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

Manatee features for e-machine integrators

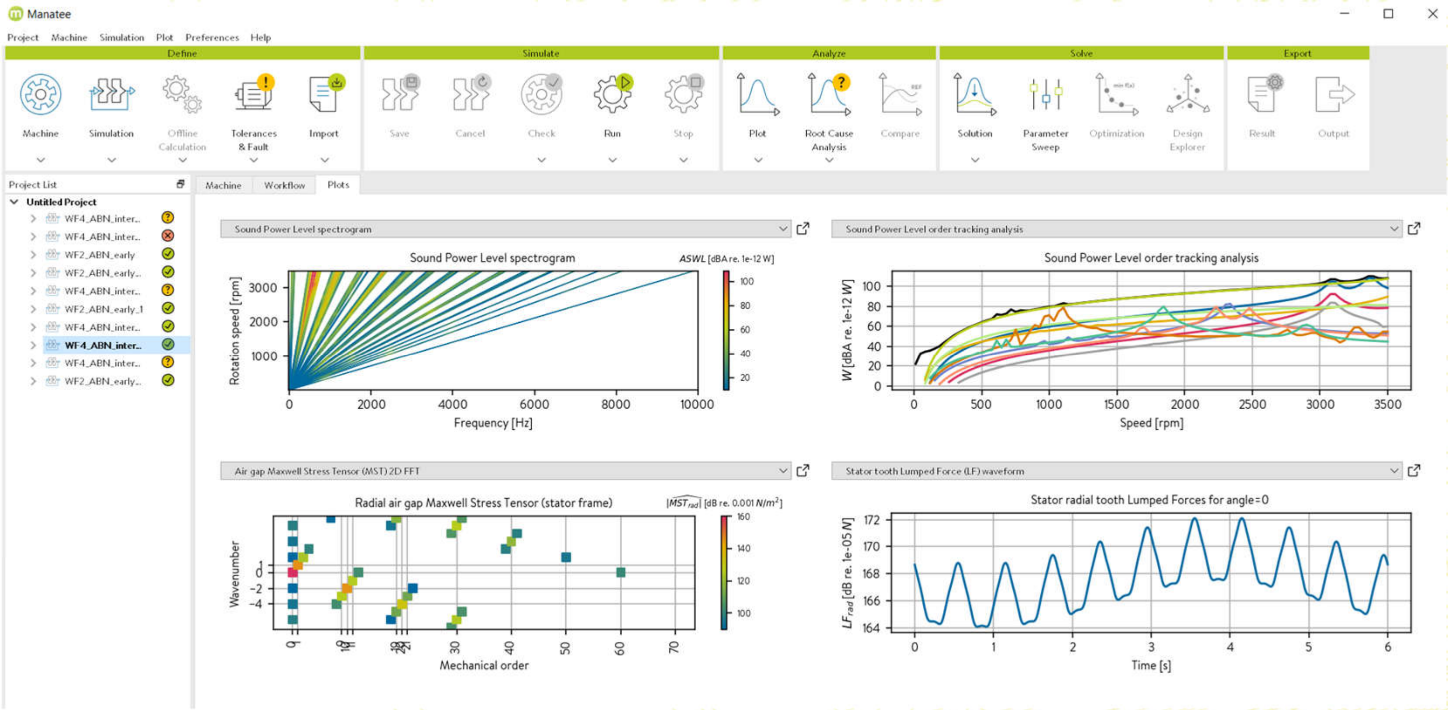
20231125

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



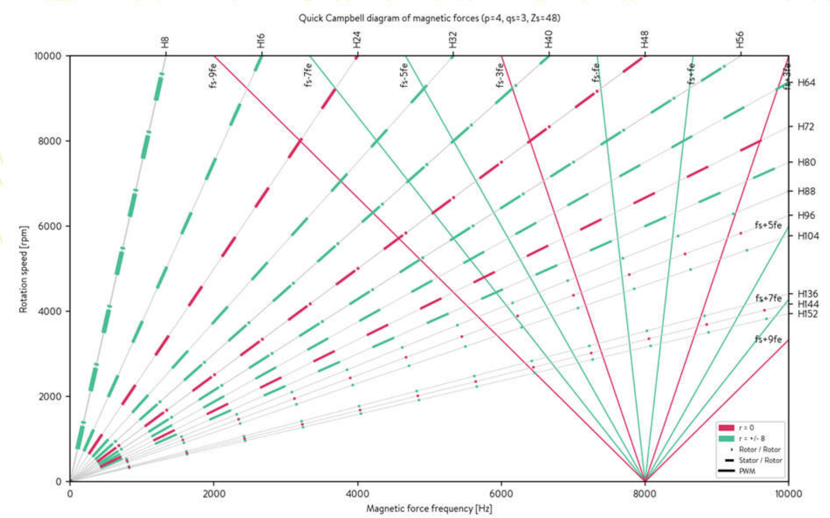
SOLUTION 1: Quick Campbell diagram

- 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.

