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中国·上海

电力及电子变压器设计新功能培训

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ANSYS 中国

大纲

- 电子变压器设计新功能培训
- 电力变压器涡流场仿真新功能培训

ETK 综述

- ETK (Electronic Transformer Kit) 可以做什么?
 - ETK采用python脚本的方式自动生成平面磁性元件的涡流场求解模型。模型采用线性、频变磁导率，Steinmetz损耗系数也采用频变模式。另外，ETK利用Network Data Explorer生成可以在Simplorer和Pspice中使用的频变状态空间模型 (state-space model)。
- ETK的建模对象？
 - ETK用于建立工作频率在100kHz范围内的铁氧体磁芯变压器和电感 (但不包括50-50Hz范围内的油浸变压器)
- ETK易用性?
 - Python有3个输入面板，所有参数可以在10-15分钟内设置完毕。

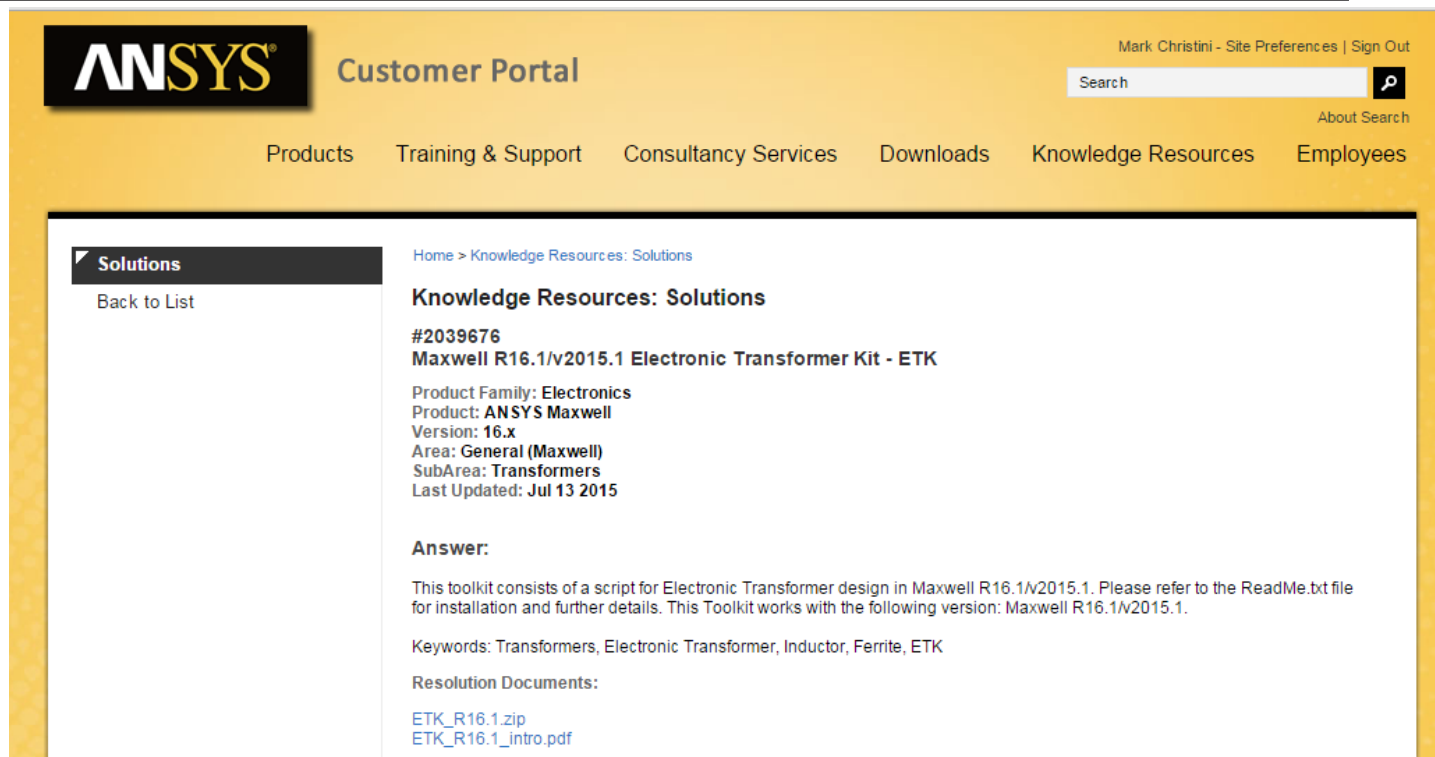
ETK 综述

- ETK包含厂商元件库吗？
 - 在当前发布的ETK版本中，包含Philips和Ferroxcube各15种大类的磁芯形状。另外用户可以手动修改一个特定Excel文件以加入更多的磁性形状和材料。
- ETK和PExprt的区别？
 - “Electronic Transformer Kit”是基于Maxwell 3D 的免费脚本，提供基于预先定义的设计输入的FEA求解模型（非解析模型），而PExprt可生成整个设计。ETK不考虑Litz线和twisted双绞线，也不自动考虑绕组电容，除非手动生成一个额外的electrostatic design。

ETK脚本下载地址

- 访问 Customer Portal: Knowledge Resources > Solutions

https://support.ansys.com/AnsysCustomerPortal/en_us/Knowledge%20Resources/Solutions/Maxwell/2039676



The screenshot shows the ANSYS Customer Portal interface. The top navigation bar includes the ANSYS logo, the text "Customer Portal", a search bar, and links for "Mark Christini - Site Preferences | Sign Out". Below the navigation bar are tabs for "Products", "Training & Support", "Consultancy Services", "Downloads", "Knowledge Resources", and "Employees". The "Knowledge Resources" tab is selected, and the "Solutions" sub-tab is active. The main content area displays the title "Knowledge Resources: Solutions" and the specific solution "#2039676 Maxwell R16.1/v2015.1 Electronic Transformer Kit - ETK". It provides details about the product family, product, version, area, sub-area, and last updated date. The "Answer" section describes the toolkit's purpose and provides keywords and resolution documents.

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#2039676
Maxwell R16.1/v2015.1 Electronic Transformer Kit - ETK

Product Family: Electronics
Product: ANSYS Maxwell
Version: 16.x
Area: General (Maxwell)
SubArea: Transformers
Last Updated: Jul 13 2015

Answer:

This toolkit consists of a script for Electronic Transformer design in Maxwell R16.1/v2015.1. Please refer to the ReadMe.txt file for installation and further details. This Toolkit works with the following version: Maxwell R16.1/v2015.1.

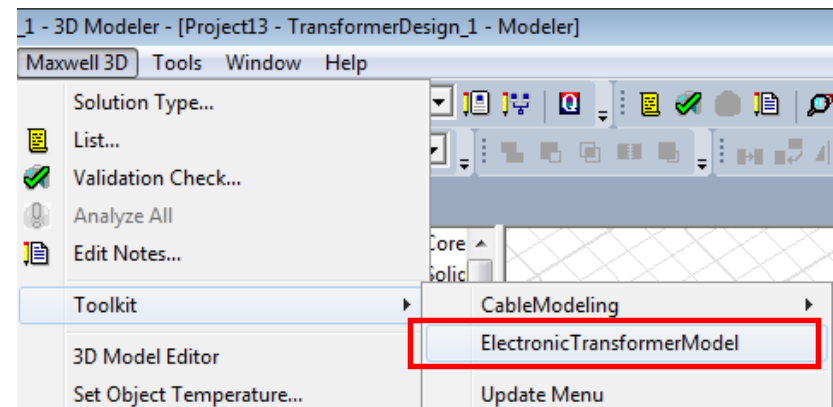
Keywords: Transformers, Electronic Transformer, Inductor, Ferrite, ETK

Resolution Documents:

[ETK_R16.1.zip](#)
[ETK_R16.1_intro.pdf](#)

