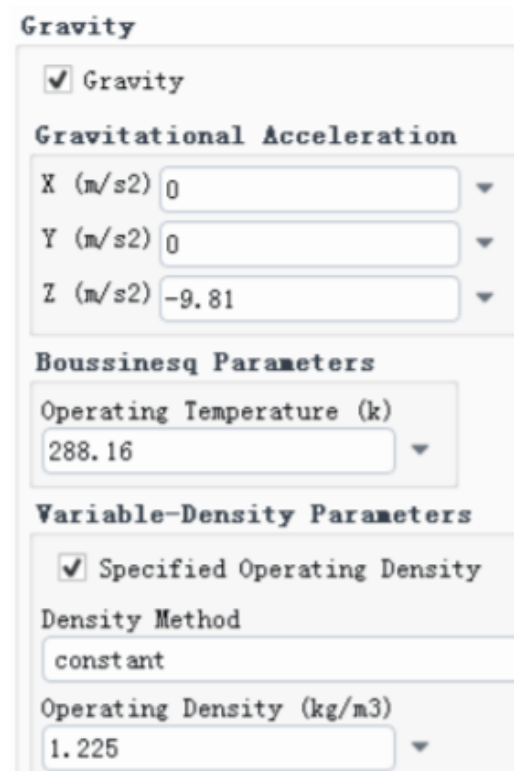
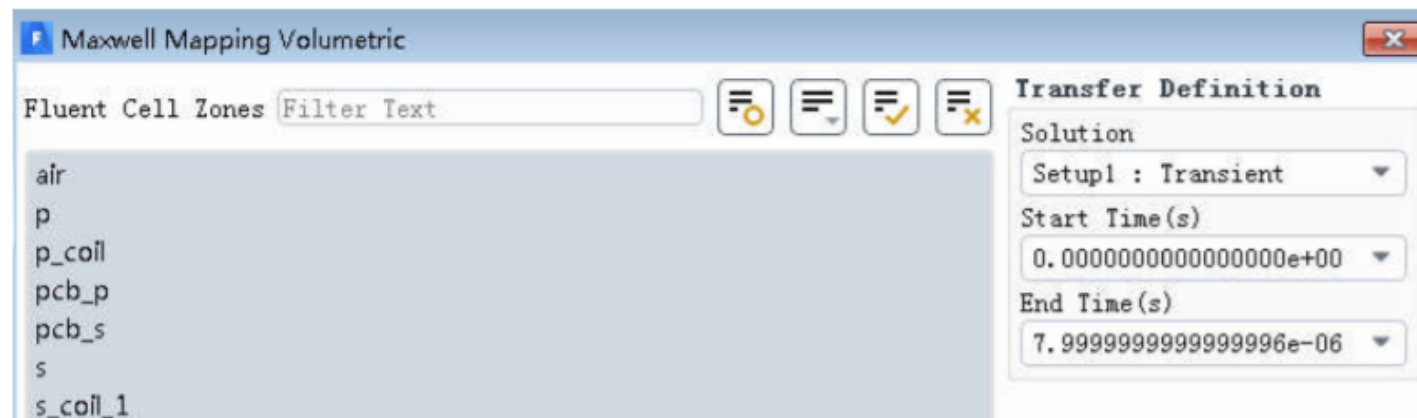
仿真设计过程详解

- 将模型导入Mesh模块，针对温度场仿真进行模型前处理并划分网格。



仿真设计过程详解

- 将Maxwell中的损耗数据通过EM Mapping导入到Fluent中。修改自然对流散热相关选项



```
Fluent generated 'Input_to_Ansoft.xml' file successfully

Launching D:\ProgramFiles\AnsysEM\AnsysEM19.3\Win64\ansysedt.exe ....
05/14/2020 18:01:19 [Info] Server started at ws://0.0.0.0:0 (actual port 55858)
Reading EM loss file "loss-data-t1"

Total loss is : 7.4543e-01 (Watt)

Total loss on zone 10 is 1.904e-01 (Watt)
Total loss on zone 9 is 7.065e-02 (Watt)
Total loss on zone 13 is 1.800e-03 (Watt)
Total loss on zone 12 is 8.534e-03 (Watt)
Total loss on zone 11 is 4.021e-01 (Watt)
Total loss on zone 8 is 7.190e-02 (Watt)
```

仿真设计过程详解

- 修改材料参数、边界条件及求解器相关选项

Properties

Density (kg/m3)	incompressible-ideal-gas
-----------------	--------------------------

Fluent Solid Materials

	fr4
Mixture	none

Properties

Density (kg/m3)	constant
	700
Cp (Specific Heat) (j/kg-k)	constant
	2310
Thermal Conductivity (w/m-k)	constant
	0.2

Zone Name

p-outlet

Momentum	Thermal	Radiation	Species
----------	---------	-----------	---------

Backflow Reference Frame Absolute

Gauge Pressure (pascal) 0

Fluent Solid Materials

	pc95
Mixture	none

Properties

Density (kg/m3)	constant
	700
Cp (Specific Heat) (j/kg-k)	constant
	2310
Thermal Conductivity (w/m-k)	constant
	2.5