Angle
(from 0 to angle_max in rad)

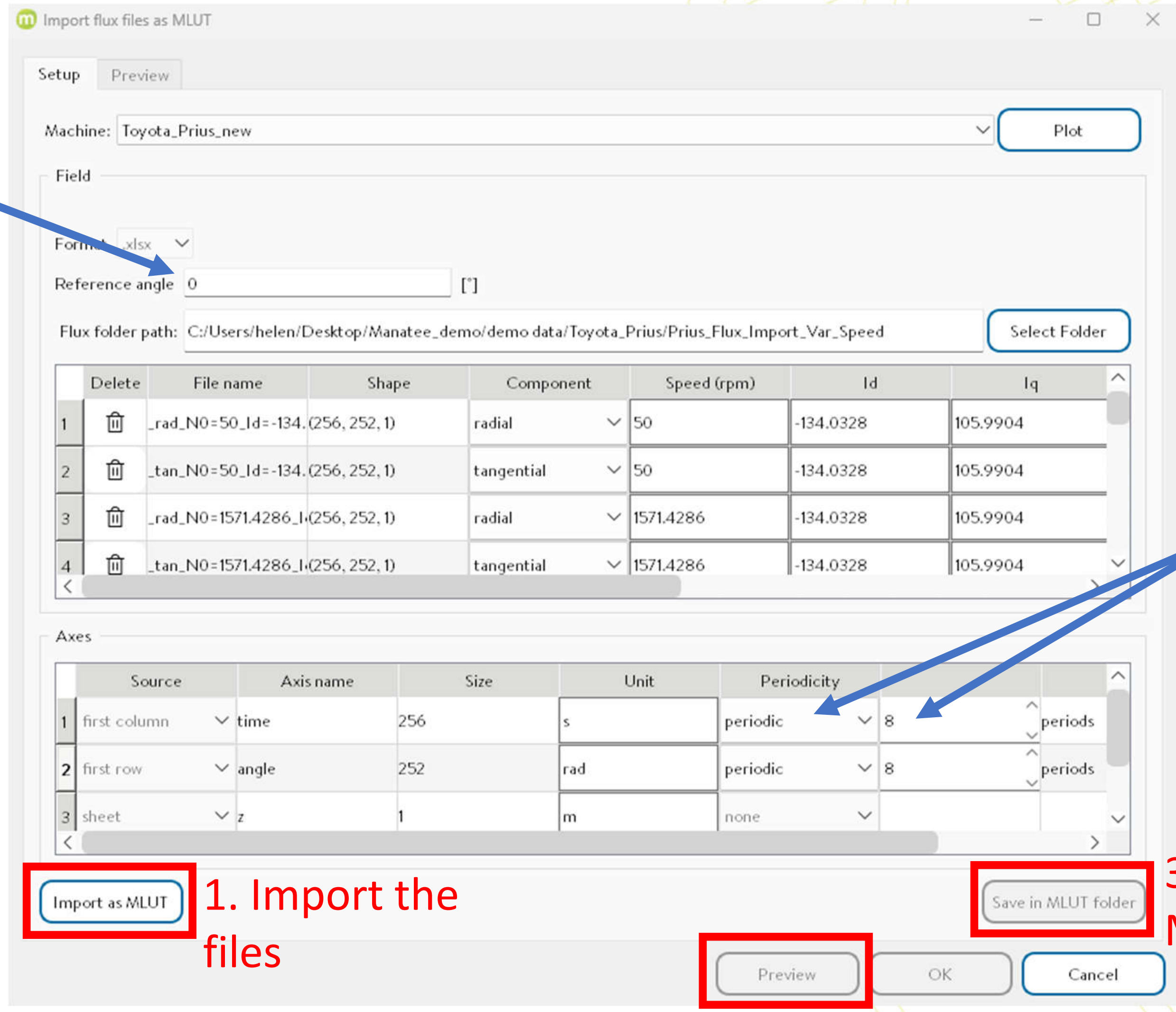
	A	B	C	D
1	time/angle	0	0.00311666	0.00623332
2	0	0.938	0.869	0.806
3	1.8643E-05	0.983	0.902	0.836
4	3.7287E-05	1.035	0.948	0.869
5	5.593E-05	1.076	1.002	0.915
6	7.4574E-05	1.108	1.046	0.97
7	9.3217E-05	1.134	1.079	1.015
8	0.00011186	1.161	1.105	1.047
9	0.0001305	1.18	1.131	1.071
10	0.00014915	1.195	1.152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

Time
(from 0 to t_max)

A) IMPORT INTO MANATEE (1/2)

