

上海盖盛数字科技有限公司

ANSYS Motor-CAD2024版本更新

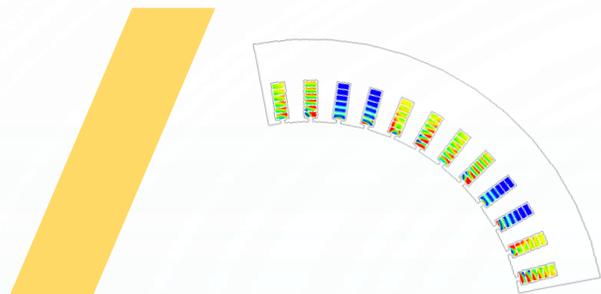


汇报人：陈开



2024年4月





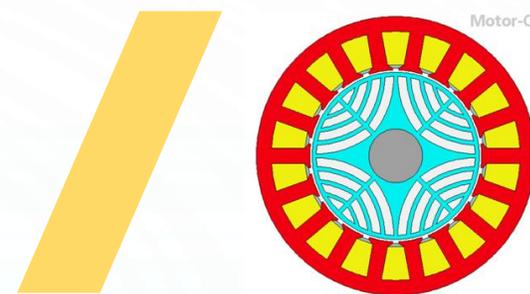
更高精度

- ✓ 高保真的效率Map和工况性能分析
- ✓ 新的感应电机方法
- ✓ NVH 模态修正
- ✓ 电路和系统影响



更快速度

- ✓ 改进多线程
- ✓ 更快的分析求解器
- ✓ 新的电磁求解方法

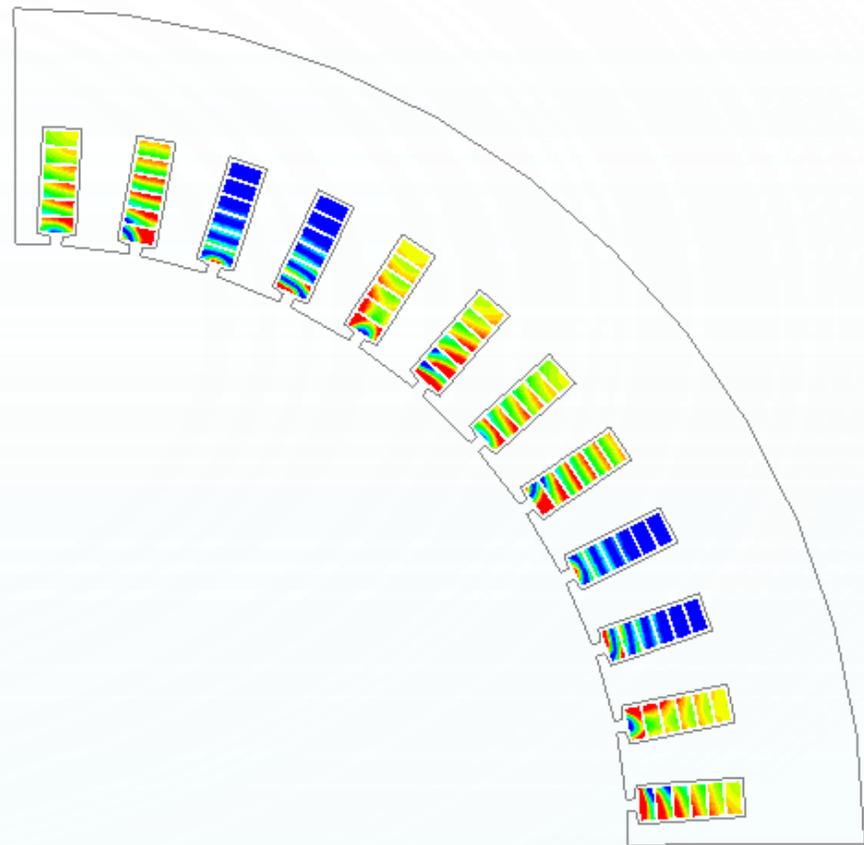
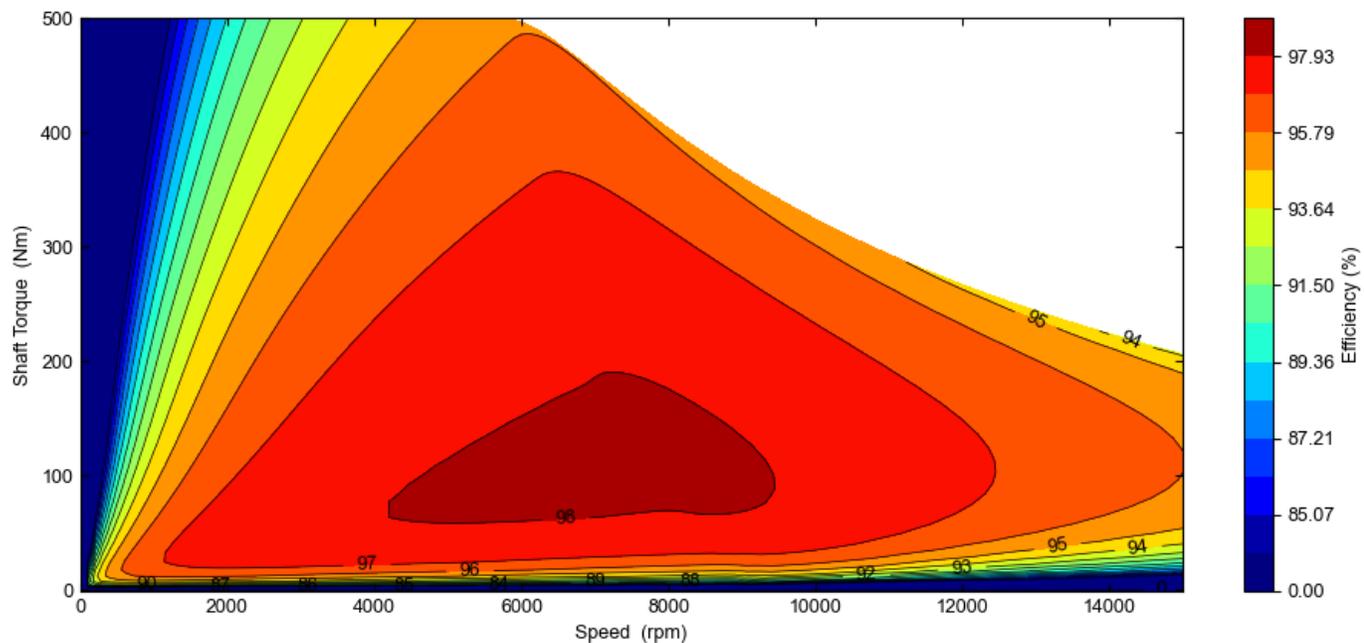


功能创新

- ✓ 修改几何模板产生新的自适应设计模板，设计更灵活
- ✓ 增加转子径向喷油选项
- ✓ 灵活的转子磁化方向设置，和改进的扁线优化设计

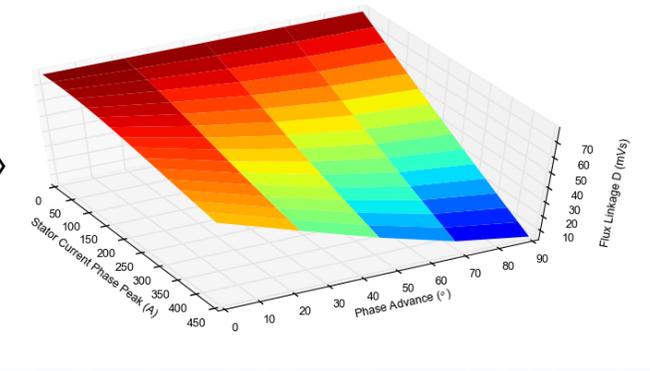
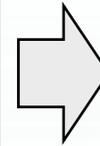
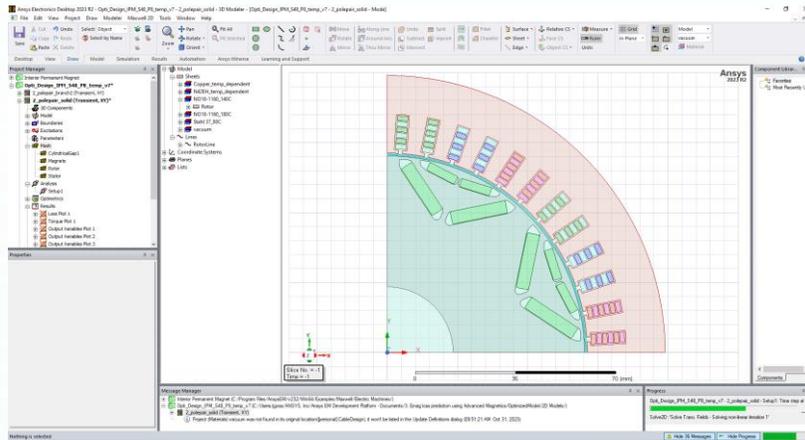
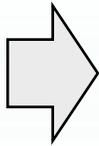
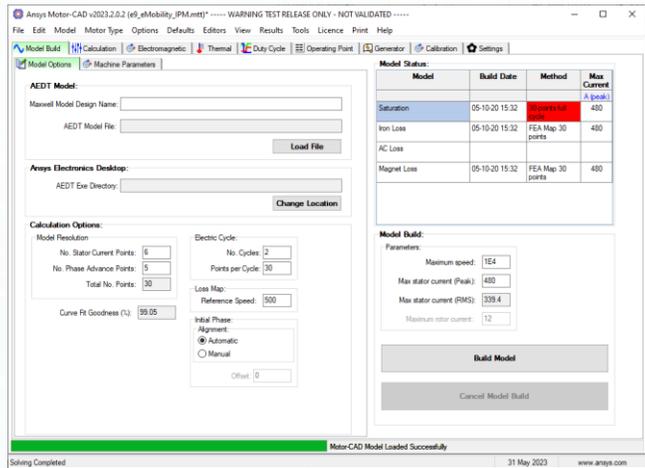
高保真度效率Map计算

- 在概念设计和细节设计阶段，可采用新的效率map图计算方法
- 更准确，更灵活



调用Maxwell求解器用于Map图计算

- MotorCAD界面自动调用Maxwell求解器，自动有限元求解和数据抽取，后处理在MotorCAD中完成
- 支持HPC



Maxwell2D输出——剖分改进

- 输出模型到Maxwell的时候，自动设置好band mapping angle

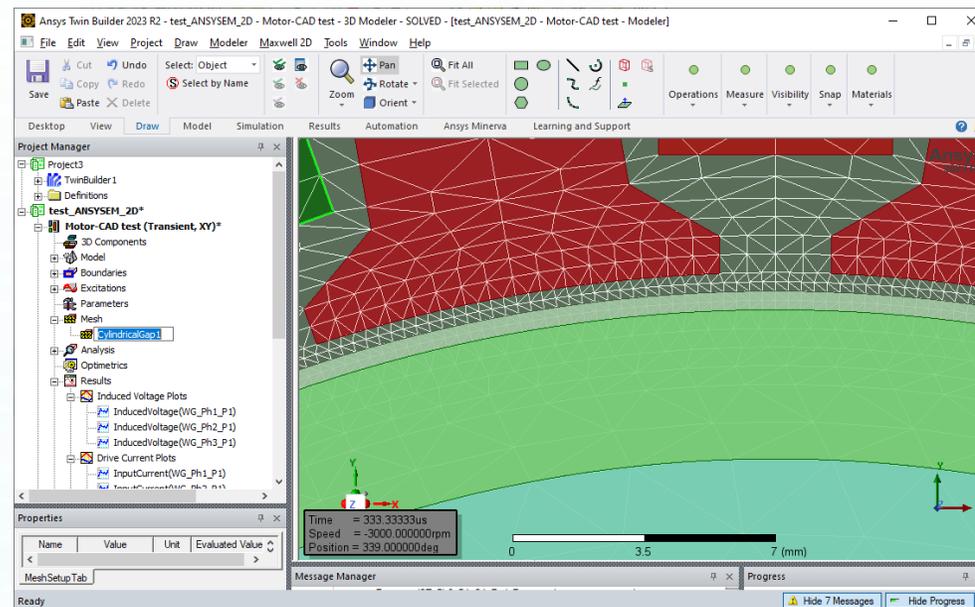
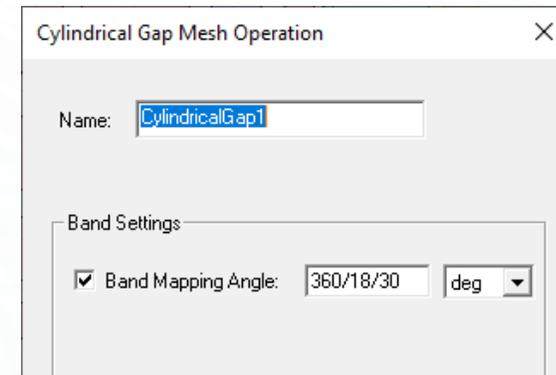
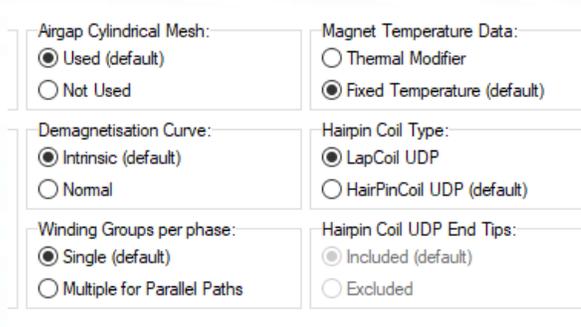
网格剖分

