



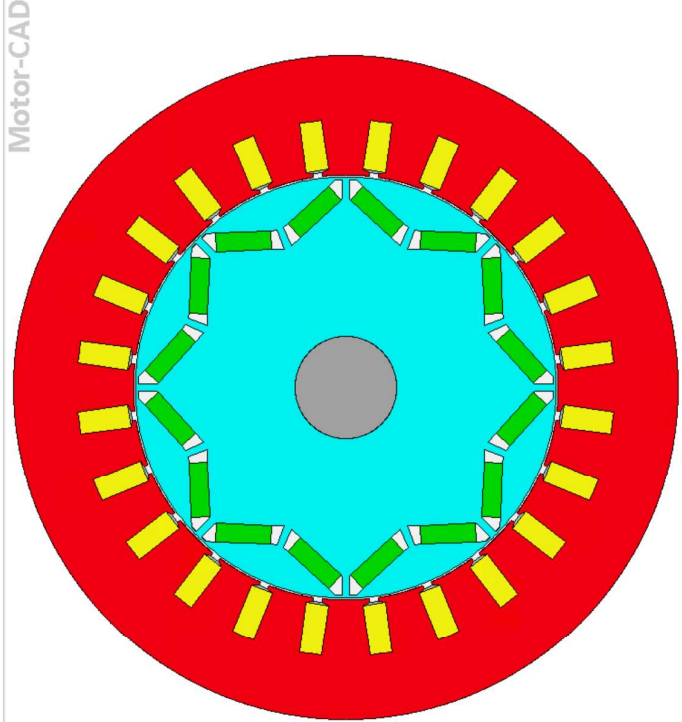
THERMAL ANALYSIS – MOTOR-CAD EXAMPLE

- Overview of Motor-CAD
- Electromagnetic Analysis
- Thermal Analysis
- Thermo-Electromagnetic Analysis (steady-state)
- Transient Thermal Analysis
- Duty Cycle Analysis

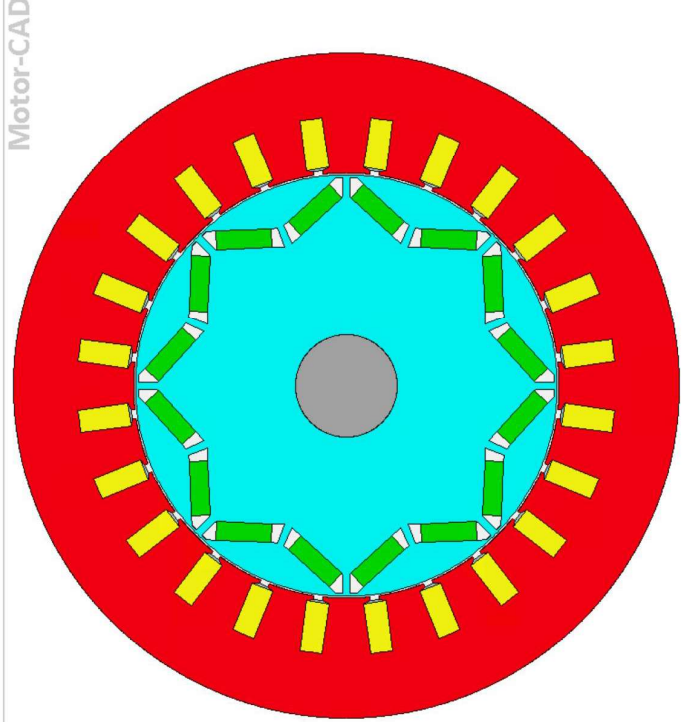
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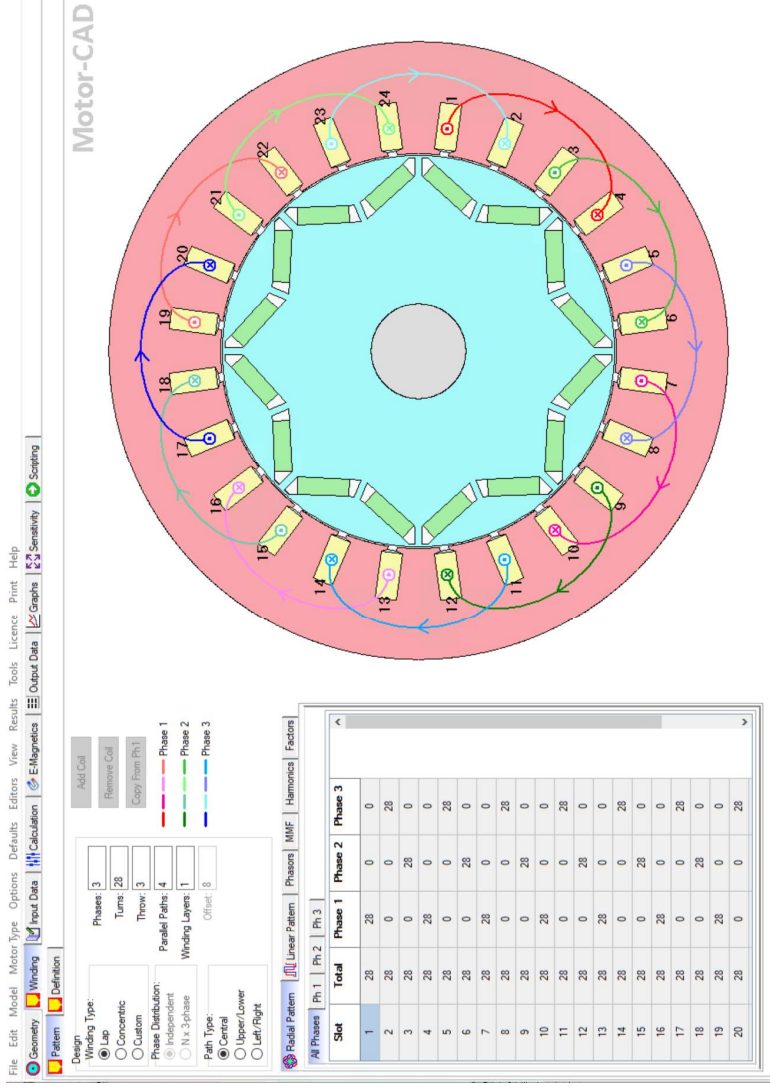
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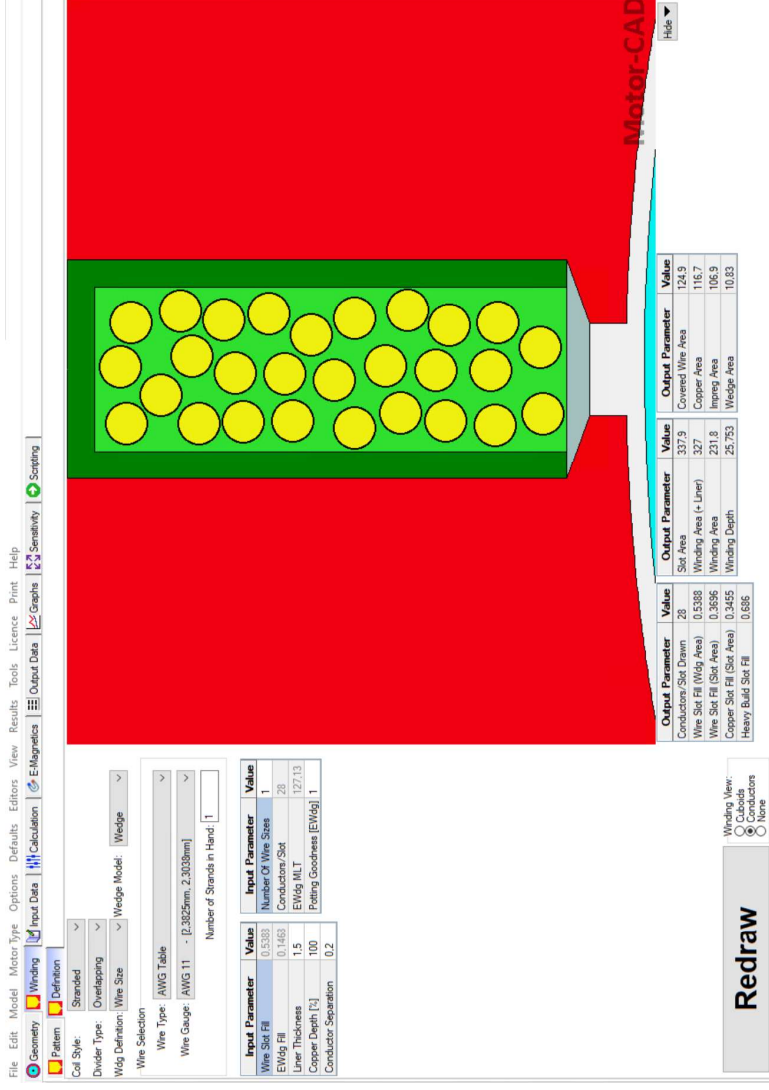
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MOTOR-CAD E-MAGNETIC WINDING



MOTOR-CAD E-MAGNETIC WINDING



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

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

Col Style Stranded Overlapping

Wdg Definition Wire Size Wedge Model: Wedge

Wire Selection

Wire Type: AWG Table

Wire Gauge: AWG 11 - [2.3825mm, 2.3038mm]

Number of Strands in Hand: 1

Input Parameter	Value	Input Parameter	Value
Wire Size Fill	0.5388	Number of Wire Sizes	1
EWdg Fill	0.1463	Conductors / Slot	28
EWdg MLT	1.5	EWdg MLT	127.13
Copper Depth [%]	100	Potting Goodness [EWdg]	1
Conductor Separation	0.2		

