



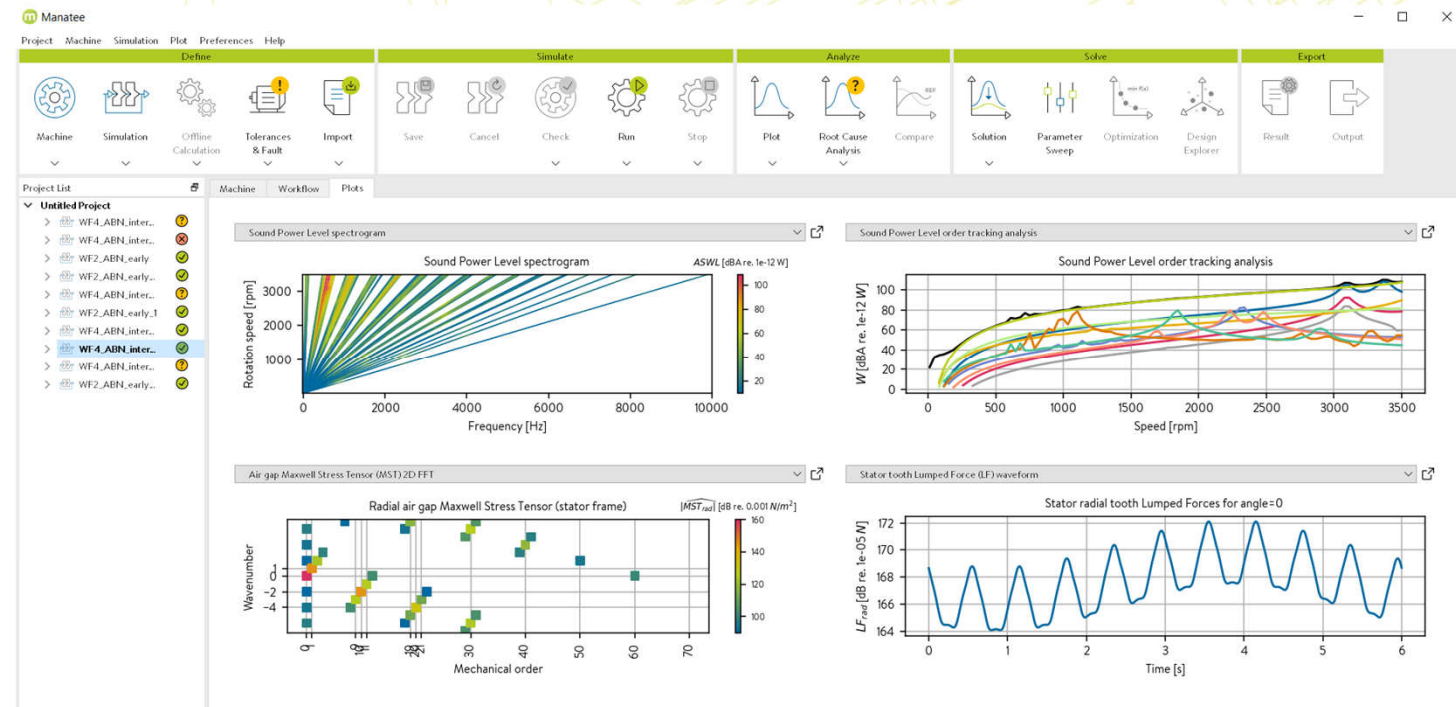
How to use Manatee CAE e-NVH platform without electrical machine geometry?

Manatee features for e-machine integrators



e-NVH CHALLENGES FOR E-MACHINE INTEGRATORS

- Problem: How to ensure e-NVH requirements at system level when there is no access to e-machine design parameters?
- Solutions proposed by Manatee:
 1. Quick Campbell diagram
 2. Airgap flux import
 3. Frequency Response Functions
 4. Magnetic force import