- Band mapping angle 剖分设置

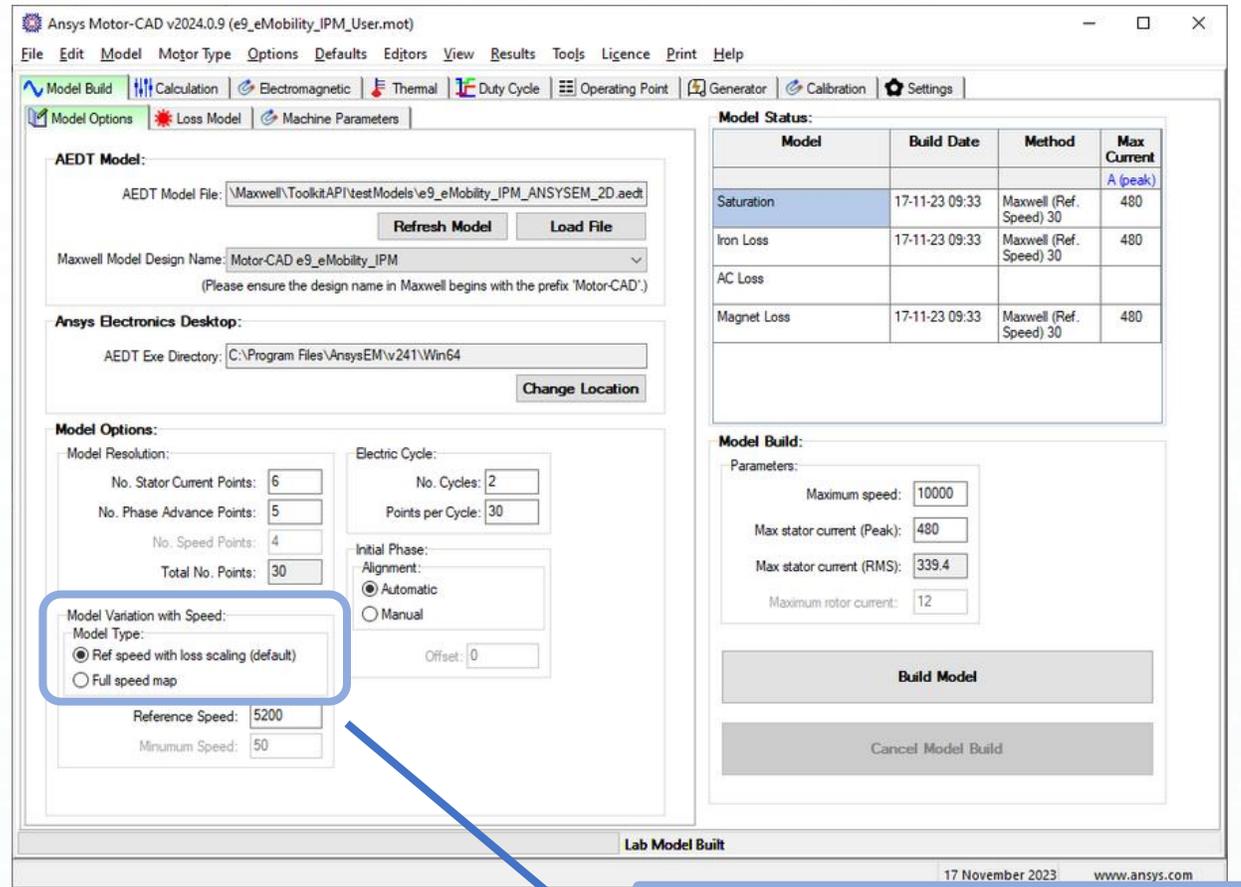
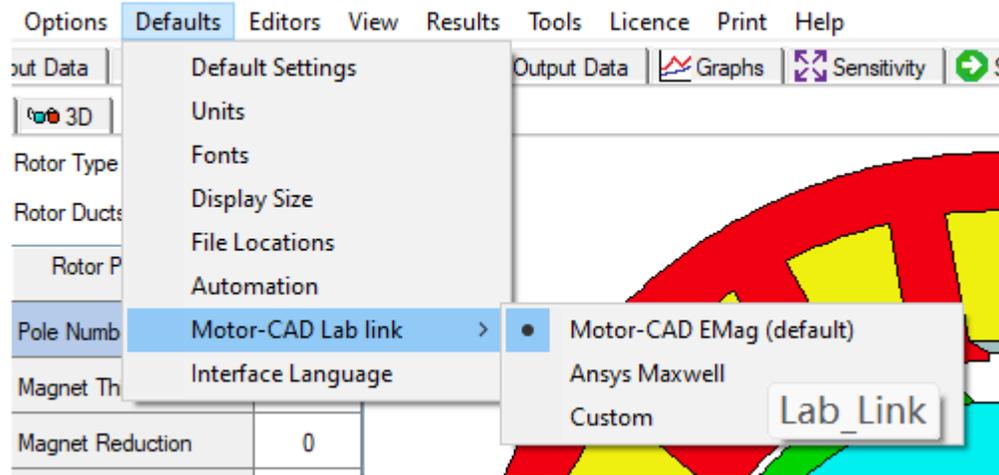
- 精确的band网格剖分控制
- Band区域具有相同的三角形网格

- 避免剖分带来的计算误差

- 特别是NVH、齿槽转矩或转矩脉动分析的时候



扩展MotorCAD的Lab模块功能

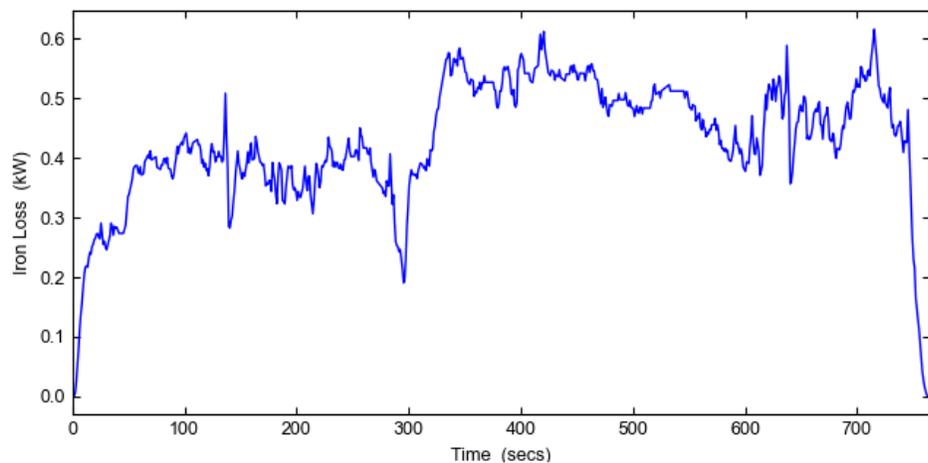


Full Speed Map: 导入Maxwell电磁仿真数据进行计算时可以增加速度这一维度

Model Variation with Speed:
Model Type:
 Ref speed with loss scaling (default)
 Full speed map

扩展MotorCAD的Lab模块功能

- 自动检测 Maxwell 模型
- 支持BPM/SYNCREL/SYNC
- Motorcad建立饱和和损耗模型时，可扫描速度
 - 涡流损耗（磁钢、绕组） VS 转速
 - 考虑转速和频率对场的影响



The screenshot displays the MotorCAD software interface. The **Machine Parameters** section includes:

- Pole Number: 8
- Slot Number: 48
- Winding Connection: Star Connection (default), Delta Connection

The **Machine Components** section includes:

- Import Components from Maxwell (button)
- Component Filter: Magnets, Sleeve, Banding
- Select Magnets (button)
- Selected Magnet Components: (empty list)

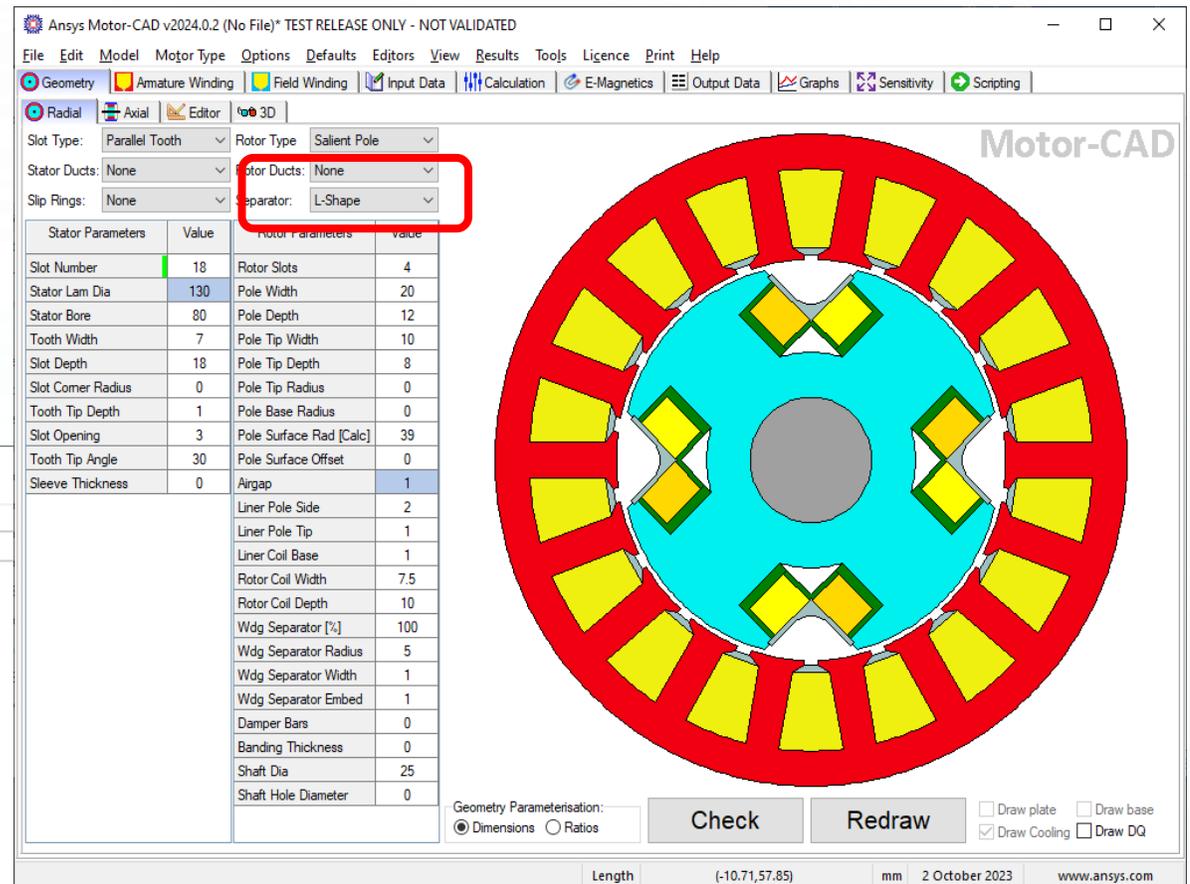
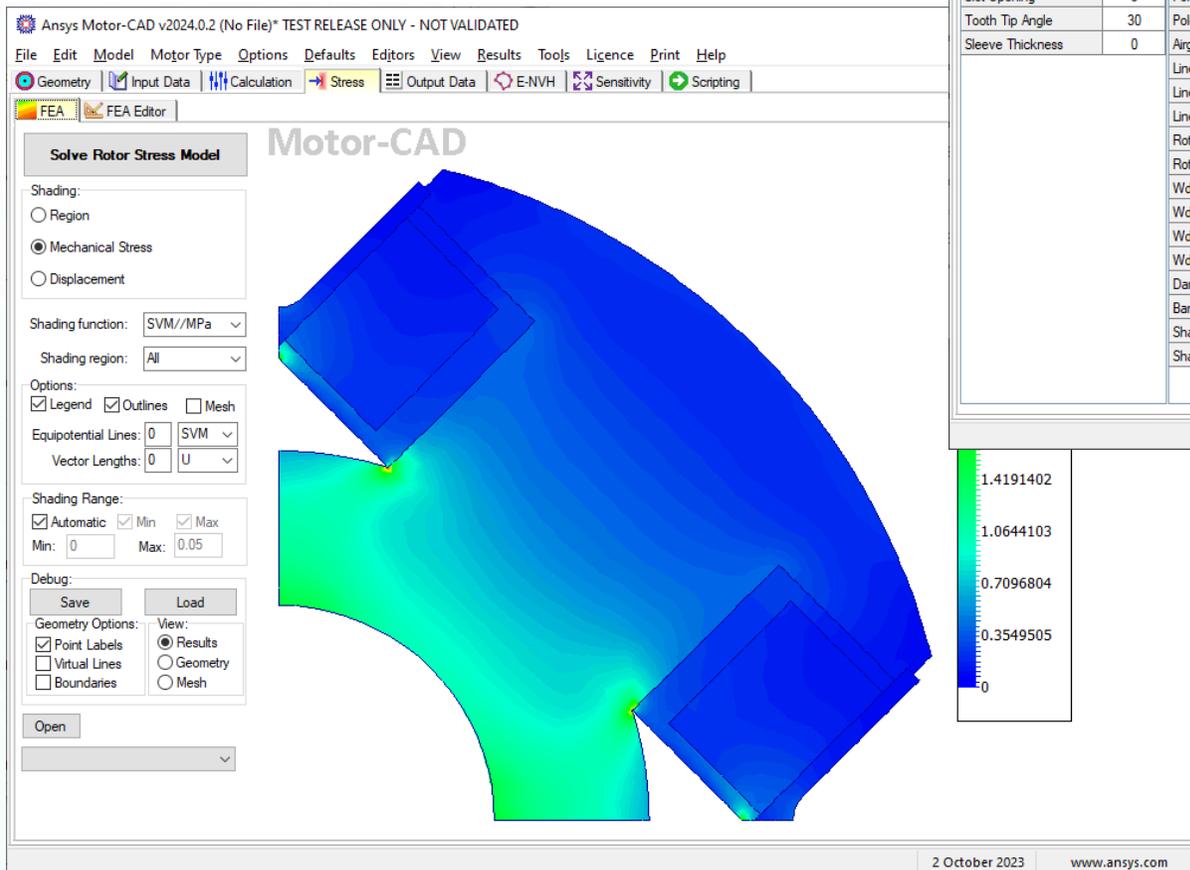
A **Select Magnet Component** dialog box is open, showing a table of components with checkboxes for selection:

