2022 R1

Ansys Motor-CAD 新技術

虎門科技CAE事業群
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Ansys

Outline

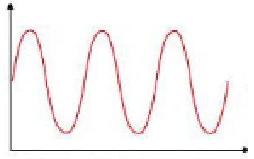
- New NVH Solution
- Integration with Ansys
- Usability (UX)

New NVH Solution
Motor-CAD Standalone

NVH: Analysis Workflow

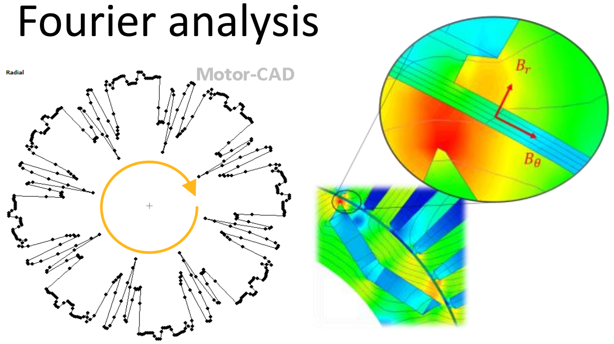
Electric Power Supply → **Electromagnetic System** → Electromagnetic Forces → **Mechanical System** → Displacement → **Acoustic Environment** → Acoustic Noise

- Current driven



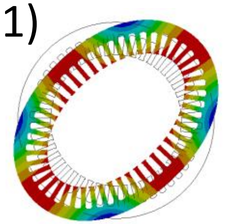
Sinusoidal currents

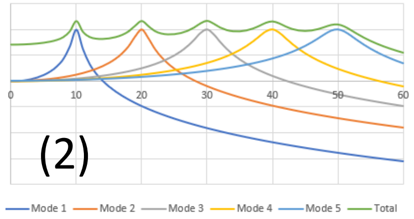
- FE based model
- Airgap forces calculation
- Maxwell stress tensor method
- Fourier analysis



- Analytical based models
- Free motion response (1)
- Forced response (2)

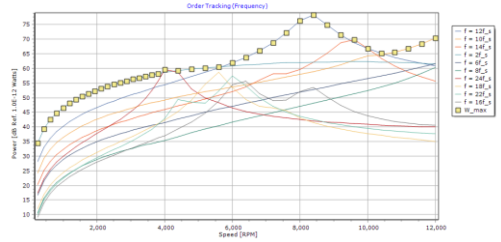
(1)





(2)

- Analytical based model
- Sound pressure levels



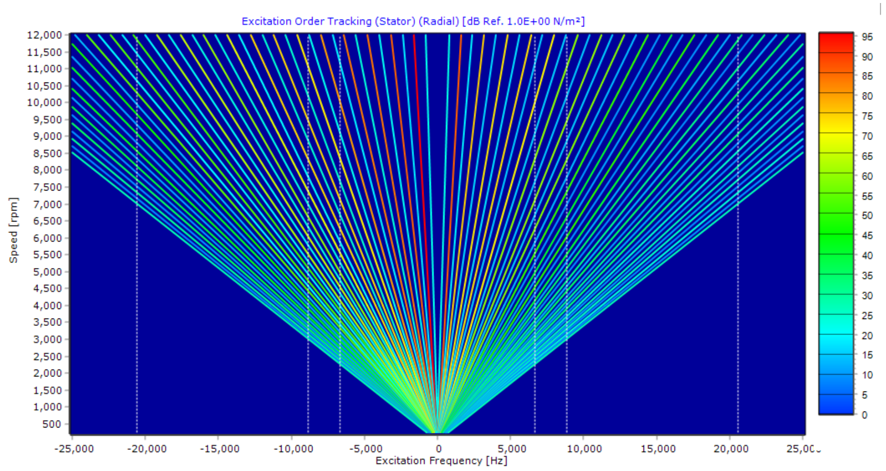
Operating point (torque, speed, temperatures)

NVH simulation loop: single and multiple operating points

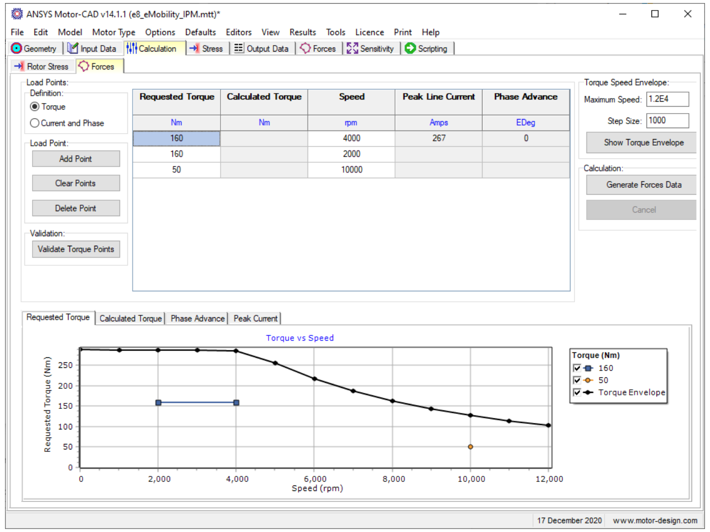
NVH: Excitation Forces

- 1D and 2D Time and Frequency analysis of radial forces using Motor-CAD Electromagnetic FEA Solver.
- Force calculations for single/multiple operating points
- Campbell diagram shows dominant harmonics across speed range
- Force export for high fidelity NVH analysis in dedicated tools
- Available for BPM, SYNCREL and SRM machine types

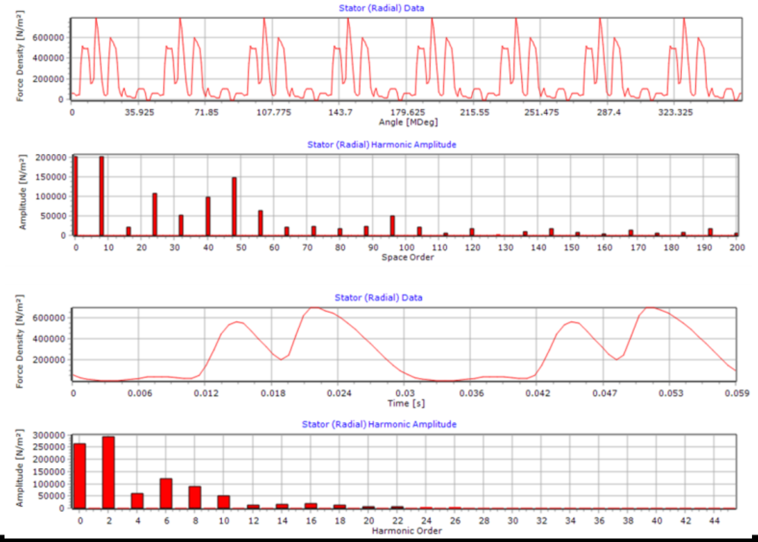
Campbell Diagram



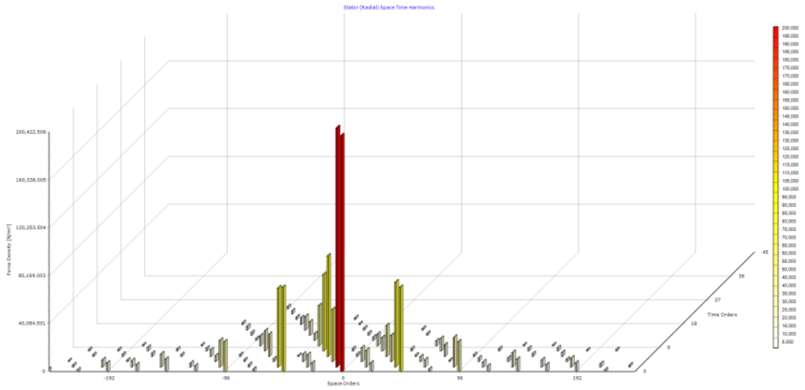
Multiple operating point calculations



1D Time & Space Force Analysis



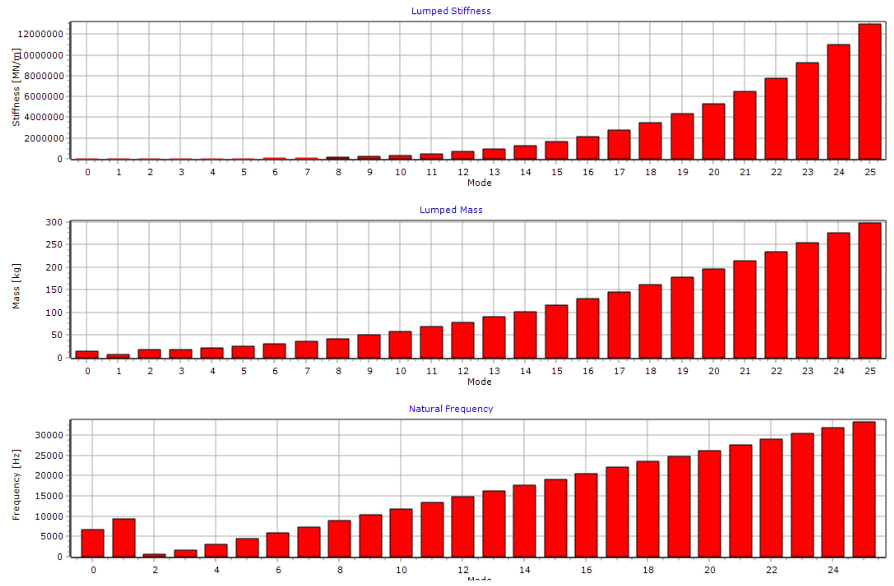
2D Frequency Domain Force Analysis



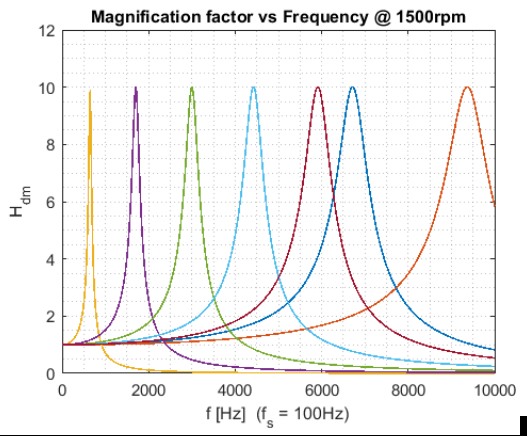
NVH: Structural Analysis

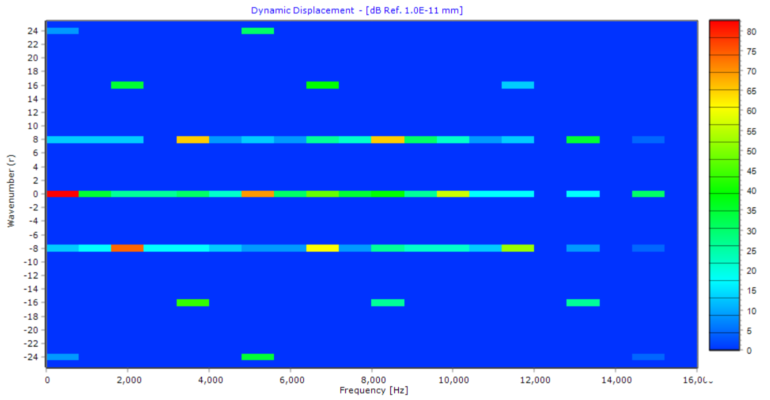
- Based on fast analytical structural models
- Free motion response:
  - Modal Analysis based on equivalent thin ring model
  - Calculate natural frequencies of stator structure
- Forced response:
  - Static displacement calculation
  - Effect of resonance visualised as magnification factor
  - Dynamic displacement calculation
  - Dynamic velocity provides input into acoustic models
  - Dynamic acceleration direct measure for vibration

Modal analysis results



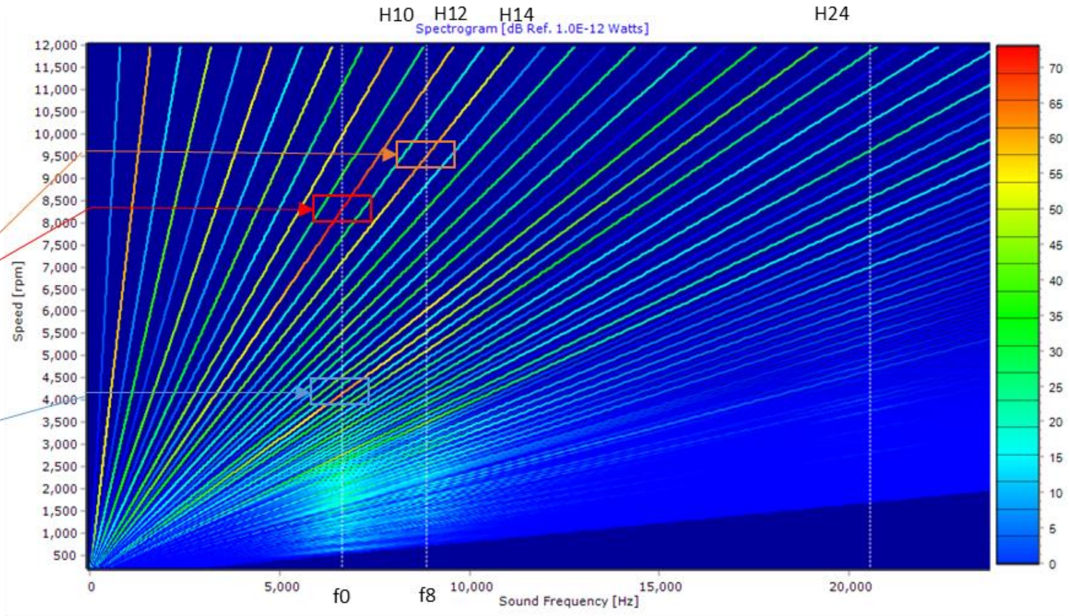
Dynamic displacement and magnification factors

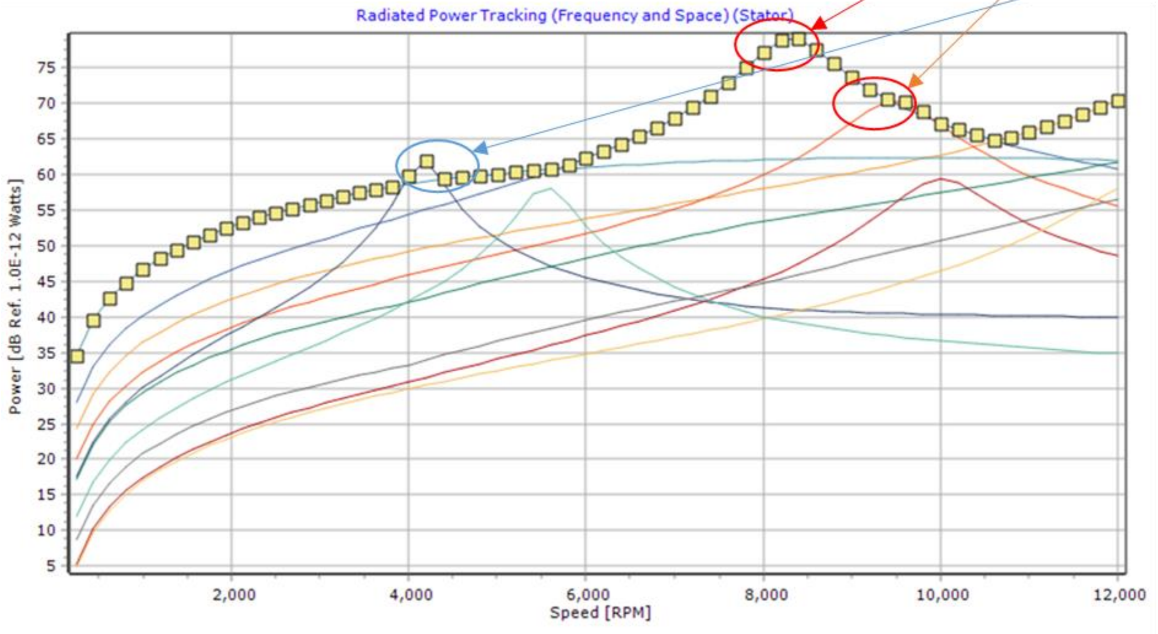




NVH: Acoustic analysis

- Based on fast analytical acoustic models
- Spectrograms and spatiograms quantify acoustic response across speed range
- Order tracking provides further insight for root cause analysis and identifying measures to reduce noise



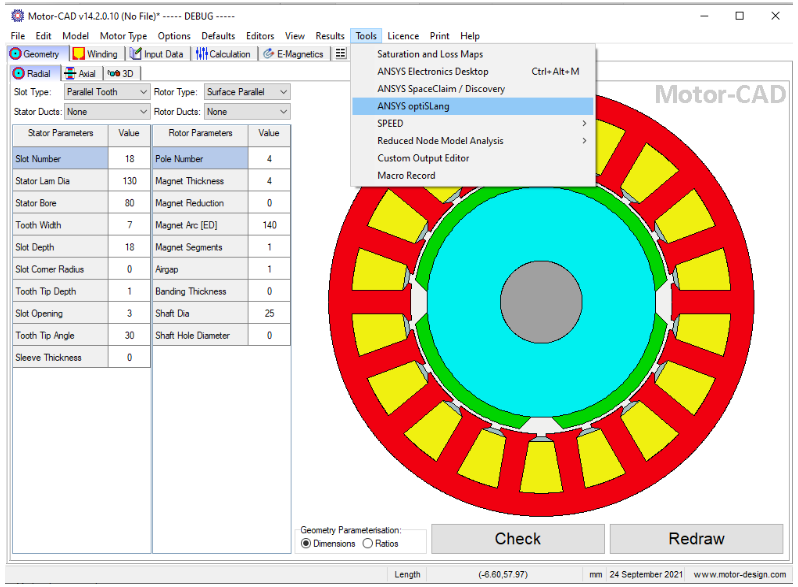


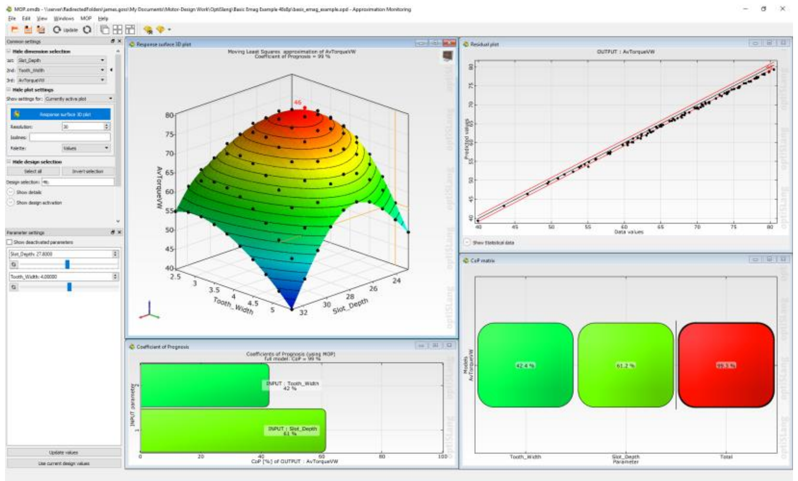
- New Motor-CAD NVH Solution:
  - Quickly compare noise for different motor concepts
  - Easily identify the cause of any motor noise early on
  - Provide the tools to enable a motor designer to make changes to reduce noise
- Avoid noise issues before they become a problem.

