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YIDUO TECHNOLOGY

MotorXP-AFM

Design and Analysis of Axial Flux Machines with Permanent Magnets

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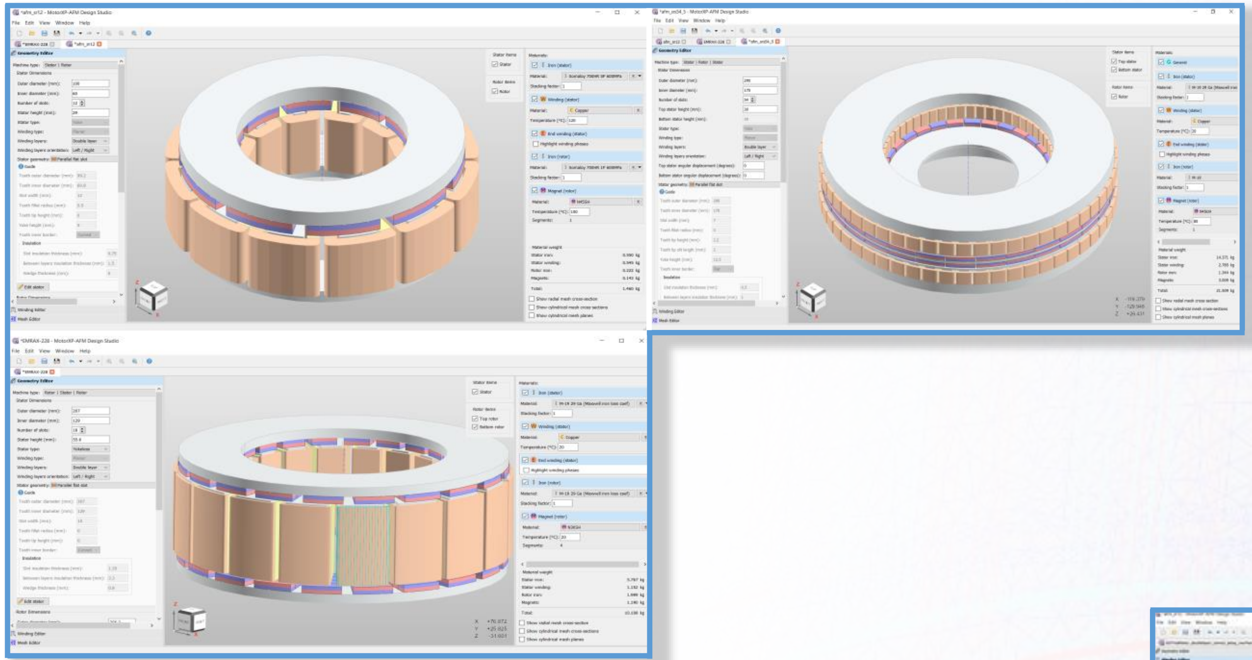

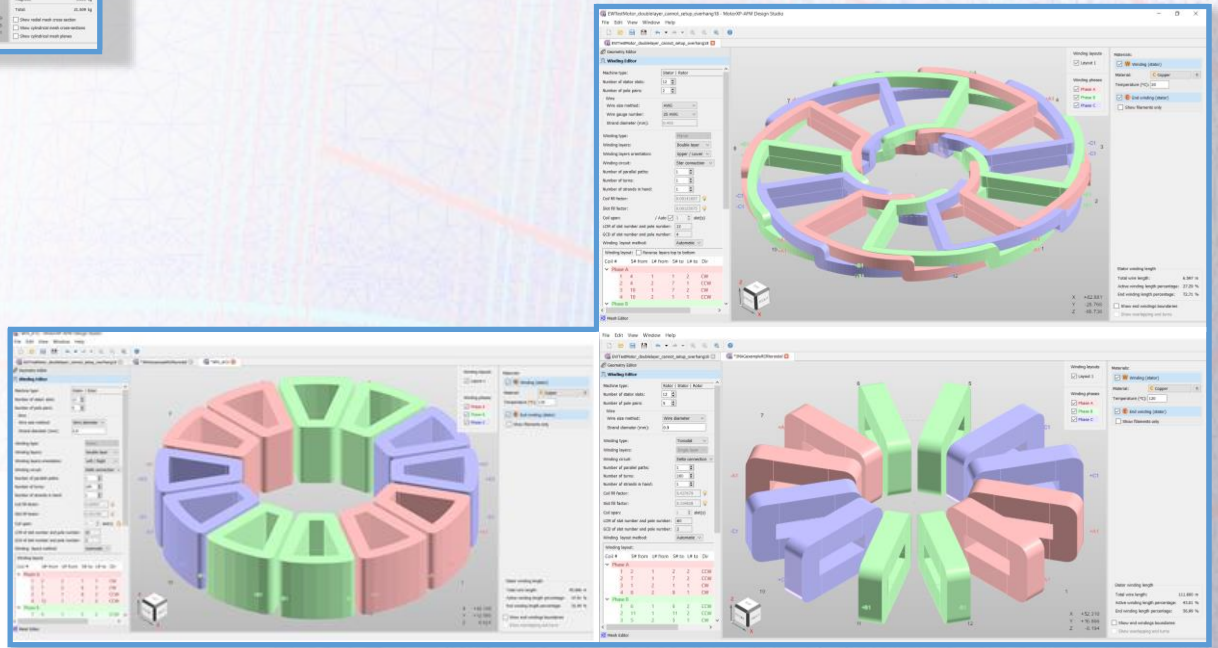

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May 2022

PROTOTYPING

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- **Stator-Rotor, Stator-Rotor-Stator (with yoke or yokeless rotor) and Rotor- Stator-Rotor (with yoke or yokeless stator) topologies**
- **3D stator and rotor geometry templates**