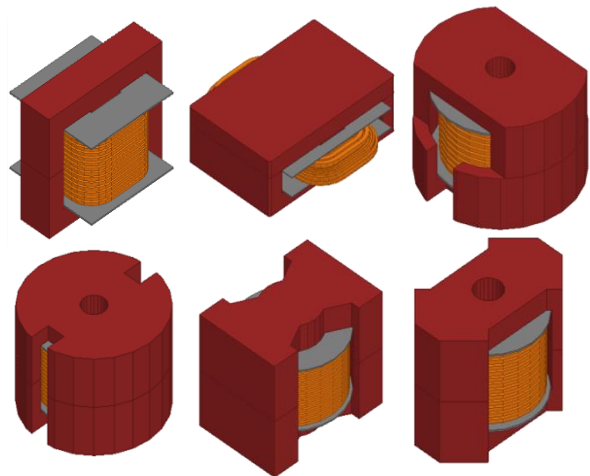
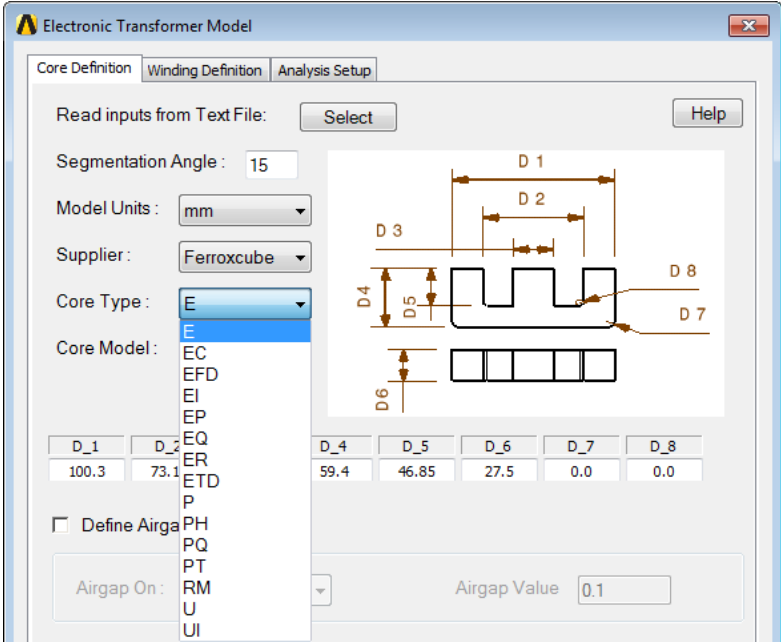
安装和运行

1. 复制粘贴文件夹**CoreUDM** 到: Maxwell Installation directory
 \AnsysEM16.0\Win64\Maxwell\syslib\UserDefinedModels\Lib **OR**
 \AnsysEM16.0\Win64\Maxwell\userlib\UserDefinedModels\Lib
2. 复制粘贴文件**ElectronicTransformerModel.py** 到: Maxwell Installation directory
 \AnsysEM16.0\Win64\Maxwell\syslib\Toolkits\Maxwell3D
3. 打开Maxwell文件，并插入一个Maxwell 3D design
4. 菜单操作: **Draw > User Defined Model > Update Menu**
5. 运行脚本及调用ETK界面: **Maxwell 3D > Toolkit > ElectronicTransformerModel**



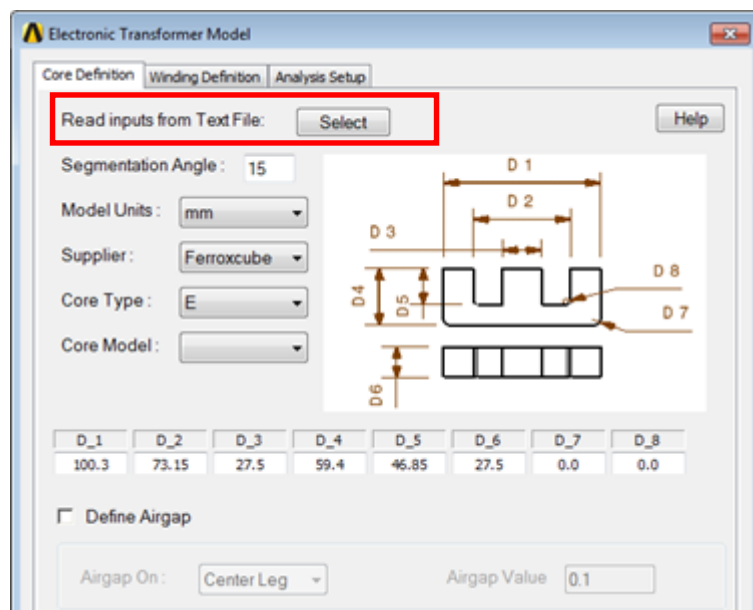
输入界面1/3: 定义铁心

- 两种方法设置变压器模型:
 1. 直接读入一个之前记录的.tab 文本文件。
 2. 生成一个全新的设计。
- 设置 Model Units, Supplier, Core Type, Core Model。
- 包含Philips/Ferroxcube的15种磁芯基本类型。
- 选择磁芯的默认尺寸或手动修改尺寸。



记录输入文件 - 用于下次直接复用生成模型

- 一个.tab格式的文件在脚本运行时被自动记录，并保存于Maxwell默认的工程文件目录下。
- 通过选择“core definition”输入界面上的“Read Data from Text File”按钮，可以重新运行已有的.tab格式输入文件(*note Core Model box will remain blank*)
- .tab格式的文件也可以在text编辑器中手动修改参数后，再调用运行



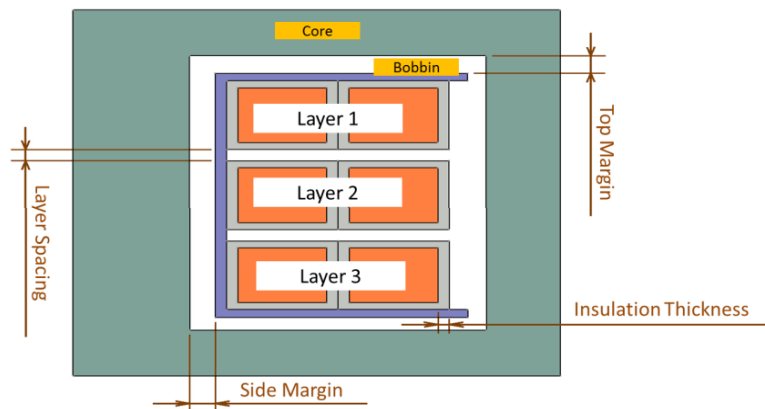
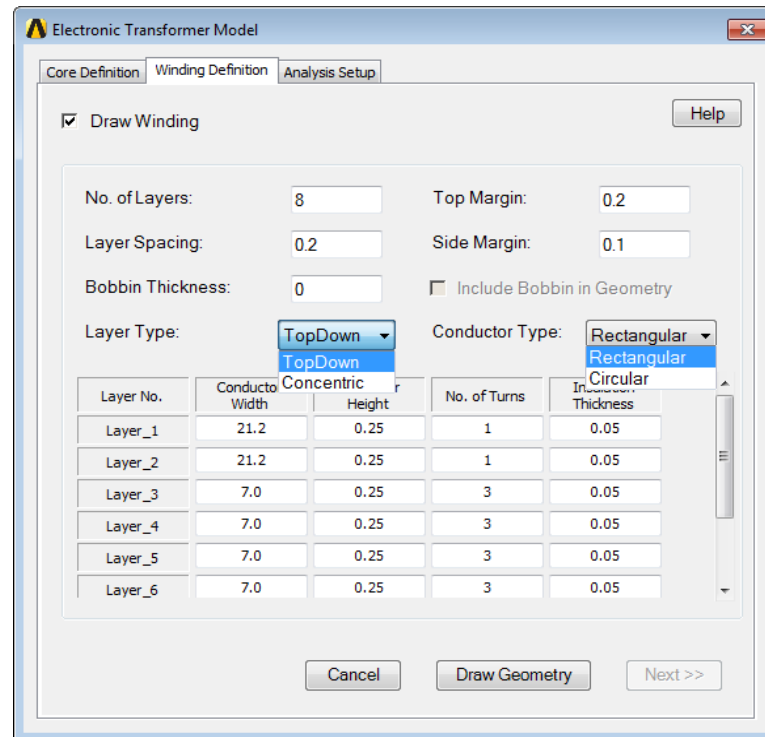
```

1 15 %Segmentation Angle: should be between 0 to 20
2 mm %Model Units: mm or inches
3 Phillips %Supplier Name
4 EI %Core Type
5 64.0 53.8 10.2 10.2 5.1 50.8 0.64 5.08 %CoreDimensions: D1,D2,D3,D4,D5,D6,D7,D8
6 0 %Include Airgap: 0 to exclude, 1 for Airgap on central leg, 2 for Side leg, 3 for both
7 1 %Winding Status: 1 for Create Winding, 0 for exclude winding
8 8 %Number of Layers
9 0.2 0.1 0.2 0 %Margin Dimensions (Top Margin, Side Margin, Layer Spacing, Bobbin Thickness)
10 0 %Bobbin Status 0:Exclude bobbin from Geometry 1:Include Bobbin in Geometry
11 1 %Winding Type 1:TopDown 2:Concentric
12 1 %Conductor Type 1:Rectangular 2:Circular
13 21.2 0.25 1 0.05 %Layer 1 specifications :Conductor Width, Conductor Height, Number of Turn
14 21.2 0.25 1 0.05 %Layer 2 specifications :Conductor Width, Conductor Height, Number of Turn
15 7 0.25 3 0.05 %Layer 3 specifications :Conductor Width, Conductor Height, Number of Turns, I
16 7 0.25 3 0.05 %Layer 4 specifications :Conductor Width, Conductor Height, Number of Turns, I
17 7 0.25 3 0.05 %Layer 5 specifications :Conductor Width, Conductor Height, Number of Turns, I
18 7 0.25 3 0.05 %Layer 6 specifications :Conductor Width, Conductor Height, Number of Turns, I
19 21.2 0.25 1 0.05 %Layer 7 specifications :Conductor Width, Conductor Height, Number of Turn
20 21.2 0.25 1 0.05 %Layer 8 specifications :Conductor Width, Conductor Height, Number of Turn
    
```


