

ANSYS Maxwell 2022R1 功能更新

新科益系统与咨询(上海)有限公司



目录

- 求解器技术
- HPC
- 易用性
- 电机性能
- 多物理场



About Ansys?Electromagnetics Suite 2022 R1

Ansys?Electromagnetics Suite

Release 2022 R1 (Build: 2021-11-22 22:18:25)

Executing from C:\Program Files\AnsysEM\v221\Win64\ansysedt.exe

求解器

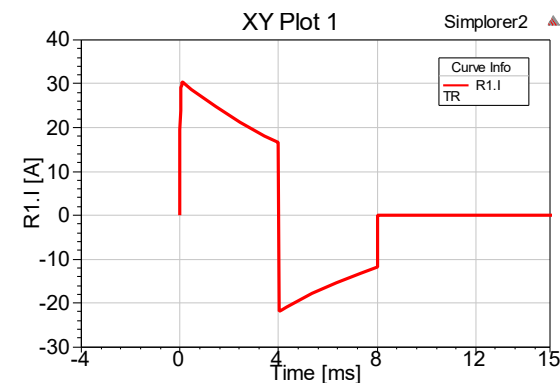
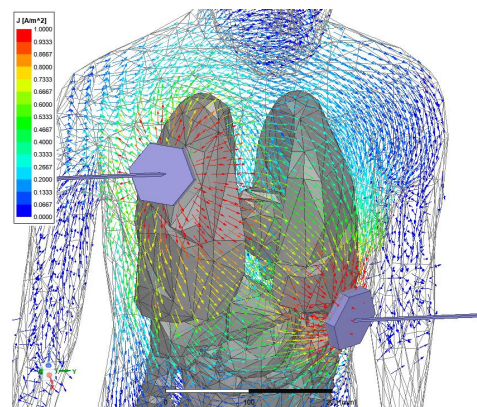
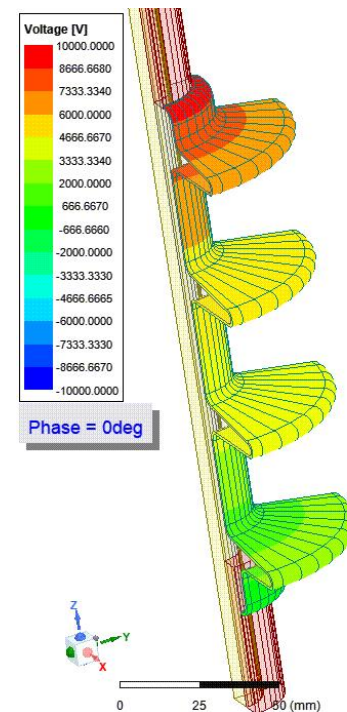
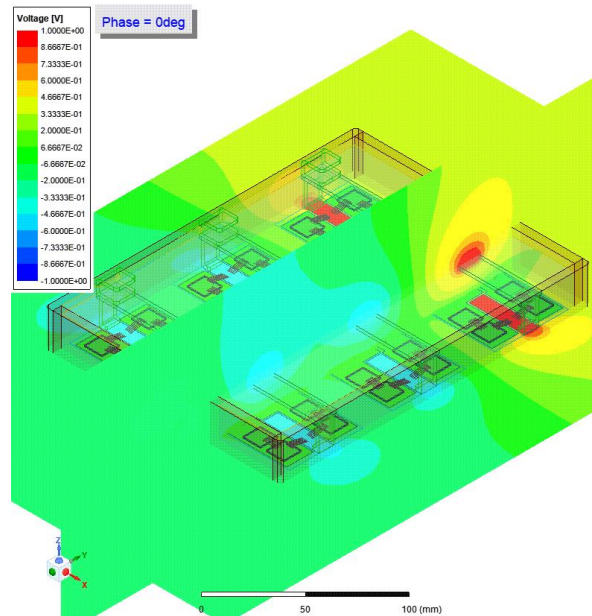
三维交流传导场求解器 (正式版首次发布)

• 三维电频域求解器

- 温度相关材料属性
- 非线性材料
- 热求解器双向耦合
- 阻抗边界条件
- Field results
- Field quantities (Energy and Qsurf)

• 应用范围

- PCB板
- 电路寄生参数抽取
- 考虑有损材料的高压应用
- 医疗应用, 如电阻抗断层成像
- 传感器



三维瞬态A-Phi求解器改进

- A-Phi 求解器适用于开路多端口母排仿真
- 电容矩阵增强
- 计算端口电压、电流
- object或element频域力计算（表面力和体积力），支持第二方工具接口
- 时间平均场结果(损耗密度)，可用于多物理场分析
- **支持非线性永磁体，铁损场效应，磁滞效应，充磁与退磁**

2021 R2

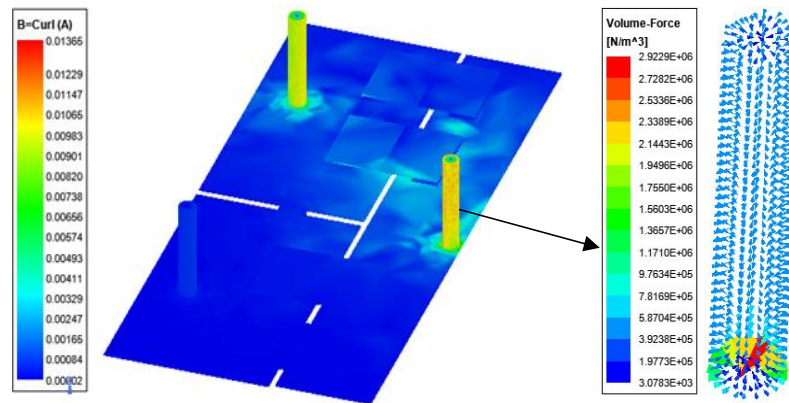
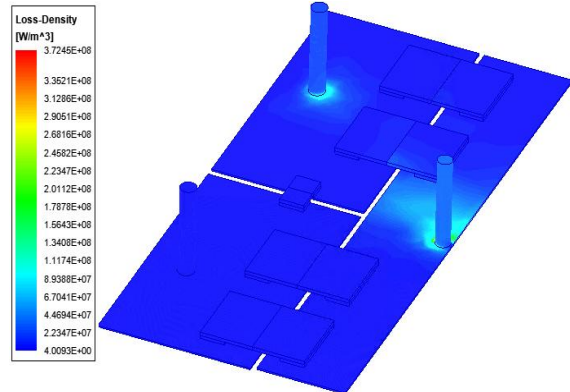
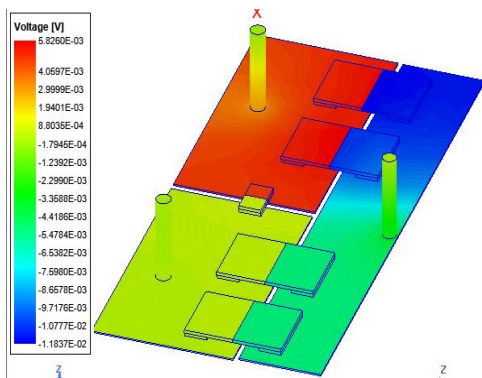
Parameter: Matrix1 Type: Capacitance
Time: 39us Capacitance Units: pF