SOLUTION 1: Quick Campbell diagram

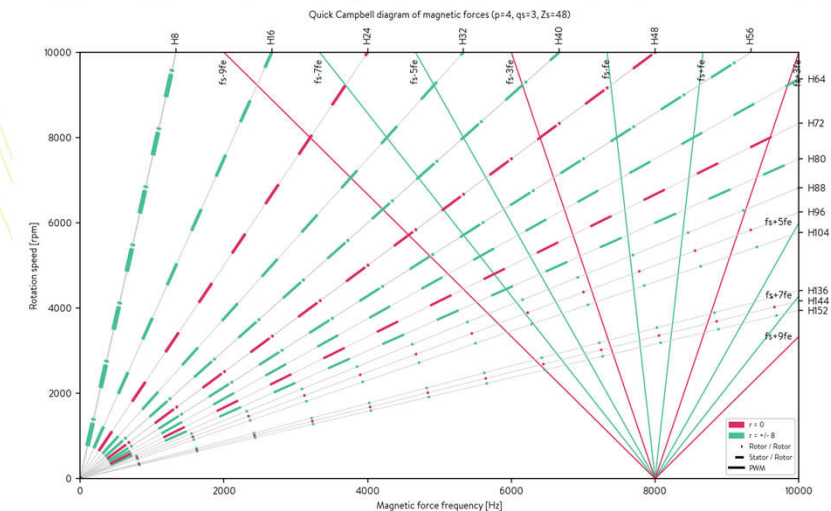
- Problem: How to compare the e-NVH behaviour of different supplier topologies with minimum number of inputs?
- Solution: Quick Campbell feature of Manatee based on topology, slot/pole numbers and speed range
- Outcome: comparison of the frequency signature of different topologies for early e-NVH risk analysis (identification of the presence of low wavenumber forces), prediction of main resonance speeds when position of structural modes are known
- Limitations: no quantification of vibration & noise levels

More information:

<https://www.youtube.com/watch?v=Nmbn4ZFKW14>

<https://www.training.eomys.com/magnetic-force-signature-analysis/147-signature-analysis.html>

2023_01_04 MFSA Magnetic Frequency Signature Analysis documentation



SOLUTION 2: Airgap flux import

- Problem: How to run e-NVH calculations on a third party electric machine without having access to detailed magnetic circuit dimensions?
- Solution: A) import of airgap flux distribution provided by third party + B) definition of an equivalent stator with tuned parameters to fit a known modal basis
- Outcome: possibility to rank e-NVH behaviour of several third party suppliers of electric machines using same modeling assumption + partial troubleshoot of the e-NVH problem + identification of lines exceeding NVH requirements (e.g. -15 dB needed on $6f_e$ at 3000 RPM)
- Limitations: no possibility to implement noise mitigation techniques

A) INPUT FORMAT (1/2)

- See <https://manatee.eomys.com/how-to-get-the-airgap-flux-distribution-from-ansys-maxwell/> for the procedure to export airgap flux density B from Ansys Maxwell
- See Prius_Flux_Import_Var_Speed.zip sent by e-mail for the Excel format
- One Excel file per operating point and per direction (Br, Btheta)
- File name should contain _rad or _tan, and operating point data: _N0=... for the rotation speed (rpm), _Id=... and _Iq=... for the currents (Arms)
- Files should contain as many sheets as there are slices, named **Slice**=... (number of the slice, starting at 0), _z=... (axial position of the slice, in meters)

A) INPUT FORMAT (2/2)

- First column is the time vector (s), first row is the angular position (rad)
- Angular and time discretisation are up to you, we recommend
- You can export the smallest periodicity in the signal. You need to exclude the last point to avoid numerical errors during the Fourier transforms.

	A	B	C	D
1	time/angle	0	0.00311666	0.00623332
2	0	0.938	0.869	0.806
3	1.8643E-05	0.983	0.902	0.836
4	3.7287E-05	1.035	0.948	0.869
5	5.593E-05	1.076	1.002	0.915
6	7.4574E-05	1.108	1.046	0.97
7	9.3217E-05	1.134	1.079	1.015
8	0.00011186	1.161	1.105	1.047
9	0.0001305	1.18	1.131	1.071
10	0.00014915	1.195	1.152	1.096

Time
(from 0 to t_max)

Angle
(from 0 to angle_max in rad)

A) IMPORT INTO MANATEE (1/2)

See <https://manatee.eomys.com/airgap-flux-import/>

Angle of the first tooth center ($^{\circ}$), in trigonometric direction

Machine: Toyota_Prius_new

Field: Form

Reference angle: 0

Flux folder path: C:/Users/helen/Desktop/Manatee_demo/demo data/Toyota_Prius/Prius_Flux_Import_Var_Speed