Machine Components	
L1_1Magnet2N1_1_1	<input type="checkbox"/>
L1_1Magnet1N1_1_1	<input type="checkbox"/>

Buttons at the bottom of the dialog include: Deselect All, Select All, Set Magnets, and Cancel. A status bar at the bottom indicates "Components imported successfully." and "Motor-CAD Model Lo".

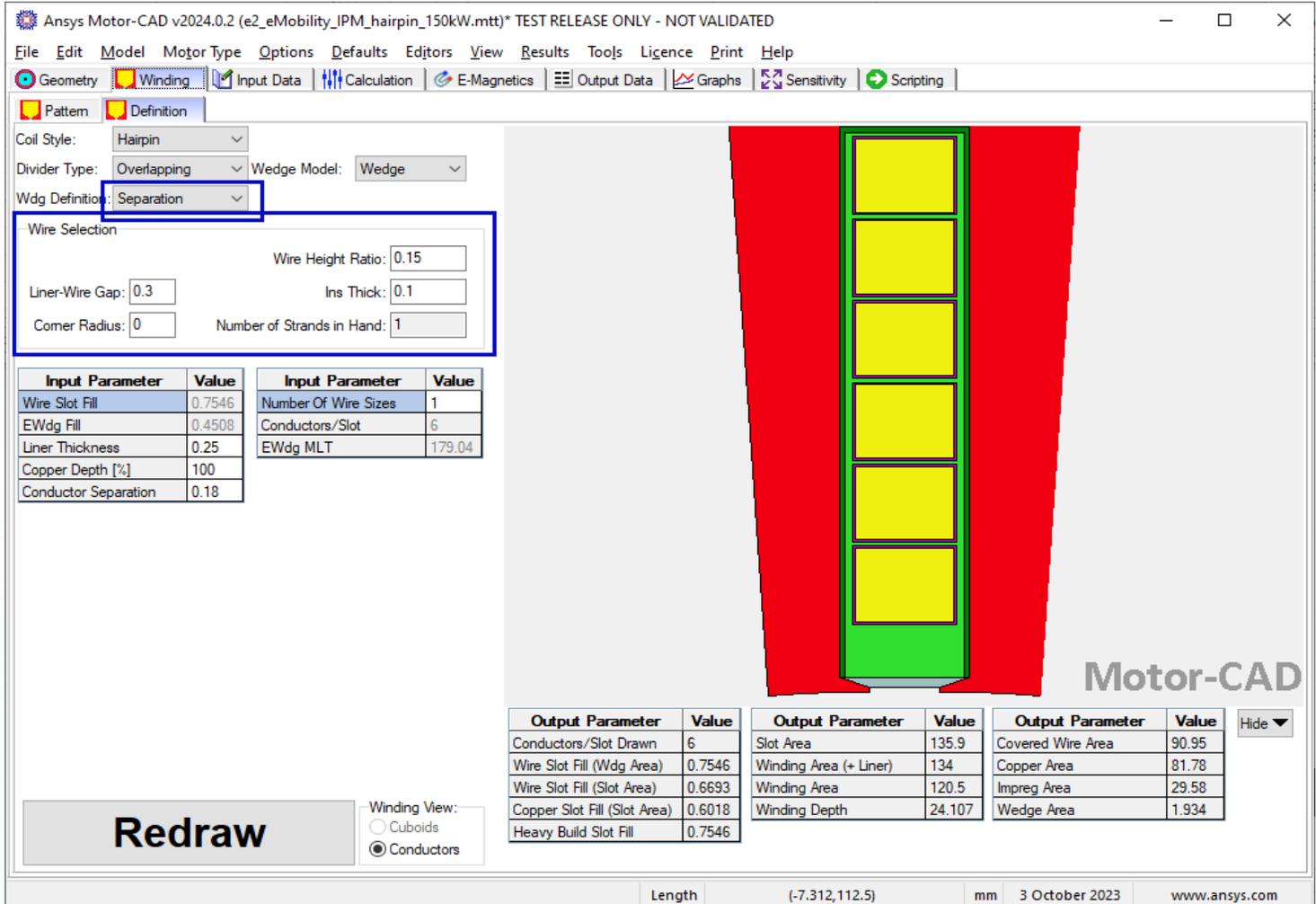
新的电励磁几何模板

- 改进转子绕组线圈和嵌套的定义方法
- 更准确的评估转子线圈对离心力的影响
- 电励磁同步电机SWFM，多物理场优化改进



基于比例的扁线模型

- 扁线尺寸由间隔距离和比例定义
- 可用于优化分析
- 在更大的设计空间内，自动寻优



Ansys Motor-CAD v2024.0.2 (e2_eMobility_IPM_hairpin_150kW.mtt)* TEST RELEASE ONLY - NOT VALIDATED

File Edit Model Motor Type Options Defaults Editors View Results Tools Licence Print Help

Geometry Winding Input Data Calculation E-Magnetics Output Data Graphs Sensitivity Scripting

Pattern Definition

Coil Style: Hairpin

Divider Type: Overlapping Wedge Model: Wedge

Wdg Definition: Separation

Wire Selection

Wire Height Ratio: 0.15

Liner-Wire Gap: 0.3 Ins Thick: 0.1

Comer Radius: 0 Number of Strands in Hand: 1

Input Parameter	Value	Input Parameter	Value
Wire Slot Fill	0.7546	Number Of Wire Sizes	1
EWdg Fill	0.4508	Conductors/Slot	6
Liner Thickness	0.25	EWdg MLT	179.04
Copper Depth [%]	100		
Conductor Separation	0.18		

Redraw

Winding View:
 Cuboids
 Conductors

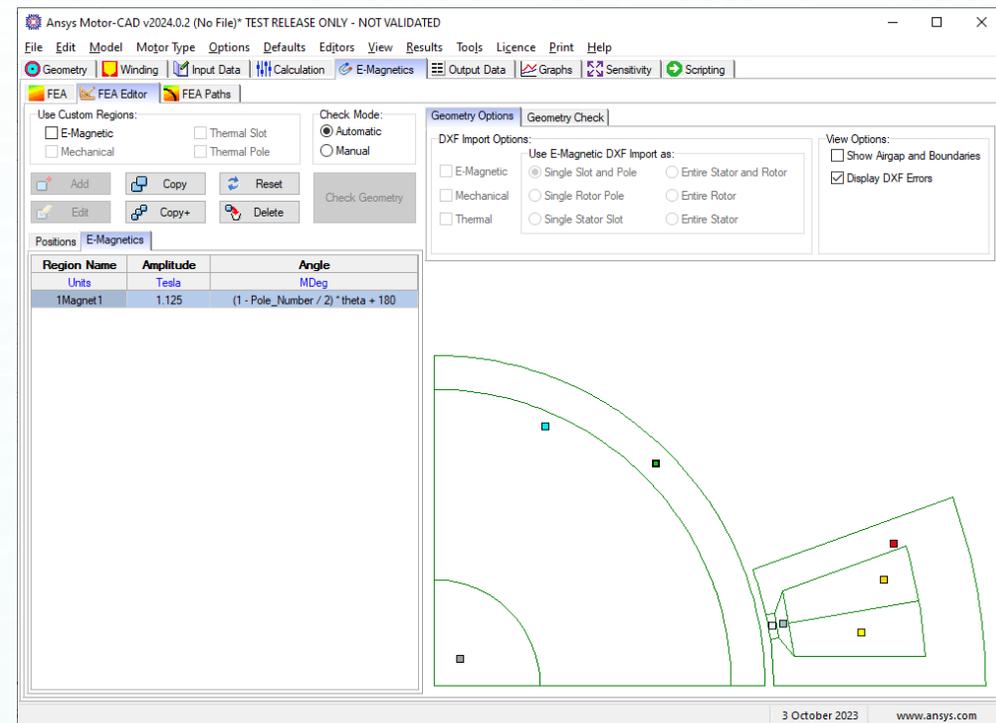
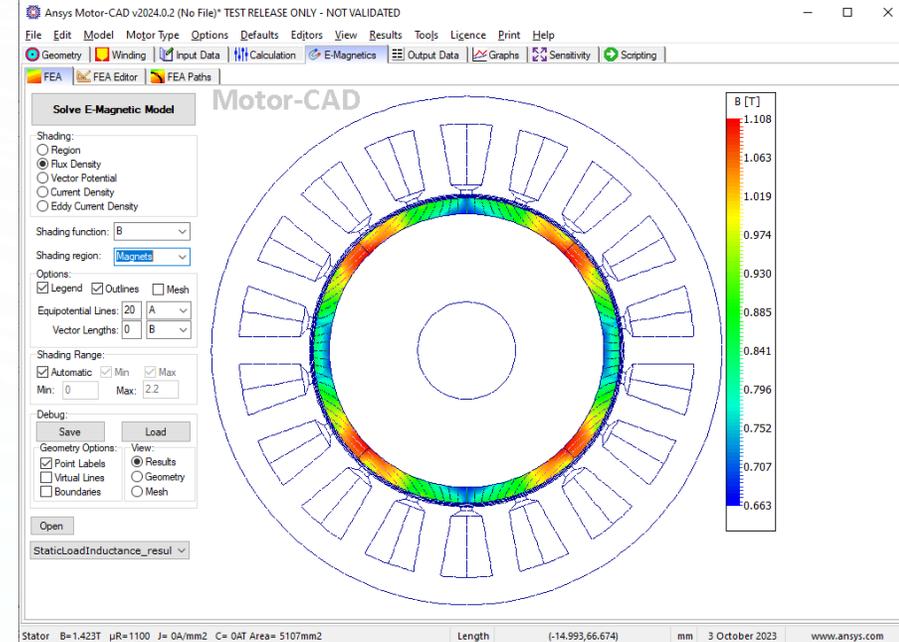
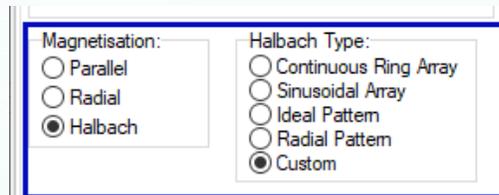
Output Parameter	Value	Output Parameter	Value	Output Parameter	Value
Conductors/Slot Drawn	6	Slot Area	135.9	Covered Wire Area	90.95
Wire Slot Fill (Wdg Area)	0.7546	Winding Area (+ Liner)	134	Copper Area	81.78
Wire Slot Fill (Slot Area)	0.6693	Winding Area	120.5	Impreg Area	29.58
Copper Slot Fill (Slot Area)	0.6018	Winding Depth	24.107	Wedge Area	1.934
Heavy Build Slot Fill	0.7546				