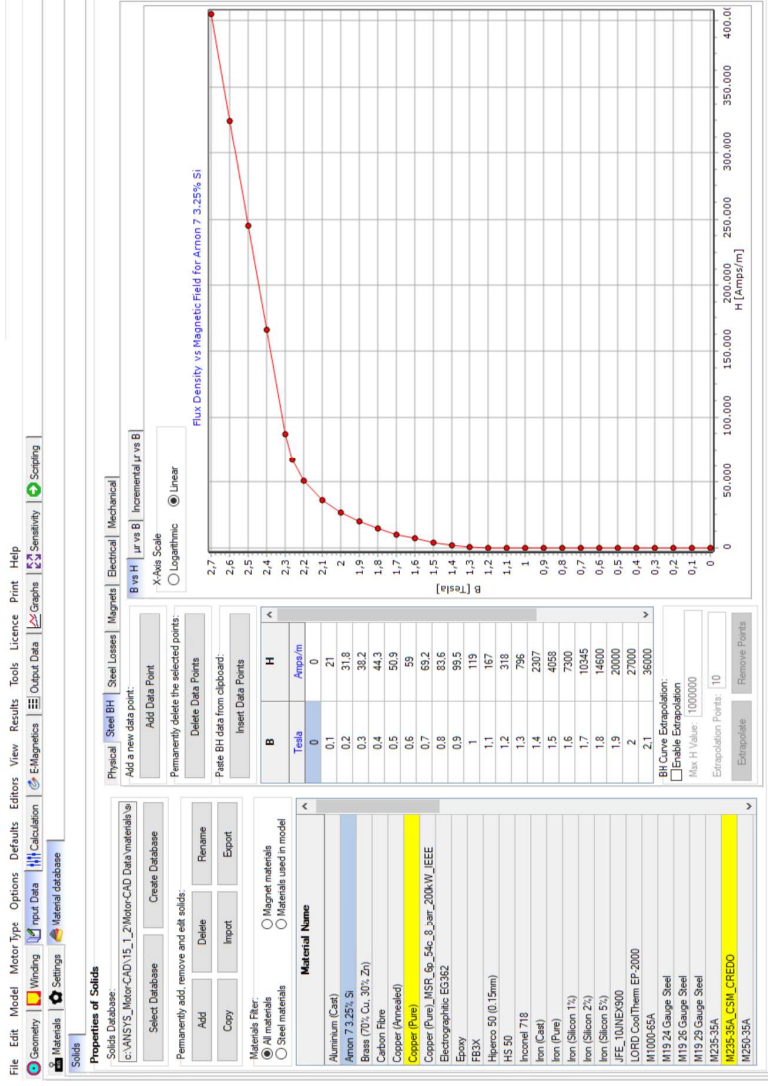
Redraw

Winding View:
☒ Conductors
☐ Cuboids
☐ None

Output Parameter	Value	Output Parameter	Value
Conductors / Slot Drawn	28	Slot Area	134.9
Wire Size Fill (Wdg Area)	0.5388	Conductor Wire Area	337.9
Wire Size Fill (Slot Area)	0.3656	Copper Area	116.7
Copper Slot Fill (Slot Area)	0.3455	Winding Area	231.8
Heavy Build Slot Fill	0.655	Winding Depth	25.753
		Wedge Area	10.83

Motor-CAD

MOTOR-CAD E-MAGNETIC MATERIAL



100

Drive:

Shunt Speed	3000
-------------	------

Live Current Definition:

- ☒ Peak
- ☐ RMS
- ☐ RMS Current Density

Peak Current	225
RMS Current	159.1
RMS Current Density	9.54
DC Bus Voltage	820
	25

Phase Advance [elec deg]

Drive:

- ☒ Defined Currents (Default)
- ☐ Calculated Currents

Drive Mode:

- ☒ Sine
- ☐ Square
- ☐ Custom
- ☐ Passive Generator

Winding Connection:

- ☒ Star Connection (default)
- ☐ Delta Connector

Magnetisation:

- ☒ Parallel
- ☐ Radial
- ☐ Halbach Continuous Ring Array
- ☐ Halbach Stator/Stator Array

Temperatures:

Anature Winding Temperature:	25
Magnet Temperature:	25
Stator Lamination Temperature:	98.43
Rotor Lamination Temperature:	119.3

Shaft Temperature:

Airgap Temperature:	20
Bearing Temperature [°]:	20
Bearing Temperature [°]:	20

E-Magnetic ↔ Thermal Coupling:

- ☐ Electromagnetic → Thermal Coupling
- ☒ No Coupling (Default)
- ☐ Electromagnetic ← Thermal
- ☐ Electromagnetic ↔ Thermal/Temperatures
- ☐ Iterate to Converged Solution

Slew:

Slew Type:

- ☒ None (default)
- ☐ Sator
- ☐ Rotor

Satur Slew:

	0
Rotor slew:	1

Performance Tests:

Single operating points:

- ☐ Open Circuit
- ☒ Drive current only
- ☒ On Load

Open Circuit:

- ☐ Back EMF
- ☐ Clogging Torque
- ☐ Electromagnetic Forces

On Load:

- ☒ Torque
- ☐ Torque Speed Curve
- ☐ Demagnetization
- ☐ Electromagnetic Forces

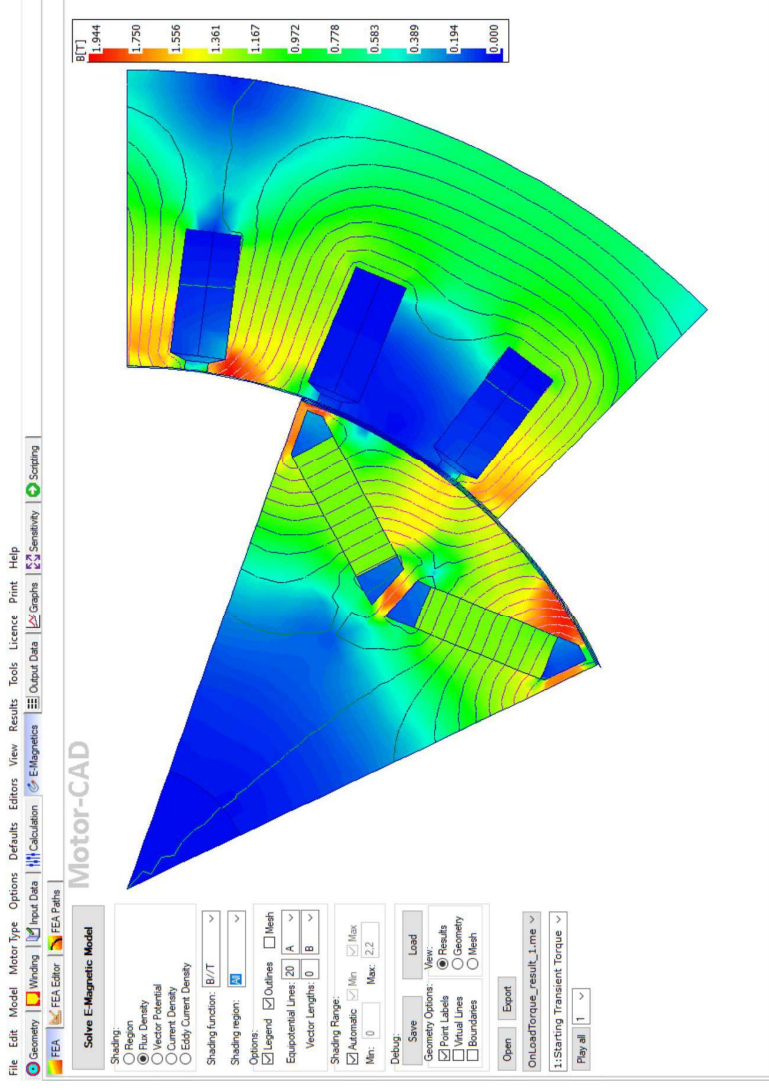
Parameters:

- ☐ Self and Mutual Inductances
- ☐ Transient
- ☐ Sudden short circuit
- ☐ Rotor Stresses
- ☐ Centrifugal Forces

Solve E-Magnetic Model

Cancel Solving

MOTOR-CAD FEA RESULTS



MOTOR-CAD OUTPUT DATA

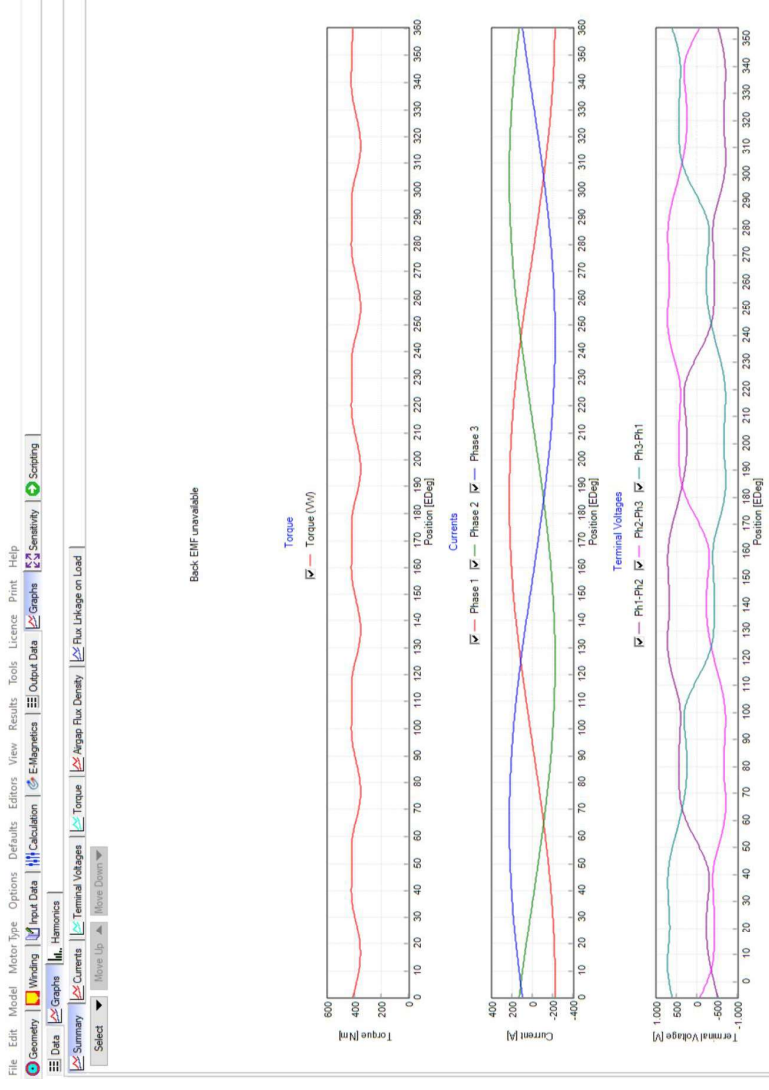
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Geometry Winding Input Data E-Magnetics Calculation Output Data Graphs Sensitivity Scripting

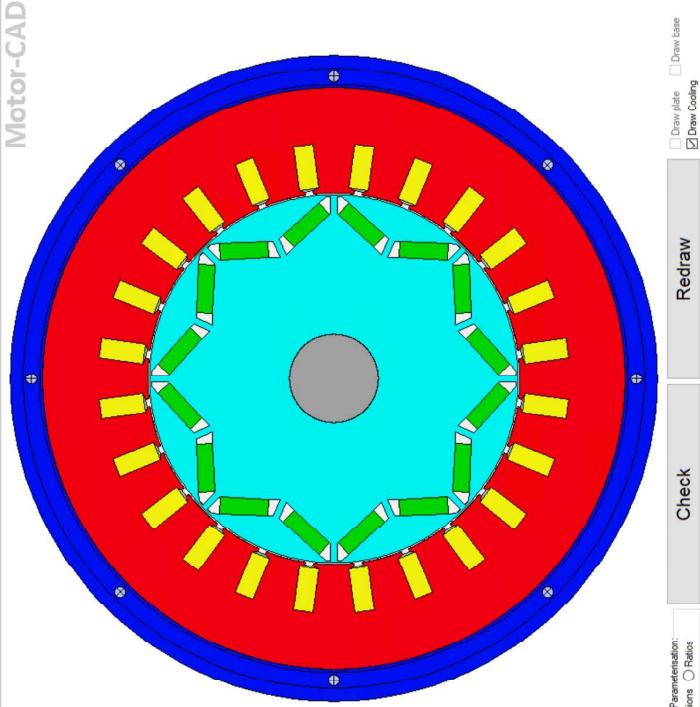
Drive E-Magnetics Phasor Diagram Equivalent Circuit Flux Densities Losses Winding Miscellaneous Materials