输入界面2/3: 定义线圈

• 定义以下参数：

- 线圈层数, 层间间距, 骨架厚度, 顶部间隙, 侧面间隙
- 线圈类型: 上下式或者同心式
- 导线类型: 方线或者圆线
- 每层参数: 导体宽度/导体高度, 线径, 匝数, 绝缘厚度
- 点击“Draw Geometry”预览, 然后点击Next



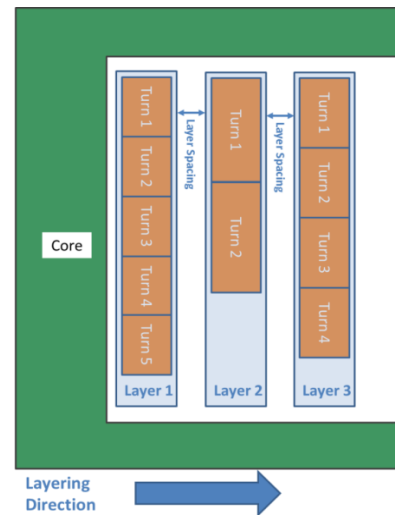
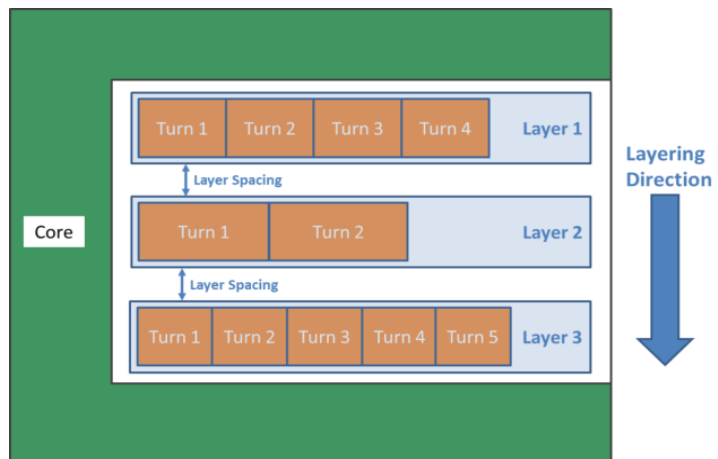
上下结构vs同心结构

TopDown

- 导线各层在磁芯中从上到下排布.
- 每层中的线圈从内向外径向排布.

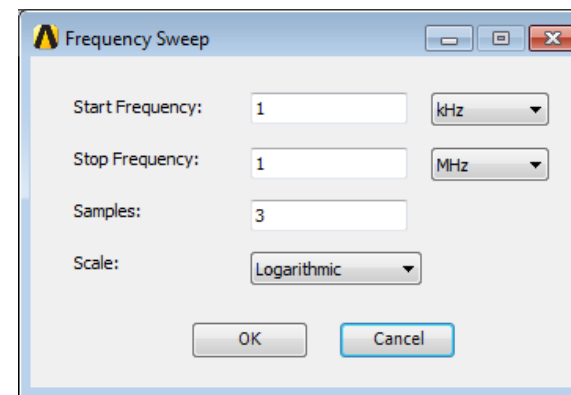
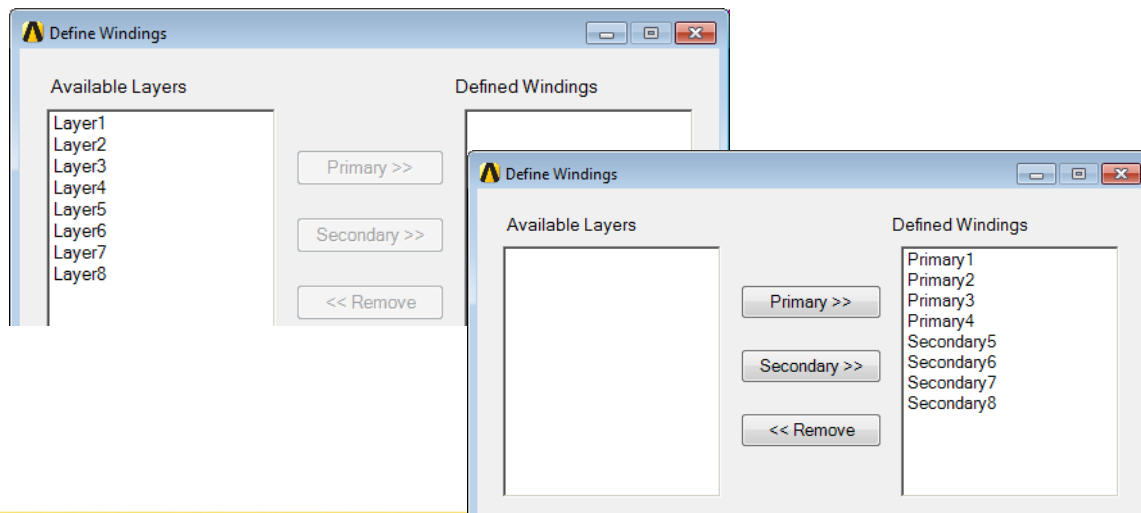
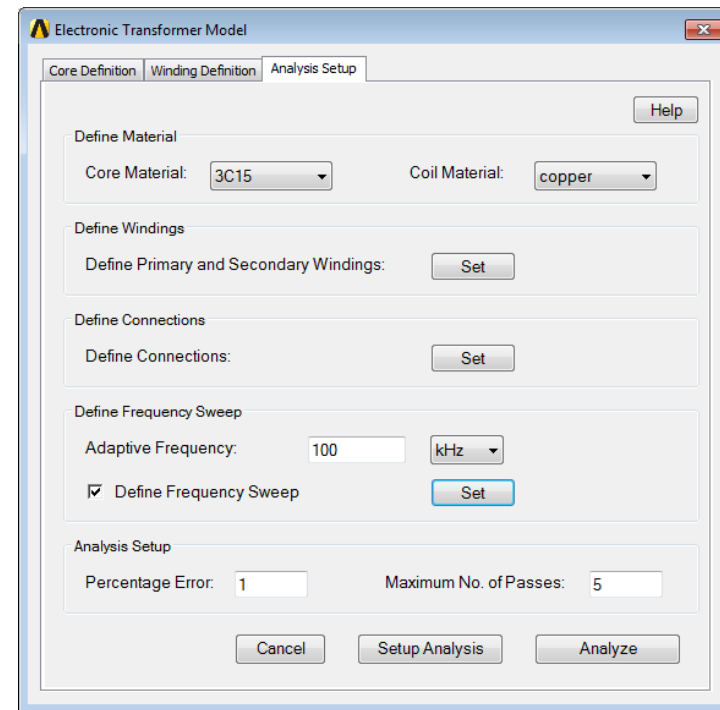
Concentric