Delete	File name	Shape	Component	Speed (rpm)	Id	Iq
1	_rad_N0=50_Id=-134.(256, 252, 1)	radial	50	-134.0328	105.9904	
2	_tan_N0=50_Id=-134.(256, 252, 1)	tangential	50	-134.0328	105.9904	
3	_rad_N0=1571.4286_Id=(256, 252, 1)	radial	1571.4286	-134.0328	105.9904	
4	_tan_N0=1571.4286_Id=(256, 252, 1)	tangential	1571.4286	-134.0328	105.9904	

Source	Axis name	Size	Unit	Periodicity
1 first column	time	256	s	periodic
2 first row	angle	252	rad	periodic
3 sheet	z	1	m	none

Import as MLUT

Preview

OK

Cancel

Save in MLUT folder

Set to periodic to indicate how many periods must be reconstructed to get the signal over a complete rotation

1. Import the files

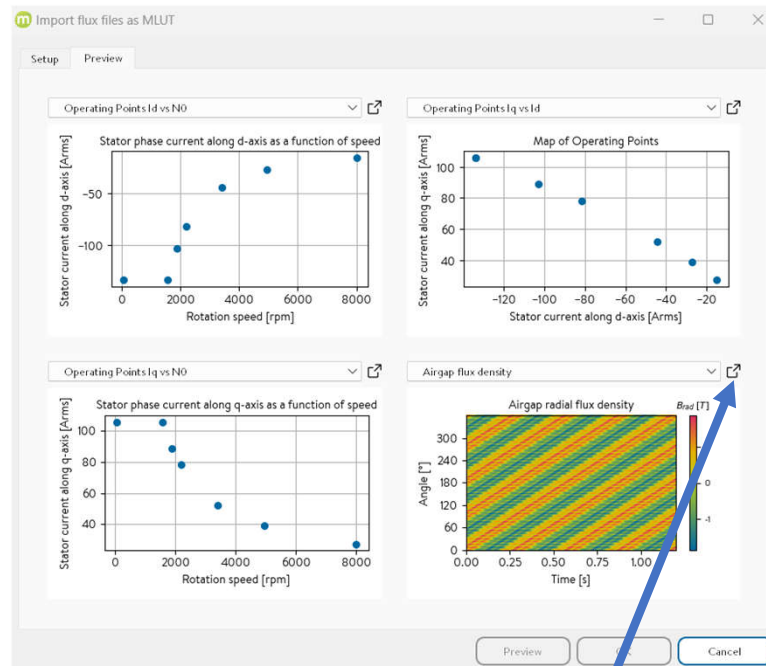
2. Preview to check periodicity (cf next slide)