Integration with Ansys

Ansys optiSLang Export (1/3)

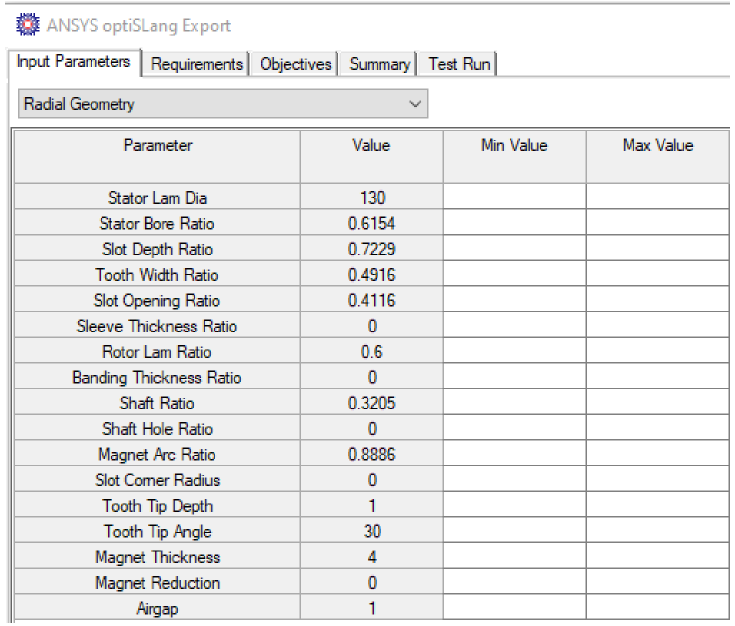
- Allows users to create a fully set-up optiSLang project ready to run based upon a base machine design in Motor-CAD. Template based optimisation.
- No scripting required, removes a significant amount of the workflow. Can go from a Motor-CAD file to an optiSLang MOP just via GUI interaction.
- Also useful for more experienced users. The exported script can be used as a template to customise and create more complex procedures. Fully compatible with the current Python node methodology.
- Available for BPM, SYNCREL and IM machine types.



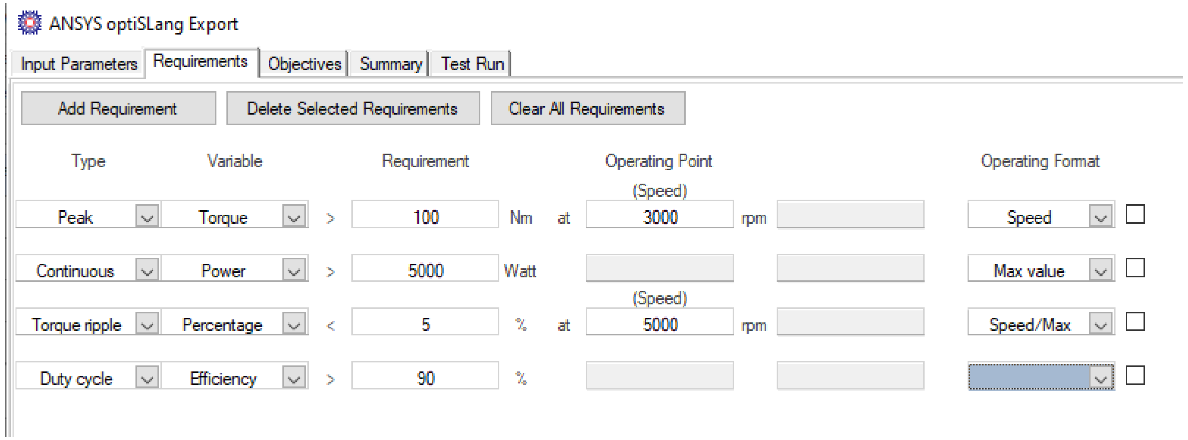


Ansys optiSLang Export (2/3)

- User can pick from a range of input parameters and specify upper and lower bounds.
- Geometry, magnetic model and winding parameters.
- Outputs (requirements/constraints and objectives) can then be specified. Peak & continuous performance, mechanical analysis, torque ripple, duty cycle analysis, volume and mass.

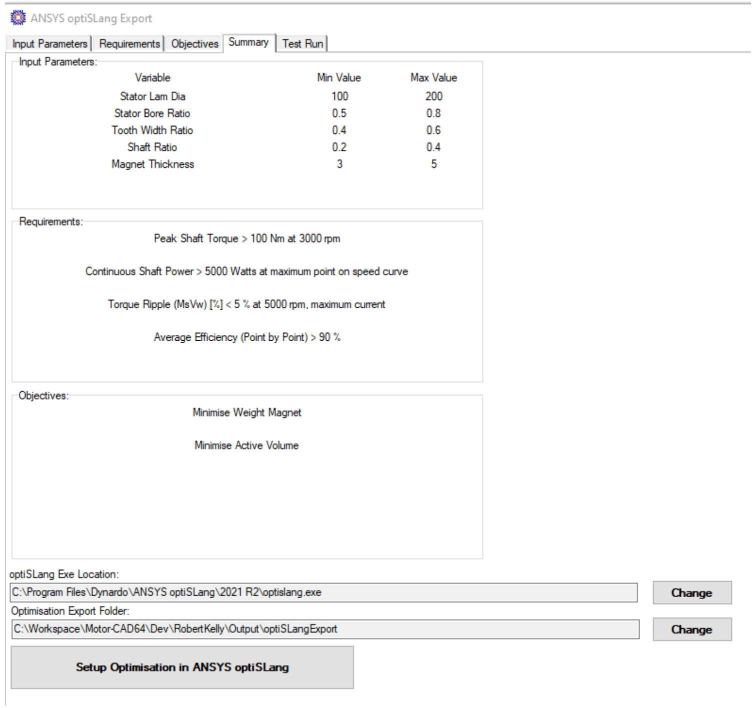


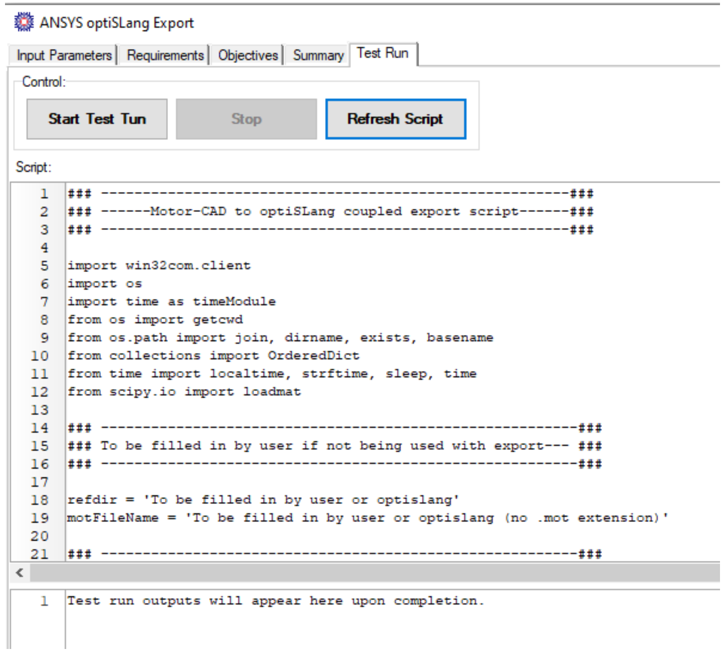
Parameter	Value	Min Value	Max Value
Stator Lam Dia	130		
Stator Bore Ratio	0.6154		
Slot Depth Ratio	0.7229		
Tooth Width Ratio	0.4916		
Slot Opening Ratio	0.4116		
Sleeve Thickness Ratio	0		
Rotor Lam Ratio	0.6		
Banding Thickness Ratio	0		
Shaft Ratio	0.3205		
Shaft Hole Ratio	0		
Magnet Arc Ratio	0.8886		
Slot Corner Radius	0		
Tooth Tip Depth	1		
Tooth Tip Angle	30		
Magnet Thickness	4		
Magnet Reduction	0		
Airgap	1		



Ansys optiSLang Export (3/3)

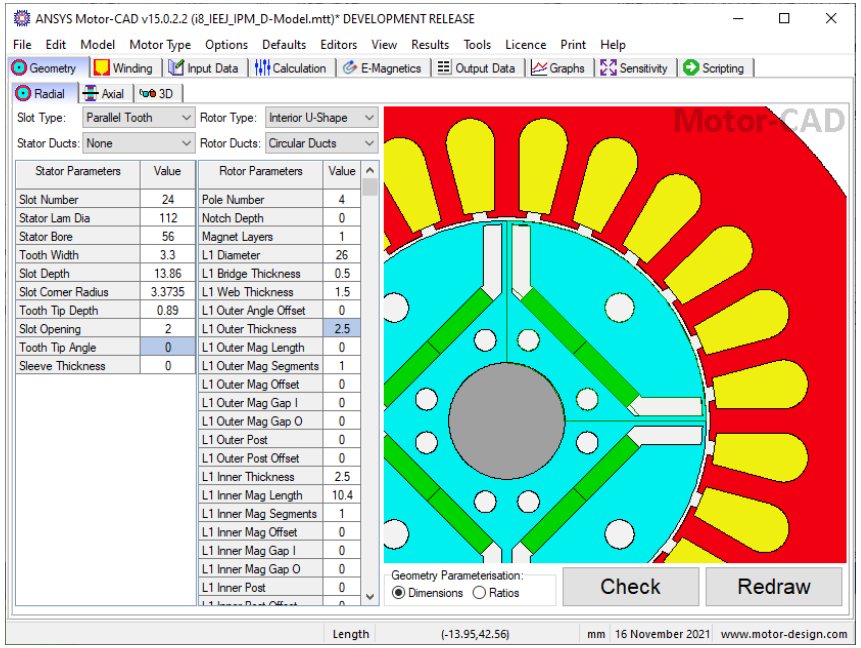
- A summary of the optimisation is shown before exporting. Users just have to specify the optiSLang exe to be used and the export directory. Everything else should be handled by the install.
- Test run feature also available. This shows the Python script that will be used and allows users to see the output values for the current design and roughly how long a single run takes.

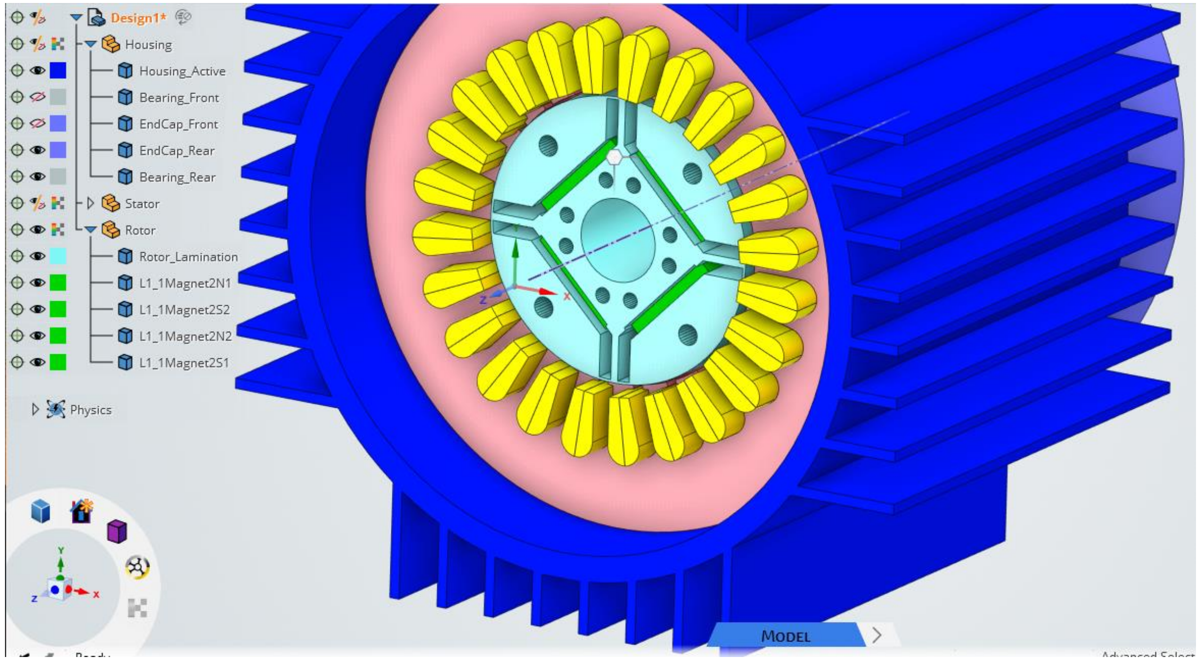




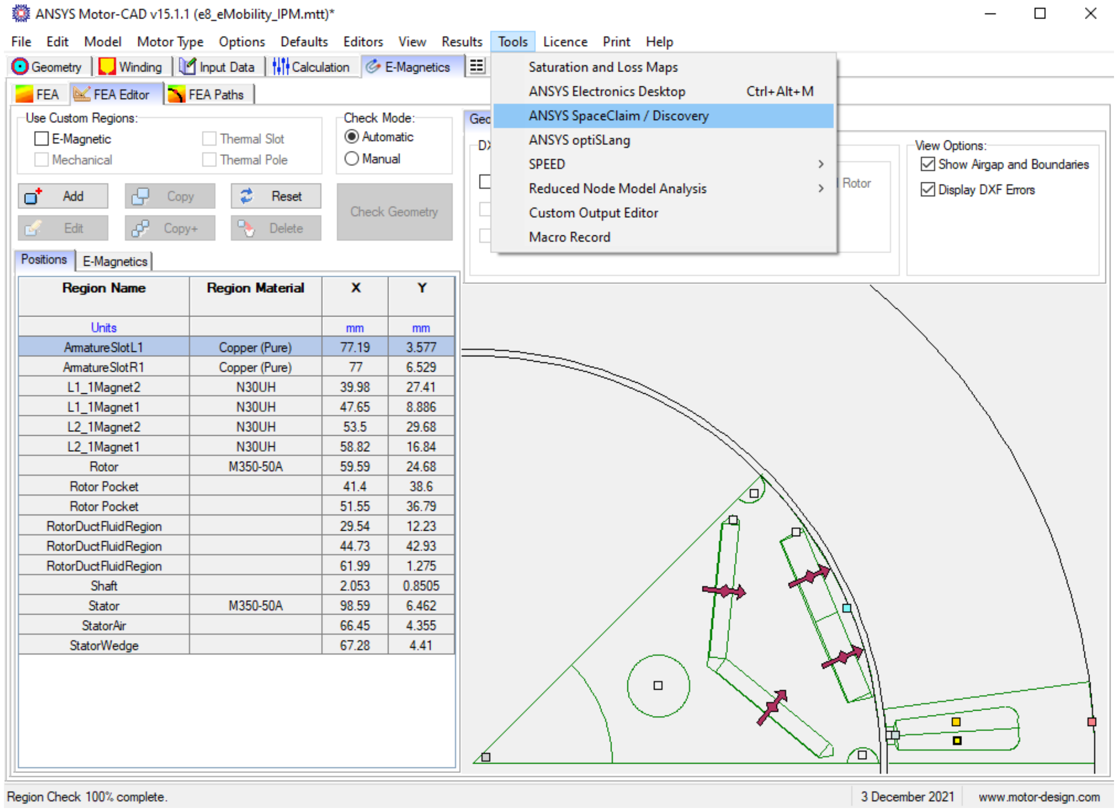
Export of geometries to Ansys Discovery (1/4)

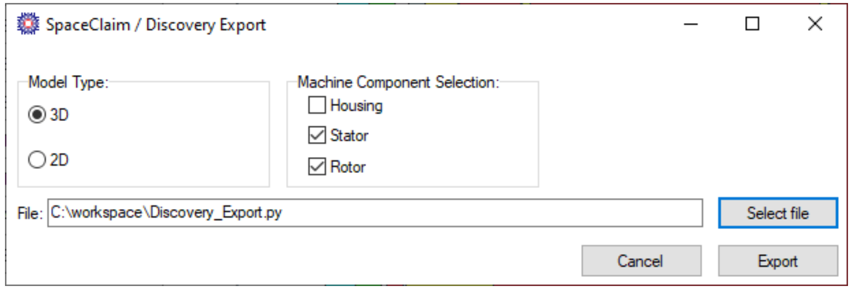
- Export of 3D geometries from Motor-CAD into Discovery for use in Ansys Toolset.
- Is achieved using Python scripting
- Ability to have export of geometry that is not available in Motor-CAD template.
  - Export custom geometry in Motor-CAD defined from dxf

