



joins



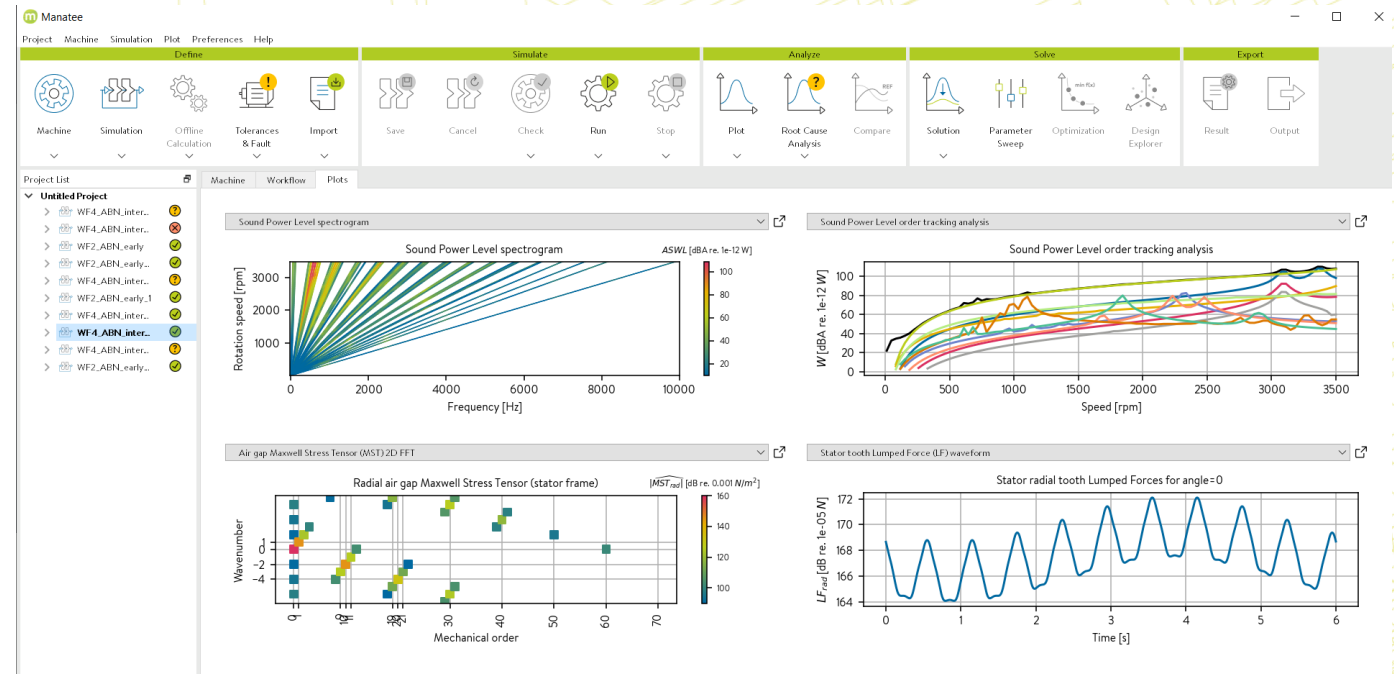
How to use Manatee CAE e-NVH platform without electrical machine geometry?

