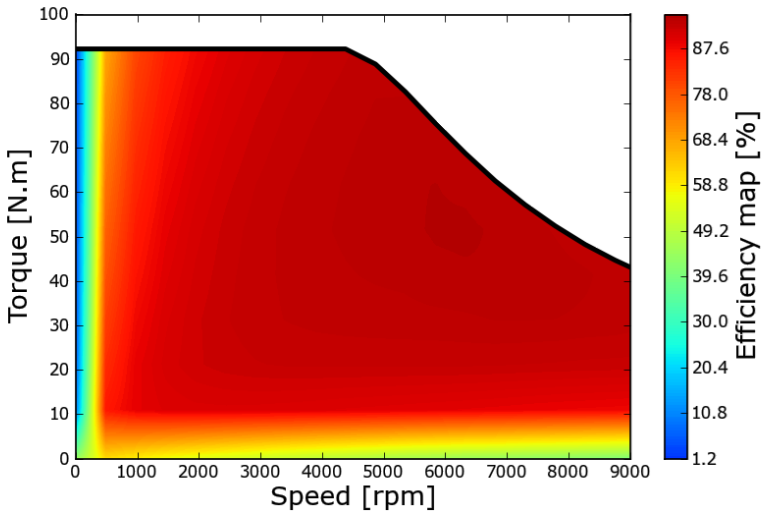
电机与变压器Tool kits培训
Motor and transformer Tool kits

庄百兴
区域技术经理

提纲

1. ETK电子变压器设计工具包介绍

2. Motor Design Toolkits提升电机自动化仿真流程



1. ETK电子变压器设计工具包介绍--综 述

- **“Electronic Transformer Kit” 简称ETK，能做什么?**

  → 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建模对象是什么？**

  → 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使用简便吗？**

  → The Python script consists of (3) input panels which can be setup in 10-15 minutes

综 述2

- **ETK包含厂商材料库吗？**

  → Philips and Ferroxcube with (15) core shapes are included in the initial release. In addition, users can modify an Excel spreadsheet to add more core shapes and materials.

  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与ANSYS PExprt的差异？**

  → The “Electronic Transformer Kit” is a free script using Maxwell 3D (not Maxwell 2D).

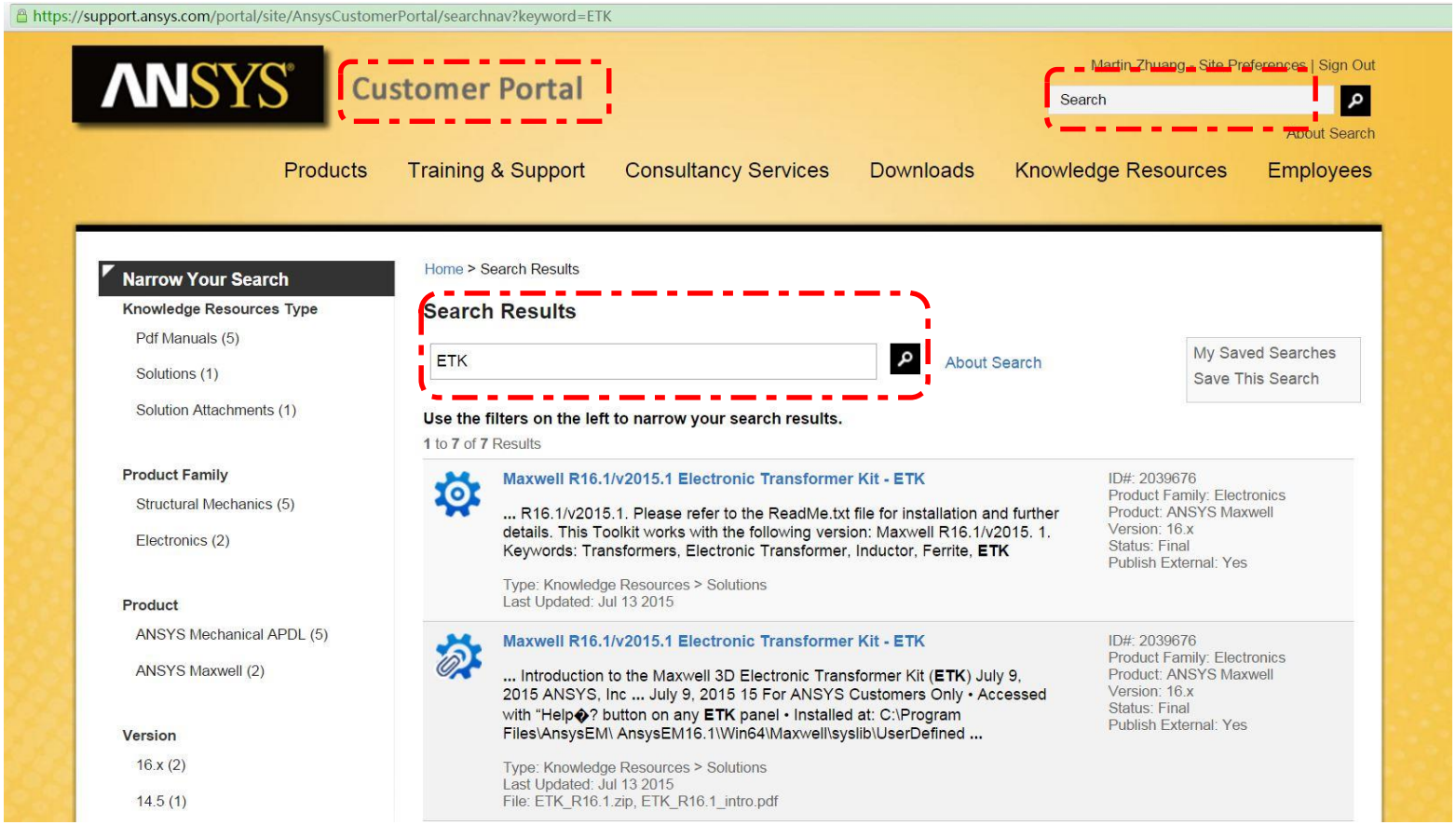
  → It provides an FEA based solution (not analytical).

  → Litz and twisted wire cannot be considered.

  → Capacitance is not considered unless a separate electrostatic design is created manually.

如何获得此功能脚本？

用户登录ANSYS Customer Portal，搜索 ETK关键词



如何获得此功能脚本？

进入下载页面

Home > Knowledge Resources: Solutions

Knowledge Resources: Solutions

#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:

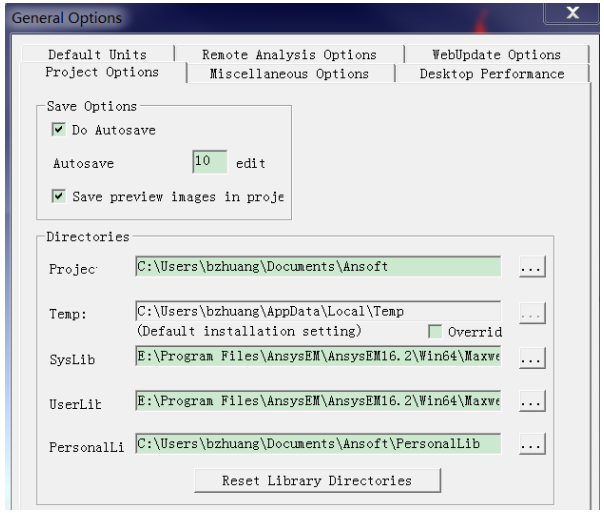
ETK_R16.1.zip
ETK_R16.1_intro.pdf

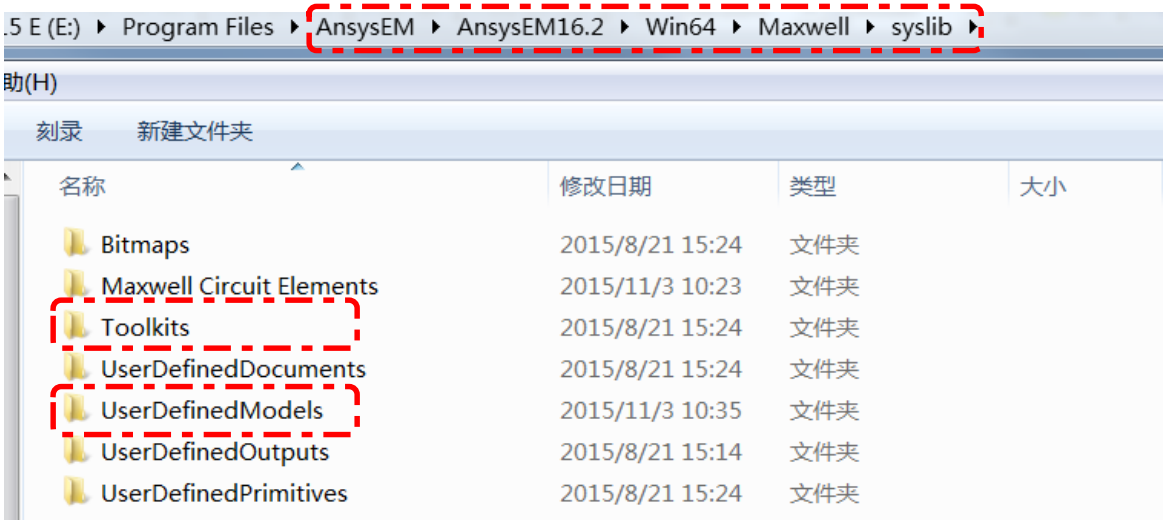
如何安装和使用？

1. 复制脚本文件夹到指定路径

- Copy the folder CoreUDM in: Maxwell Installation directory
  \AnsysEM16.0\Win64\Maxwell\syslib\UserDefinedModels\Lib
  或者
  \AnsysEM16.0\Win64\Maxwell\userlib\UserDefinedModels\Lib

2. 复制文件 ElectronicTransformerModel.py in: Maxwell Installation directory
   \AnsysEM16.0\Win64\Maxwell\syslib\Toolkits\Maxwell3D

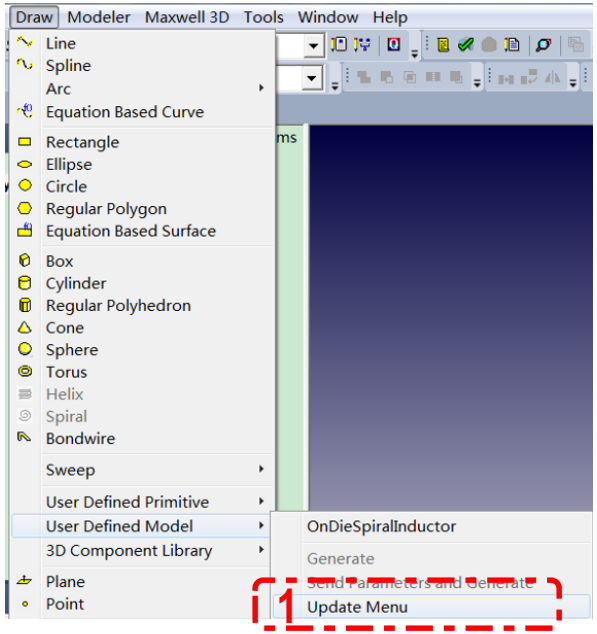


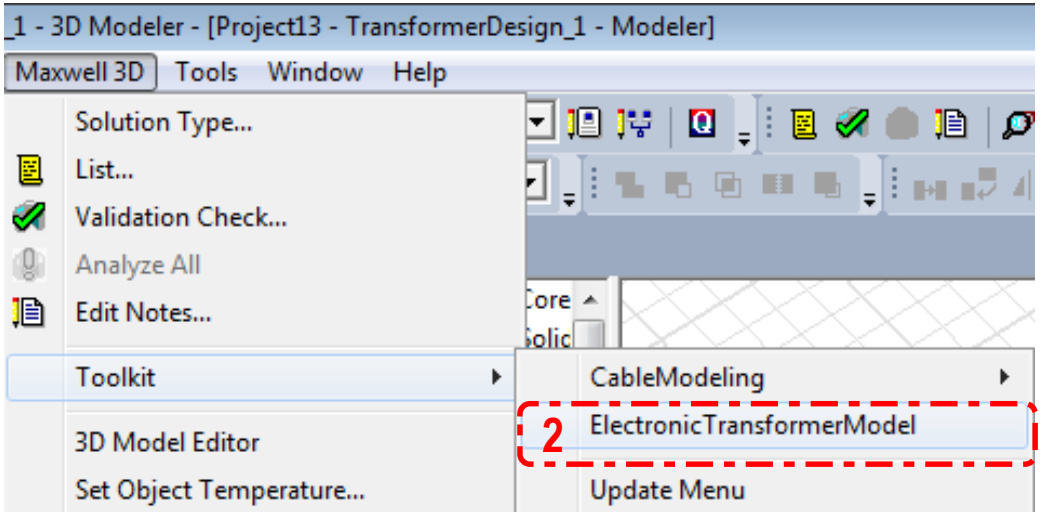


Tools\Options\General Options...

