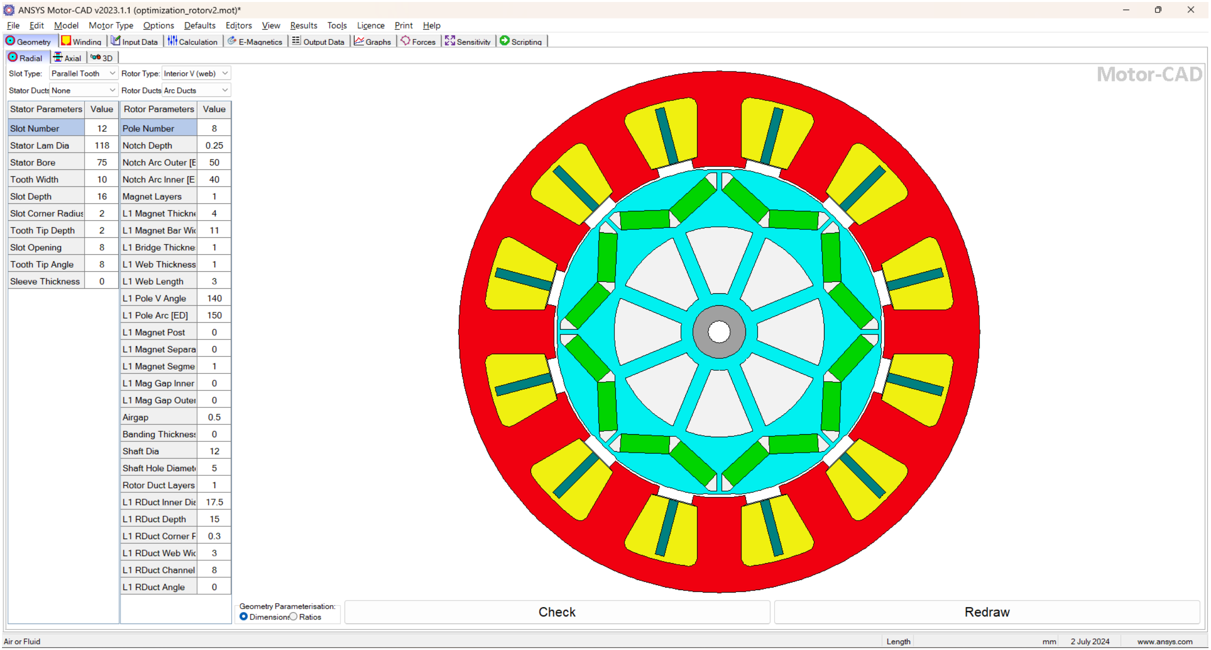
8 Pole



ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
File Edit Model Motor Type Options Defaults Editors View Results Tools Licence Print Help
Geometry Winding Input Data Calculation E-Magnetics Output Data Graphs Forces Sensitivity Scripting
Radial Axial 3D
Slot Type: Parallel Tooth
Rotor Type: Interior V (web)
Stator Ducts None
Rotor Ducts Arc Ducts
Stator Parameters | Value
Slot Number | 12
Stator Lam Dia | 118
Stator Bore | 75
Tooth Width | 10
Slot Depth | 16
Slot Corner Radius | 2
Tooth Tip Depth | 2
Slot Opening | 8
Tooth Tip Angle | 8
Sleeve Thickness | 0
Rotor Parameters | Value
Pole Number | 8
Notch Depth | 0.25
Notch Arc Outer [E | 50
Notch Arc Inner [E | 40
Magnet Layers | 1
L1 Magnet Thickn | 4
L1 Magnet Bar Wi | 11
L1 Bridge Thickne | 1
L1 Web Thickness | 1
L1 Web Length | 3
L1 Pole V Angle | 140
L1 Pole Arc [ED] | 150
L1 Magnet Post | 0
L1 Magnet Separa | 0
L1 Magnet Segme | 1
L1 Mag Gap Inner | 0
L1 Mag Gap Outer | 0
Airgap | 0.5
Banding Thickness | 0
Shaft Dia | 12
Shaft Hole Diamet | 5
Rotor Duct Layers | 1
L1 RDuct Inner Dia | 17.5
L1 RDuct Depth | 15
L1 RDuct Corner F | 0.3
L1 RDuct Web Wi | 3
L1 RDuct Channel | 8
L1 RDuct Angle | 0
Motor-CAD
Geometry Parameterisation:
Dimensions Ratios
Check
Redraw
Air or Fluid
Length
mm
2 July 2024
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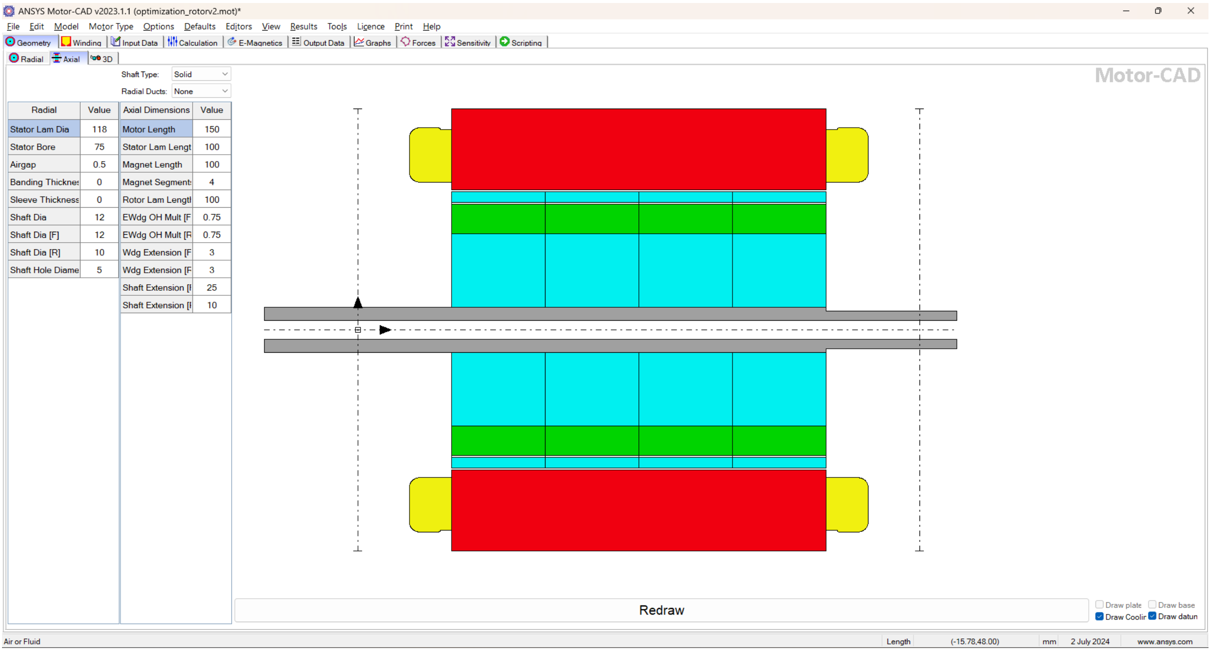

ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
File Edit Model Motor Type Options Defaults Editors View Results Tools Licence Print Help
Geometry Winding Input Data Calculation E-Magnetics Output Data Graphs Forces Sensitivity Scripting
Radial Axial 3D
Shaft Type: Solid
Radial Ducts: None
Radial | Value
Stator Lam Dia | 118
Stator Bore | 75
Airgap | 0.5
Banding Thicknes | 0
Sleeve Thickness | 0
Shaft Dia | 12
Shaft Dia [F] | 12
Shaft Dia [R] | 10
Shaft Hole Diame | 5
Axial Dimensions | Value
Motor Length | 150
Stator Lam Lengt | 100
Magnet Length | 100
Magnet Segments | 4
Rotor Lam Lengtl | 100
EWdg OH Mult [F | 0.75
EWdg OH Mult [R | 0.75
Wdg Extension [F | 3
Wdg Extension [F | 3
Shaft Extension [I | 25
Shaft Extension [I | 10
Motor-CAD
Redraw
Draw plate Draw base
Draw Coolir Draw datum
Air or Fluid
Length
(-15.78,48.00)
mm
2 July 2024
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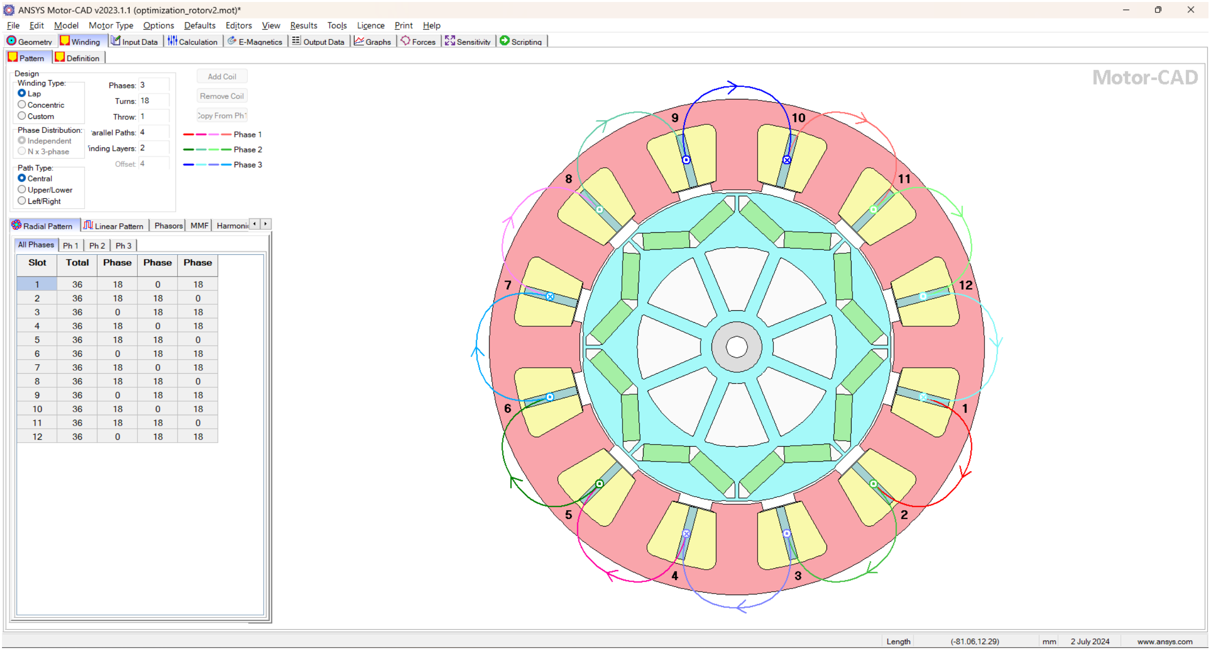
ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
File Edit Model Motor Type Options Defaults Editors View Results Tools Licence Print Help
Geometry Winding Input Data Calculation E-Magnetics Output Data Graphs Forces Sensitivity Scripting
Pattern Definition
Motor-CAD
Phase 1
Phase 2
Phase 3
Slot Total Phase Phase Phase
Length
mm
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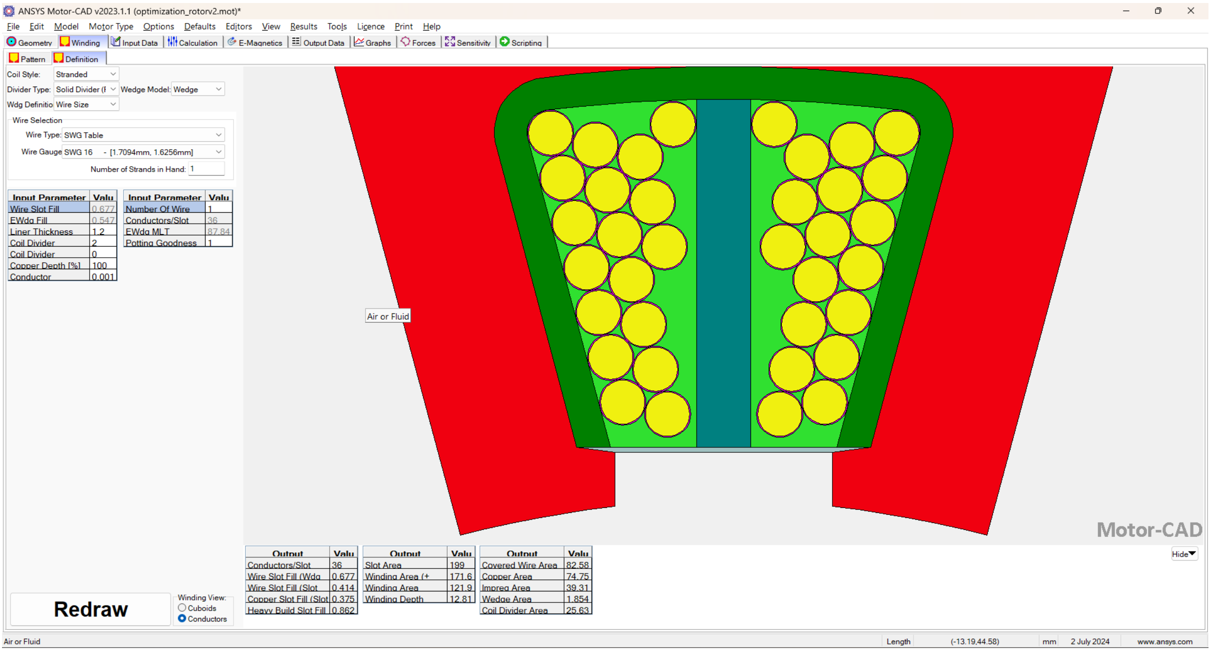
ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
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Geometry Winding Input Data Calculation E-Magnetics Output Data Graphs Forces Sensitivity Scripting
Pattern Definition
Air or Fluid
Motor-CAD
Redraw
Length
mm
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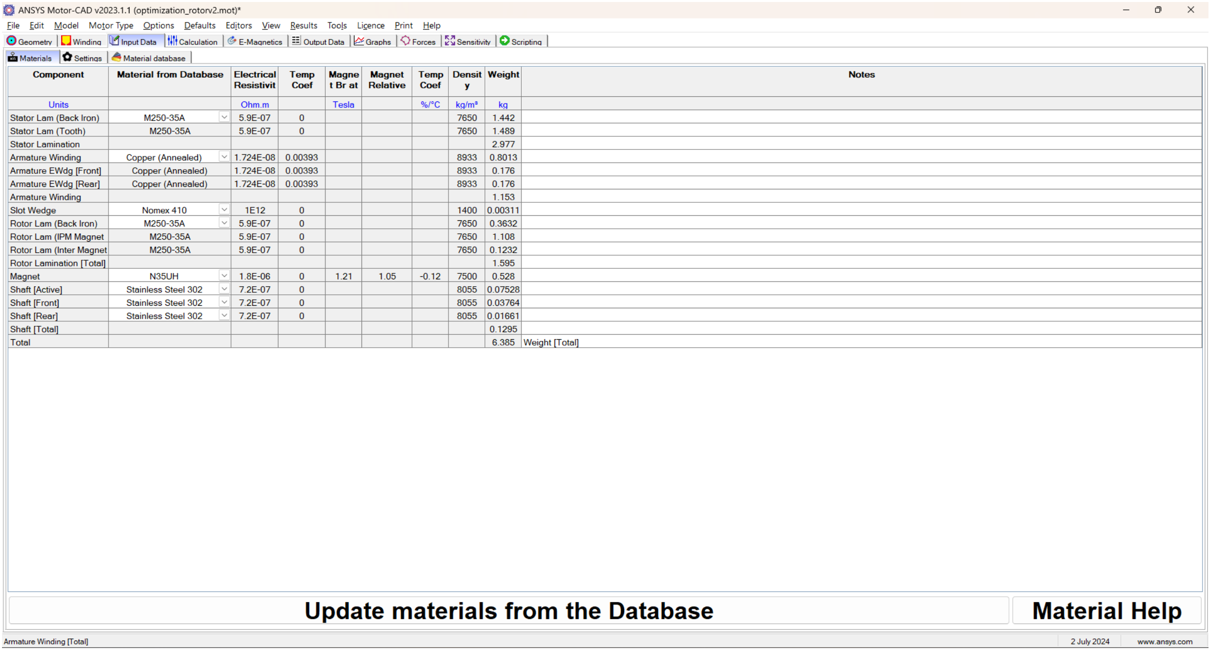
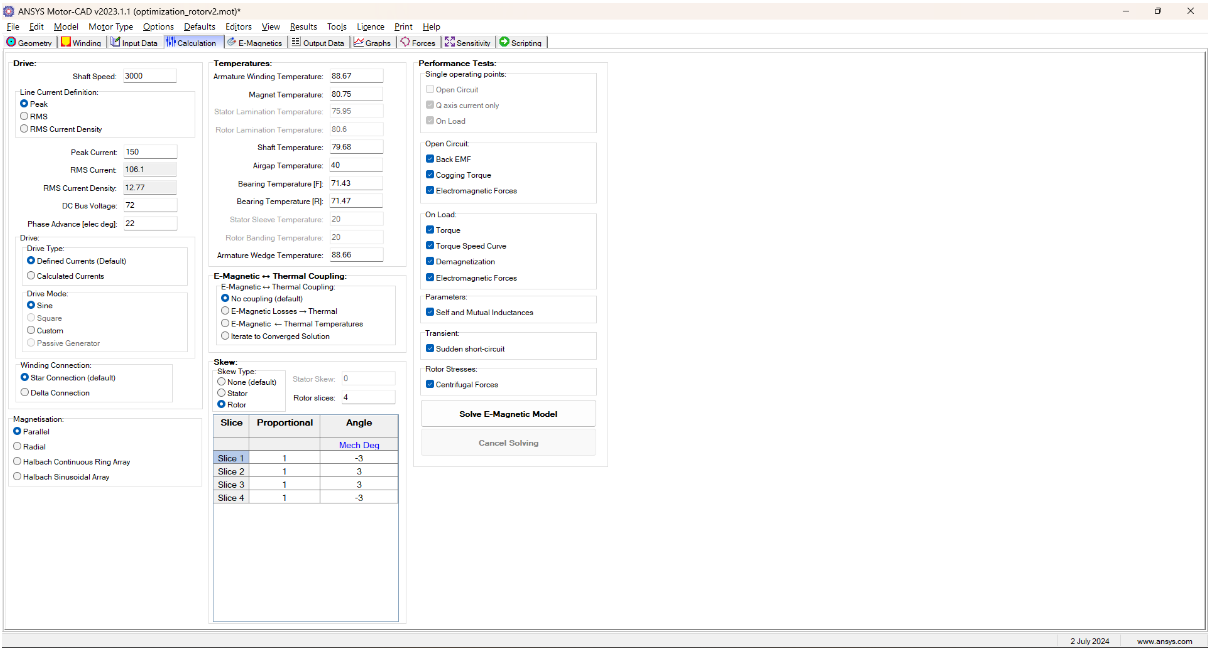