Motor-CAD

Length (-7.312,112.5) mm 3 October 2023 www.ansys.com

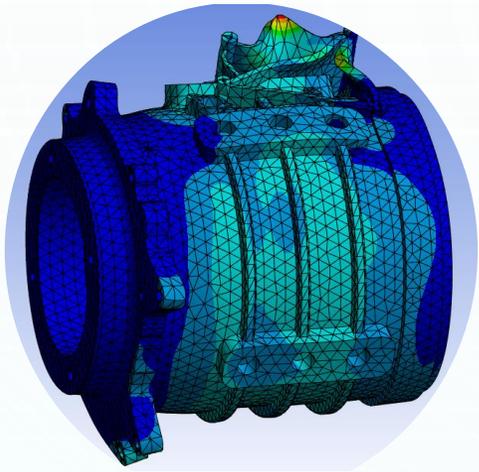
Halbach 阵列定义改进

- 新增理想、径向以及用户自定义的函数化磁化方式，以实现反电势的正弦
- 理想型
 - 磁化角度随转子每块磁钢的局部坐标系正弦变化
- 径向
 - 剩磁幅值随转子每块磁钢的局部坐标系正弦变化
- 用户自定义函数
 - 磁化角度和剩磁幅值可以指定为是位置参数的方程



NVH 结构模态修正

- 修正结构模态参数，用于NVH分析
 - 调整模态刚度、固有频率或阻尼比
 - 基于模态敲击试验结果或结构有限元分析，来修正
- 保证速度的情况下，提高设计和优化分析的准确性



Ansys Motor-CAD v2024.0.2 (e9_eMobility_IPM.mtt)* TEST RELEASE ONLY - NOT VALIDATED

File Edit Model Motor Type Options Defaults Editors View Results Tools Licence Print Help

Geometry Input Data Calculation Stress Output Data E-NVH Sensitivity Scripting

Modal Torque Forces Structural Acoustic Settings

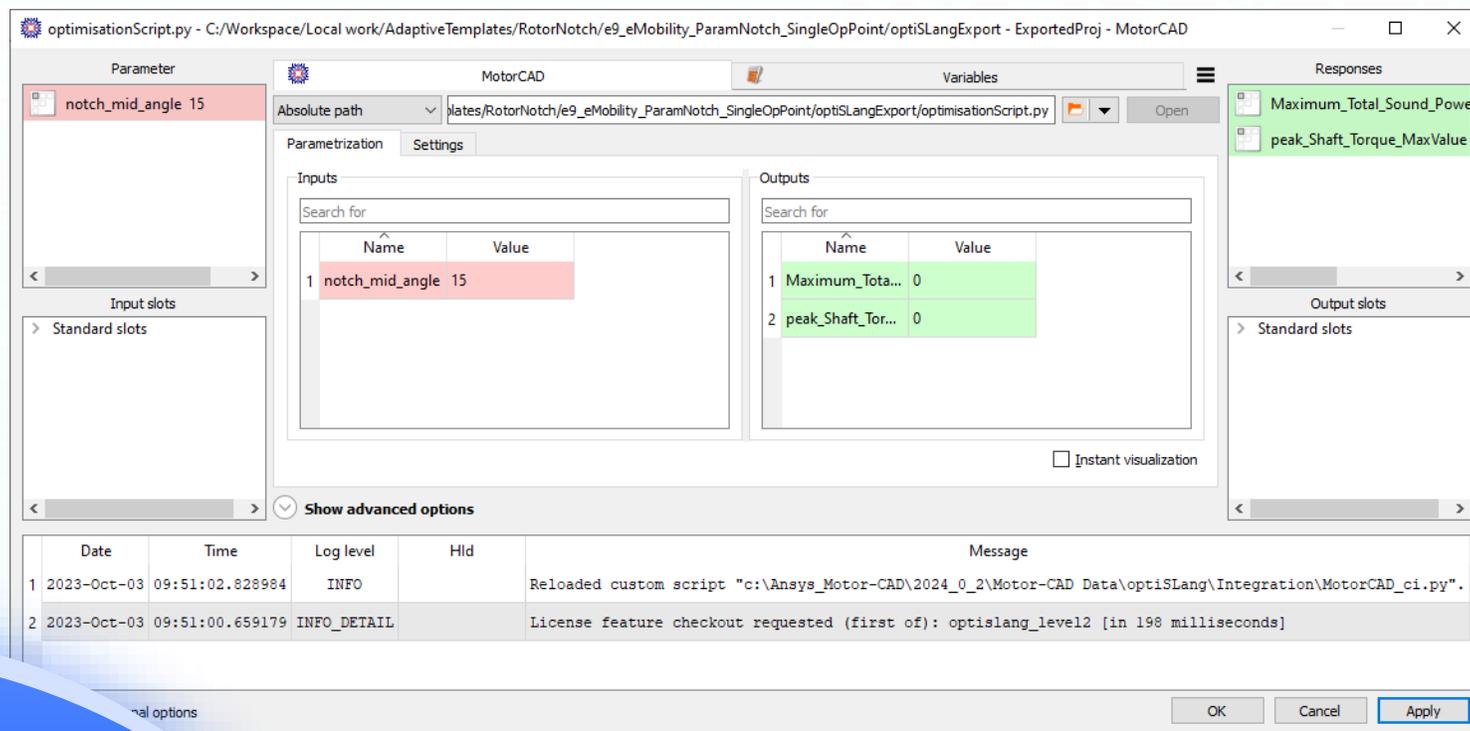
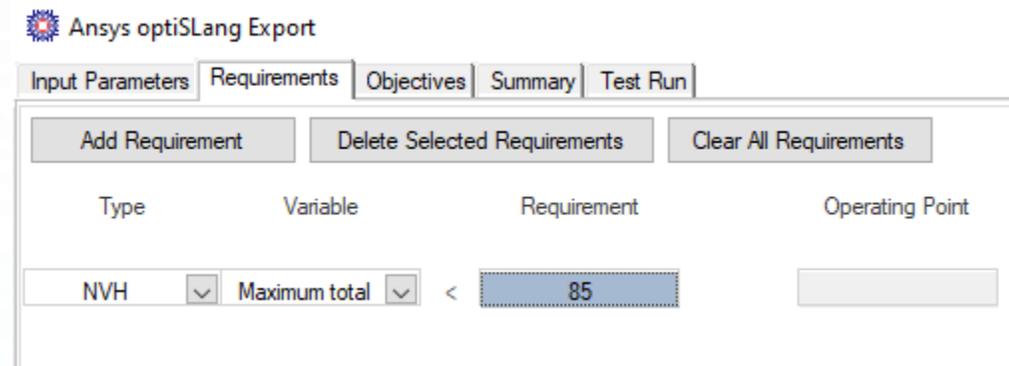
Modal Adjust Modal Results

Add Row Delete Row Clear Table

Mode shape	Calculated stiffness	Required stiffness	Calculated natural frequency	Required natural frequency	Default damping ratio	Required damping ratio
	MN/m	MN/m	Hz	Hz		
0	23997.7	0	6658.47	6750	0.05	0.02
8	132150	0	8858.68	9010	0.05	0.03

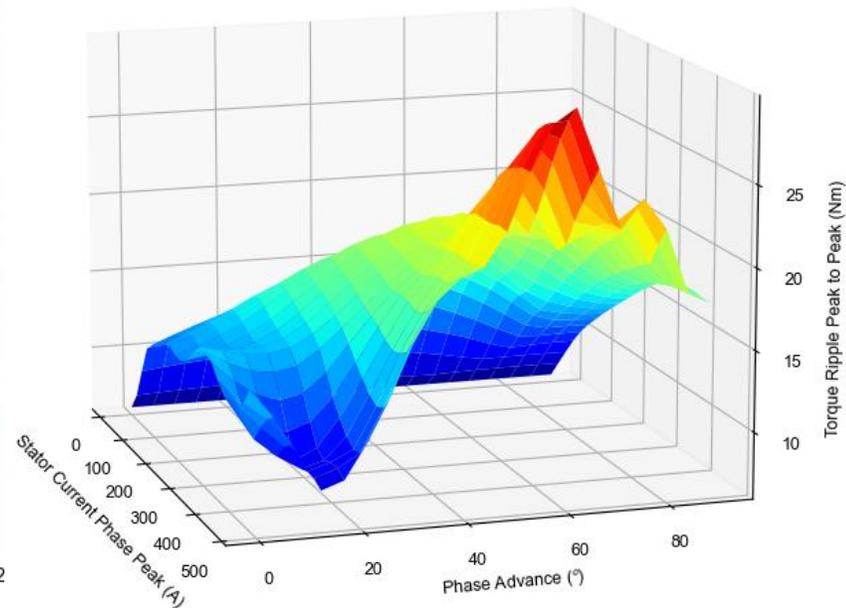
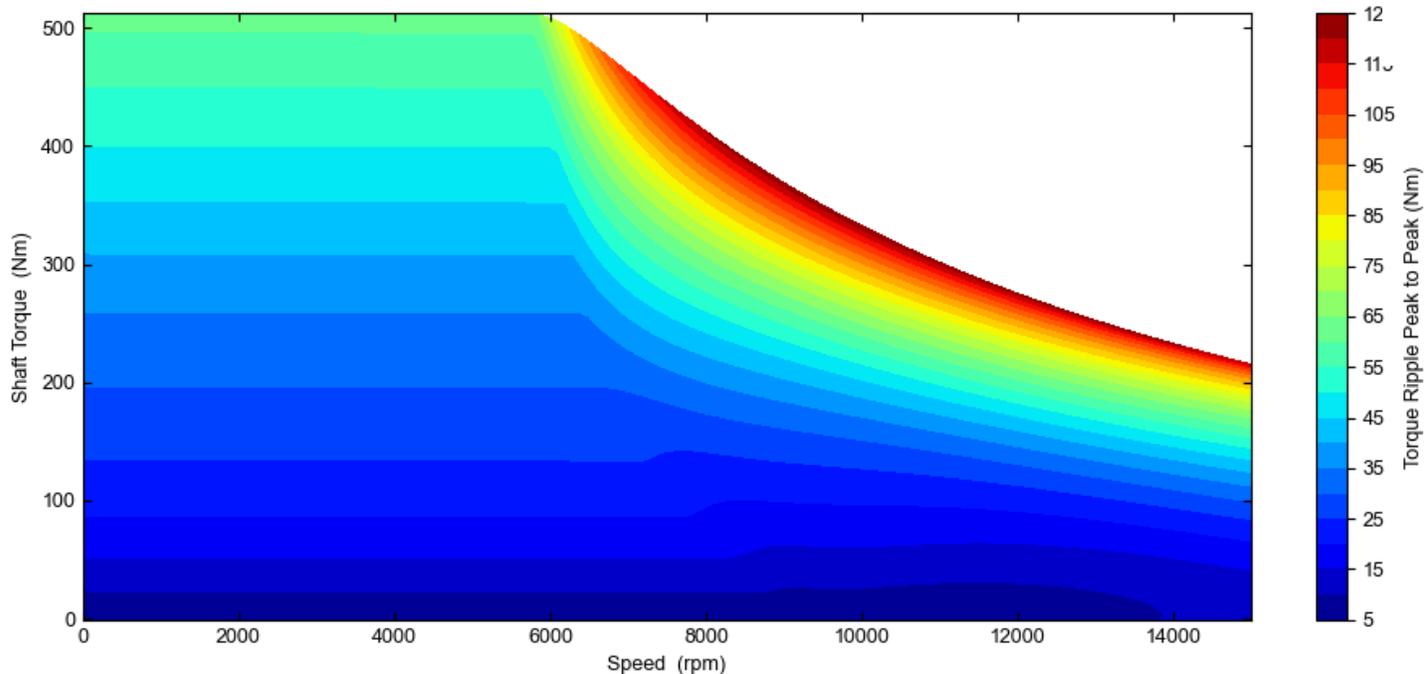
NVH性能优化

- NVH是现代电机的典型设计指标
- NVH结果，现在自动包含ANSYS optislang的优化选项中
- 优化分析中，可以抓取所有的设计需求



转矩脉动Map图

- 效率Map和工况性能分析现在支持**转矩脉动**map
- 更好地了解全工况下的转矩脉动
- 需要更高采样分辨率以避免插值引起的误差
- 支持BPM, BPMOR, SYNCREL 和 SYNC



高保真度感应电机Lab模型选项

- 转子漏感和电阻（可选）可以查表计算
- 相较于Emag有限元求解，速度更快，精度更高
- 感应电机单点负载有限元计算，采用新的自动收敛判据
- 定子漏感现在可以默认采用查表法

Saturation Model:

Model Type:

Analytical

FEA Map (recommended)

FEA Map Advanced

Rotor Leakage Model Resolution:

No. Stator Current Points:

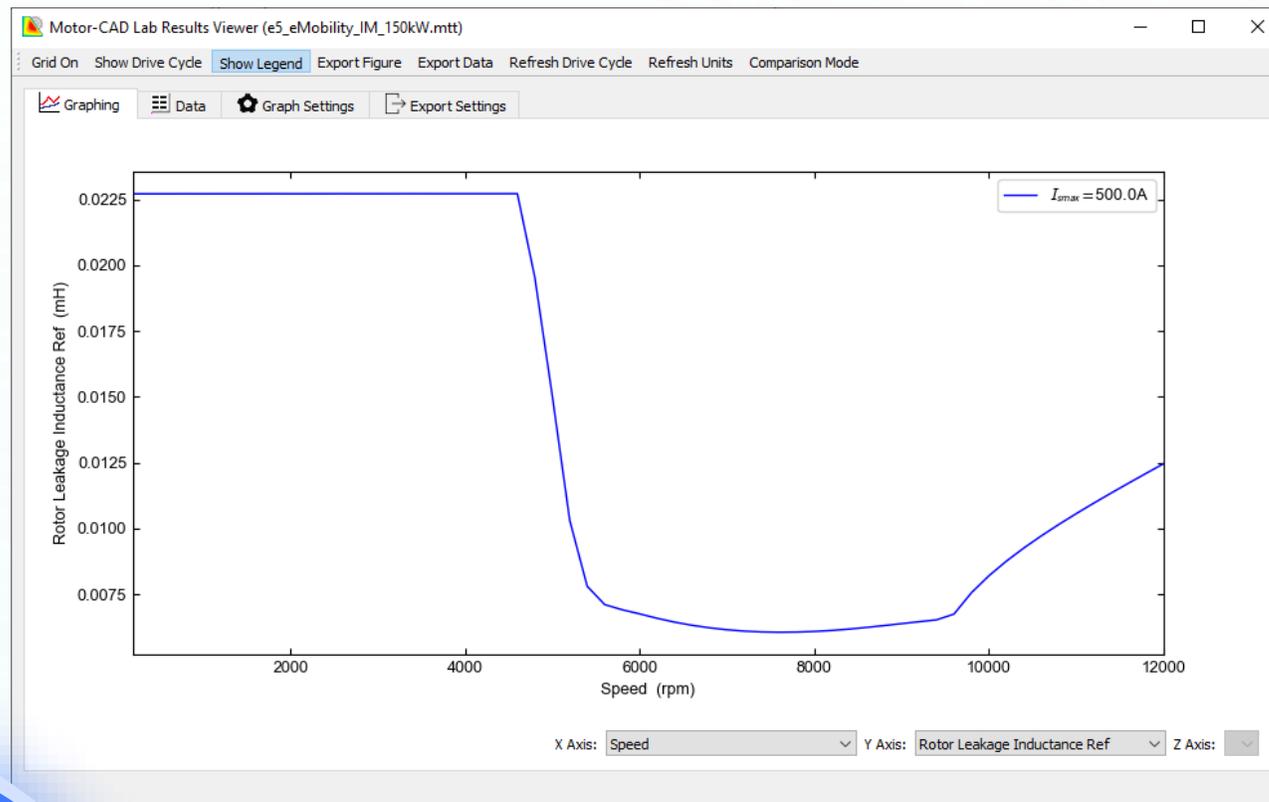
Rotor Resistance Model Resolution:

Rotor Resistance Model Type:

Analytical (recommended)

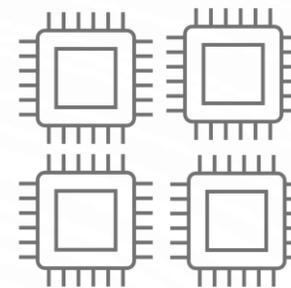
FEA Map

No. Rotor Frequency Points:

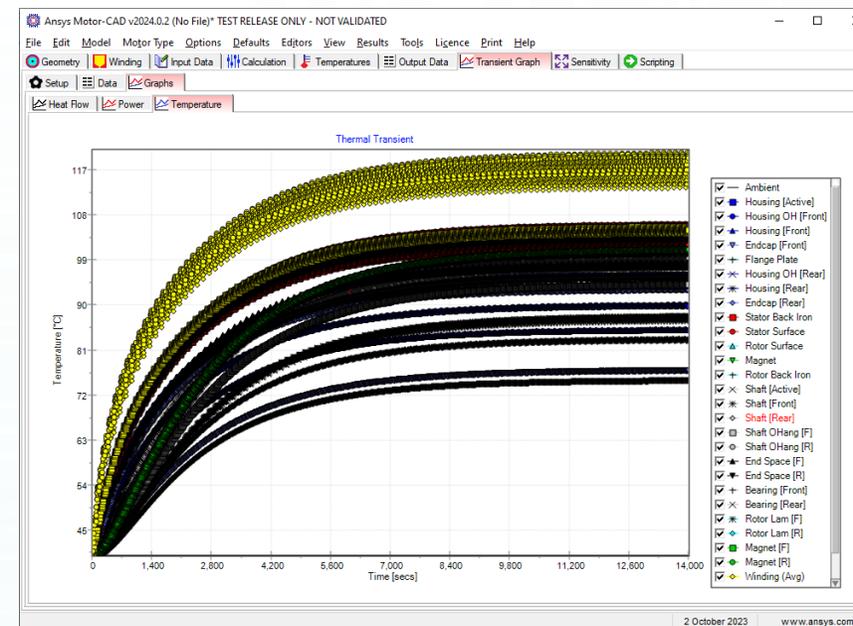


求解速度提升

- 建立Lab模型时，采用多线程
 - 速度更快
 - 利用多核更有效



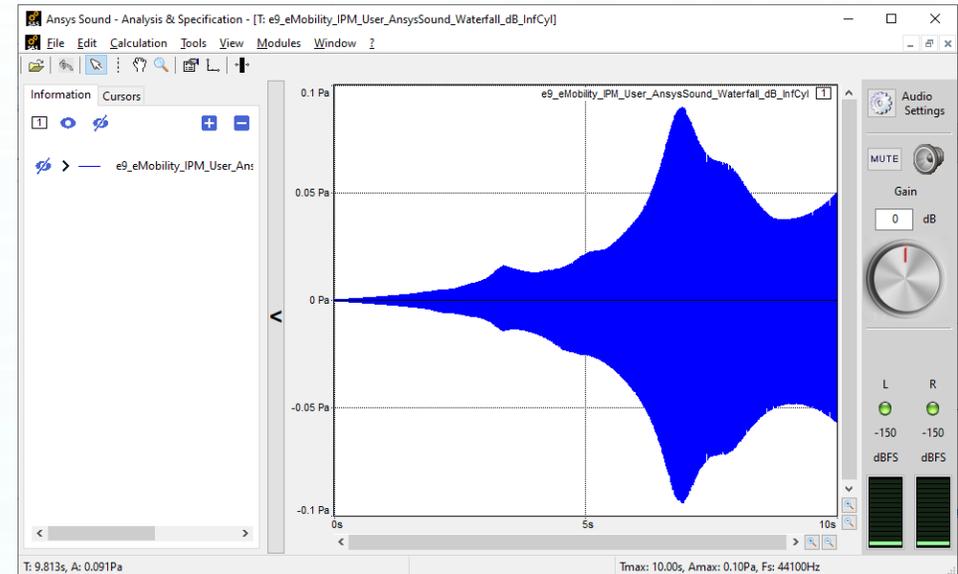
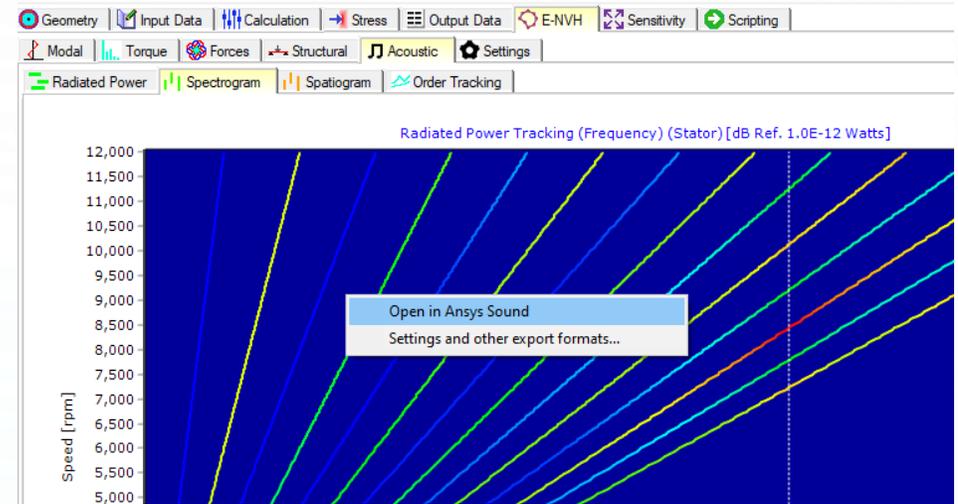
- 热瞬态求解器
 - 相比于2023R2，2024R1有2倍速度提升



Ansys Sound 集成

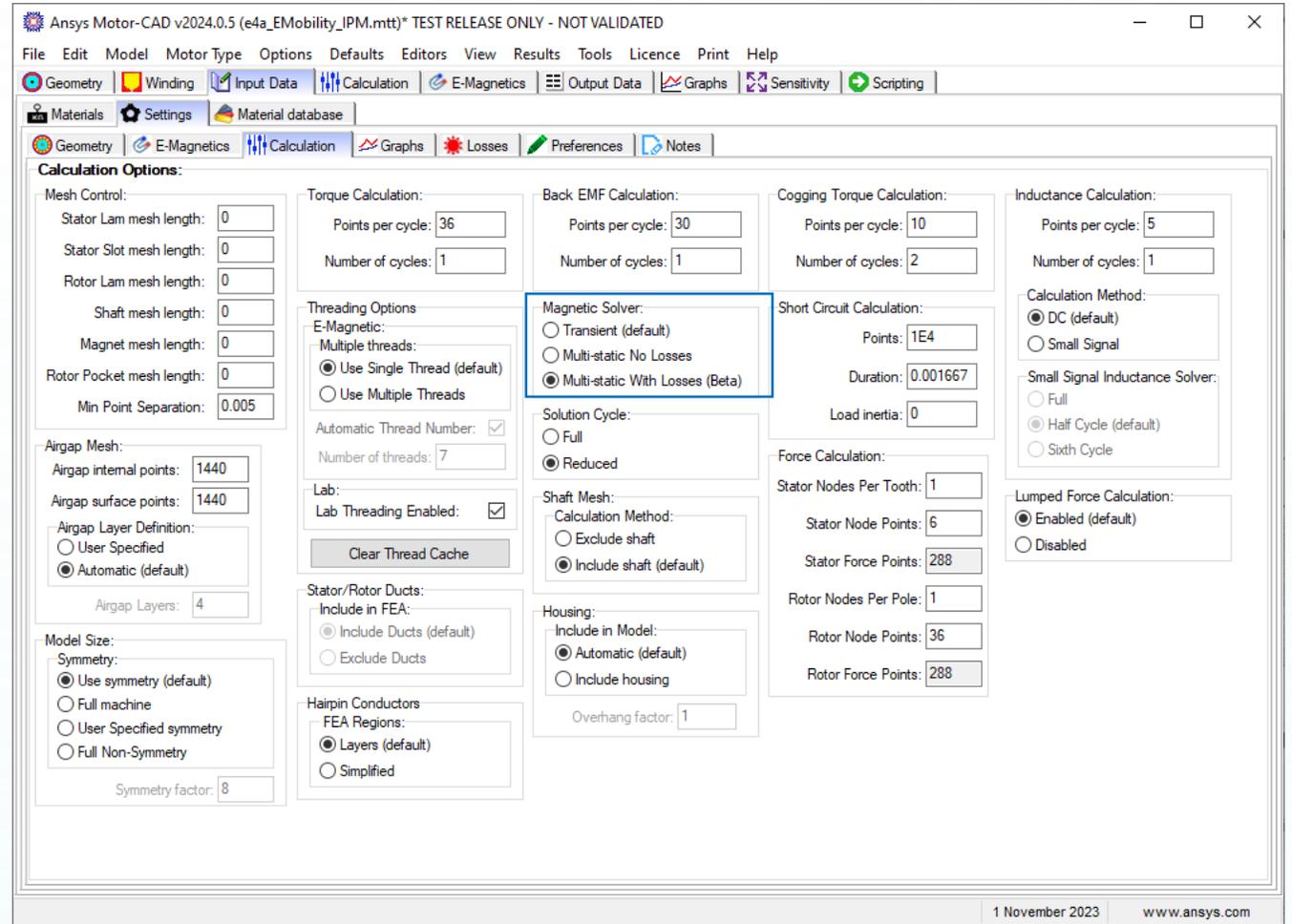
- 右击任意噪声分析图，可以直接启动Ansys Sound
 - 听电机噪声
 - 编辑声音，将电机声音与其他声音组合
 - 设置声音的传递函数
 - 计算高级声音指标