Solution Methods

Pressure-Velocity Coupling

Scheme Coupled

Spatial Discretization

Gradient

Least Squares Cell Based

Pressure

Second Order

Momentum

Second Order Upwind

Turbulent Kinetic Energy

First Order Upwind

Turbulent Dissipation Rate

First Order Upwind

Energy

Transient Formulation

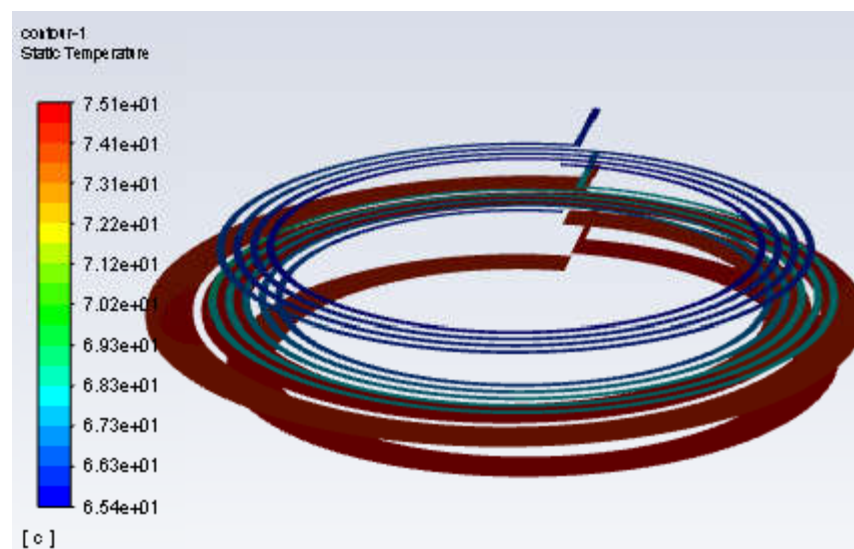
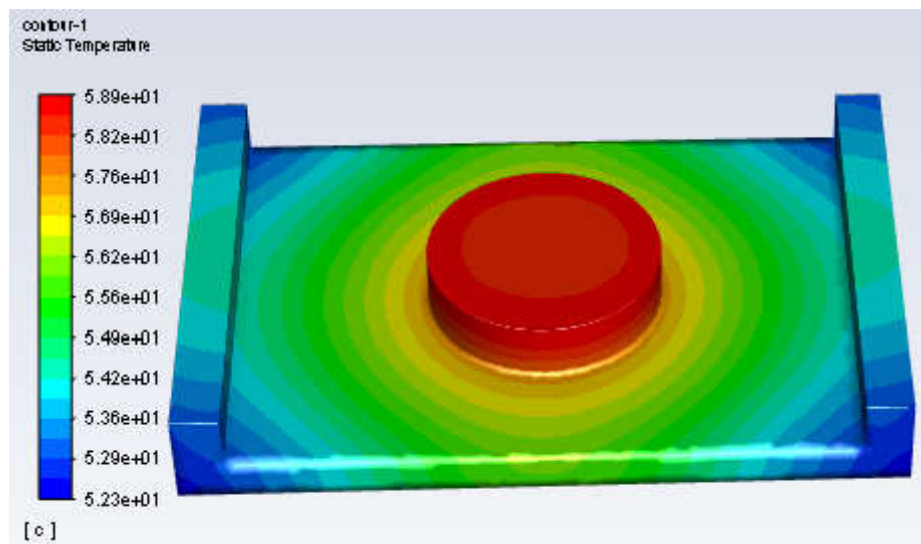
☐ Non-Iterative Time Advancement

☐ Frozen Flux Formulation

☒ Pseudo Transient

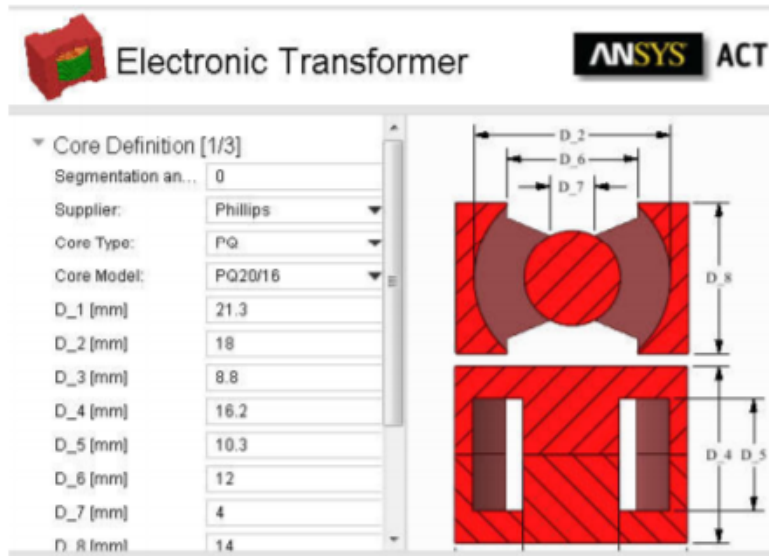
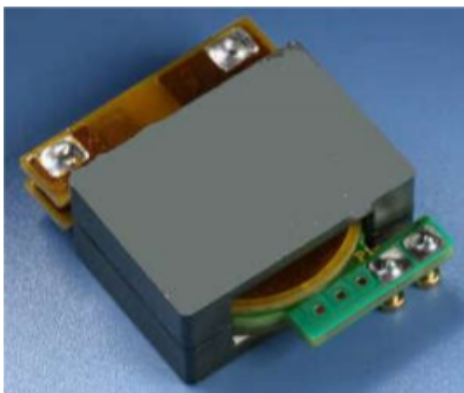
仿真设计结果

- 查看磁芯及绕组的温度分布



小结

- 使用ETK插件，先建立与仿真模型形状及尺寸近似的模型，再修改模型能极大的提升建模效率。
- 通过对比不同绕组简化模型的结果对仿真结果的影响，发现按绕组形状建模得到的电感矩阵及温升分别更接近实测值。
- 希望ANSYS的ETK插件能提供更多公司（例如TDK公司）的磁芯模型数据库。



Ansys
INNOVATION
C O N F E R E N C E
2020