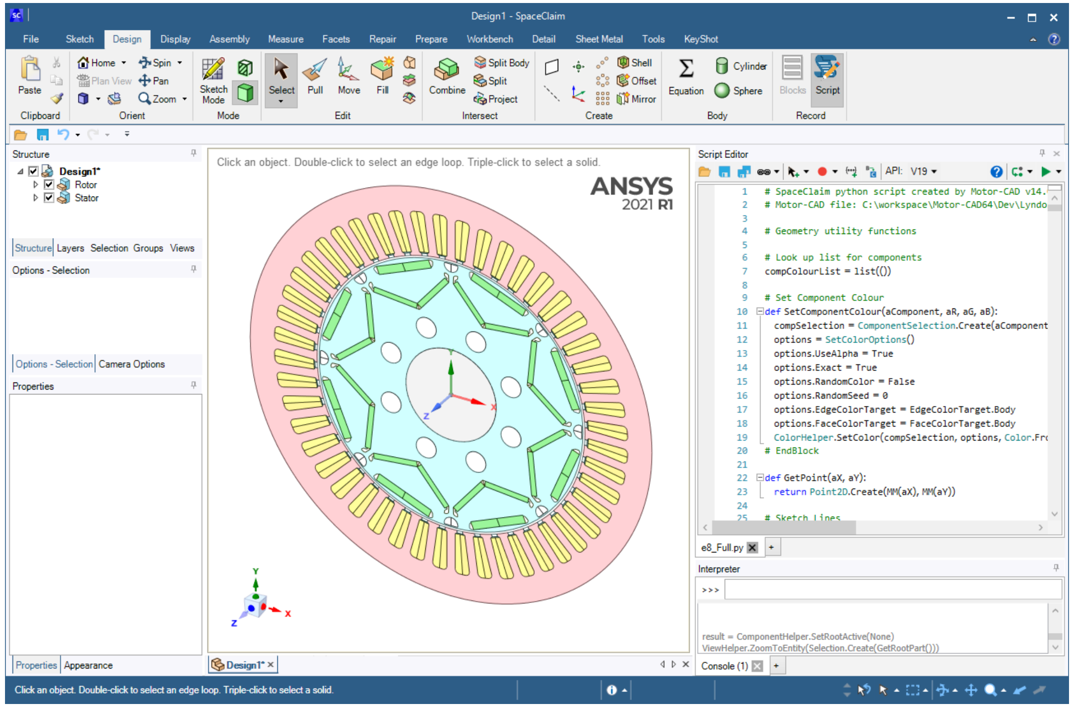




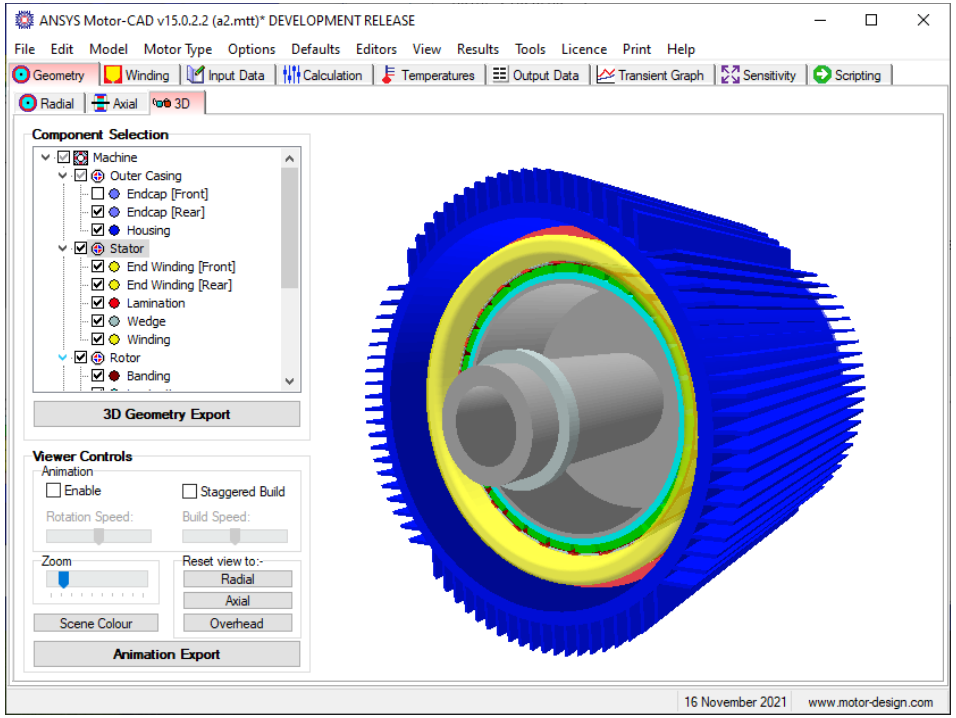
Export of geometries to Ansys Discovery (2/4)

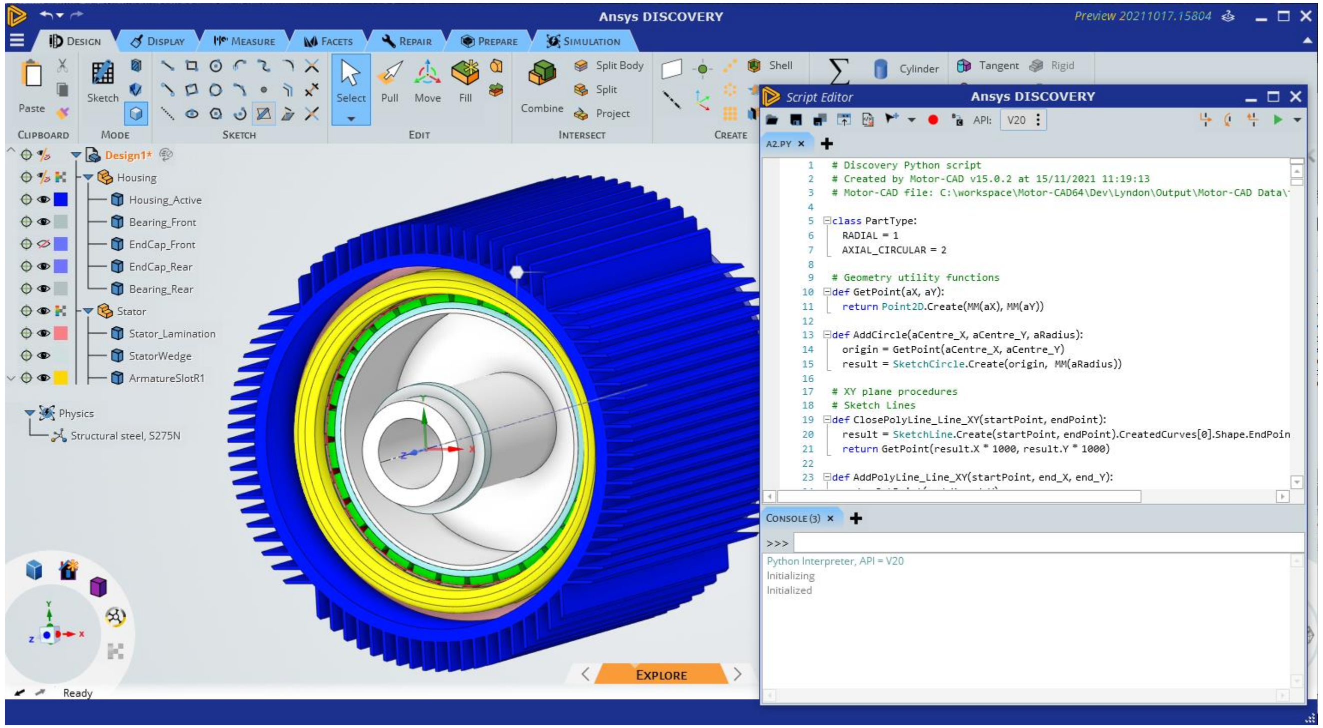






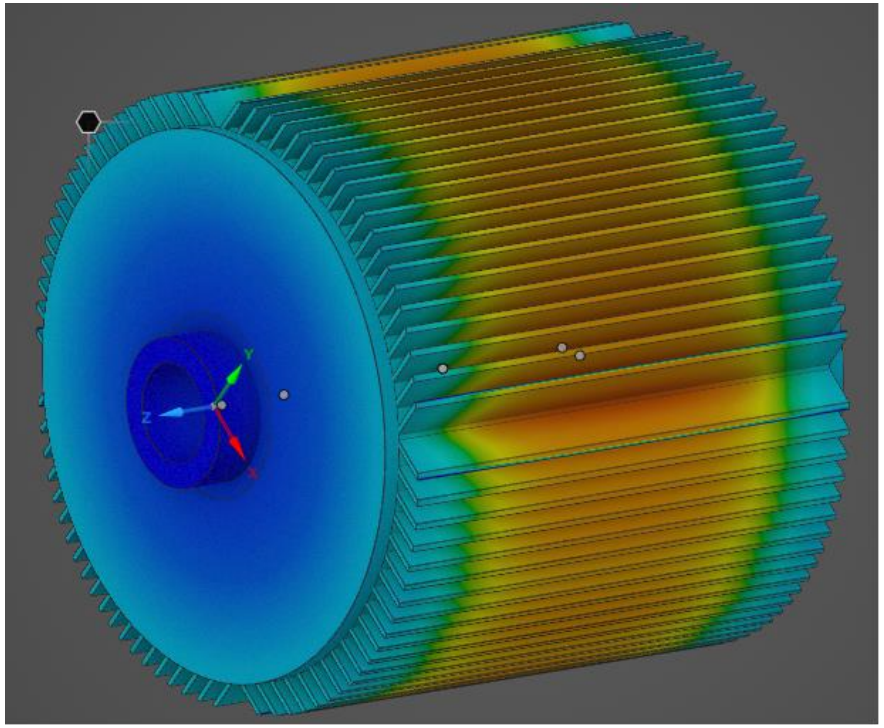
Export of geometries to Ansys Discovery (3/4)

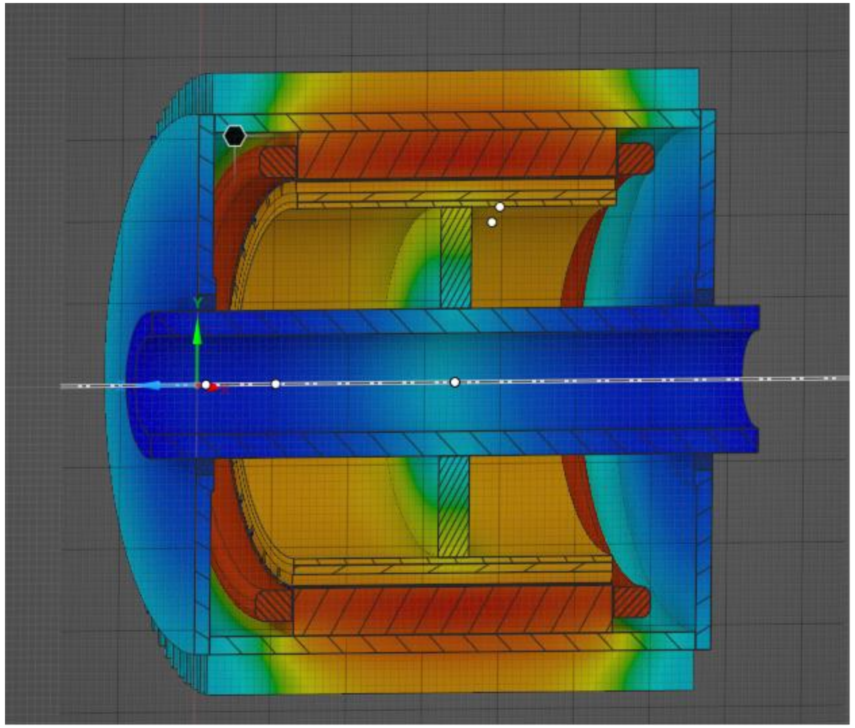




Thermal Analysis in Ansys Discovery (4/4)

- Geometry exported from Motor-CAD can then be used for more detailed analysis in Ansys Discovery
- This example shows thermal analysis of the machine in Ansys Discovery





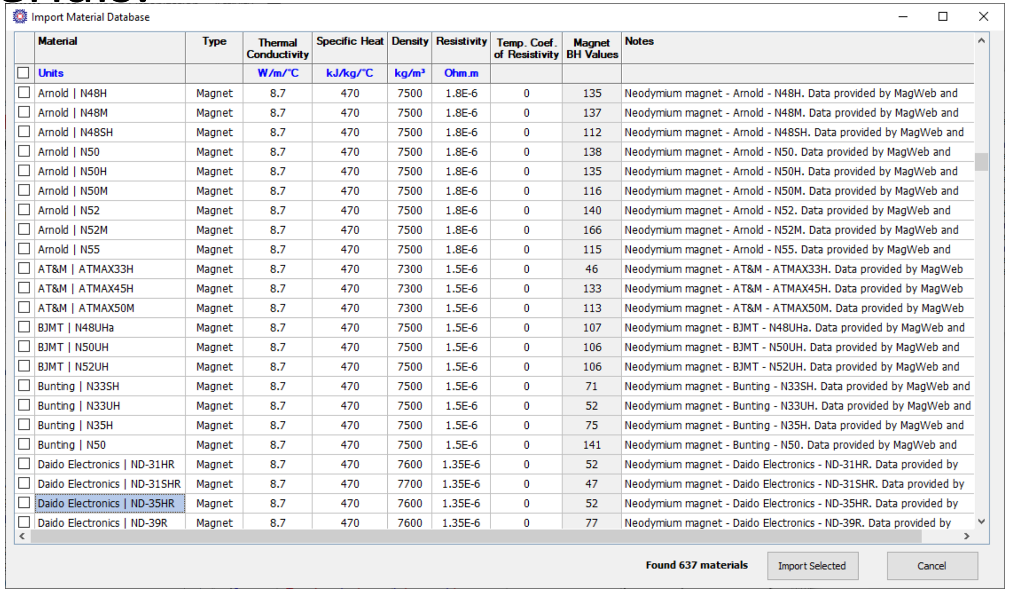
Granta Material Database (1/2)

Large database of Magnet and Electrical Steel materials from Granta are now included with Motor-CAD (>800 materials).

- Import materials from Granta databases.
- Granta licence required to access these materials.

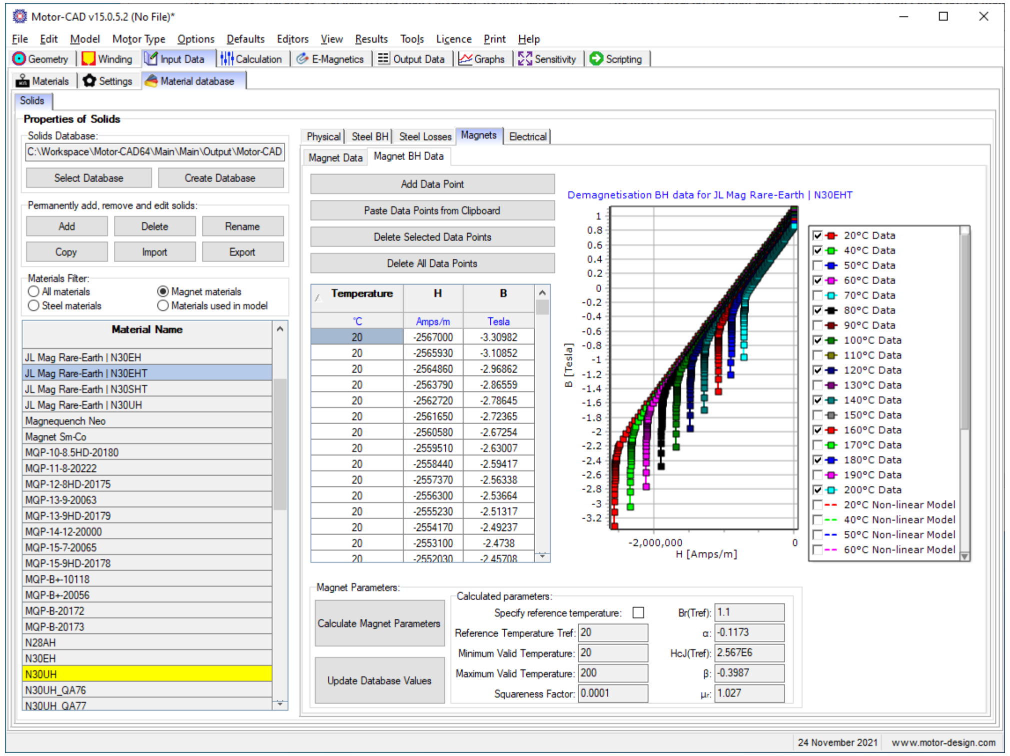
AlNiCo_magnet.gdb
Bonded_molded_magnet.gdb
Ferrite_ceramic_magnet.gdb
Neodymium_magnet.gdb
Neodymium_magnet_JL_Mag.gdb
Samarium_cobalt_magnet.gdb

Alloy_powder_core.gdb
Cobalt_steel.gdb
Electrical_steel_grain_oriented.gdb
Electrical_steel_non_grain_oriented.gdb
Ferrite_core.gdb
Iron_powder_core_plus_SMC.gdb
Metglas_and_nanocrystalline.gdb
Nickel_steel.gdb