Component	Material from Database	Electrical Resistivit	Temp Coef	Magne t Br at	Magnet Relative	Temp Coef	Densit y	Weight	Notes
Units		Ohm.m		Tesla		%/°C	kg/m³	kg	
Stator Lam (Back Iron)	M250-35A	5.9E-07	0				7650	1.442	
Stator Lam (Tooth)	M250-35A	5.9E-07	0				7650	1.489	
Stator Lamination								2.977	
Armature Winding	Copper (Annealed)	1.724E-08	0.00393				8933	0.8013	
Armature EWdg [Front]	Copper (Annealed)	1.724E-08	0.00393				8933	0.176	
Armature EWdg [Rear]	Copper (Annealed)	1.724E-08	0.00393				8933	0.176	
Armature Winding								1.153	
Slot Wedge	Nomex 410	1E12	0				1400	0.00311	
Rotor Lam (Back Iron)	M250-35A	5.9E-07	0				7650	0.3632	
Rotor Lam (IPM Magnet	M250-35A	5.9E-07	0				7650	1.108	
Rotor Lam (Inter Magnet	M250-35A	5.9E-07	0				7650	0.1232	
Rotor Lamination [Total]								1.595	
Magnet	N35UH	1.8E-06	0	1.21	1.05	-0.12	7500	0.528	
Shaft [Active]	Stainless Steel 302	7.2E-07	0				8055	0.07528	
Shaft [Front]	Stainless Steel 302	7.2E-07	0				8055	0.03764	
Shaft [Rear]	Stainless Steel 302	7.2E-07	0				8055	0.01661	
Shaft [Total]								0.1295	
Total								6.385	Weight [Total]



Slice	Proportional	Angle
		Mech Deg
Slice 1	1	-3
Slice 2	1	3
Slice 3	1	3
Slice 4	1	-3

ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*

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

Drive | E-Magnetics | Phasor Diagram | Equivalent Circuit | Flux Densities | Losses | Winding | Rotor Stress | Forces | Miscellaneous | Materials

Variable	Value	Units
DC Bus Voltage	72	Volts
Line-Line Supply Voltage (rms)	50.91	Volts
Phase Supply Voltage (rms)	29.39	Volts
Line-Line Terminal Voltage (peak)	68.72	Volts
Line-Line Terminal Voltage (rms)	47.18	Volts
Phase Terminal Voltage (peak)	41.05	Volts
Phase Terminal Voltage (rms)	27.24	Volts
Harmonic Distortion Line-Line Terminal Voltage	9.541	%
Harmonic Distortion Phase Terminal Voltage	9.541	%
Back EMF Line-Line Voltage (peak)	58.23	Volts
Back EMF Line-Line Voltage (peak) (fundamental)	58.98	Volts
Back EMF Phase Voltage (peak)	35.38	Volts
Back EMF Line-Line Voltage (rms)	41.72	Volts
Back EMF Phase Voltage (rms)	24.08	Volts
Harmonic Distortion Back EMF Line-Line Voltage	2.448	%
Harmonic Distortion Back EMF Phase Voltage	2.448	%
Max Line-Line / Phase Voltage Ratio	1.732	

DC Supply Current (mean)	114	Amps
Line Current (peak)	150	Amps
Line Current (rms)	106.1	Amps
Phase Current (peak)	150	Amps
Phase Current (rms)	106.1	Amps

Phase Advance	22	EDeg
Drive Offset Angle (Open Circuit)	30	EDeg
Drive Offset Angle (On load)	30	EDeg
Phase Advance to give maximum torque	16.7	EDeg

Phasor Offset Angle	330	EDeg
Phasor Angle (Ph1)	0	EDeg
Phasor Angle (Ph2)	120	EDeg
Phasor Angle (Ph3)	240	EDeg
Max Angle Between Phasors	120	EDeg

Variable	Value	Units
D Axis Inductance	0.07651	mH
Q Axis Inductance	0.1367	mH
Line-Line Inductance (DQ)	0.2184	mH
Self Inductance	0.1294	mH
Mutual Inductance	-0.06313	mH
Line-Line Inductance	0.385	mH
Armature End Winding Inductance	0.002315	mH

D Axis Current (rms)	-39.73	Amps
Q Axis Current (rms)	98.34	Amps
Torque Constant (Kt)	0.1643	Nm/A
Motor Constant (Km)	1.148	Nm/(Watts^0.5)
Back EMF Constant (Ke)	0.1854	Vs/Rad
Back EMF Constant (Ke) (fundamental)	0.1877	Vs/Rad
Electrical Constant	7.808	msec
Mechanical Constant	0.6687	msec
Electrical Loading	4.862E004	Amps/m

Stall Current	2636	Amps
Stall Torque	433.1	Nm

Short Circuit Line Current (peak)	308	Amps
Short Circuit Current Density (peak)	37.08	Amps/mm²
Short Circuit Current Density (rms)	26.22	Amps/mm²
Short Circuit Braking Torque	-6.186	Nm
Short Circuit Max Braking Torque	-25.66	Nm
Short Circuit Max Braking Torque Speed	377.8	rpm
Short Circuit Max Demagnetizing Current	-537.5	Amps

Fundamental Frequency	200	Hz
Shaft Speed	3000	rpm

The peak Phase Voltage at the terminals of the machine (taken from terminal voltage graph) {PeakPhaseVoltage} | 2 July 2024 | www.ansys.com

ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*

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

Drive | E-Magnetics | Phasor Diagram | Equivalent Circuit | Flux Densities | Losses | Winding | Rotor Stress | Forces | Miscellaneous | Materials

Variable	Value	Units
Maximum torque possible (DQ)	24.856	Nm
Average torque (virtual work)	24.659	Nm
Average torque (loop torque)	24.538	Nm
Torque Ripple (MsVw)	1.2832	Nm
Torque Ripple (MsVw) [%]	5.2069	%
Cogging Torque Ripple (Ce)	2.3778	Nm
Cogging Torque Ripple (Vw)	2.2127	Nm
Speed limit for constant torque	3258.4	rpm
No load speed	3709.1	rpm
Speed limit for zero q axis current	INF	rpm

Electromagnetic Power	7742.2	Watts
Input Power	8205.2	Watts
Total Losses (on load)	540.44	Watts
Output Power	7664.8	Watts
System Efficiency	93.414	%

Shaft Torque	24.398	Nm

Power Factor [Waveform] (lagging)	0.95142	
Power Factor Angle [Waveform]	17.932	EDeg
Power Factor [THD]	0.94712	
Power Factor [Phasor] (lagging)	0.9563	
Power Factor Angle [Phasor]	17	EDeg
Load Angle [Phasor]	38.908	EDeg
Phase Terminal Voltage (rms) [Phasor]	27.768	Volts

Rotor Inertia	0.0014913	kg.m²
Shaft Inertia	2.645E-006	kg.m²
Total Inertia	0.0014939	kg.m²
Torque per rotor volume	57.301	kNm/m³
Rotor peripheral velocity (on load)	11.624	m/s

Variable	Value	Units
Flux Linkage D (Q axis current)	26.2378	mVs
Flux Linkage Q (Q axis current)	17.8925	mVs
Flux linkage D (On load)	21.9386	mVs
Flux linkage Q (On load)	19.0165	mVs

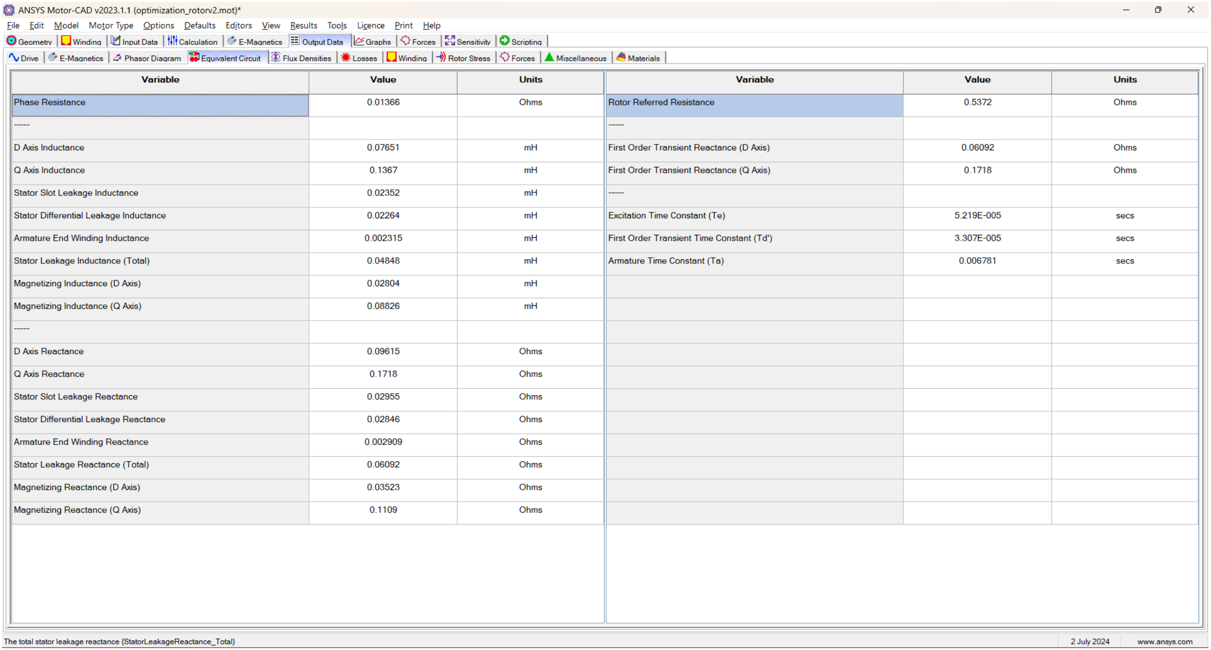
Torque Constant (Kt)	0.164294	Nm/A
Motor Constant (Km)	1.14792	Nm/(Watts^0.5)
Back EMF Constant (Ke)	0.185366	Vs/Rad
Back EMF Constant (Ke) (fundamental)	0.187731	Vs/Rad

Stall Current	2636.16	Amps
Stall Torque	433.105	Nm

Cogging Period	15	MDeg
Cogging Frequency	1200	Hz
Fundamental Frequency	200	Hz
Mechanical Frequency	50	Hz
Optimum Skewing Angle	15	MDeg

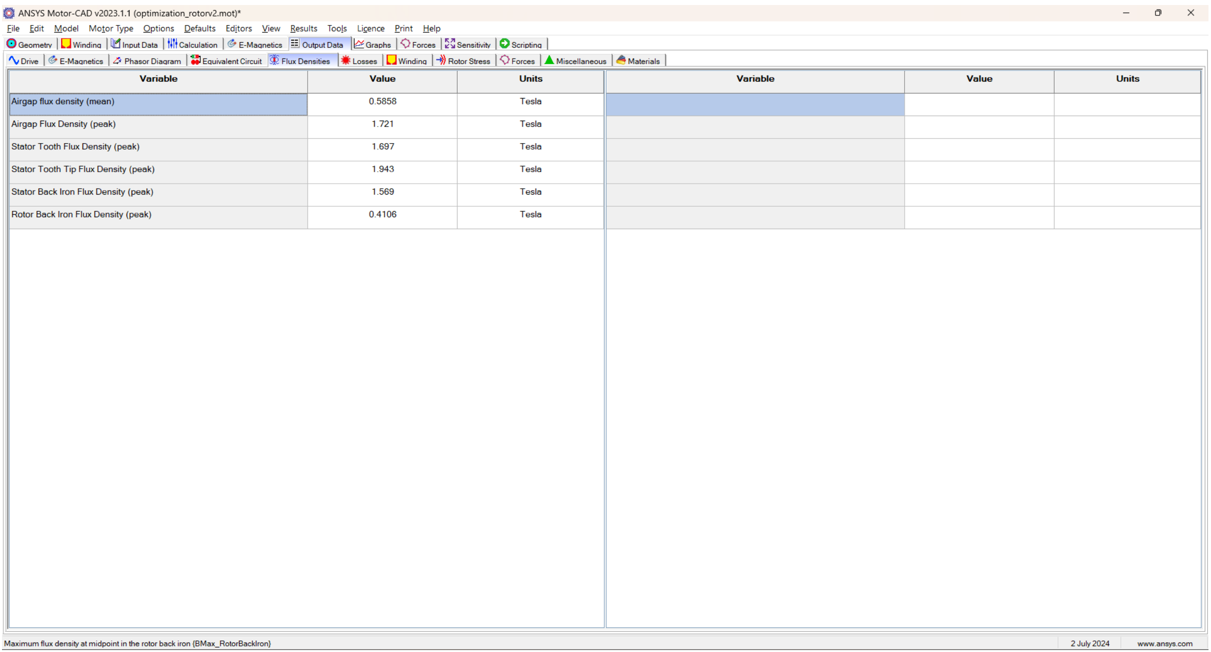
Magnetic Symmetry Factor	4	
Magnetic Axial Length (Slice1)	25	mm
Magnetic Axial Length (Slice2)	25	mm
Magnetic Axial Length (Slice3)	25	mm
Magnetic Axial Length (Slice4)	25	mm

Electrical input power {InputPower} | 2 July 2024 | www.ansys.com



Variable	Value	Units	Variable	Value	Units
Phase Resistance	0.01366	Ohms	Rotor Referred Resistance	0.5372	Ohms
-----			-----		
D Axis Inductance	0.07651	mH	First Order Transient Reactance (D Axis)	0.06092	Ohms
Q Axis Inductance	0.1367	mH	First Order Transient Reactance (Q Axis)	0.1718	Ohms
Stator Slot Leakage Inductance	0.02352	mH	-----		
Stator Differential Leakage Inductance	0.02264	mH	Excitation Time Constant (Te)	5.219E-005	secs
Armature End Winding Inductance	0.002315	mH	First Order Transient Time Constant (Td')	3.307E-005	secs
Stator Leakage Inductance (Total)	0.04848	mH	Armature Time Constant (Ta)	0.006781	secs
Magnetizing Inductance (D Axis)	0.02804	mH			
Magnetizing Inductance (Q Axis)	0.08826	mH			

D Axis Reactance	0.09615	Ohms			
Q Axis Reactance	0.1718	Ohms			
Stator Slot Leakage Reactance	0.02955	Ohms			
Stator Differential Leakage Reactance	0.02846	Ohms			
Armature End Winding Reactance	0.002909	Ohms			
Stator Leakage Reactance (Total)	0.06092	Ohms			
Magnetizing Reactance (D Axis)	0.03523	Ohms			
Magnetizing Reactance (Q Axis)	0.1109	Ohms			



Variable	Value	Units	Variable	Value	Units
Airgap flux density (mean)	0.5858	Tesla			
Airgap Flux Density (peak)	1.721	Tesla			
Stator Tooth Flux Density (peak)	1.697	Tesla			
Stator Tooth Tip Flux Density (peak)	1.943	Tesla			
Stator Back Iron Flux Density (peak)	1.569	Tesla			
Rotor Back Iron Flux Density (peak)	0.4106	Tesla			

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

Drive | E-Magnetics | Phasor Diagram | Equivalent Circuit | Flux Densities | Losses | Winding | Rotor Stress | Forces | Miscellaneous | Materials

Variable	Value	Units	Variable	Value	Units
Armature DC Copper Loss (on load)	460.9	Watts	Armature DC Copper Loss (open circuit)	0	Watts
Magnet Loss (on load)	2.163	Watts	Magnet Loss (open circuit)	0.2666	Watts
Stator iron Loss [total] (on load)	58.31	Watts	Stator iron Loss [total] (open circuit)	48.66	Watts
Rotor iron Loss [total] (on load)	13.87	Watts	Rotor iron Loss [total] (open circuit)	8.99	Watts
Wedge Loss (on load)	0	Watts	Wedge Loss (open circuit)	0	Watts
Windage Loss (calculated)	0.1455	Watts	Windage Loss (calculated)	0.1455	Watts
Friction Loss (calculated)	5.056	Watts	Friction Loss (calculated)	5.056	Watts
Shaft Loss [total] (on load)	5.516E-007	Watts	Shaft Loss [total] (open circuit)	6.991E-007	Watts
------			------		
Total Losses (on load)	540.4	Watts	Total Losses (open circuit)	63.11	Watts
------			------		
Magnet Block Width	11	mm	Magnet Block Width	11	mm
Magnet Loss Factor	0.6284		Magnet Loss Factor	0.6284	
Magnet Loss (on load)	2.163	Watts	Magnet Loss (open circuit)	0.2666	Watts
------			------		
Stator back iron Loss [hysteresis - fundamental] (on load)	15.54	Watts	Stator back iron Loss [hysteresis - fundamental] (open circuit)	13.32	Watts
Stator back iron Loss [hysteresis - minor loops] (on load)	1.614	Watts	Stator back iron Loss [hysteresis - minor loops] (open circuit)	0.9041	Watts
Stator back iron Loss [hysteresis] (on load)	17.16	Watts	Stator back iron Loss [hysteresis] (open circuit)	14.22	Watts
Stator back iron Loss [eddy] (on load)	9.093	Watts	Stator back iron Loss [eddy] (open circuit)	7.568	Watts
Stator back iron Loss [excess] (on load)	0	Watts	Stator back iron Loss [excess] (open circuit)	0	Watts
Stator back iron Loss [total] (on load)	26.25	Watts	Stator back iron Loss [total] (open circuit)	21.79	Watts
------			------		
Stator tooth Loss [hysteresis - fundamental] (on load)	22.88	Watts	Stator tooth Loss [hysteresis - fundamental] (open circuit)	18.92	Watts
Stator tooth Loss [hysteresis - minor loops] (on load)	0.1856	Watts	Stator tooth Loss [hysteresis - minor loops] (open circuit)	0.1098	Watts
Stator tooth Loss [hysteresis] (on load)	23.07	Watts	Stator tooth Loss [hysteresis] (open circuit)	19.03	Watts
Stator tooth Loss [eddy] (on load)	8.986	Watts	Stator tooth Loss [eddy] (open circuit)	7.835	Watts
Stator tooth Loss [excess] (on load)	0	Watts	Stator tooth Loss [excess] (open circuit)	0	Watts
Stator tooth Loss [total] (on load)	32.06	Watts	Stator tooth Loss [total] (open circuit)	26.87	Watts
------			------		
Stator iron Loss [total] (on load)	58.31	Watts	Stator iron Loss [total] (open circuit)	48.66	Watts
------			------		
Rotor back iron Loss [hysteresis] (on load)	0.7232	Watts	Rotor back iron Loss [hysteresis] (open circuit)	0.5173	Watts
Rotor back iron Loss [eddy] (on load)	0.4604	Watts	Rotor back iron Loss [eddy] (open circuit)	0.2643	Watts
Rotor back iron Loss [excess] (on load)	0	Watts	Rotor back iron Loss [excess] (open circuit)	0	Watts
Rotor back iron Loss [total] (on load)	1.184	Watts	Rotor back iron Loss [total] (open circuit)	0.7816	Watts
------			------		
Rotor magnet pole Loss [hysteresis] (on load)	7.388	Watts	Rotor magnet pole Loss [hysteresis] (open circuit)	4.377	Watts
Rotor magnet pole Loss [eddy] (on load)	5.296	Watts	Rotor magnet pole Loss [eddy] (open circuit)	3.831	Watts
Rotor magnet pole Loss [excess] (on load)	0	Watts	Rotor magnet pole Loss [excess] (open circuit)	0	Watts
Rotor magnet pole Loss [total] (on load)	12.68	Watts	Rotor magnet pole Loss [total] (open circuit)	8.208	Watts
------			------		
Rotor iron Loss [total] (on load)	13.87	Watts	Rotor iron Loss [total] (open circuit)	8.99	Watts
------			------		
Shaft Loss [eddy] (on load)	5.516E-007	Watts	Shaft Loss [eddy] (open circuit)	6.991E-007	Watts