如何安装和使用？--独立的脚本运行

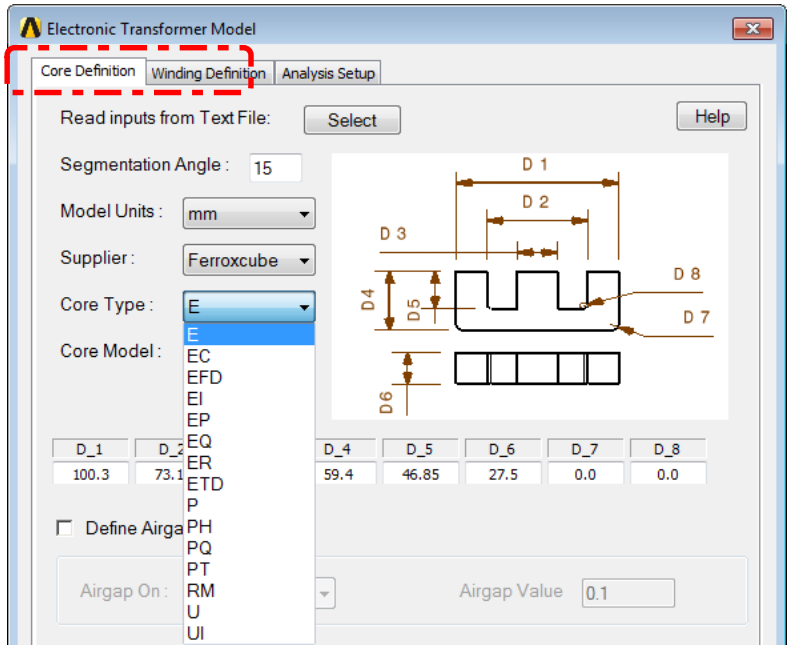
•It is not necessary to place the "ElectronicTransformerModel.py" under Toolkit. Users can place this file under any convenient location and run the toolkit via Run Script or External Tool option



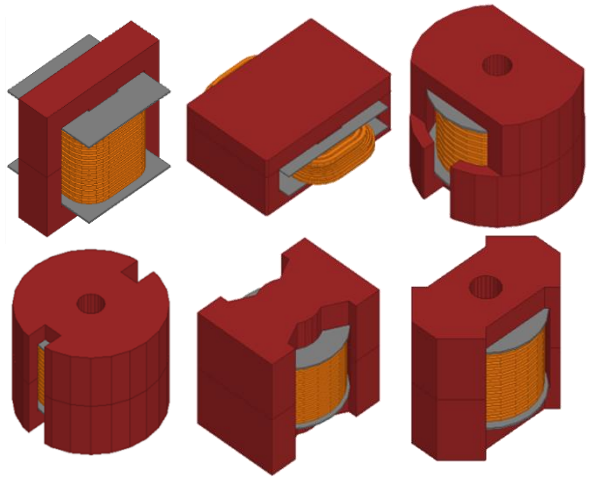


输入界面1/3: Core Definition

- **Two options to set-up a transformer model:**
  1. Read input data from a previously recorded .tab text file
  2. Create a totally new design
- **Select Model Units, Supplier, Core Type, Core Model**
- **(15) available core shapes from Philips/Ferroxcube**
- **Choose default dimensions or manually modify**