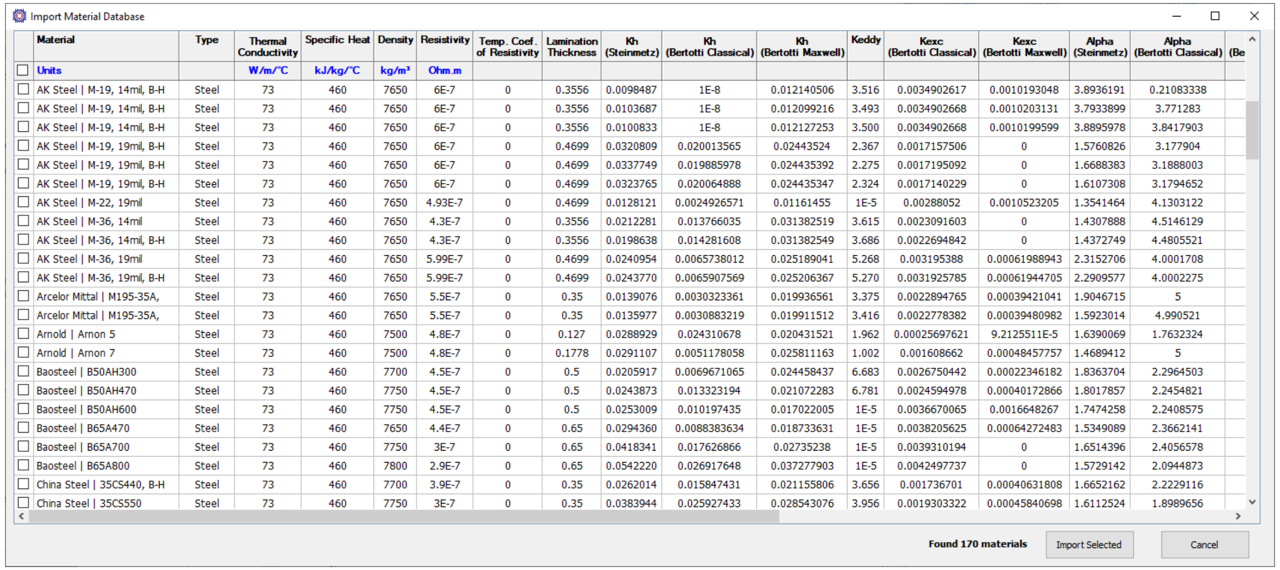

Import Material Database

Material	Type	Thermal Conductivity	Specific Heat	Density	Resistivity	Temp. Coef. of Resistivity	Magnet BH Values	Notes
Units		W/m/°C	kJ/kg/°C	kg/m³	Ohm.m			
Arnold | N48H	Magnet	8.7	470	7500	1.8E-6	0	135	Neodymium magnet - Arnold - N48H. Data provided by MagWeb and
Arnold | N48M	Magnet	8.7	470	7500	1.8E-6	0	137	Neodymium magnet - Arnold - N48M. Data provided by MagWeb and
Arnold | N48SH	Magnet	8.7	470	7500	1.8E-6	0	112	Neodymium magnet - Arnold - N48SH. Data provided by MagWeb and
Arnold | N50	Magnet	8.7	470	7500	1.8E-6	0	138	Neodymium magnet - Arnold - N50. Data provided by MagWeb and
Arnold | N50H	Magnet	8.7	470	7500	1.8E-6	0	135	Neodymium magnet - Arnold - N50H. Data provided by MagWeb and
Arnold | N50M	Magnet	8.7	470	7500	1.8E-6	0	116	Neodymium magnet - Arnold - N50M. Data provided by MagWeb and
Arnold | N52	Magnet	8.7	470	7500	1.8E-6	0	140	Neodymium magnet - Arnold - N52. Data provided by MagWeb and
Arnold | N52M	Magnet	8.7	470	7500	1.8E-6	0	166	Neodymium magnet - Arnold - N52M. Data provided by MagWeb and
Arnold | N55	Magnet	8.7	470	7500	1.8E-6	0	115	Neodymium magnet - Arnold - N55. Data provided by MagWeb and
AT&M | ATMAX33H	Magnet	8.7	470	7300	1.5E-6	0	46	Neodymium magnet - AT&M - ATMAX33H. Data provided by MagWeb
AT&M | ATMAX45H	Magnet	8.7	470	7300	1.5E-6	0	133	Neodymium magnet - AT&M - ATMAX45H. Data provided by MagWeb
AT&M | ATMAX50M	Magnet	8.7	470	7300	1.5E-6	0	113	Neodymium magnet - AT&M - ATMAX50M. Data provided by MagWeb
BJMT | N48UHa	Magnet	8.7	470	7500	1.5E-6	0	107	Neodymium magnet - BJMT - N48UHa. Data provided by MagWeb and
BJMT | N50UH	Magnet	8.7	470	7500	1.5E-6	0	106	Neodymium magnet - BJMT - N50UH. Data provided by MagWeb and
BJMT | N52UH	Magnet	8.7	470	7500	1.5E-6	0	106	Neodymium magnet - BJMT - N52UH. Data provided by MagWeb and
Bunting | N33SH	Magnet	8.7	470	7500	1.5E-6	0	71	Neodymium magnet - Bunting - N33SH. Data provided by MagWeb and
Bunting | N33UH	Magnet	8.7	470	7500	1.5E-6	0	52	Neodymium magnet - Bunting - N33UH. Data provided by MagWeb and
Bunting | N35H	Magnet	8.7	470	7500	1.5E-6	0	75	Neodymium magnet - Bunting - N35H. Data provided by MagWeb and
Bunting | N50	Magnet	8.7	470	7500	1.5E-6	0	141	Neodymium magnet - Bunting - N50. Data provided by MagWeb and
Daido Electronics | ND-31HR	Magnet	8.7	470	7600	1.35E-6	0	52	Neodymium magnet - Daido Electronics - ND-31HR. Data provided by
Daido Electronics | ND-31SHR	Magnet	8.7	470	7700	1.35E-6	0	47	Neodymium magnet - Daido Electronics - ND-31SHR. Data provided by
Daido Electronics | ND-35HR	Magnet	8.7	470	7600	1.35E-6	0	52	Neodymium magnet - Daido Electronics - ND-35HR. Data provided by
Daido Electronics | ND-39R	Magnet	8.7	470	7600	1.35E-6	0	77	Neodymium magnet - Daido Electronics - ND-39R. Data provided by

Found 637 materials   Import Selected   Cancel



Granta Material Database (2/2)

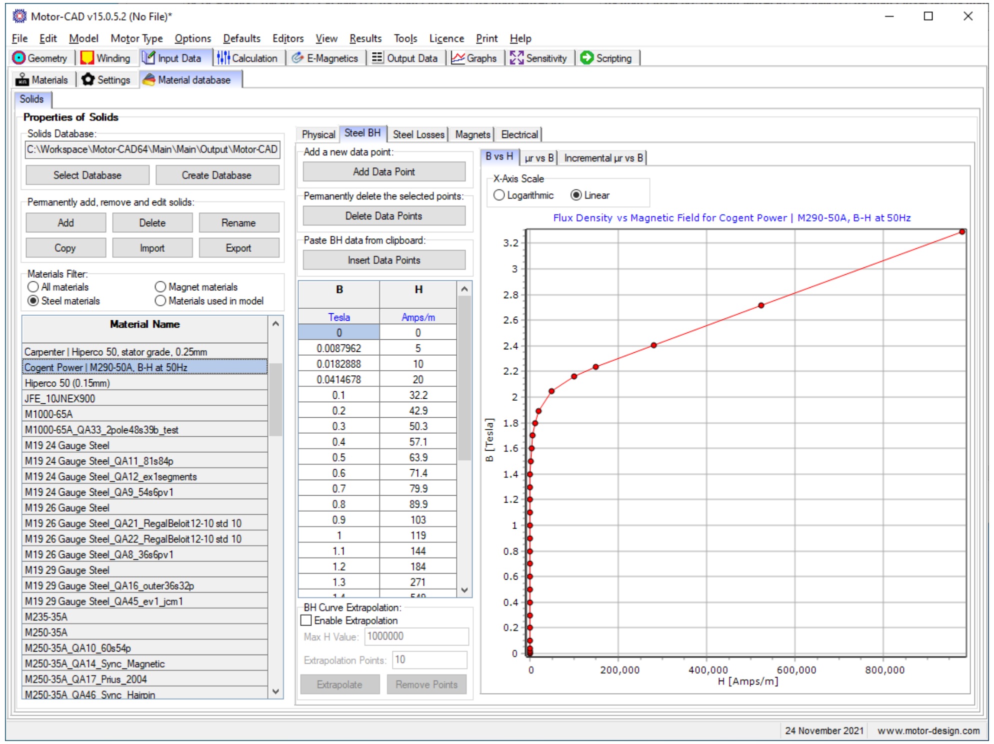


Import Material Database

	Material	Type	Thermal Conductivity	Specific Heat	Density	Resistivity	Temp. Coef. of Resistivity	Lamination Thickness	Kh (Steinmetz)	Kh (Bertotti Classical)	Kh (Bertotti Maxwell)	Keddy	Kexc (Bertotti Classical)	Kexc (Bertotti Maxwell)	Alpha (Steinmetz)	Alpha (Bertotti Classical)
☐	Units		W/m/°C	kJ/kg/°C	kg/m³	Ohm.m										
☐	AK Steel | M-19, 14mil, B-H	Steel	73	460	7650	6E-7	0	0.3556	0.0098487	1E-8	0.012140506	3.516	0.0034902617	0.0010193048	3.8936191	0.21083338
☐	AK Steel | M-19, 14mil, B-H	Steel	73	460	7650	6E-7	0	0.3556	0.0103687	1E-8	0.012099216	3.493	0.0034902668	0.0010203131	3.7933899	3.771283
☐	AK Steel | M-19, 14mil, B-H	Steel	73	460	7650	6E-7	0	0.3556	0.0100833	1E-8	0.012127253	3.500	0.0034902668	0.0010199599	3.8895978	3.8417903
☐	AK Steel | M-19, 19mil, B-H	Steel	73	460	7650	6E-7	0	0.4699	0.0320809	0.020013565	0.02443524	2.367	0.0017157506	0	1.5760826	3.177904
☐	AK Steel | M-19, 19mil, B-H	Steel	73	460	7650	6E-7	0	0.4699	0.0337749	0.019885978	0.024435392	2.275	0.0017195092	0	1.6688383	3.1888003
☐	AK Steel | M-19, 19mil, B-H	Steel	73	460	7650	6E-7	0	0.4699	0.0323765	0.020064888	0.024435347	2.324	0.0017140229	0	1.6107308	3.1794652
☐	AK Steel | M-22, 19mil	Steel	73	460	7650	4.93E-7	0	0.4699	0.0128121	0.0024926571	0.01161455	1E-5	0.00288052	0.0010523205	1.3541464	4.1303122
☐	AK Steel | M-36, 14mil	Steel	73	460	7650	4.3E-7	0	0.3556	0.0212281	0.013766035	0.031382519	3.615	0.0023091603	0	1.4307888	4.5146129
☐	AK Steel | M-36, 14mil, B-H	Steel	73	460	7650	4.3E-7	0	0.3556	0.0198638	0.014281608	0.031382549	3.686	0.0022694842	0	1.4372749	4.4805521
☐	AK Steel | M-36, 19mil	Steel	73	460	7650	5.99E-7	0	0.4699	0.0240954	0.0065738012	0.025189041	5.268	0.003195388	0.00061988943	2.3152706	4.0001708
☐	AK Steel | M-36, 19mil, B-H	Steel	73	460	7650	5.99E-7	0	0.4699	0.0243770	0.0065907569	0.025206367	5.270	0.0031925785	0.00061944705	2.2909577	4.0002275
☐	Arcelor Mittal | M195-35A,	Steel	73	460	7650	5.5E-7	0	0.35	0.0139076	0.0030323361	0.019936561	3.375	0.0022894765	0.00039421041	1.9046715	5
☐	Arcelor Mittal | M195-35A,	Steel	73	460	7650	5.5E-7	0	0.35	0.0135977	0.0030883219	0.019911512	3.416	0.0022778382	0.00039480982	1.5923014	4.990521
☐	Arnold | Arnon 5	Steel	73	460	7500	4.8E-7	0	0.127	0.0288929	0.024310678	0.020431521	1.962	0.00025697621	9.2125511E-5	1.6390069	1.7632324
☐	Arnold | Arnon 7	Steel	73	460	7500	4.8E-7	0	0.1778	0.0291107	0.0051178058	0.025811163	1.002	0.001608662	0.00048457757	1.4689412	5
☐	Baosteel | B50AH300	Steel	73	460	7700	4.5E-7	0	0.5	0.0205917	0.0069671065	0.024458437	6.683	0.0026750442	0.00022346182	1.8363704	2.2964503
☐	Baosteel | B50AH470	Steel	73	460	7750	4.5E-7	0	0.5	0.0243873	0.013323194	0.021072283	6.781	0.0024594978	0.00040172866	1.8017857	2.2454821
☐	Baosteel | B50AH600	Steel	73	460	7750	4.5E-7	0	0.5	0.0253009	0.010197435	0.017022005	1E-5	0.0036670065	0.0016648267	1.7474258	2.2408575
☐	Baosteel | B65A470	Steel	73	460	7650	4.4E-7	0	0.65	0.0294360	0.0088383634	0.018733631	1E-5	0.0038205625	0.00064272483	1.5349089	2.3662141
☐	Baosteel | B65A700	Steel	73	460	7750	3E-7	0	0.65	0.0418341	0.017626866	0.02735238	1E-5	0.0039310194	0	1.6514396	2.4056578
☐	Baosteel | B65A800	Steel	73	460	7800	2.9E-7	0	0.65	0.0542220	0.026917648	0.037277903	1E-5	0.0042497737	0	1.5729142	2.0944873
☐	China Steel | 35CS440, B-H	Steel	73	460	7700	3.9E-7	0	0.35	0.0262014	0.015847431	0.021155806	3.656	0.001736701	0.00040631808	1.6652162	2.2229116
☐	China Steel | 35CS550	Steel	73	460	7750	3E-7	0	0.35	0.0383944	0.025927433	0.028543076	3.956	0.0019303322	0.00045840698	1.6112524	1.8989656

Found 170 materials | Import Selected | Cancel

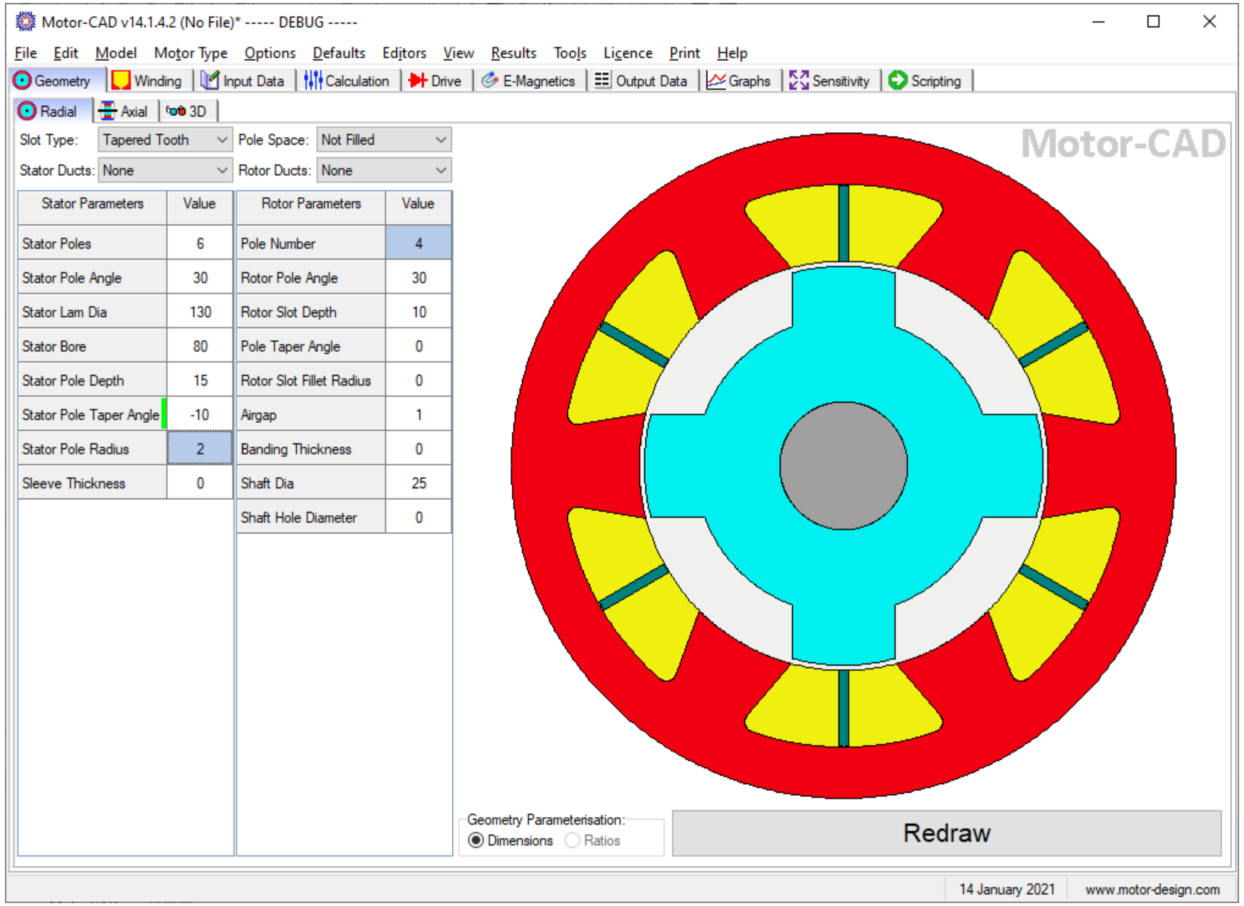
- AlNiCo_magnet.gdb
- Bonded_molded_magnet.gdb
- Ferrite_ceramic_magnet.gdb
- Neodymium_magnet.gdb
- Neodymium_magnet_JL_Mag.gdb
- Samarium_cobalt_magnet.gdb
- Alloy_powder_core.gdb
- Cobalt_steel.gdb
- Electrical_steel_grain_oriented.gdb
- Electrical_steel_non_grain_oriented.gdb
- Ferrite_core.gdb
- Iron_powder_core_plus_SMC.gdb
- Metglas_and_nanocrystalline.gdb
- Nickel_steel.gdb