3. Do not forget to save in MLUT folder if preview is OK

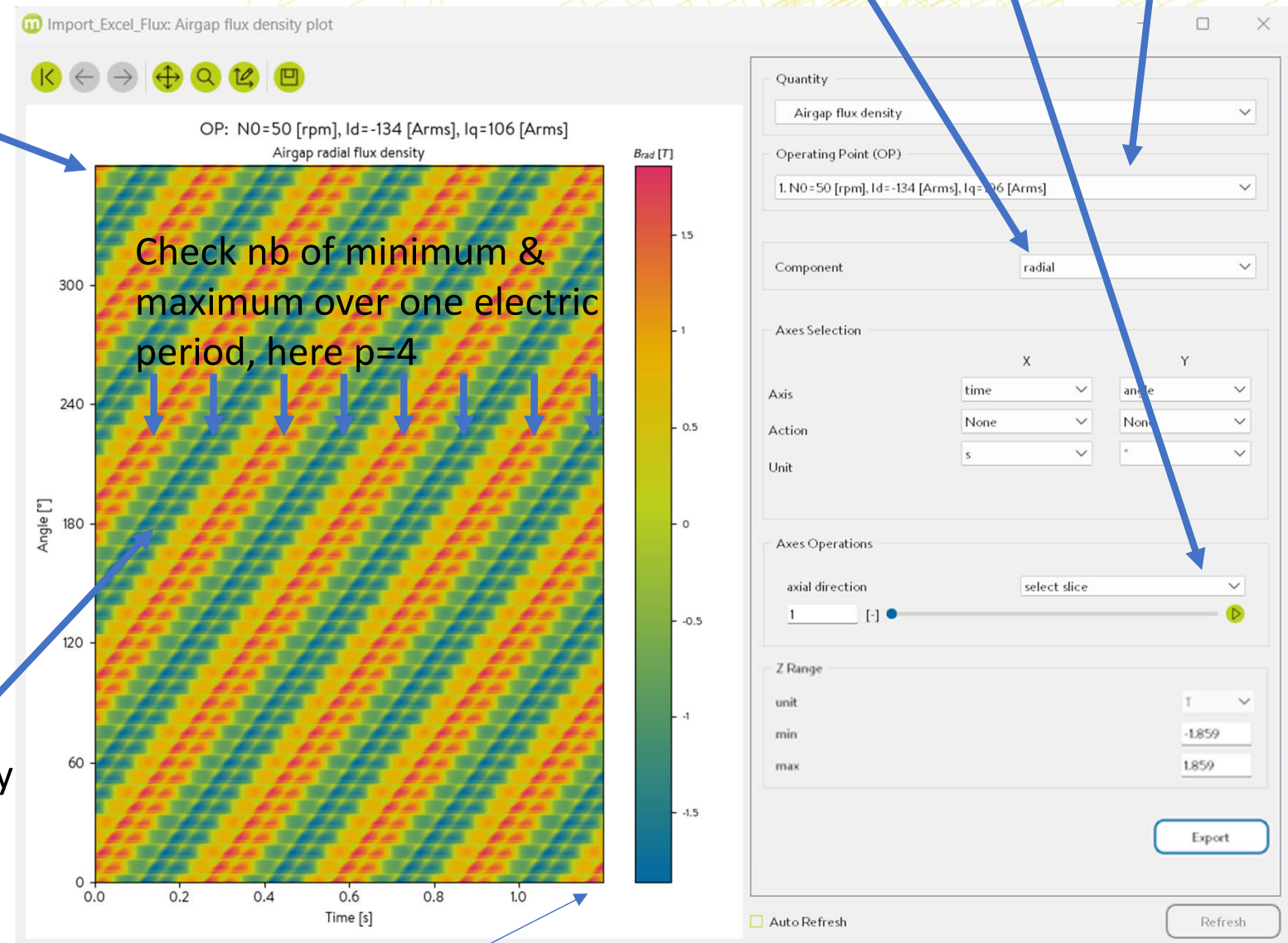
A) IMPORT INTO MANATEE (2/2)

See <https://manatee.eomys.com/airgap-flux-import/>

Check preview



360°



Check for every component, slice and OP

Check nb of minimum & maximum over one electric period, here p=4

No discontinuity

Undock flux density plot to check periodicity

60/N0 [s]

B) DEFINE SIMPLIFIED MACHINE (1/2)

- Edit Toyota_Prius to match your stator design (inner/outer radii, slot depth):

Machine

Workflow

Plots

Import from Library

1: Machine Type

2: Machine Dimensions

3: Stator Slot

4: Stator Winding

5: Stator Conductor

6: Stator Lamination

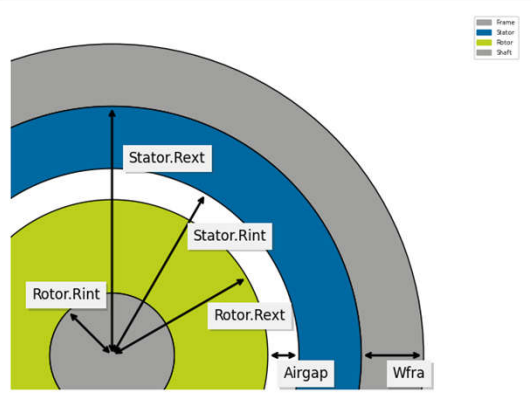
7: Rotor Hole

8: Rotor Lamination

9: Rotor Skew

10: Machine Summary

Export to Library



Stator

Rext 109.8269 [mm]

Rint 75.8228 [mm]

Rotor

Rext 74.963 [mm]

Rint 23.144 [mm]

Airgap magnetic width = 0.8598 [mm]

☒ Shaft

Shaft Material M400-50A

Edit Materials

☐ Frame

Frame Material

Edit Materials

Previous

Next

on Library

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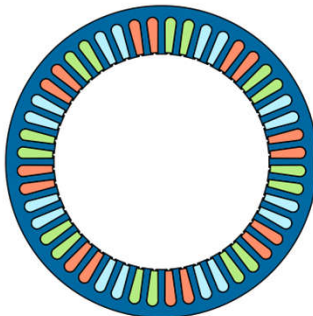
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o Library