Variable	Value	Units	Variable	Value	Units
Armature DC Copper Loss (on load)	1017	Watts			
Magnet Loss (on load)	2329	Watts			
Stator iron Loss [total] (on load)	806.6	Watts			
Rotor iron Loss [total] (on load)	119.4	Watts			
Wedge Loss (on load)	0	Watts			
Windage Loss (user input)	0	Watts			
Friction Loss (user input)	0	Watts			
Shaft Loss [total] (on load)	0	Watts			
Total Losses (on load)	1946	Watts			
Magnet Block Width	30	mm			
Magnet Loss Factor	0.2377				
Magnet Loss (on load)	2329	Watts			
Stator back iron Loss [fundamental] (on load)	234.6	Watts			
Stator back iron Loss [harmonics - minor losses] (on load)	1373	Watts			
Stator back iron Loss [fundamental] (on load)	238.1	Watts			
Stator back iron Loss [eddy] (on load)	118.3	Watts			
Stator back iron Loss [hysteresis] (on load)	0	Watts			
Stator back iron Loss [total] (on load)	354.5	Watts			
Stator tooth Loss [fundamental] (on load)	289.5	Watts			
Stator tooth Loss [harmonics - minor losses] (on load)	7746	Watts			
Stator tooth Loss [fundamental] (on load)	306.2	Watts			
Stator tooth Loss [eddy] (on load)	145.9	Watts			
Stator tooth Loss [hysteresis] (on load)	0	Watts			
Stator tooth Loss [total] (on load)	462.2	Watts			
Stator iron Loss [total] (on load)	806.6	Watts			
Rotor back iron Loss [fundamental] (on load)	1493	Watts			
Rotor back iron Loss [eddy] (on load)	0.066504	Watts			
Rotor back iron Loss [hysteresis] (on load)	0	Watts			
Rotor back iron Loss [total] (on load)	1.559	Watts			
Rotor magnet pole Loss [fundamental] (on load)	61.28	Watts			
Rotor magnet pole Loss [eddy] (on load)	56.51	Watts			
Rotor magnet pole Loss [hysteresis] (on load)	0	Watts			
Rotor magnet pole Loss [total] (on load)	117.8	Watts			
Rotor iron Loss [total] (on load)	119.4	Watts			

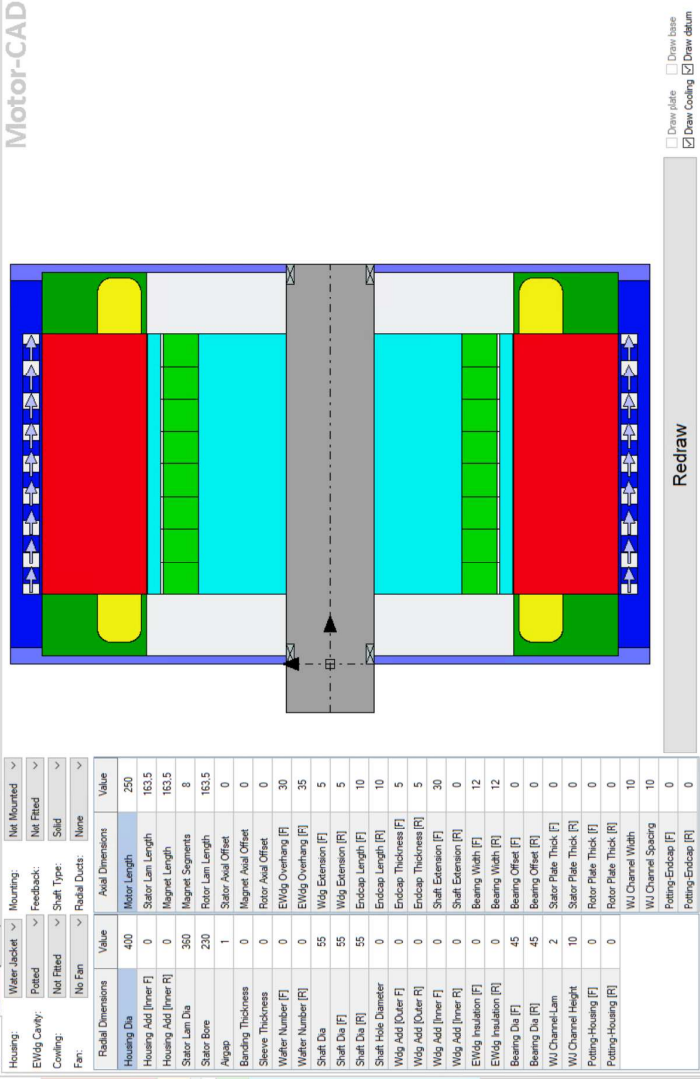
MOTOR-CAD GRAPHS



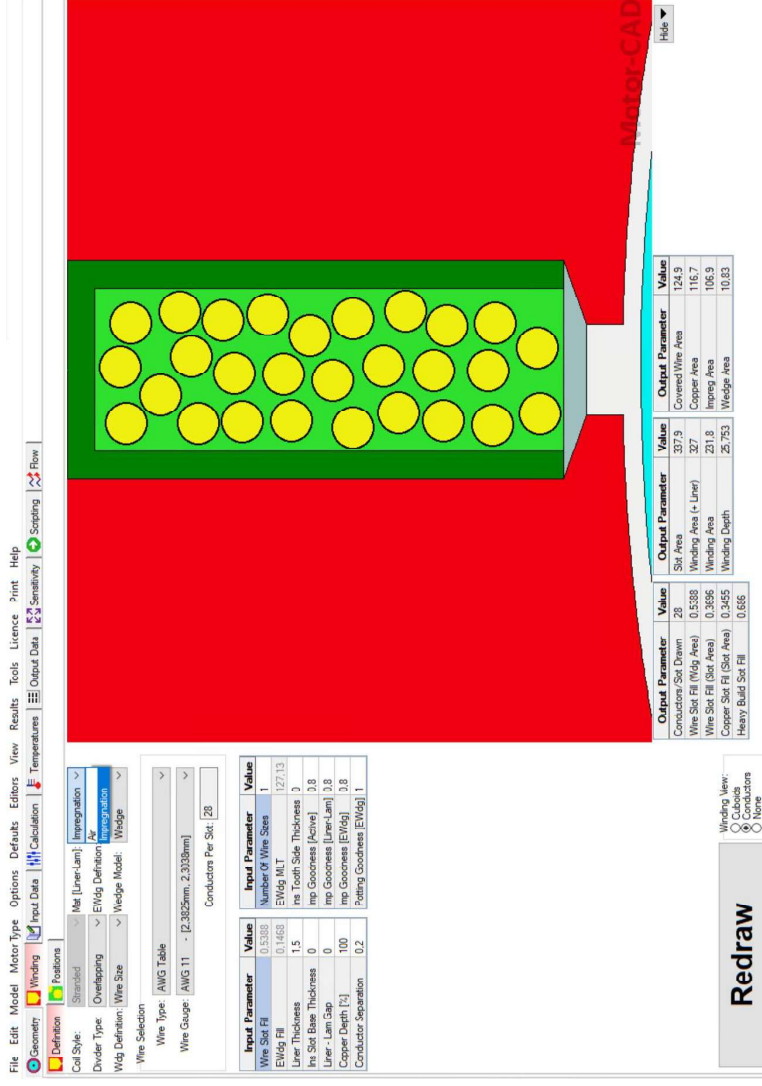
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MOTOR-CAD THERMAL WINDINGS



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

Geometry Winding Input Data Calculation Temperatures Output Data Sensitivity Snapping Flow

Definition Positions

Coil Style: Standard Dividers Type: Overlapping Wdg Definition: Wire Size Wire Selection: Wire Type: AMG Table Wire Gauge: AMG 11 - [2.3825mm, 2.3339mm] Conductors Per Slot: 28

Input Parameter	Value
Wire Slot Fit	0.5368
EWdg Fill	0.4463
Lin Thickness	1.5
Lin Slot Base Thickness	0
Lin Slot Gap	0
Lin Slot Side Thickness	0
Lin Goodness (Inner)	0.8
Lin Goodness (Inner-Lam)	0.8
Lin Goodness (EWdg)	0.8
Copper Depth [T]	100
Conductor Separation	0.2

Output Parameter	Value
Conductor/Slot Down	28
Wire Slot Fit (Wdg Area)	0.5368
Wire Slot Fit (Slot Area)	0.3656
Copper Slot Fit (Slot Area)	0.3455
Heavy Build Slot Fit	0.665
Slot Area	337.9
Winding Area (+ Liner)	327
Winding Area	231.8
Winding Depth	25.753
Covered Wire Area	124.9
Copper Area	116.7
Wedge Area	106.9

Redraw

Winding View:
☒ Cuboids
☐ Conductors
☐ None

100

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

Geometry | Windings | Input Data | Calculation | Temperatures | Output Data | Sensitivity | Scripting | Flow

Cooling | Losses | Materials | Interfaces | Radiation | Natural Convection | Settings | End Space | Material database

Loss Models | Loss Distribution

Loss Variation with Speed
 $P_{\text{speed}} = P_{\text{load}} \times \left(\frac{\text{Speed}}{\text{Speed(REF)}}\right)^{\text{coef(A)}}$
Shift Speed: 3000
Single value of Speed(REF) [rpm]: 3000

Component

Units

PI(totals)

Speed(REF)
[rpm]

coef(A)

W/kg

P(speed)

Loss [Armature Copper]	Watts	1017	3000	0	179	1017
Loss [Stator Back Iron]		354.5	3000	1.5	8.282	354.5
Loss [Stator Tooth]		452.2	3000	1.5	22.43	452.2
Loss [Magnet]		2.329	3000	0	0.388	2.329
Loss [Embedded Magnet Pole]		117.8	3000	0	6.72	117.8
Loss [Rotor Back Iron]		1.559	3000	0	0.00004	1.559
Loss [Friction - F Bearing]		0	3000	1	0	0
Loss [Friction - R Bearing]		0	3000	1	0	0
Loss [Windage]		0	3000	3	0	0
Loss [Windage] (Ext Fan)		0	3000	3	0	0

Copper Loss Variation with Temperature:

☐ Copper losses vary with temperature.
Winning Temperature at which Stator Copper Losses Input.