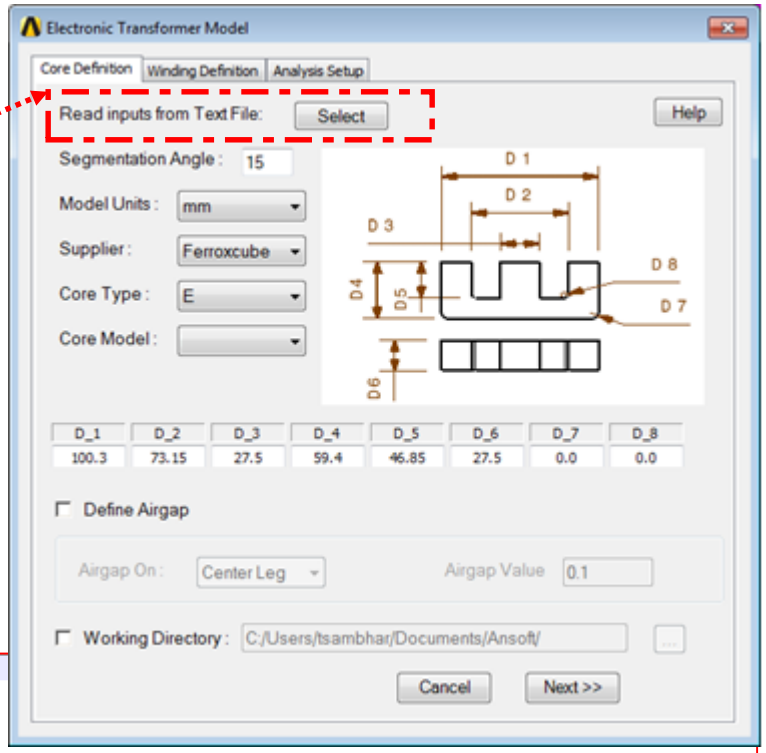


自动创建磁芯各种形状几何



项目文件数据记录功能：下次直接复用

- 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

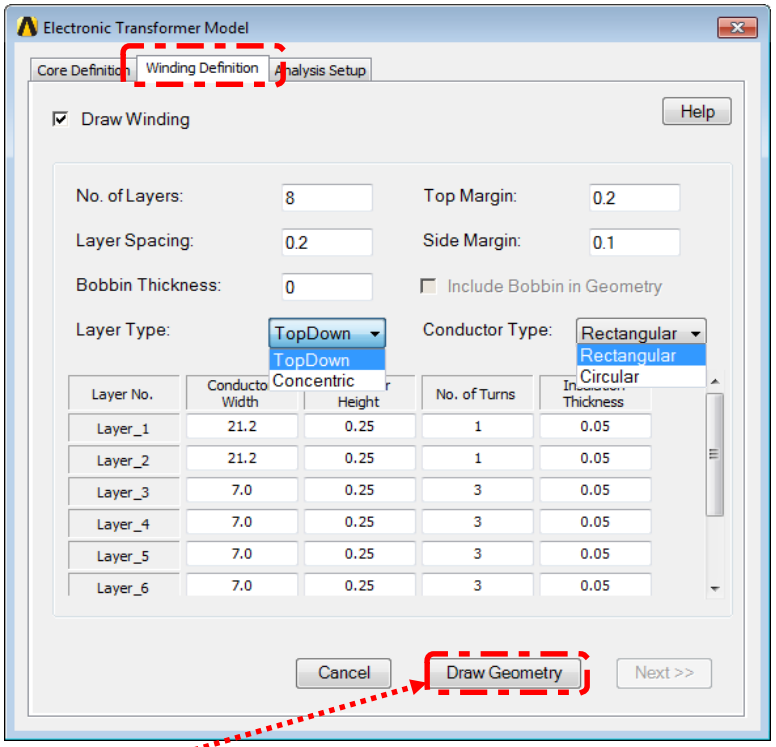


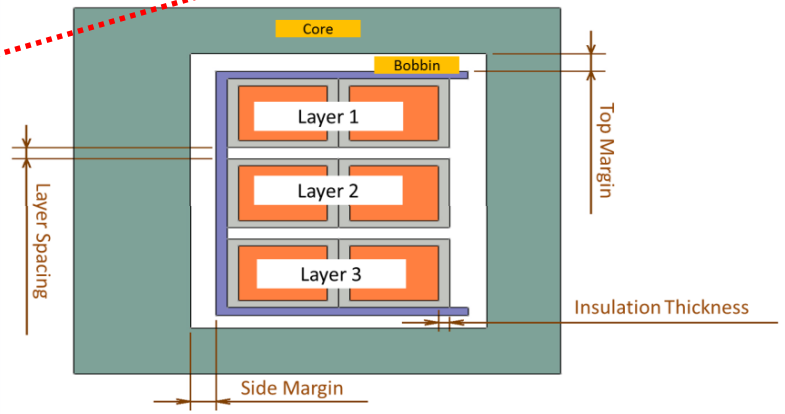

```
15              %Segmentation Angle: should be between 0 to 20
mm              %Model Units: mm or inches
Phillips                %Supplier Name
EI              %Core Type
64.0    53.8    10.2    10.2    5.1 50.8    0.64    5.08            %CoreDimensions: D1,D2,D3,D4,D5,D6,D7,D8
0              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

输入界面2/3：Winding Definition

自动创建多层绕组

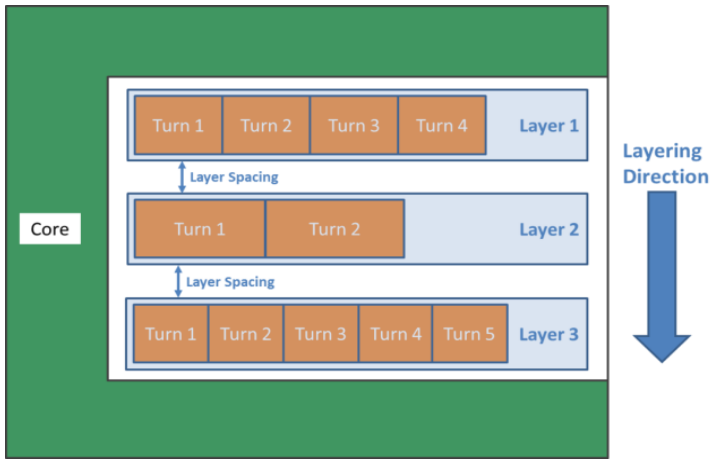
- Number of Layers, Layer Spacing, Bobbin Thickness, Top Margin size, Side Margin size
- Layer Type: Top Down or Concentric
- Conductor Type: Rectangular or Circular
- For each layer: Conductor Width, Conductor Height, Number of Turns, and Insulation Thickness
- **Click on "Draw Geometry"** to preview the Maxwell model before clicking on Next>>

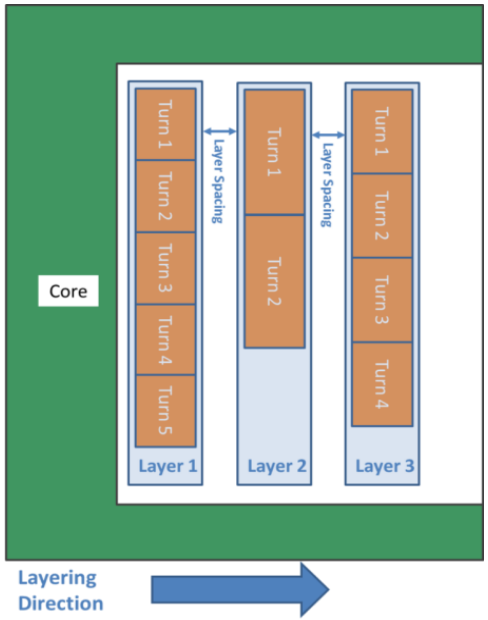




上下绕组 vs 同轴绕组

TopDown	Concentric
• 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.	• 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(top to bottom).

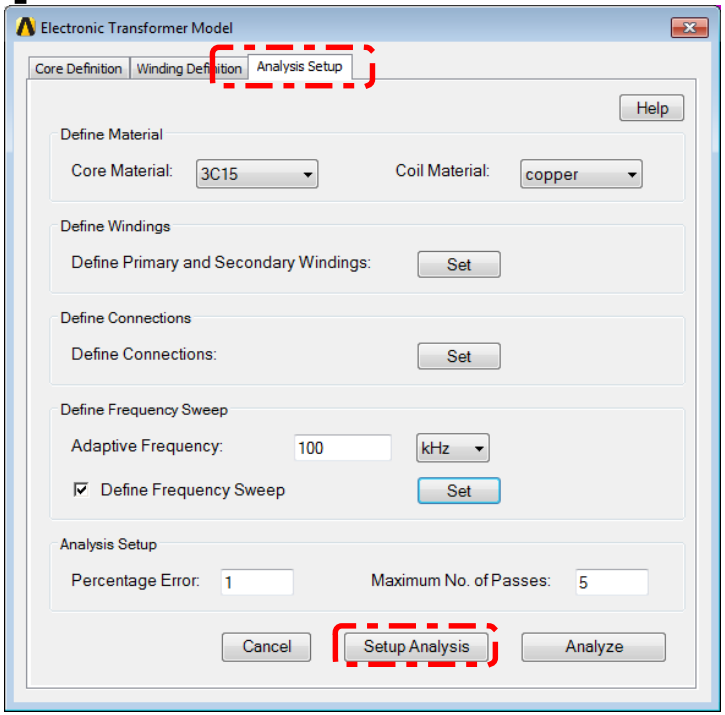


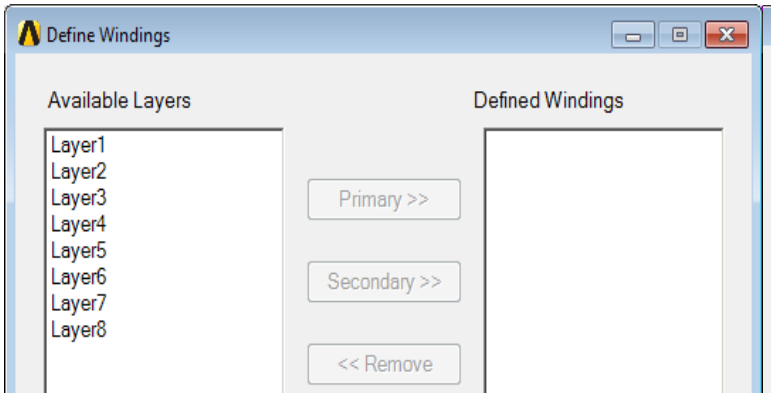


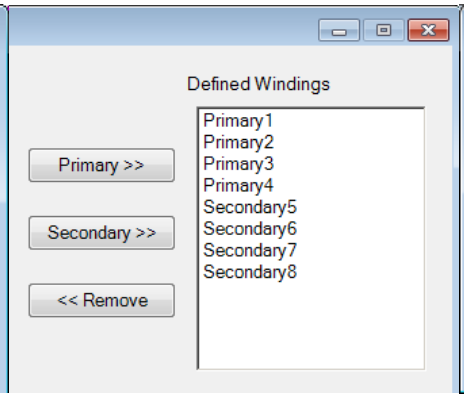
输入界面3/3：Analysis Setup