Stator with winding



Li: 83.82 [mm]

Kf: 0.95

Lamination Material M400-50A

Edit Materials

☐ Axial cooling duct

Axial: 0 set (0 ducts)

Set Axial Ducts

☐ Radial cooling duct

Nrwd: 0

Wrwd: 0 [mm]

Stator total length = 83.82 [mm]

☐ Notches

0 set (0 notches)

Set Notches

Previous

Next

Machine

Workflow

Plots

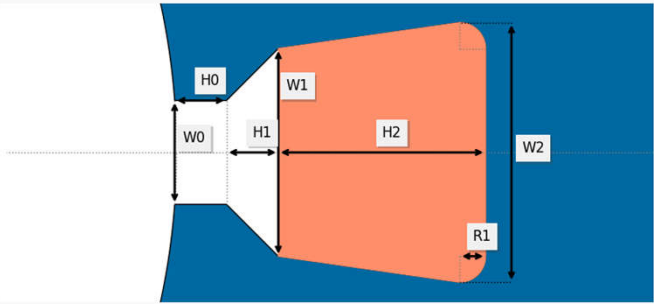
Import from Library

Slot Type II

Zs: 48

Slot pitch = 360 / Zs = 7.5 [°] (0.1309 [rad])

Export to Library



W0 1.93 [mm]

W1 5 [mm]

W2 8 [mm]

H0 1 [mm]

H1 0 [mm]

H2 25 [mm]

R1 4 [mm]

☐ Wedge

Output

Slot height: 25.99 [mm]

Yoke height: 8.01 [mm]

Active surface: 161.6 [mm²]

Slot surface: 163.6 [mm²]

Opening angle: 0.02545 [rad]

Previous

Previous

Next

Workflow

Plots

Import from Library

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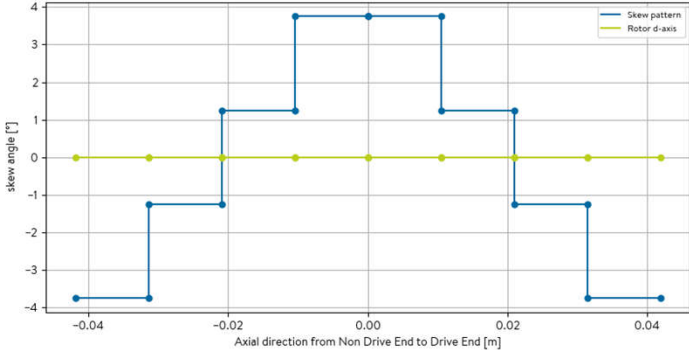
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summary

rt to Library

Preview



☒ Activate Rotor Skew

Type of Skew V-shape

Step/Continuous Step

Number of steps 8

Skew Angle 7.5 [°]

Inclination Angle 0 [°]

Stator slot pitch = 7.5 [°] / Skew rate = 100%

Skew Angles [°]

1 -3.75

2 -1.25

3 1.25

4 3.75

5 3.75

6 1.25

7 -1.25

8 -3.75

Previous

Next

B) DEFINE SIMPLIFIED MACHINE (2/2)

- Adjust end-winding length (Lewout) to get correct winding mass:

Machine Workflow Plots

Import from Library

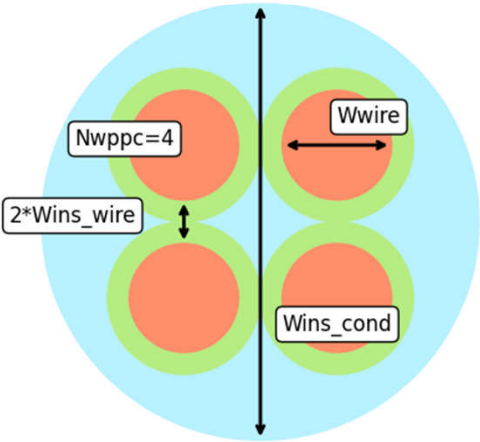
1: Machine Type
2: Machine Dimensions
3: Stator Slot
4: Stator Winding
5: Stator Conductor
6: Stator Lamination
7: Rotor Hole
8: Rotor Lamination
9: Rotor Skew
10: Machine Summary