Losses Notes:
Type in user Losses notes here

25

Check Data

MOTOR-CAD THERMAL INTERFACES

Geometry | Winding | Input Data | Calculation | Interfaces | Temperatures | Output Data | Sensitivity | Scripting | Flow | Cooling | Losses | Materials | Radiation | Natural Convection | Housing Water Jacket | End Space | Settings | Material database

Component	Gap	Interface Material	Thermal Conductivity	Details	Resistance @T=100.0°C	Conductance @T=100.0°C	Notes
Units							
Stator Lam - Housing	0.03	Ar (Motor-CAD model)	0.03171	Lamination-Metal - Average surface Contact	0.0009459	1057	
Housing - O-ring [F]	0	Ar (Motor-CAD model)	0.03171	No Gap - Perfect surface Contact	0	1E09	
Housing - O-ring [R]	0	Ar (Motor-CAD model)	0.03171	No Gap - Perfect surface Contact	0	1E09	
Housing - Endcap [F]	0.005	Ar (Motor-CAD model)	0.03171	Metal-Metal - Average surface Contact	0.0001577	6341	
Housing - Endcap [R]	0.005	Ar (Motor-CAD model)	0.03171	Metal-Metal - Average surface Contact	0.0001577	6341	
Magnet - Rotor Lam	0.005	Ar (Motor-CAD model)	0.03171	Metal-Metal - Average surface Contact	0.0001577	6341	
Magnet - Magnet	0.005	Ar (Motor-CAD model)	0.03171	Metal-Metal - Average surface Contact	0.0001577	6341	
Rotor Lam - Shaft	0.005	Ar (Motor-CAD model)	0.03171	Metal-Metal - Average surface Contact	0.0001577	6341	
Bearing Effective Gap [F]	0.4	Ar (Motor-CAD model)	0.03171	High Effective Gap [Torque Testing]	0.01261	79.3	
Bearing Effective Gap [R]	0.4	Ar (Motor-CAD model)	0.03171	High Effective Gap [Torque Testing]	0.01261	79.3	
Bearing - Endcap [F]	0.0073	Ar (Motor-CAD model)	0.03171	Stainless-Aluminum - Medium surface Contact	0.0002302	4344	
Bearing - Endcap [R]	0.0073	Ar (Motor-CAD model)	0.03171	Stainless-Aluminum - Medium surface Contact	0.0002302	4344	
Bearing - Shaft [F]	0.0112	Ar (Motor-CAD model)	0.03171	Stainless-Stainless - Medium surface Contact	0.0003532	2831	
Bearing - Shaft [R]	0.0112	Ar (Motor-CAD model)	0.03171	Stainless-Stainless - Medium surface Contact	0.0003532	2831	
Potting Housing [F]	0	Ar (Motor-CAD model)	0.03171	No Gap - Perfect surface Contact	0	1E09	
Potting Housing [R]	0	Ar (Motor-CAD model)	0.03171	No Gap - Perfect surface Contact	0	1E09	
Potting Endcap [F]	0	Ar (Motor-CAD model)	0.03171	No Gap - Perfect surface Contact	0	1E09	
Potting Endcap [R]	0	Ar (Motor-CAD model)	0.03171	No Gap - Perfect surface Contact	0	1E09	

Check Data

Check Data

MOTOR-CAD THERMAL RADIATION

File

Edit

Model

Motor Type

Options

Defaults

Editors

View

Results

Tools

Licence

Print

Help

Geometry

Winding

Input Data

Calculation

Temperatures

Output Data

Sensitivity

Flow

Cooling

Losses

Materials

Interfaces

Radiation

Natural Convection

Housing Water Jacket

End Space

Settings

Material database

☒ Include Radiation in Lump Circuit Model
☐ Include Internal Radiation in Lump Circuit Model
☒ Single Emissivity value: 0.9

dt used in table below - External Radiation [degC]: 100

dt used in table below - Internal Radiation [degC]: 10

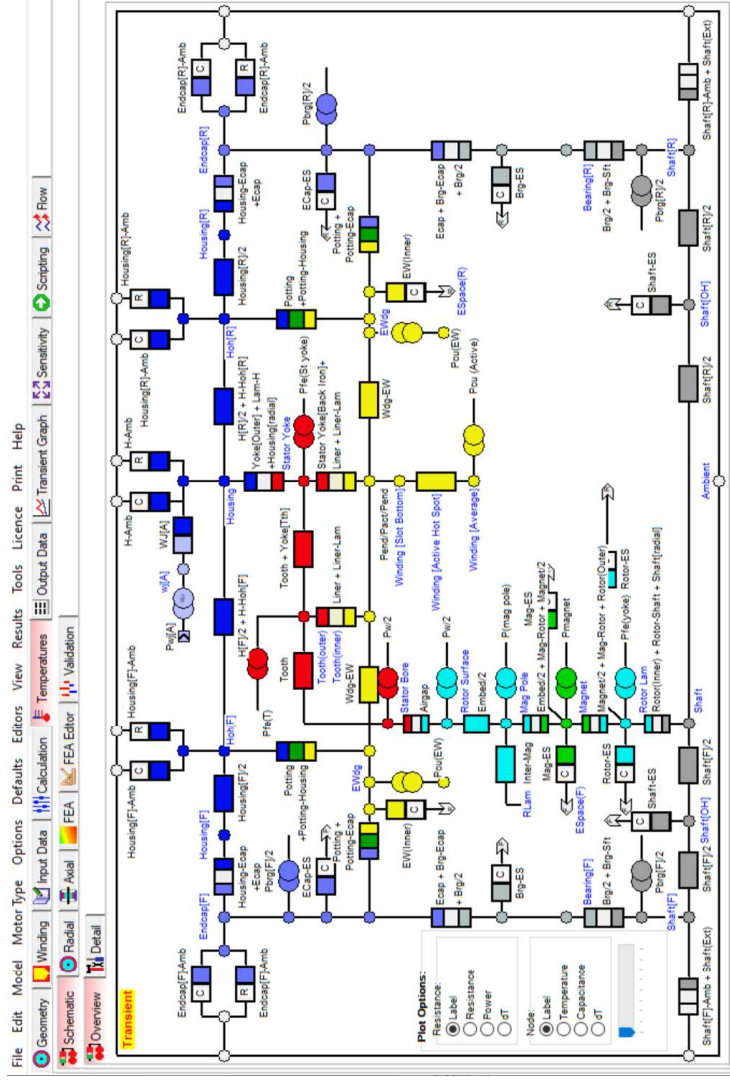
Component	Emissivity	View Factor	h _r @dT=100.0°C	Area	R _t @dT=100.0°C	Notes
Units			W/m²°C	mm²	°C/W	
Housing [Front]	0.9	1	9.961	4.178E04	2.403	
Housing [Active]	0.9	1	9.961	2.055E05	0.4886	
Housing [Rear]	0.9	1	9.961	4.178E04	2.403	
Endcap [Front] - Radial Area	0.9	1	9.961	1.257E04	7.989	
Endcap [Front] - Axial Area	0.9	1	9.961	1.233E05	0.8143	
Endcap [Rear] - Radial Area	0.9	1	9.961	1.257E04	7.989	
Endcap [Rear] - Axial Area	0.9	1	9.961	1.257E05	0.7989	