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

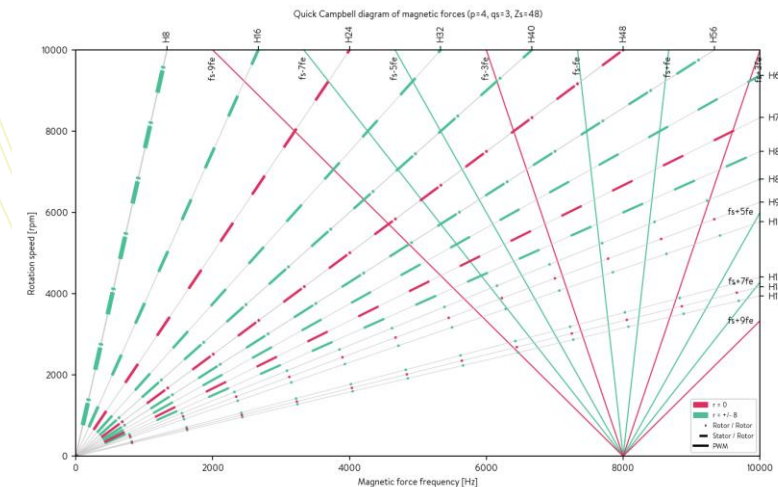
- Problem: How to compare the e-NVH behaviour of different supplier topologies with minimum number of inputs?
- Solution: Quick Campbell feature of Manatee based on topology, slot/pole numbers and speed range
- Outcome: comparison of the frequency signature of different topologies for early e-NVH risk 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 our airgap flux distribution feature presentation 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

Angle
(from 0 to angle_max in rad)

Time
(from 0 to t_max)

A) IMPORT INTO MANATEE (1/2)

See our presentation of the airgap flux import

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

Machine: Toyota_Prius_new

Field

Format: xlsx

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

Axes

	Source	Axis name	Size	Unit	Periodicity	
1	first column	time	256	s	periodic	8 periods
2	first row	angle	252	rad	periodic	8 periods
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)

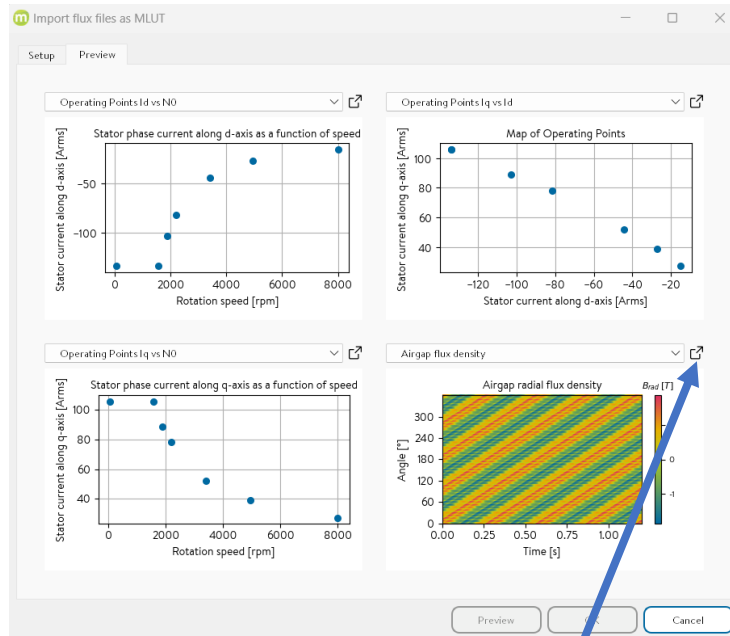
3. Do not forget to save in MLUT folder if preview is OK

A) IMPORT INTO MANATEE (2/2)