Export to Library

Conductor type: Random Round Wire

mat_wind: Copper1 Edit Materials

ins_mat: Insulator1 Edit Materials



Output

Nwppc 13

Wwire 0.912 [mm]

☒ Insulation

Wins_cond 15 [mm]

Wins_wire 0.001 [mm]

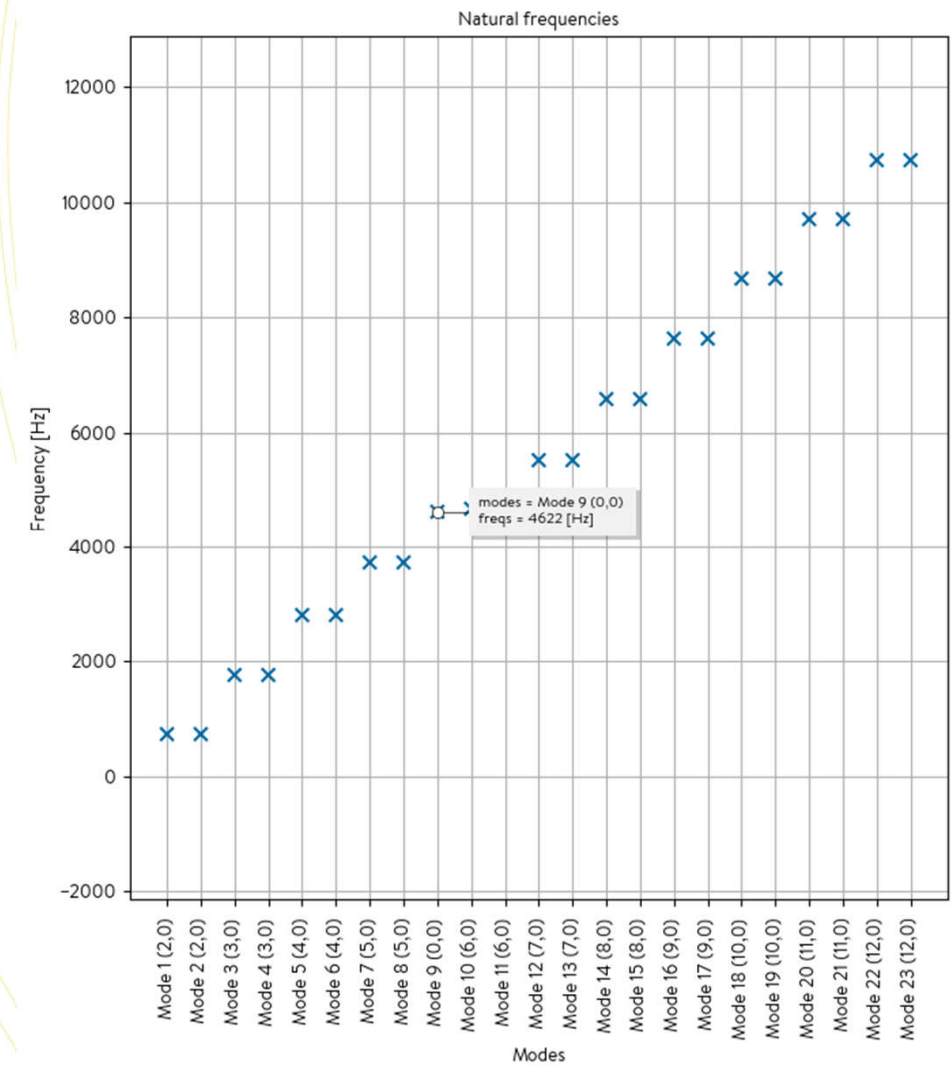
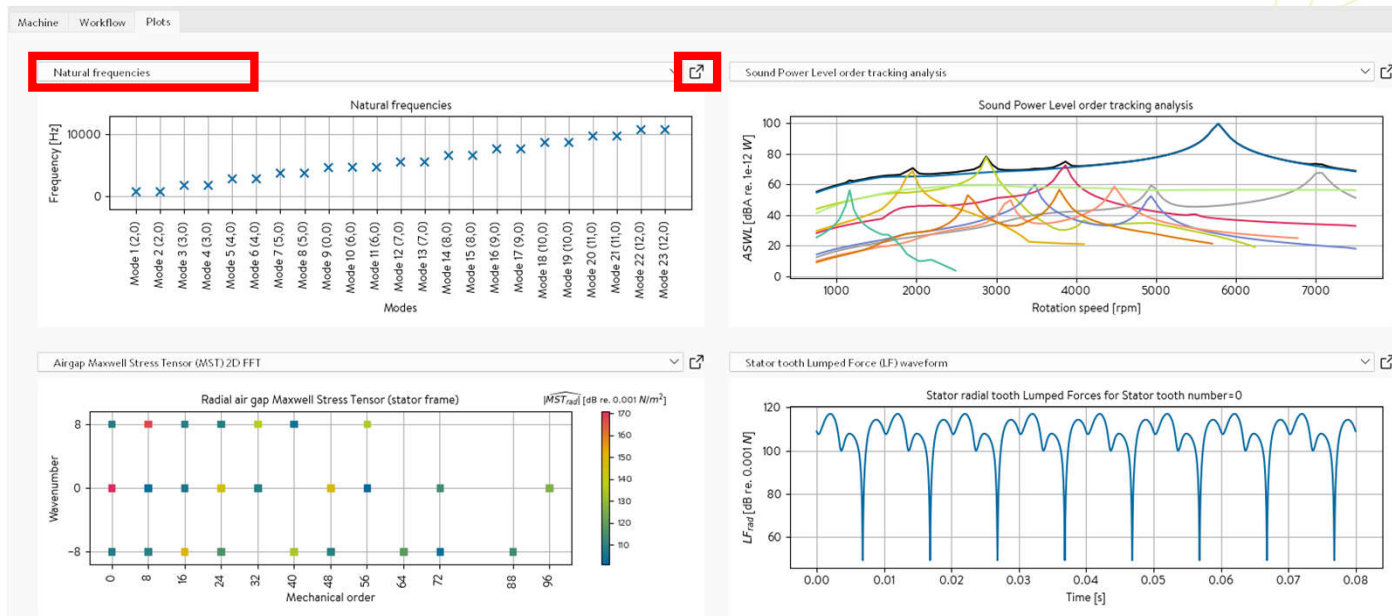
Lewout 25 [mm]