- 更好的了解NVH的影响



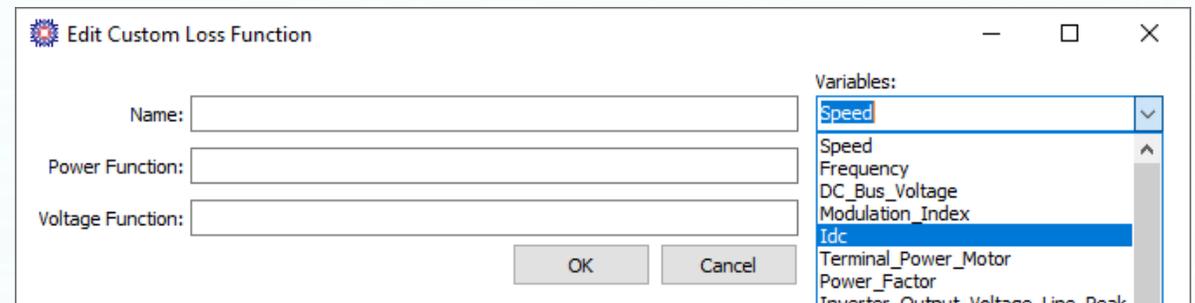
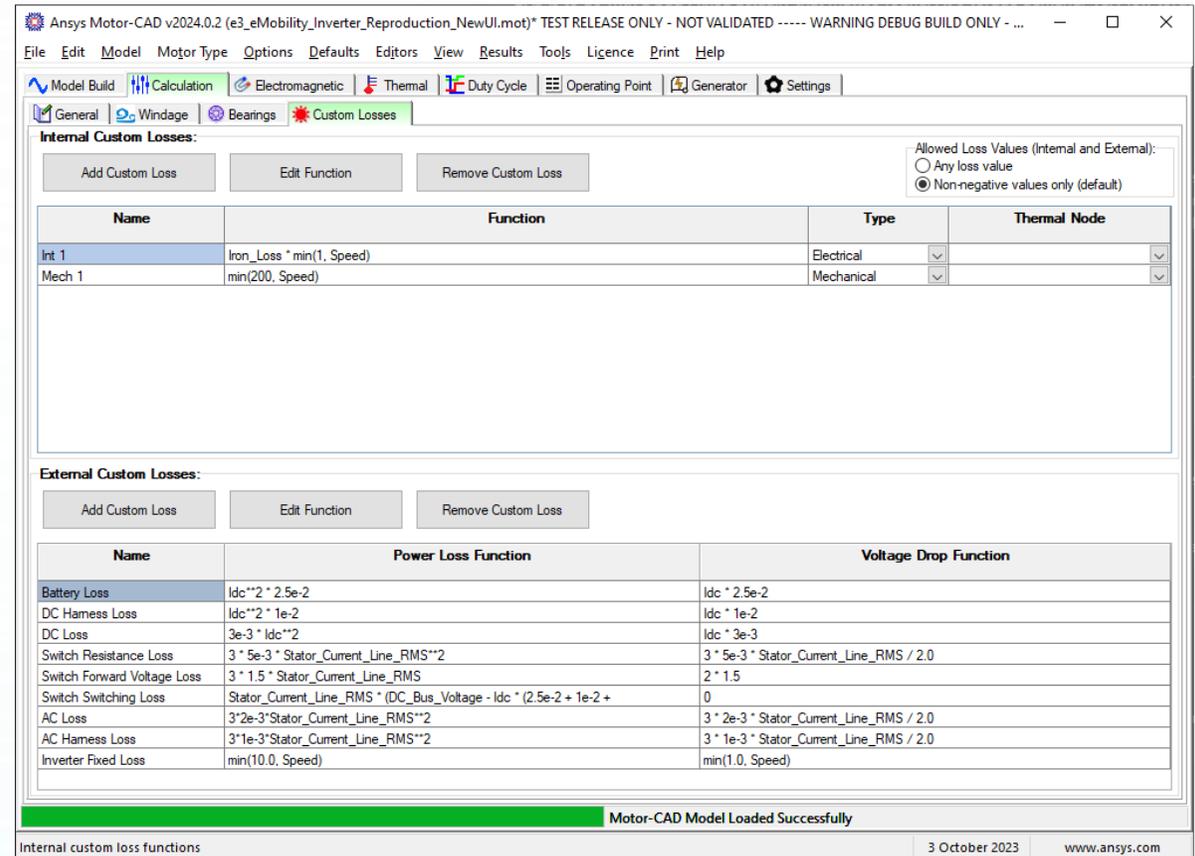
Reduced Cycle Magnetostatic Solver with Losses (Beta)

- 利用绕组和激励的周期性来节省计算时间
- 在很多情况下，只需要计算1/6个电周期
- 自动检测电机几何的周期性
- 磁通、转矩和铁耗与全有限元的计算结果高度吻合
- 实体导体里的涡流损耗，使用解析/有限元混合算法求解
- 能够极大地加速设计迭代和优化分析



用户自定义的损耗模型

- 用户自定义损耗选项
 - 电机以外的电气损耗
 - 电压降函数
- 损耗可以是电机电参数和Idc的函数
- 电压降可以影响电机的端电压和运行工作点
- 考虑系统对电机性能的影响，分析更准确



Space Vector Drive Mode

- 基于计算的正弦电流得到的SVPWM电流波形
- 提高三角形连接电机的准确性。此时线电流是正弦的，但是相电流含有三次倍数谐波。

Drive:

Drive Type:

Defined Currents (Default)

Calculated Currents

Drive Mode:

Sine

Square

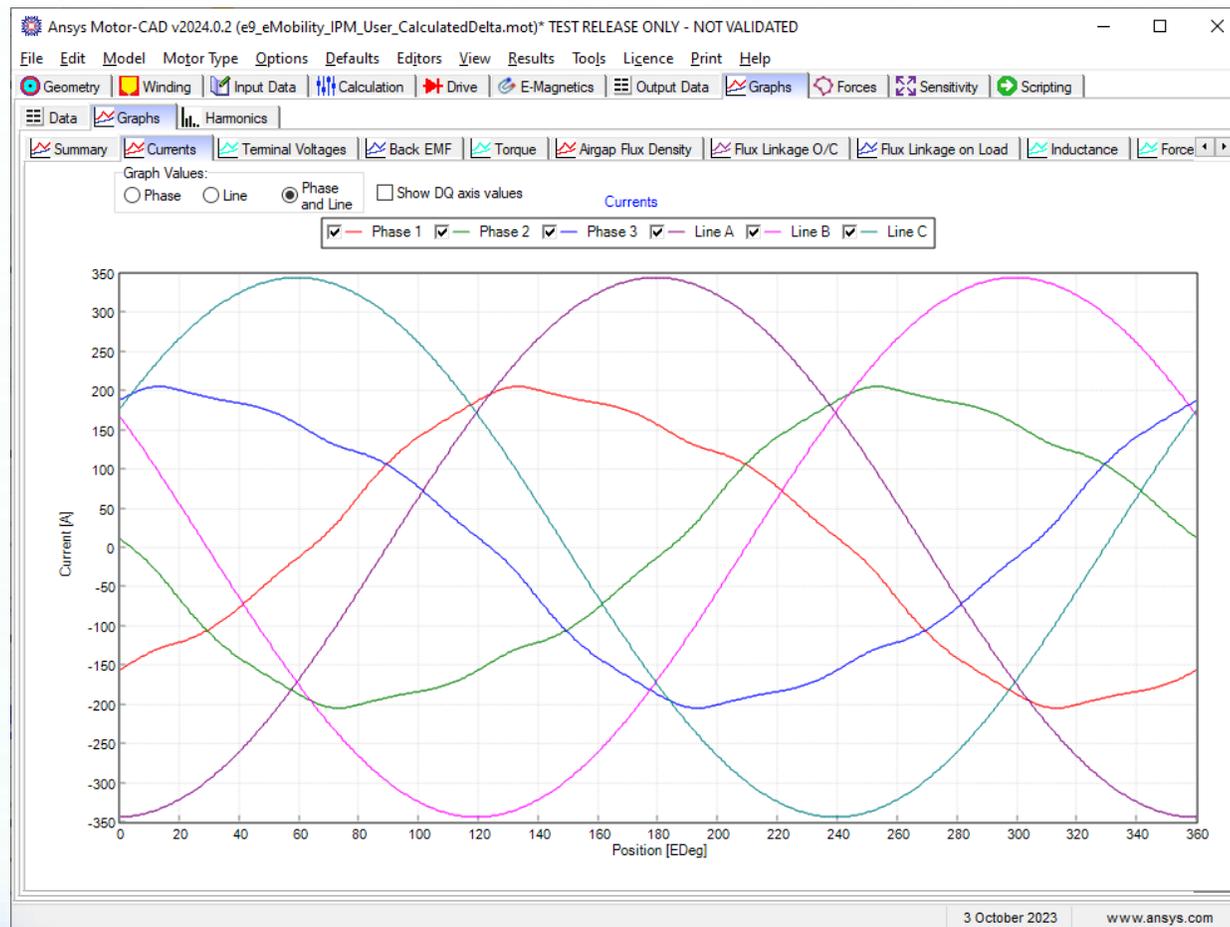
Custom

Passive Generator

Winding Connection:

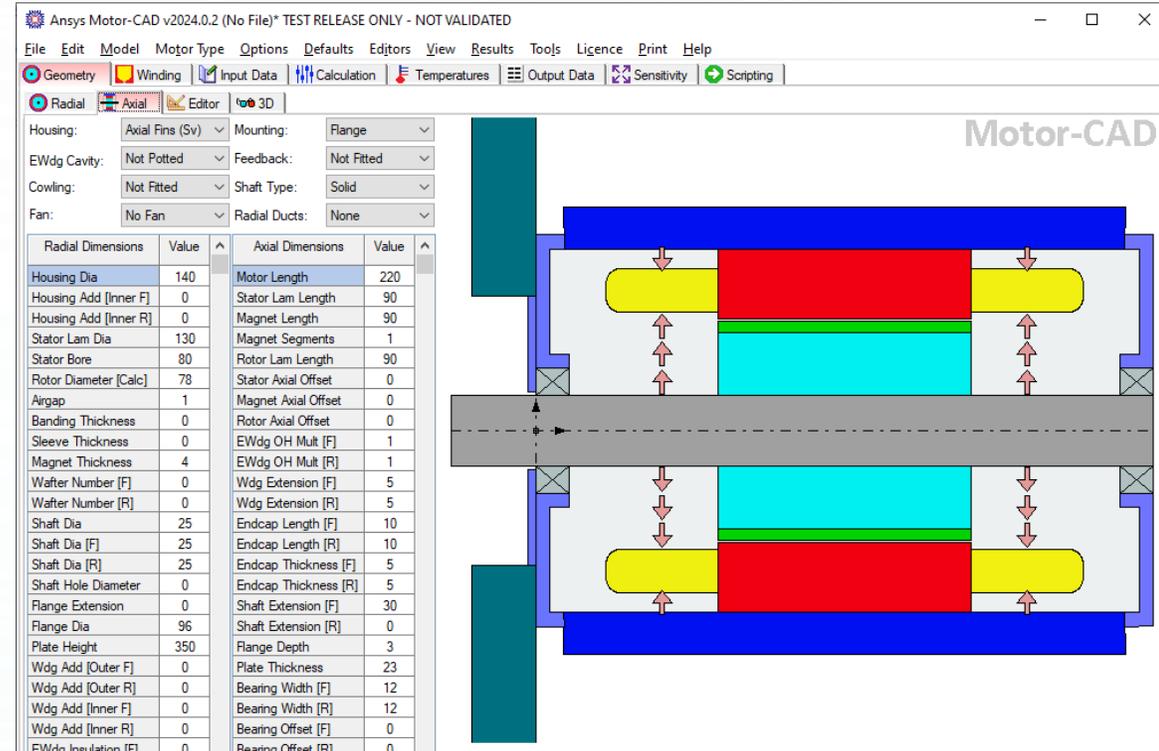
Star Connection (default)

Delta Connection



转子径向喷油冷却选项

- 新的转子径向喷油冷却选项
- 使用实验得到的传热系数，考虑从轴到转子端部表面的油冲击
- 轴的旋转速度影响传热系数
- 改进模型中，可以对驱动端和非驱动端的进油温度单独控制
- 能够与定子机壳径向冷却同时考虑



Flow Options: Radial (from Housing) | Radial (from Rotor)

Fluid Flow | Heat Transfer

Component	Input h?	Correlation	Stationary h[input] or h[adjust]	Rotational h[input] or h[adjust]	Area Multiplier	Sprayed Area	h Stationary	h Rotational	Correlation Factor
Units					p.u.	mm ²	W/m ² /°C	W/m ² /°C	p.u.
EW Inner [Front] (Layer a)	<input type="checkbox"/>	Radial Jets (from Shaft)	1	1	1	1.042E04	3986	1.48E04	1
EW Outer [Front] (Layer a)	<input type="checkbox"/>	Radial Jets (from Shaft)	1	1	1	1.042E04	3986	1.48E04	0.05
EW Front [Front] (Layer a)	<input type="checkbox"/>	Radial Jets (from Shaft)	1	1	1	8448	3986	1.48E04	0.1
EW Rear [Front] (Layer a)	<input type="checkbox"/>	Radial Jets (from Shaft)	1	1	1	8448	3986	1.48E04	0.1

Spray cooling correlation:

Submerged Jet

Free-Surface Jet (default)