Check Data

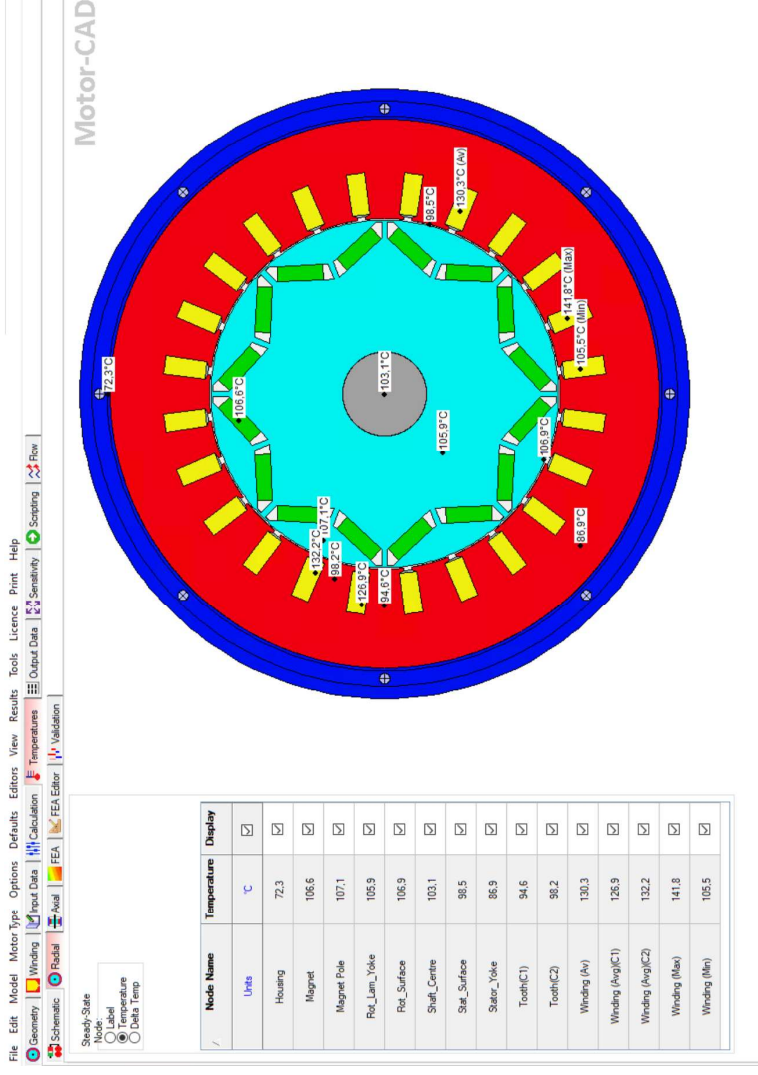
MOTOR-CAD THERMAL CALCULATION STEADY STATE



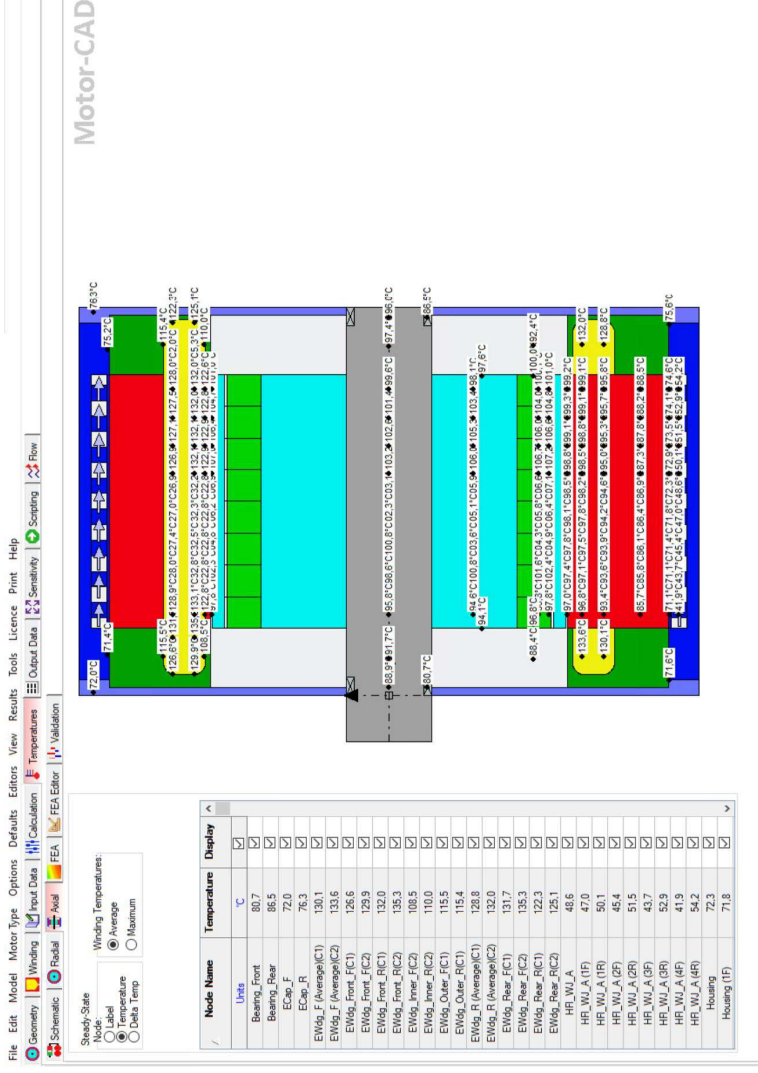
MOTOR-CAD THERMAL CALCULATION STEADY STATE



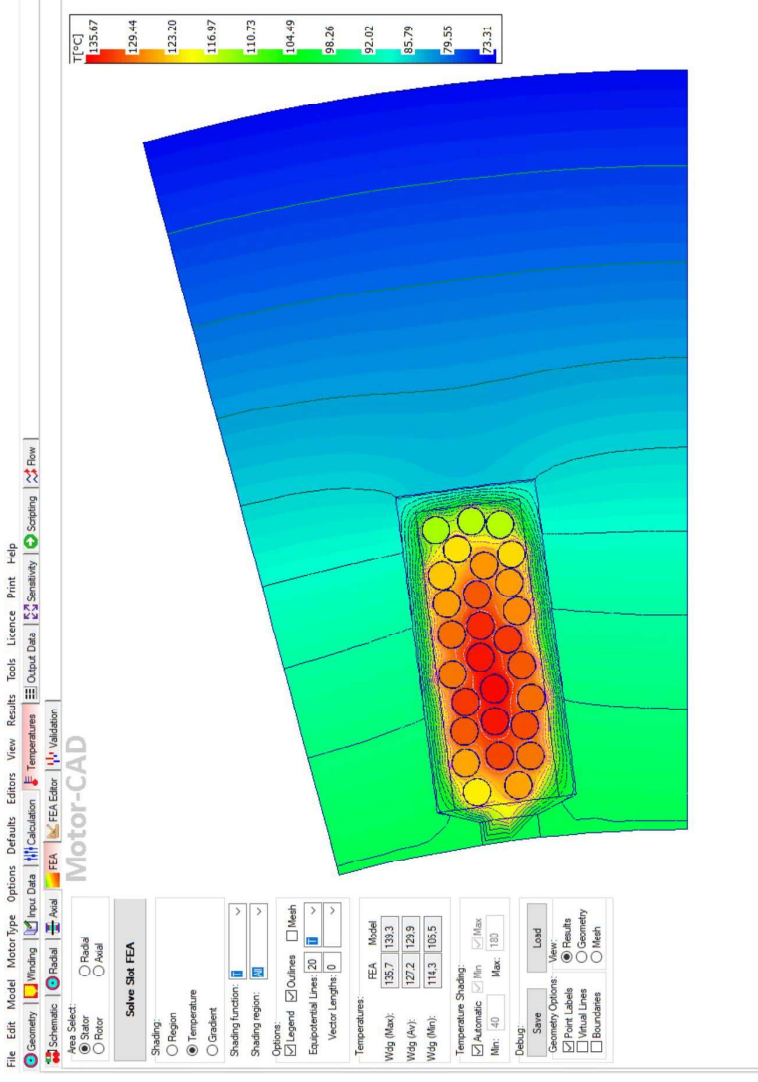
MOTOR-CAD THERMAL RESULTS



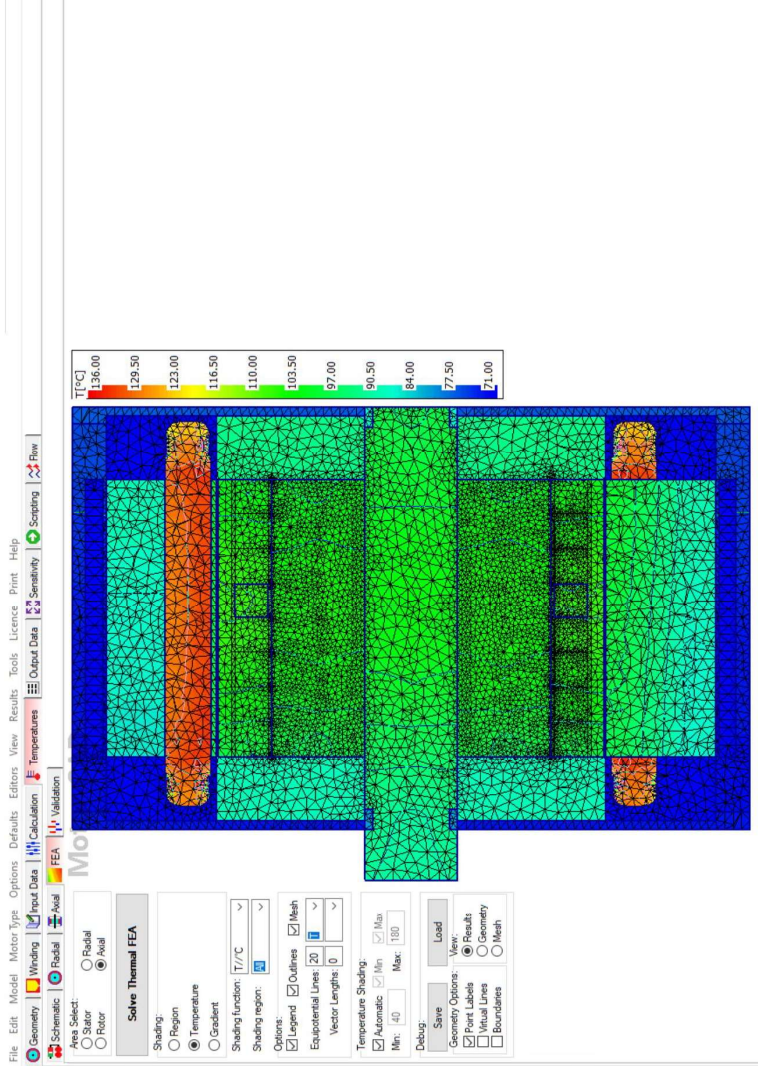
MOTOR-CAD THERMAL RESULTS



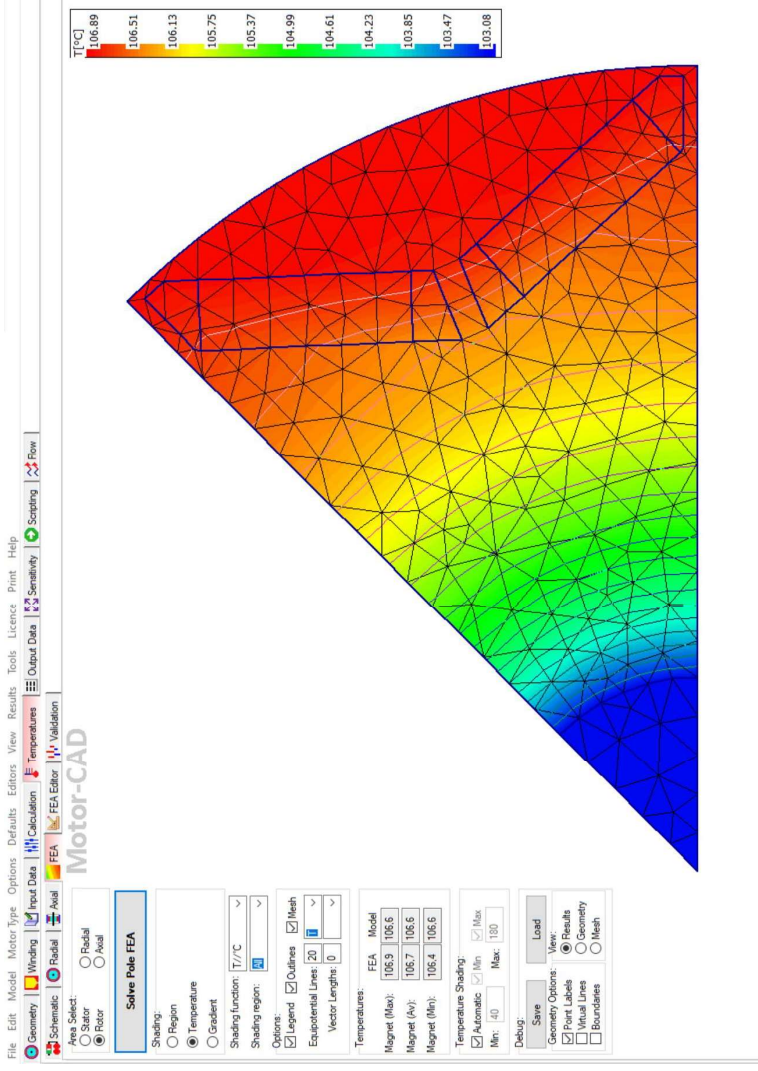
MOTOR-CAD THERMAL FEA RESULTS



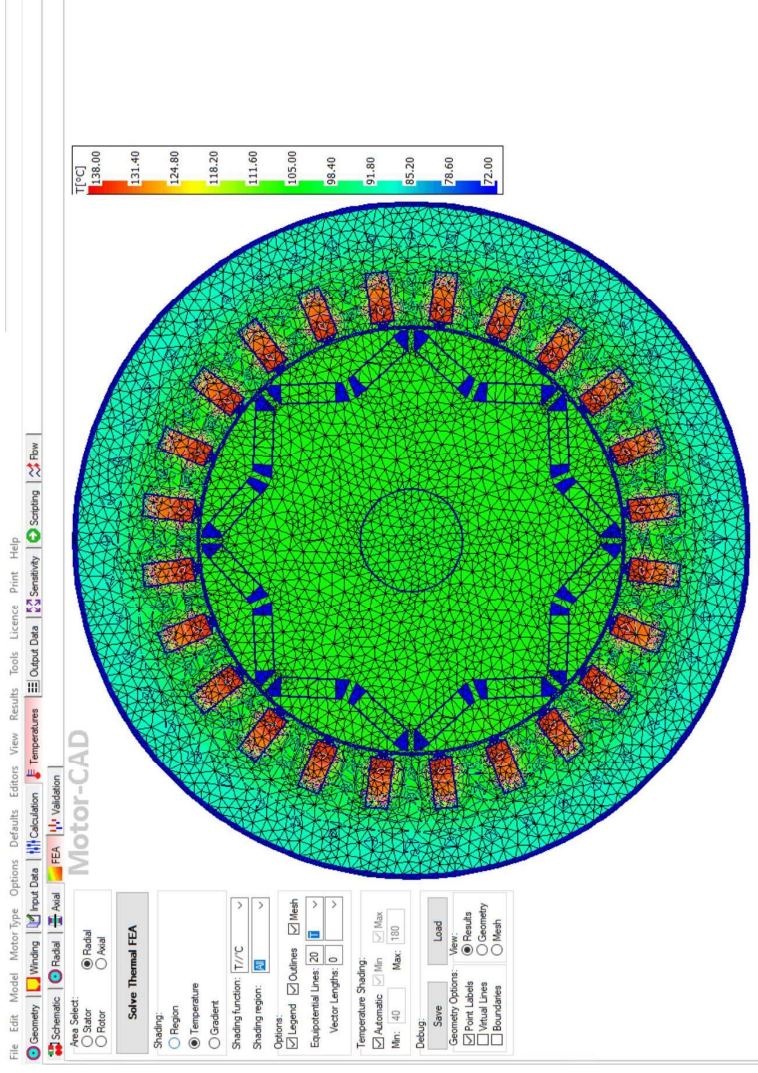
MOTOR-CAD THERMAL FEA RESULTS



MOTOR-CAD THERMAL FEA RESULTS



MOTOR-CAD THERMAL FEA RESULTS



MOTOR-CAD THERMO-ELECTROMAGNETIC ANALYSIS

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

Drive: Shaft Speed: 3000

Line Current Definition:

- ☒ Peak
- ☐ RMS
- ☐ RMS Current Density

Peak Current: 125

RMS Current: 159.1

RMS Current Density: 9.542

DC Bus Voltage: 820

Phase Advance [elec deg]: 25

Drive Type:

- ☒ Defined Currents (Default)
- ☐ Calculated Currents

Drive Mode:

- ☒ Sine
- ☐ Square
- ☐ Custom
- ☐ Passive Generator

Winding Connection:

- ☒ Star Connection (default)
- ☐ Delta Connection

Magnetisation:

- ☒ Parallel
- ☐ Radial
- ☐ Halbach Continuous Ring Array
- ☐ Halbach Sinusoidal Array

Temperatures:

Armature Winding Temperature: 153.7

Magnet Temperature: 118

Stator Lamination Temperature: 98.62

Rotor Lamination Temperature: 120.6

Shaft Temperature: 117.4

Airgap Temperature: 117.7

Bearing Temperature [F]: 90.71

Bearing Temperature [C]: 98.12

E-Magnetic - Thermal Coupling:

E-Magnetic - Thermal Coupling:

- ☐ No coupling (default)
- ☐ E-Magnetic Losses → Thermal
- ☐ E-Magnetic ← Thermal
- ☒ Iterate to Converged Solution

Skew:

Skew Type:

- ☒ None (default)
- ☐ Rotor
- ☐ Stator

Stator Skew: 0

Rotor Skew: 1

Performance Tests:

Single operating points:

- ☐ Open Circuit
- ☒ Q axis current only
- ☒ On Load

Open Circuit:

- ☐ Back EMF
- ☐ Cogging Torque
- ☐ Electromagnetic Forces

On Load:

- ☒ Torque
- ☐ Torque Speed Curve
- ☐ Demagnetization
- ☐ Electromagnetic Forces

Parameters:

- ☐ Self and Mutual Inductances

Transient:

- ☐ Sudden short circuit

Rotor Stresses:

- ☐ Centrifugal Forces

Solve E-Magnetic Model

Cancel Solving

MOTOR-CAD THERMO-ELECTROMAGNETIC ANALYSIS

File	Edit	Model	MotorType	Options	Defaults	Editors	View	Results	Tools	Licence	Print	Help
Geometry	Winding	Input Data	Calculation	E-Magnetics	Output Data	Graphs	Scripting	Sensitivity				
Drive	E-Magnetics	Phasor Diagram	Equivalent Circuit	Flux Densities	Losses	Winding	Miscellaneous	Materials				

Variable	Value	Units	Variable	Value	Units
Maximum torque possible (DQ (for Phase-Advance of 21.43 EDeg))	370.58	Nm	Flux Linkage D (Q axis current)	249.471	mVs
Average torque (total work)	367.34	Nm	Flux Linkage Q (Q axis current)	234.845	mVs
Average torque (load torque)	366.82	Nm	Flux Linkage D (On load)	195.826	mVs
Torque Ripple (MVs/Vs)	45.867	Nm	Flux Linkage Q (On load)	227.708	mVs
Torque Ripple (MVs/Vs) [%]	12.633	%	---	---	---