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

Angle of the first tooth center (°), in trigonometric direction



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

1. Import the files

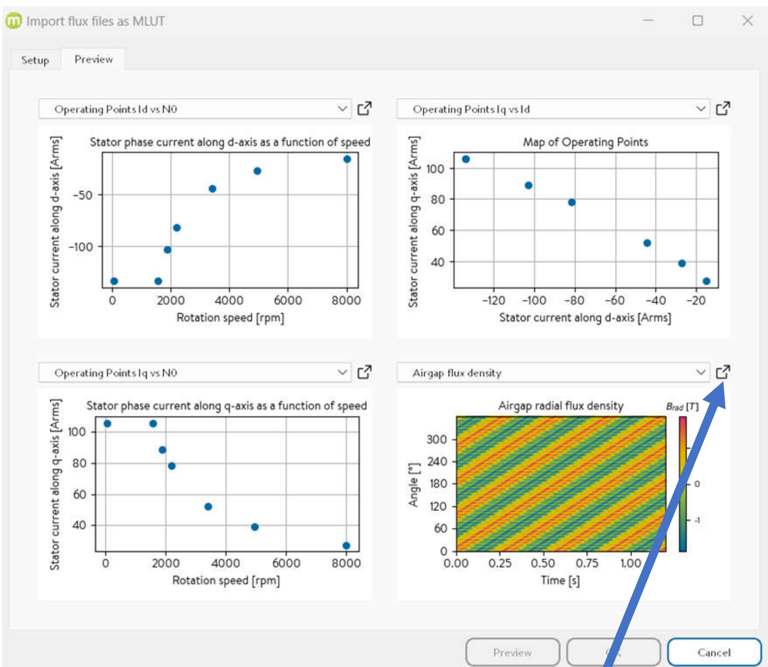
3. Do not forget to save in MLUT folder if preview is OK

2. Preview to check periodicity (cf next slide)

A) IMPORT INTO MANATEE (2/2)