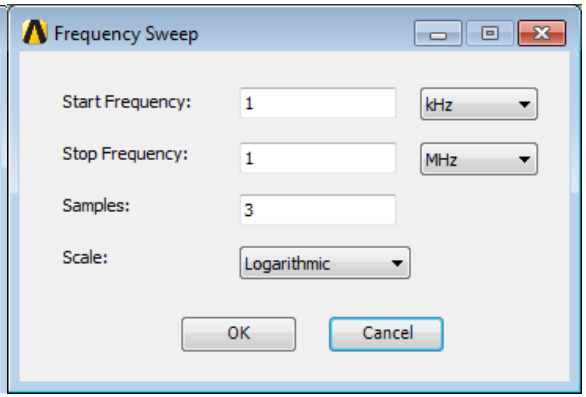
- Define Core Material and Coil Material
- Define Primary and Secondary Windings
- Define series or parallel connections for primary and secondary windings
- Define adaptive frequency, frequency sweep, % error and max number of passes
- Setup Analysis to create design OR Analyze to setup and solve design

自动赋材料，绕组激励，求解设置等









用户自定子添加磁芯尺寸和材料

- If the required core model is not available readily in the core definition panel, users can add their own core model
- A file with the name “CoreData.tab” is available under the folder “CoreUDM”
- This file can be opened in Excel or a text interface
- Users can add Supplier name, Core Type, Model name and dimensions of the core and overwrite the .tab file in tab delimited format
- The added core model will be available for selection for the next script run
- Note that even though core models can be added, Core types will still be limited to 15 types that are currently implemented

	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

用户自定子添加磁芯尺寸和材料

If the required Core material is not available in the analysis setup panel, it can be added by the following steps:

1. **Create a tab file for frequency versus permeability for the required core**
2. **Name the tab file same as the name of the material to be added**