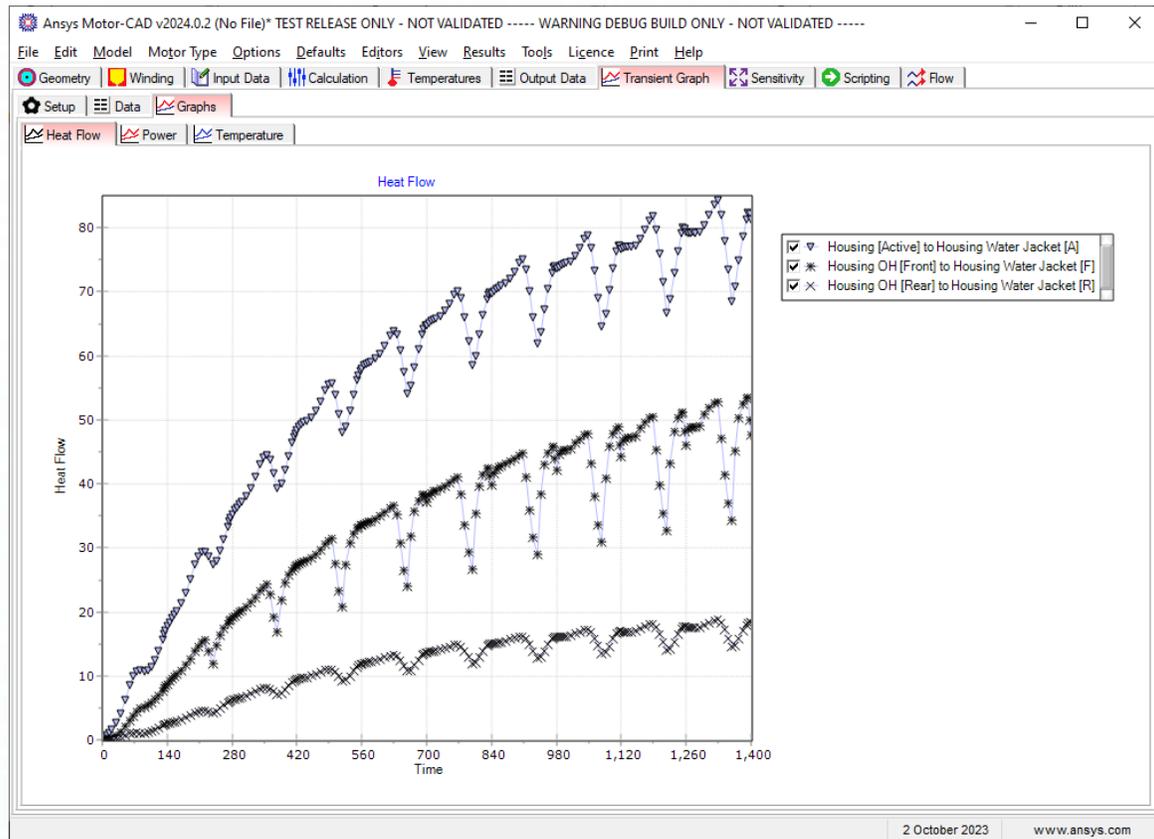
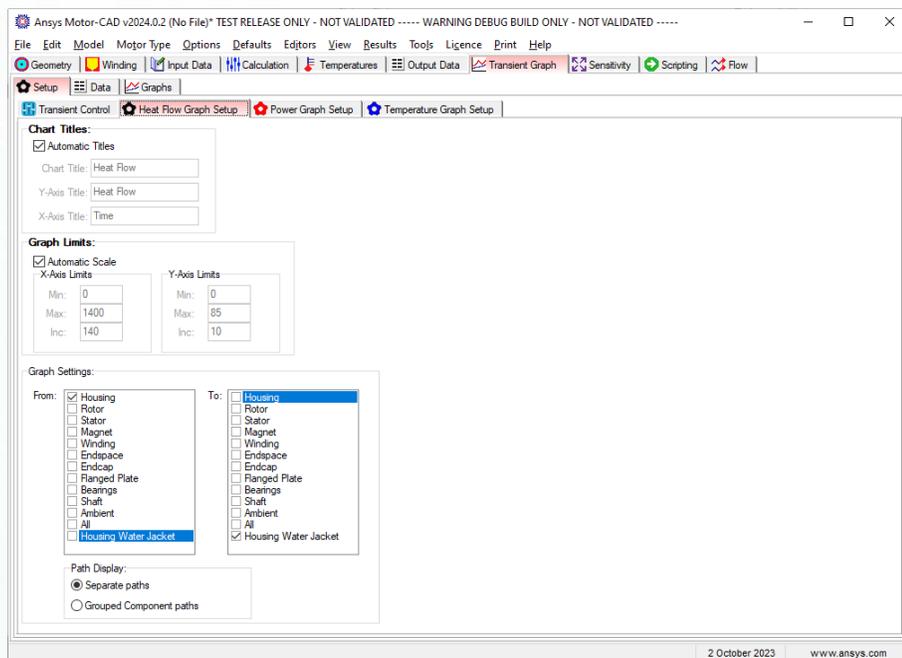
Spray cooling nozzle definition:

User defined (default)

Grouped by source

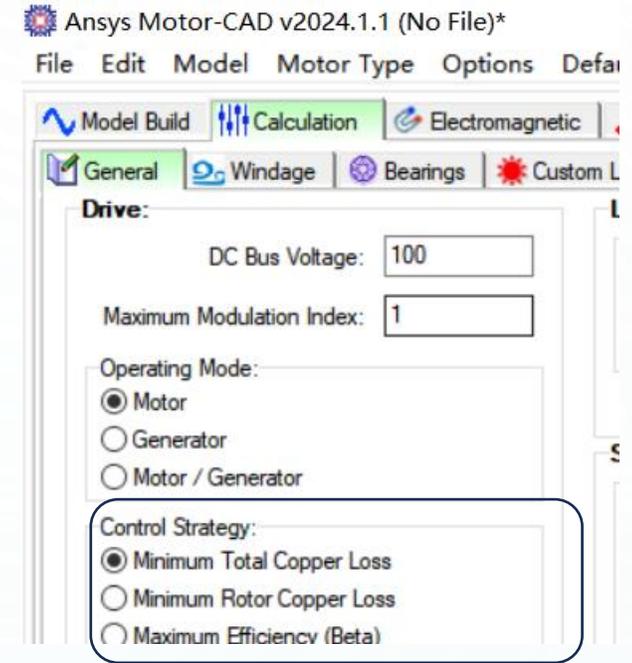
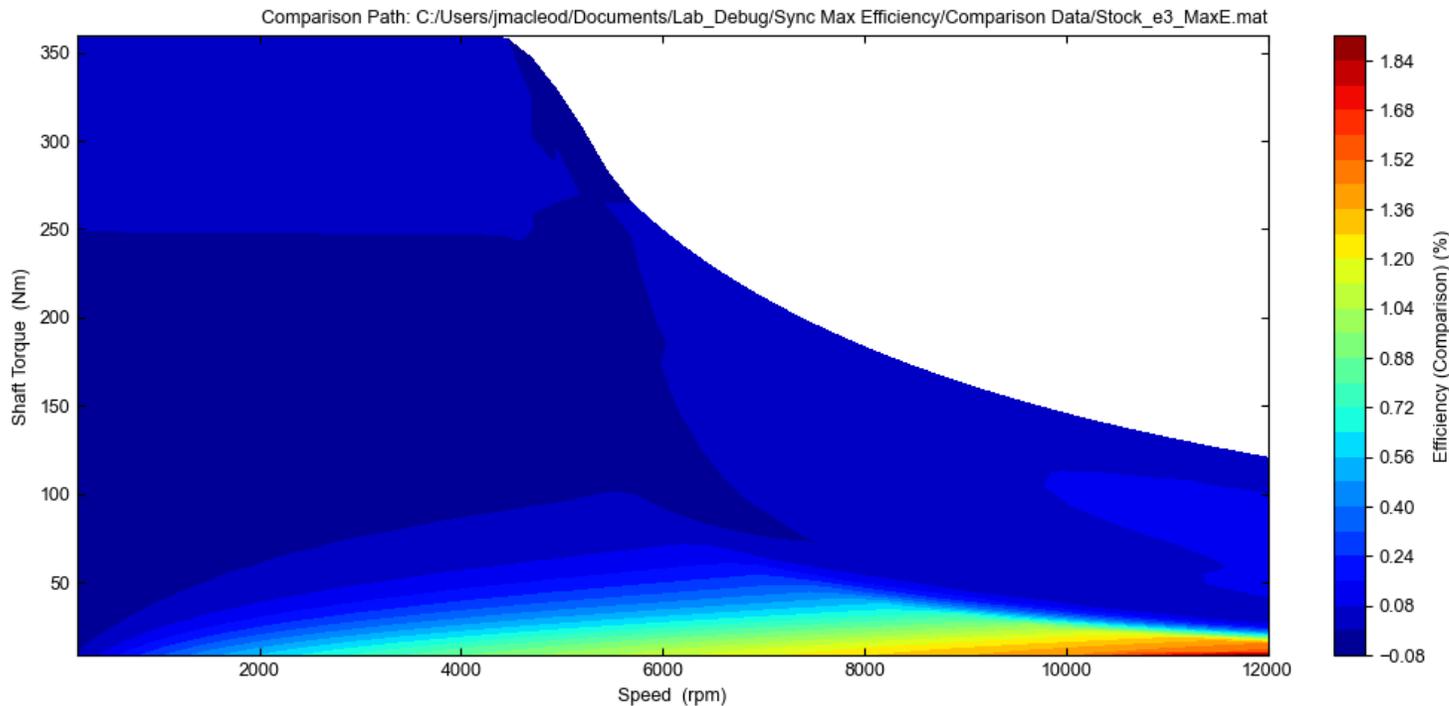
热流显示

- 新的数据可视化选项
- 显示不同部件之间的热流
- 能够选择多个不同的部件
- 目的是更好的理解工况运行时冷却路径



Sync 最大效率控制(Beta)

- 增加最大效率控制策略
- 改变控制策略能够提高电励磁同步电机的效率
- 高转速低转矩区间影响最大，因为相较于铜耗，此时铁耗更大



最大效率 vs 最小铜耗控制

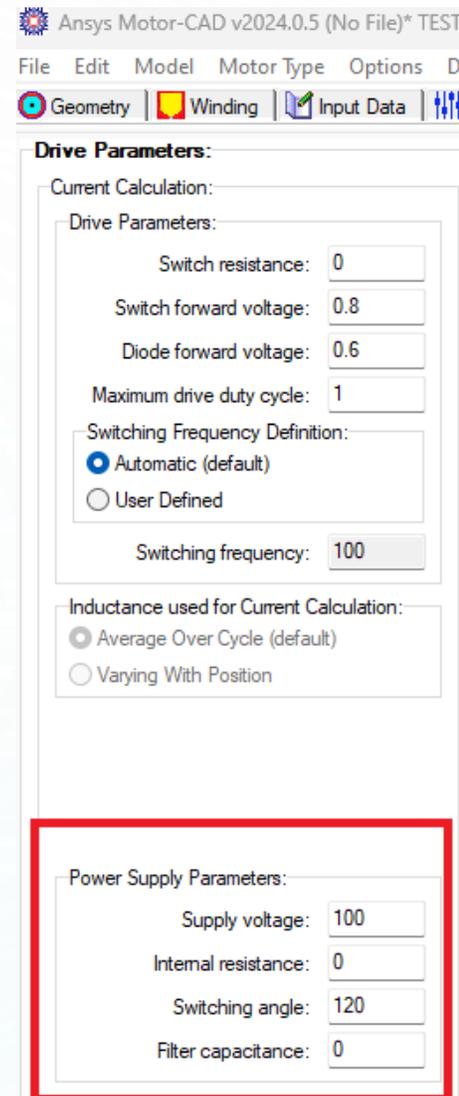
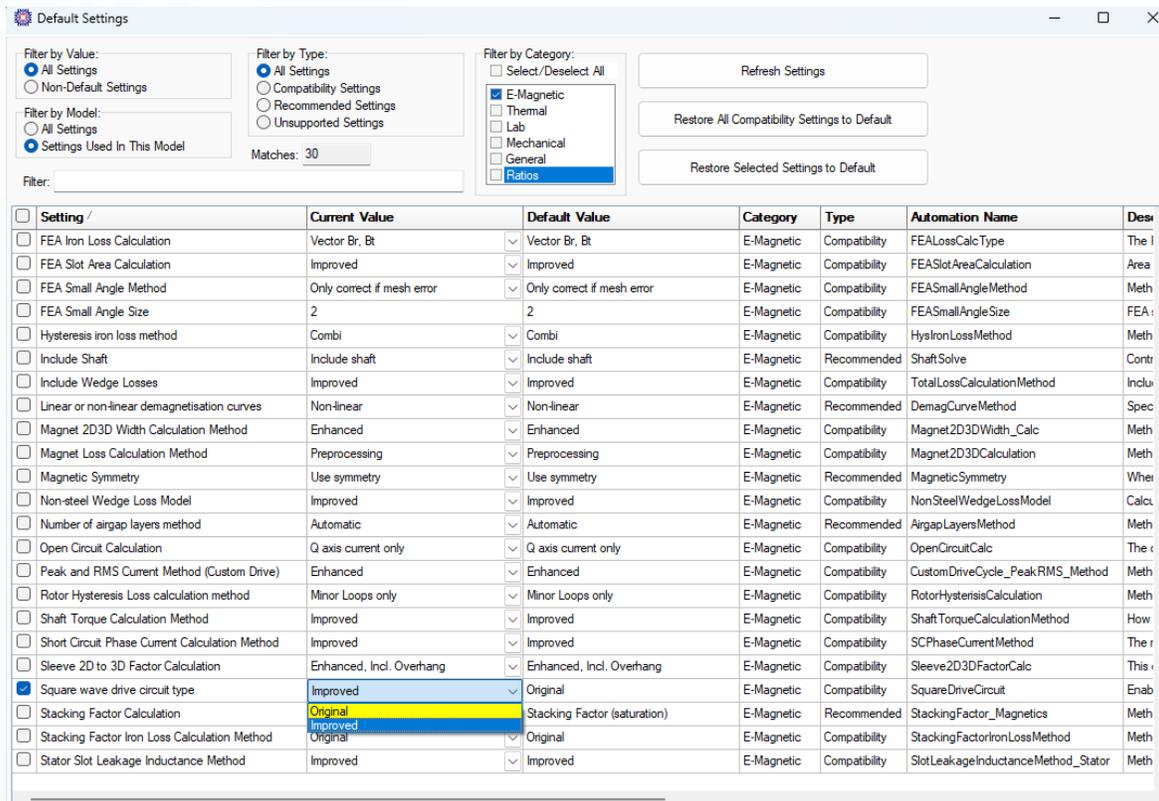


Control Strategy In Synchronous wound field machines L_d is typically larger than L_q which means that unlike a salient BPM machine, Maximum Torque per Amp (MTPA) is achieved with positive d-axis current and negative phase advance. At higher speeds when in the field weakening region it may seem logical that the voltage is simply controlled by reducing the rotor excitation current. However, reducing the rotor excitation will result in a low power factor, therefore to maximise the peak power at high speeds the WFSM is operated as a BPM with negative d-axis current used to oppose the rotor excitation field.