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

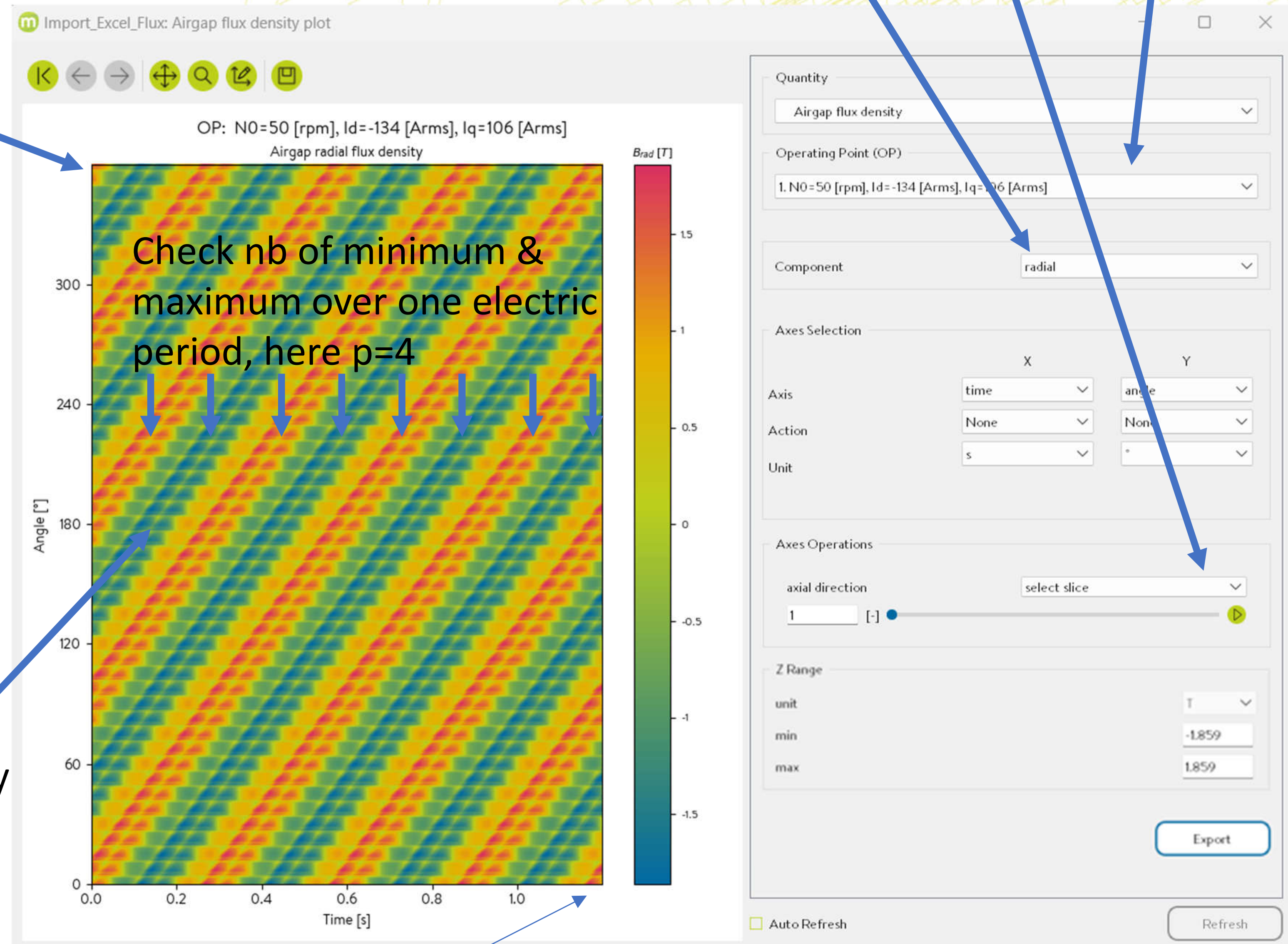
Check preview



Undock flux density plot to check periodicity

Check for every component, slice and OP

360°