View Format Export

| | Current1 | Current2 | Current3 | Current4 | Current5 |
|----------|-------------|-------------|-------------|-------------|-------------|
| Current1 | 0.7291 | -0.00011818 | 5.4672E-05 | 3.8858E-05 | 9.7629E-05 |
| Current2 | -0.00011818 | 0.68447 | 6.1799E-05 | 4.5925E-05 | 0.00010298 |
| Current3 | 5.4672E-05 | 6.1799E-05 | 0.6767 | -9.7157E-05 | -0.00014074 |
| Current4 | 3.8858E-05 | 4.5925E-05 | -9.7157E-05 | 0.58137 | -0.00011279 |
| Current5 | 9.7629E-05 | 0.00010298 | -0.00014074 | -0.00011279 | 0.22494 |

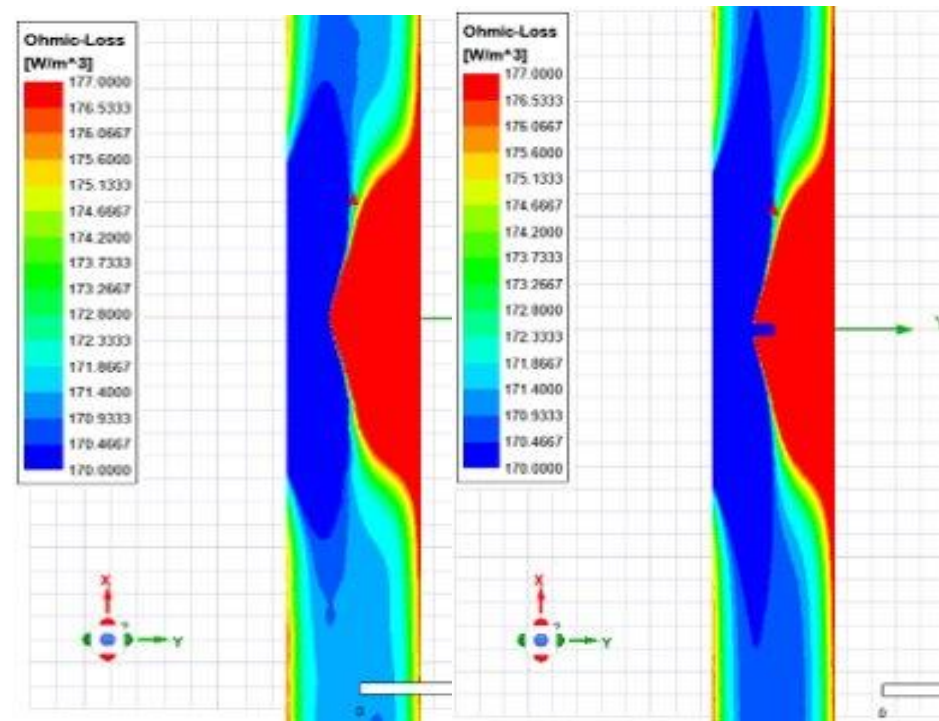
| TerminalCurrent(Current1) [mA] Setup1 : Transient | TerminalCurrent(Current2) [mA] Setup1 : Transient | TerminalCurrent(Current3) [mA] Setup1 : Transient |
|--|--|--|
| 1.978630 | 1.978630 | 16481.877200 |

2022 R1



涡流场求解器支持层电阻模型(Resistive Sheet)

- 层电阻模型的支持从瞬态场扩展到涡流场
- 当导体符合下述条件时可定义层电阻
 - 实心导体
 - 任何类型的实心导体绕组
 - 支持导体设置eddy effect
- 求解器假设电流垂直于电阻片
- 支持 DDM
- 可显示表面损耗密度场图

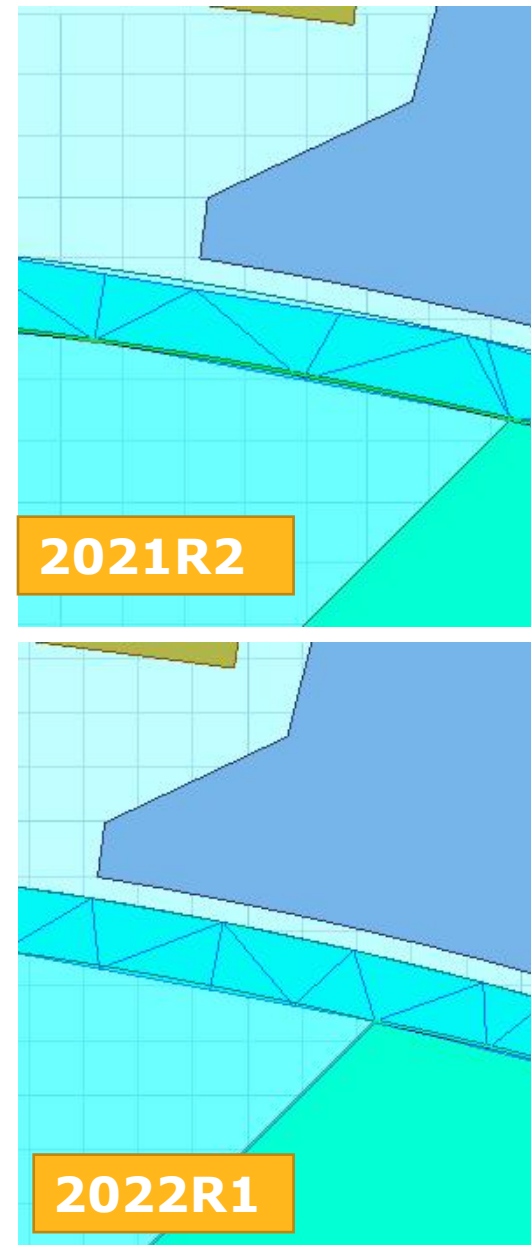


Resistive Sheet

Thin Box

2D Band 支持Tau Mesh

- Maxwell 2D 瞬态场支持Cylindrical gap网格设置
 - 设置方式与3D相同
- Tau Mesh会考虑Cylindrical gap网格设置，以确保Band 网格质量
 - 在以往版本中，软件采用Band自动识别算法。新版中，在用户设置Band的时候，软件最自动设置Cylindrical gap 网格设置
 - Tau Mesh将重新对Band进行网格剖分，确保band网格节点精确定位在线上
 - 如果用户未设置Cylindrical gap 网格， Tau Mesh 仍会启用传统的Band自动识别算法



HPC



OpenMP与MPI

- **OpenMP**

- 共享内存，用于本地的并行计算

- **MPI**

- 分布式内存，用于多主机之间的通信
- 意味着更大的内存，更多的可用计算资源

- **Maxwell的HPC计算**

- 传统的HPC都是基于OpenMP的单机多核并行计算
- Maxwell 2021之后，逐渐开始实现基于MPI的多机多核并行计算
 - 涡流场：Maxwell 2019 R1+
 - 静磁场：Maxwell 2020 R2+
 - 瞬态场：Maxwell 2022 R1+

瞬态场加速效果 2022R1

| | | | | |
|-----------------------------|----------|----------|--------|----------------------------------|
| Mesh (volume, seed) | 00:04:48 | 00:05:03 | 802 M | 616214 tetrahedra |
| | | | | Length1 |
| Start Simulation | 00:00:53 | 00:00:53 | 3.58 G | 616214 tetrahedra |
| Solver DRS19, Hp Assignment | 00:00:00 | 00:00:00 | 213 M | 113 matrix, 0KB disk |
| Solver Progress | | | | Requested from t = 0 to t = 0.02 |
| Solve TD19 | 00:00:51 | 00:00:51 | 3.76 G | 616214 tetrahedra |
| Solver DRS19, 5 iterations | 00:00:59 | 00:14:12 | 8.45 G | 1227054 matrix, 0KB disk |
| Solve TD19 | 00:01:41 | 00:22:45 | 13.4 G | 616214 tetrahedra |
| Solver Progress | | | | Completed time point 0s |
| Solver DRS19, 6 iterations | 00:01:11 | 00:17:08 | 8.5 G | 1227054 matrix, 0KB disk |
| Solve TD19 | 00:02:00 | 00:27:05 | 13.7 G | 616214 tetrahedra |