See our presentation of the airgap flux import

Check for every component, slice and OP

Check preview

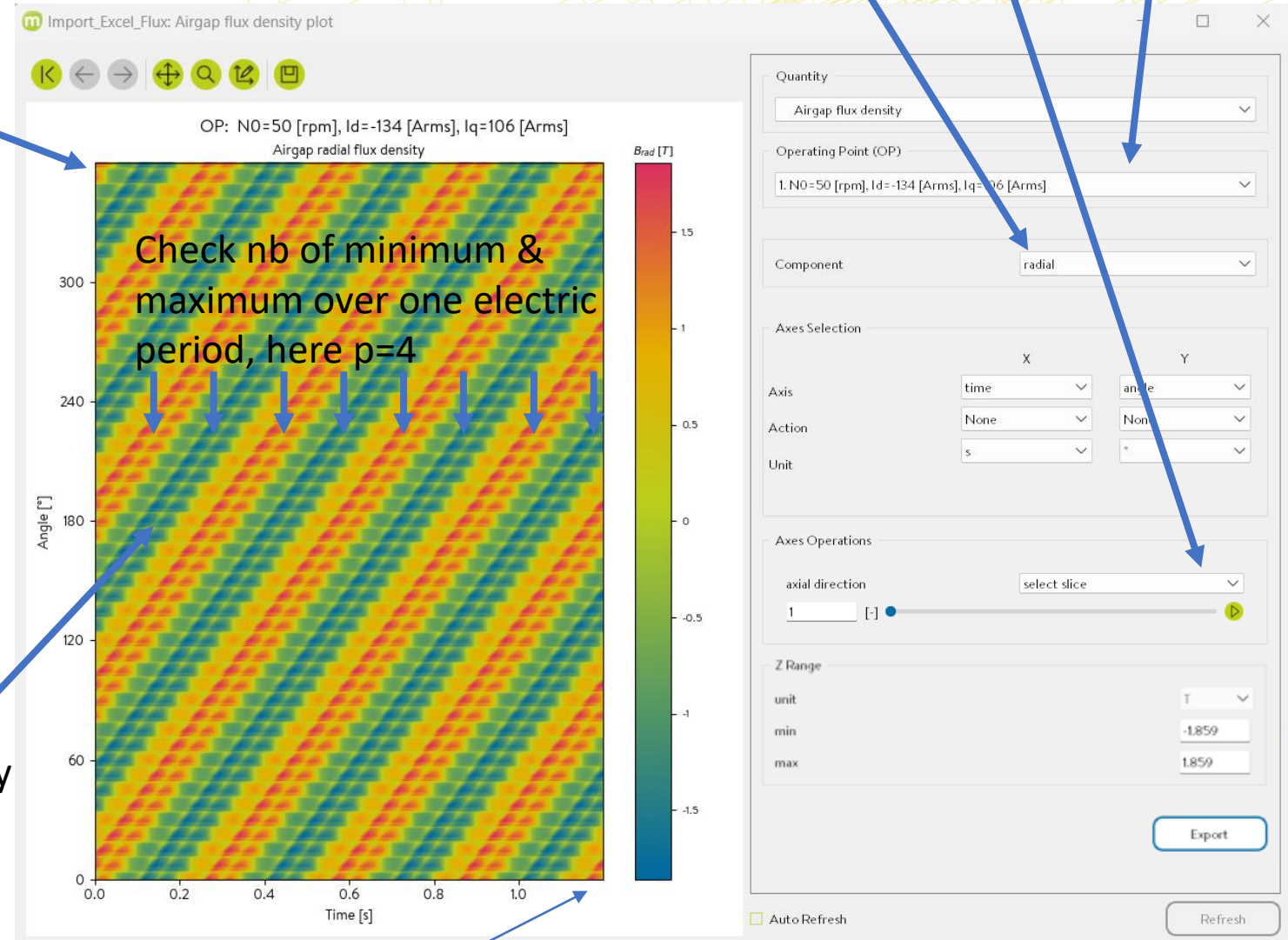


360°

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 with winding

Stator: Rest 109.8269 [mm], Rint 75.8228 [mm]
Rotor: Rest 74.963 [mm], Rint 23.144 [mm]
Airgap magnetic width = 0.8598 [mm]
Shaft: Shaft Material M400-50A
Frame: Frame Material

Stator Dimensions: Lt: 83.82 [mm], Kf1: 0.95, Lamination Material M400-50A
Axial cooling duct: Axial: 0 set (0 ducts)
Radial cooling duct: Nrwd: 0, Wrwd: 0, Stator total length = 83.82 [mm]
Notches: 0 set (0 notches)

Machine Workflow Plots

Slot Type II, Zs: 48, Slot pitch = 360 / Zs = 7.5 [°] (0.1309 [rad])