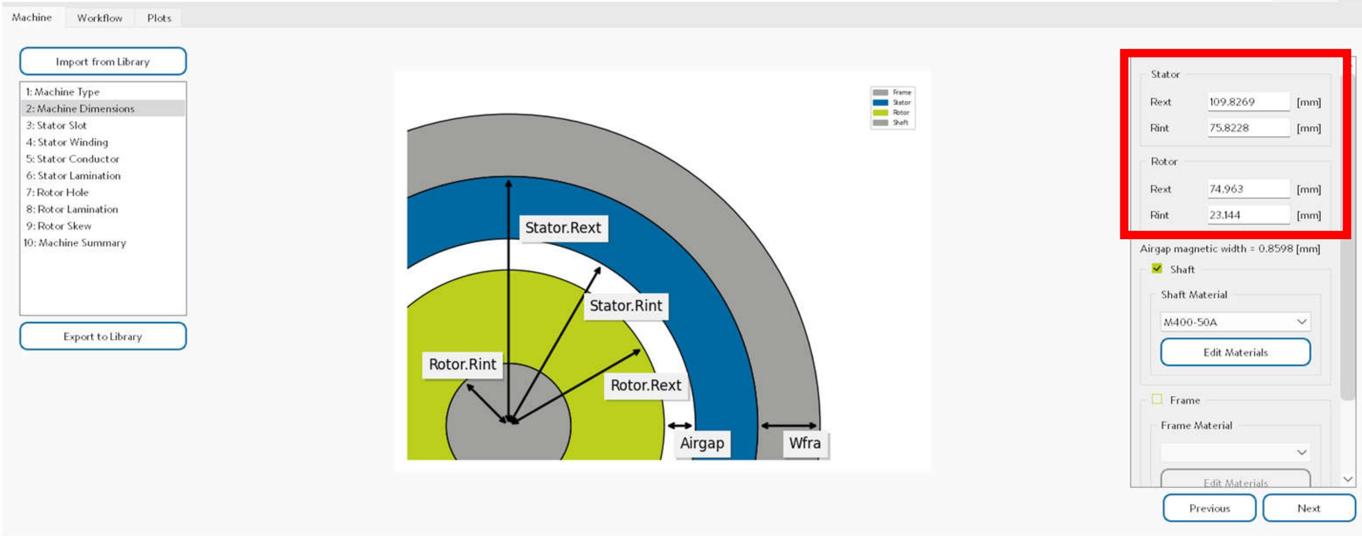


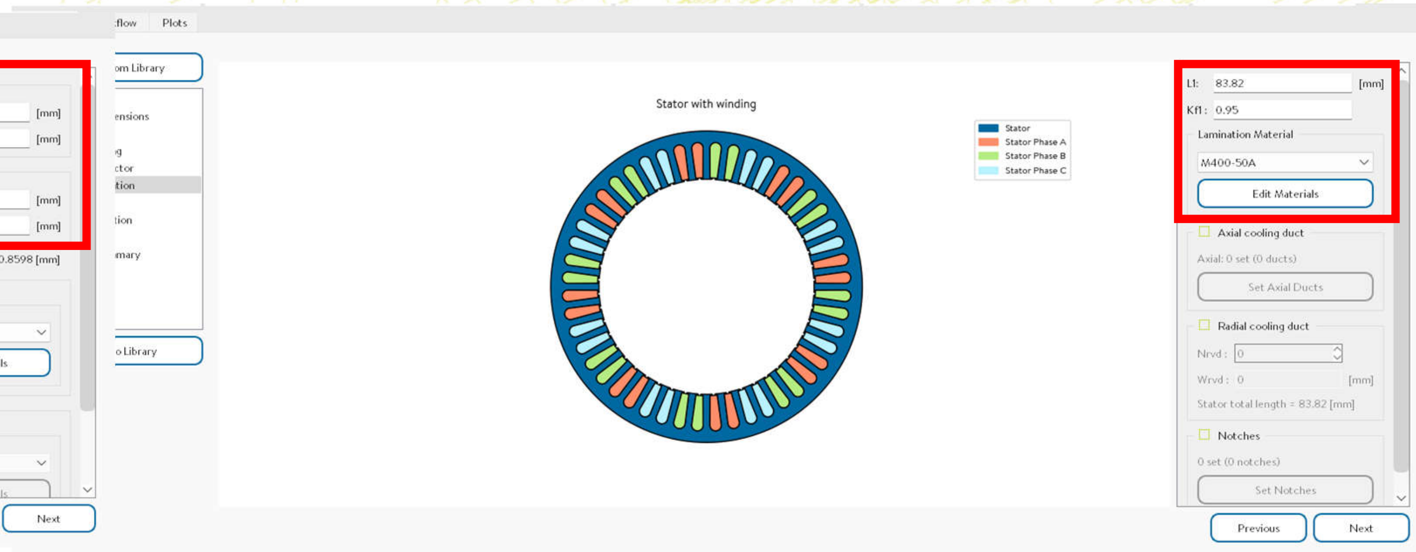
No discontinuity

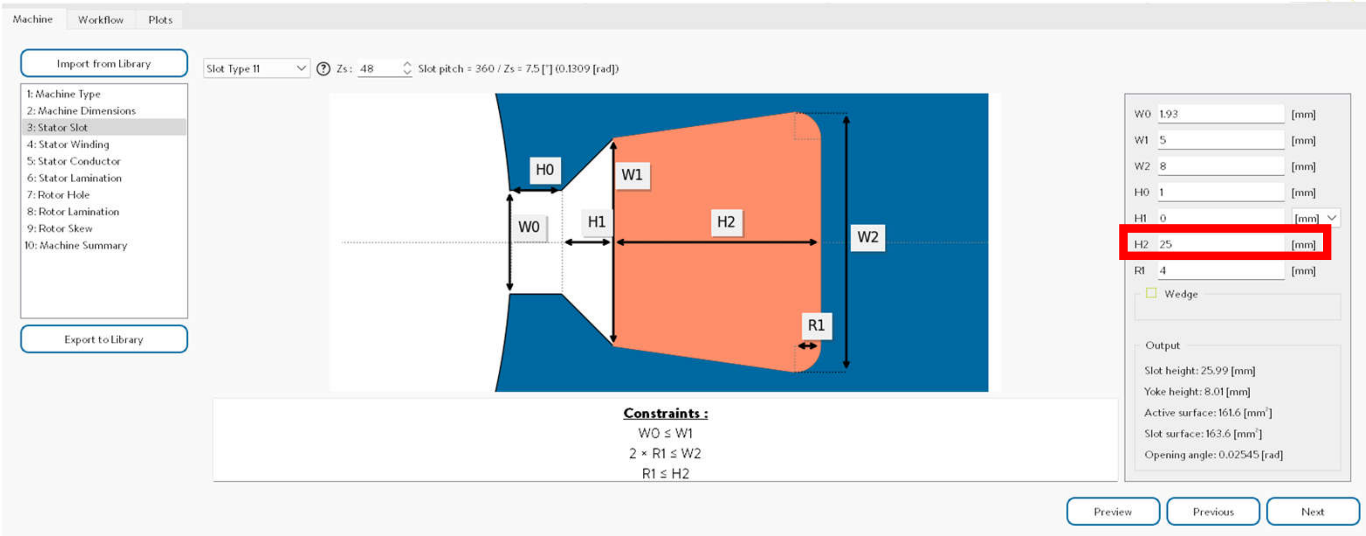
60/N0 [s]

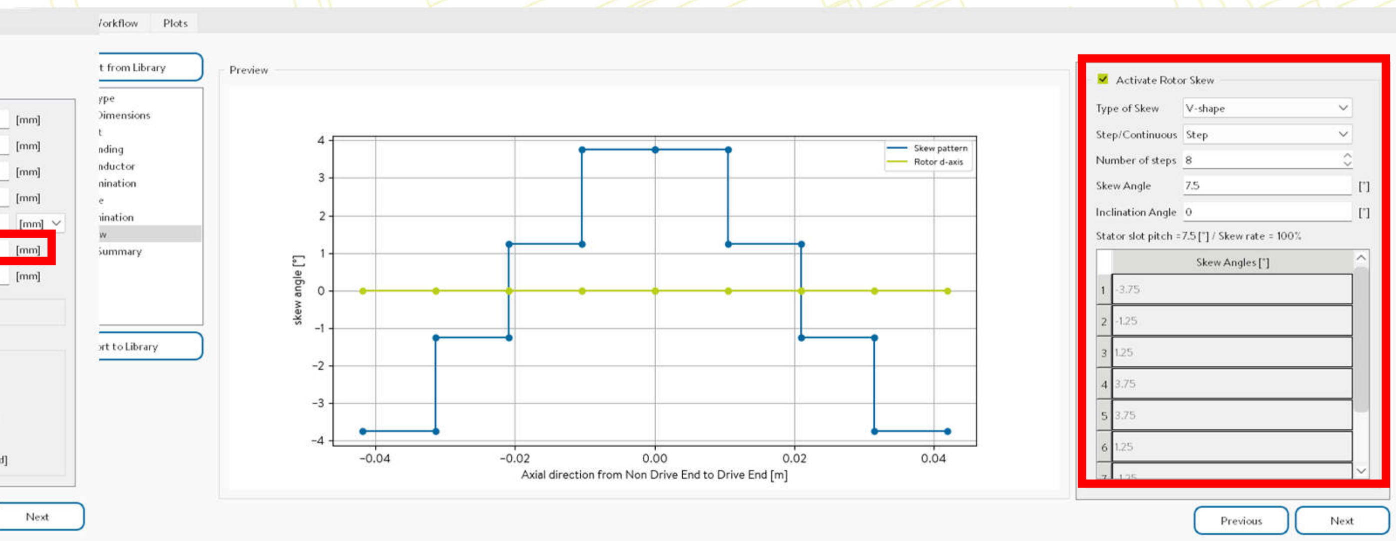
B) DEFINE SIMPLIFIED MACHINE (1/2)