使用单台电脑19核CPU计算，网格数量61.6万

| | | | | |
|----------------------------|----------|----------|--------|--|
| Solve TD19 | 00:02:11 | 00:30:46 | 13.8 G | 616214 tetrahedra |
| Solver Progress | | | | Completed time point 0.019s |
| Solver DRS19, 6 iterations | 00:01:11 | 00:17:42 | 8.57 G | 1227054 matrix, 0KB disk |
| Solve TD19 | 00:03:24 | 00:34:17 | 13.8 G | 616214 tetrahedra |
| Solver Progress | | | | Completed through t = 0.02 |
| | | | | Time: 01/29/2022 18:53:03, Status: Normal Completion |
| Total | 01:11:57 | 14:41:25 | | Elapsed time : 01:42:02, ComEngine Memory : 81.2 M |

求解矩阵时间1小时12分，总的求解时间1小时42分

| | | | | |
|--|----------|----------|--------|-------------------------------------|
| Mesh (volume, seed) | 00:04:28 | 00:04:41 | 801 M | 616214 tetrahedra |
| | | | | Length1 |
| TDM | 00:00:00 | 00:00:00 | 25 M | 2 tasks 38 total cores |
| Start Preprocessing for TDM General Transient Model | 00:00:01 | 00:00:00 | 25 M | 1 Time Domains |
| Finish Preprocessing for TDM General Transient Model | 00:00:01 | 00:00:01 | 25 M | 1 Time Domains |
| Solver Progress | | | | Requested from t = 0 to t = 0.02 |
| Start TDM Simulation | 00:00:51 | 00:00:51 | 3.58 G | 616214 tetrahedra |
| TDM General Transient Model Subdivision 1 | 00:07:02 | 00:07:02 | 13.8 G | 7 Nonlinear iterations 1 Time steps |
| Solver Progress | 00:00:00 | 00:00:00 | 10.3 G | Completed time point 0s |
| TDM General Transient Model Subdivision 2 | 00:02:17 | 00:02:16 | 13.8 G | 2 Nonlinear iterations 1 Time steps |
| Solver Progress | 00:00:00 | 00:00:00 | 10.3 G | Completed time point 0.001s |
| TDM General Transient Model Subdivision 3 | 00:02:19 | 00:02:17 | 13.8 G | 2 Nonlinear iterations 1 Time steps |

使用DDM功能，两台电脑共38核CPU计算

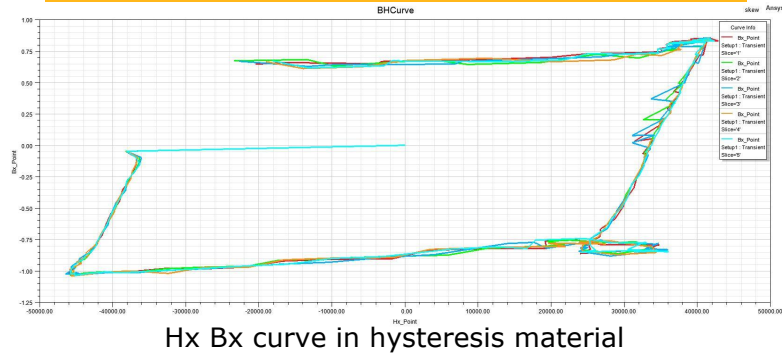
| | | | | |
|--|----------|----------|--------|--|
| TDM General Transient Model Subdivision 18 | 00:02:12 | 00:02:11 | 14.6 G | 2 Nonlinear iterations 1 Time steps |
| Solver Progress | 00:00:00 | 00:00:00 | 10.3 G | Completed time point 0.017s |
| TDM General Transient Model Subdivision 19 | 00:02:12 | 00:02:11 | 14.6 G | 2 Nonlinear iterations 1 Time steps |
| Solver Progress | 00:00:00 | 00:00:00 | 10.3 G | Completed time point 0.018s |
| TDM General Transient Model Subdivision 20 | 00:03:14 | 00:03:13 | 14.6 G | 2 Nonlinear iterations 1 Time steps |
| Solver Progress | 00:00:00 | 00:00:00 | 10.3 G | Completed time point 0.019s |
| | | | | Time: 01/29/2022 16:56:11, Status: Normal Completion |
| Total | 00:57:29 | 00:57:25 | | Elapsed time : 01:03:36, ComEngine Memory : 79.2 M |

求解矩阵时间57分，总的求解时间1小时3分

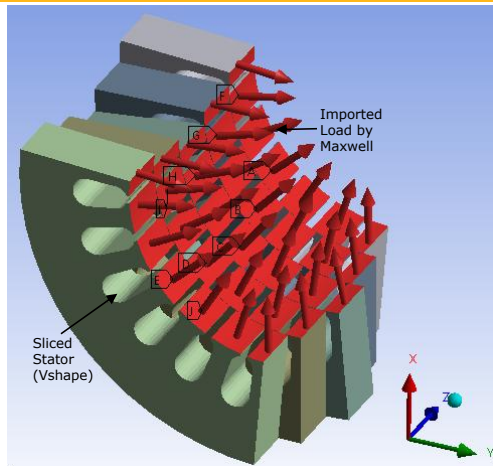
求解时间缩短40%

MPI支持斜极模型

- 支持磁滞效应



- 支持频域力计算(object-based)



- 支持暂停-继续求解

Use Automatic Settings

Num variations to distribute: 1

Machines | Options

Machines for Distributed Analysis

Total Enabled Cores: 16

| Name | Cores | RAM Limit (%) | Enabled |
|-----------|-------|---------------|-------------------------------------|
| localhost | 16 | 90 | <input checked="" type="checkbox"/> |

Remove Move up

- 支持铁损效应



- 支持自动HPC设置

Analysis Configuration

Configuration name: MPISkew

Use Automatic Settings

Machines | Job Distribution | Options

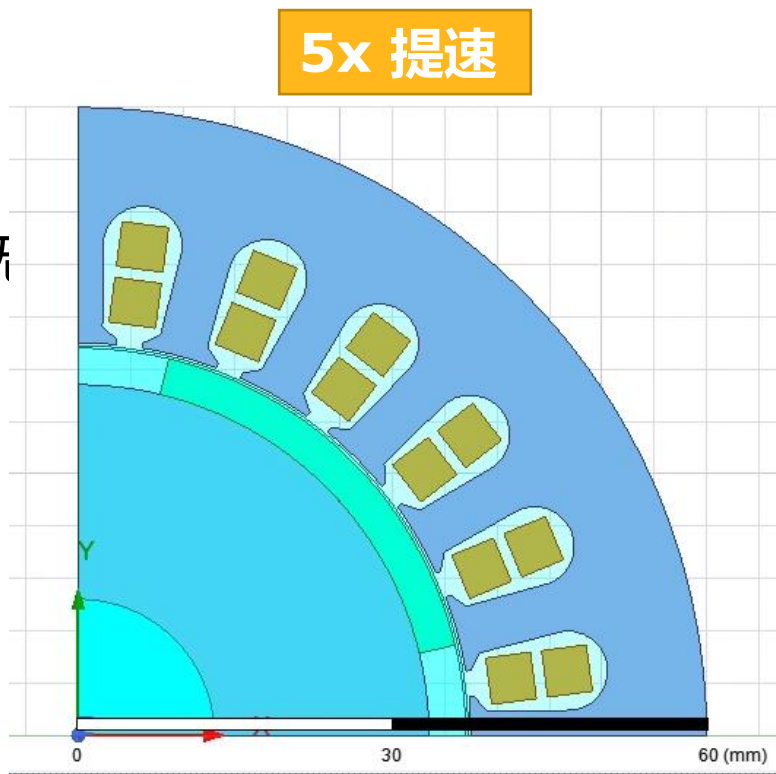
Enable Distribution Types:

| Enabled | Distribution Type |
|-------------------------------------|------------------------|
| <input checked="" type="checkbox"/> | Optimetrics Variations |
| <input checked="" type="checkbox"/> | Frequencies |
| <input type="checkbox"/> | Transient Solver |
| <input type="checkbox"/> | Solution Matrix |
| <input checked="" type="checkbox"/> | Skew Model |