Stator tooth losses from hysteresis

Stator tooth losses from hysteresis {StatorToothLoss_Fundamental_Hys} | 2 July 2024 | www.ansys.com

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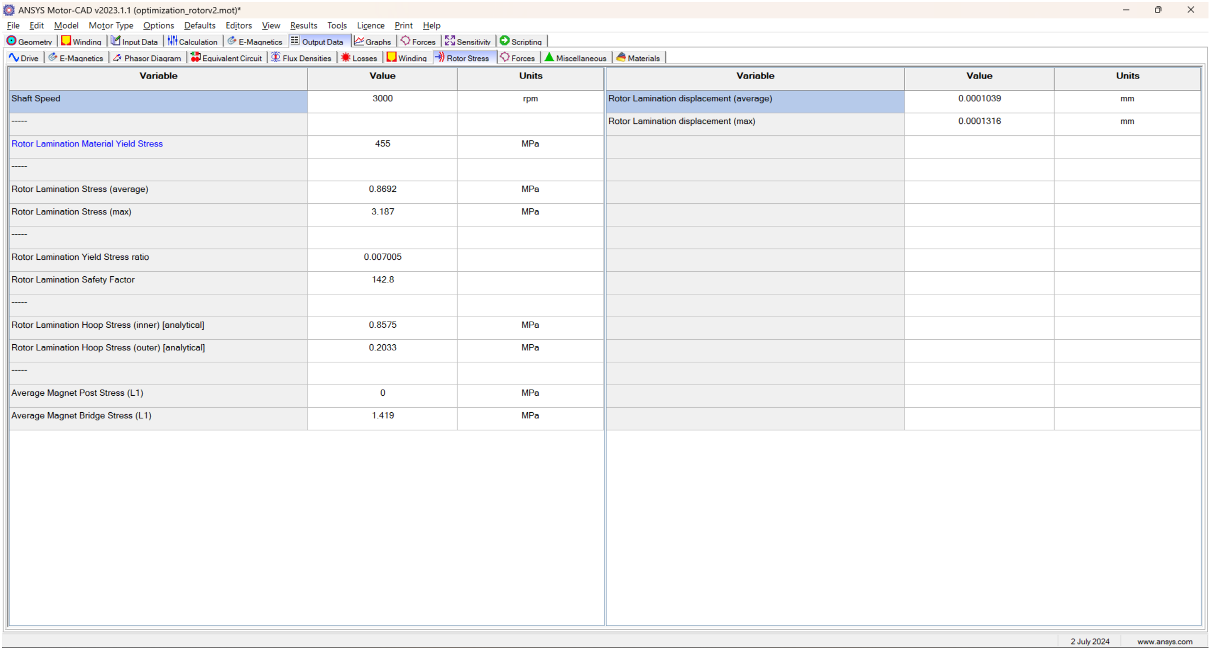
Drive | E-Magnetics | Phasor Diagram | Equivalent Circuit | Flux Densities | Losses | Winding | Rotor Stress | Forces | Miscellaneous | Materials

Variable	Value	Units	Variable	Value	Units
Armature Conductor CSA	2.076	mm^2	Copper Slot Fill (Wdg Area)	0.6133	
Armature Conductor Current Density	12.77	$Amps/mm^2$	Wire Slot Fill (Slot Area)	0.4149	
Armature Conductor MLT	287.8	mm	Copper Slot Fill (Slot Area)	0.3756	
Armature Turns per Phase	18		Heavy Build Slot Fill	0.8626	
Armature Turns per Coil	18		Slot Area (Slot 1)	199	mm^2
Length of phase	2.072E004	mm	Winding Area (+ Liner) (Slot 1)	171.6	mm^2
Phase Resistance	0.01366	Ohms	Slot Area (FEA)	197.2	mm^2
Line-Line Resistance	0.02731	Ohms	Wedge Area	1.854	mm^2
Armature Conductor Temperature	88.67	°C	Slot Opening Area	14.86	mm^2
Mean Coil Pitch (Calculated)	24.14	mm	Liner-Lam Imp Area (Slot 1)	0	mm^2
Mean Coil Pitch (Used)	24.14	mm	Impreg Area (Slot 1)	39.31	mm^2
Fundamental Winding Factor	0.866		Liner Area (Slot 1)	49.68	mm^2
Winding Factor Sum	0.09009		Coil Divider Area (Slot 1)	25.63	mm^2
Wire Ins Thickness	0.0415	mm	Volume Copper EWdg Front	2.022E004	mm^3
Copper Diameter	1.626	mm	Volume Copper Active	8.97E004	mm^3
Conductors/Slot	36		Volume Copper EWdg Rear	2.022E004	mm^3

Armature End Winding MLT (Used)	87.84	mm			

Mean length per turn of armature conductor endwindings used in the calculation {EWdg_MLT} | 2 July 2024 | www.ansys.com



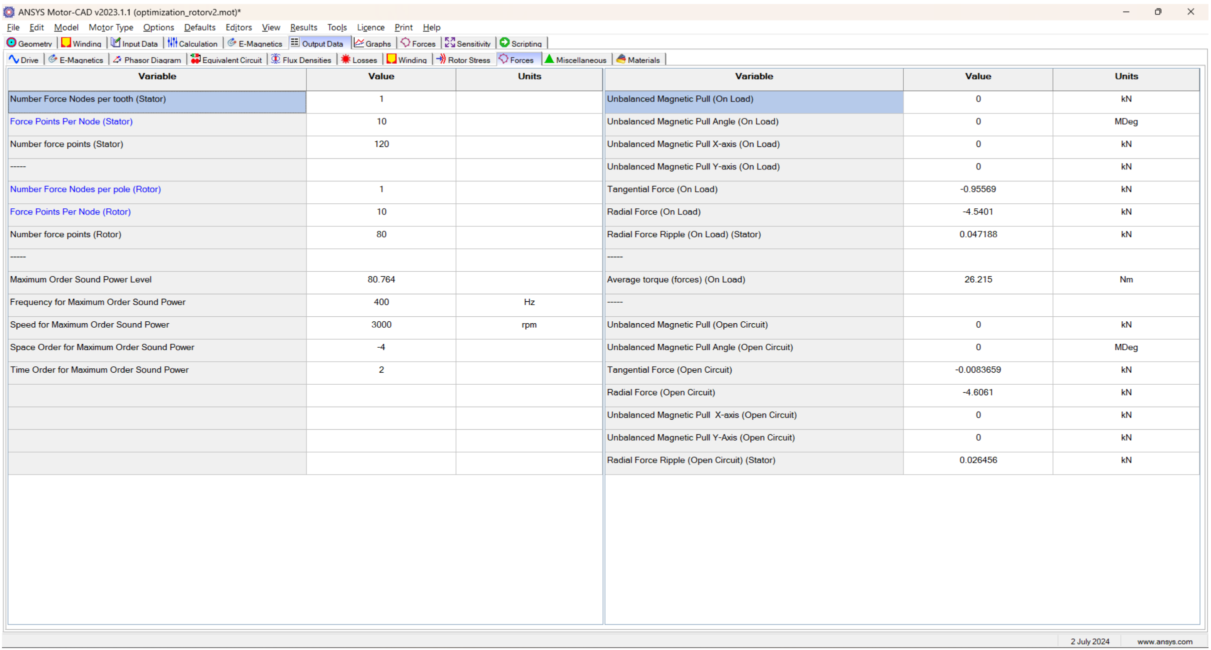
Variable	Value	Units	Variable	Value	Units
Shaft Speed	3000	rpm	Rotor Lamination displacement (average)	0.0001039	mm
-----			Rotor Lamination displacement (max)	0.0001316	mm
Rotor Lamination Material Yield Stress	455	MPa			

Rotor Lamination Stress (average)	0.8692	MPa			
Rotor Lamination Stress (max)	3.187	MPa			

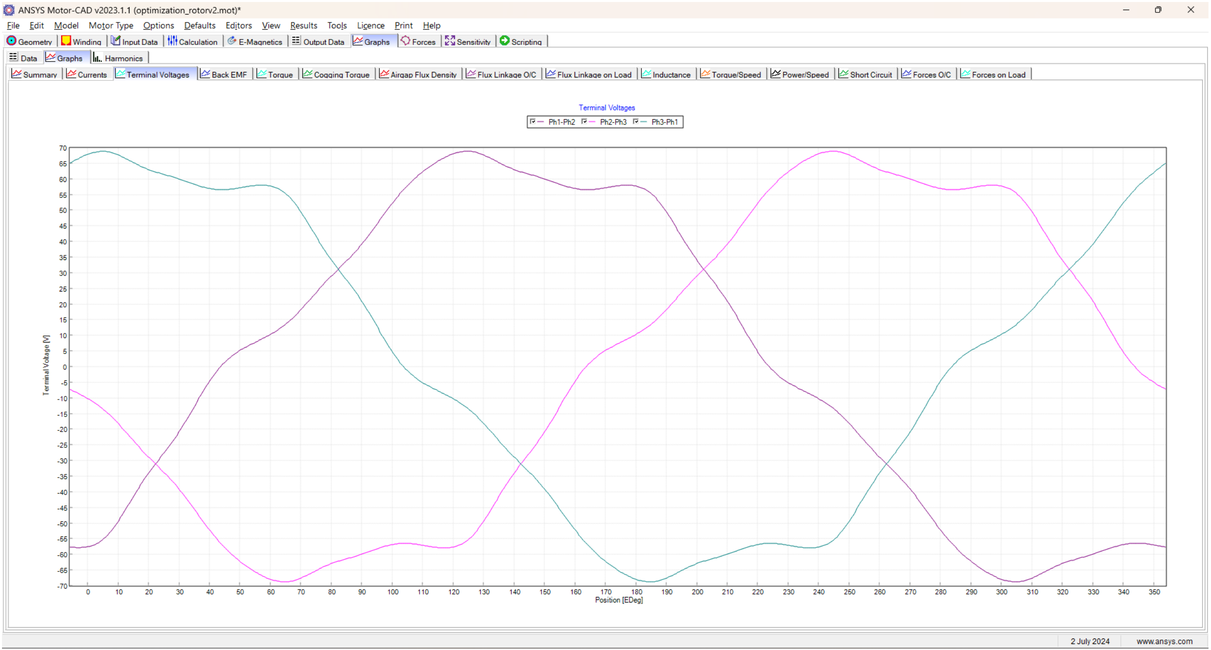
Rotor Lamination Yield Stress ratio	0.007005				
Rotor Lamination Safety Factor	142.8				

Rotor Lamination Hoop Stress (inner) [analytical]	0.8575	MPa			
Rotor Lamination Hoop Stress (outer) [analytical]	0.2033	MPa			

Average Magnet Post Stress (L1)	0	MPa			
Average Magnet Bridge Stress (L1)	1.419	MPa			



Variable	Value	Units	Variable	Value	Units
Number Force Nodes per tooth (Stator)	1		Unbalanced Magnetic Pull (On Load)	0	kN
Force Points Per Node (Stator)	10		Unbalanced Magnetic Pull Angle (On Load)	0	MDeg
Number force points (Stator)	120		Unbalanced Magnetic Pull X-axis (On Load)	0	kN
-----			Unbalanced Magnetic Pull Y-axis (On Load)	0	kN
Number Force Nodes per pole (Rotor)	1		Tangential Force (On Load)	-0.95569	kN
Force Points Per Node (Rotor)	10		Radial Force (On Load)	-4.5401	kN
Number force points (Rotor)	80		Radial Force Ripple (On Load) (Stator)	0.047188	kN
-----			-----		
Maximum Order Sound Power Level	80.764		Average torque (forces) (On Load)	26.215	Nm
Frequency for Maximum Order Sound Power	400	Hz	-----		
Speed for Maximum Order Sound Power	3000	rpm	Unbalanced Magnetic Pull (Open Circuit)	0	kN
Space Order for Maximum Order Sound Power	-4		Unbalanced Magnetic Pull Angle (Open Circuit)	0	MDeg
Time Order for Maximum Order Sound Power	2		Tangential Force (Open Circuit)	-0.0083659	kN
			Radial Force (Open Circuit)	-4.6061	kN
			Unbalanced Magnetic Pull X-axis (Open Circuit)	0	kN
			Unbalanced Magnetic Pull Y-Axis (Open Circuit)	0	kN
			Radial Force Ripple (Open Circuit) (Stator)	0.026456	kN


ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
Terminal Voltages
Ph1-Ph2 Ph2-Ph3 Ph3-Ph1
Terminal Voltage [V]
Position [EDeg]
2 July 2024
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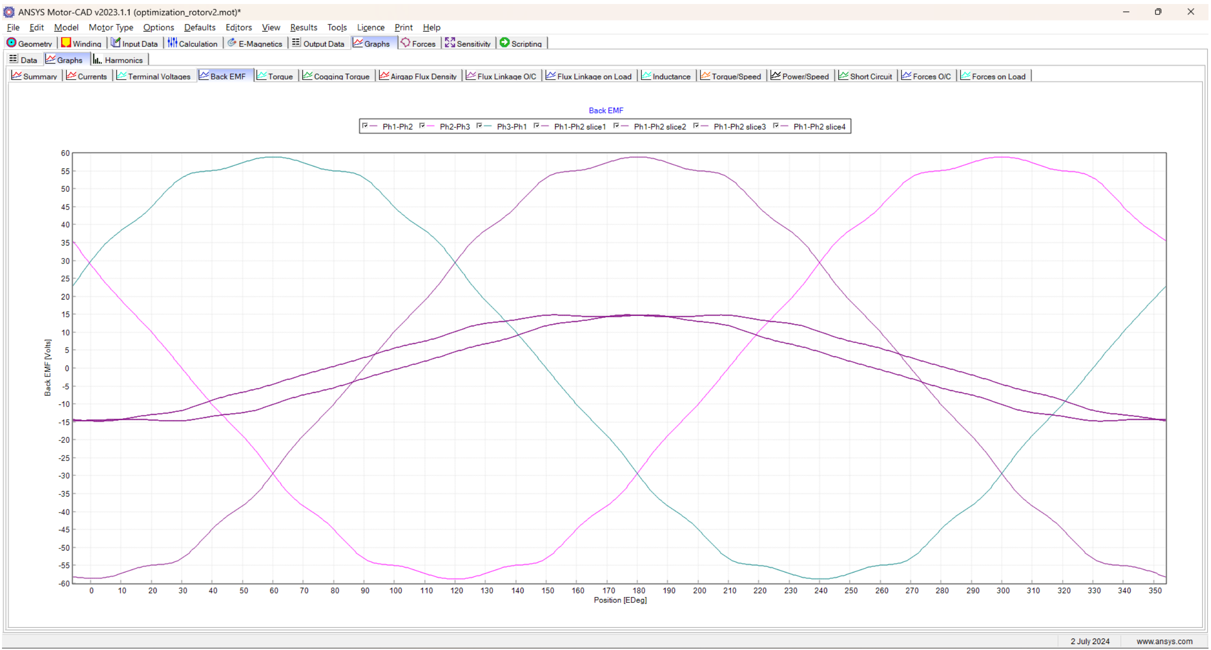
ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
Back EMF
Ph1-Ph2 Ph2-Ph3 Ph3-Ph1 Ph1-Ph2 slice1 Ph1-Ph2 slice2 Ph1-Ph2 slice3 Ph1-Ph2 slice4
Back EMF [Volts]
Position [EDeg]
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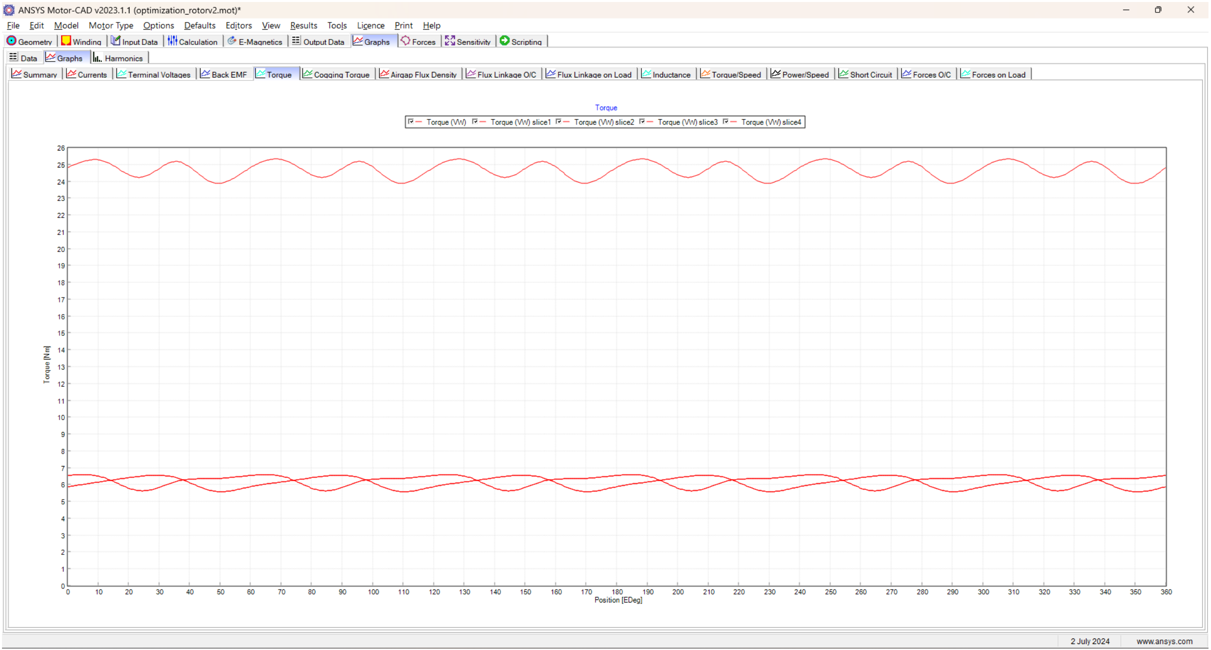
ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
Torque
Torque (VW)
Torque (VW) slice1
Torque (VW) slice2
Torque (VW) slice3
Torque (VW) slice4
Torque [Nm]
Position [EDeg]
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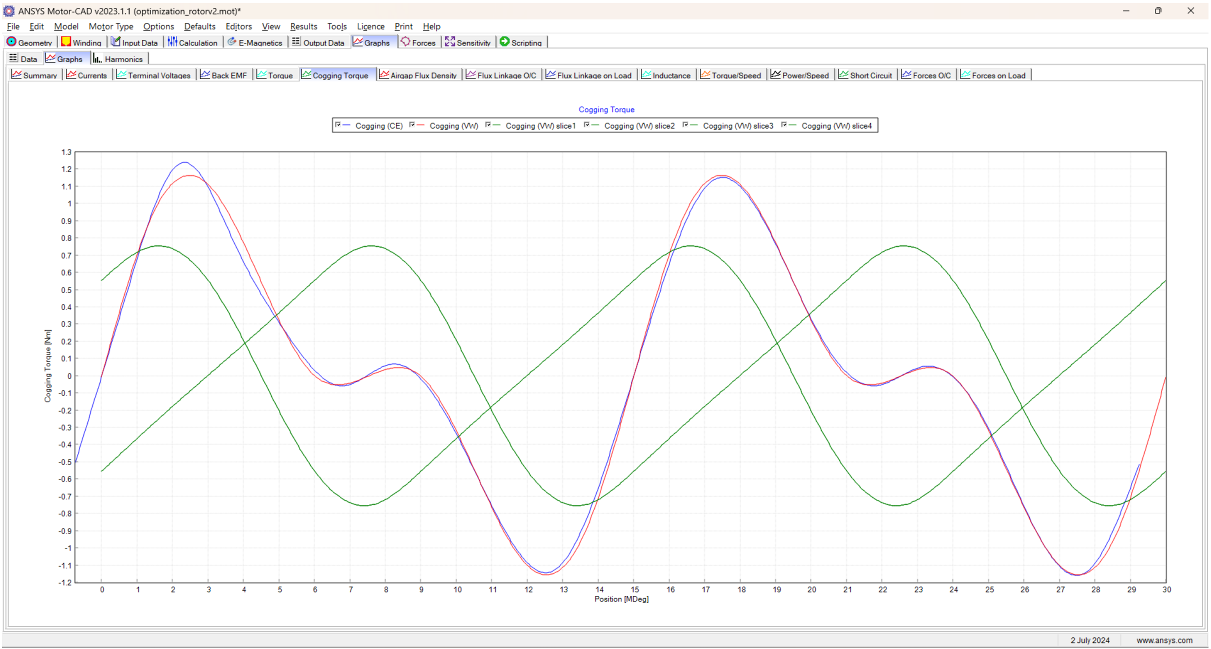
ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
Cogging Torque
Cogging (CE)
Cogging (VW)
Cogging (VW) slice1
Cogging (VW) slice2
Cogging (VW) slice3
Cogging (VW) slice4
Cogging Torque [Nm]
Position [MDeg]
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ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
Airgap Flux Density
B Gap (on load) (Slice 2)
Br Gap (on load) (Slice 2)
Bt Gap (on load) (Slice 2)
Flux Density [Tesla]
Angle [EDeg]
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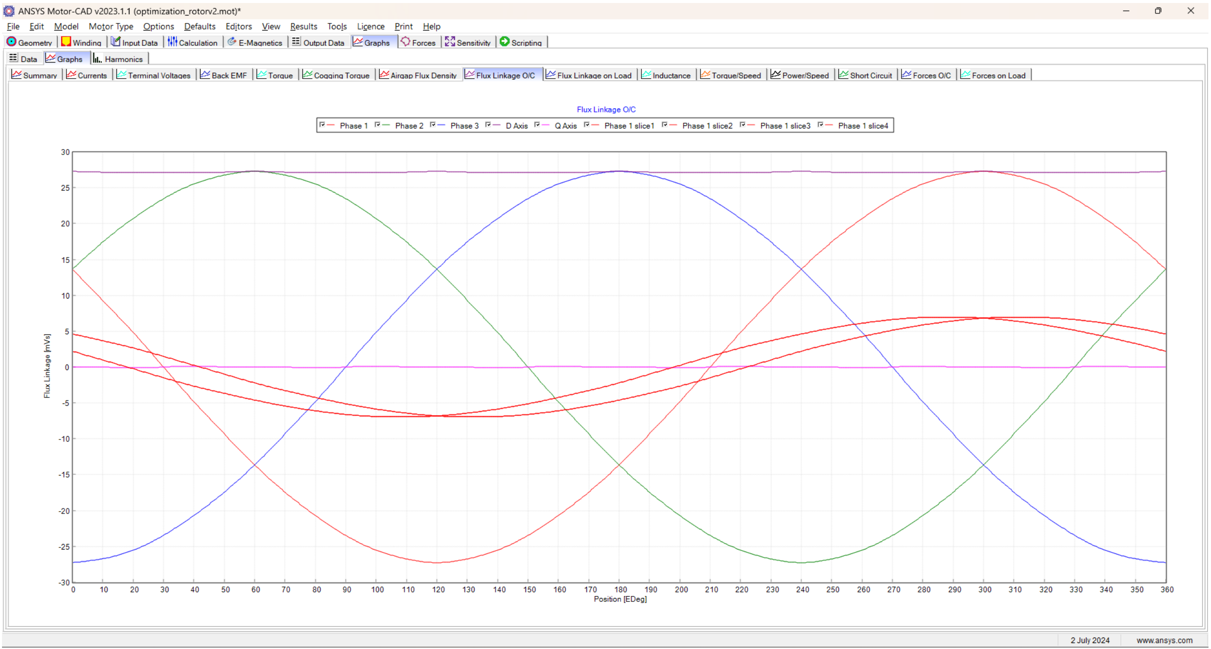
ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
Flux Linkage O/C
Phase 1
Phase 2
Phase 3
D Axis
Q Axis
Phase 1 slice1
Phase 1 slice2
Phase 1 slice3
Phase 1 slice4
Flux Linkage [mVs]
Position [EDeg]
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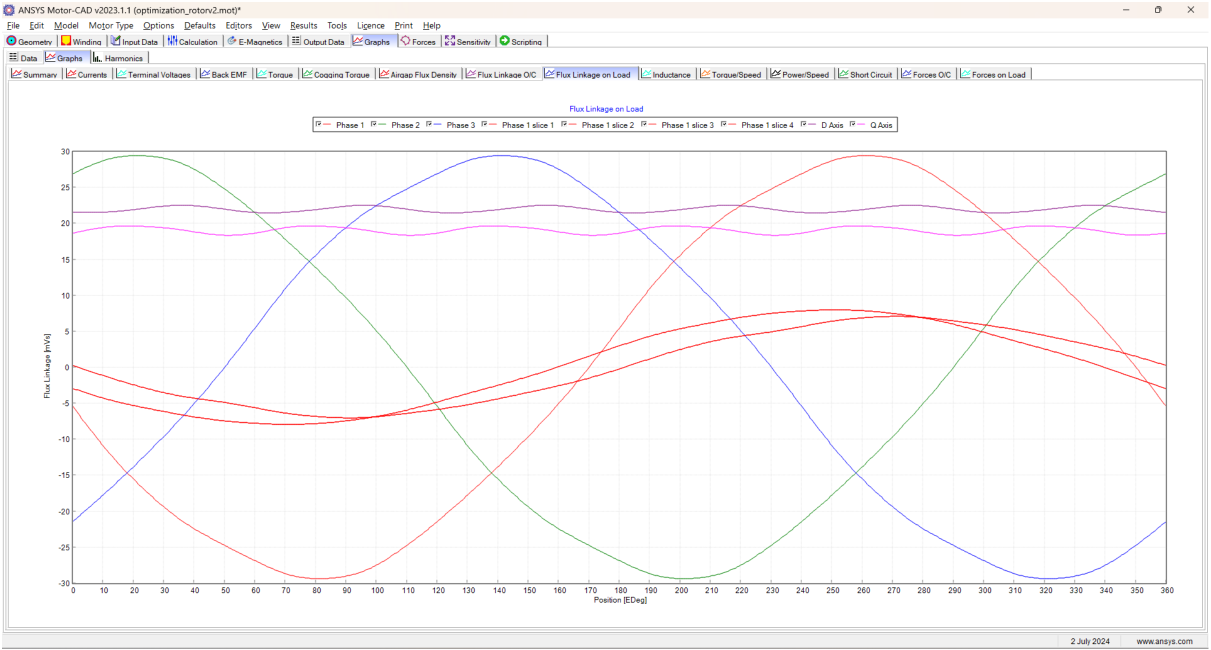
ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
Flux Linkage on Load
Phase 1
Phase 2
Phase 3
Phase 1 slice 1
Phase 1 slice 2
Phase 1 slice 3
Phase 1 slice 4
D Axis
Q Axis
Flux Linkage [mVs]
Position [EDeg]
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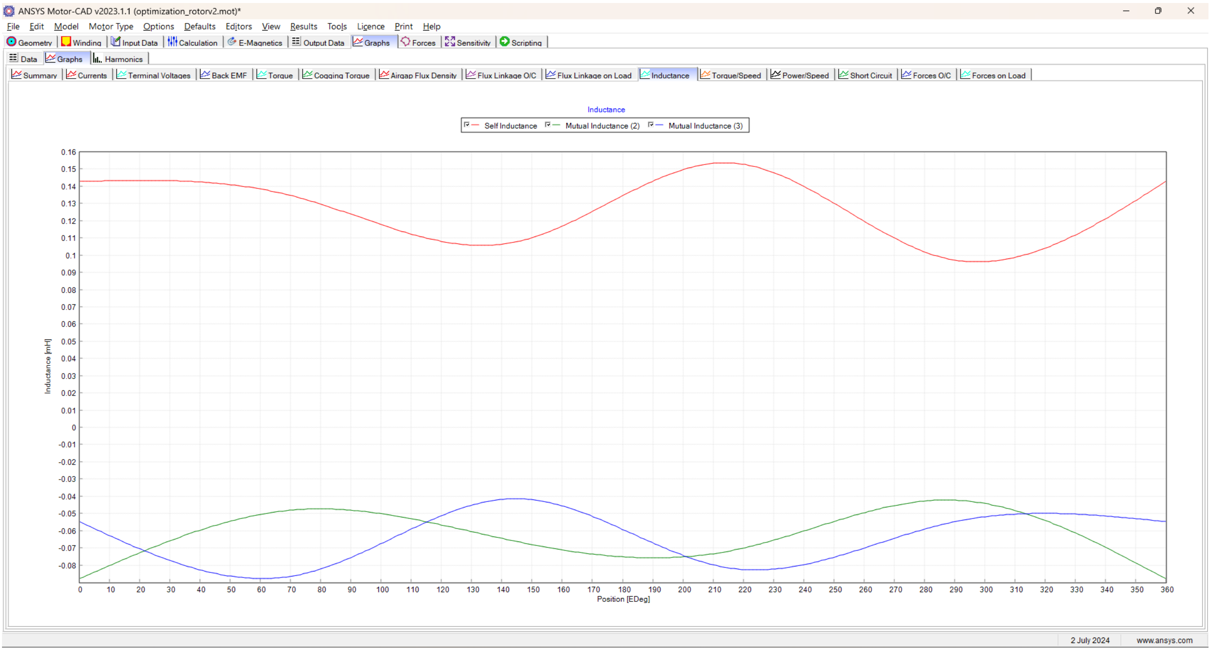
ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
Inductance
Self Inductance
Mutual Inductance (2)
Mutual Inductance (3)
Inductance [mH]
Position [EDeg]
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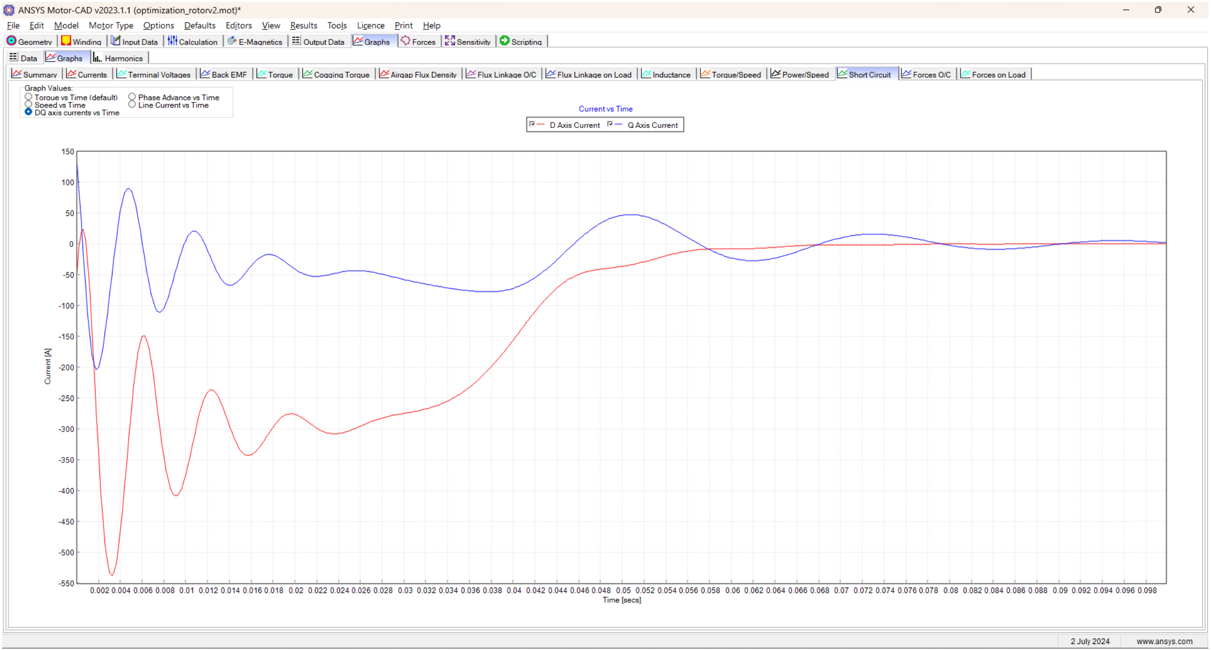
ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
Current vs Time
D Axis Current
Q Axis Current
Current [A]
Time [secs]
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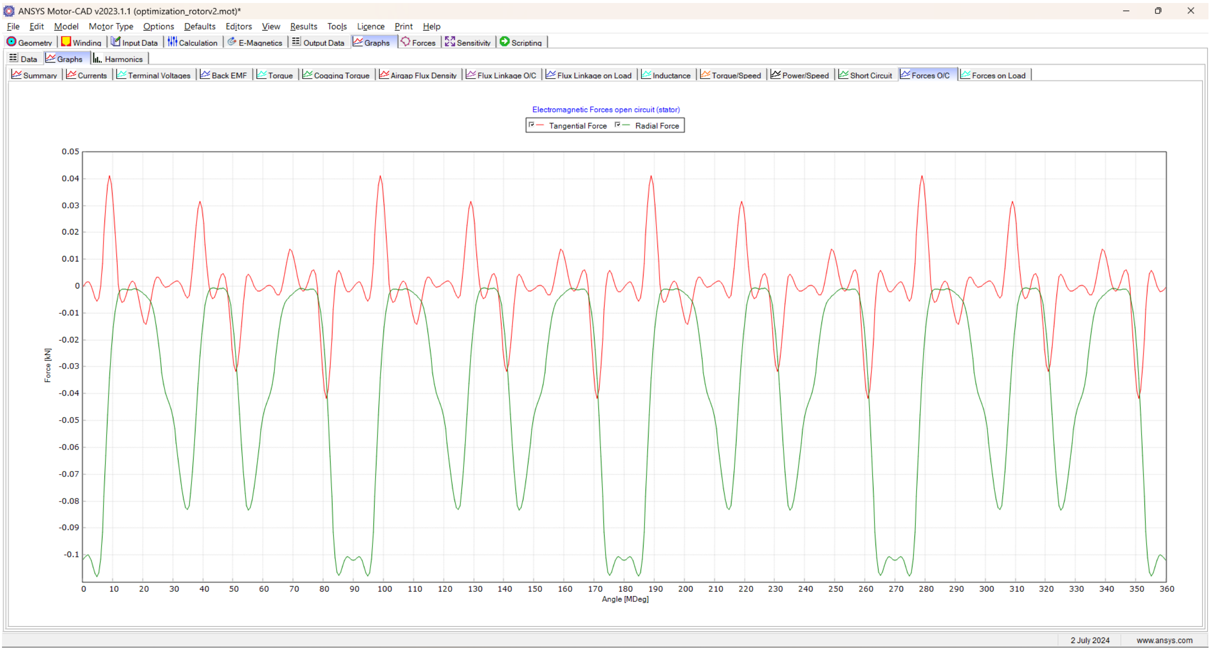
ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
Electromagnetic Forces open circuit (stator)
Tangential Force
Radial Force
Force [kN]
Angle [MDeg]