- 导线各层在磁芯中随层数增加从内向外径向排布.
- 各层中的线圈垂直排布



输入界面3/3: 求解设置

- 定义 Core Material and Coil Material
- 定义 原副边绕组
- 定义 原副边绕组串联或并联连接
- 定义 adaptive frequency, frequency sweep, and max number of passes
- 选择 “Setup Analysis” 生成Design , 或者 “Analyze” 生成并求解Design



用户自定义添加新的磁芯模型（尺寸）

- 如果需要的磁芯模型在输入界面上找不到，用户可以自定义磁芯模型
- 在文件夹“CoreUDM”有一个“CoreData.tab” 文件
- 该文件可以用Excel或文本编辑器打开
- 用户可以添加供应商名称、磁芯类型、模型名称和模型尺寸（添加的时候采用tab分隔符格式）
- 添加的磁芯模型在下次脚本运行时可供选择

	A	B	C	D	E	F	G	H	I	J	K
1	Supplier	Core Type	Core Mod	D1	D2	D3	D4	D5	D6	D7	D8
2	Phillips	E	E5.3/2.7/2	5.25	3.8	1.4	2.65	1.9	2	0	0
3	Phillips	E	E6.3/2.9/2	6.3	3.6	1.4	2.9	1.85	2	0	0
4	Phillips	E	E8.8/4.1/2	9	5.2	1.9	4.1	2.03	2	0	0
5	Phillips	E	E13/6/3	12.7	9.5	3.2	5.7	4.1	3.18	0	0
6	Phillips	E	E13/6/6	12.7	9.5	3.2	5.7	4.1	6.4	0	0
7	Phillips	E	E13/7/4	12.6	8.9	3.7	6.5	4.5	3.7	0	0
8	Phillips	E	E16/8/5	16	11.3	4.7	8.2	5.7	4.7	1	0
9	Phillips	E	E16/12/5	16	12	4	12.25	10.25	4.85	0	0
10	Phillips	E	E19/8/5	19.1	14.3	4.7	8.1	5.7	4.7	0	0
11	Phillips	E	E19/8/9	19.05	14.33	4.75	8.05	5.69	8.71	0	0
12	Phillips	E	E20/10/5	20.7	12.8	5.2	10	6.3	5.3	1	0.5
13	Phillips	E	E20/10/6	20	14.1	5.9	10.2	7	5.9	1.5	0
14	Phillips	E	E20/14/5	20	14.3	4.55	13.55	11.15	5	0	0
15	Phillips	E	E22/16/10	22	13	8	15.75	9.75	10	0	0
16	Phillips	E	E25/9/6	25.4	19.3	6.35	9.45	6.5	6.3	0	0

用户自定义添加新的磁芯模型（材料）

如果用户需要的磁芯材料不在库里，可以按照如下的步骤添加：

1. 建立一个与frequency versus permeability 文件（tab格式）
2. Tab文件命名为所添加的材料名
3. 把tab文件放到如下目录 “CoreUDM /MaterialData”
4. 在Excel中打开目录“CoreUDM /MaterialData”下的“matdata.tab” 文件
5. 为新加的材料添加一行，并指定电导率、损耗系数和密度等其它材料参数
6. 保存文件

1	"X"	"Y"
2	0	1800
3	98459.681589469503	1805
4	128193.25309275401	1810
5	164335.10138502999	1815
6	197983.598439825	1836
7	246043.12589684501	1880
8	296421.78101870802	1923.2
9	346199.02680051897	2014.5999999999999
10	391975.05251181999	2086
11	450746.729490244	2160
12	502485.57112693402	2236.5
13	596047.538592714	2426

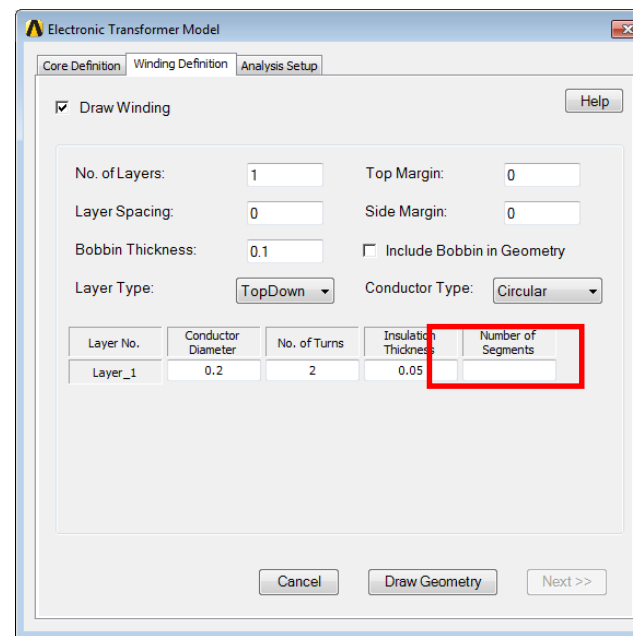
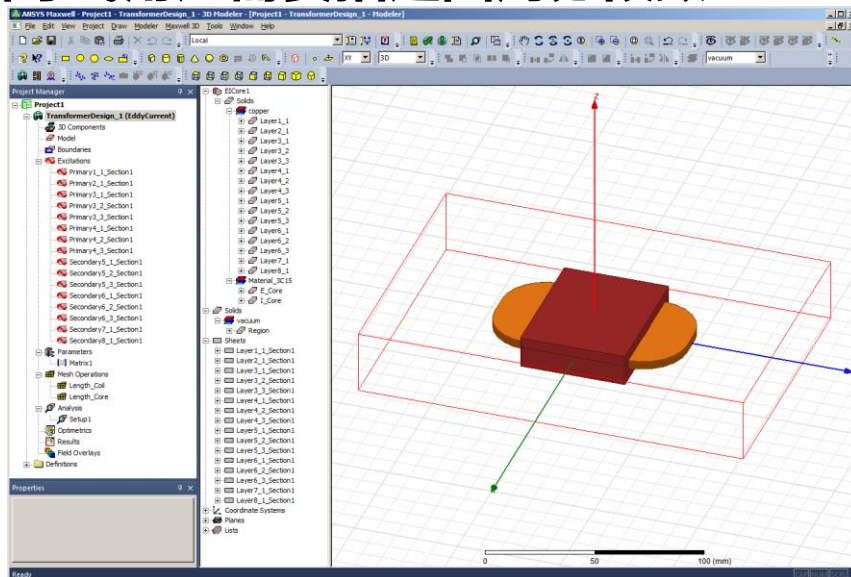
frequency versus permeability