Expression Cache执行速度显著提高

测试案例

- 2D 非Skew模型
- 对比 2021R2 与 2022R2
- 参数化分析, 10个任务
- 14个expression cache
- 12核处理器, 6个并行任务, 无



2021R2 – 23:42 minutes

| Variation | Le1 | R1 | conds | delta | fractions | Start | Stop | Elapsed | Analysis Machine |
|-----------|--------|-------|-------|--------|-----------|----------|----------|--------------|------------------|
| 1 | 0.0... | 1.... | 26 | 0deg | 4 | 18:29... | 18:42... | 00:13:11:519 | localhost |
| 2 | 0.0... | 1.... | 26 | 10d... | 4 | 18:29... | 18:43... | 00:13:28:141 | localhost |
| 3 | 0.0... | 1.... | 26 | 20d... | 4 | 18:29... | 18:43... | 00:13:53:985 | localhost |
| 4 | 0.0... | 1.... | 26 | 30d... | 4 | 18:29... | 18:43... | 00:13:58:233 | localhost |
| 5 | 0.0... | 1.... | 26 | 40d... | 4 | 18:29... | 18:43... | 00:14:00:472 | localhost |
| 6 | 0.0... | 1.... | 26 | 50d... | 4 | 18:30... | 18:44... | 00:14:05:312 | localhost |
| 7 | 0.0... | 1.... | 26 | 60d... | 4 | 18:42... | 18:52... | 00:10:09:132 | localhost |
| 8 | 0.0... | 1.... | 26 | 70d... | 4 | 18:43... | 18:53... | 00:10:04:516 | localhost |
| 9 | 0.0... | 1.... | 26 | 80d... | 4 | 18:43... | 18:53... | 00:09:43:161 | localhost |
| 10 | 0.0... | 1.... | 26 | 90d... | 4 | 18:43... | 18:53... | 00:09:32:743 | localhost |

2022R1 – 4:27 minutes

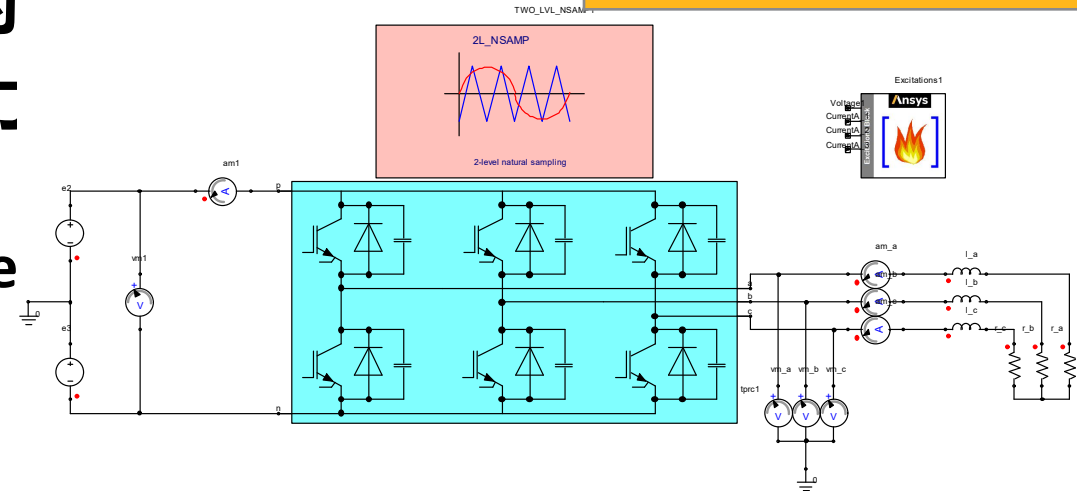
| Variation | Le1 | R1 | conds | delta | fractions | Start | Stop | Elapsed | Analysis Machine |
|-----------|--------|-------|-------|--------|-----------|----------|----------|--------------|------------------|
| 1 | 0.0... | 1.... | 26 | 0deg | 4 | 17:29... | 17:32... | 00:02:28:163 | localhost |
| 2 | 0.0... | 1.... | 26 | 10d... | 4 | 17:29... | 17:32... | 00:02:26:117 | localhost |
| 3 | 0.0... | 1.... | 26 | 20d... | 4 | 17:29... | 17:32... | 00:02:25:671 | localhost |
| 4 | 0.0... | 1.... | 26 | 30d... | 4 | 17:29... | 17:32... | 00:02:23:815 | localhost |
| 5 | 0.0... | 1.... | 26 | 40d... | 4 | 17:29... | 17:32... | 00:02:25:652 | localhost |
| 6 | 0.0... | 1.... | 26 | 50d... | 4 | 17:29... | 17:32... | 00:02:23:548 | localhost |
| 7 | 0.0... | 1.... | 26 | 60d... | 4 | 17:32... | 17:34... | 00:01:55:893 | localhost |
| 8 | 0.0... | 1.... | 26 | 70d... | 4 | 17:32... | 17:34... | 00:01:56:787 | localhost |
| 9 | 0.0... | 1.... | 26 | 80d... | 4 | 17:32... | 17:34... | 00:01:57:407 | localhost |
| 10 | 0.0... | 1.... | 26 | 90d... | 4 | 17:32... | 17:34... | 00:01:57:124 | localhost |

易用性

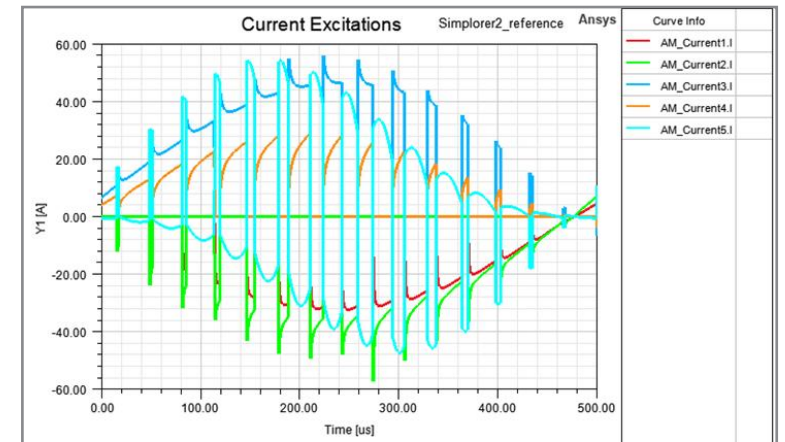
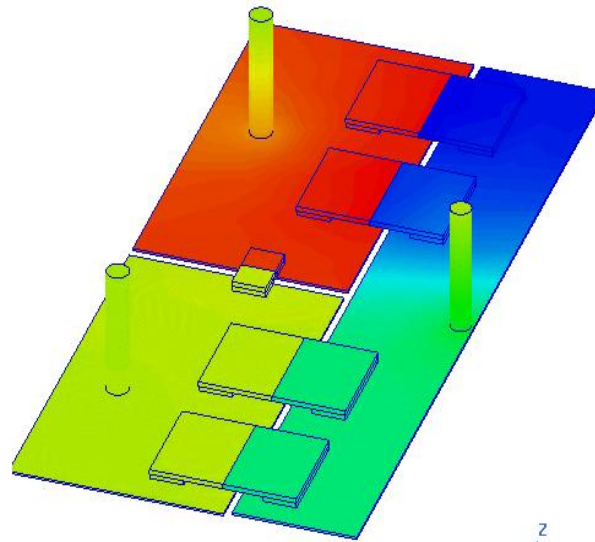
2D/3D 瞬态磁场求解器支持Simplorer Push-Back激励