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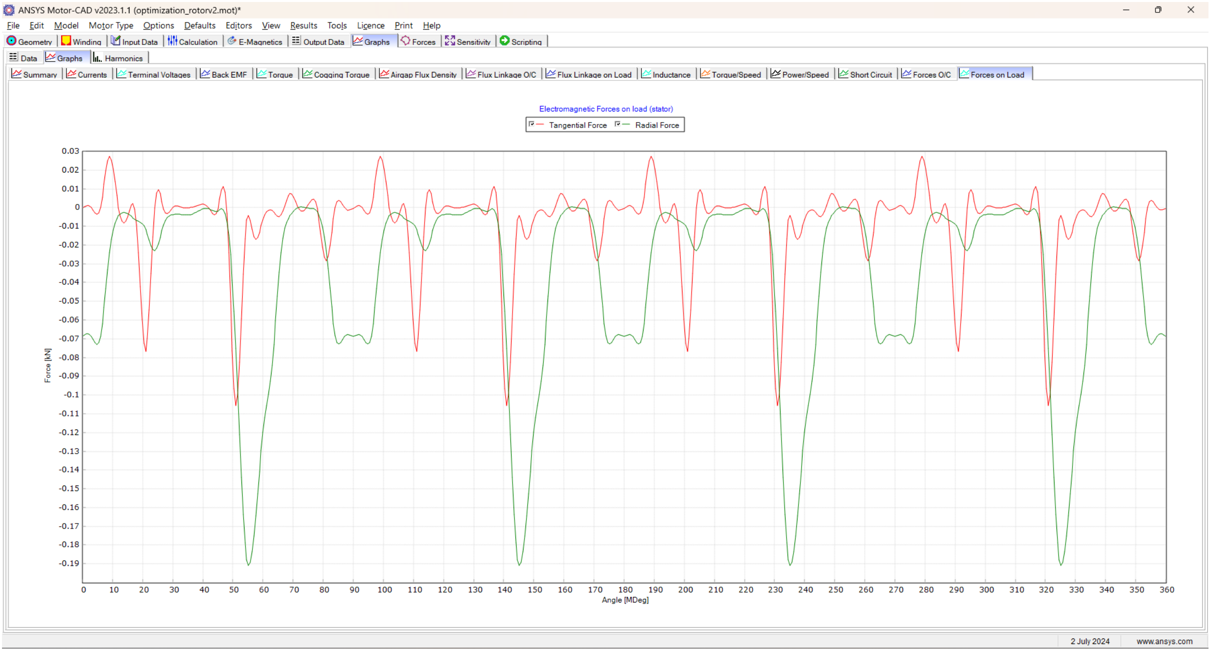
ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
Electromagnetic Forces on load (stator)
Tangential Force
Radial Force
Force [kN]
Angle [MDeg]
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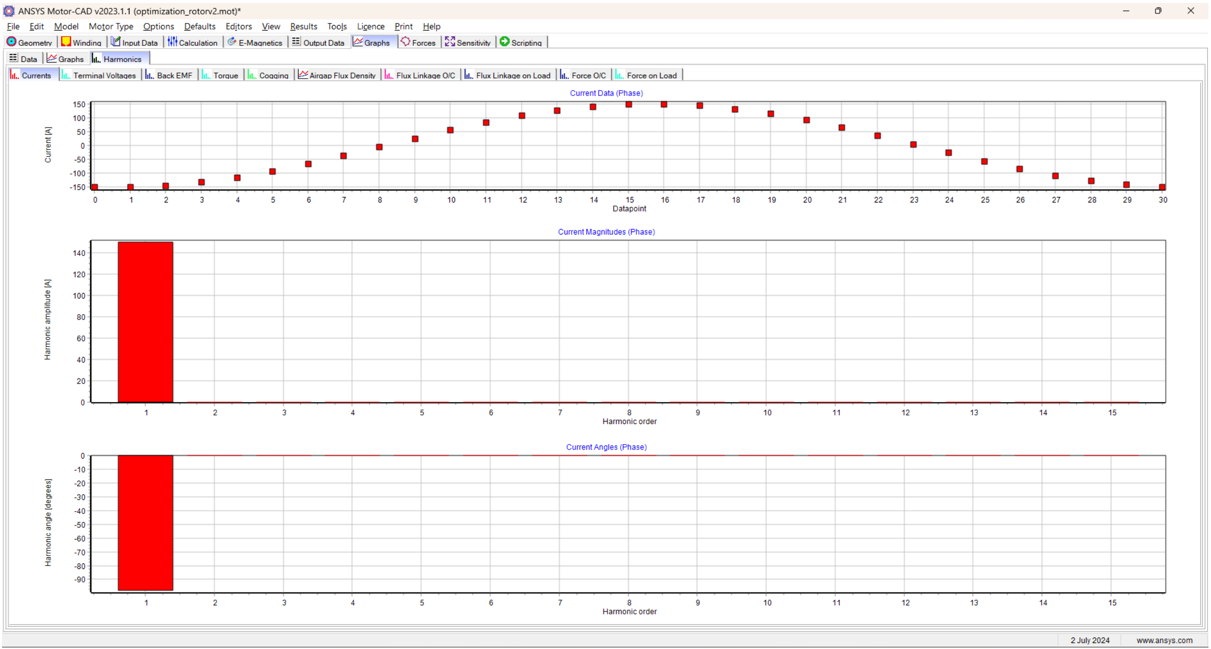
ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
Current Data (Phase)
Current [A]
Datapoint
Current Magnitudes (Phase)
Harmonic amplitude [A]
Harmonic order
Current Angles (Phase)
Harmonic angle [degrees]
Harmonic order
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ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
Terminal Voltage Data (Line-Line)
Voltage [V]
Datapoint
Terminal Voltage Magnitudes (Line-Line)
Harmonic amplitude [V]
Harmonic order
Terminal Voltage Angles (Line-Line)
Harmonic angle [degrees]
Harmonic order
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ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
Back EMF Data (Line-Line)
Back EMF [V]
Datapoint
Back EMF Magnitudes (Line-Line)
Harmonic amplitude [V]
Harmonic order
Back EMF Angles (Line-Line)
Harmonic angle [degrees]
Harmonic order
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ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
File Edit Model Motor Type Options Defaults Editors View Results Tools Licence Print Help
Geometry Winding Input Data Calculation E-Magnetics Output Data Graphs Forces Sensitivity Scripting
Data Graphs Harmonics
Currents Terminal Voltages Back EMF Torque Cogging Airgap Flux Density Flux Linkage O/C Flux Linkage on Load Force O/C Force on Load
Torque (MsVw) Data
Torque [Nm]
Datapoint
Torque Magnitudes
Harmonic amplitude [Nm]
Harmonic order (Electrical)
Torque Angles
Harmonic angle [degrees]
Harmonic order (Electrical)
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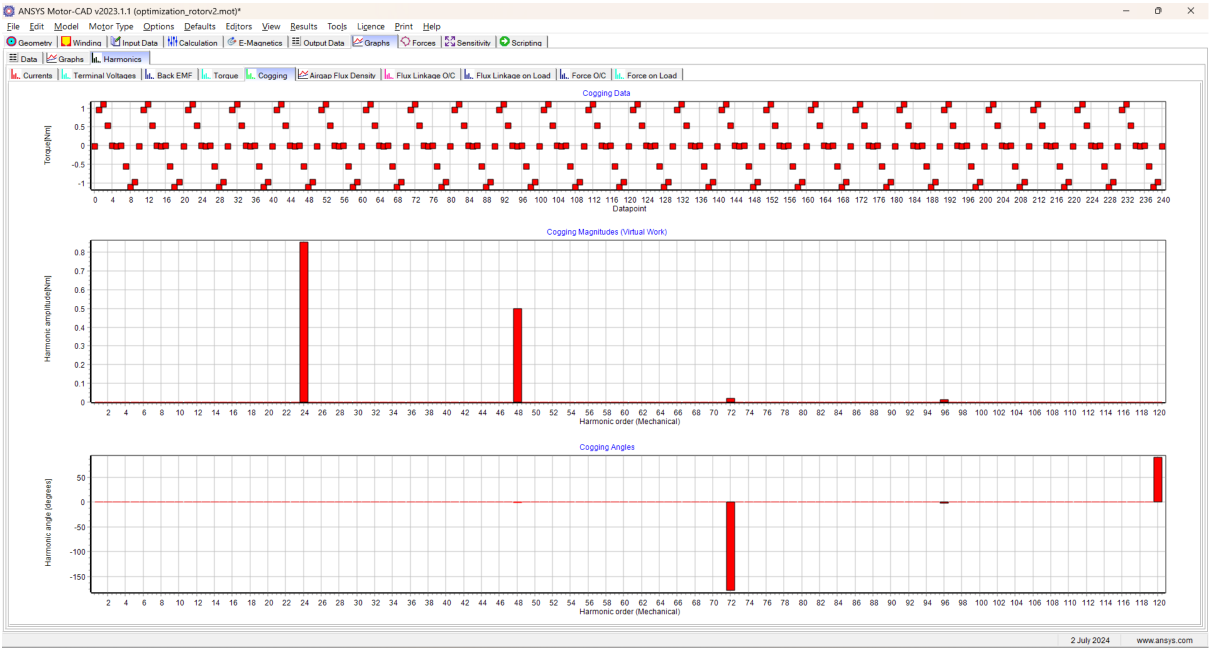
ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
File Edit Model Motor Type Options Defaults Editors View Results Tools Licence Print Help
Geometry Winding Input Data Calculation E-Magnetics Output Data Graphs Forces Sensitivity Scripting
Data Graphs Harmonics
Currents Terminal Voltages Back EMF Torque Cogging Airgap Flux Density Flux Linkage O/C Flux Linkage on Load Force O/C Force on Load
Cogging Data
Torque[Nm]
Datapoint
Cogging Magnitudes (Virtual Work)
Harmonic amplitude[Nm]
Harmonic order (Mechanical)
Cogging Angles
Harmonic angle [degrees]
Harmonic order (Mechanical)
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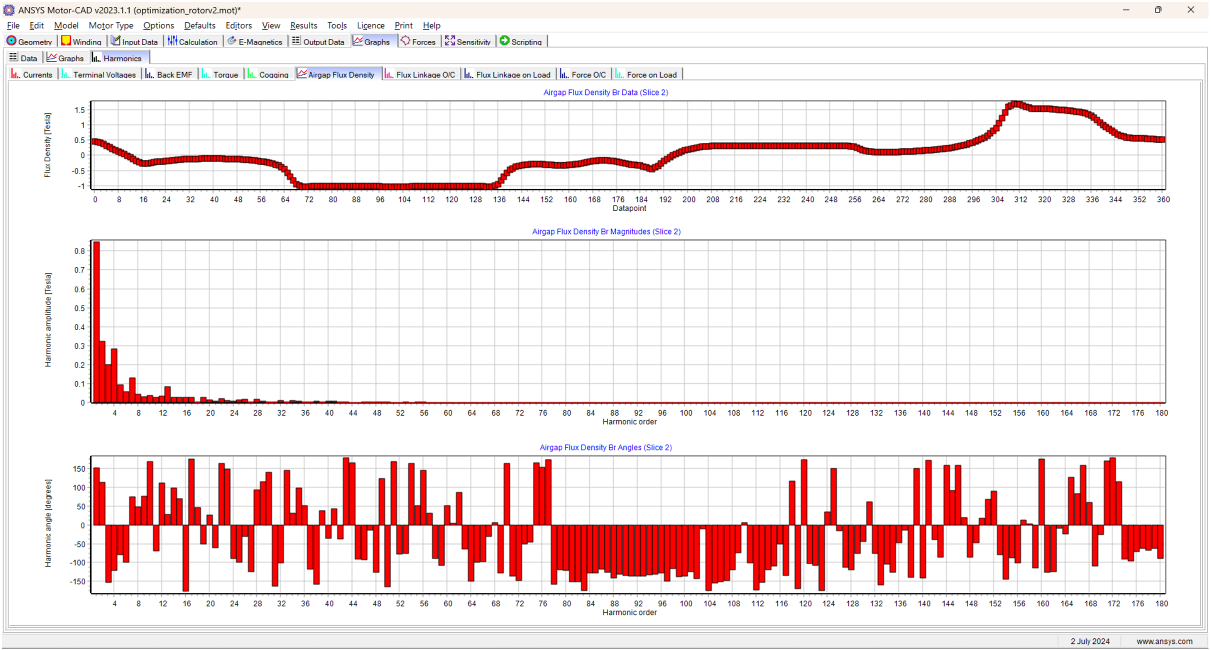