1	Material	Conductiv	Cm	x	y	density
2	3C15	1	0.535	1.615	2.766	4800
3	3C30	0.5	0.867	1.533	2.7	4800
4	3C34	0.2	1.06	1.5	2.8	4800
5	3C81	1	2.55	1.485	2.51	4800
6	3C91	0.2	1.9	1.5	2.875	4800
7	3C90	0.2	0.823	1.54	2.69	4800
8	3C94	0.2	2.18	1.44	2.725	4800
9	3C96	0.2	0.244	1.6	2.576	4800
10	3F3	0.5	0.195	1.561	2.15	4750
11	3F4	0.1	2.981	1.368	2.1	4700
12	3F35	0.1	0.718	1.577	2.744	4750
13	4F1	0.000001	15.358	1.29	2.181	4600

matdata.tab

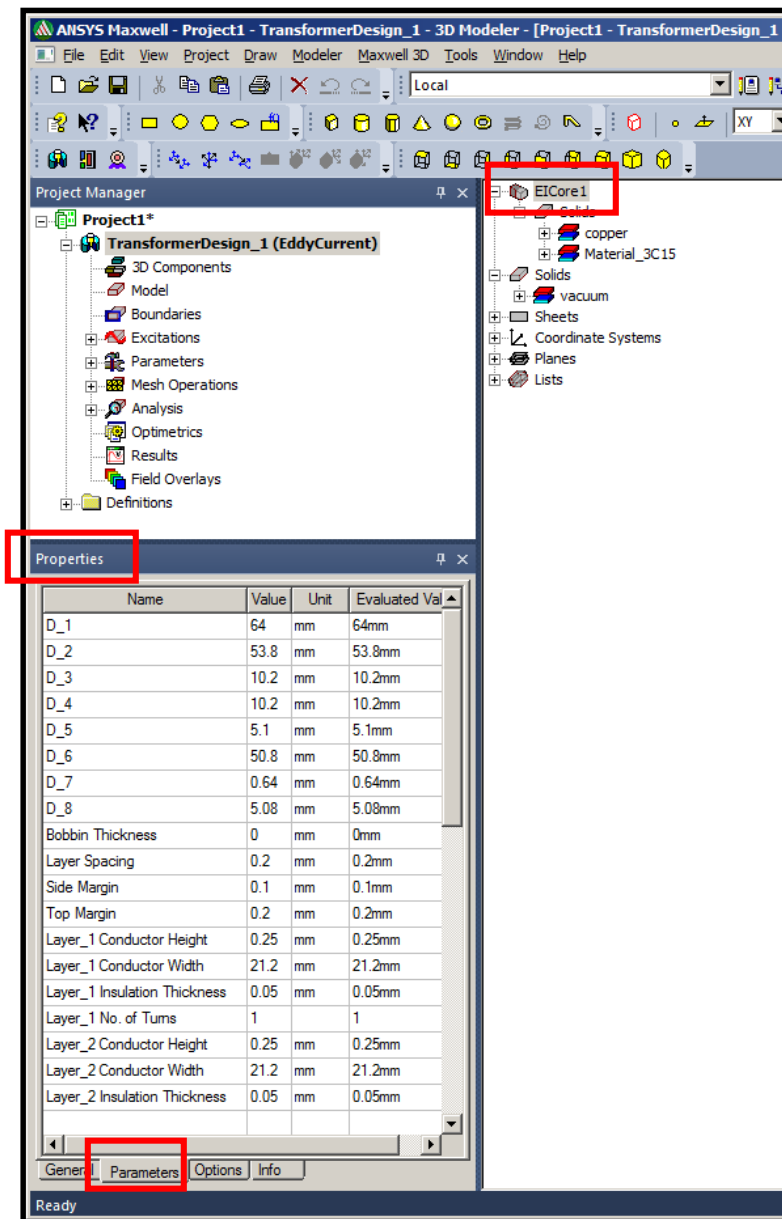
Maxwell求解设置

- 以下设置都自动设置: geometry, materials, sources, matrix, mesh operations, and analysis setup
- 求解区域自动设置, 导线圆角半径和倒角自动选择.
- 对于圆导线用户需要指定圆周分段数

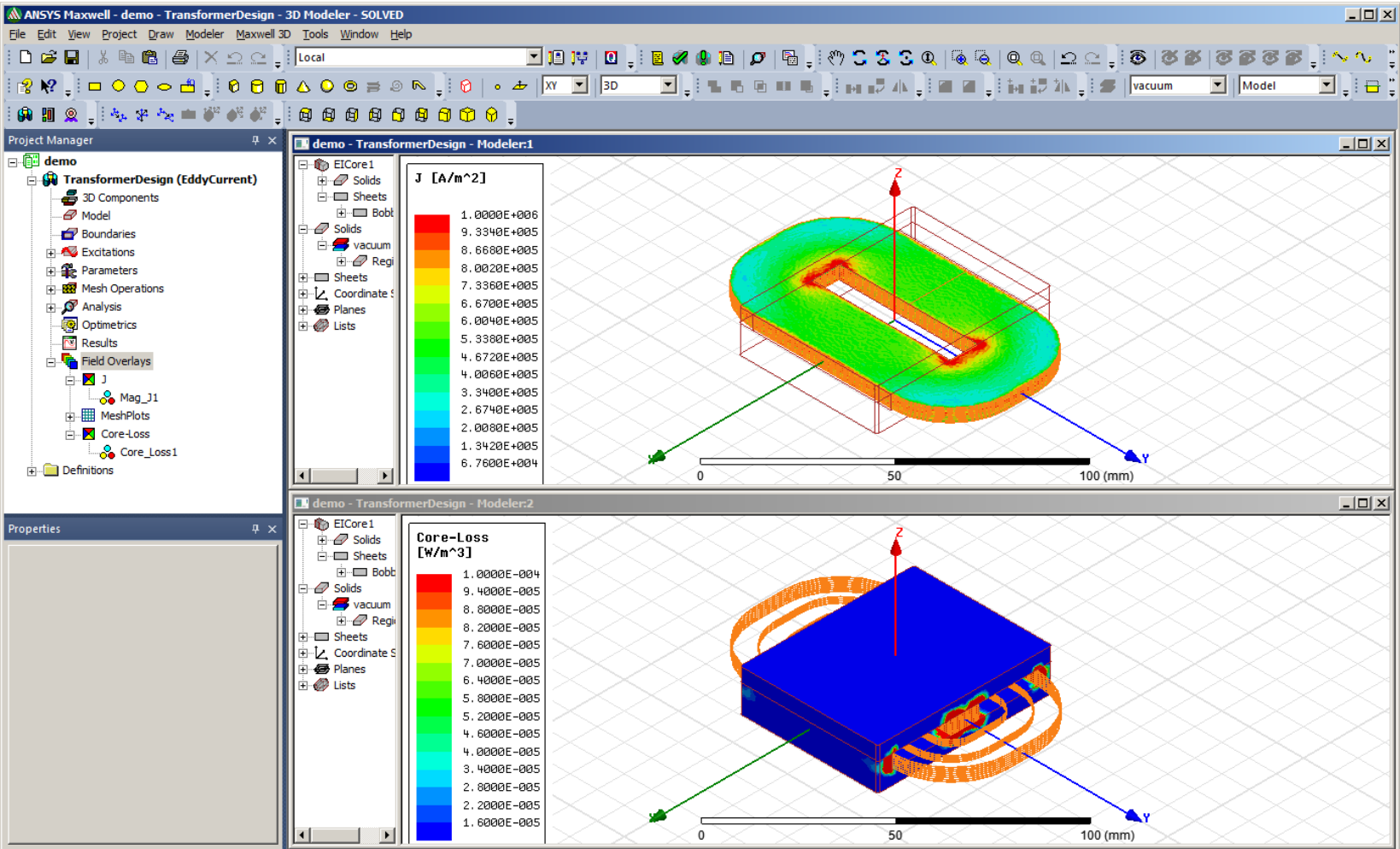


设计全参数化

- 模型所有的几何尺寸数据在Maxwell Design 中都以参数化的形式指定
- 几何尺寸可手动修改（不需要重新运行 Python脚本）
- 几何尺寸在Maxwell中可以手动修改，但如果要修改线圈层数或线圈匝数则必须重新运行脚本文件