Usability (UX)

New tapered tooth SRM geometry

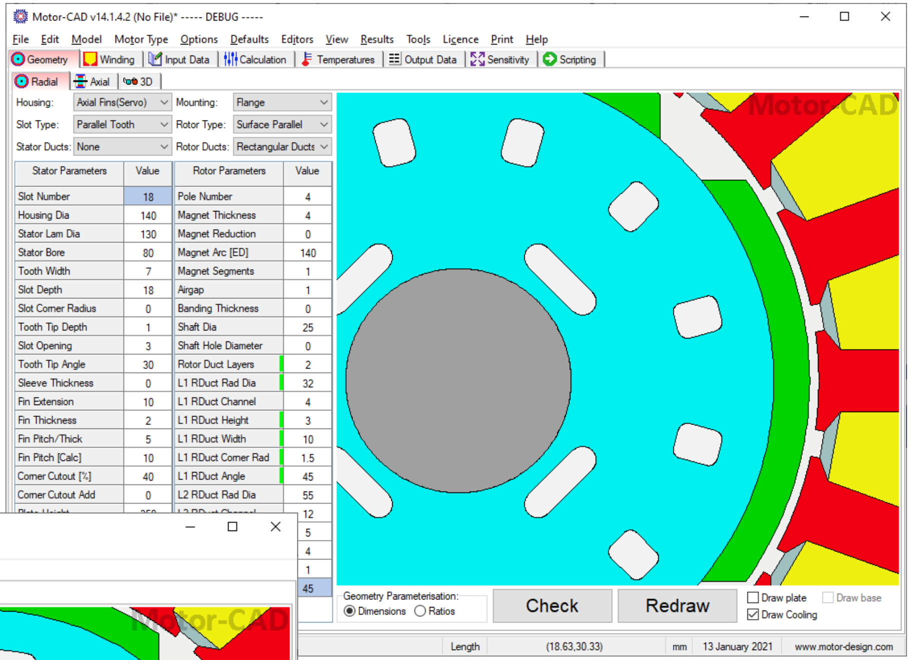
- New taper angle of stator pole option

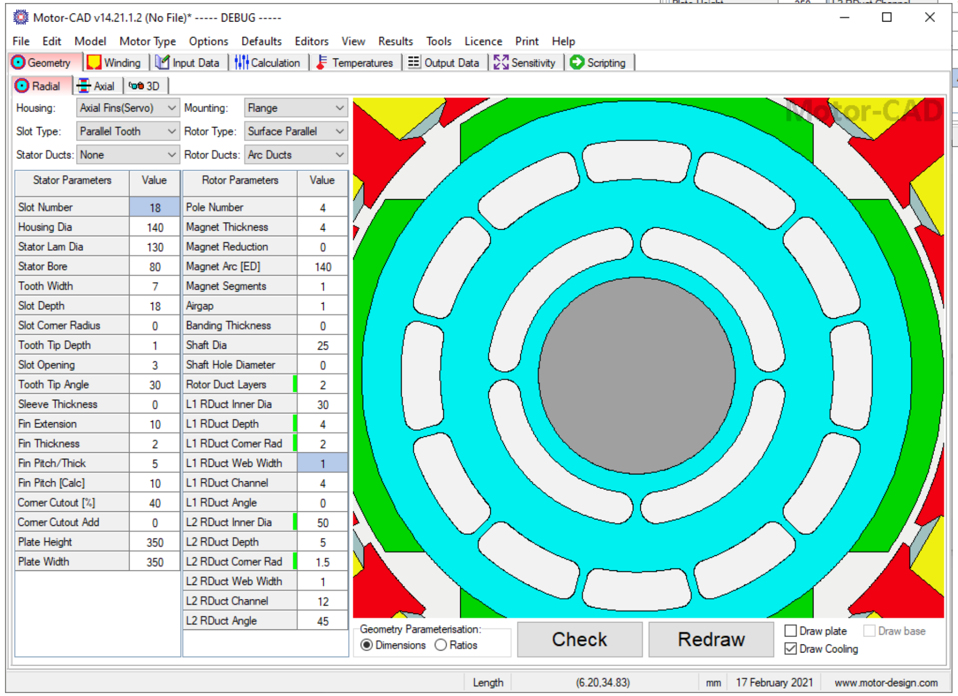


Rounding of duct corners

Important for Emag and mechanical calculations

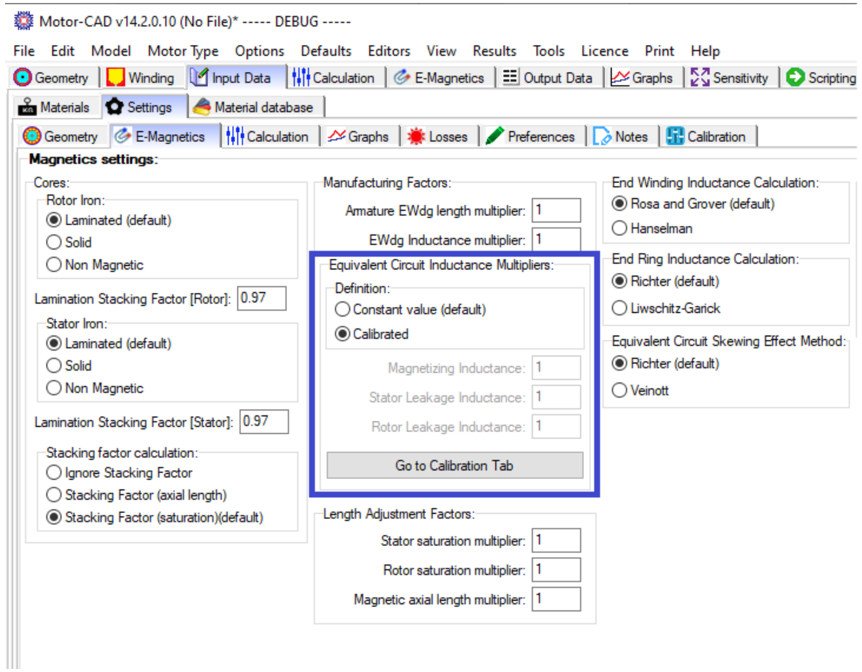
- Rectangular ducts
- Arc ducts
- Separate rounding parameter for each duct layer
- Stator, housing and rotor ducts

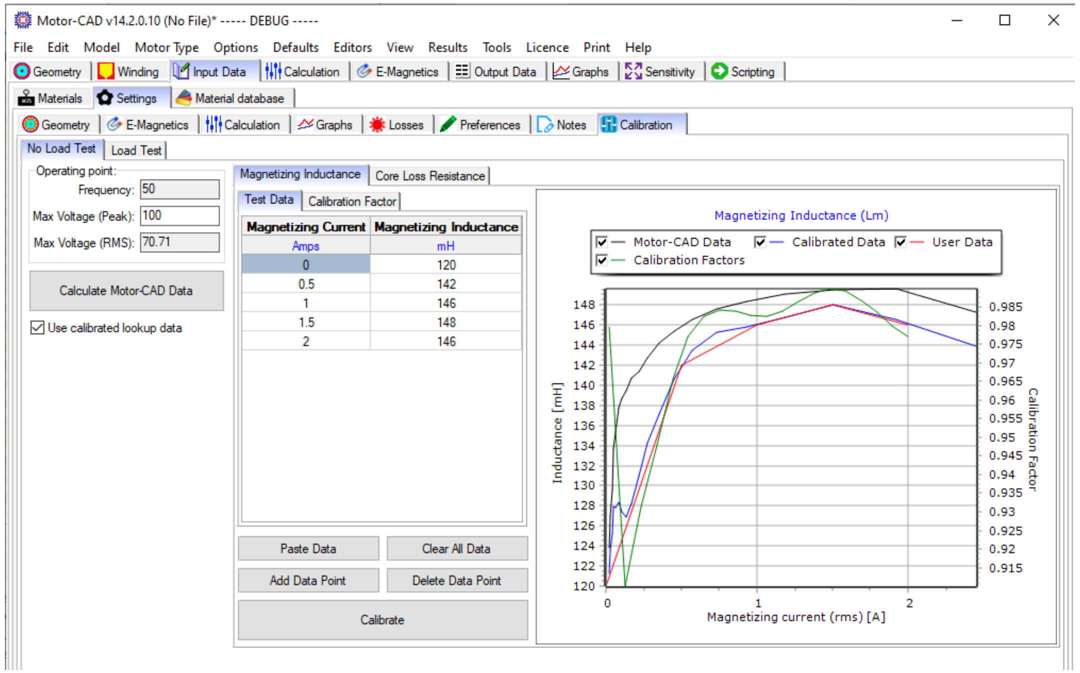




Calibrated of Induction Machine equivalent circuit parameters

- Calibration of equivalent circuit multipliers from test data.
  - No-load test -> Lm and Rfe as functions of magnetizing current and Back EMF. Used for calibrating lookup data.
  - Load test -> L1, L2 and R2 as functions of speed.

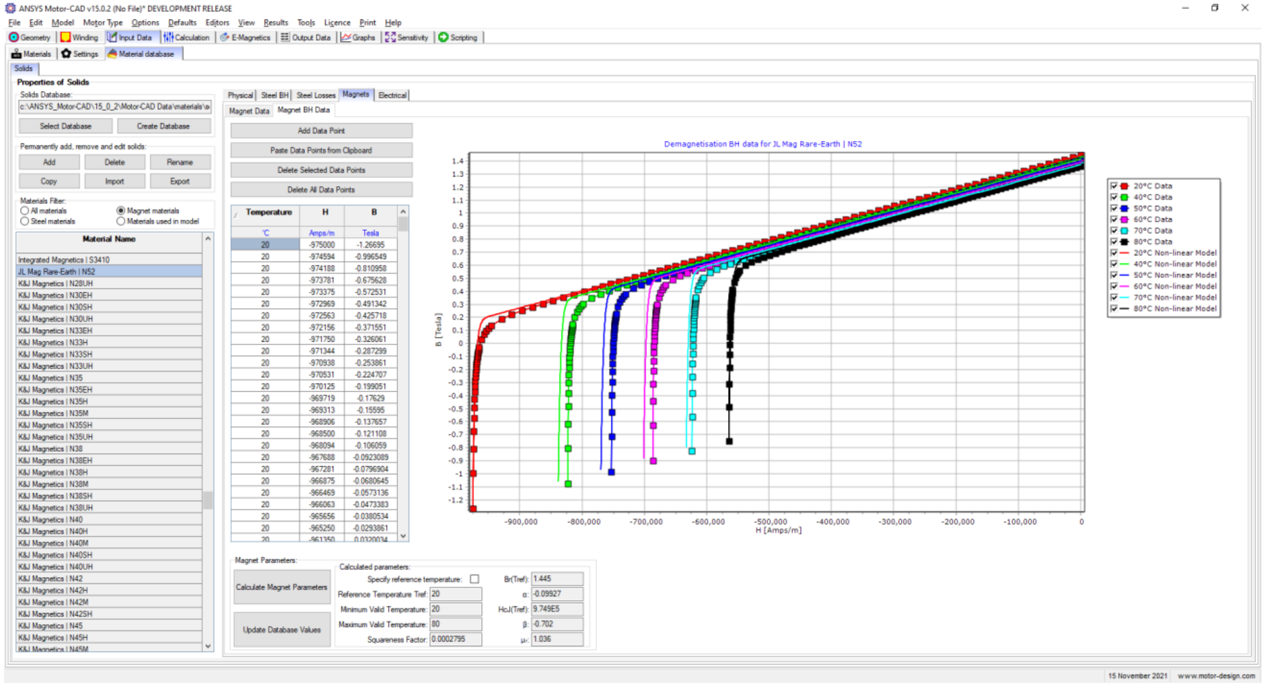


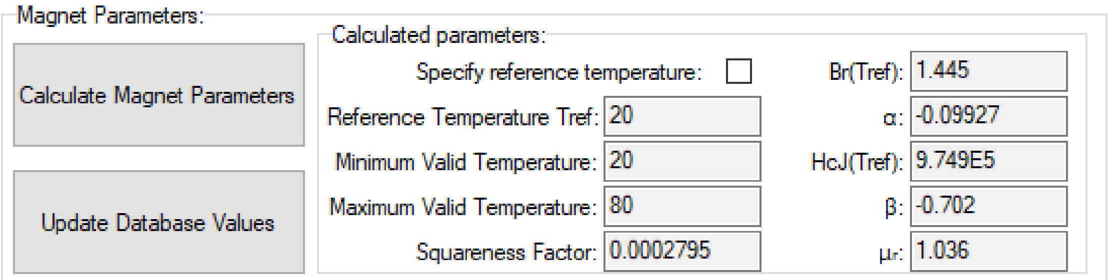


Magnet Data Fitting

New functionality to use demagnetisation curves:

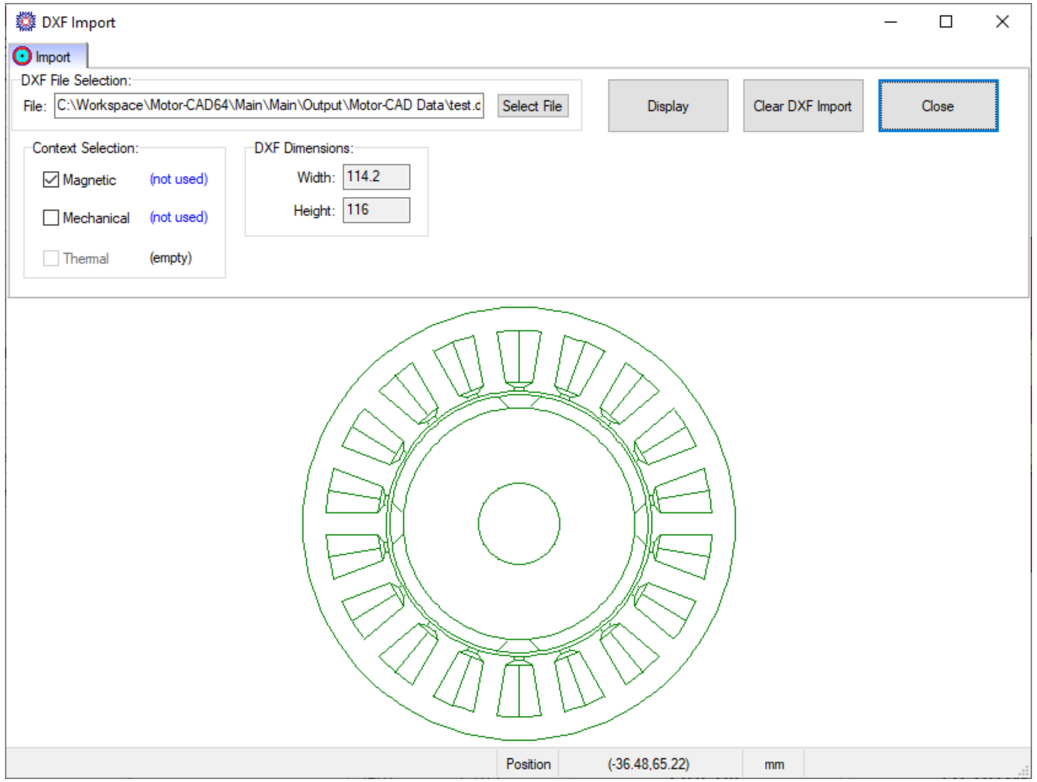
- Similar functionality to iron losses, each point needs a temperature, B value and H value
- Calculate magnet parameters from the data to use in Motor-CAD model:
  - Br(Tref)
  - HcJ(Tref)
  - α
  - β
  - μr
  - Squareness factor
- Can specify reference temperature to increase accuracy for most 'useful' magnet temperature