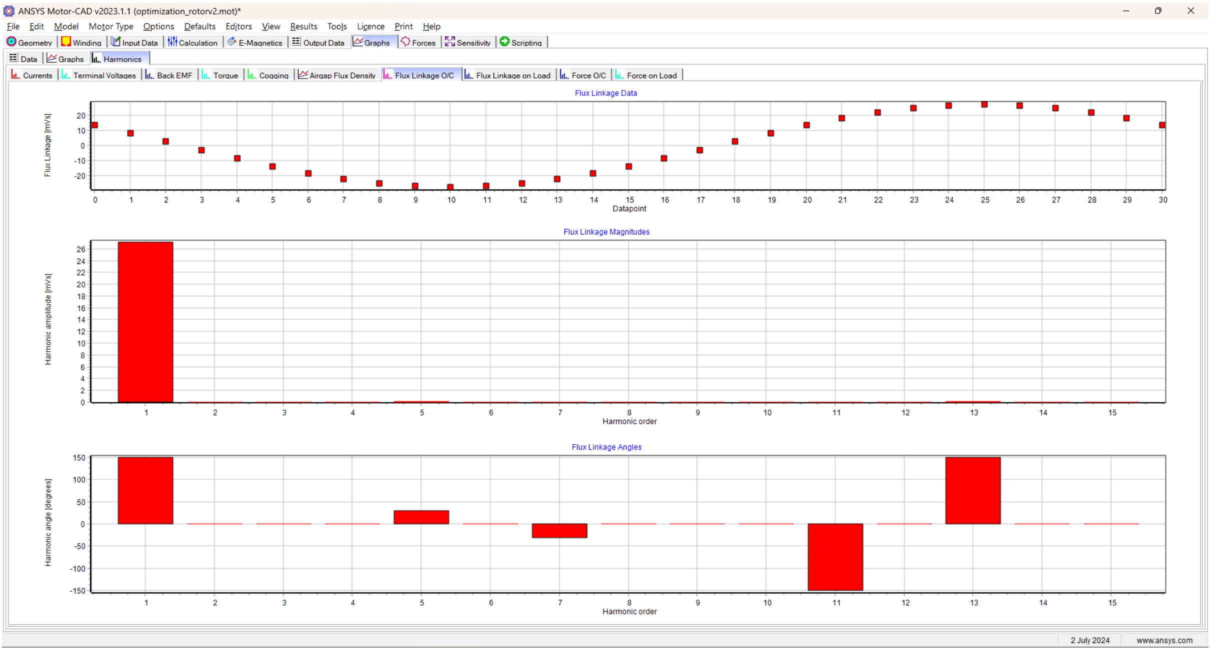

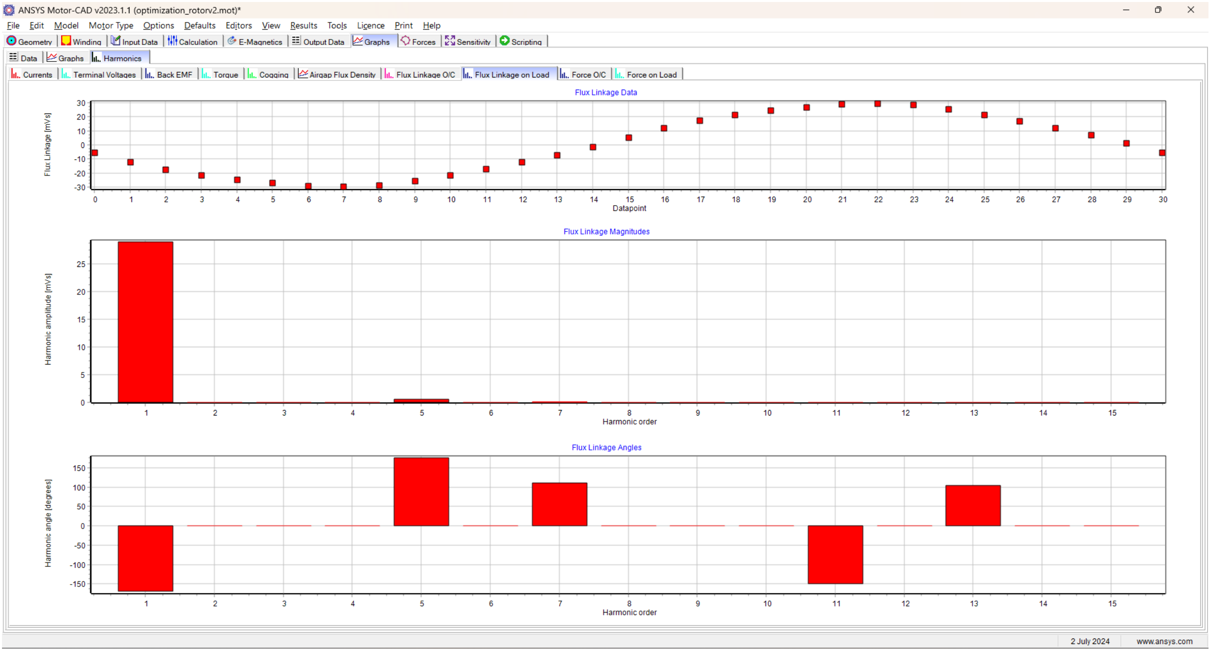
ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
File Edit Model Motor Type Options Defaults Editors View Results Tools Licence Print Help
Geometry Winding Input Data Calculation E-Magnetics Output Data Graphs Forces Sensitivity Scripting
Data Graphs Harmonics
Currents Terminal Voltages Back EMF Torque Cogging Airgap Flux Density Flux Linkage O/C Flux Linkage on Load Force O/C Force on Load
Flux Linkage Data
Flux Linkage [mVs]
Datapoint
Flux Linkage Magnitudes
Harmonic amplitude [mVs]
Harmonic order
Flux Linkage Angles
Harmonic angle [degrees]
Harmonic order
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ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
File Edit Model Motor Type Options Defaults Editors View Results Tools Licence Print Help
Geometry Winding Input Data Calculation E-Magnetics Output Data Graphs Forces Sensitivity Scripting
Data Graphs Harmonics
Currents Terminal Voltages Back EMF Torque Cogging Airgap Flux Density Flux Linkage O/C Flux Linkage on Load Force O/C Force on Load
Tangential Forces
Radial Forces
Tangential Force Data (Stator)
Force [kN]
Datapoint
Tangential Force Magnitudes
Harmonic amplitude [kN]
Harmonic order
Tangential Force Angles
Harmonic angle [degrees]
Harmonic order
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ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
Tangential Forces
Radial Forces
Tangential Force Data (Stator)
Force [kN]
Datapoint
Tangential Force Magnitudes
Harmonic amplitude [kN]
Harmonic order
Tangential Force Angles
Harmonic angle [degrees]
Harmonic order
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ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
Time Harmonics 1D
Space Harmonics 1D
Time Domain 2D
Frequency Domain 2D
Polar Plot
Force Type:
Stator (Radial)
Rotor (Radial)
Stator (Tangential)
Rotor (Tangential)
On Load
Angle:
0: 0 MDeg
Stator (Tangential) () Data
Slice 1
Slice 2
Slice 3
Slice 4
Force Density [N/m²]
Time [s]
Stator (Tangential) () Harmonic Amplitude
Amplitude [N/m²]
Harmonic Order
Stator (Tangential) () Harmonic Angle
Angle [Deg]
Harmonic Order
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ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
Stator (Tangential) () Data
Force Density [N/m²]
Angle [MDeg]
Stator (Tangential) () Harmonic Amplitude
Amplitude [N/m²]
Space Order
Stator (Tangential) () Harmonic Angle
Angle [Deg]
Space Order
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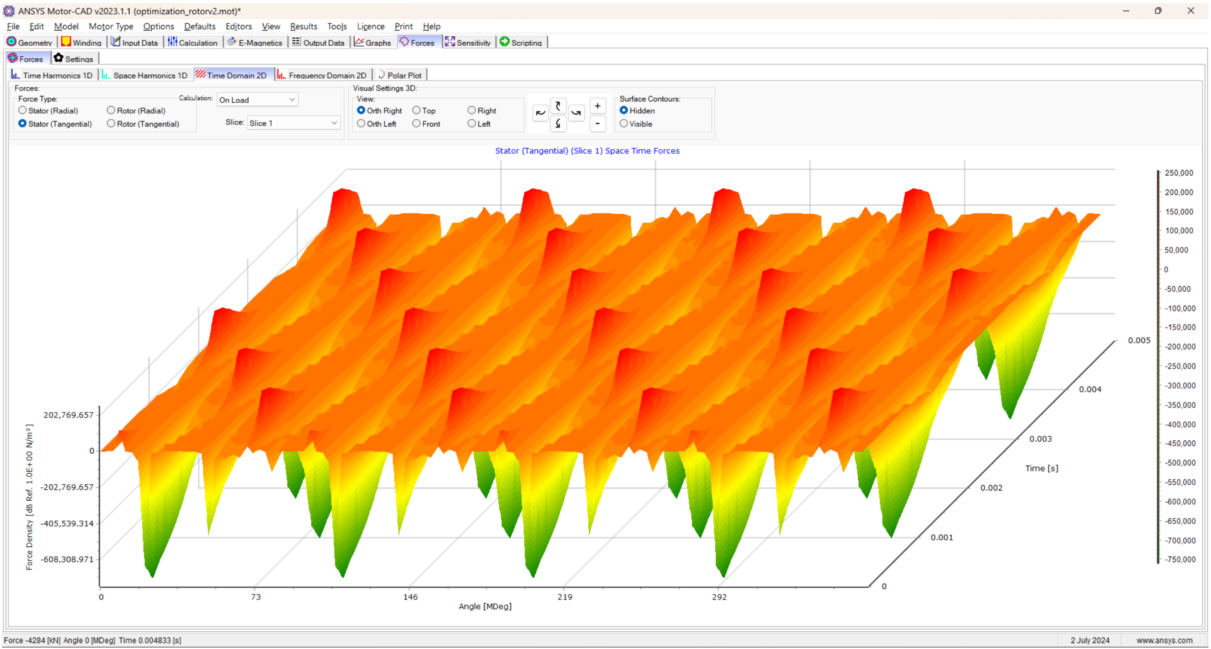
ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
Stator (Tangential) (Slice 1) Space Time Forces
Force Density [dB Ref. 1.0E+00 N/m²]
Angle [MDeg]
Time [s]
Force -4284 [kN] Angle 0 [MDeg] Time 0.004833 [s]
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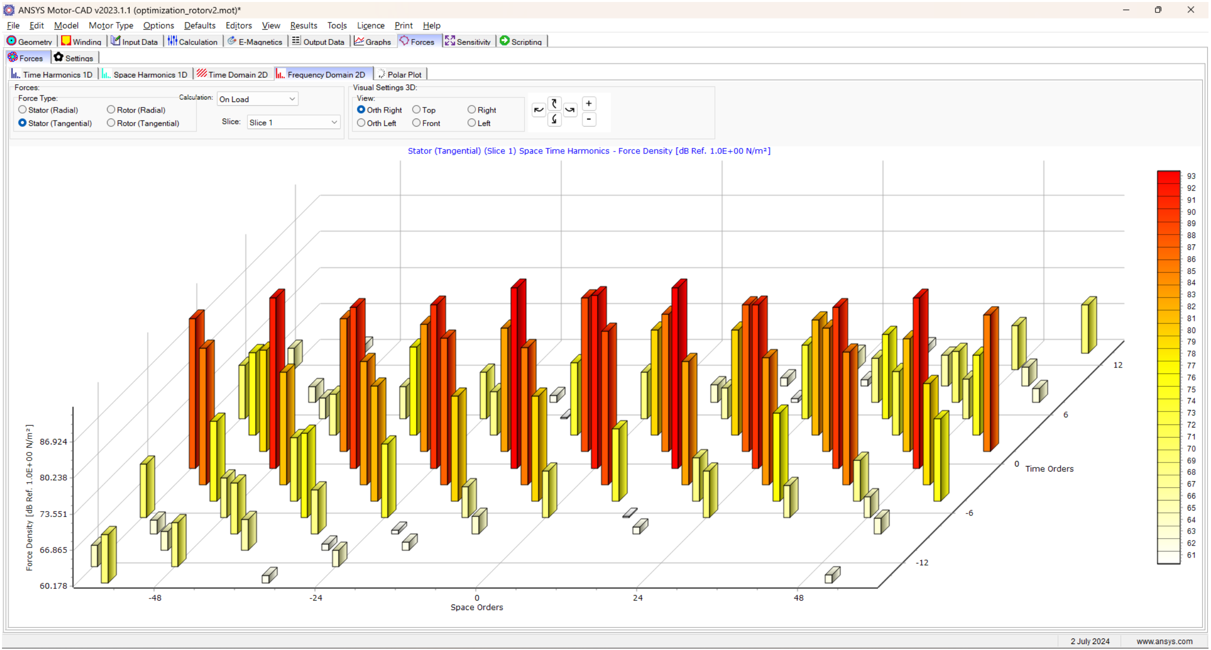
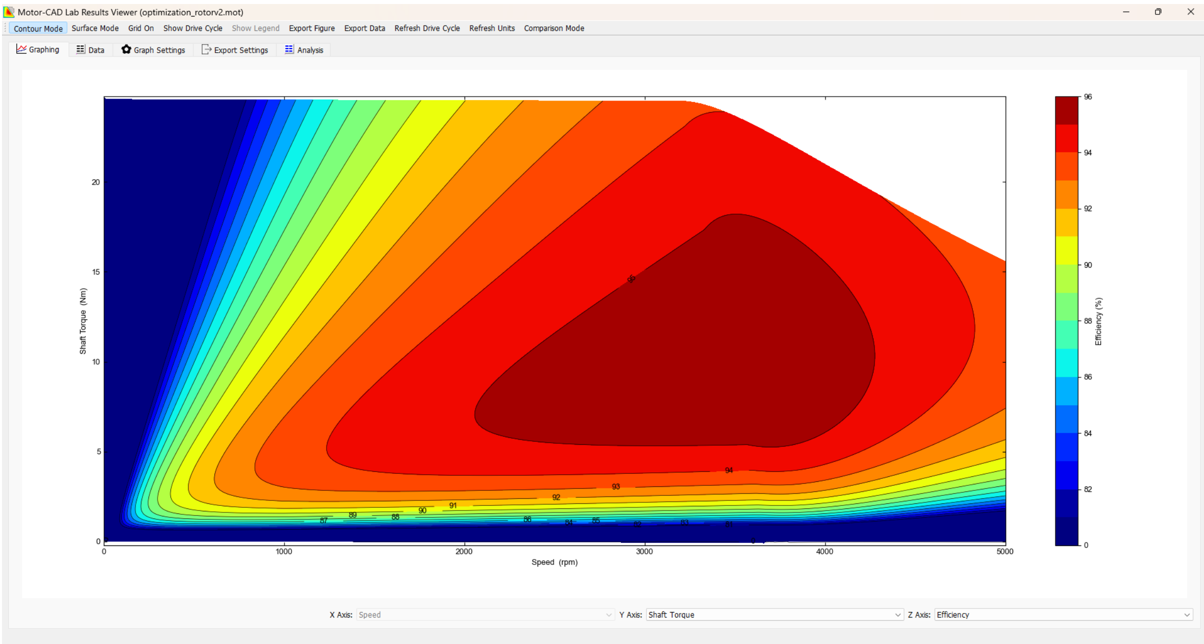
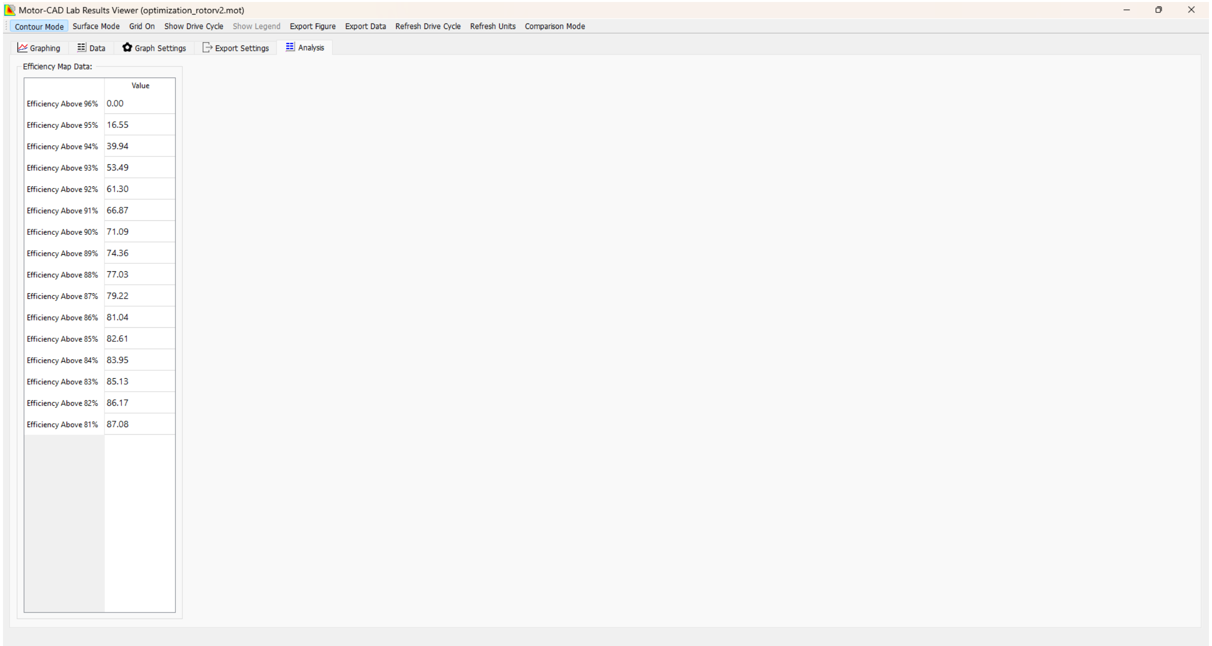


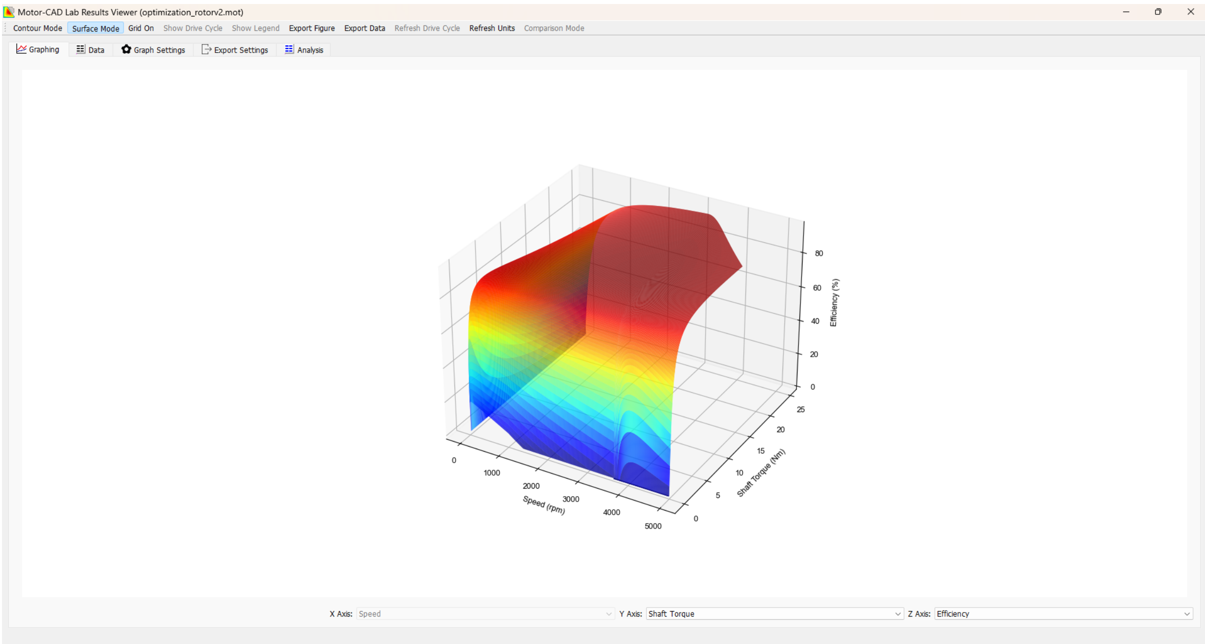
Meeting_ProposalModel

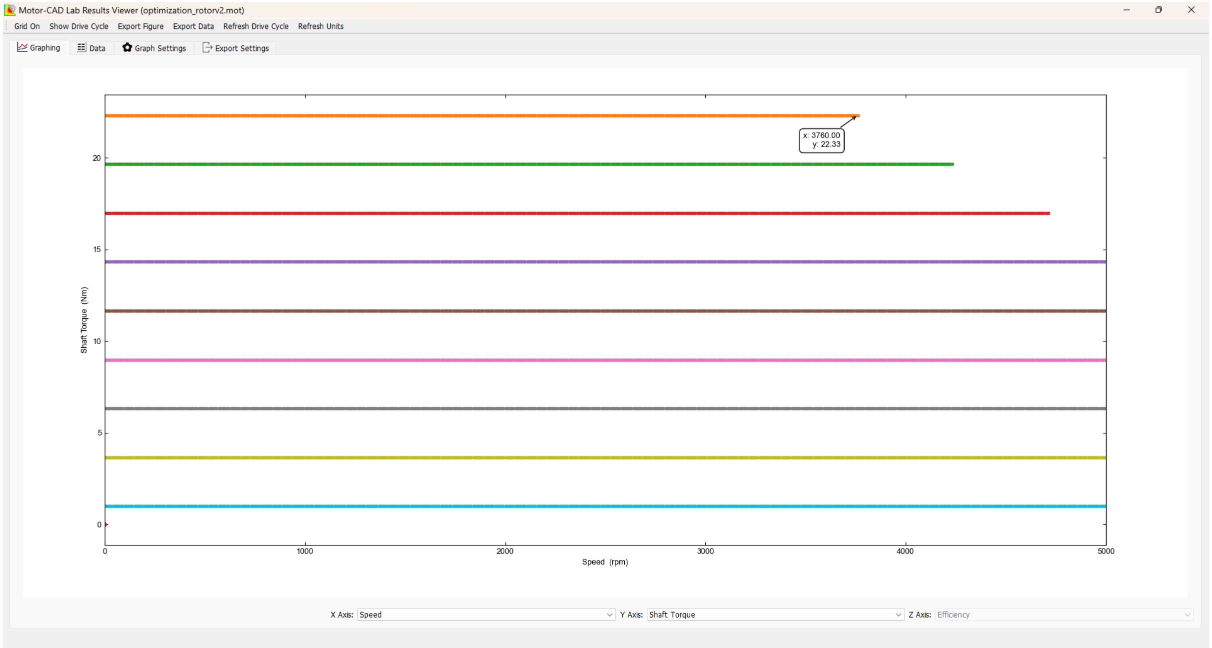
Thermal v2

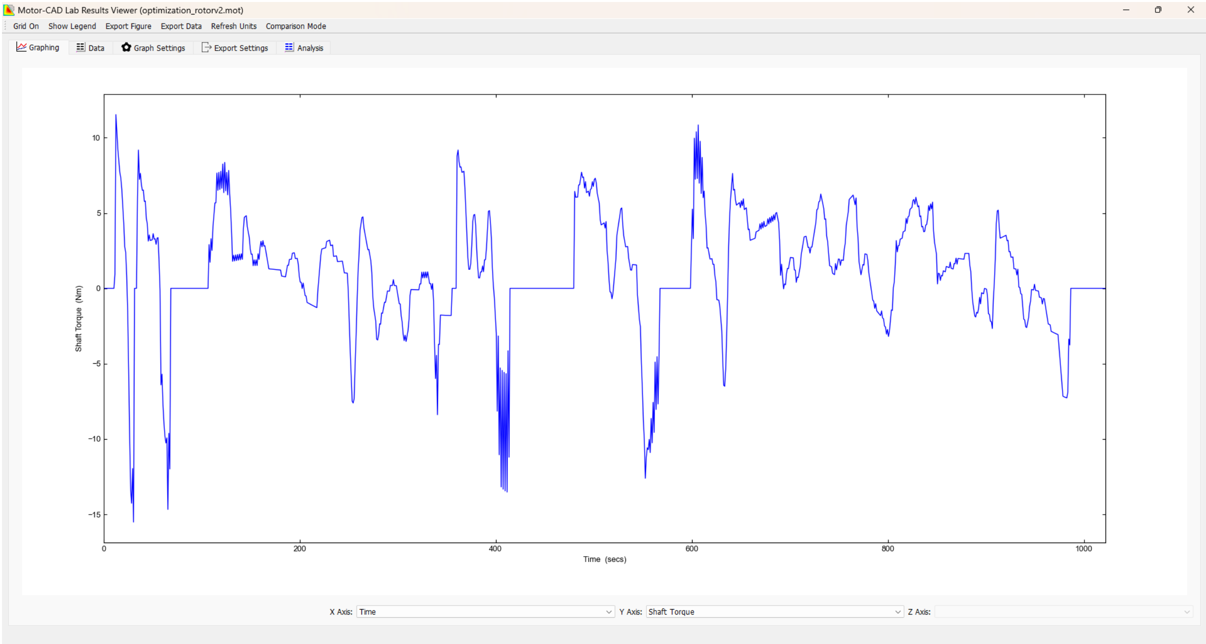


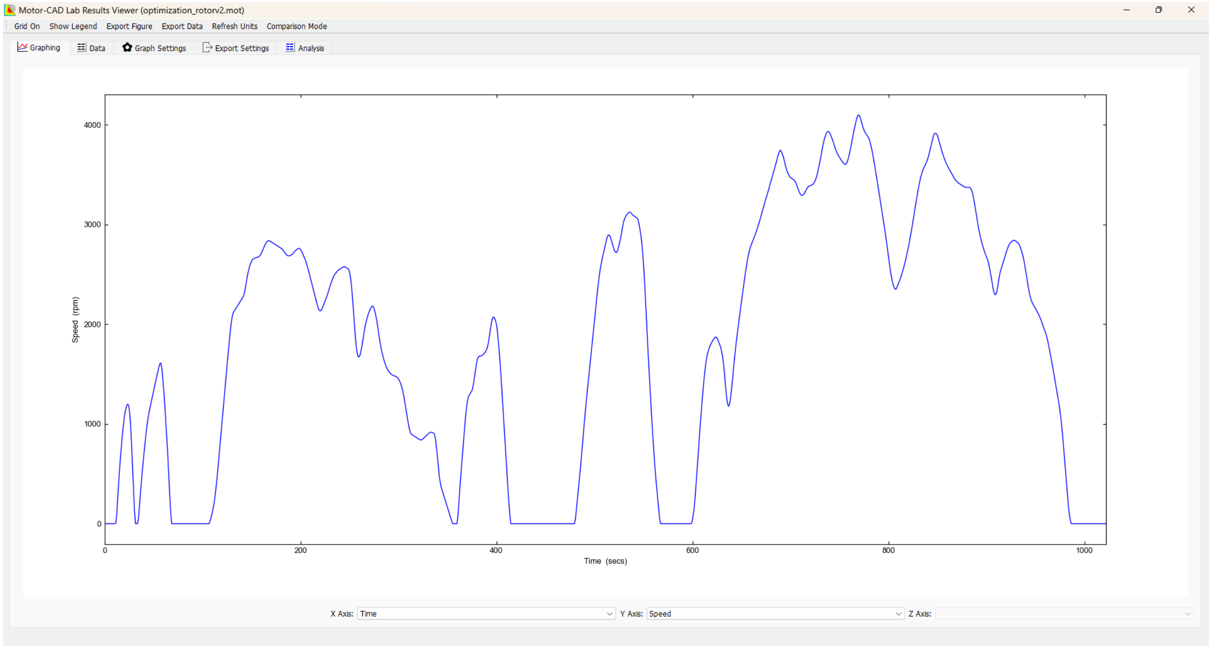


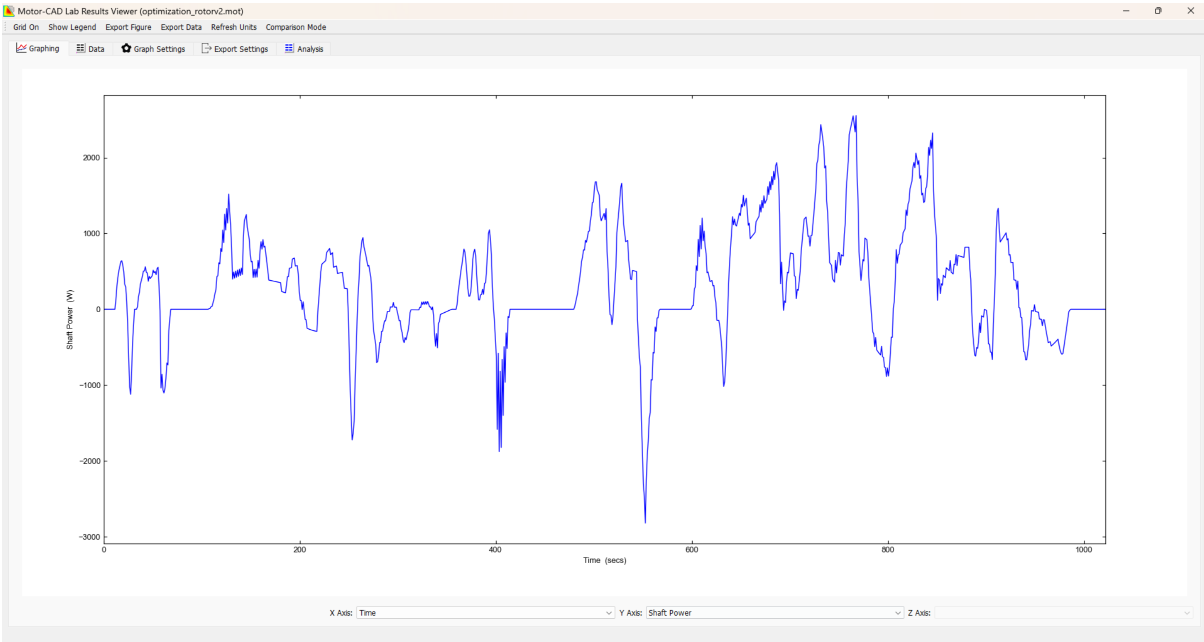
	Value
Efficiency Above 96%	0.00
Efficiency Above 95%	16.55
Efficiency Above 94%	39.94
Efficiency Above 93%	53.49
Efficiency Above 92%	61.30
Efficiency Above 91%	66.87
Efficiency Above 90%	71.09
Efficiency Above 89%	74.36
Efficiency Above 88%	77.03
Efficiency Above 87%	79.22
Efficiency Above 86%	81.04
Efficiency Above 85%	82.61
Efficiency Above 84%	83.95
Efficiency Above 83%	85.13
Efficiency Above 82%	86.17
Efficiency Above 81%	87.08