- 该功能让Maxwell在没有与Simplorer协同仿真的情况下，支持Simplorer/TB中的Push excitation器件可以将电力Maxwell瞬态求解器的绕组
- 用户只需将Maxwell设计链接起来，并将Maxwell元件

Push-Back Component



Inverter Package - Voltage Distribution



Push-Back Excitation Circuit Schematic

Harmonic Force计算功能改进

• Harmonic Force 计算功能改进

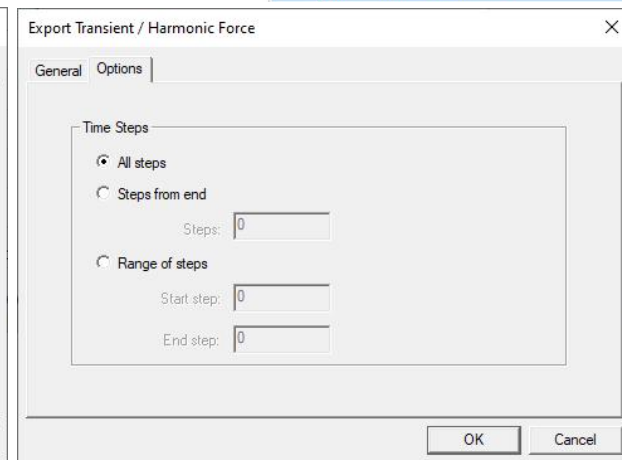
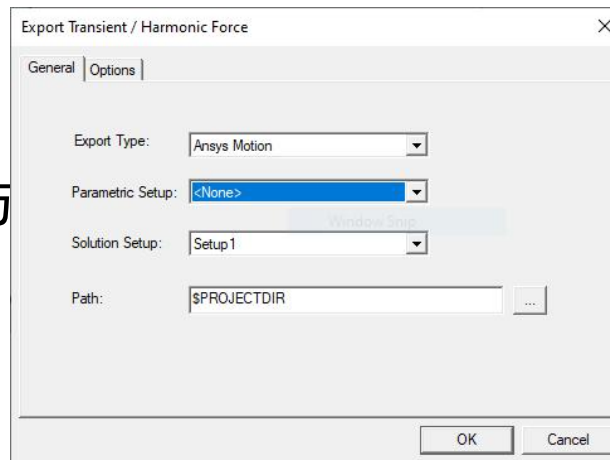
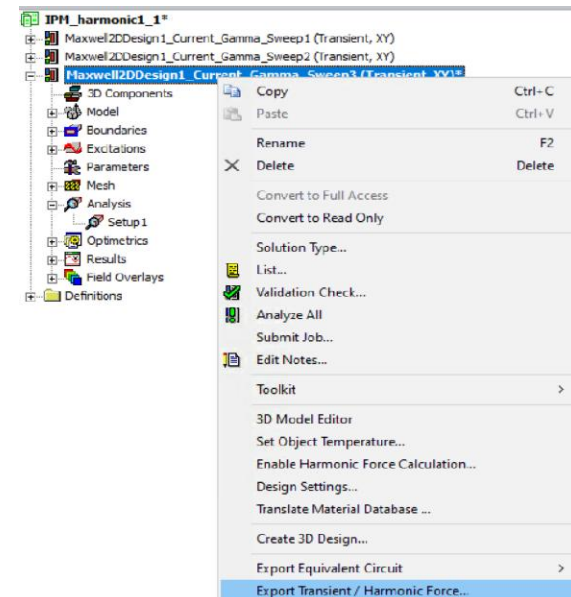
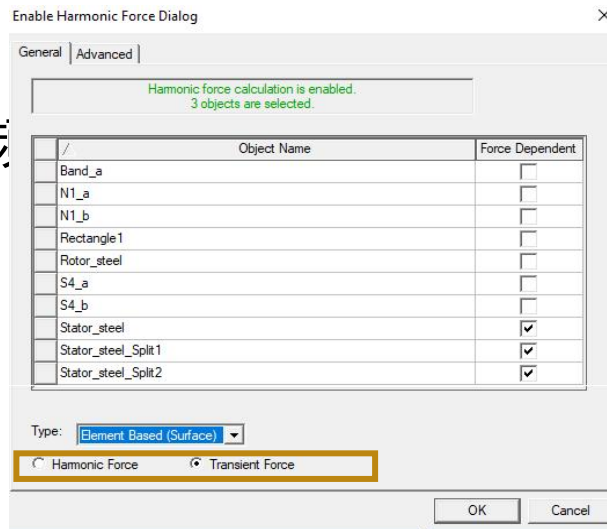
- DFT前对非恒定时间步长数据进行重构，以消除频率误差

• UI和瞬态力导出改进

- 电磁力的所有输出选项都集成在一个界面下
- 允许用户切换导出类型，且不需要重新求解
- 支持多转速扫描

• 新的时域电磁力文件输出

- 用于支持非Workbench的NVH耦合分析以及第三方



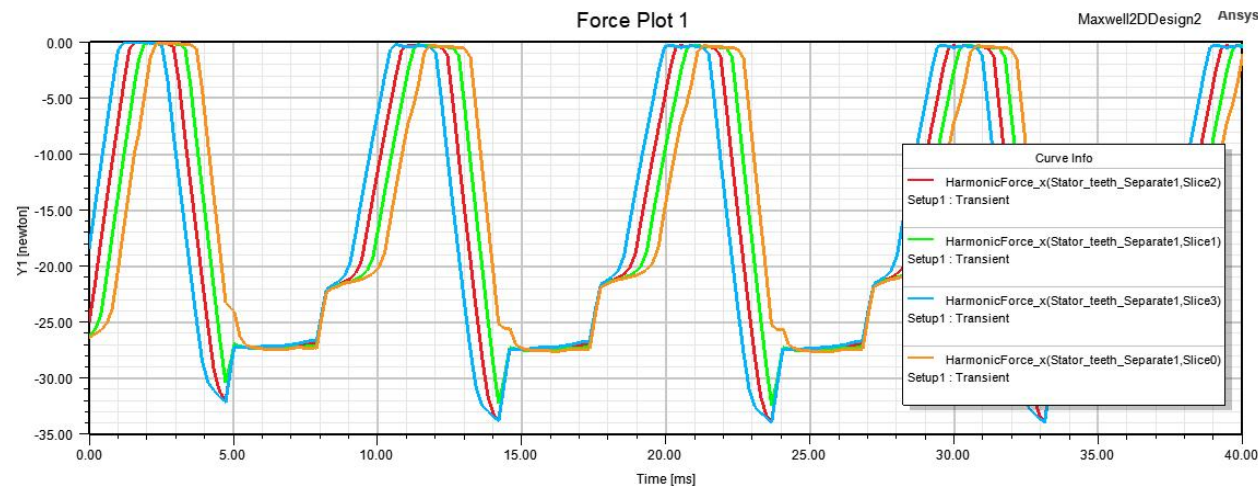
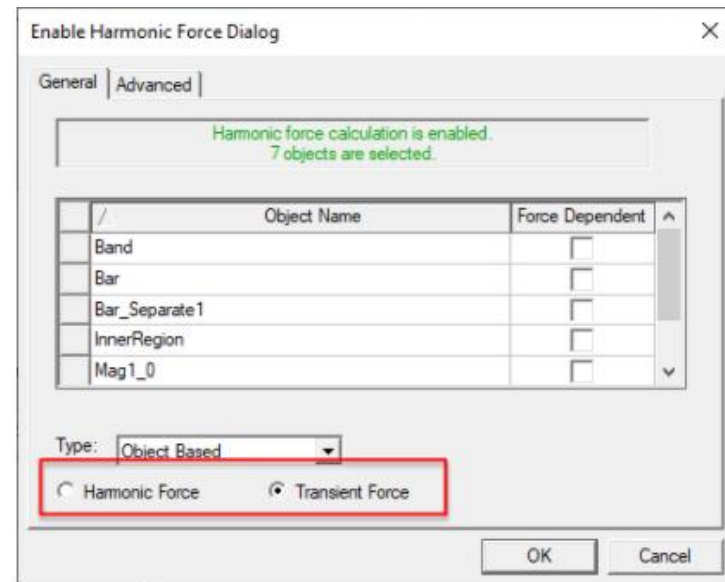
求解后选择输出电磁力