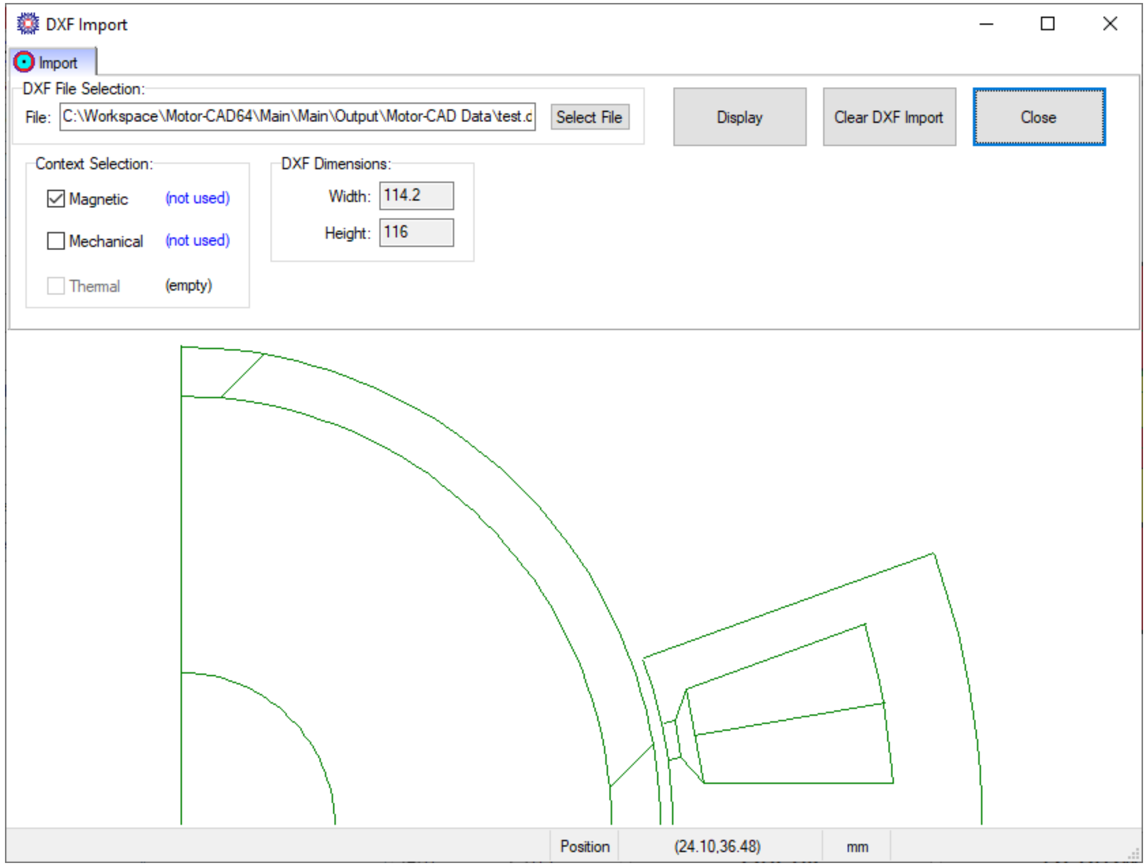




DXF Import Interface

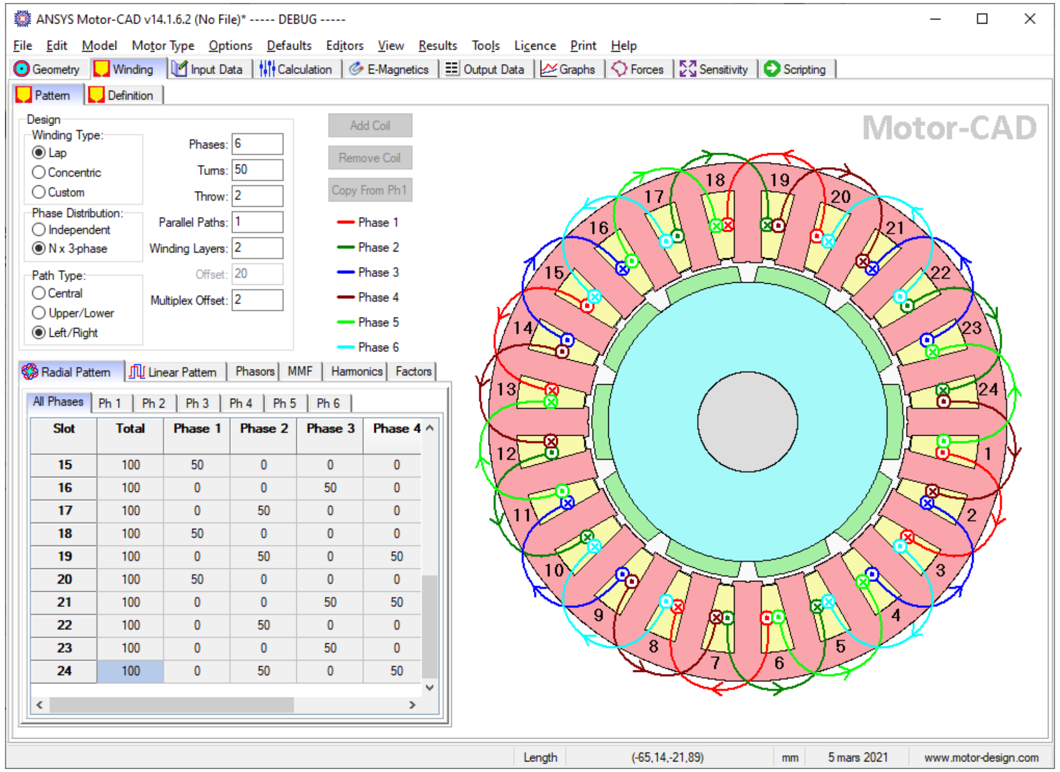
- Interface showing imported dxf
- Easier to check imported dxf geometry

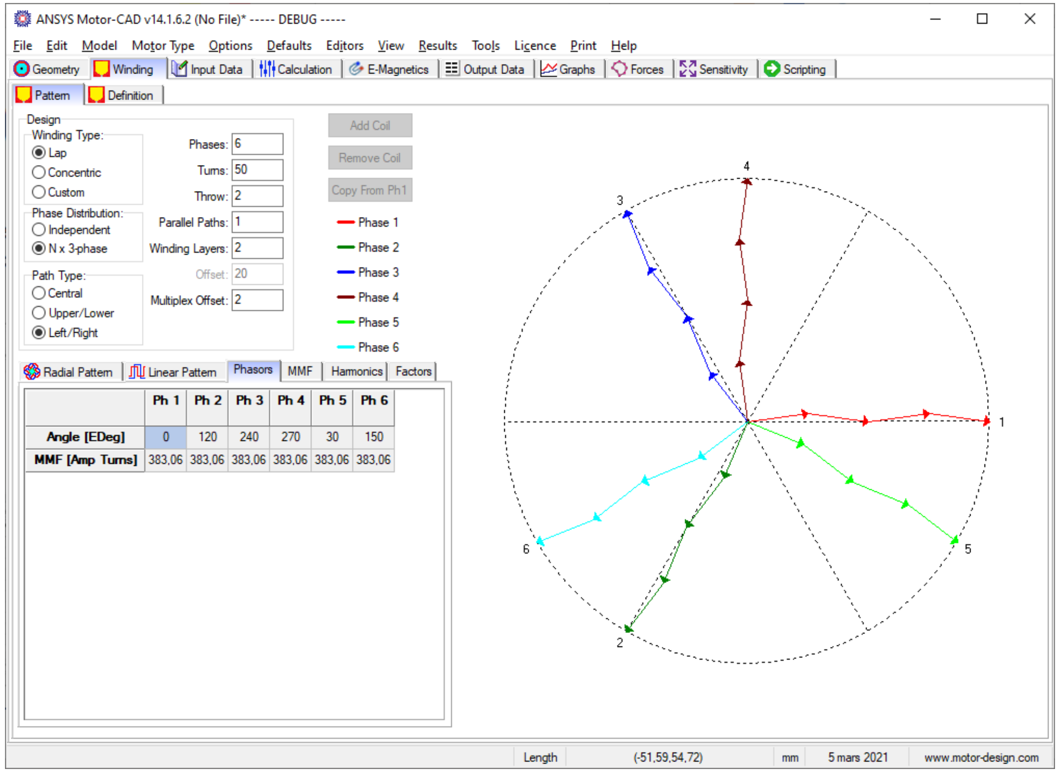




Multiphase Winding improvement

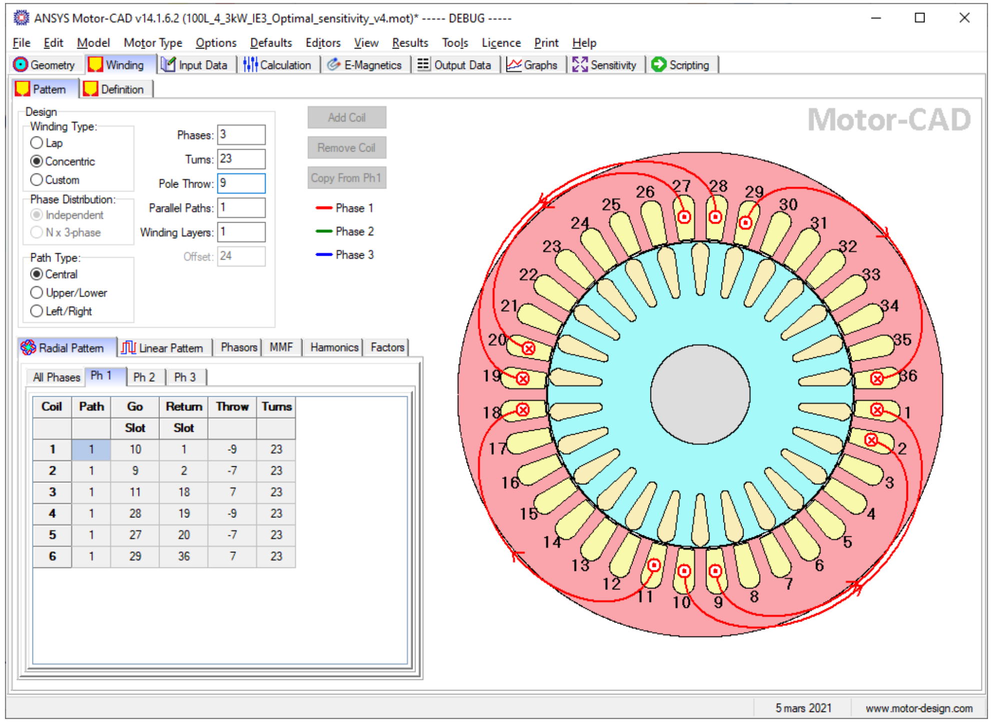
- New option to specify the multiphase offset between phasegroups

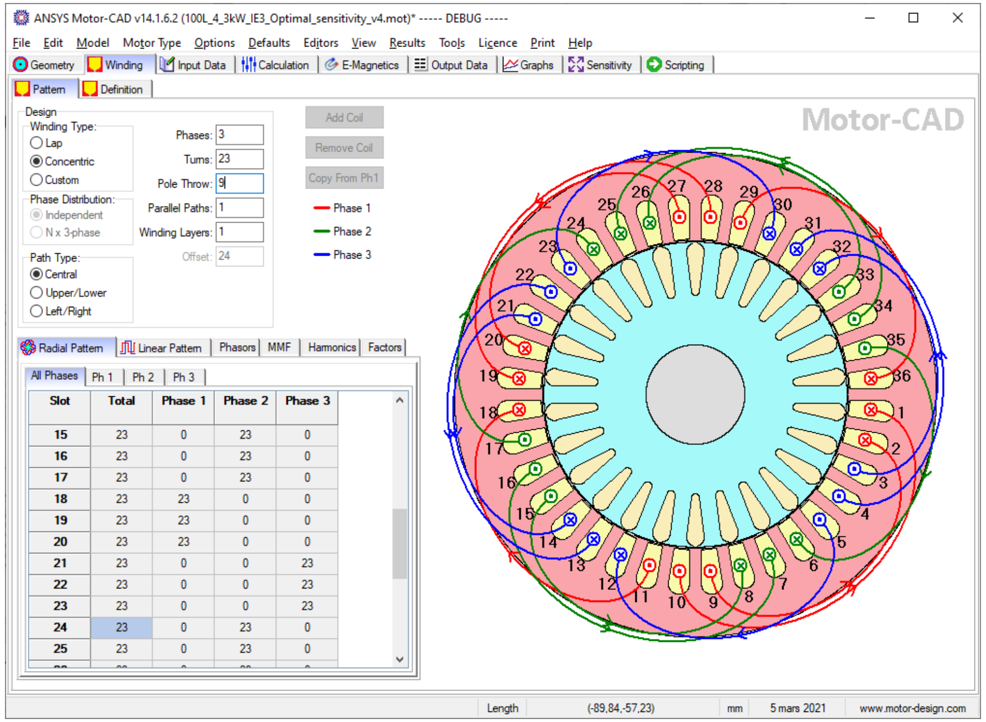




Concentric winding improvement

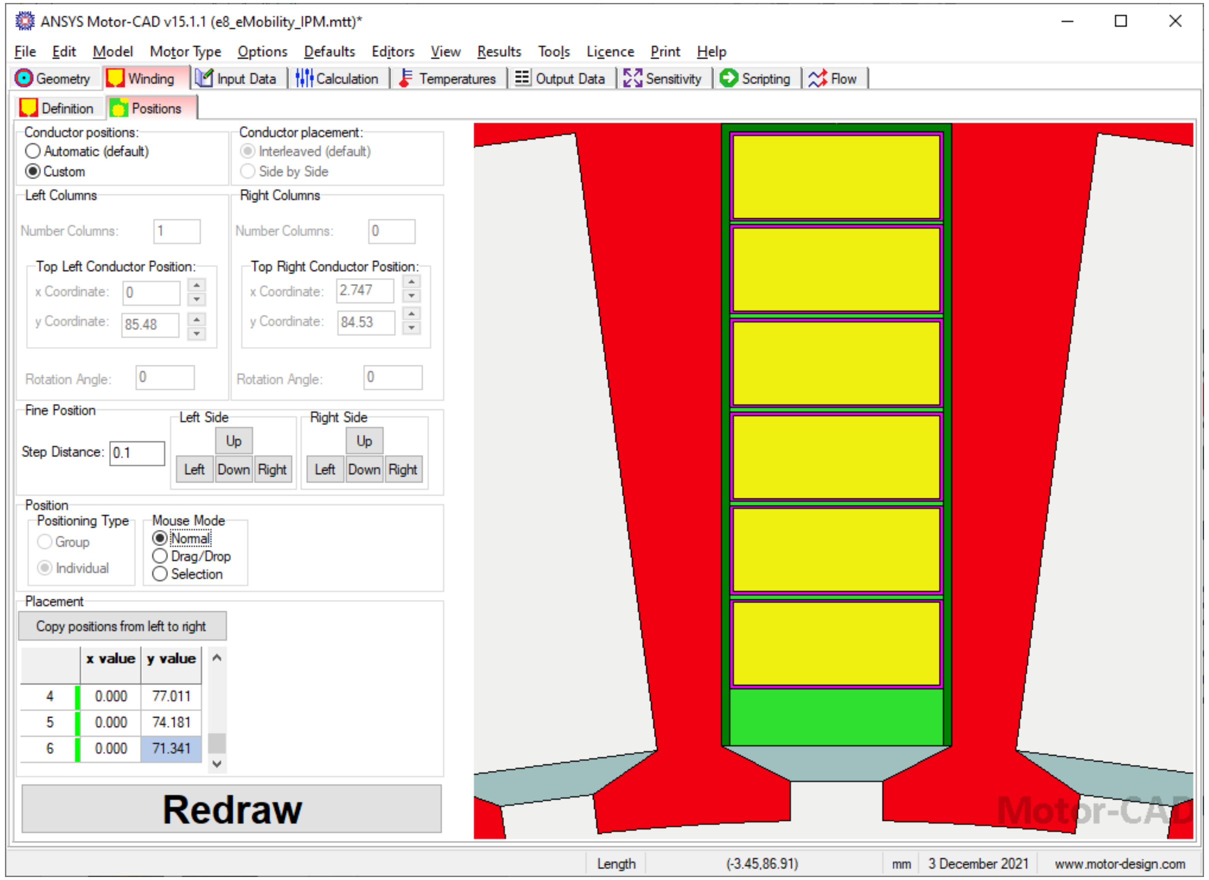
- Improved Concentric winding options
- Added winding when have non integer number of coils per pole
- e.g. For 36 slots 4 poles have average of 1.5 coils per pole





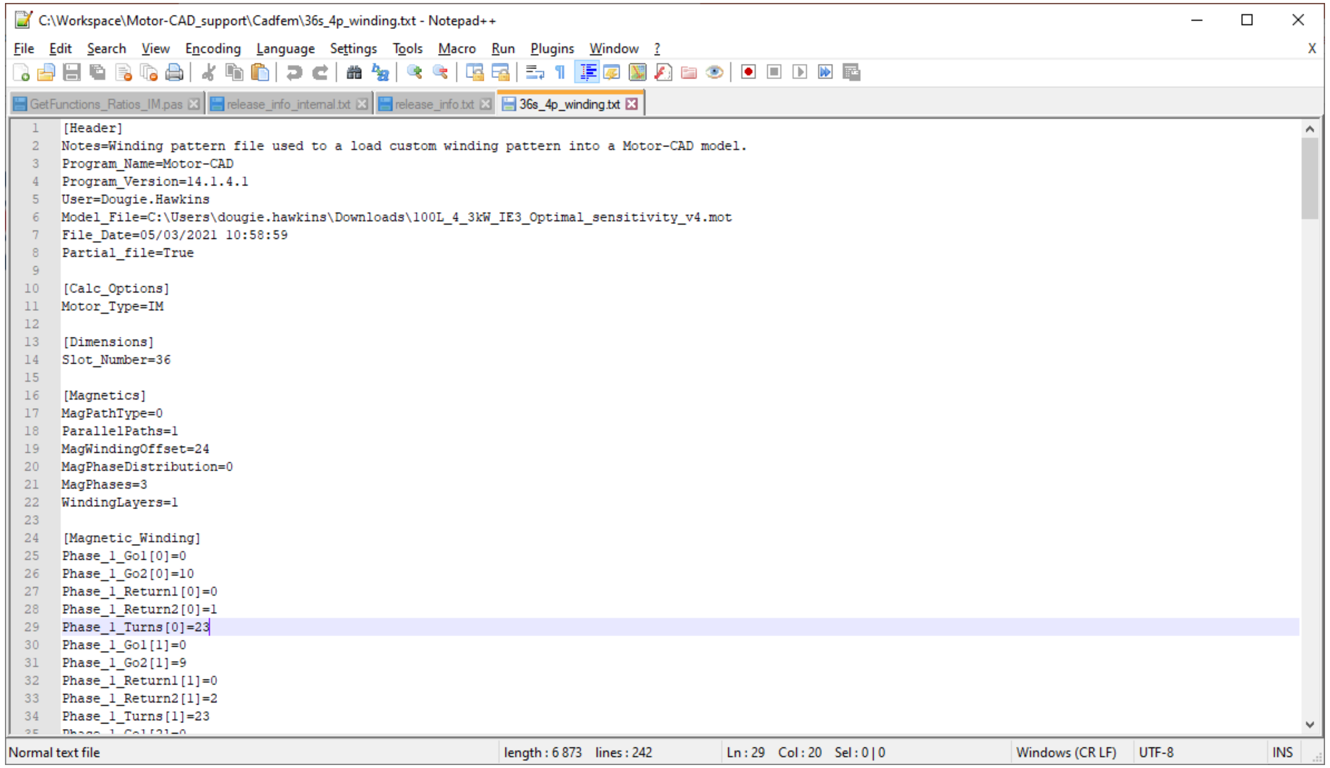
Improved custom conductor placement

- Improved interface for specifying each conductor locations in slot.
- Important for designs where AC winding losses are significant.