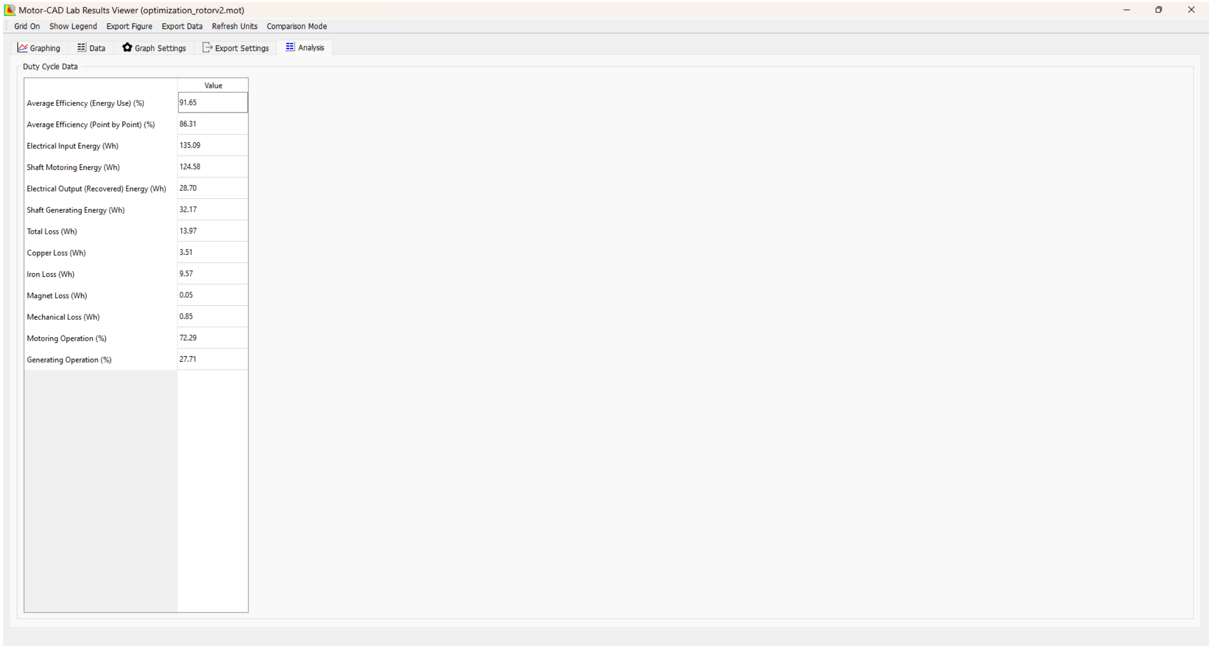


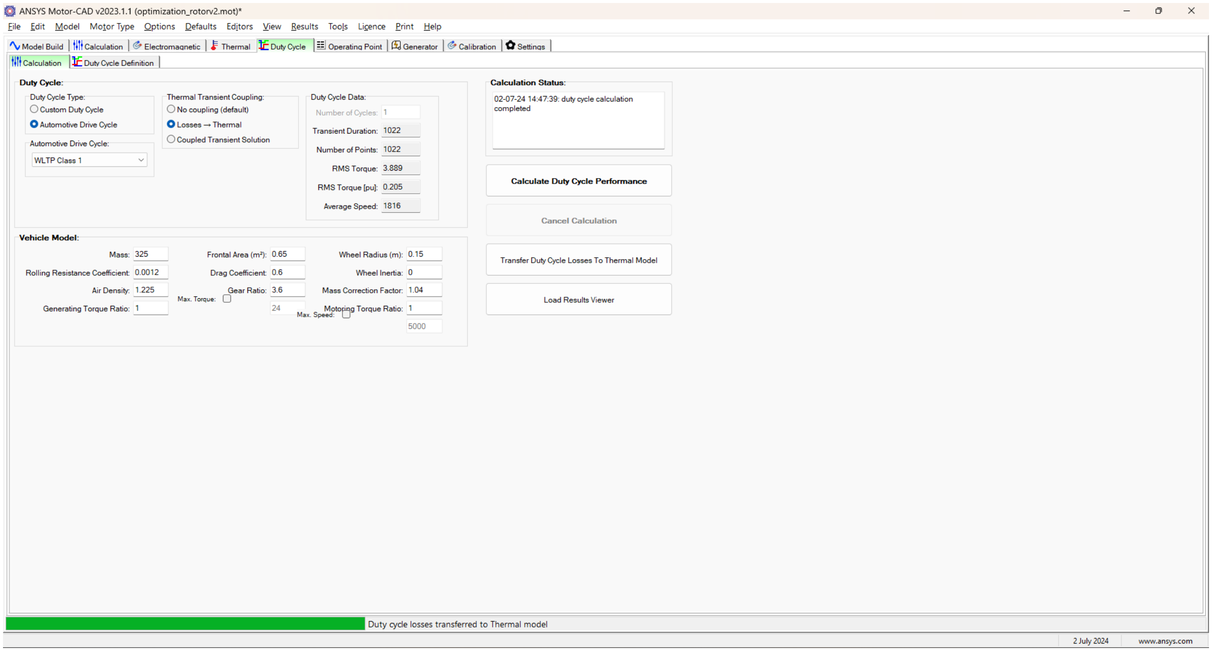

Motor-CAD Lab Results Viewer (optimization_rotorv2.mot)
Grid On Show Drive Cycle Export Figure Export Data Refresh Drive Cycle Refresh Units
Graphing Data Graph Settings Export Settings
x: 3760.00
y: 22.33
Shaft Torque (Nm)
Speed (rpm)
X Axis: Speed
Y Axis: Shaft Torque
Z Axis: Efficiency


Motor-CAD Lab Results Viewer (optimization_rotorv2.mot)
Grid On Show Legend Export Figure Export Data Refresh Units Comparison Mode
Graphing Data Graph Settings Export Settings Analysis
Shaft Torque (Nm)
Time (secs)
X Axis: Time
Y Axis: Shaft Torque
Z Axis:


Motor-CAD Lab Results Viewer (optimization_rotorv2.mot)
Grid On
Show Legend
Export Figure
Export Data
Refresh Units
Comparison Mode
Graphing
Data
Graph Settings
Export Settings
Analysis
Speed (rpm)
Time (secs)
X Axis:
Time
Y Axis:
Speed
Z Axis:


Motor-CAD Lab Results Viewer (optimization_rotorv2.mot)
Grid On
Show Legend
Export Figure
Export Data
Refresh Units
Comparison Mode
Graphing
Data
Graph Settings
Export Settings
Analysis
Shaft Power (W)
Time (secs)
X Axis:
Time
Y Axis:
Shaft Power
Z Axis:


Motor-CAD Lab Results Viewer (optimization_rotorv2.mot)
Grid On
Show Legend
Export Figure
Export Data
Refresh Units
Comparison Mode
Graphing
Data
Graph Settings
Export Settings
Analysis
Duty Cycle Data
Value
Average Efficiency (Energy Use) (%) 91.65
Average Efficiency (Point by Point) (%) 86.31
Electrical Input Energy (Wh) 135.09
Shaft Motoring Energy (Wh) 124.58
Electrical Output (Recovered) Energy (Wh) 28.70
Shaft Generating Energy (Wh) 32.17
Total Loss (Wh) 13.97
Copper Loss (Wh) 3.51
Iron Loss (Wh) 9.57
Magnet Loss (Wh) 0.05
Mechanical Loss (Wh) 0.85
Motoring Operation (%) 72.29
Generating Operation (%) 27.71


ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
File Edit Model Motor Type Options Defaults Editors View Results Tools Licence Print Help
Model Build
Calculation
Electromagnetic
Thermal
Duty Cycle
Operating Point
Generator
Calibration
Settings
Calculation
Duty Cycle Definition
Duty Cycle:
Duty Cycle Type:
Custom Duty Cycle
Automotive Drive Cycle
Automotive Drive Cycle:
WLTP Class 1
Thermal Transient Coupling:
No coupling (default)
Losses → Thermal
Coupled Transient Solution
Duty Cycle Data:
Number of Cycles: 1
Transient Duration: 1022
Number of Points: 1022
RMS Torque: 3.889
RMS Torque [pu]: 0.205
Average Speed: 1816
Calculation Status:
02-07-24 14:47:39: duty cycle calculation completed
Calculate Duty Cycle Performance
Cancel Calculation
Transfer Duty Cycle Losses To Thermal Model
Load Results Viewer
Vehicle Model:
Mass: 325
Rolling Resistance Coefficient: 0.0012
Air Density: 1.225
Generating Torque Ratio: 1
Frontal Area (m²): 0.65
Drag Coefficient: 0.6
Gear Ratio: 3.6
Max. Torque:
24
Wheel Radius (m): 0.15
Wheel Inertia: 0
Mass Correction Factor: 1.04
Motoring Torque Ratio: 1
Max. Speed:
5000
Duty cycle losses transferred to Thermal model
2 July 2024
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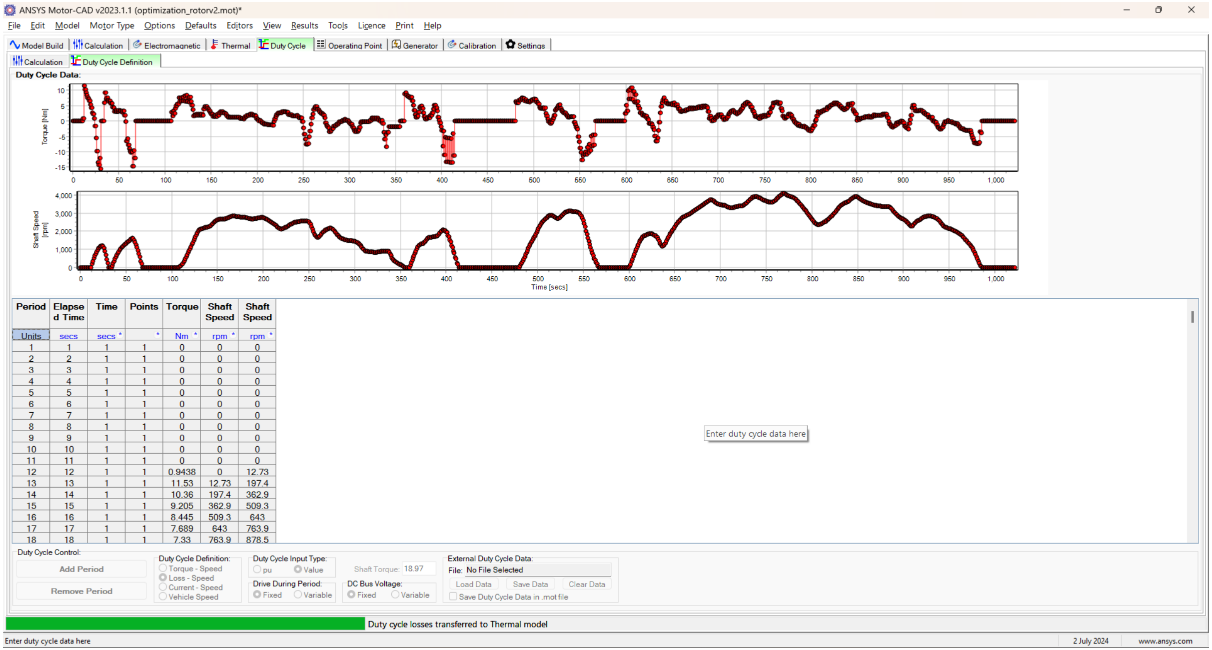
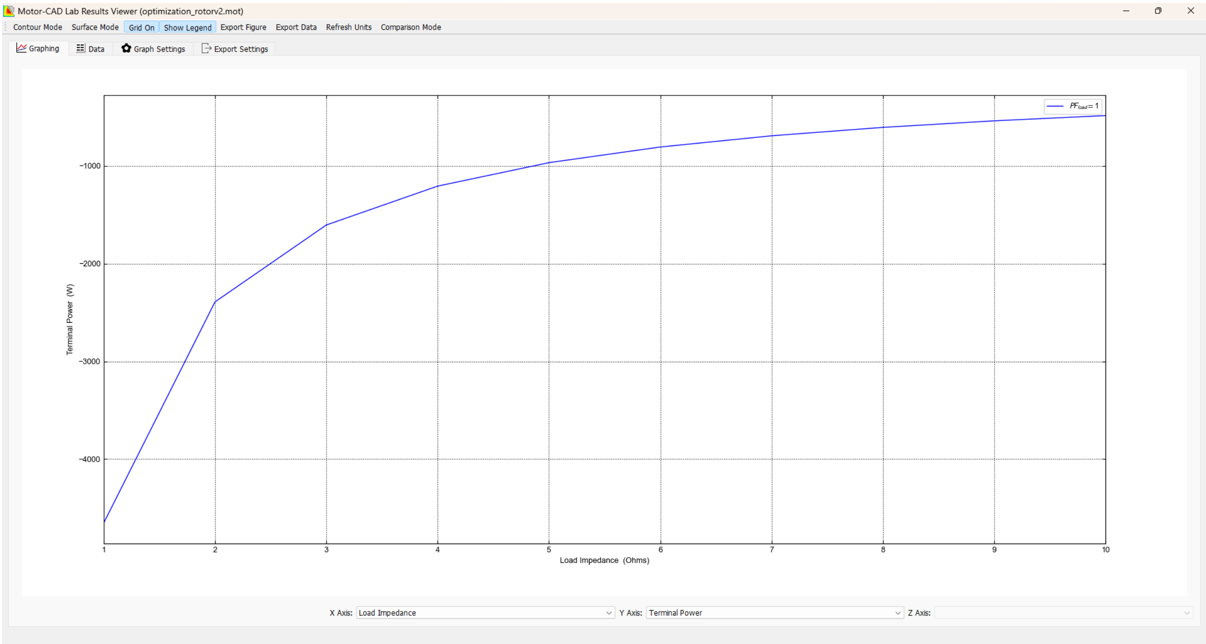
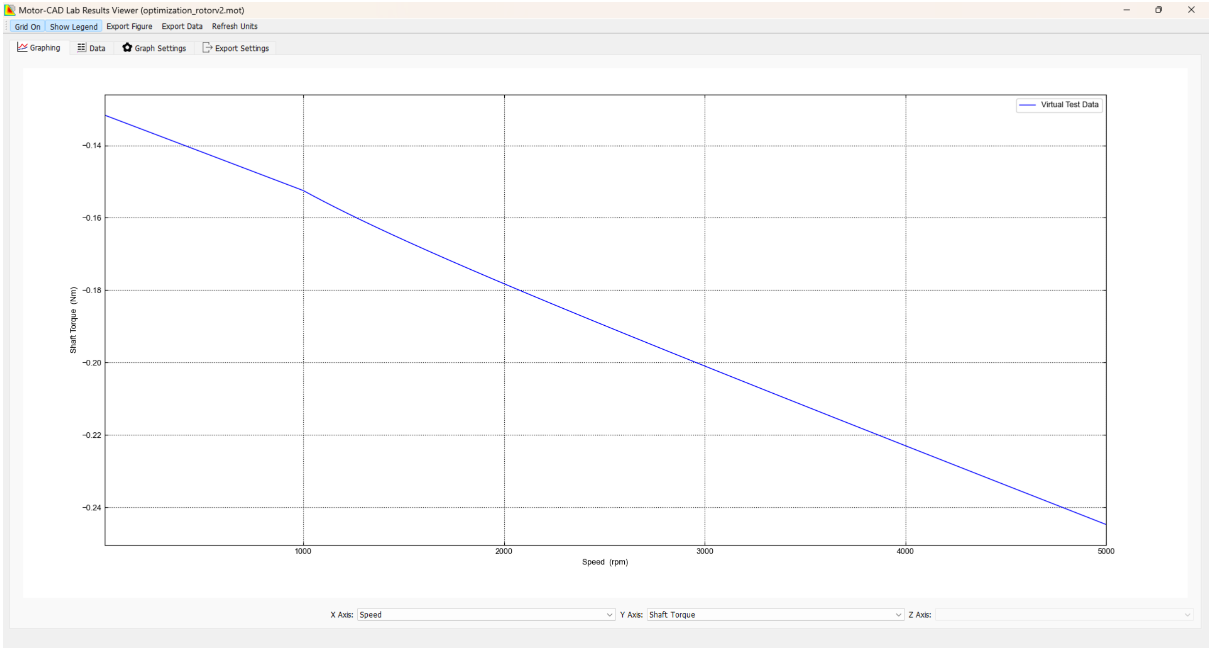
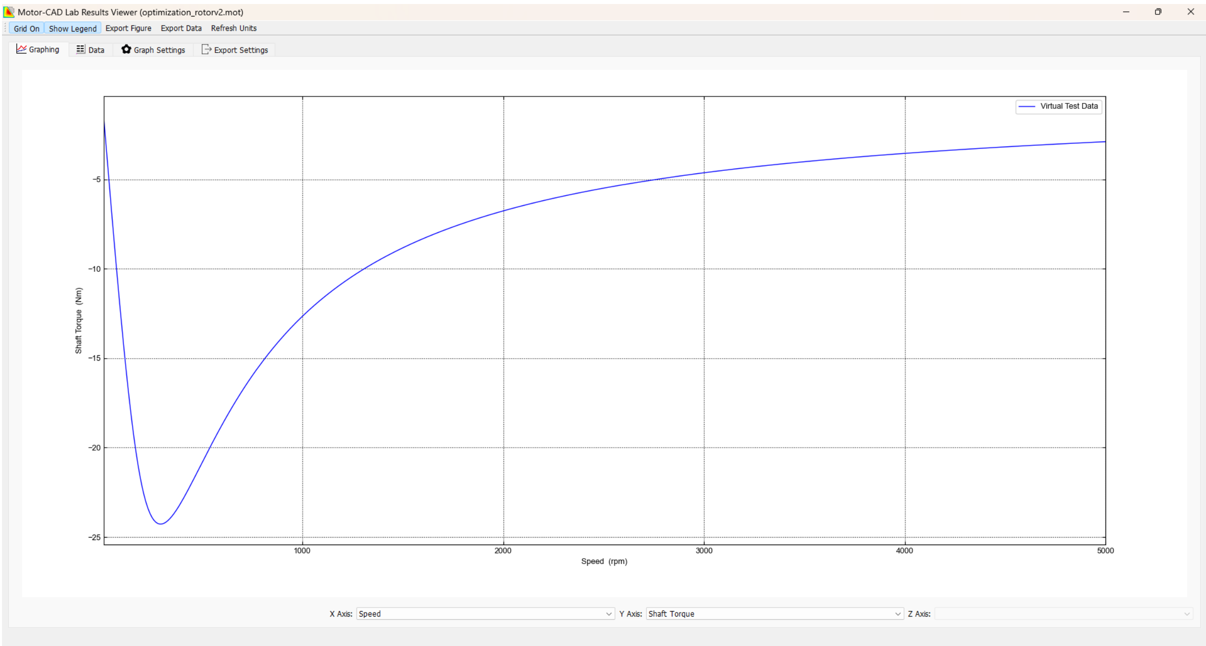