瞬态场中直接输出基于object的时域电磁力曲线

- 可在后处理报告中直接输出基于object的时域电磁力曲线
- 预定义的object-based频域力计算对象上的时域力
 - 电磁力的时间范围: 0 ~ tend, 所有时间步
 - 电磁力的分量, 幅值与方向分量
 - 支持2D/3D 瞬态求解器
 - 支持2D skew 模型
 - 支持TDM HPC

瞬态报告

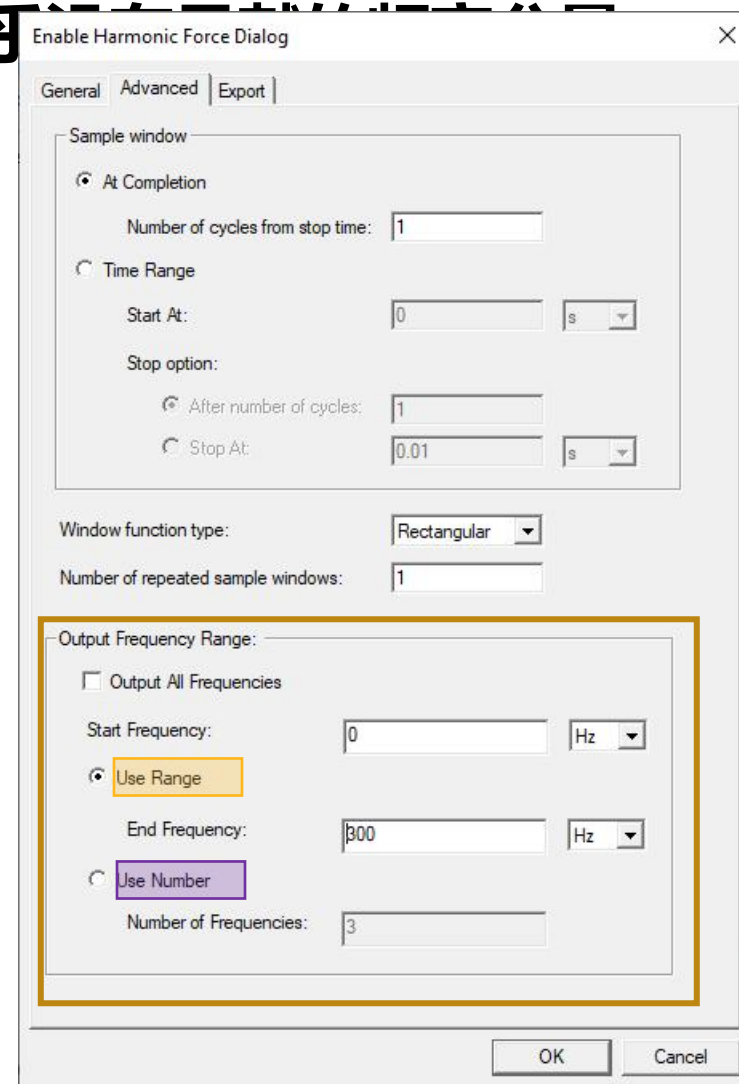
- 电磁力分量 vs 时间
- 实时动态更新
- 可堆叠绘图 (多视图)
- 支持瞬态数据导出
- 可对曲线进行FFT



不同分段上的定子齿电磁力

Harmonic Force 计算可设置频率范围

- 允许用户定义频域力的输出频率范围，过滤对NVH几乎没有影响的频率成分
- 改进数据映射效率，降低Mechanical侧的求解负荷
- Range 选项: 起始和结束频率
- Number 选项: 起始频率和频率点数
- FFT 窗口函数类型:



电机相关

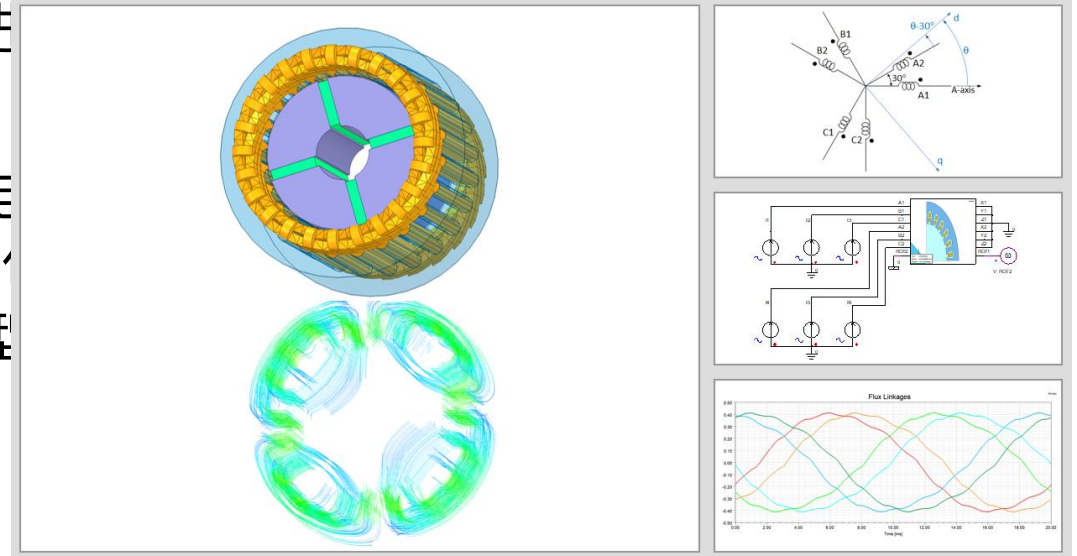
支持多相电机降阶模型

• 六相 (双三相) 电机

- 优点：高功率密度，低转矩脉动，高可靠性
- 应用：风力涡轮机，电动汽车，机车牵引，船舶推进

• 六相电机的ECE模型

- 灵活：该模型可与其他ECE模型结合，用于创建6相电
- 精确：基于基波等效模型考虑饱和响应；dq0磁链中
- 计算效率：只需扫描一组dq轴电流；相对3相ECE模型
- 便捷：自动双3相模型