3. **Place the tab file in the folder “CoreUDM /MaterialData”**
4. **Open “matdata.tab” file, which is in the folder “CoreUDM /MaterialData”,in Excel**
5. **Add a row for the material to be added and specify name and other material properties**
6. **Save the file with same name**

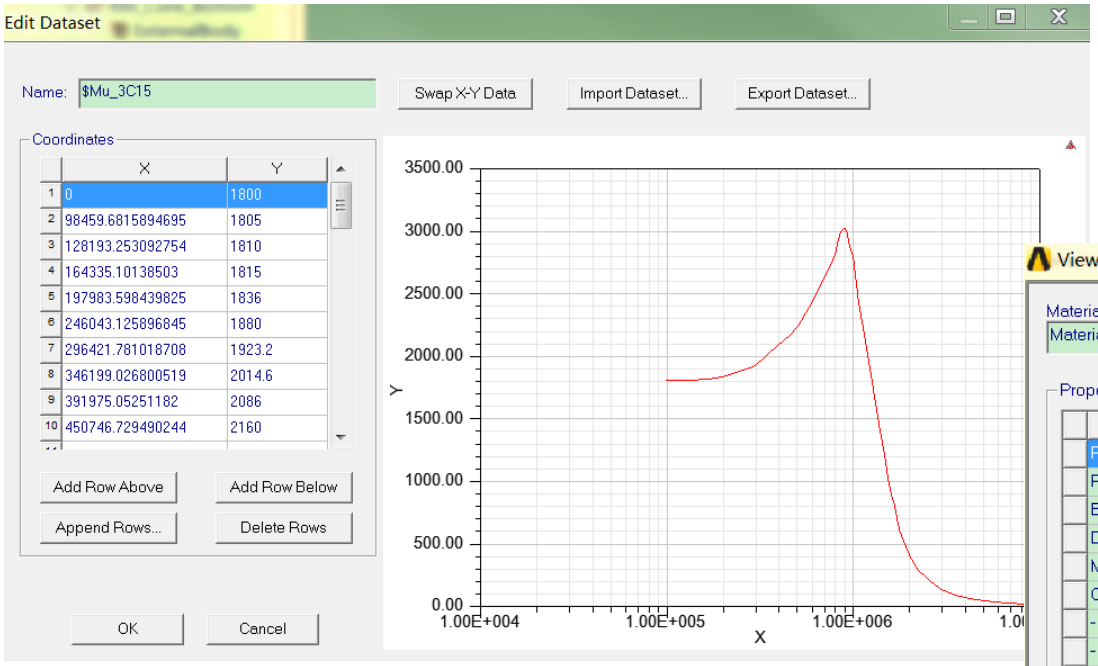
```
"X"      "Y"
0    1800
98459.681589469503   1805
128193.25309275401   1810
164335.10138502999   1815
197983.598439825     1836
246043.12589684501   1880
296421.78101870802   1923.2
346199.02680051897   2014.5999999999999
391975.05251181999   2086
450746.729490244     2160
502485.57112693402   2236.5
596047.538592714     2426
```

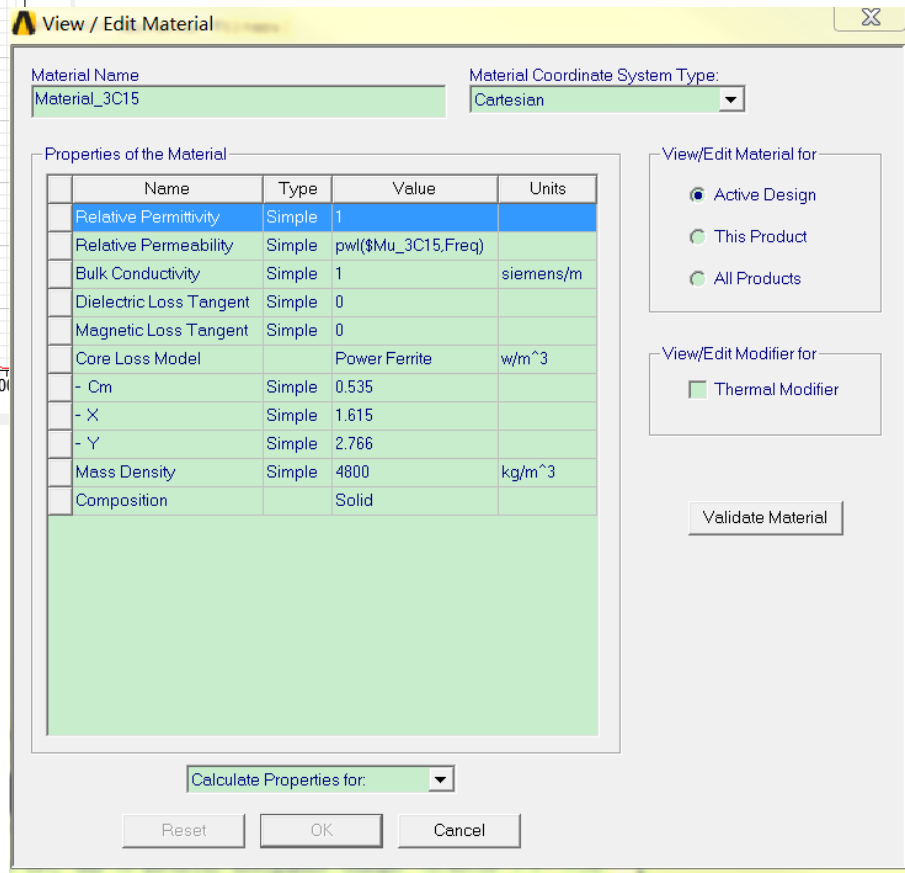
frequency versus permeability

	Material N	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

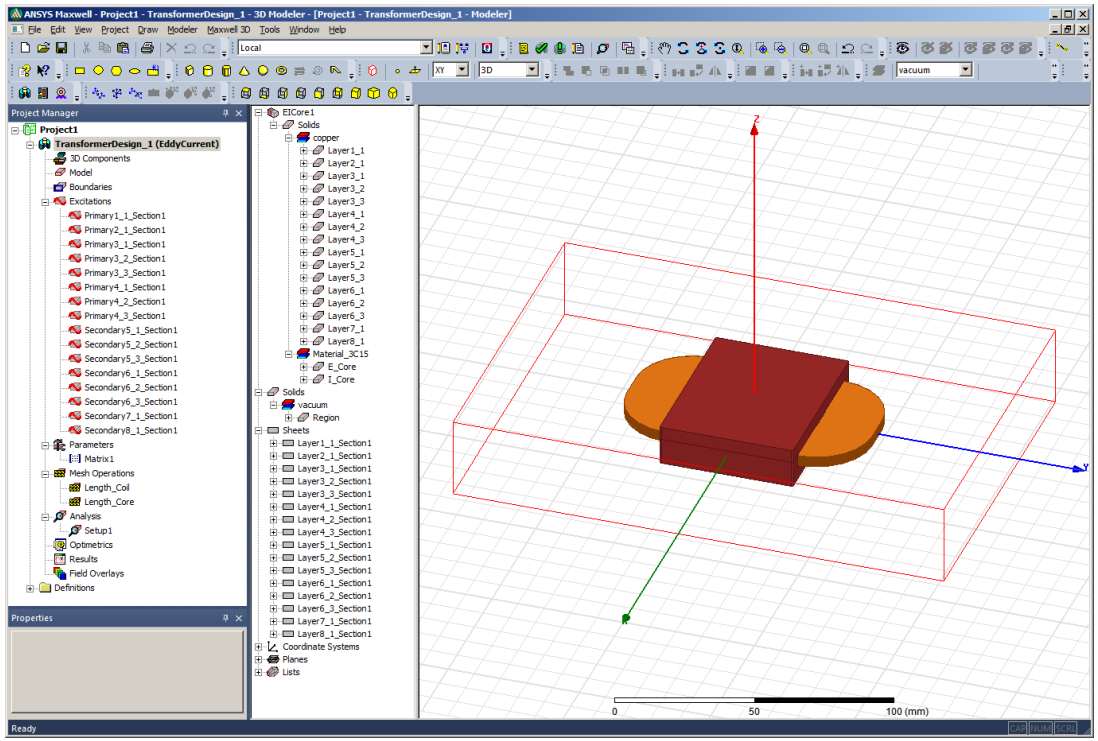
频率变磁导率和磁芯损耗模式的定义格式
Frequency versus permeability and Coreloss Model

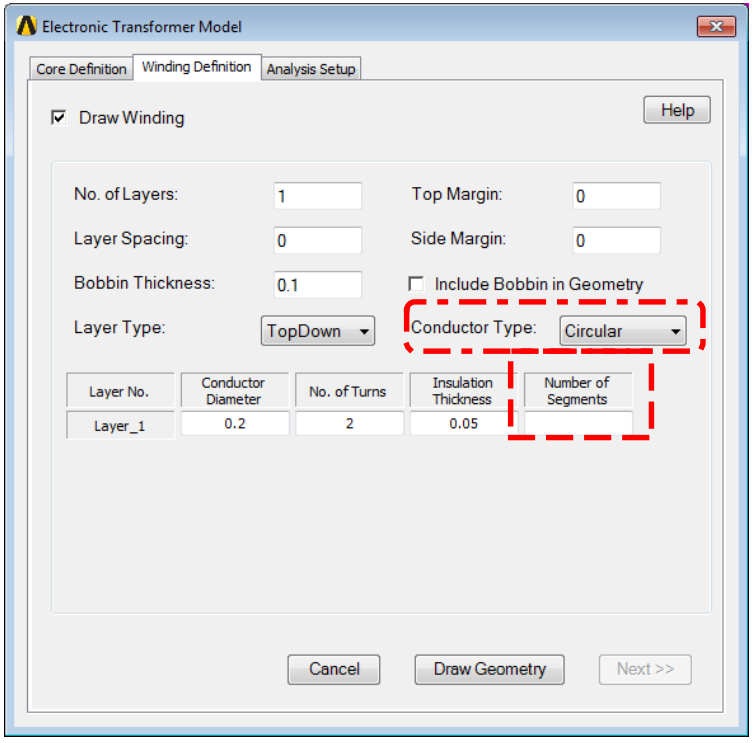




Maxwell求解设置

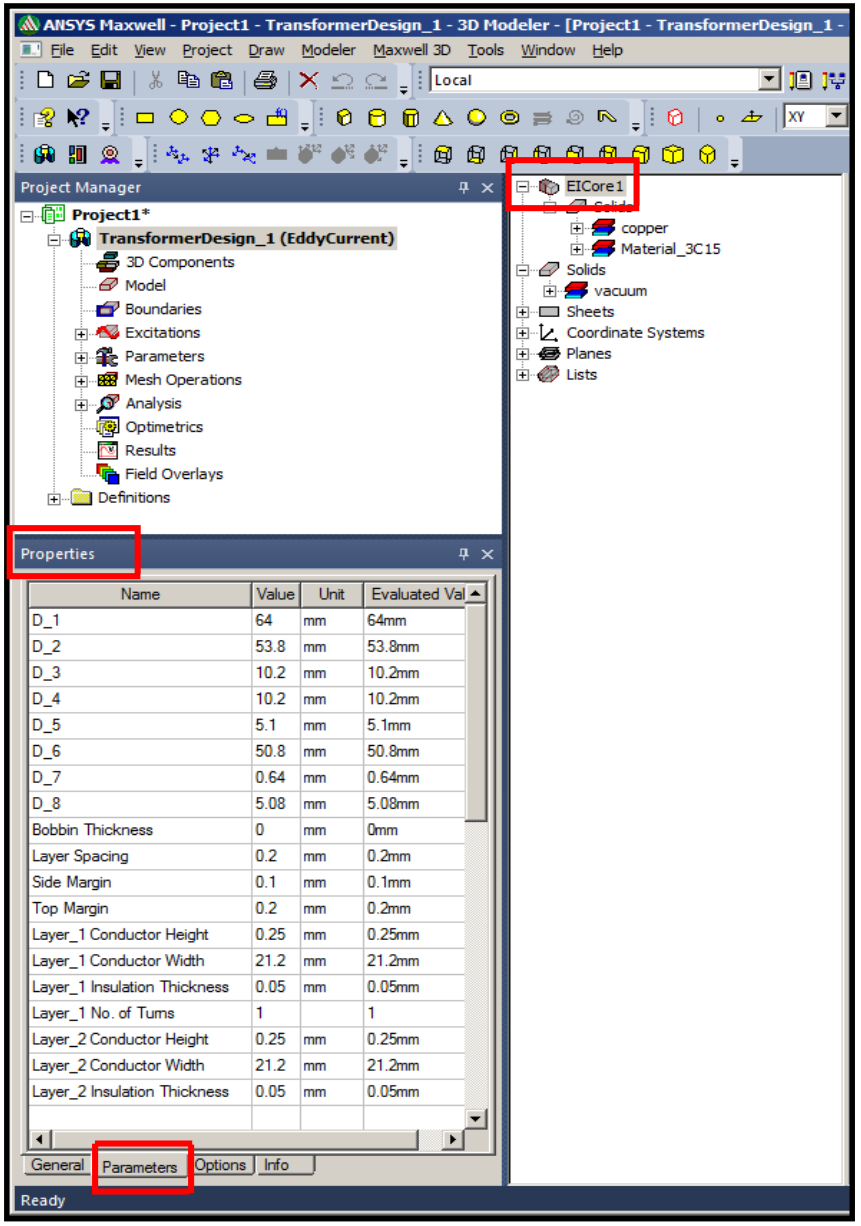
- Automatic setup includes:
- geometry, materials, sources, matrix, mesh operations, and analysis setup
- Region automatically sized, corner radius and fillets are automatically chosen.
- User specifies Number of Segments for round conductors





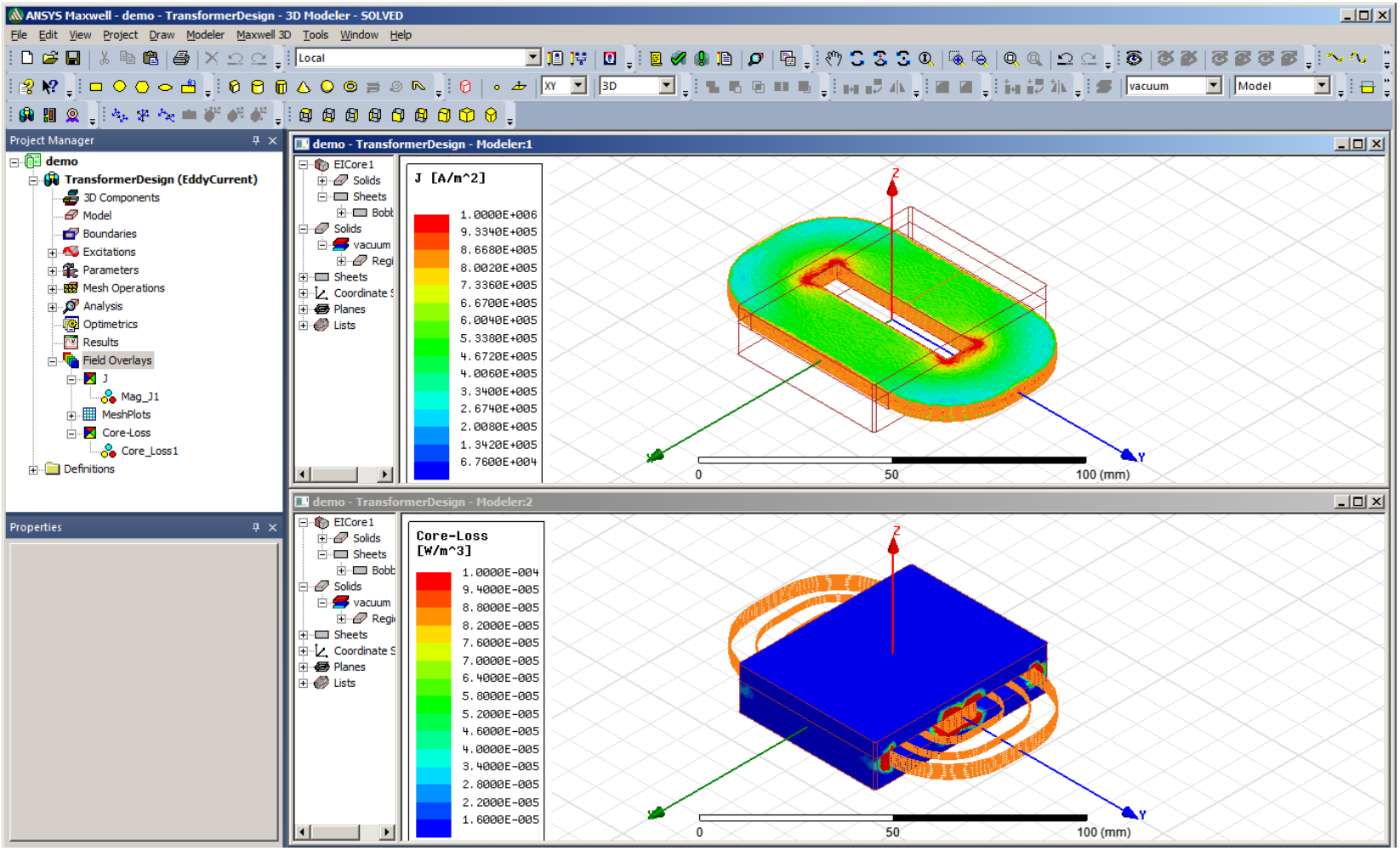
设计全参数化

- All dimensions are saved as parameters on the Properties tab for the component model