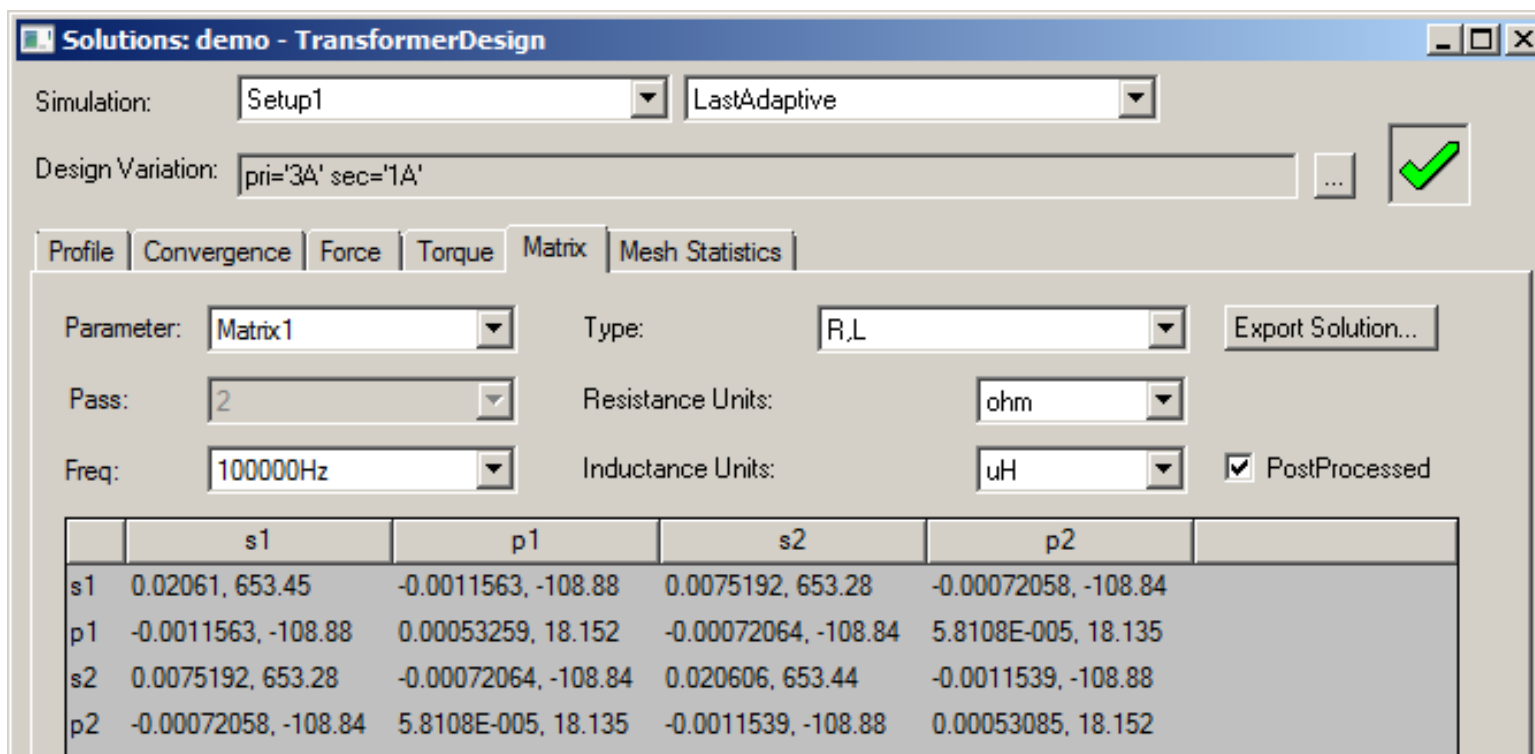


Maxwell 求解结果 – 场图



Maxwell 求解结果 – 阻抗矩阵

- 求解频率下的阻抗矩阵

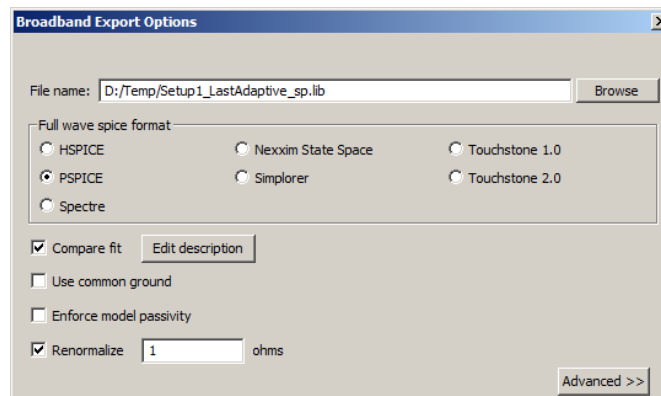


Maxwell 求解结果 – 网表

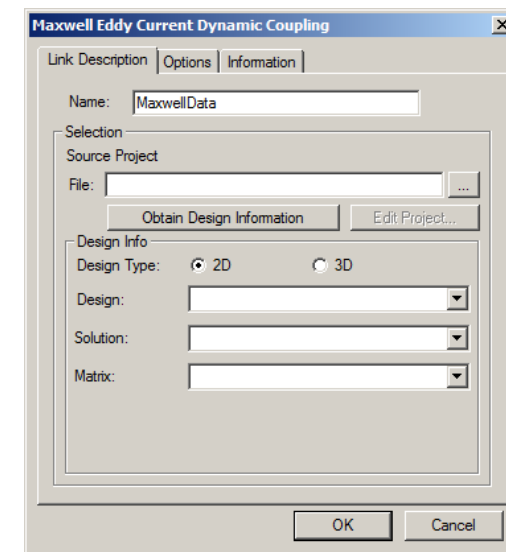
- 通过Simplorer中的“Dynamic Eddy Current” 链接，可以把求解结果以频变状态空间模型的形式输入到Simplorer中用于电路仿真
- 频变网表模型也可以通过 “Network Data Explorer ” 的方式输出到Pspice中进行仿真分析

- Right-click on Analysis / Setup1
- In the NDE window, click on Export Broadband
- Choose PSPICE (Renormalize to 1 ohm)

Maxwell to PSpice



Maxwell to Simplorer



如何获取帮助信息

- 通过点击ETK界面中的“Help” 按钮获得
- 查看html格式的文件: C:\Program Files\AnsysEM\AnsysEM16.1\Win64\Maxwell\syslib\UserDefinedModels\Lib\CoreUDM\Help\ElectronicTransformerKit_help.html
- 在相同的文件位置查看PDF文件