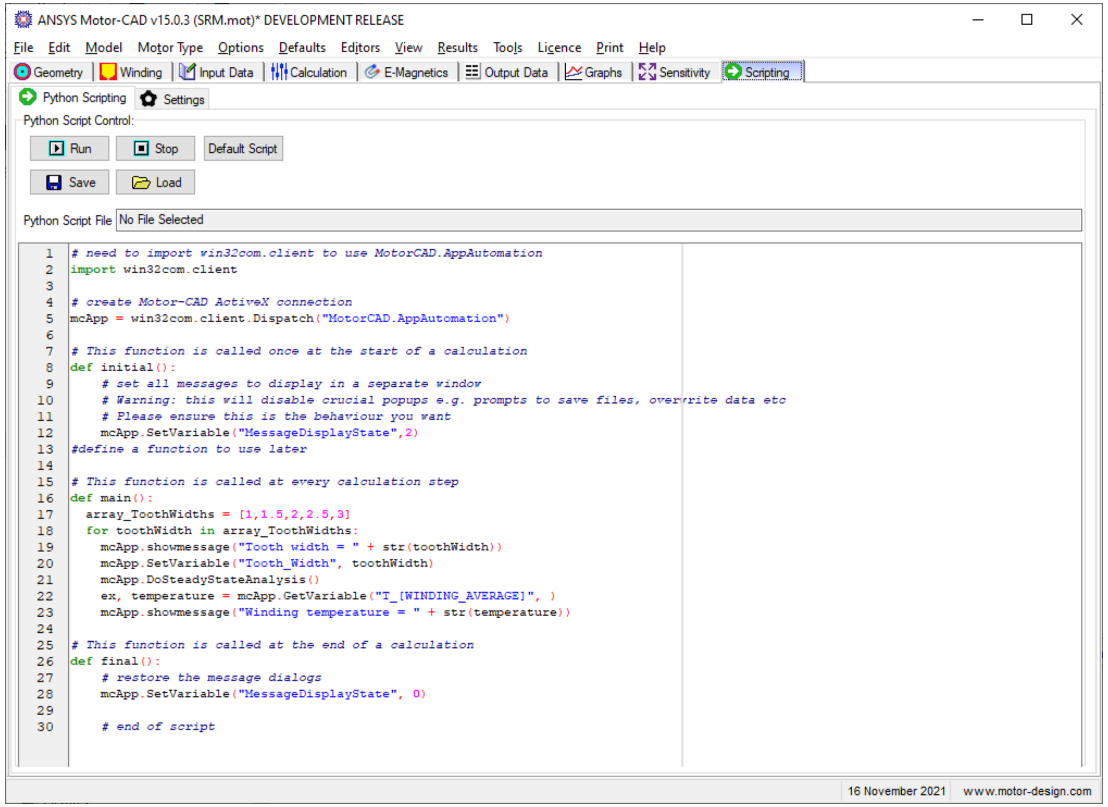
Load / save winding pattern

- New option to load or save a winding pattern from a file
- Also enabled for ActiveX



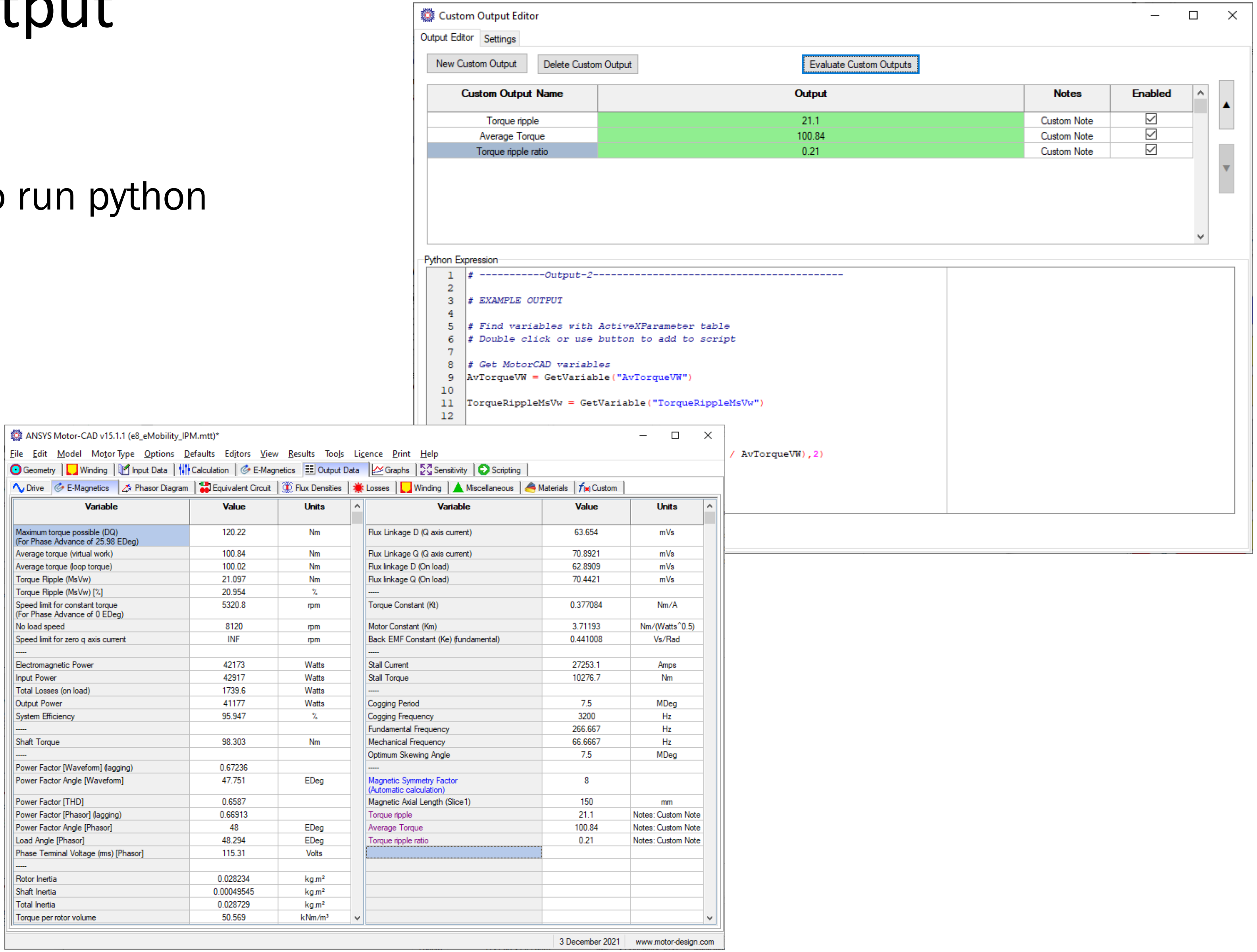
Python scripting interface

- User interface to allow users to run python scripts.
- Gives full functionality of Python to user scripts.
- Examples:
  - Generate non template geometries
  - Calculate currents during EMag calculations
  - Calculate heat transfer coefficients during thermal calcs
  - Calculate losses in thermal calcs
  - Automate workflows with Ansys tools (Maxwell, Discovery, Fluent)



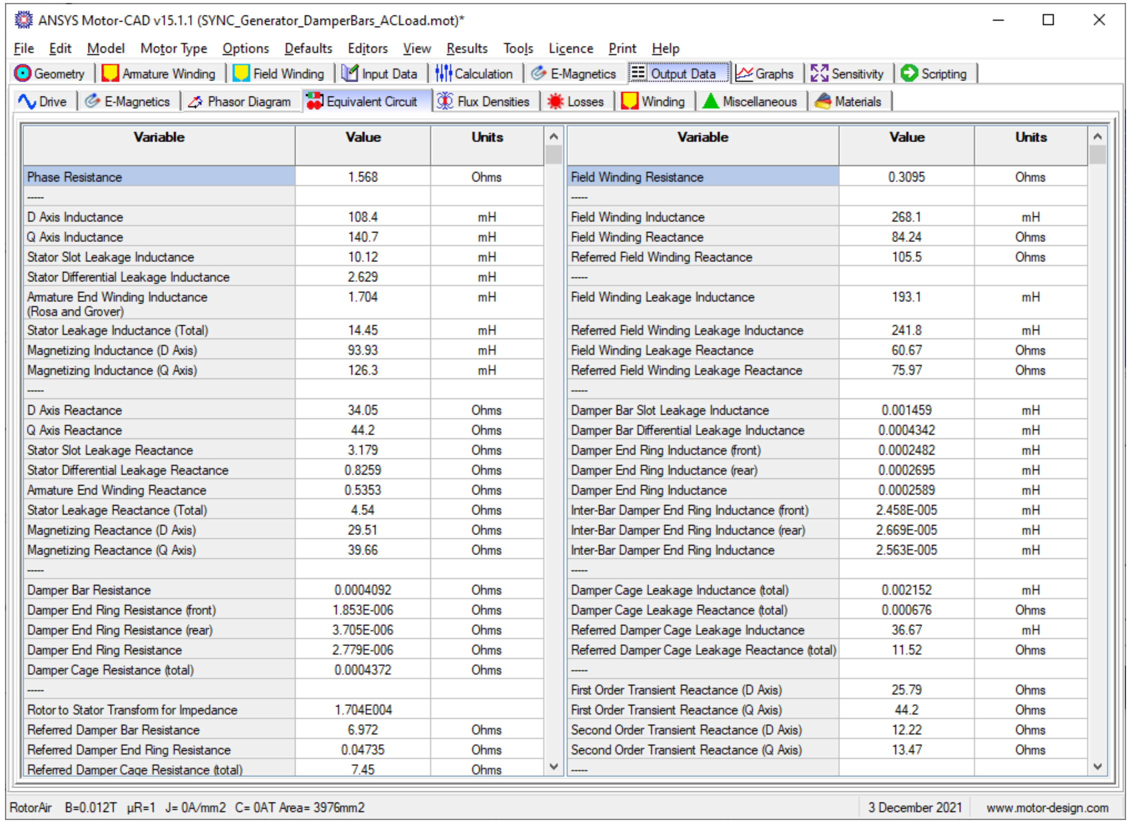
Improved custom output

- User interface to allow users to run python scripts for custom outputs.
- Very flexible able to get:
  – Calculated values
  – Graph values
  – Thermal circuit values
  – FEA result values

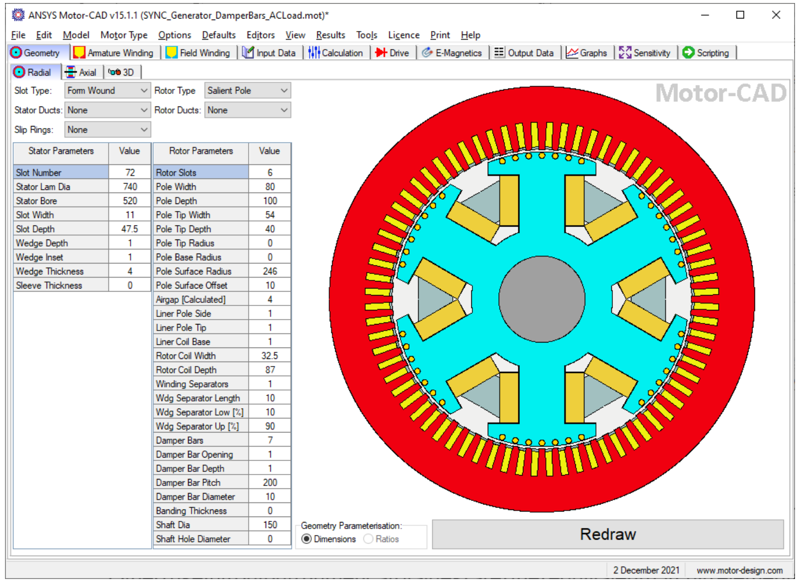


SYNC machine Rotor Damper Bars

- New modelling of rotor damper bars

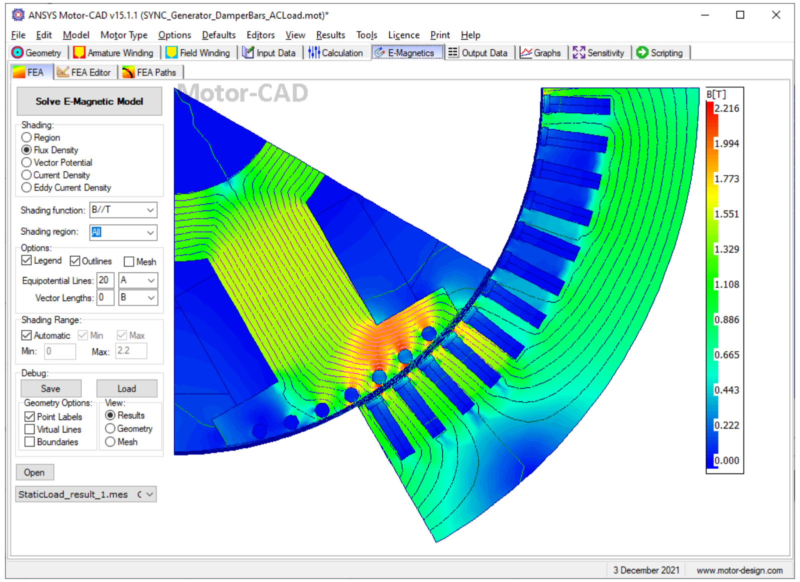


Variable	Value	Units	Variable	Value	Units
Phase Resistance	1.568	Ohms	Field Winding Resistance	0.3095	Ohms
-----			-----		
D Axis Inductance	108.4	mH	Field Winding Inductance	268.1	mH
Q Axis Inductance	140.7	mH	Field Winding Reactance	84.24	Ohms
Stator Slot Leakage Inductance	10.12	mH	Referred Field Winding Reactance	105.5	Ohms
Stator Differential Leakage Inductance	2.629	mH	-----		
Amature End Winding Inductance (Rosa and Grover)	1.704	mH	Field Winding Leakage Inductance	193.1	mH
Stator Leakage Inductance (Total)	14.45	mH	Referred Field Winding Leakage Inductance	241.8	mH
Magnetizing Inductance (D Axis)	93.93	mH	Field Winding Leakage Reactance	60.67	Ohms
Magnetizing Inductance (Q Axis)	126.3	mH	Referred Field Winding Leakage Reactance	75.97	Ohms
-----			-----		
D Axis Reactance	34.05	Ohms	Damper Bar Slot Leakage Inductance	0.001459	mH
Q Axis Reactance	44.2	Ohms	Damper Bar Differential Leakage Inductance	0.0004342	mH
Stator Slot Leakage Reactance	3.179	Ohms	Damper End Ring Inductance (front)	0.0002482	mH
Stator Differential Leakage Reactance	0.8259	Ohms	Damper End Ring Inductance (rear)	0.0002695	mH
Amature End Winding Reactance	0.5353	Ohms	Damper End Ring Inductance	0.0002589	mH
Stator Leakage Reactance (Total)	4.54	Ohms	Inter-Bar Damper End Ring Inductance (front)	2.458E-005	mH
Magnetizing Reactance (D Axis)	29.51	Ohms	Inter-Bar Damper End Ring Inductance (rear)	2.669E-005	mH
Magnetizing Reactance (Q Axis)	39.66	Ohms	Inter-Bar Damper End Ring Inductance	2.563E-005	mH
-----			-----		
Damper Bar Resistance	0.0004092	Ohms	Damper Cage Leakage Inductance (total)	0.002152	mH
Damper End Ring Resistance (front)	1.853E-006	Ohms	Damper Cage Leakage Reactance (total)	0.000676	Ohms
Damper End Ring Resistance (rear)	3.705E-006	Ohms	Referred Damper Cage Leakage Inductance	36.67	mH
Damper End Ring Resistance	2.779E-006	Ohms	Referred Damper Cage Leakage Reactance (total)	11.52	Ohms
Damper Cage Resistance (total)	0.0004372	Ohms	-----		
-----			First Order Transient Reactance (D Axis)	25.79	Ohms
Rotor to Stator Transform for Impedance	1.704E004		First Order Transient Reactance (Q Axis)	44.2	Ohms
Referred Damper Bar Resistance	6.972	Ohms	Second Order Transient Reactance (D Axis)	12.22	Ohms
Referred Damper End Ring Resistance	0.04735	Ohms	Second Order Transient Reactance (Q Axis)	13.47	Ohms
Referred Damper Cage Resistance (total)	7.45	Ohms	-----		