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



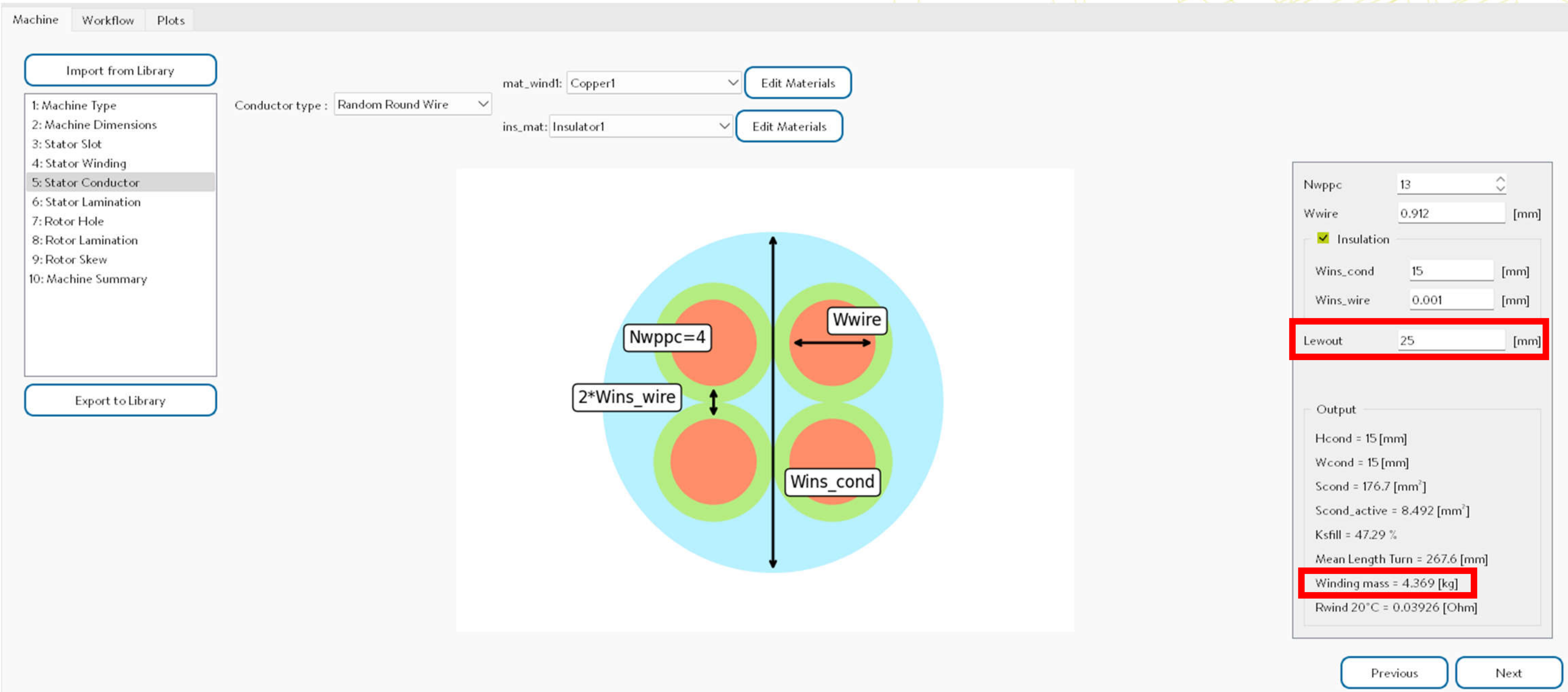






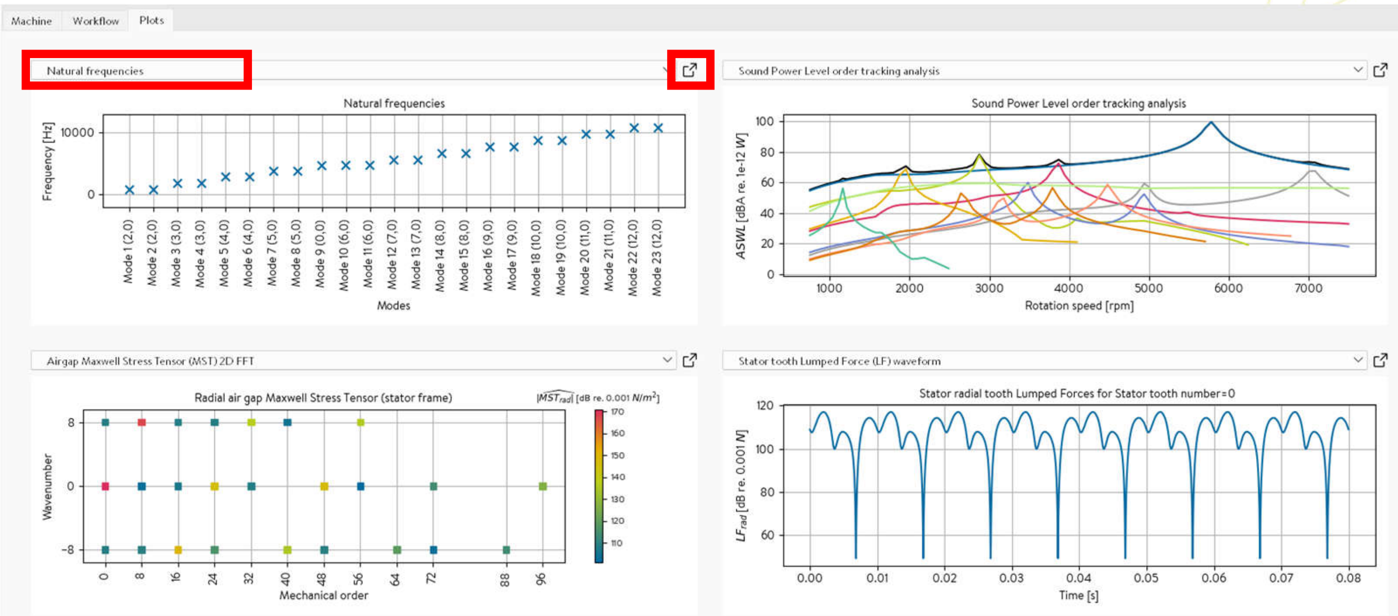