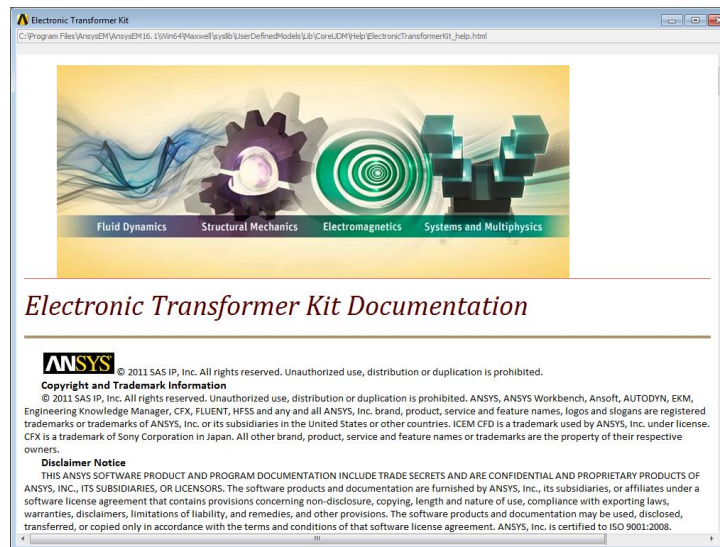


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Defining Working Directory

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Panel #3 - Analysis Setup

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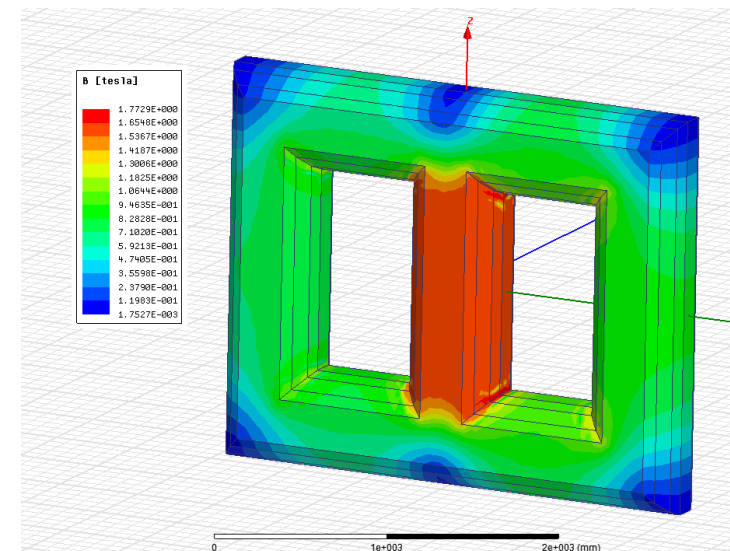
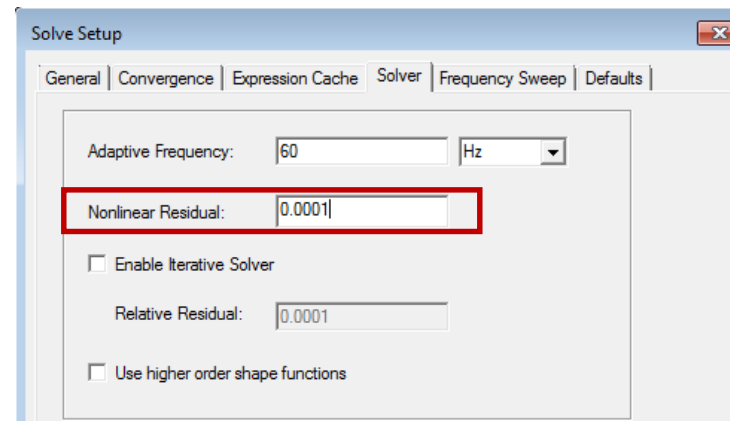
Maximum Number of Passes

大纲

- 电子变压器设计新功能培训
- 电力变压器涡流场仿真新功能培训

Maxwell 3D涡流场新功能

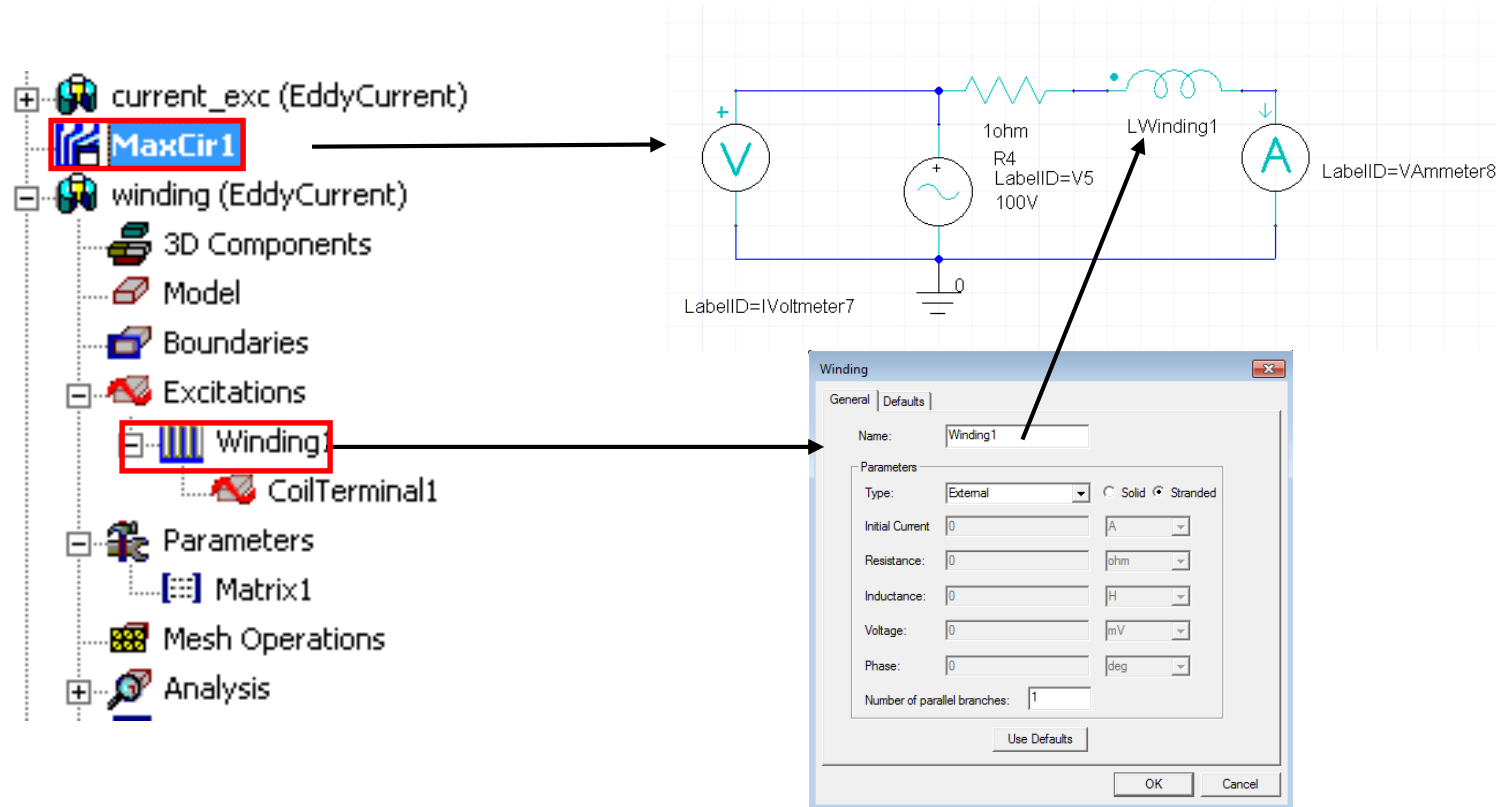
- **涡流场求解器支持非线性铁磁材料:**
 - 非线性BH曲线建模过程与瞬态场中建模过程完全一致
 - Maxwell在求解时通过迭代确定等效工作点