基于有限元的六相电机ROM

效率Map图同时显示电动和发电模式

• 功能说明

- ACT 将电机的电动模式计算和发电模式计算的结果合并，并在时显示电动和发电模式的Map图
- 优点：
 - 电动机和发电机模式的输入指标可以不同
 - 支持LS-DSO, periodic TDM, fast DOE
 - 支持Machine Toolkit中所有电机类型
 - 无需重复的参数化分析

• UI 界面变更

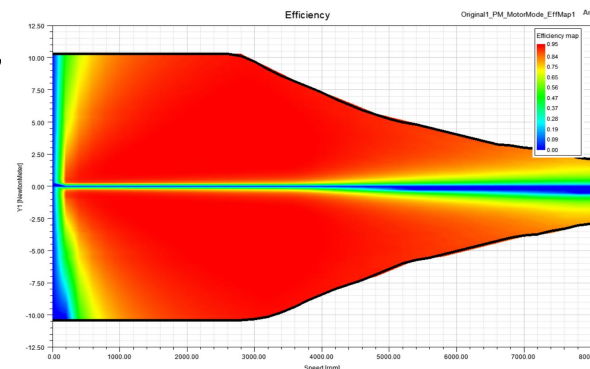
- “Simulation Mode”中增加新选项“Motor and Generator”
- 当“Motor and Generator”选中时，UI会显示“Motor-mode design”选项

Project/Design Selection
Project: IM_PM_toolkit
Design: IPM
 Prefill settings using saved configuration file

Electrical Machine Characteristics
Machine Type: PM Synchronous
Number of Poles: 4
Number of Stator Phases: 3
Voltage Control: Line-Line RMS Voltage
Control Strategy: MTPA
Line-Line RMS Voltage [V]: 270.0
RMS Line Current [A]: 7.0
Connection type: Wye

Simulation Mode
Simulation Mode: Motor and Generator
Motor-mode design: IPM_PM_MotorMode_EffMap1
Generator-mode design: IPM_PM_GeneratorMode_EffMap1

设计中同



”设置选

第一和第四象限

感应电机参数扫描从频率改为转速

• 方法

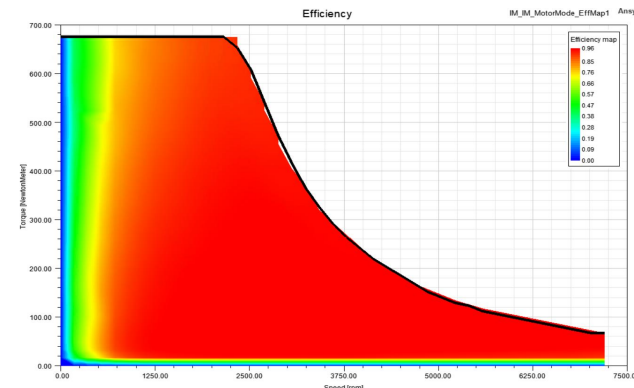
- 扫描变量: 转速(取代频率)、转差率、定子端部电压

• 优势:

- 对于发电和电动运行模式, map图的转速上限与用户定义的最大转速相匹配
- 转矩-转速曲线和map图更平滑
- 提高高速区的计算精度

• 增加 UI 设置选项

- 对于感应电机, 用户可定义2个转差率扫描间隔, 便于合理定义高转差率区间采样点, 以满足低速区的map精度要求
- 用户可以在map图中定义扭矩限制, 扭矩超过该限制的样本将被排除在map图之外, 从而在低速区域形成平坦的转矩-转速曲线



▼ DOE Settings

| | |
|---|----|
| Number of time steps per period | 20 |
| Number of voltage sweep points | 10 |
| <input checked="" type="checkbox"/> Define 2 slip sweep intervals | |
| Number of slip sweep points in 1st interval | 10 |
| Number of slip sweep points in 2nd interval | 10 |
| Number of speed sweep points | 12 |

▼ Map Characteristics

| | |
|--|-------|
| <input type="checkbox"/> Use speed steps | |
| Number of speed points | 40 |
| <input type="checkbox"/> Use torque steps | |
| Number of torque points | 40 |
| <input checked="" type="checkbox"/> Use torque limit | |
| Torque limit [Nm] | 675 |
| Maximum speed [rpm] | 7200 |
| Minimum slip | 0.001 |
| Maximum slip of 1st interval | 0.2 |
| Maximum slip of 2nd interval | 0.8 |
| <input type="checkbox"/> Separate stator and rotor core losses | |
| <input type="checkbox"/> Define duty cycle from File | |

多物理场

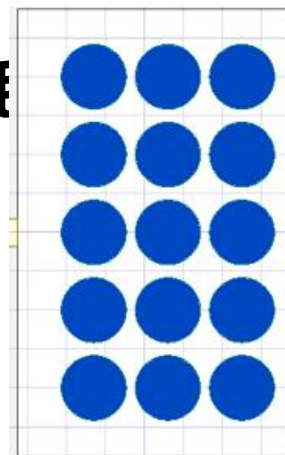
Litz线损耗的双向电热耦合

• stranded绕组的Litz线损耗（直流损耗和交流损耗于电热耦合

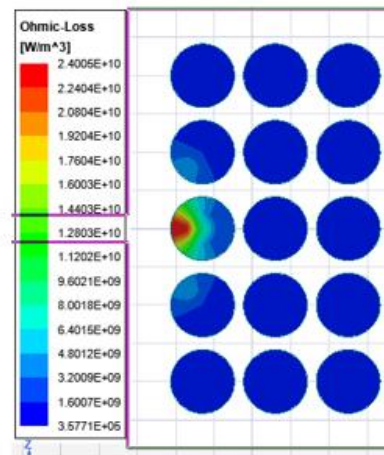
- 支持显示Emloss场图(stranded绕组的Litz线损耗)
- 瞬态场求解器中集成Litz线损耗
- 3D涡流场求解器Litz损耗在.lss 文件输出
- 支持2D/3D 涡流场/瞬态场求解器