方波驱动模型改进(Beta)

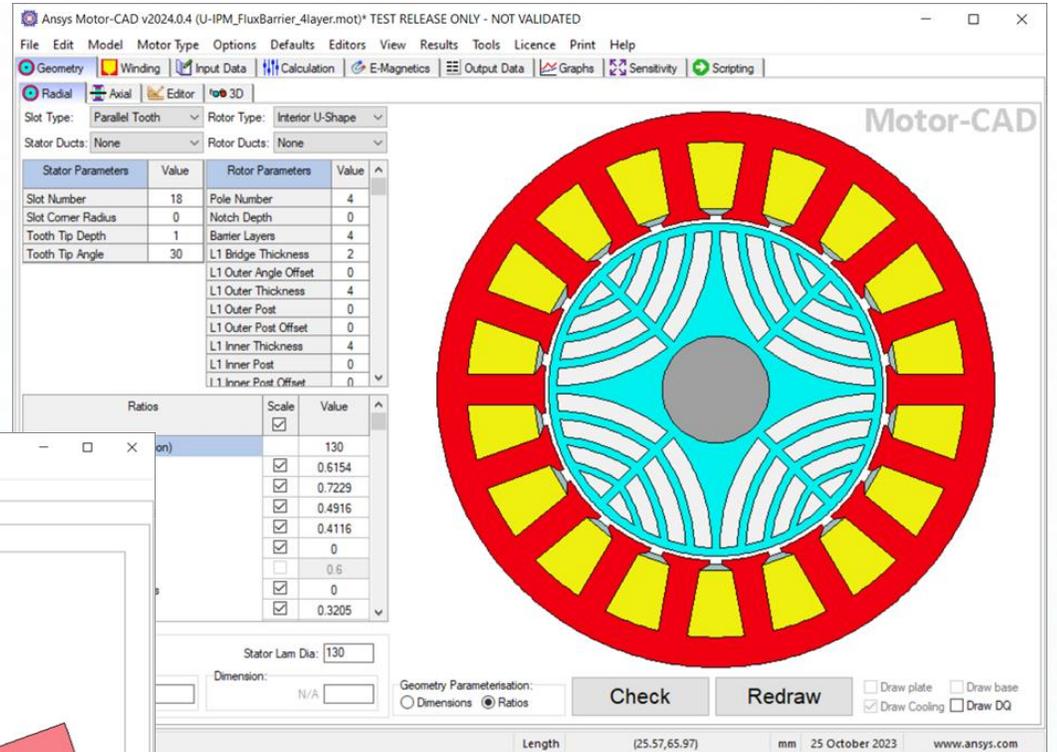
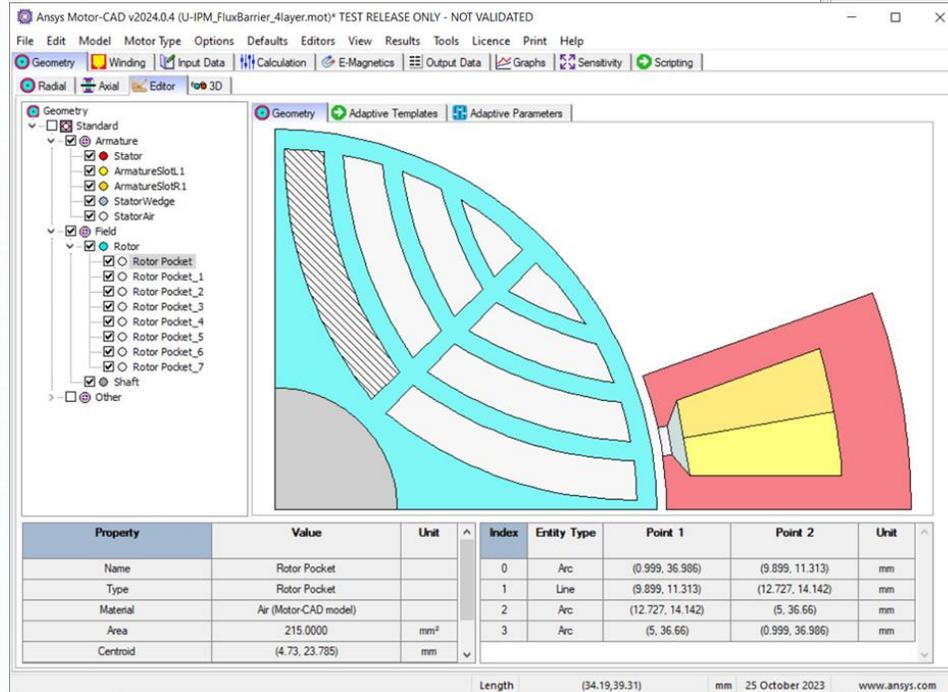
- 增加

- 方波驱动电压源内电阻
- 电压源的并联滤波电容
- 所有三相电机，导通角在60~180度变化



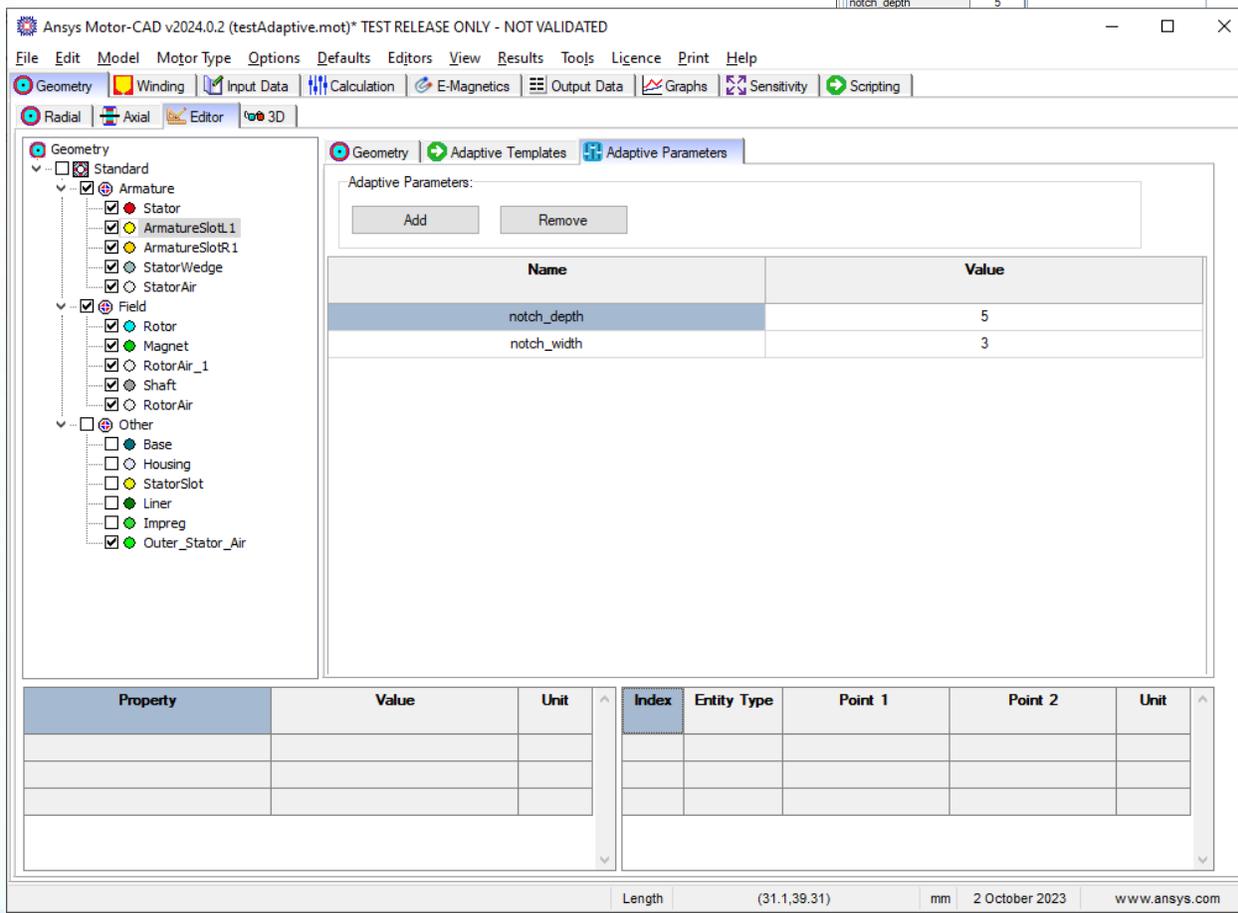
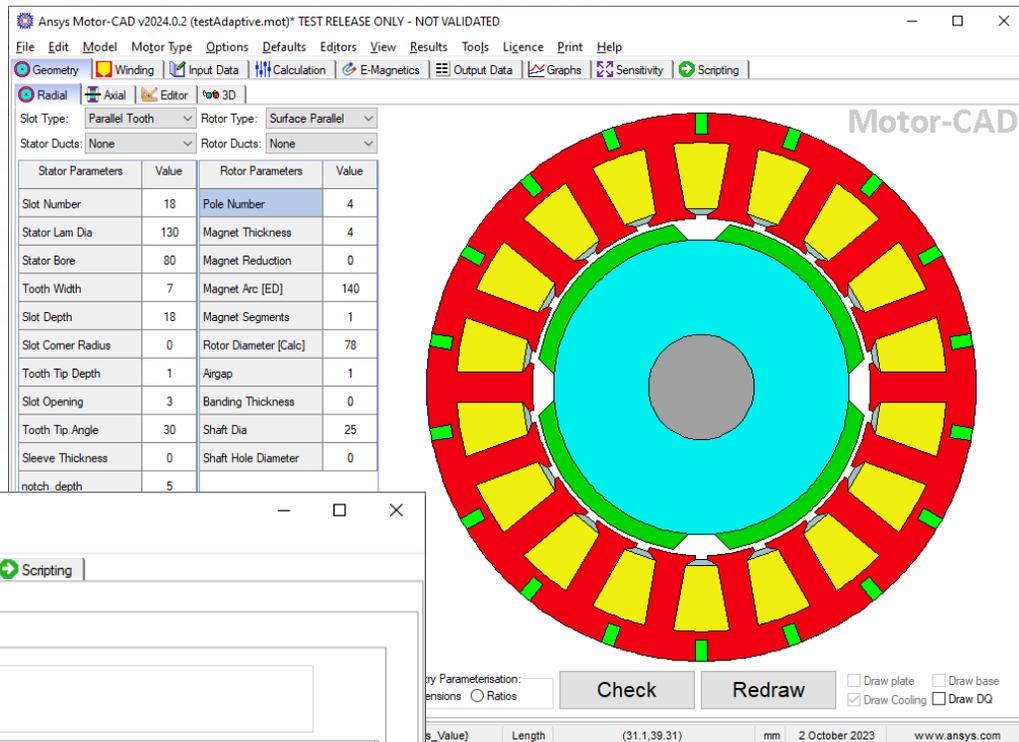
自适应模板

- 通过Python，重新参数化或定制内嵌的电机几何模板
- 增加用户定义的几何参数
- 充分发挥几何模板的便捷性和参数化分析的速度
- 用于用户自己建库



自适应模板：示例

- 增加两个参数：notch_depth 与 notch_width
- 使用Python，来定义形状、位置以及布尔相减
- 更新几何模型，新定义的参数在界面中显示
- 支持pyMotor-CAD



感谢聆听