W0: 1.93 [mm], W1: 5 [mm], W2: 8 [mm], H0: 1 [mm], H1: 0 [mm], H2: 25 [mm], R1: 4 [mm]

Constraints:
 $W0 \leq W1$
 $2 \times R1 \leq W2$
 $R1 \leq H2$

Output:
Slot height: 25.99 [mm]
Yoke height: 8.01 [mm]
Active surface: 161.6 [mm]
Slot surface: 163.6 [mm]
Opening angle: 0.02545 [rad]

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

Preview

skew angle [°] vs Axial direction from Non Drive End to Drive End [m]

Previous Next

B) DEFINE SIMPLIFIED MACHINE (2/2)

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

Machine Workflow Plots

Import from Library

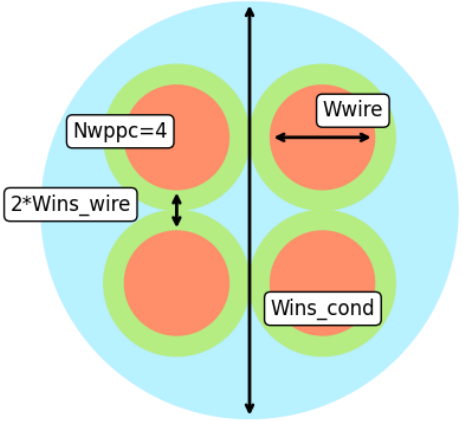
1: Machine Type
2: Machine Dimensions
3: Stator Slot
4: Stator Winding
5: Stator Conductor
6: Stator Lamination
7: Rotor Hole
8: Rotor Lamination
9: Rotor Skew
10: Machine Summary