B) DEFINE SIMPLIFIED MACHINE (2/2)

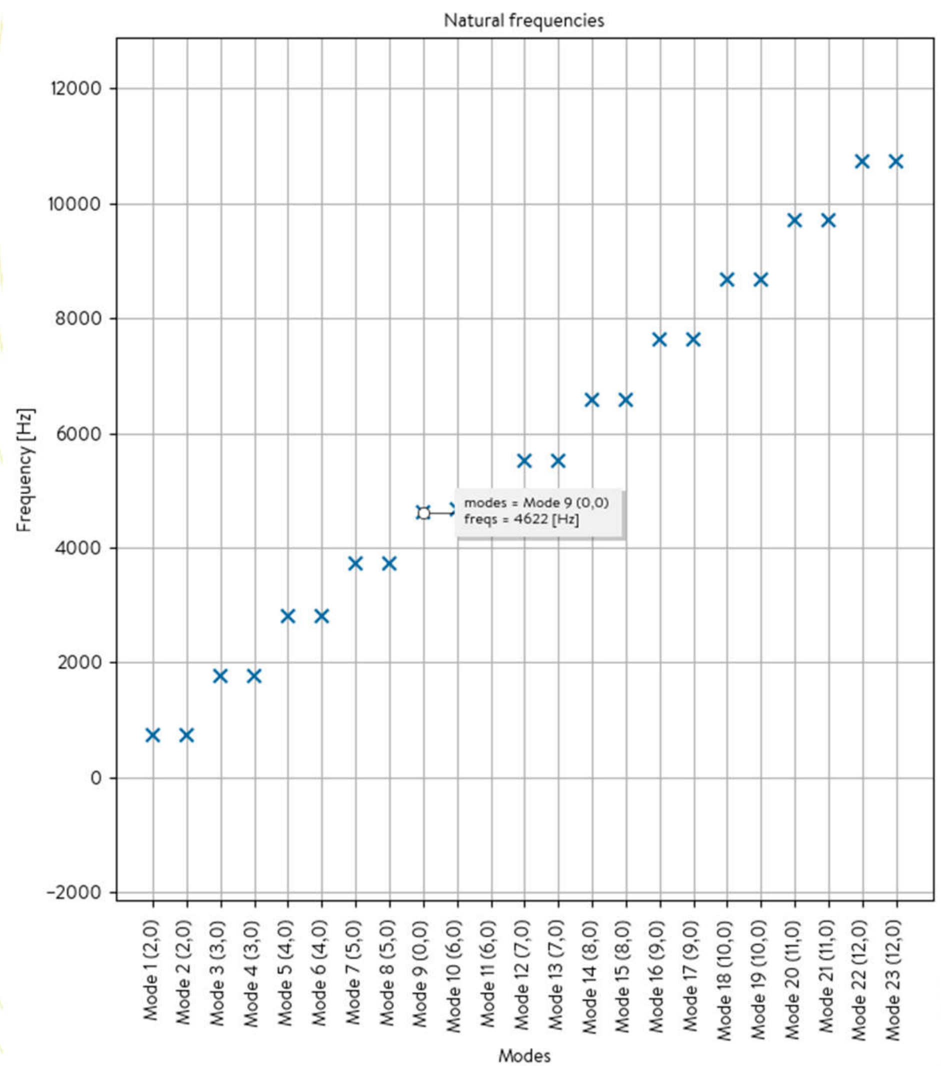
- Adjust end-winding length (Lewout) to get correct **winding mass:**