Speed limit for constant torque (for Phase-Advance of 25 EDeg)	3729.9	rpm	Torque Constant (Kt)	1.61368	Nm/A
No load speed	4530.5	rpm	Motor Constant (Km)	9.21606	Nm/(Watt ^{0.5})
Speed limit for zero Q axis current	INF	rpm	Back EMF Constant (Ke) (Fundamental)	1.72839	Vs/Rad
---	---	---	---	---	---
Electromagnetic Power	1.1486E05	Watts	Stall Current	20060	Amps
Input Power	1.1562E05	Watts	Stall Torque	32370.4	Nm
Total Losses (on load)	2457.8	Watts	---	---	---
Output Power	1.1316E05	Watts	Cogging Period	15	MDeg
System Efficiency	97.874	%	Cogging Frequency	1200	Hz
---	---	---	Fundamental Frequency	200	Hz
Shaft Torque	360.2	Nm	Mechanical Frequency	50	Hz
---	---	---	Optimum Steering Angle	15	MDeg
Power Factor (Wavelength) (lagging)	0.91339		---	---	---
Power Factor Angle (Wavelength)	24.022	EDeg	Magnetic Symmetry Factor (Automatic calculation)	8	
Power Factor (THD)	0.86573		Magnetic Axial Length (Slot l)	163.5	mm
Power Factor (Phasor) (lagging)	0.91355		---	---	---
Power Factor Angle (Phasor)	24	EDeg	---	---	---
Load Angle (Phasor)	45.021	EDeg	---	---	---
Phase Terminal Voltage (Ims) (Phasor)	259.83	Volts	---	---	---
---	---	---	---	---	---
Rotor Inertia	0.30912	kg m ²	---	---	---
Shaft Inertia	0.001962	kg m ²	---	---	---
Total Inertia	0.31108	kg m ²	---	---	---
Torque per rotor volume	54.39	kNm/m ³	---	---	---
Rotor peripheral velocity (on load)	35.814	m/s	---	---	---

MOTOR-CAD THERMO-ELECTROMAGNETIC ANALYSIS

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

Geometry Winding Input Data Calculation EMagnetics Output Data Graphs Sensitivity Scoping

Drive EMagnetics Phasor Diagram Equivalent Circuit Flux Densities Losses Winding Modelling Materials

Variable	Value	Units	Variable	Value	Units
Armature DC Copper Loss (on load)	1552	Watts			
Magnet Loss (on load)	1.879	Watts			
Stator iron Loss [total] (on load)	780.3	Watts			
Rotor iron Loss [total] (on load)	123.6	Watts			
Wedge Loss (on load)	0	Watts			
Windage Loss (user input)	0	Watts			
Friction Loss (user input)	0	Watts			
Shaft Loss [total] (on load)	0	Watts			

Total Losses (on load)	2458	Watts			

Magnet Block Width	30	mm			
Magnet Loss Factor	0.2377				
Magnet Loss (on load)	1.879	Watts			

Stator back iron Loss [hysteresis - fundamental] (on load)	228.6	Watts			
Stator back iron Loss [hysteresis - minor loops] (on load)	0.6714	Watts			
Stator back iron Loss [hysteresis] (on load)	229.3	Watts			
Stator back iron Loss [eddy] (on load)	113.7	Watts			
Stator back iron Loss [excitation] (on load)	0	Watts			
Stator back iron Loss [total] (on load)	343	Watts			

Stator tooth Loss [hysteresis - fundamental] (on load)	288.5	Watts			
Stator tooth Loss [hysteresis - minor loops] (on load)	7.517	Watts			
Stator tooth Loss [hysteresis] (on load)	296.1	Watts			
Stator tooth Loss [eddy] (on load)	141.3	Watts			
Stator tooth Loss [excitation] (on load)	0	Watts			
Stator tooth Loss [total] (on load)	437.3	Watts			