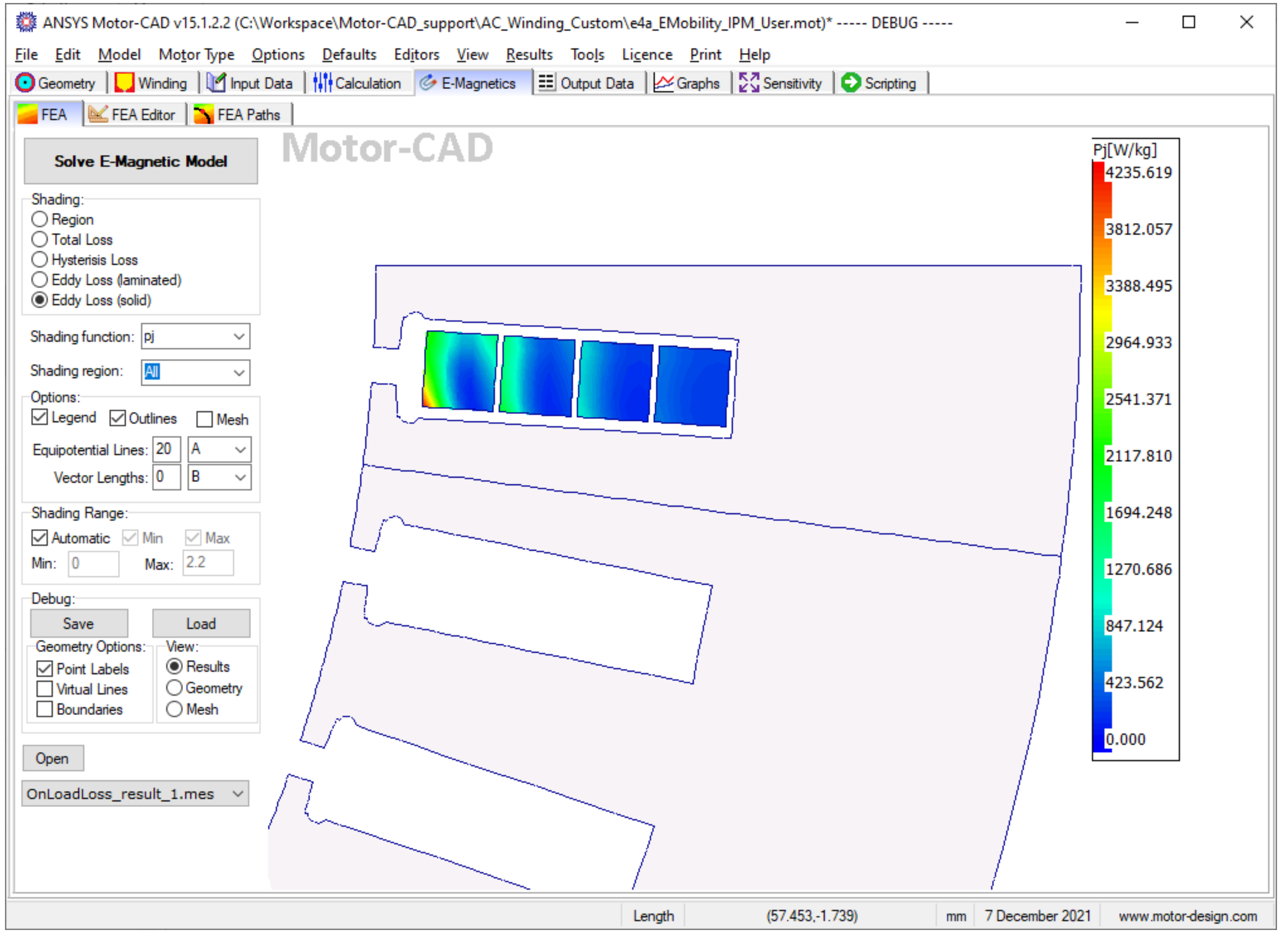
Stator Parameters	Value
Slot Number	72
Stator Lam Dia	740
Stator Bore	520
Slot Width	11
Slot Depth	47.5
Wedge Depth	1
Wedge Inset	1
Wedge Thickness	4
Sleeve Thickness	0

Rotor Parameters	Value
Rotor Slots	6
Pole Width	80
Pole Depth	100
Pole Tip Width	54
Pole Tip Depth	40
Pole Tip Radius	0
Pole Base Radius	0
Pole Surface Radius	246
Pole Surface Offset	10
Airgap [Calculated]	4
Liner Pole Side	1
Liner Pole Tip	1
Liner Coil Base	1
Rotor Coil Width	32.5
Rotor Coil Depth	87
Winding Separators	1
Wdg Separator Length	10
Wdg Separator Low [%]	10
Wdg Separator Up [%]	90
Damper Bars	7
Damper Bar Opening	1
Damper Bar Depth	1
Damper Bar Pitch	200
Damper Bar Diameter	10
Banding Thickness	0
Shaft Dia	150
Shaft Hole Diameter	0



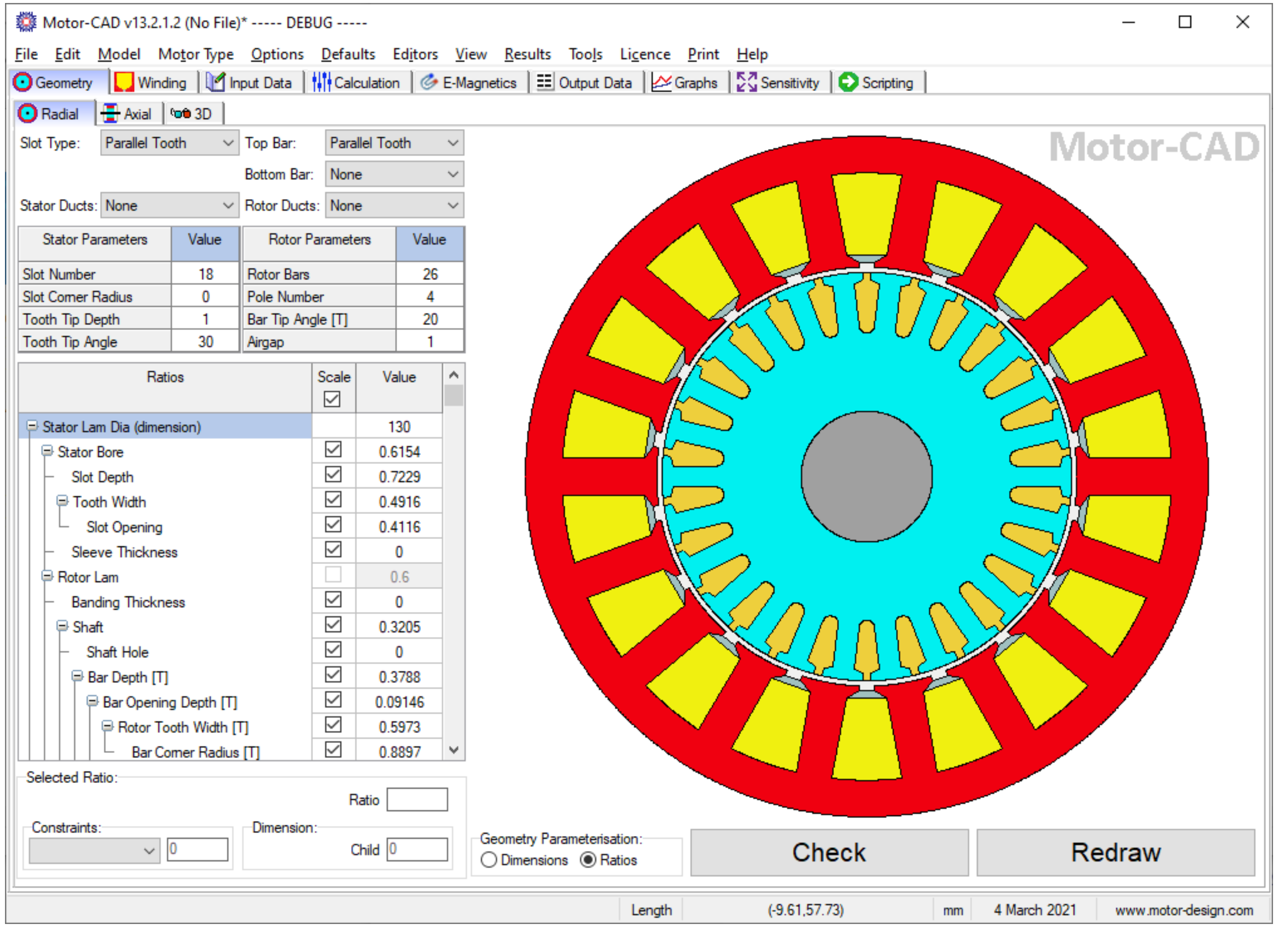
Improved AC winding loss calculation

- Now able to make a full FEA AC winding loss calculation using a custom dxf geometry
- Custom stator lamination shape can be used.
- Conductors can be positioned in slot.



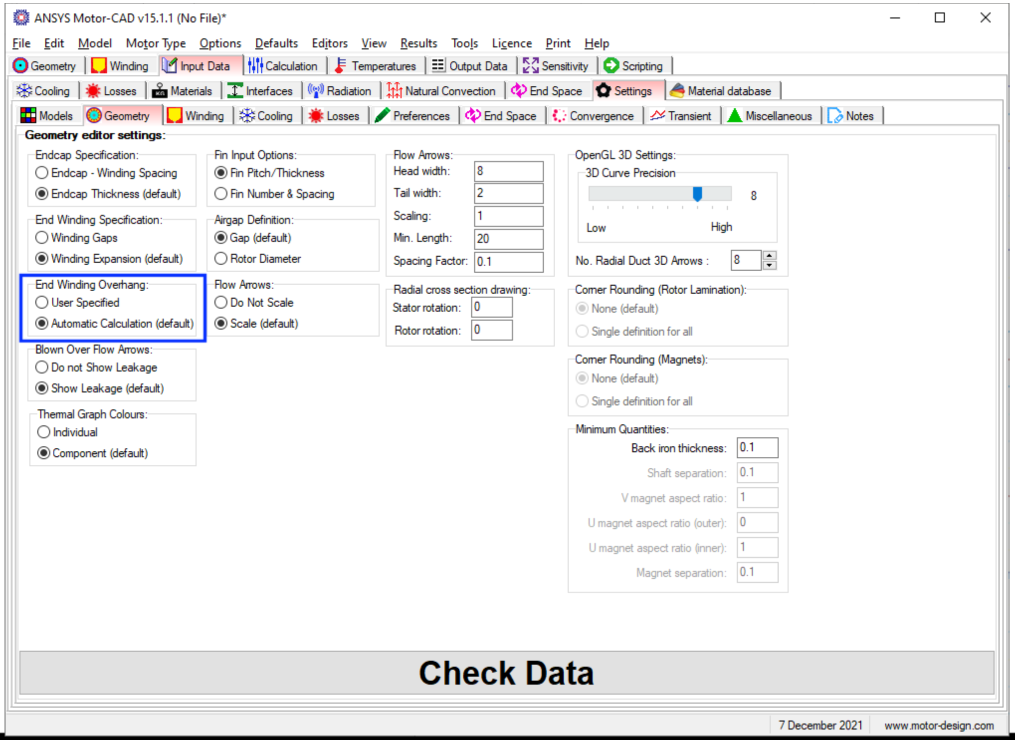
New geometry ratios for IM machines

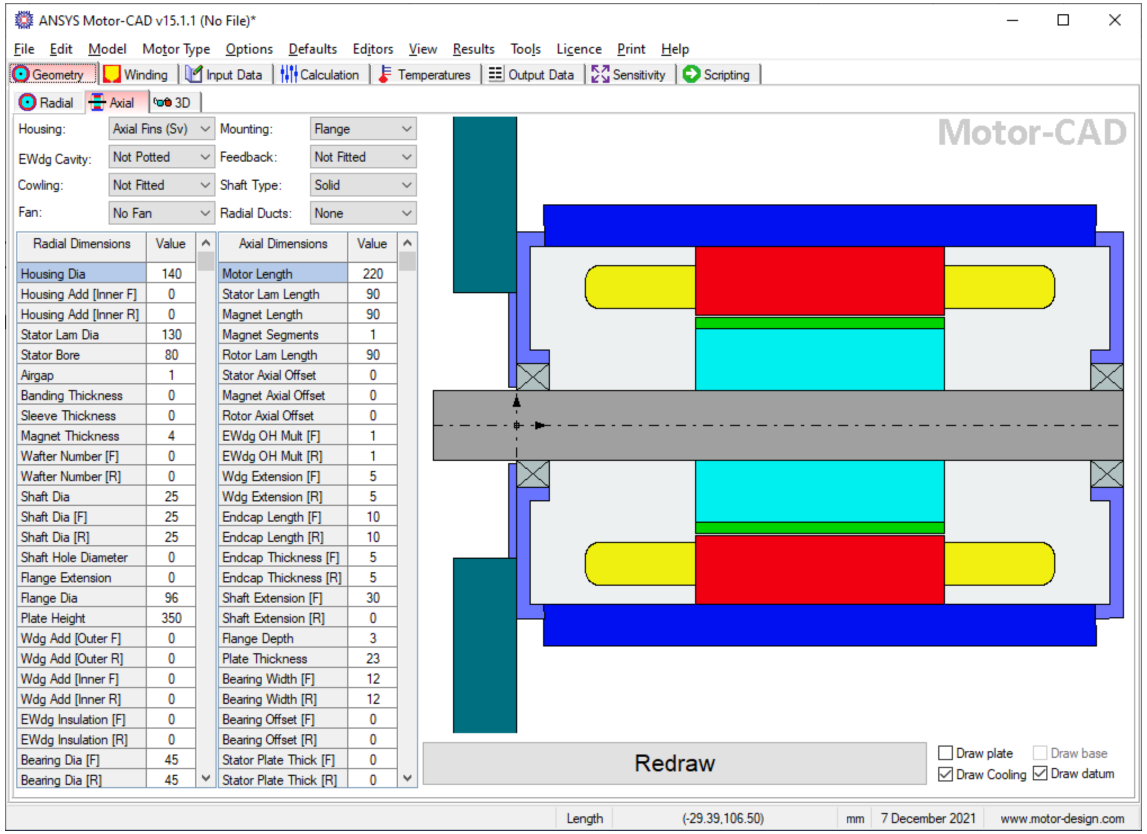
- Expanding on the BPM/SYNCREL ratios from V14.
- Useful for optimisation and required for Ansys optiSLang export.



Endwinding overhang calculation

- New option for automatic calculation of endwinding overhang.
- Overhang used for thermal calculations based on winding pattern.

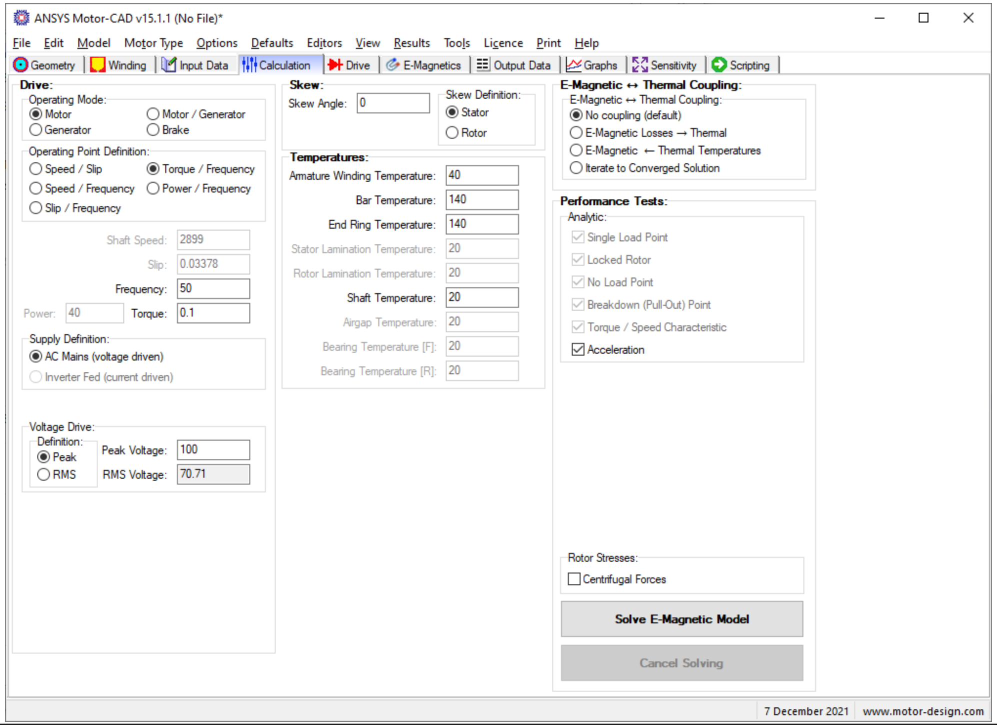


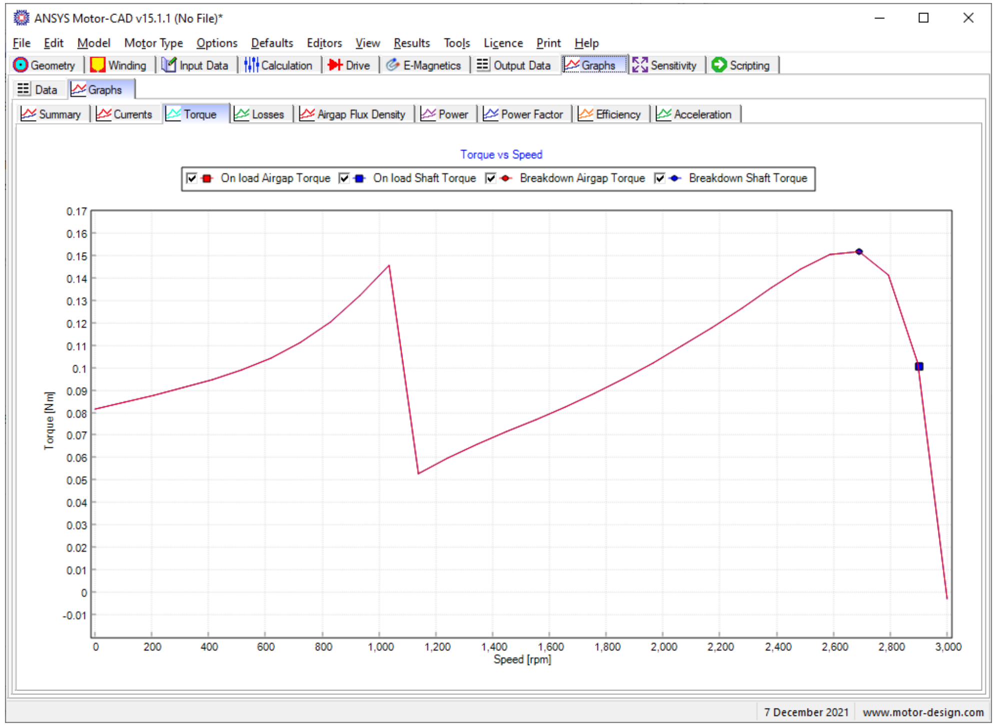


IM1PH machine added operating points

- Added operating point specifications for:
  - Torque / Frequency

    and
  - Power / Frequency





Ansys