- These can be manually changed as desired (instead of re-running Python script)
- Note that while dimensions can be modified, the script needs to be re-run in order to change the number of layers or number of turns.



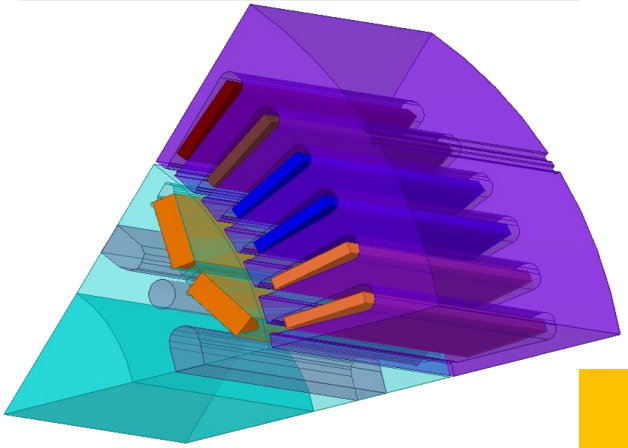
Maxwell 求解后结果 - Plots

- At this time, plots are not automatically created by the design kit

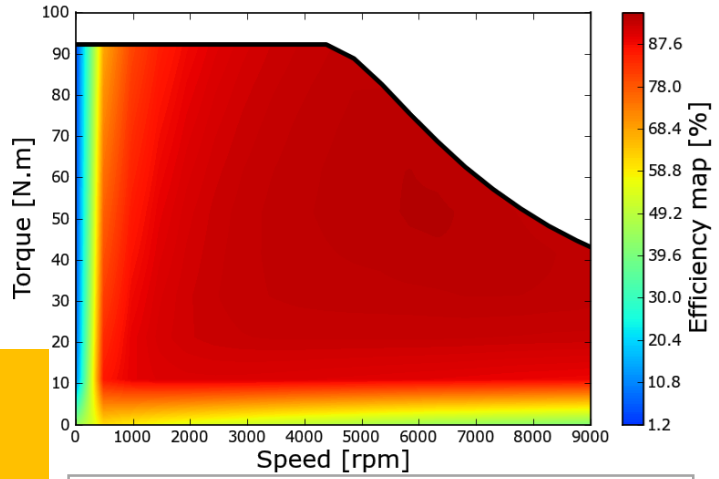


2. Motor Design Toolkits提升电机自动化仿真流程

Reduce weight, cost

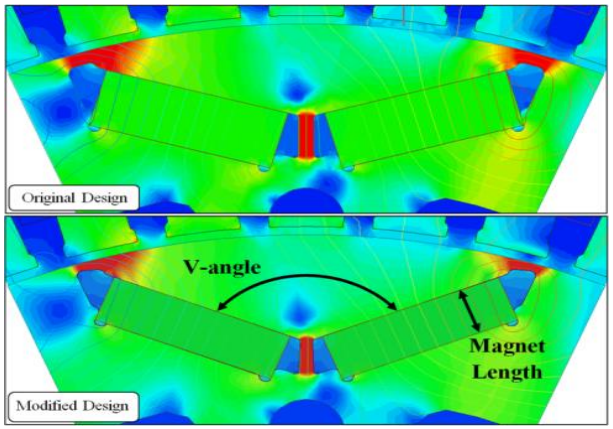


Improve efficiency

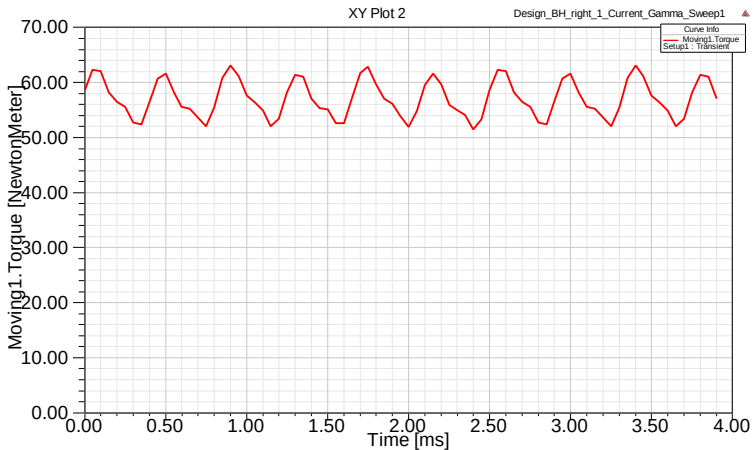


创 新

Reduce magnet size

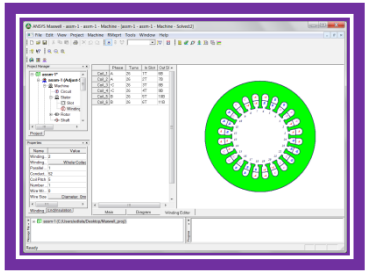


Reduce torque ripple

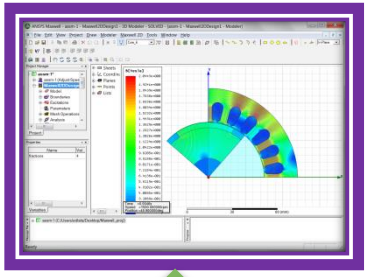


电机设计流程

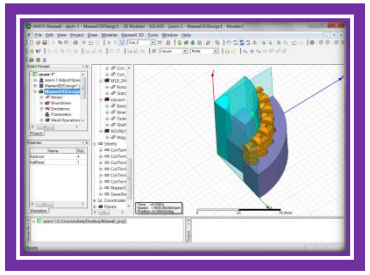
RMXprt



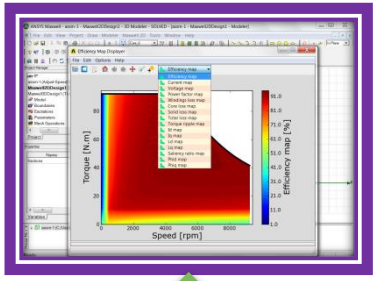
Maxwell2D



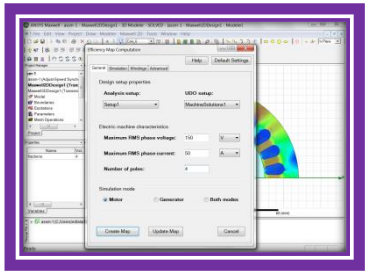
Maxwell3D



Toolkit



UDOs &Toolkit

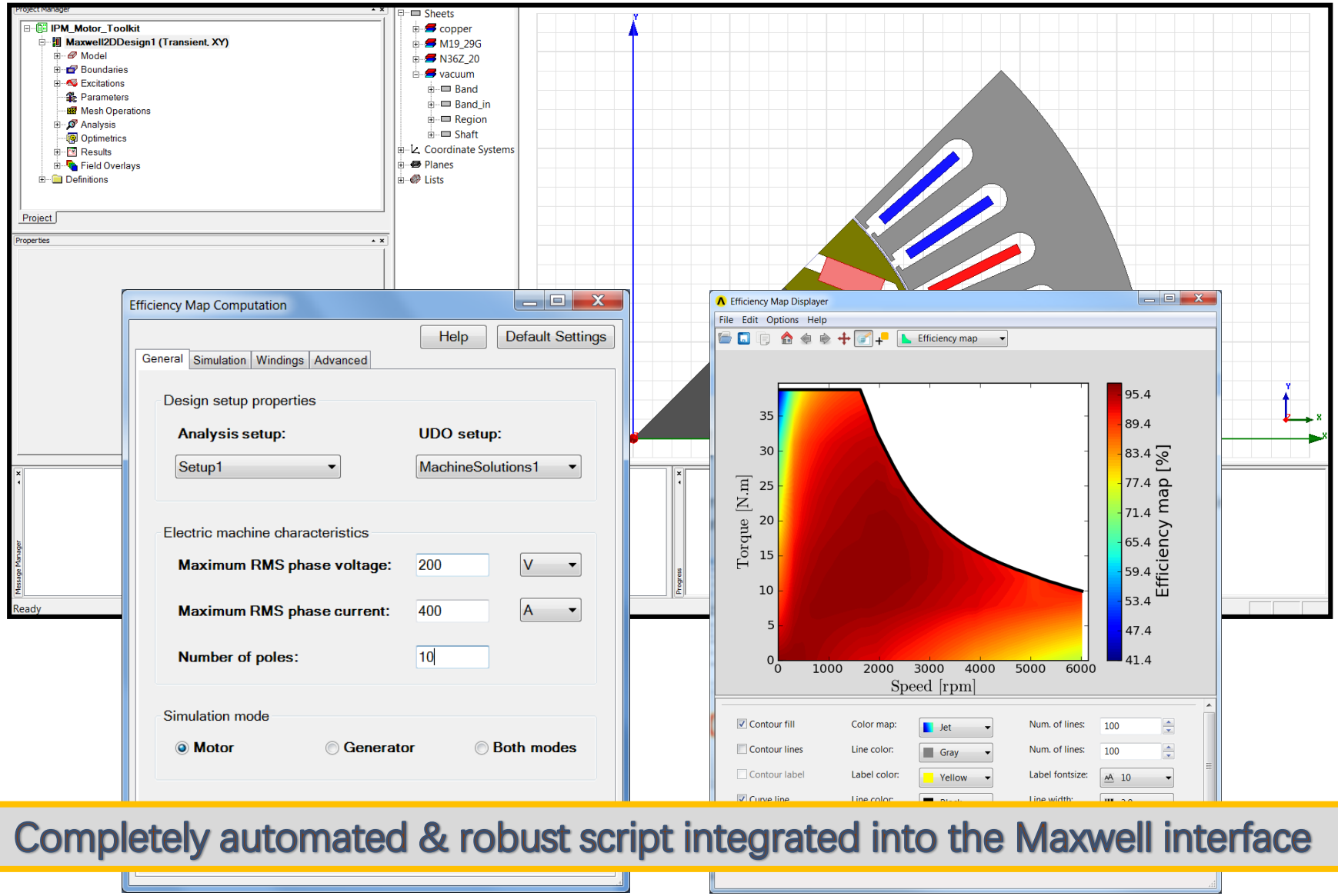


Initial Design

FE Design

Optimal Design

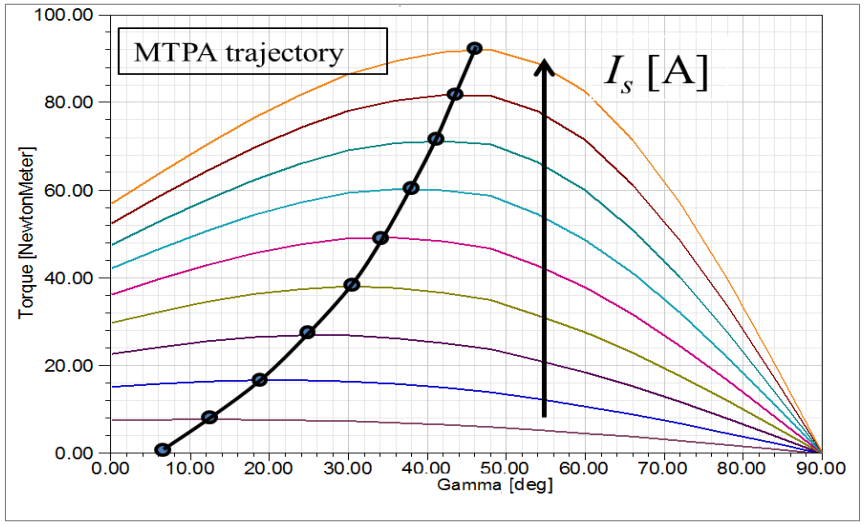
定制化电机设计工具包



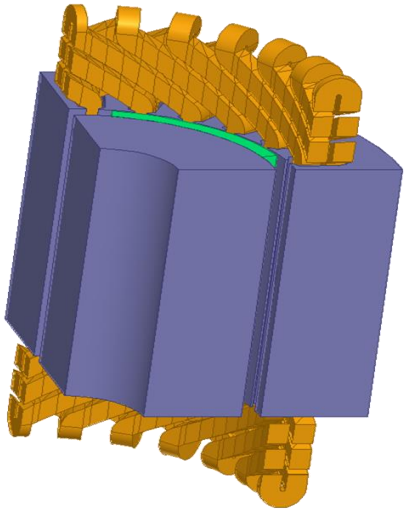
Completely automated & robust script integrated into the Maxwell interface

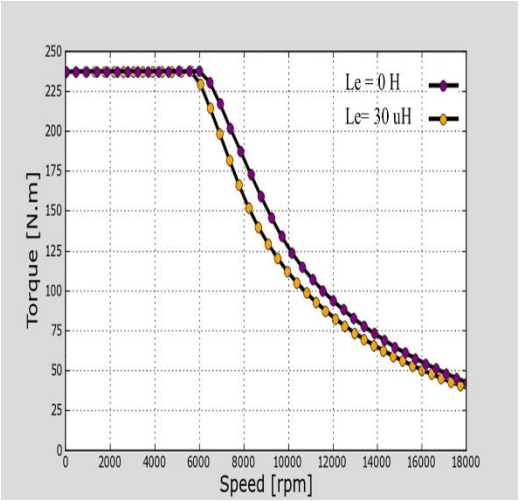
Toolkits包含了诸多高级功能和算法

最大转矩电流比控制策略 (MTPA)

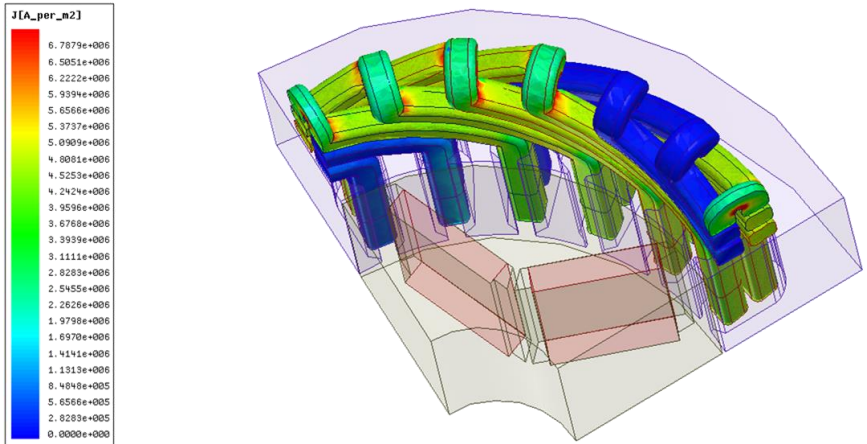


考虑绕组端部电感

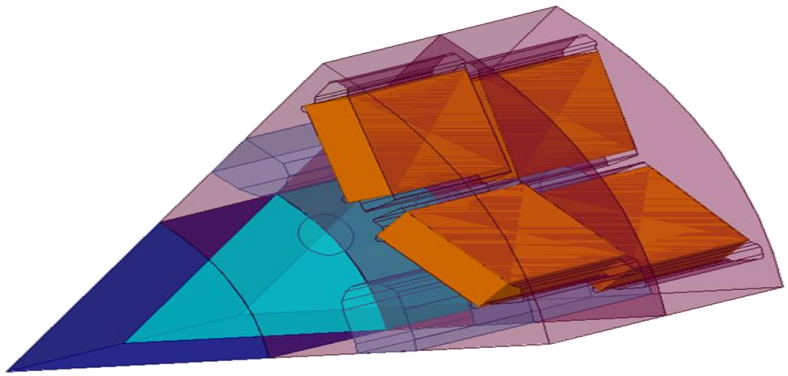