• WB/AEDT中的双向电热耦合

- 材料属性中，Litz线模型的电导率支持设置Thermal r
- WB/AEDT双向电热耦合支持温度反馈

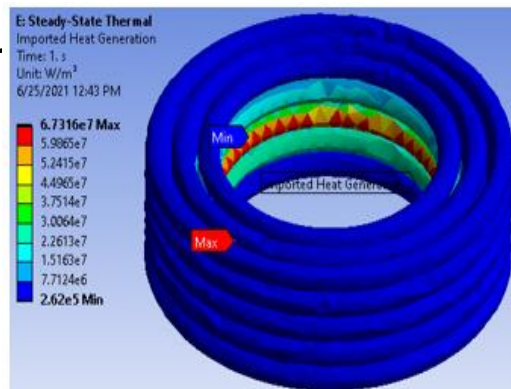


EM Loss – No Litz Wire

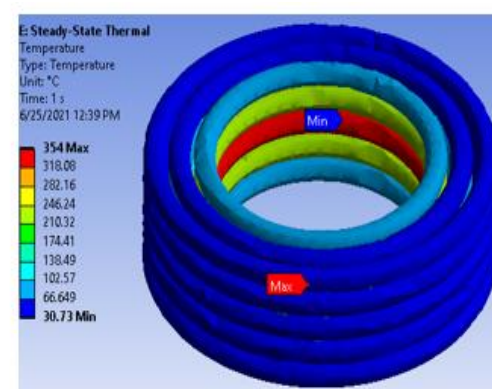


EM Loss – Litz Wire

用



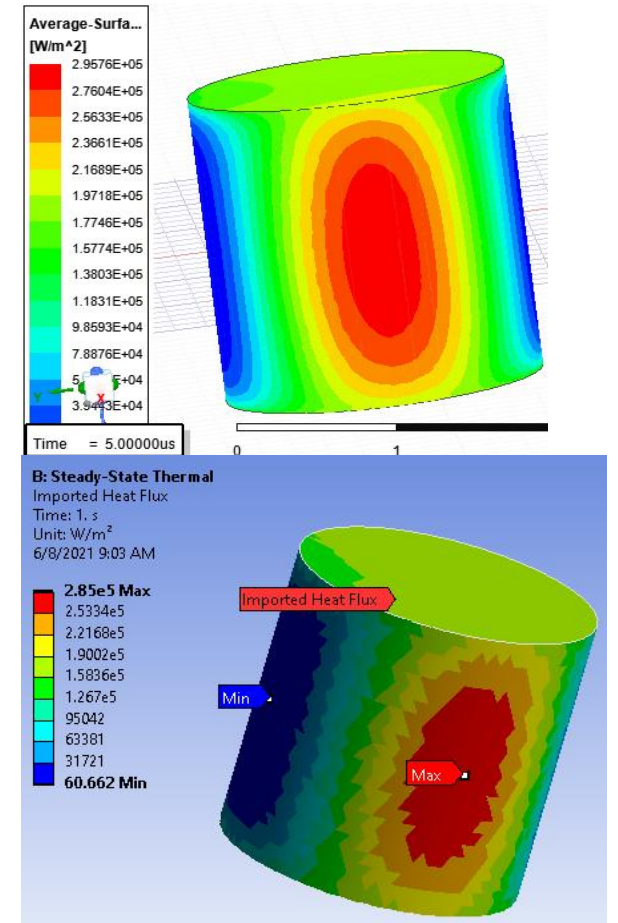
Imported Heat Generation Distribution



Temperature Field Distribution

3D瞬态场阻抗边界条件支持双向电热耦合

- 时域中支持阻抗边界条件
- 时间积分的表面损耗密度
 - 可计算用户指定时间间隔之间的平均损耗密度
 - 可在阻抗边界上显示时间平均表面损耗密度
- **WB/AEDT中的双向电热耦合**
 - 阻抗边界条件指定材料属性中电导率和磁导率支持 Thermal modifier, 以考虑温度的影响
 - 可从WB/AEDT双向电热耦合中反馈温度值
 - 可显示从双向耦合中更新的表面温度场图



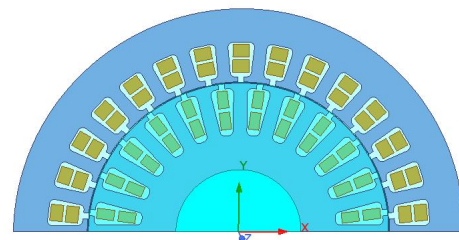
损耗密度计算值的场分布与损耗密度映射值的场分布

Multiphysics on AEDT

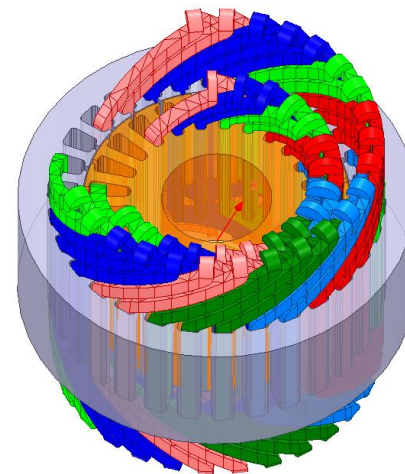
Icepak 耦合

支持从Maxwell 2D导入EM Loss

- 对二维模型数据进行拉伸



Maxwell 2D Geometry



Thermal 3D Geometry

Mechanical 耦合

支持从Maxwell 2D导入EM Loss

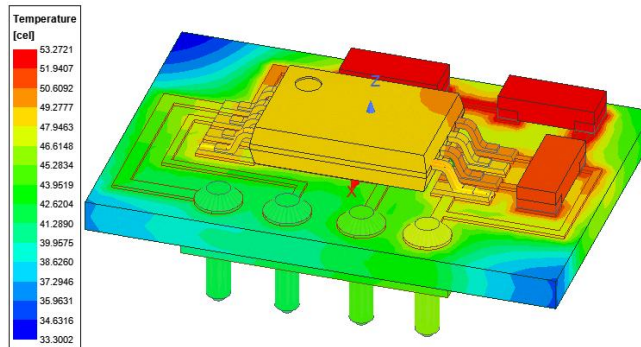
- 对二维模型数据进行拉伸

热应力耦合分析

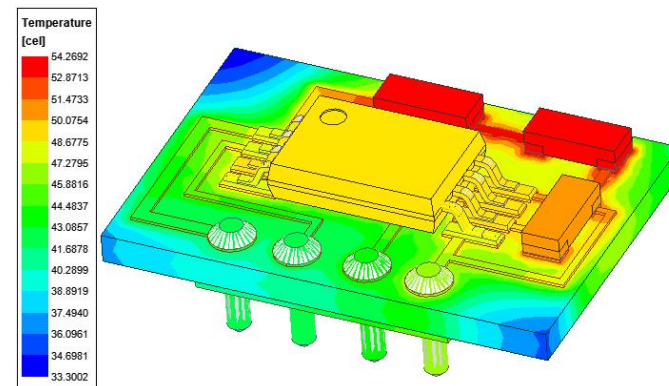
- 链接到热设计
 - System Coupling

电磁力-结构耦合分析

- 链接到Maxwell 3D 和 HFSS
 - 支持单向耦合



Thermal

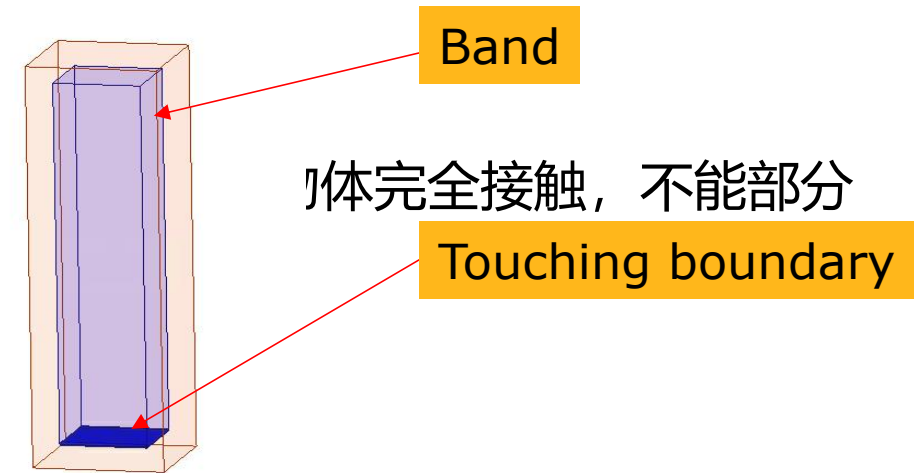


Structural

其他

直线运动分析中，运动物体可以接触静止物体

- 在非周期性直线运动(non-periodic translation motion)中，运动物体可以接触静止物体
- **Touching 边界条件的设置要求**
 - Touching 边界条件需要定义在运动物体的表面
 - 设置Touching 边界条件的表面要么与静止物体完全脱离接触
 - 设置Touching 边界条件的表面不能与Region接触





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