Hcond = 15 [mm]
Wcond = 15 [mm]
Scond = 176.7 [mm²]
Scond_active = 8.492 [mm²]
Ksfill = 47.29 %
Mean Length Turn = 267.6 [mm]
Winding mass = 4.369 [kg]
Rwind 20°C = 0.03926 [Ohm]

Previous Next

RUN WF2 TO CHECK NATURAL FREQUENCIES

- Adjust stator lamination material density / Young modulus to match breathing mode frequency



RUN WF4 WITH IMPORTED FLUX

Machine Workflow Plots

Tolerances & Fault Import Save Cancel Check Run

Voltage

Current

1. MLUT

Electrical

Electromagnetic

Set Magnetic Look-Up Table (MLUT)

Setup Preview

MLUT origin Load MLUT from library 2.

MLUT folder: >/Workspace/Data/Toyota_Prius_new/LUT/23-03-06_08h59m55_Import_Excel_Flux Select Folder

3. Select folder created during excel import

MLUT Operating Point Table

The selected MLUT contains the following Operating Point, the Operating Points from Current will be interpolated

Nb of Operating Points 7 Export to csv

	N0 [rpm]	Id [Arms]	Iq [Arms]
1	50	-134.0328	105.9904
2	1571.4286	-134.0328	105.9904
3	1877.551	-102.8787	88.7478
4	2183.6735	-81.8196	78.2161
5	3408.1633	-44.3484	52.1693
6	4938.7755	-27.0548	39.1593
7	8000	-15.1289	27.2446

Preview Ok Cancel

External Noise

Output

SOLUTION 3: Frequency Response Functions

- Problem: How to be sure to fulfil e-NVH requirements at system level when e-motor subsystem excitations are unknown?
- Solution: use of magnetic load case Frequency Response Functions of Manatee applied to a system level FEA mechanical model modal basis
- Outcome: requirements on the levels of each magnetic load type (e.g. torque ripple, pulsating radial forces, etc.) as a function of speed in N/m^2 (stress) or N (lumped force)
- Limitations: system level FEA model must be built using a concept stator and rotor with main dimensions & masses provided by e-motor supplier