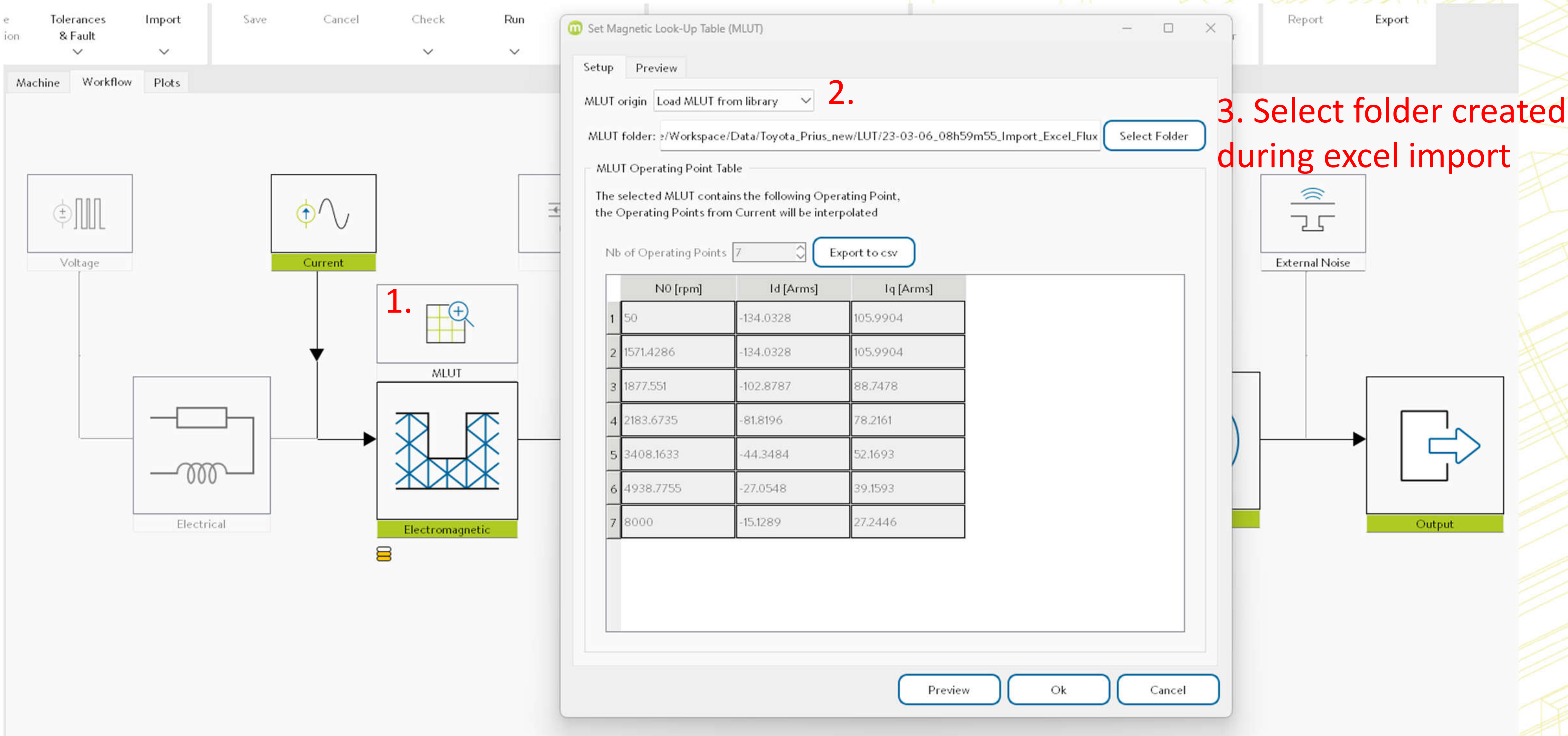
RUN WF2 TO CHECK NATURAL FREQUENCIES

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





RUN WF4 WITH IMPORTED FLUX



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