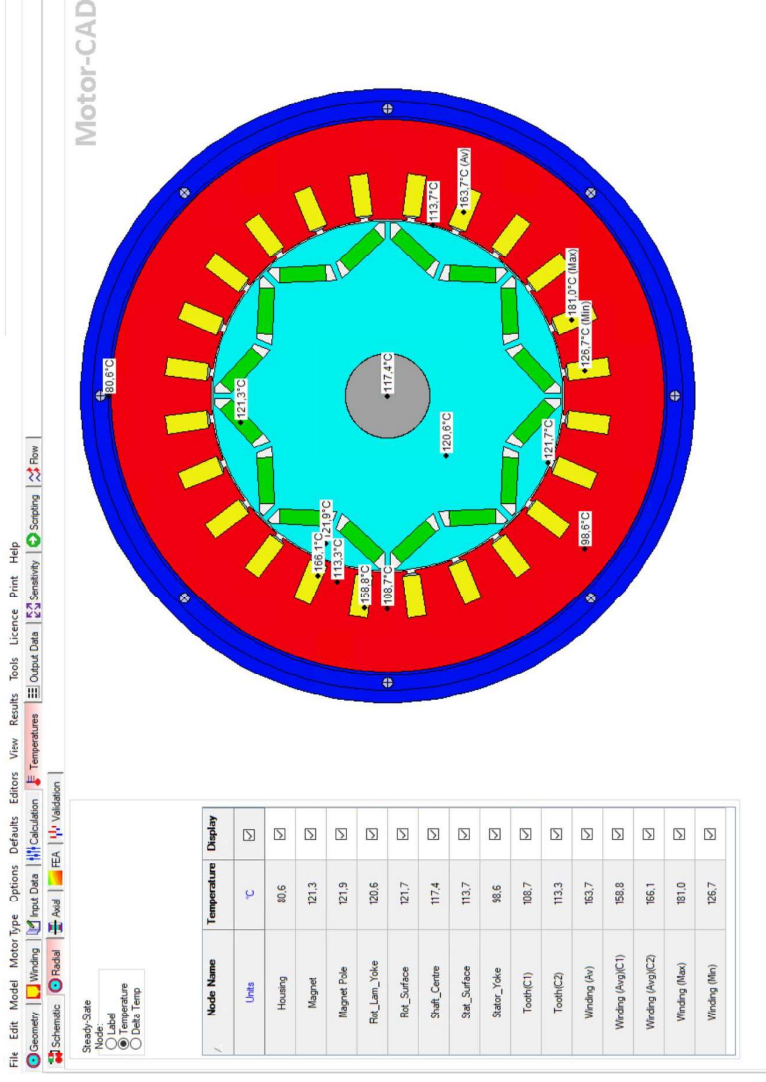
Stator iron Loss [total] (on load)	780.3	Watts			

Rotor back iron Loss [hysteresis] (on load)	1.338	Watts			
Rotor back iron Loss [eddy] (on load)	0.05594	Watts			
Rotor back iron Loss [excitation] (on load)	0	Watts			
Rotor back iron Loss [total] (on load)	1.394	Watts			

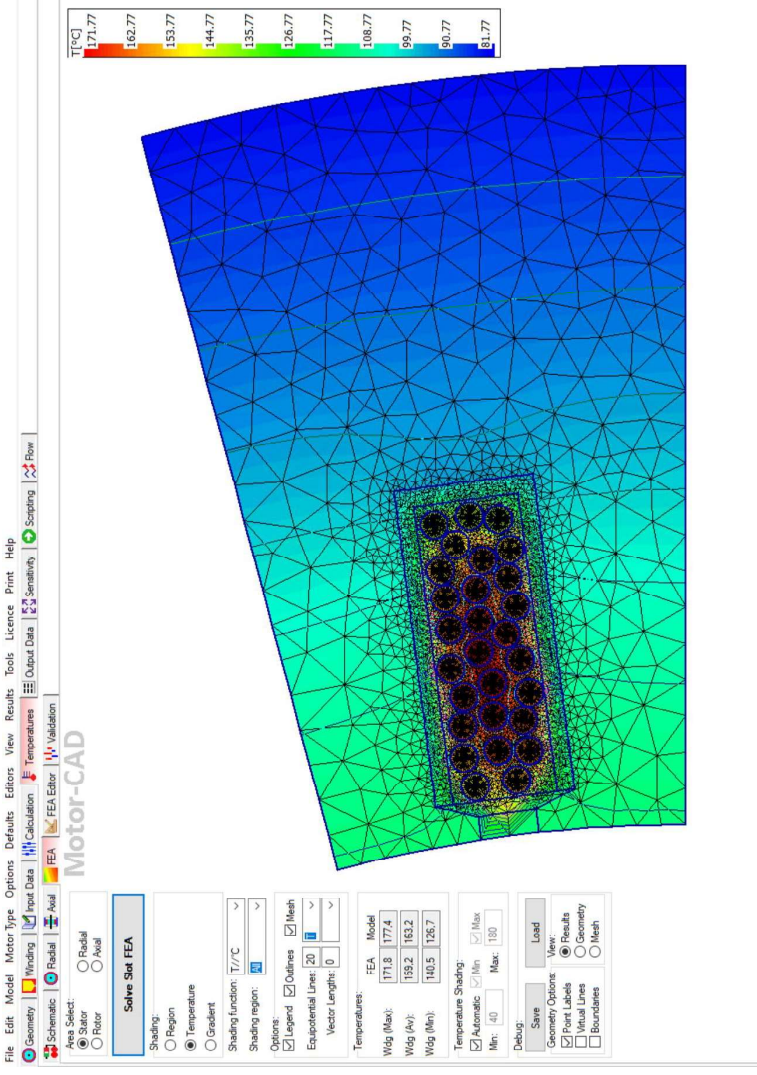
Rotor magnet pole Loss [hysteresis] (on load)	63.54	Watts			
Rotor magnet pole Loss [eddy] (on load)	58.63	Watts			
Rotor magnet pole Loss [excitation] (on load)	0	Watts			
Rotor magnet pole Loss [total] (on load)	122.2	Watts			

Rotor iron Loss [total] (on load)	123.6	Watts			

MOTOR-CAD THERMO-ELECTROMAGNETIC ANALYSIS



MOTOR-CAD THERMO-ELECTROMAGNETIC ANALYSIS



100

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** **Scoping**

Dive:

Line Current Definition:
☒ Peak
☐ RMS
☐ RMS Current Density

Shift Speed: 3000

Peak Current: 450
RMS Current: 318.2
RMS Current Density: 19.08
DC Bus Voltage: 820

Phase Advance [elec deg]: 25

Dive Type:
☒ Defined Currents (Default)
☐ Calculated Currents

Dive Mode:
☐ Sine
☐ Square
☐ Custom
☐ Permanent Generator

Winding Connection:
☒ Star Connection (default)
☐ Delta Connection

Magnetisation:
☒ Parallel
☐ Radial
☐ Halbach Continuous Ring Array
☐ Halbach Sinusoidal Array

Temperatures:

Analyse Winding Temperature: 163.7
Magnet Temperature: 118
Stator Lamination Temperature: 98.62
Rotor Lamination Temperature: 120.6
Shaft Temperature: 117.4
Airgap Temperature: 117.7
Bearing Temperature [F]: 90.71
Bearing Temperature [C]: 50.13

E-Magnetic ↔ Thermal Coupling:
☐ No coupling (default)
☒ E-Magnetic Losses → Thermal
☐ E-Magnetic ← Thermal Temperatures
☐ Iterate to Converged Solution

Slew:

Slew Type:
☐ Ramp (default)
☐ Step
☐ Rotor

Rotor Slew: 0
Rotor slope: 1

Performance Tests:

Single operating points:
☐ Open Circuit
☒ Q axis current only
☒ On Load

Open Circuit:
☐ Back EMF
☐ Cogging Torque
☐ Electromagnetic Forces

On Load:
☒ Torque
☐ Torque Speed Curve
☐ Demagnetization
☐ Electromagnetic Forces

Parameters
☐ Self and Mutual Inductances

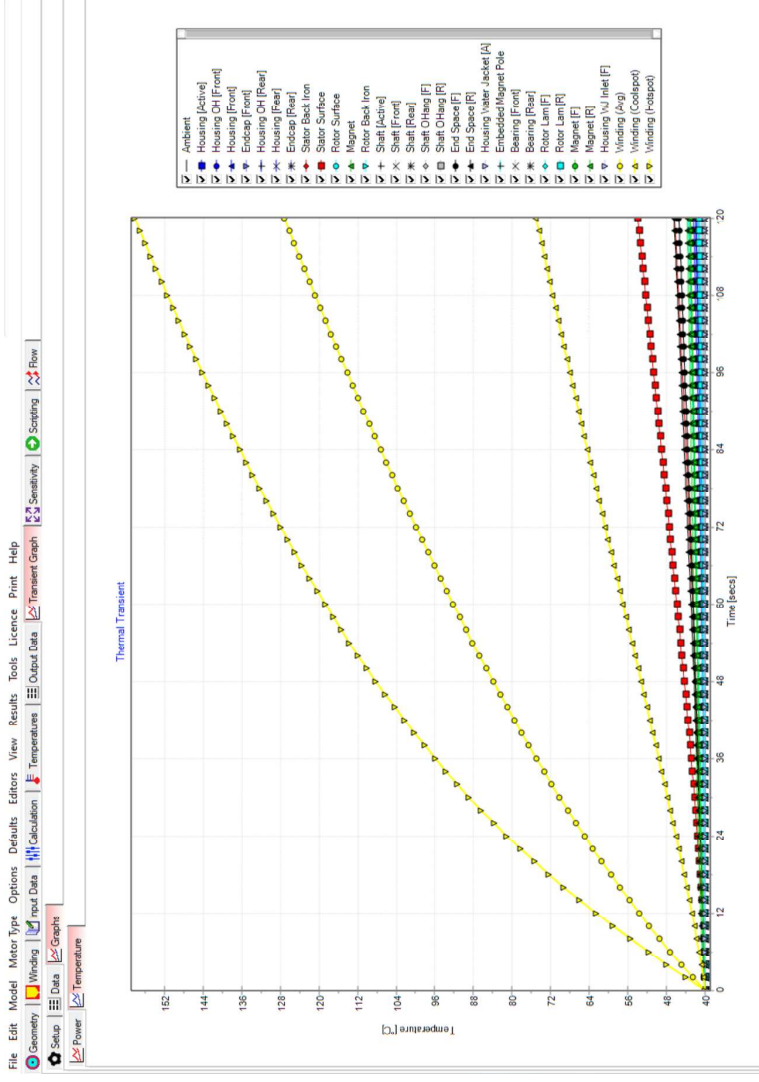
Transient:
☐ Sudden short circuit
☐ Rotor Stresses
☐ Centrifugal Forces