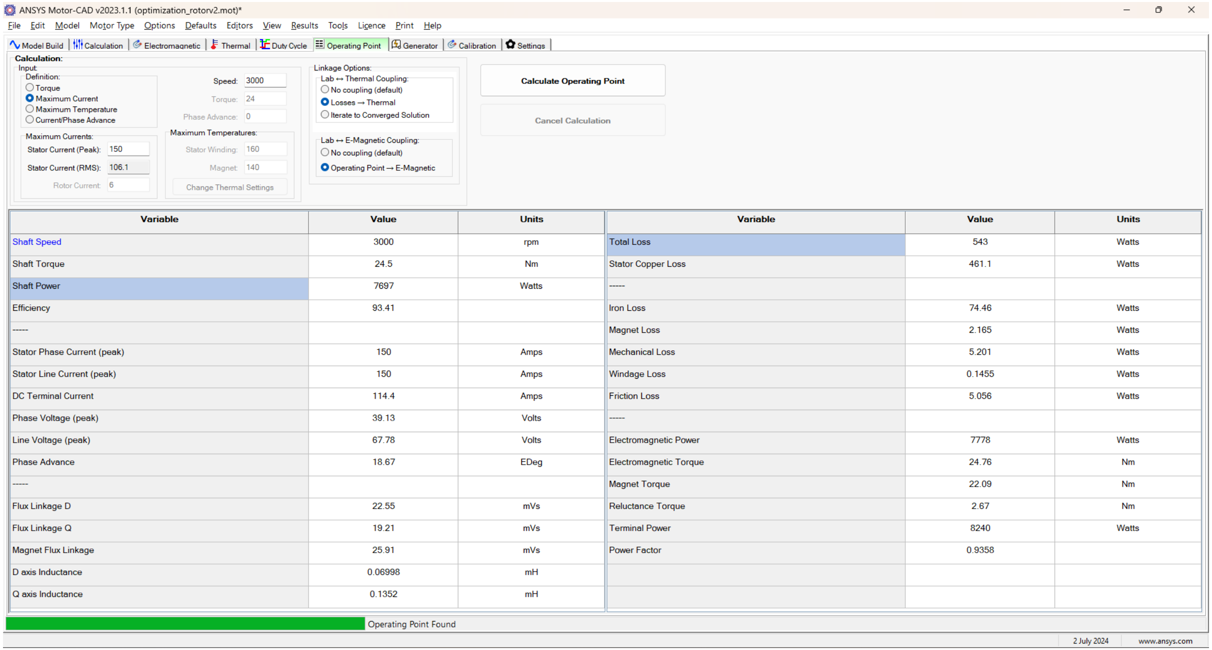


Open Circuit

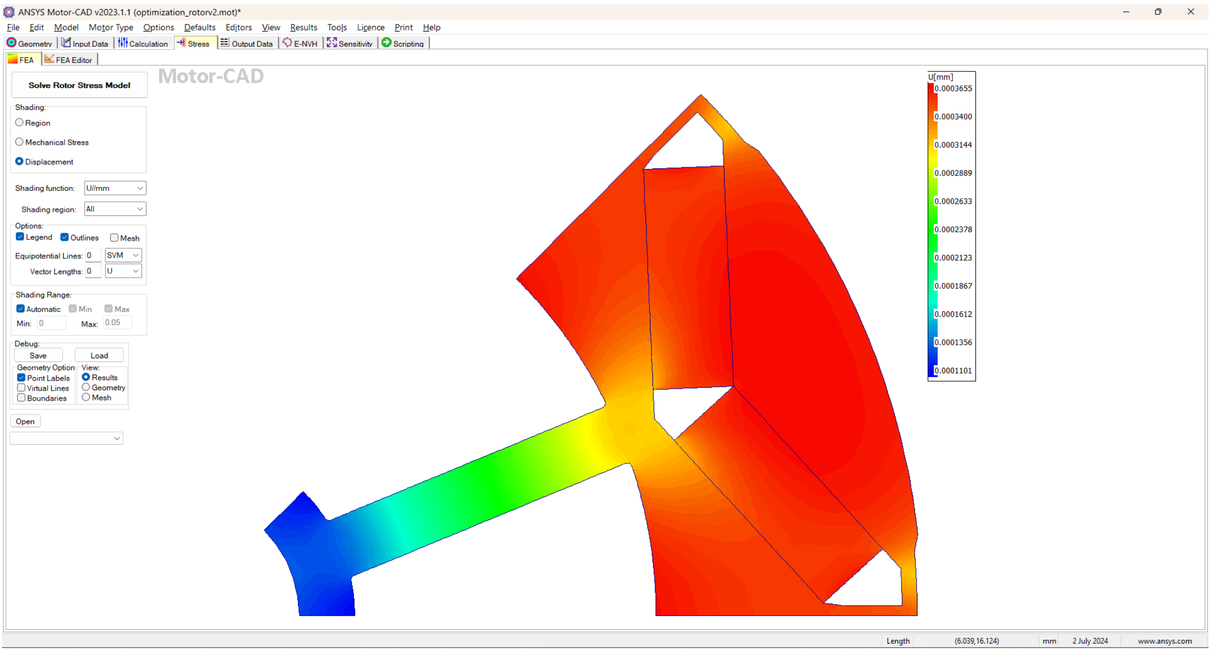


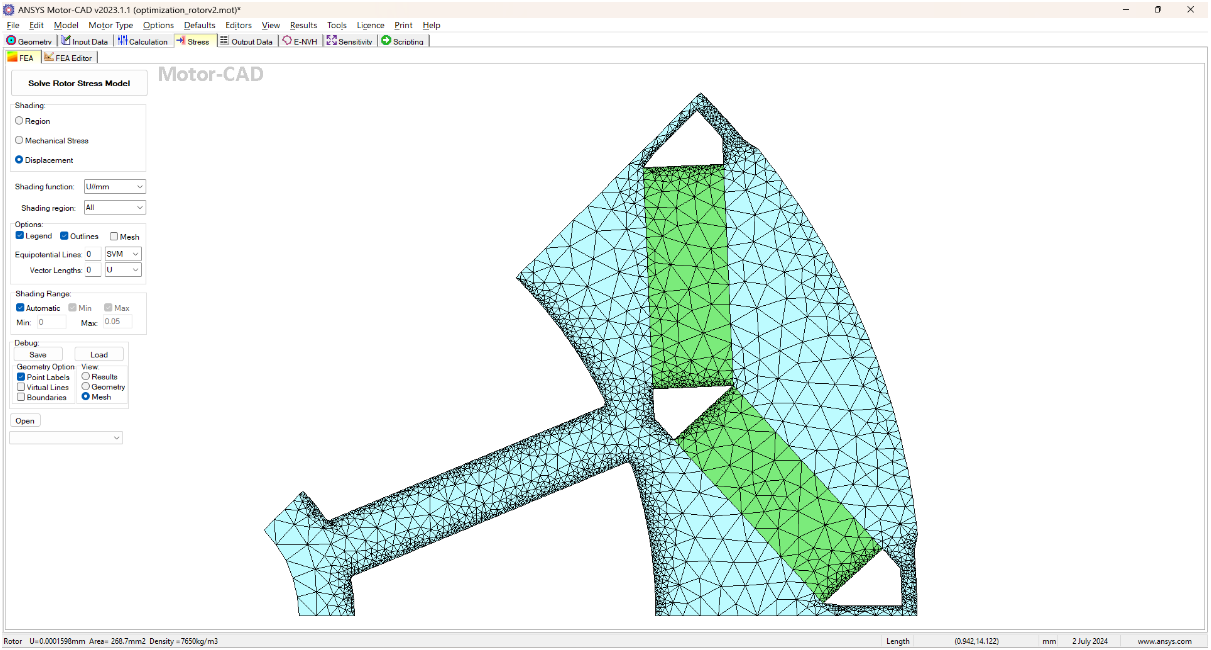
Short Circuit

Operating Point Determination @3000rpm



Mechanical Stress Analysis




ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
Solve Rotor Stress Model
Motor-CAD
Shading:
Region
Mechanical Stress
Displacement
Shading function:
Shading region:
Rotor U=0.0001598mm Area= 268.7mm2 Density =7650kg/m3
2 July 2024
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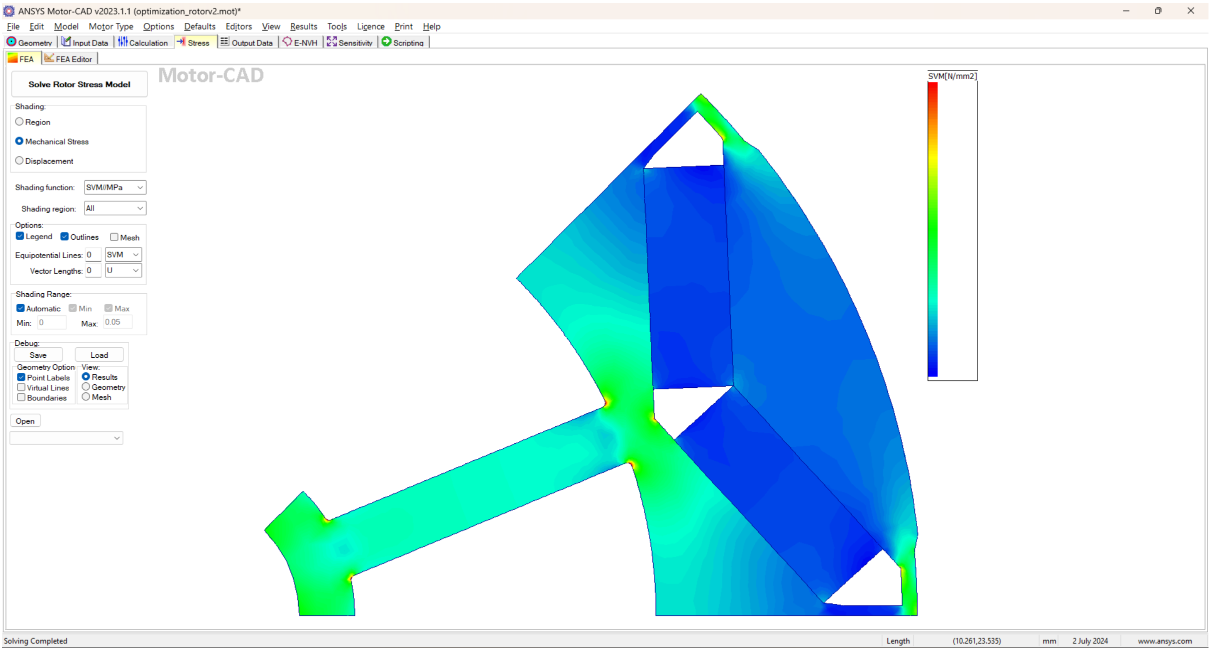
ANSYS Motor-CAD v2023.1.1 (optimization_rotorv2.mot)*
Solve Rotor Stress Model
Motor-CAD
SVM[N/mm2]
Solving Completed
2 July 2024
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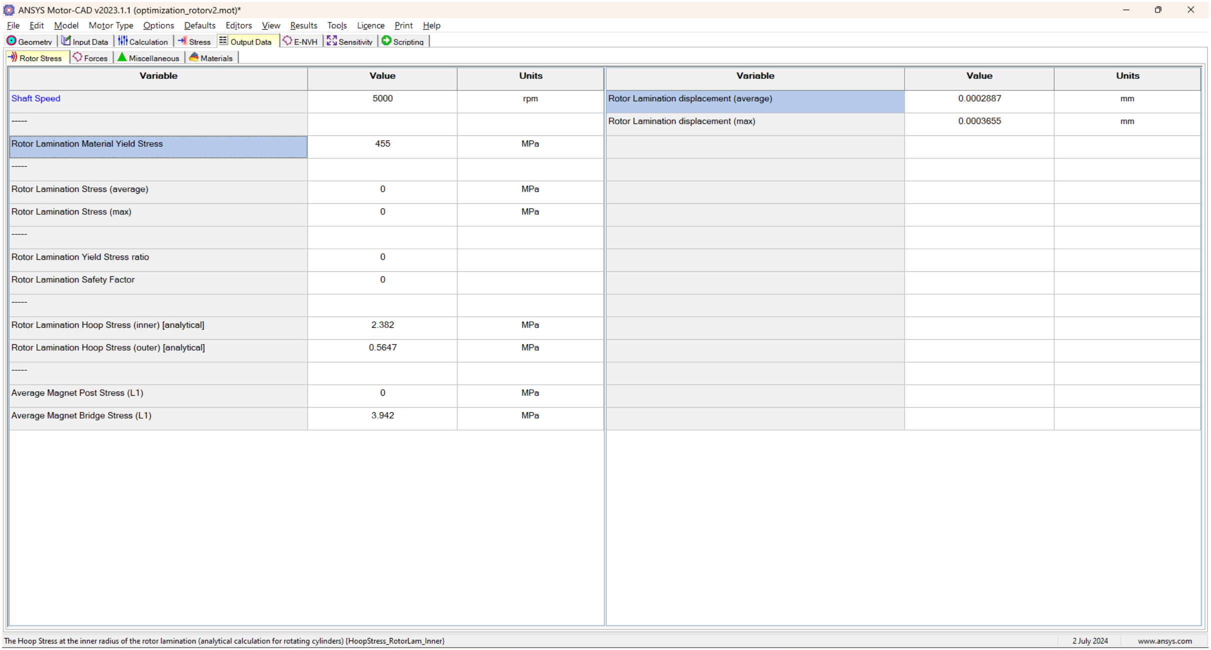


Variable	Value	Units
Shaft Speed	5000	rpm

Rotor Lamination Material Yield Stress	455	MPa

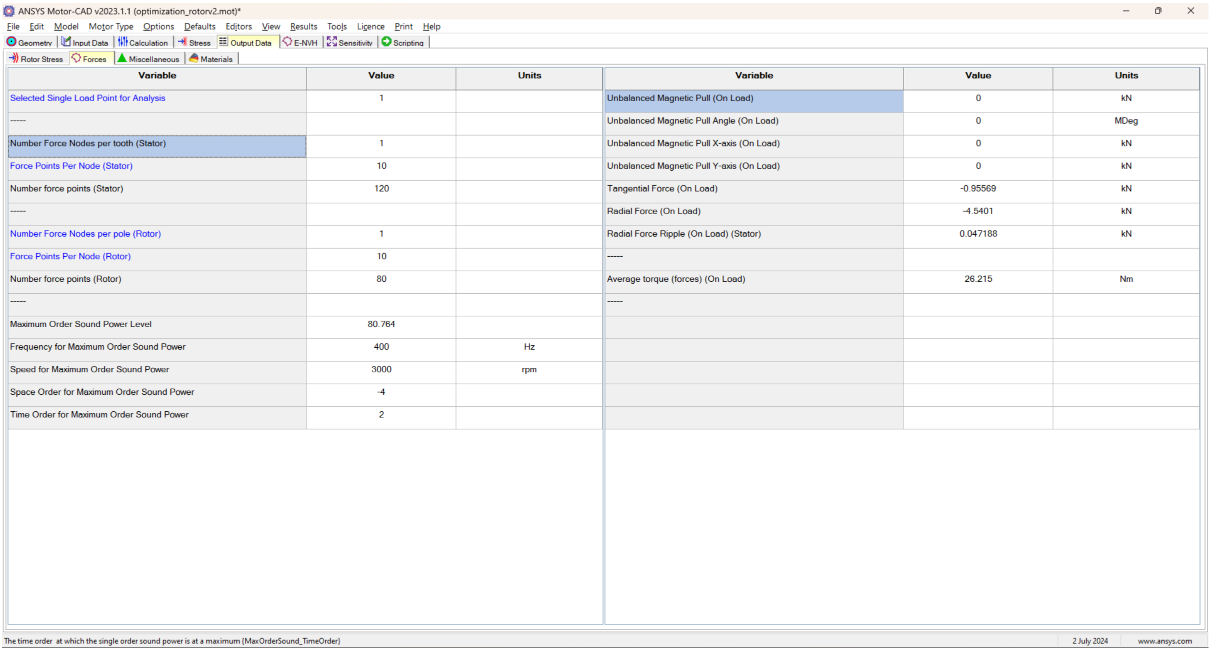
Rotor Lamination Stress (average)	0	MPa
Rotor Lamination Stress (max)	0	MPa

Rotor Lamination Yield Stress ratio	0	
Rotor Lamination Safety Factor	0	

Rotor Lamination Hoop Stress (inner) [analytical]	2.382	MPa
Rotor Lamination Hoop Stress (outer) [analytical]	0.5647	MPa

Average Magnet Post Stress (L1)	0	MPa
Average Magnet Bridge Stress (L1)	3.942	MPa

Variable	Value	Units
Rotor Lamination displacement (average)	0.0002887	mm
Rotor Lamination displacement (max)	0.0003655	mm



Variable	Value	Units
Selected Single Load Point for Analysis	1	

Number Force Nodes per tooth (Stator)	1	
Force Points Per Node (Stator)	10	
Number force points (Stator)	120	

Number Force Nodes per pole (Rotor)	1	
Force Points Per Node (Rotor)	10	
Number force points (Rotor)	80	

Maximum Order Sound Power Level	80.764	
Frequency for Maximum Order Sound Power	400	Hz
Speed for Maximum Order Sound Power	3000	rpm
Space Order for Maximum Order Sound Power	-4	
Time Order for Maximum Order Sound Power	2	

Variable	Value	Units
Unbalanced Magnetic Pull (On Load)	0	kN
Unbalanced Magnetic Pull Angle (On Load)	0	MDeg
Unbalanced Magnetic Pull X-axis (On Load)	0	kN
Unbalanced Magnetic Pull Y-axis (On Load)	0	kN
Tangential Force (On Load)	-0.95569	kN
Radial Force (On Load)	-4.5401	kN
Radial Force Ripple (On Load) (Stator)	0.047188	kN

Average torque (forces) (On Load)	26.215	Nm