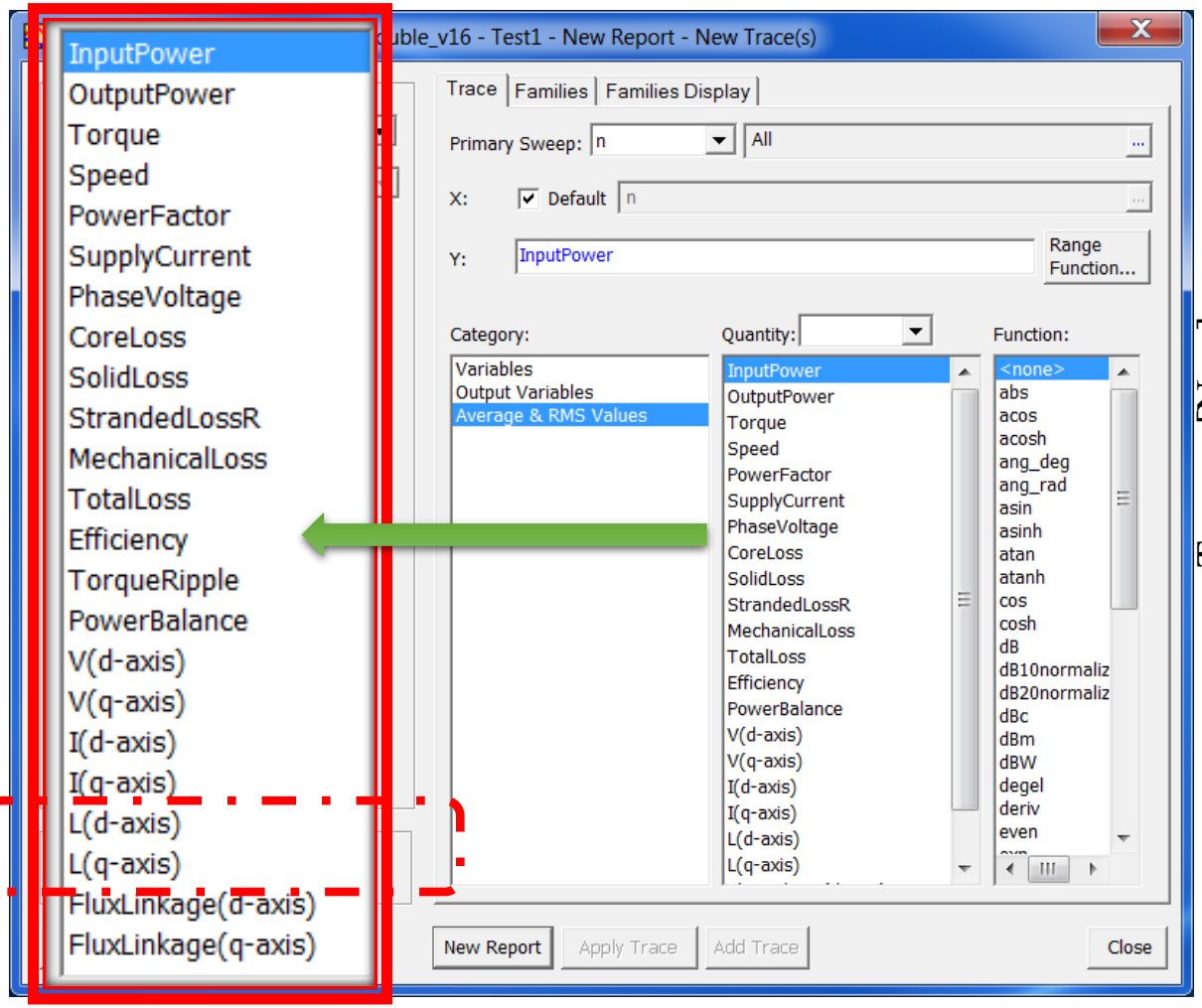
绕组交流电阻和温度效应



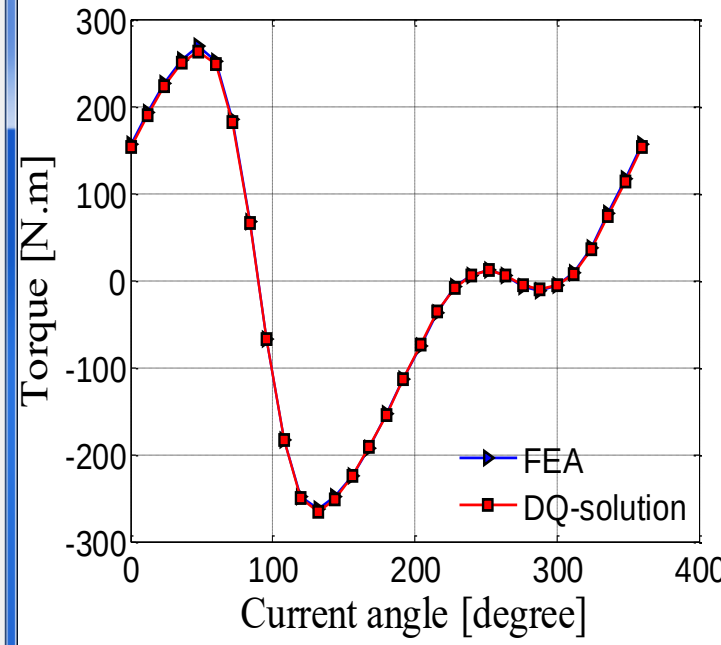
转子分段斜槽/极效应



用户自定义输出(UDOs)：DQ 精度高



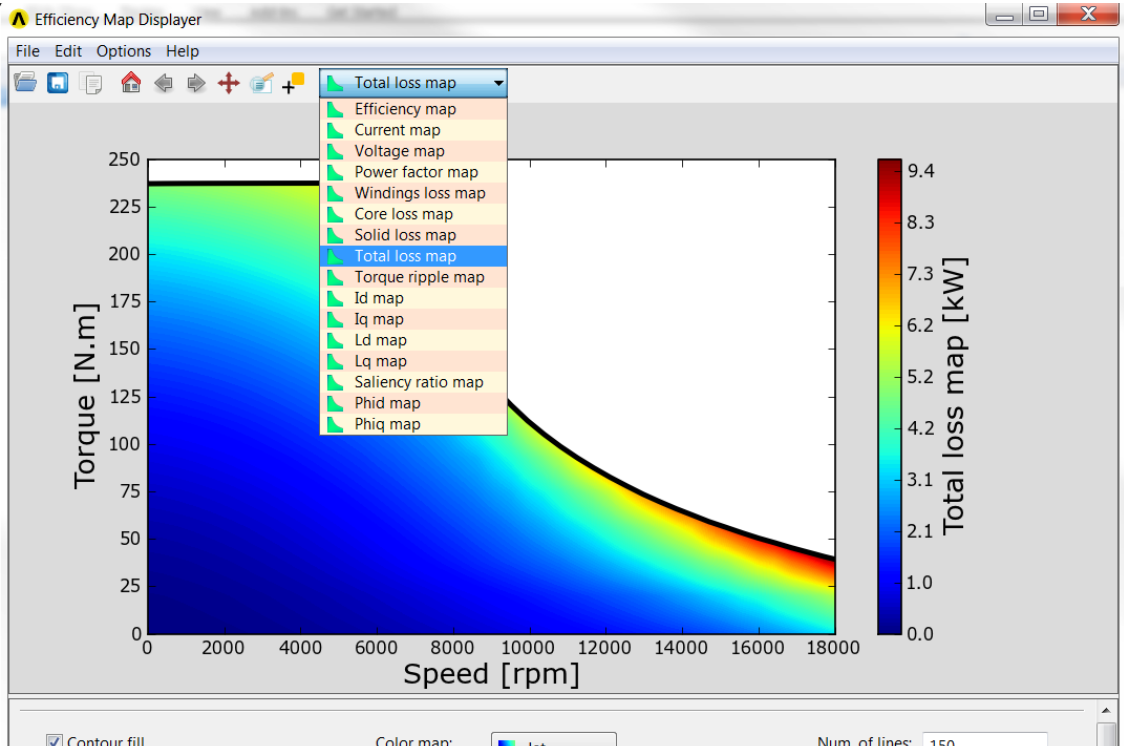
$$L_{QD} = C^T * L_{ABC} * C$$

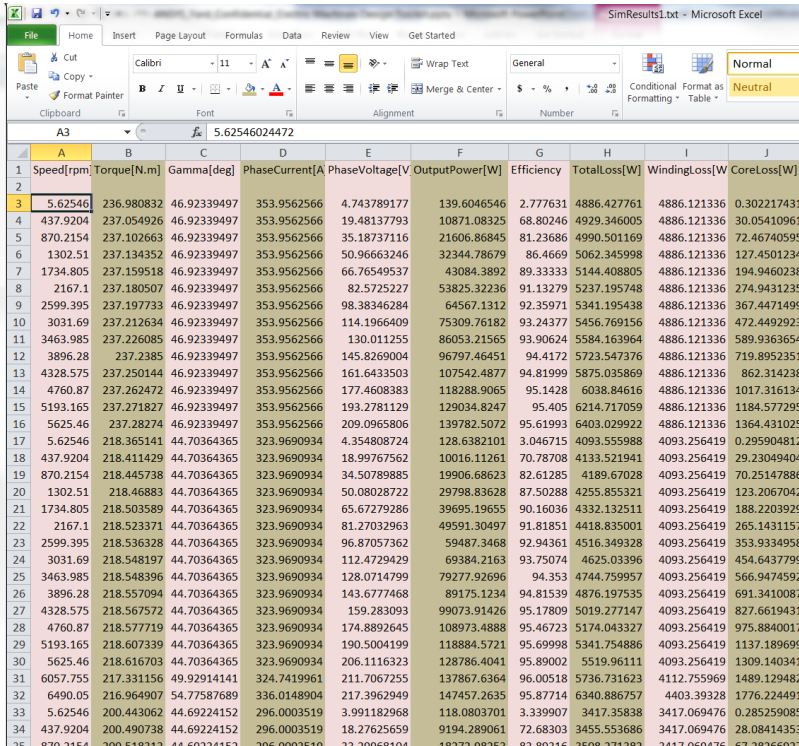


$$T = \frac{3}{2} p\left(\psi_d I_q - \psi_q I_d\right)$$

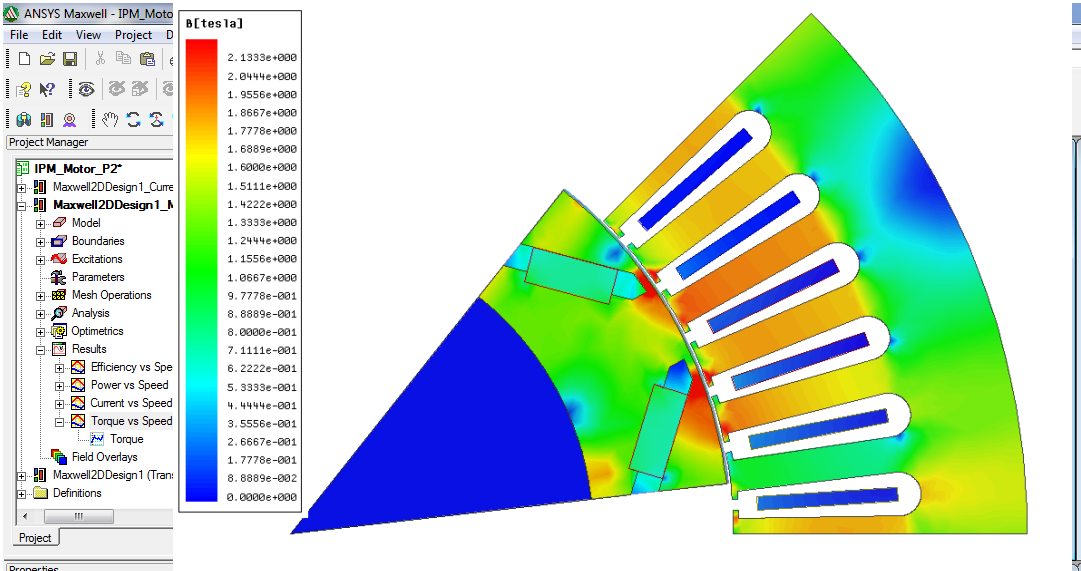
效率映射显示器: 可映射诸多结果

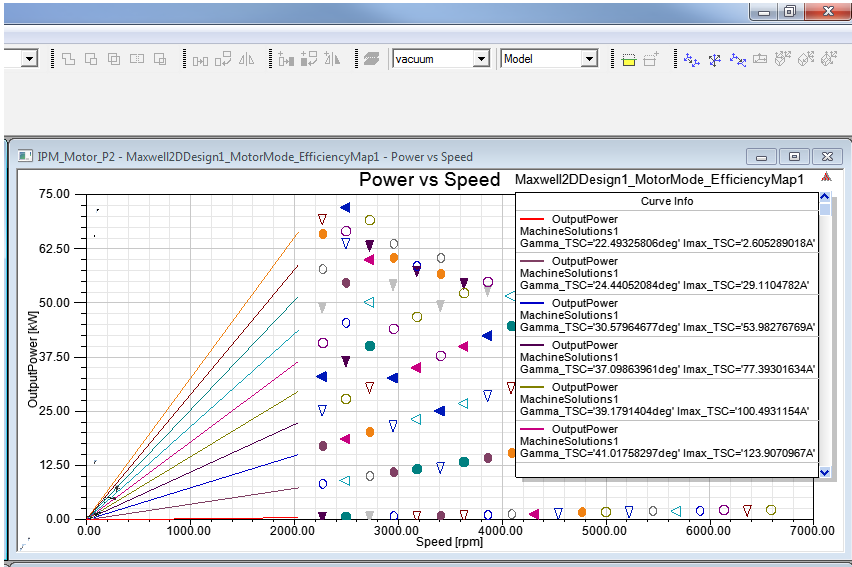
- Script offers an intuitive UI to display:

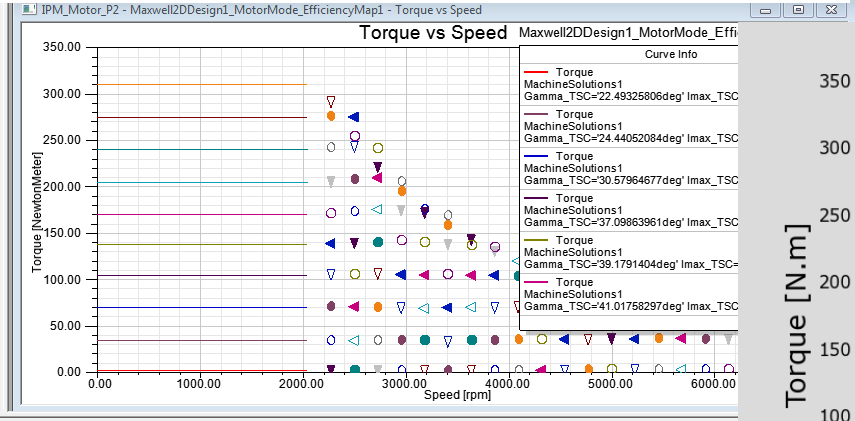


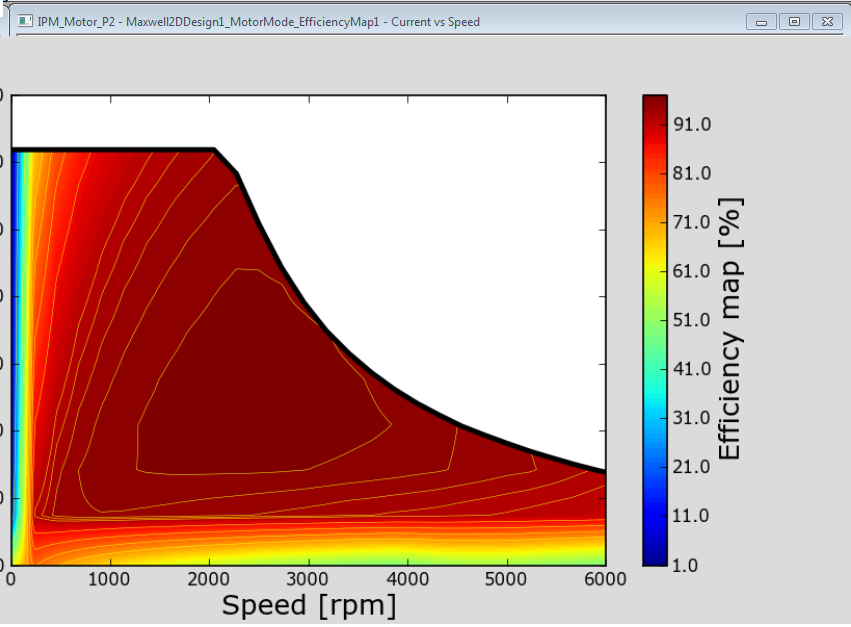


案例：效率映射Maxwell 2D仿真结果--Prius Motor



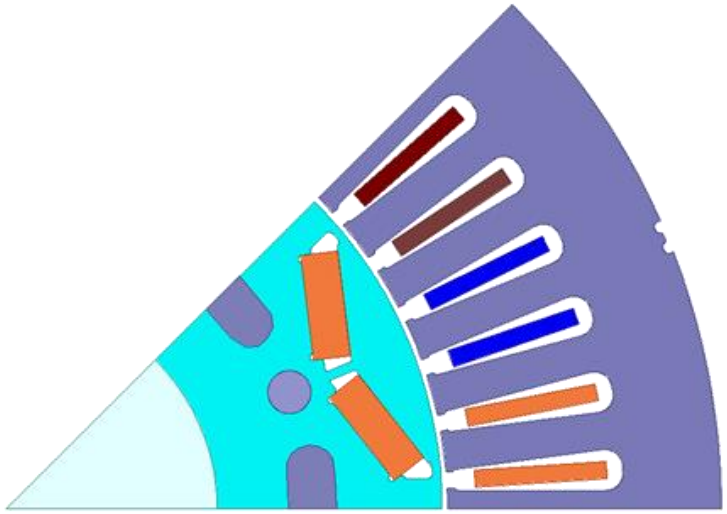


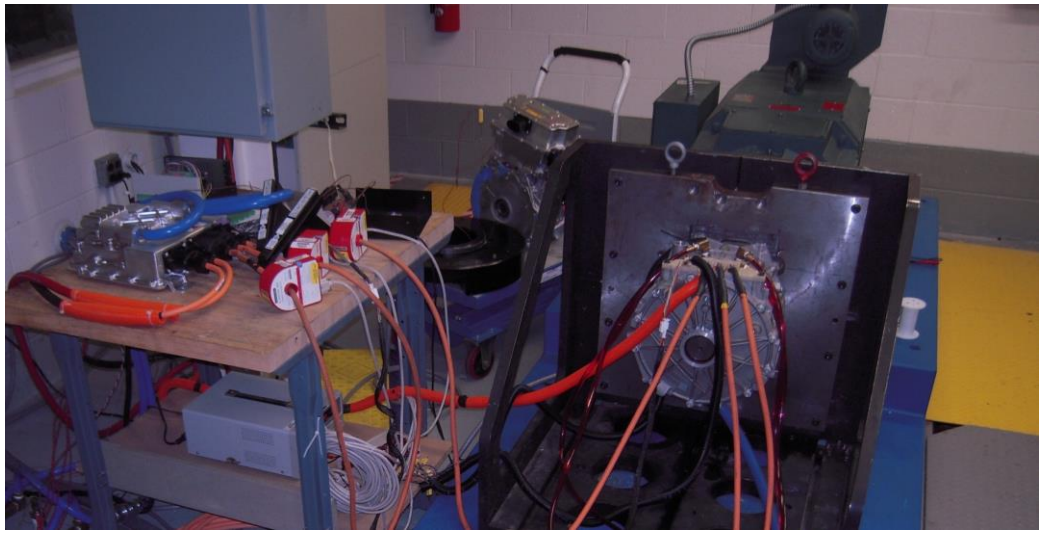




测试案例：Magna Electronics IPM

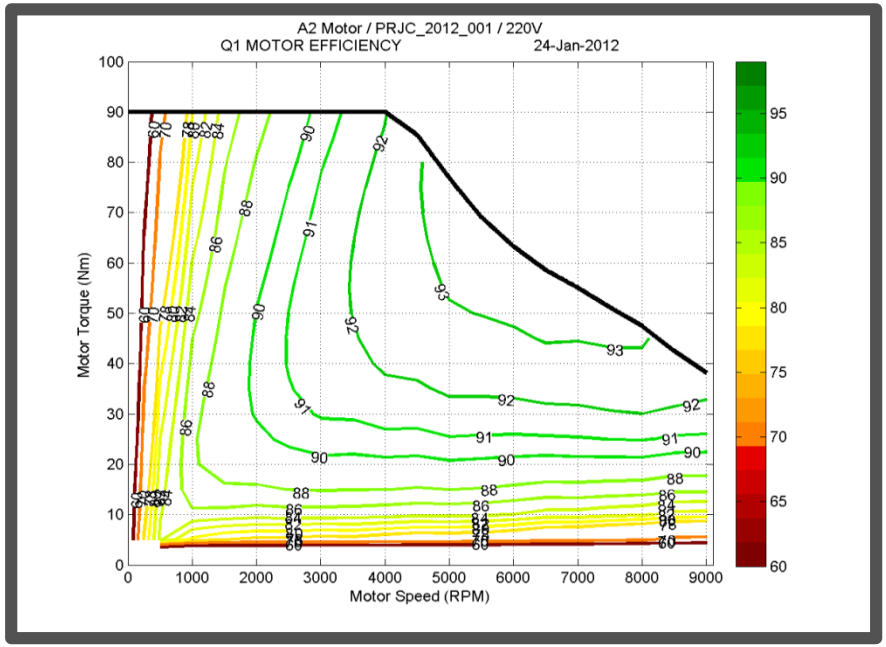
- **电机技术指标**
  - I_{max} = 300 A (peak value)
  - V_{dc} = 200 V
  - R_{dc} = 8 mohm @ 20 C (per-phase stator resistance)
  - L_e = 30 uH (per-phase end-turn inductance)
  - P = 8
  - Max. speed = 9000 rpm



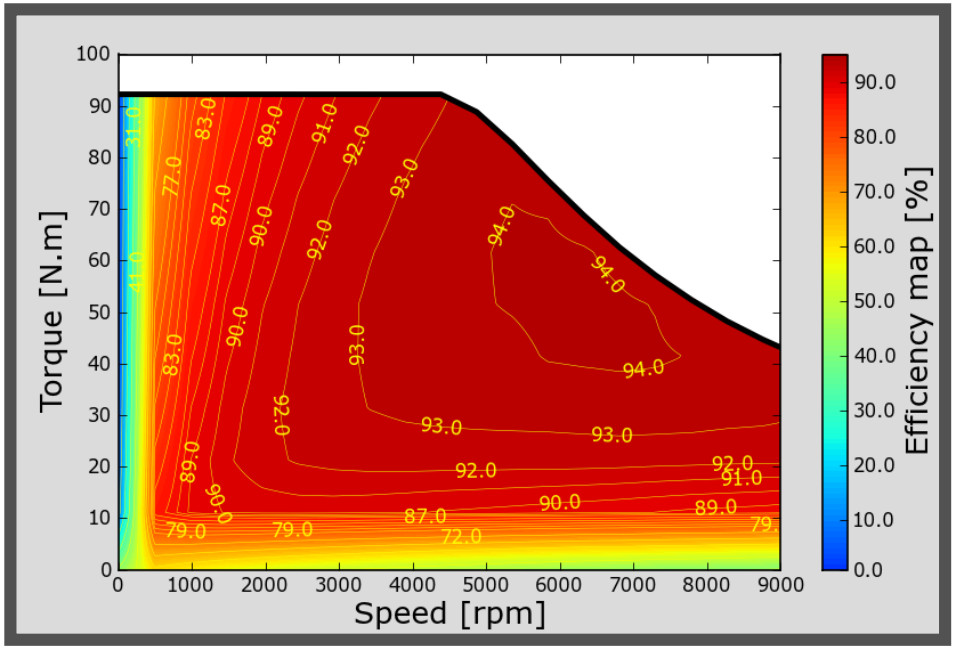


实验结果 vs. 仿真结果

Experimental

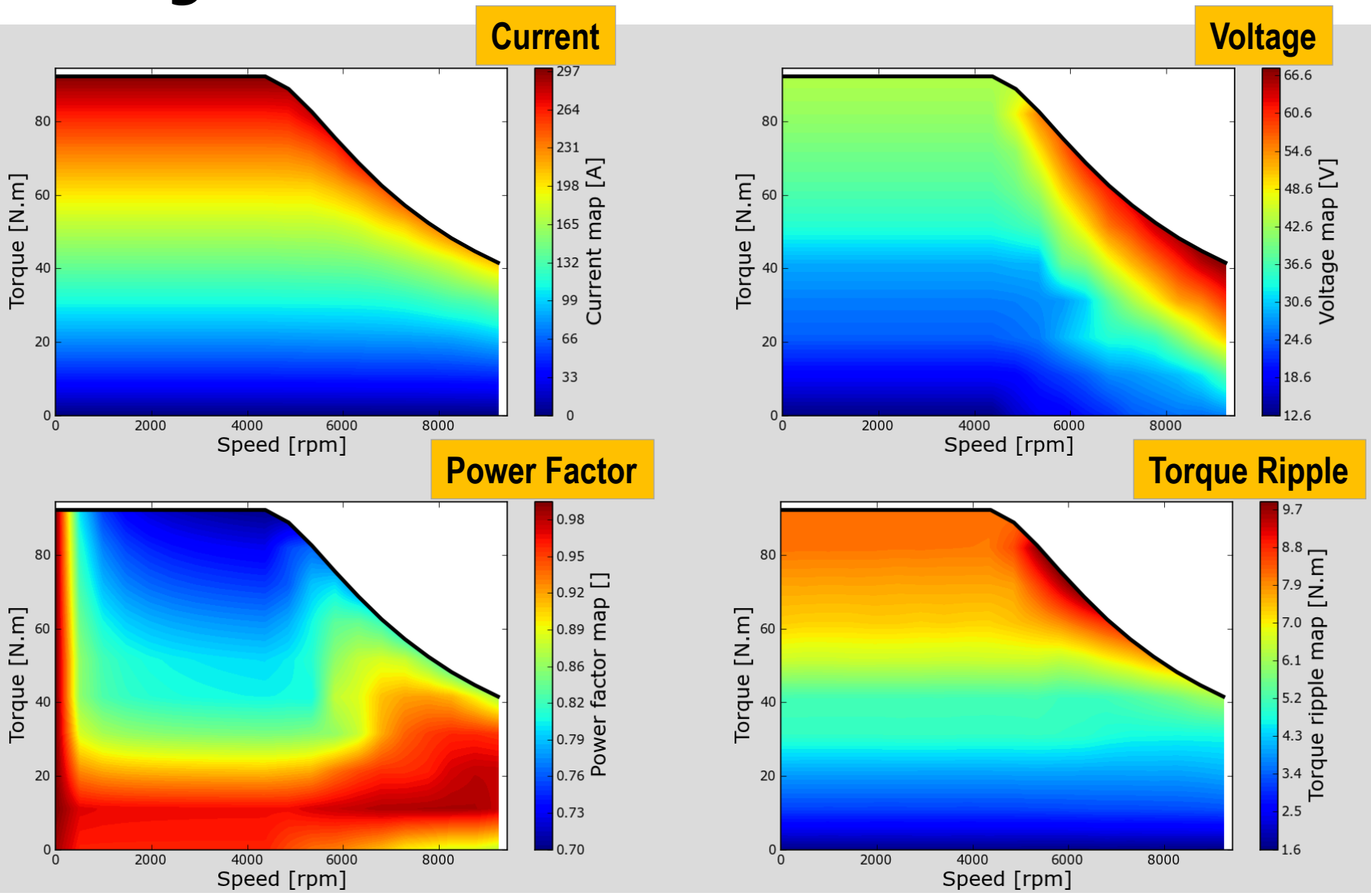


2D Simulation

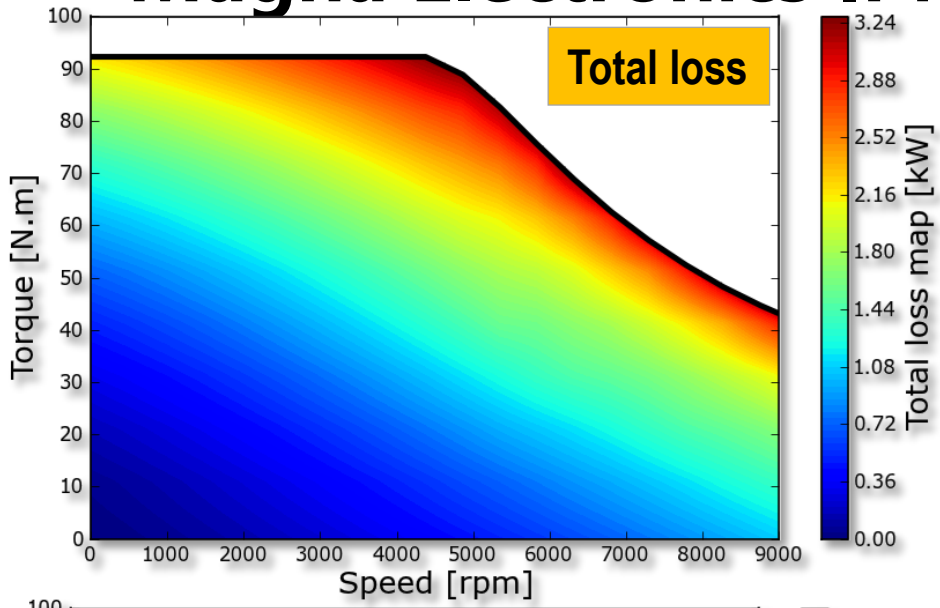


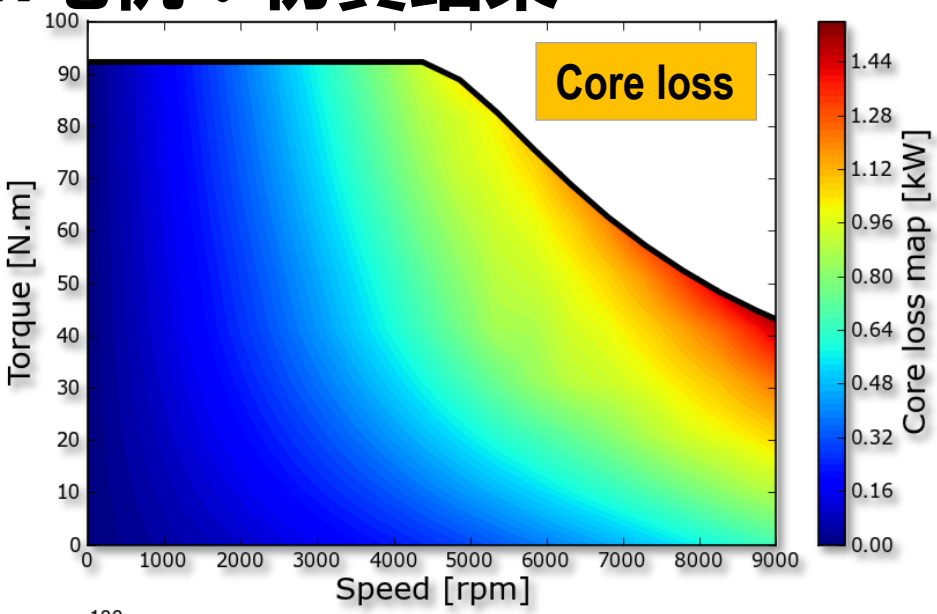
MAGNA

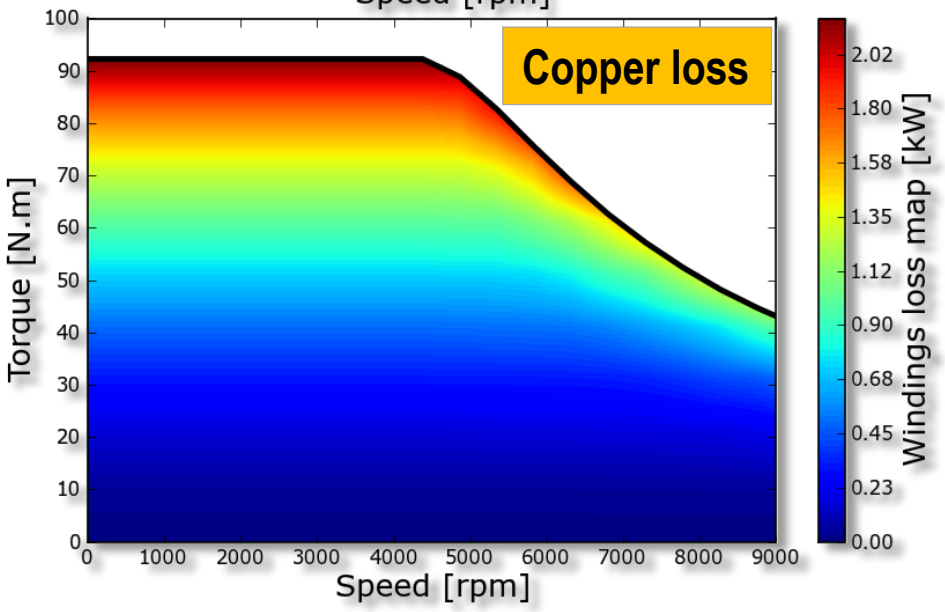
Magna Electronics IPM电机：仿真结果

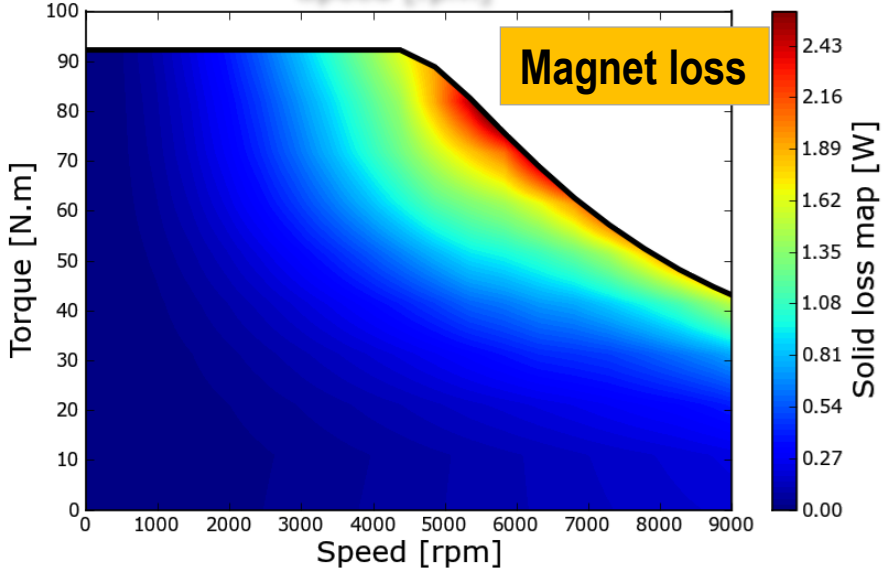


Magna Electronics IPM电机：仿真结果



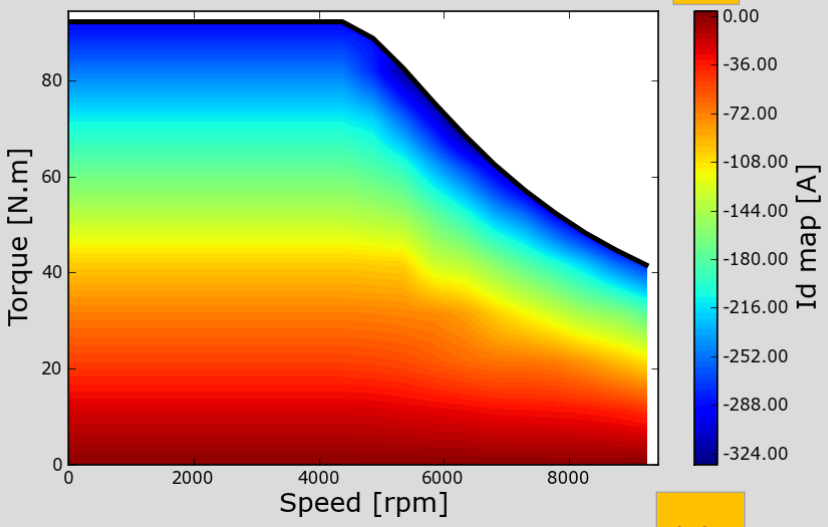