Export to Library

Conductor type: Random Round Wire

mat_wind: Copper1 Edit Materials

ins_mat: Insulator1 Edit Materials



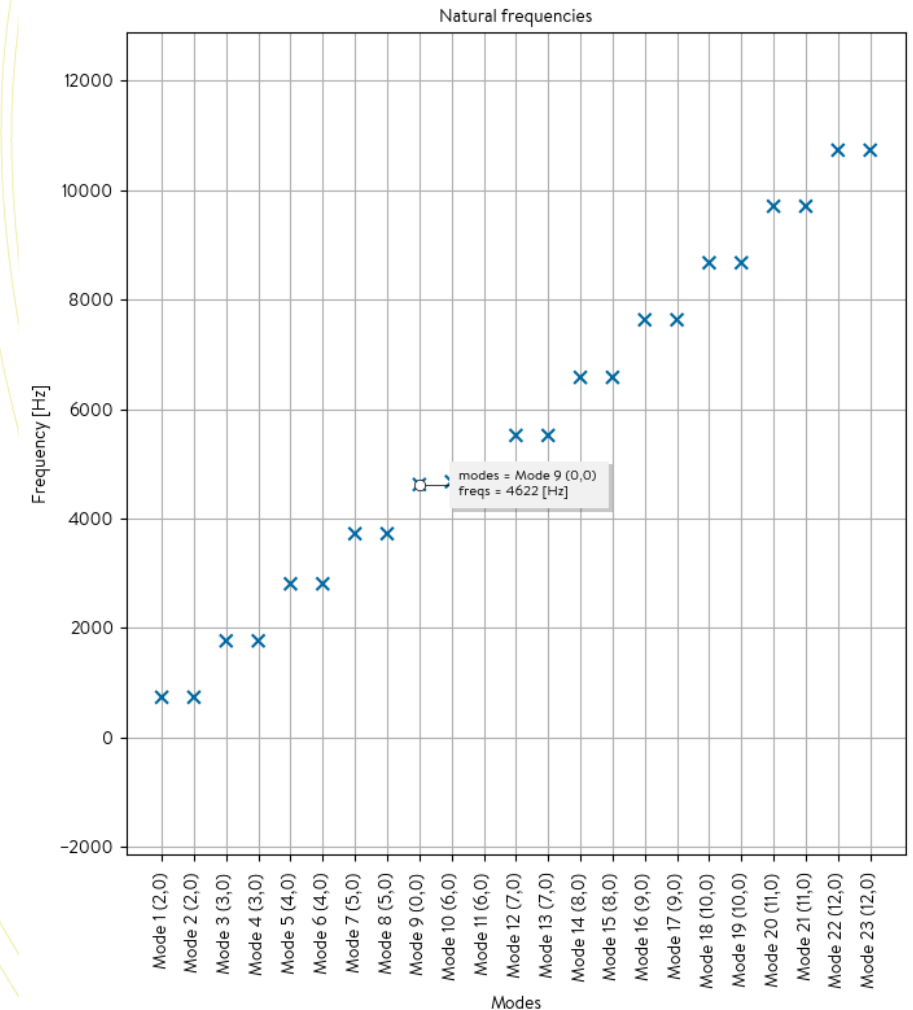
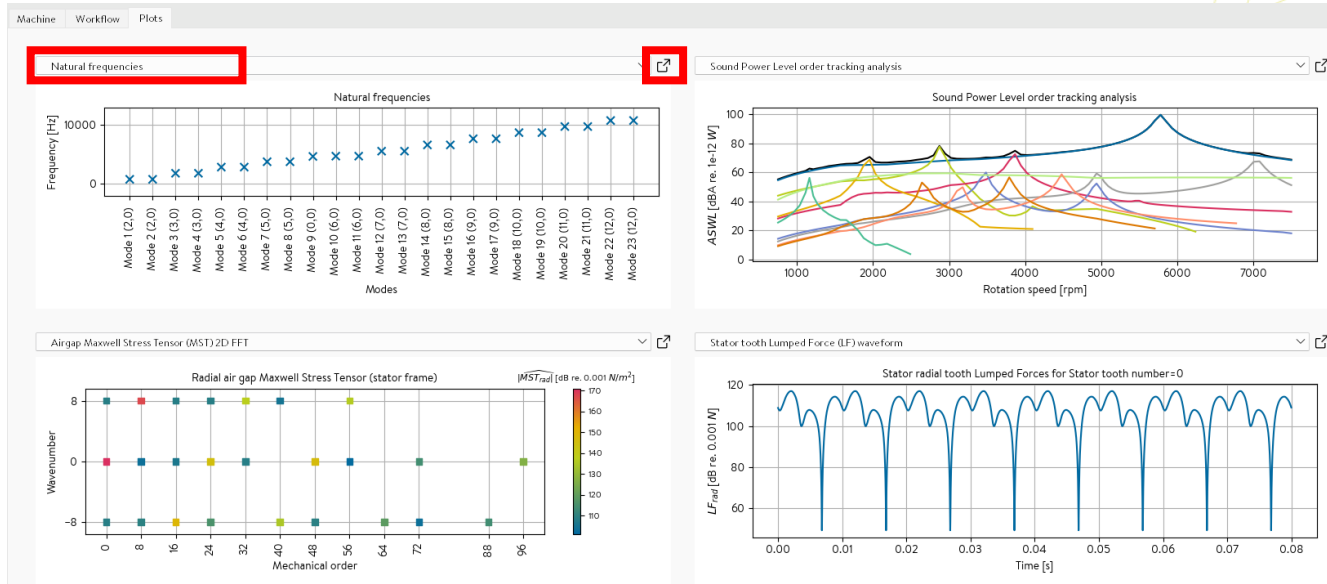
Output

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

Workflow diagram showing the process of running WF4 with imported flux. The workflow includes blocks for Voltage, Current, Electrical, MLUT (Magnetic Look-Up Table), Electromagnetic, External Noise, and Output.

1. Select the MLUT block in the workflow.

2. Set the MLUT origin to "Load MLUT from library".

3. Select the folder created during excel import.

The MLUT Operating Point Table is displayed, showing the following data:

	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

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