Maxwell 3D涡流场新功能

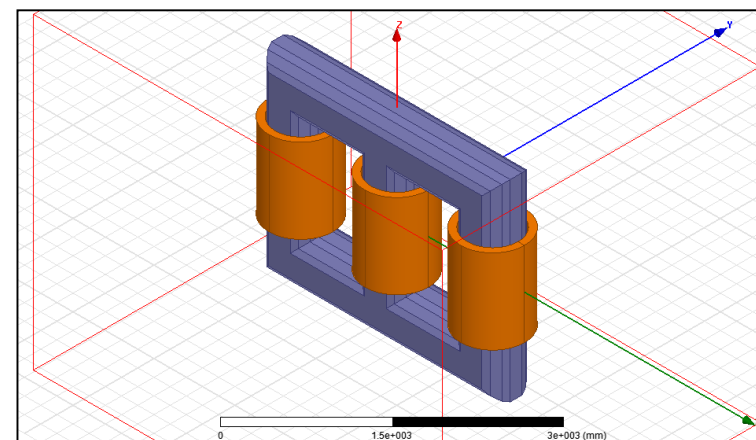
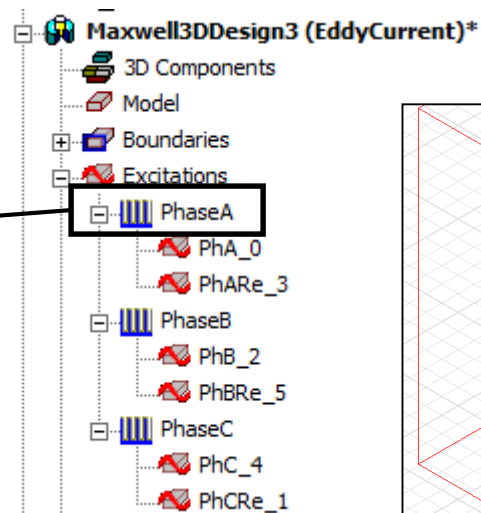
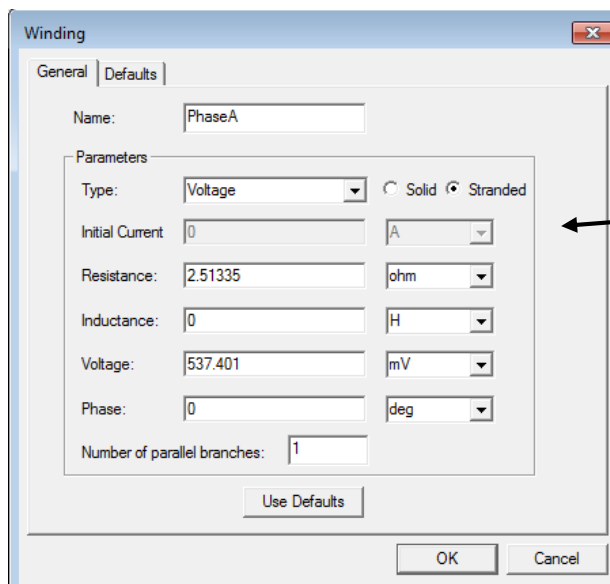
• 涡流场求解器支持求解器支持多种激励类型:

- 电压源
- 电流源
- 外电路



Maxwell 3D涡流场新功能

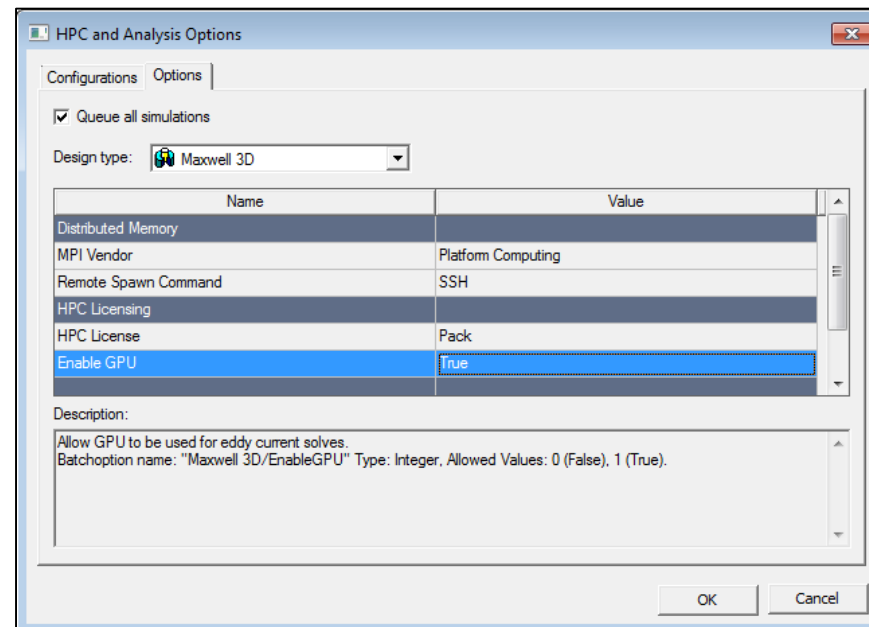
- 绕组设置功能与瞬态场求解器完全一致



New Winding Definition

Maxwell 3D涡流场新功能

- **涡流场支持GPU加速**
 - 自由度超过200万时，GPU加速功能才明显
 - 采用GPU功能时，占用一个HPC Pack license
- **在HPC and Analysis Option控制面板中完成设置**



Maxwell 3D涡流场新功能

Example: High permeable/conductive core

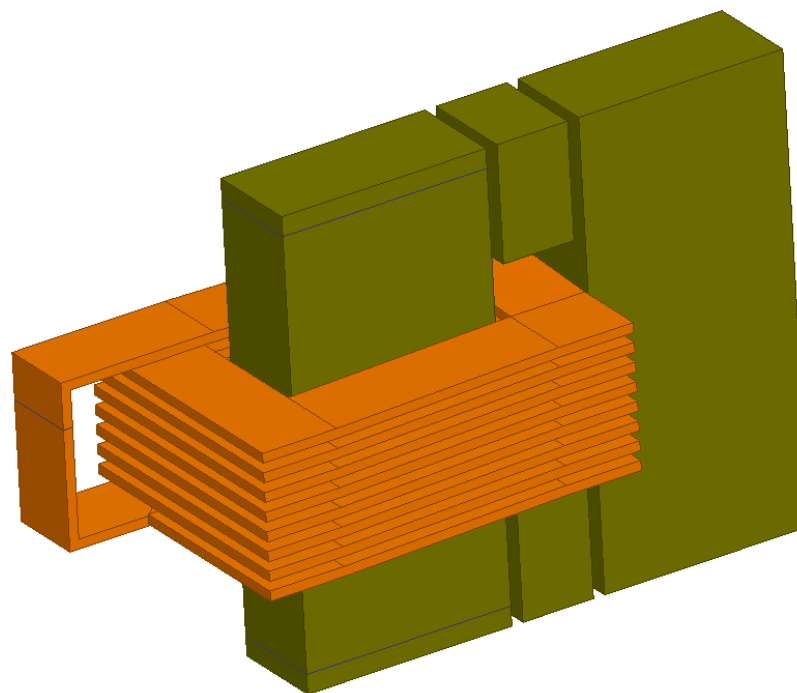
2.07 Million elements

3.51 Million unknowns

Solve time (8 cores): 40min 52

Solver time (8cores + 1 GPU): 20min26

本案例中，GPU加速功能可缩短仿真时间1倍左右



ANSYS 中国技术峰会 涡流场支持GPU加速

Example: High permeable/conductive core

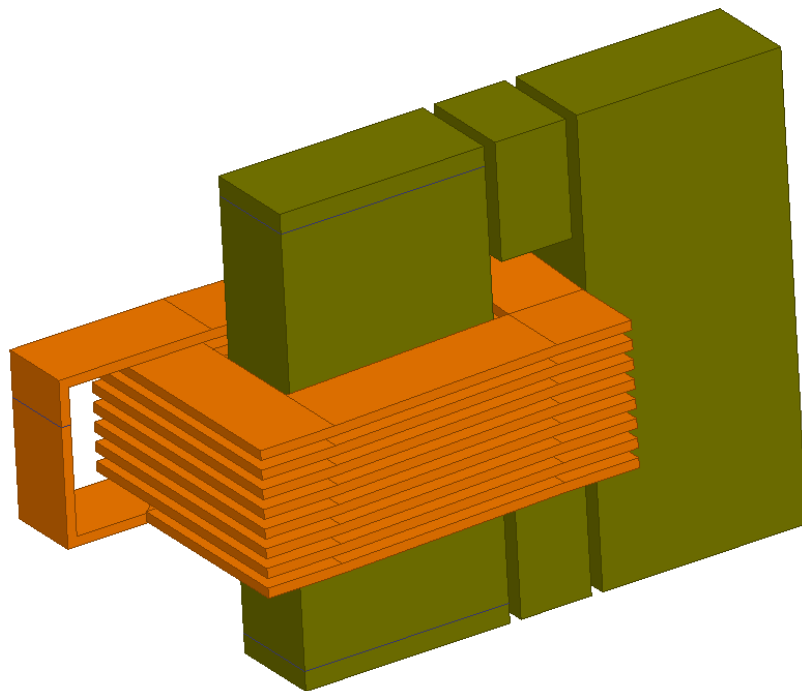
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本案例中，GPU加速功能可缩短仿真时间1倍左右



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感谢聆听