Solve E-Magnetic Model
Cancel Solving

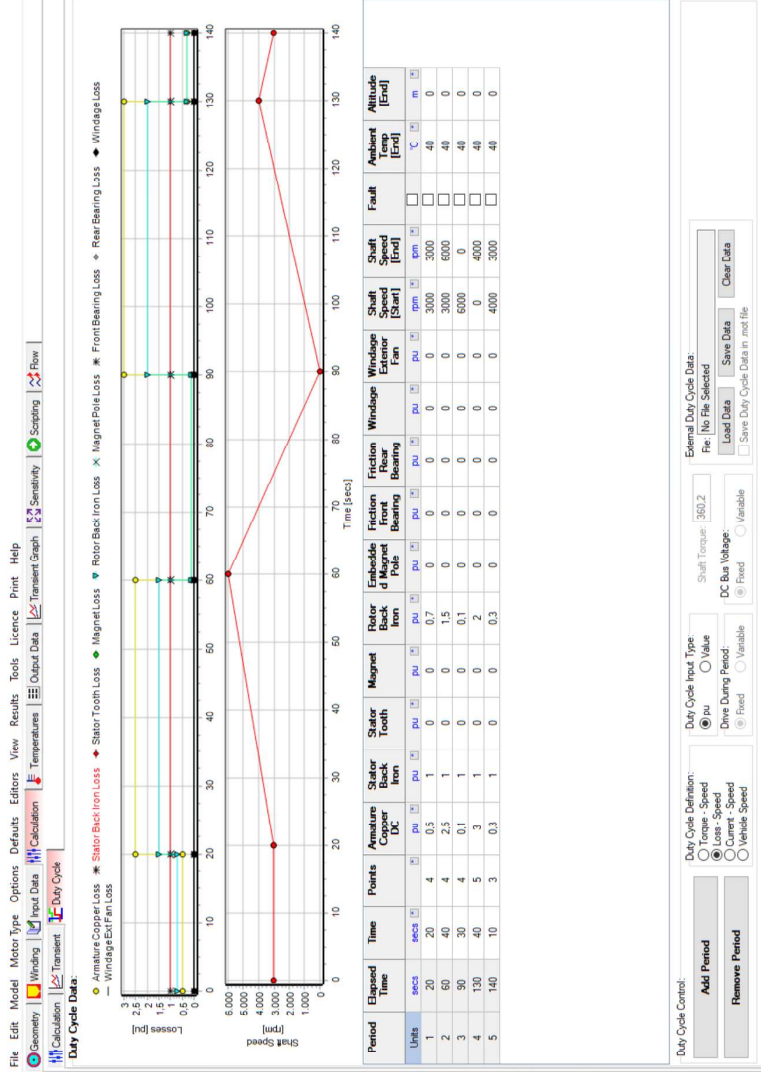
MOTOR-CAD TRANSIENT ANALYSIS

Variable	Value	Units	Variable	Value	Units
Maximum torque possible (T ₀₀) (For Phase Advance of 25.67 ElDeg)	741.9	Nm	Flux Linkage D (Q axis current)	234.457	mVs
Average torque (virtual work)	741.61	Nm	Flux Linkage Q (Q axis current)	301.663	mVs
Average torque (loop torque)	736.4	Nm	Flux Linkage D (On load)	155.31	mVs
Torque Ripple (M/Vn)	56.258	Nm	Flux Linkage Q (On load)	317.04	mVs
Torque Ripple (M/Vn) [%]	7.6359	%	---	---	---
Speed limit for constant torque (For Phase Advance of 25 ElDeg)	3152.8	rpm	Torque Constant (Kt)	1.63723	Nm/A
No load speed	4820.6	rpm	Motor Constant (K _m)	9.35023	Nm/(Watts ^{0.5})
Speed limit for zero q axis current	INF	rpm	Back EMF Constant (K _e) (Fundamental)	1.62436	Va/Rad
---	---	---	---	---	---
Electromagnetic Power	2.3146E005	Watts	Stall Current	20058.5	Amps
Input Power	2.3781E005	Watts	Stall Torque	32840.5	Nm
Total Losses (on load)	7625.8	Watts	---	---	---
Output Power	2.3018E005	Watts	Cogging Period	15	MDeg
System Efficiency	96.793	%	Cogging Frequency	1200	Hz
---	---	---	Fundamental Frequency	200	Hz
Shift Torque	732.69	Nm	Mechanical Frequency	50	Hz
---	---	---	Optimum Steering Angle	15	MDeg
Power Factor [Waveform] [lagging]	0.78619		---	---	---
Power Factor Angle [Waveform]	38.169	EDeg	Magnetic Symmetry Factor (Automatic calculation)	8	
Power Factor [THD]	0.76076		Magnetic Axial Length (Slot 1)	163.5	mm
Power Factor [Phasor] [lagging]	0.78801		---	---	---
Power Factor Angle [Phasor]	38	EDeg	---	---	---
Load Angle [Phasor]	63.167	EDeg	---	---	---
Phase Terminal Voltage [ms] [Phasor]	318.79	Vols	---	---	---
---	---	---	---	---	---
Rotor Inertia	0.30912	kgm²	---	---	---
Shift Inertia	0.001862	kgm²	---	---	---
Total Inertia	0.31108	kgm²	---	---	---
Torque per motor volume	110.37	kNm/m³	---	---	---
Rotor peripheral velocity (on load)	35.814	m/s	---	---	---

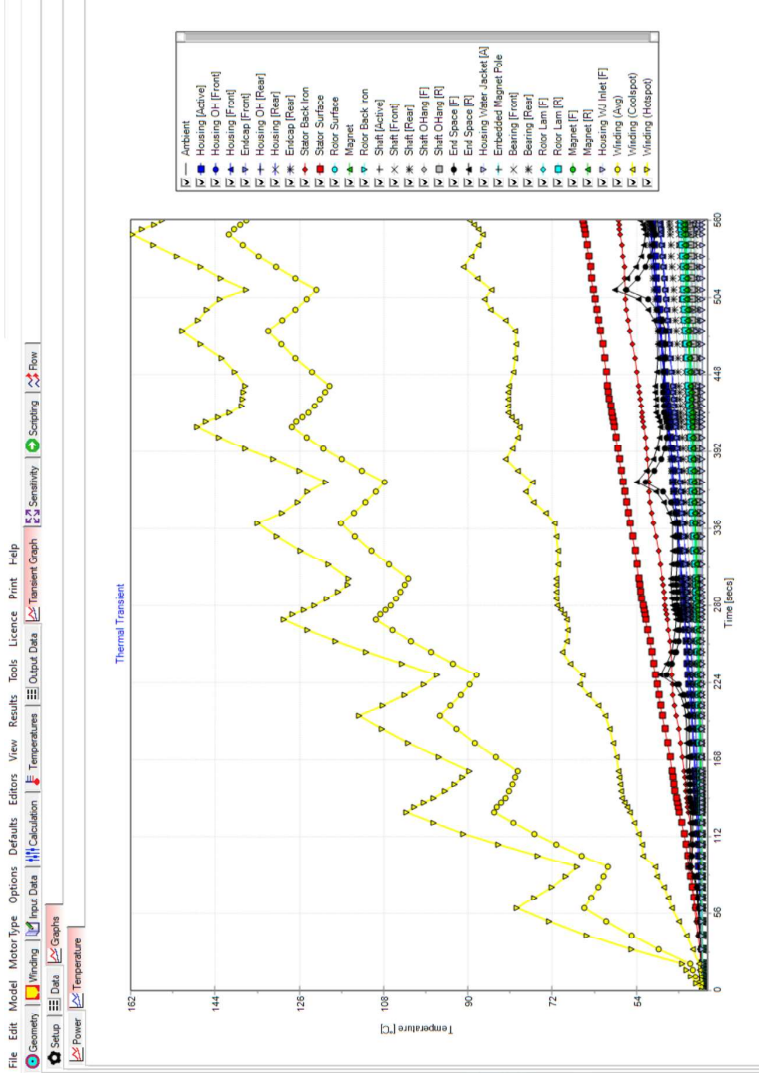
MOTOR-CAD TRANSIENT ANALYSIS



MOTOR-CAD DUTY CYCLE



MOTOR-CAD DUTY CYCLE



100

Motor-CAD Model Loaded Successfully

MOTOR-CAD LAB MODEL

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

General Windage Bearings Custom Losses

Drive:

DC Bus Voltage: 820
Maximum Modulation Index: 1

Operating Mode:
☒ Motor
☐ Generator
☐ Motor / Generator

Control Strategy:
☒ Maximum Torque / Amp
☐ Maximum Efficiency
☐ Constant Power Advance = 0
☐ User Defined

Speed	Phase Advance
0	0
1000	15
2000	30

DC Current Limit:
☒ None
☐ Current Limit
 Maximum DC Current: 80

Losses:

Iron Loss Build Factors:
 Stator: 1 Rotor: 1
 Hysteresis: 1 Eddy: 1
 Magnet Loss Build Factor: 1

Scaling:
 Turns / Coil:
 Model build reference: 28
 Resistance reference: 28
 Calculation: 28

Temperatures:

Stator Winding Temperature:
 Reference temperature: 183.7
 Calculation temperature: 183.7
 Temp. Coeff. Resistivity: 0.003862

AC Loss Temperature Scaling:
 Reference temperature: 20
 Temperature Exponent: 0.5

Magnet Temperature:
 Reference temperature: 118
 Calculation temperature: 118
 Magnet Flux Coefficient: -1.12

Mechanical Loss Temperatures

Airgap Temperature: 117.7
 Bearing Temperature [F]: 98.71
 Bearing Temperature [C]: 98.13

Motor-CAD Model Loaded Successfully

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Motor-CAD Model Loaded Successfully

MOTOR-CAD LAB MODEL

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:

Thermal Map Type:
☒ Envelope
☐ Full Map

Thermal Calculation:
☒ Steady State
☐ Transient

Thermal Limit:
☐ Stator and Magnet
☒ Stator Winding Only
☐ Stator Winding + Magnet

Maximum Winding Node:
☒ Average
☐ Hotspot

Add Custom Limit Remove Custom Limit

Speed:
Maximum: 6000
Step: 500
Minimum: 0

Maximum Temperatures:
Stator Winding: 160
Magnet: 140

Max. Current:
☐ Limit on Max. Current
Maximum (Peak): 150
Maximum (RMS): 106.1

Thermal Node Temperatures Limit

Thermal Current Estimate:
Stator Current (Peak): 100
Stator Current (RMS): 70.71
Rotor Current: 6

Calculation Status:

Calculate Thermal Performance
Cancel Calculation
Load Results Viewer

Motor-CAD Model Loaded Successfully

MOTOR-CAD LAB MODEL

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

Model Build
Calculation
Electromagnetic
Thermal
Duty Cycle
Generator
Calibration
Settings

Duty Cycle:
Duty Cycle Type:
☒ Custom Duty Cycle
☐ Automotive Drive Cycle
☐ Automotive Drive Cycle
None

Thermal Transient Coupling:
☒ No coupling (Default)
☐ Losses - Thermal
☐ Coupled Transient Solution

Duty Cycle Data:
Number of Cycles: 4
Transient Duration: 140
Number of Points: 50
RMS Torque: 764.8
RMS Torque [psi]: 1123
Average Speed: 1179

Vehicle Model:
Mass: 1350
Rolling Resistance Coefficient: 0.0054
Air Density: 1.225
Generating Torque Ratio: 1
Frontal Area [m²]: 1.746
Drag Coefficient: 0.26
Gear Ratio: 4.113
Max. Torque: 500
Wheel Radius [m]: 0.3
Wheel Perks: 0
Mass Correction Factor: 1.04
Motoring Torque Ratio: 1
Max. Speed: 254

Calculate Duty Cycle Performance
Cancel Calculation
Transfer Duty Cycle Losses To Thermal Model
Load Results Viewer

Calculation Status:

Motor-CAD Model Loaded Successfully

”

Many thanks for your attention

Andrea Credo (andrea.credo@univaq.it)

Visiting Researcher