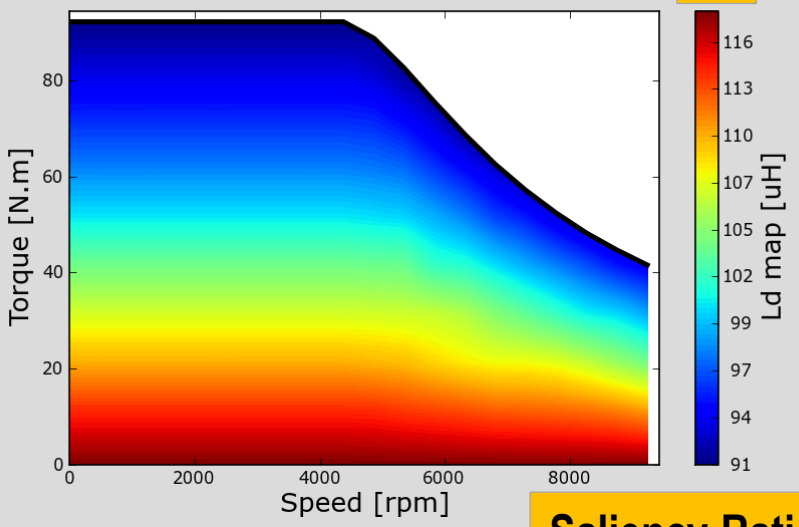


Magna Electronics IPM电机：仿真结果

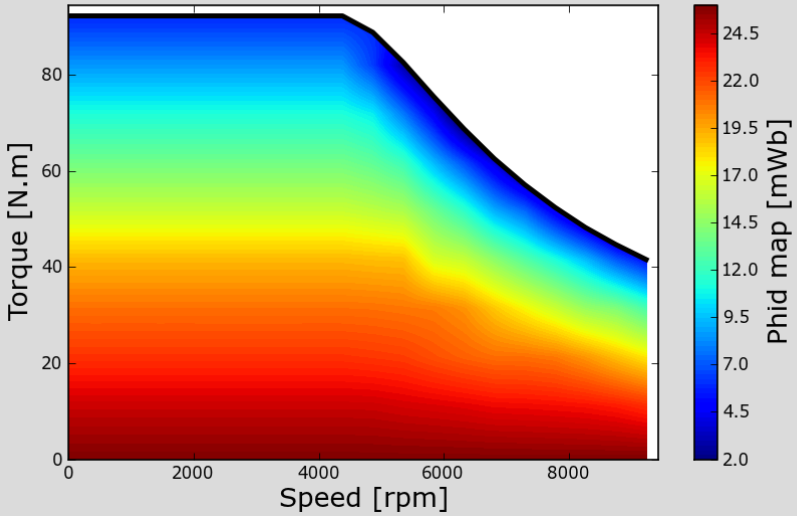
I_d



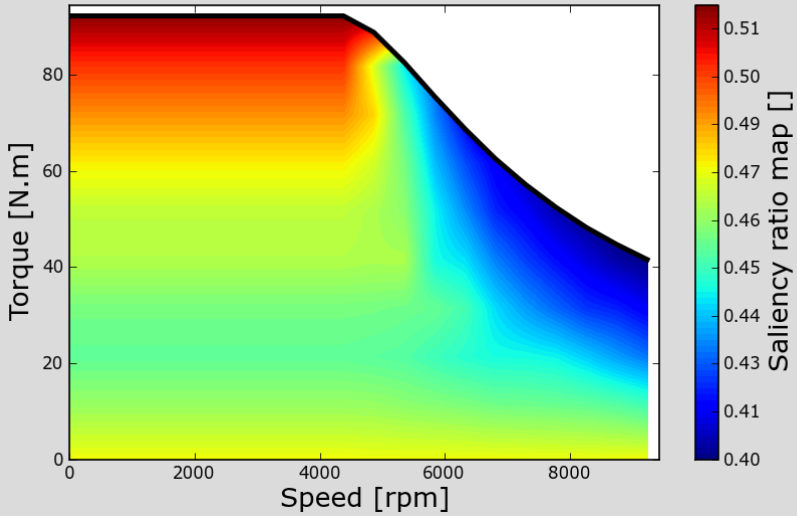
L_d



ψ_d

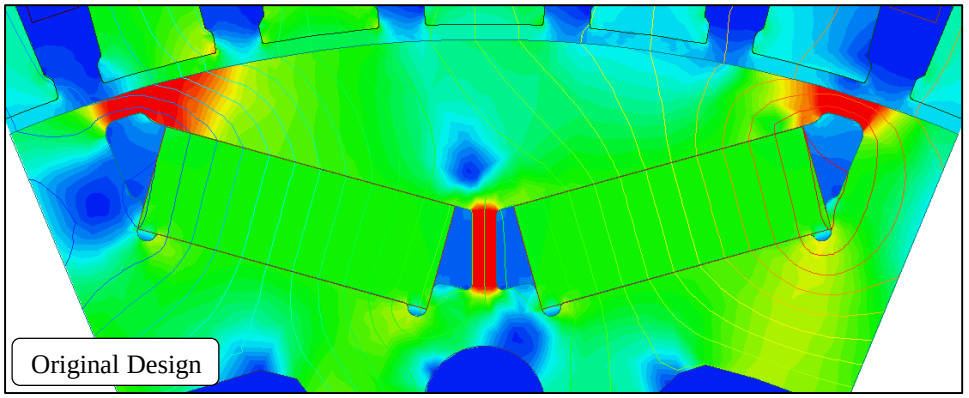


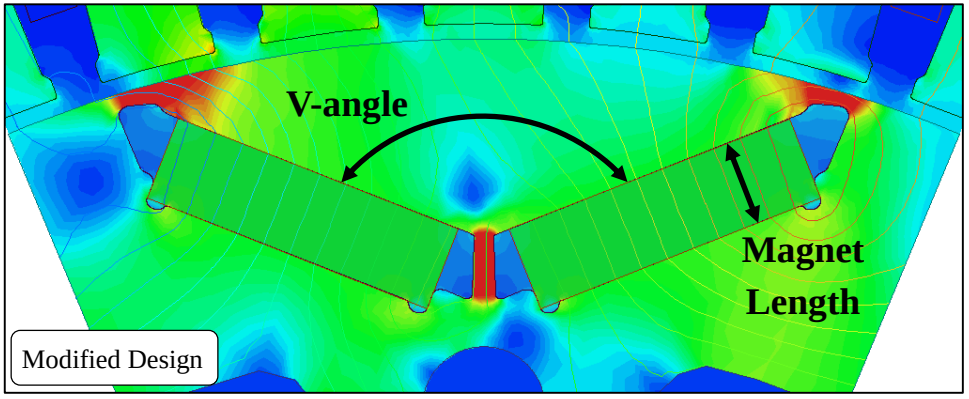
Saliency Ratio



优化案例：永磁体尺寸减少方法研究

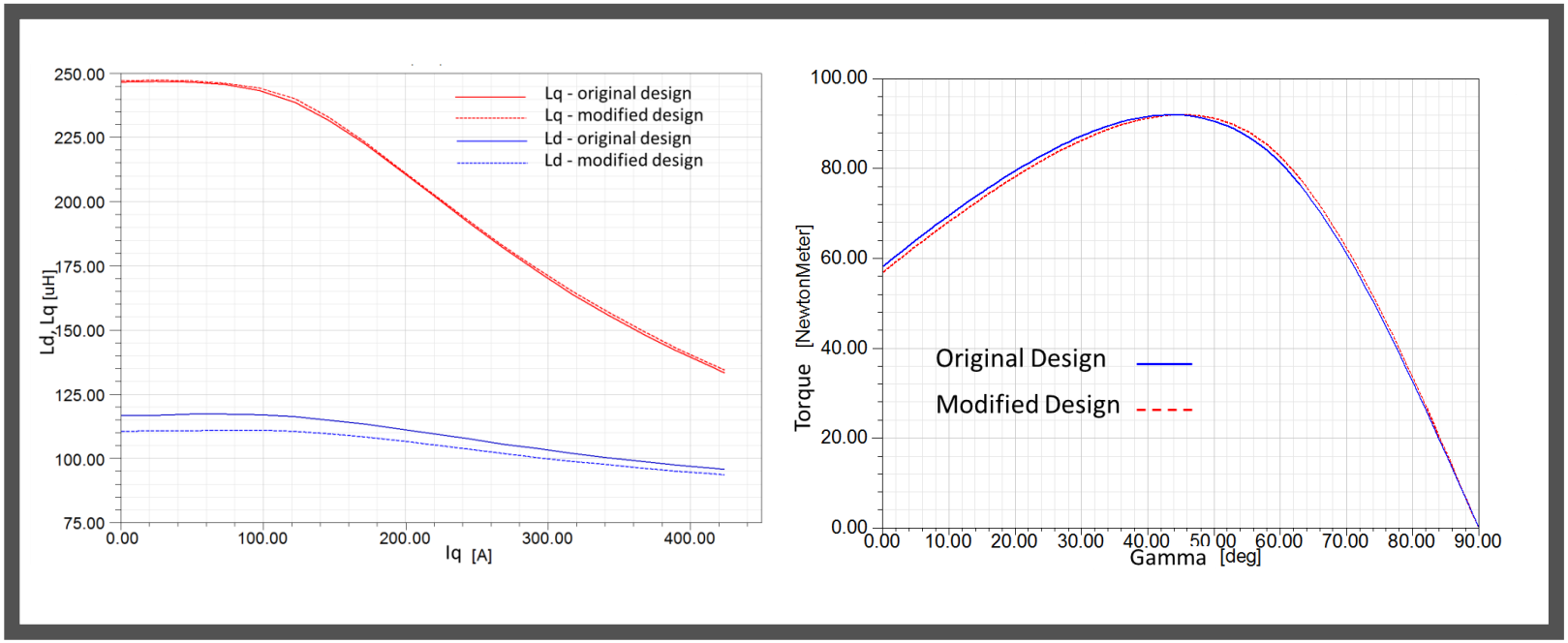
- Our goal is to reduce magnet size by 20%
- V-angle is varied in parametric analysis to maintain the maximum torque
- Same current and voltage





永磁体尺寸减少方法研究 L_d and L_q

FEA results of L_d and L_q of the original and modified designs.

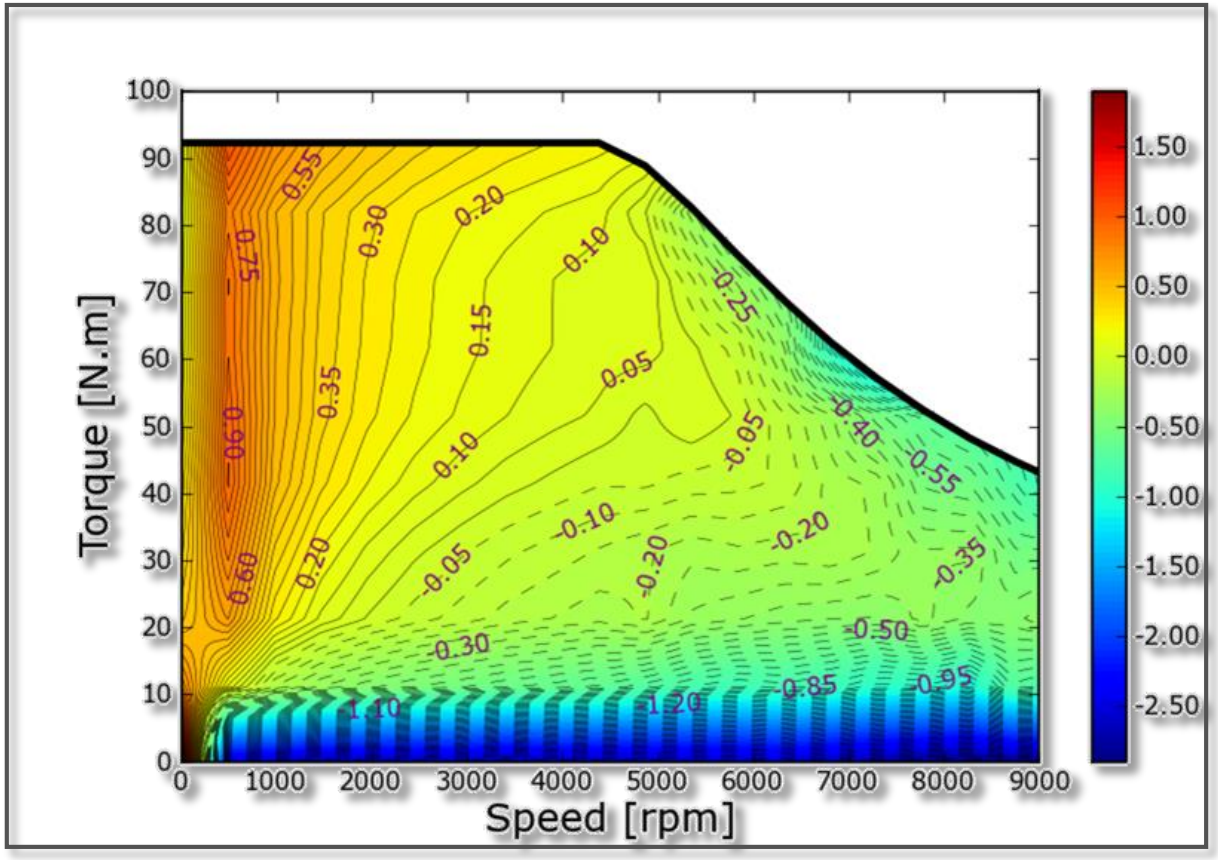


The increase in the saliency of the modified design is illustrated by the slight increase of L_q, and the decrease of L_d which is due to the magnet reduction.

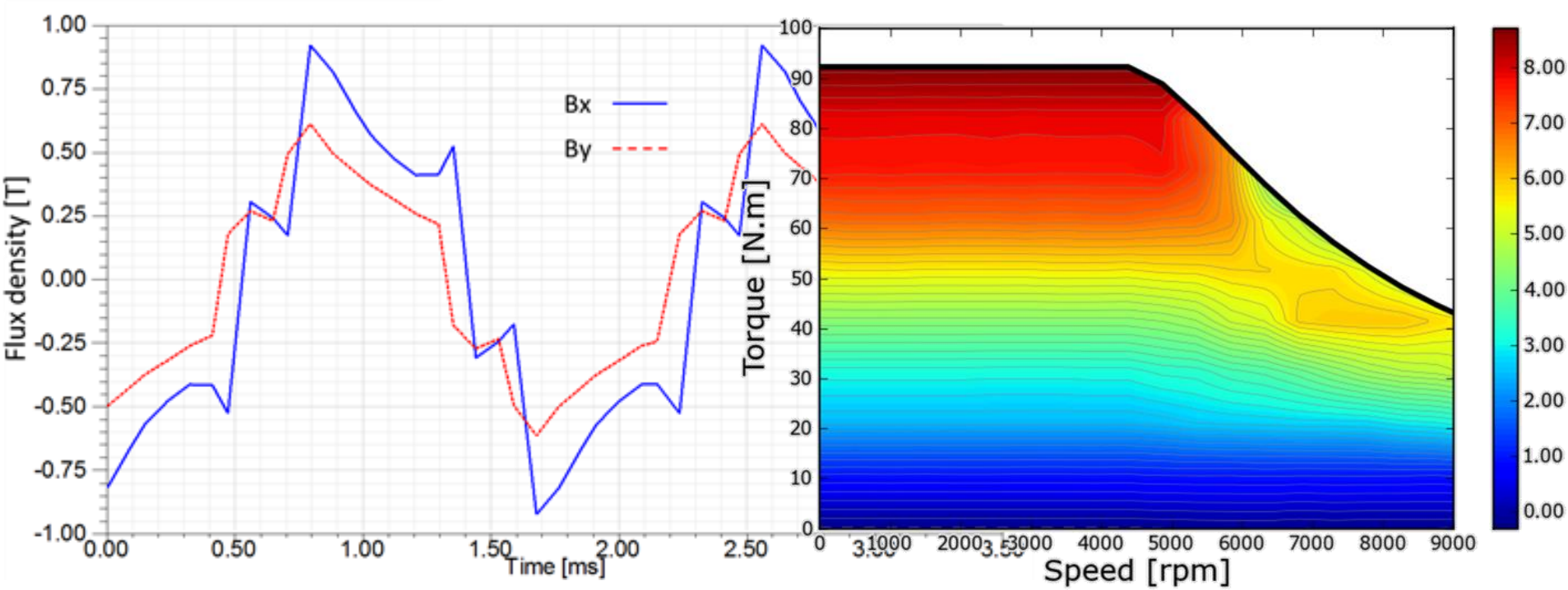
$$T_e = \frac{3}{2} p\left[\psi_{PM} I_q - \left(L_q - L_d\right) I_d I_q\right]$$

永磁体尺寸减少方法研究：效率

- Percentage difference of efficiency between the original and modified designs
- The positive scale means that an increase of the efficiency is gained in the modified design.



永磁体尺寸减少方法研究：谐波 & 转矩纹波



- Absolute difference in the torque ripple in N·m between the modified & original designs.

在线演示

DEMO

更多内容，欢迎大家联络索要视频

庄百兴
18675506525
Baixing.Zhuang@ansys.com


ANSYS
ANSYS
CONVERGENCE
CONFERENCES
2016
ANSYS中国技术大会
中国·上海

感谢聆听