Stator geometries: Parallel flat slot, Parallel round slot
Rotor geometries: Trapezoidal magnet, Rectangular magnet, Halbach array

- **Custom geometry templates**

Create fully parameterized 3D geometry templates for custom stator and rotor geometries of arbitrary complexity

- **3D geometry export into STEP file**
- **Concentrated, distributed and toroidal winding types**
- **Manual or automatic winding layout for all possible pole/slot combinations**
- **Different wire sizing methods**

AWG, SWG, wire diameter and slot or coil fill factor

- **Calculation of different winding parameters**

Fundamental winding factor and harmonic winding factors, LCM and GCD of slot number and pole number, phase resistance and end turns inductance

- **Materials library and custom materials**
- **Custom transistors and diodes**

These can be added using data sheet parameters for inverter losses calculation

ANALYSIS

- High accuracy and high computational speed ***quasi-3D finite element modelling approach***

About 50 times faster than full 3D FEA without reducing the accuracy

- **FEA and analytical analysis methods including ultra-fast hybrid FEA-DQ method**
- **Sinewave, PWM and six step drives are supported**
- **All types of losses: winding losses, eddy current and hysteresis iron losses (including higher harmonics and minor hysteresis loops), magnet losses, etc.**
- **Permanent magnet demagnetization analysis**
- **Inverter losses calculation for IGBT and MOSFET transistors (including SiC MOSFETs)**

RESULTS

- **Time-series waveform plots and frequency spectrums**

Current, voltage, back-EMF, torque, powers, losses, etc.

- **Air gap distribution waveform plots and frequency spectrums**

Air gap flux density magnitude, air gap flux density tangential and normal components, radial force, etc.

- **Field plots and flux contours**

Flux density distribution, current density distribution, loss distribution, etc.

- **Animated air gap distribution and field plots versus time**
- **Machine constants**
- **Flux density levels in different parts of the machine automatically calculated**
- **Steady-state performance characteristics taking into account field weakening**

Torque vs. speed, torque vs. advance angle, voltage vs. speed, etc.

- **Steady-state performance maps**

Efficiency maps, losses maps, etc.

- **Extraction of the D-Q model parameters (such as Ld, Lq, magnet flux linkage)**

These can be used in third-party applications

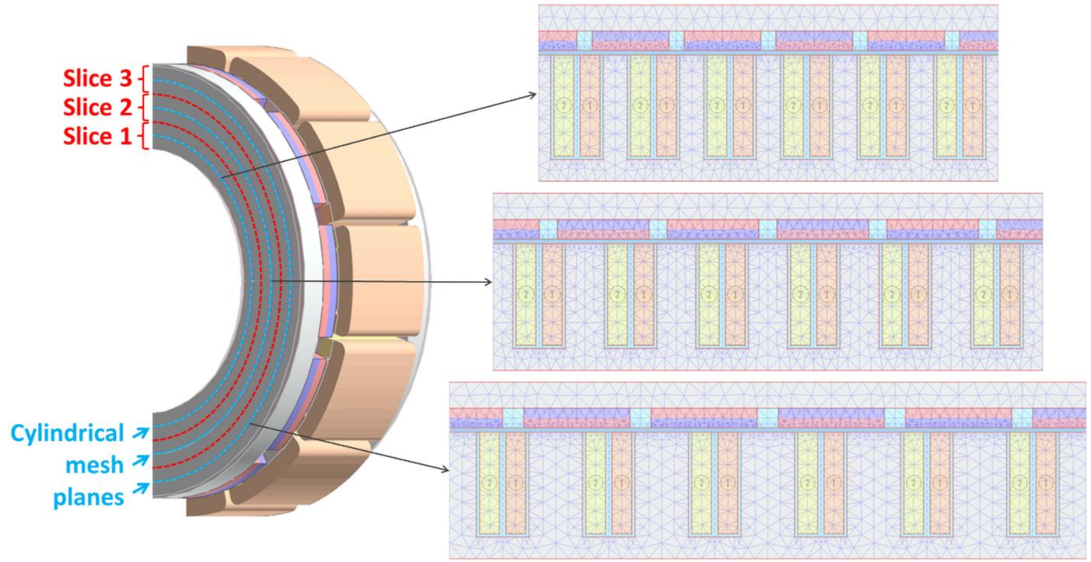
- **Id and Iq lookup tables extracted from the efficiency map data**

These can be uploaded into controller for optimal motor performance

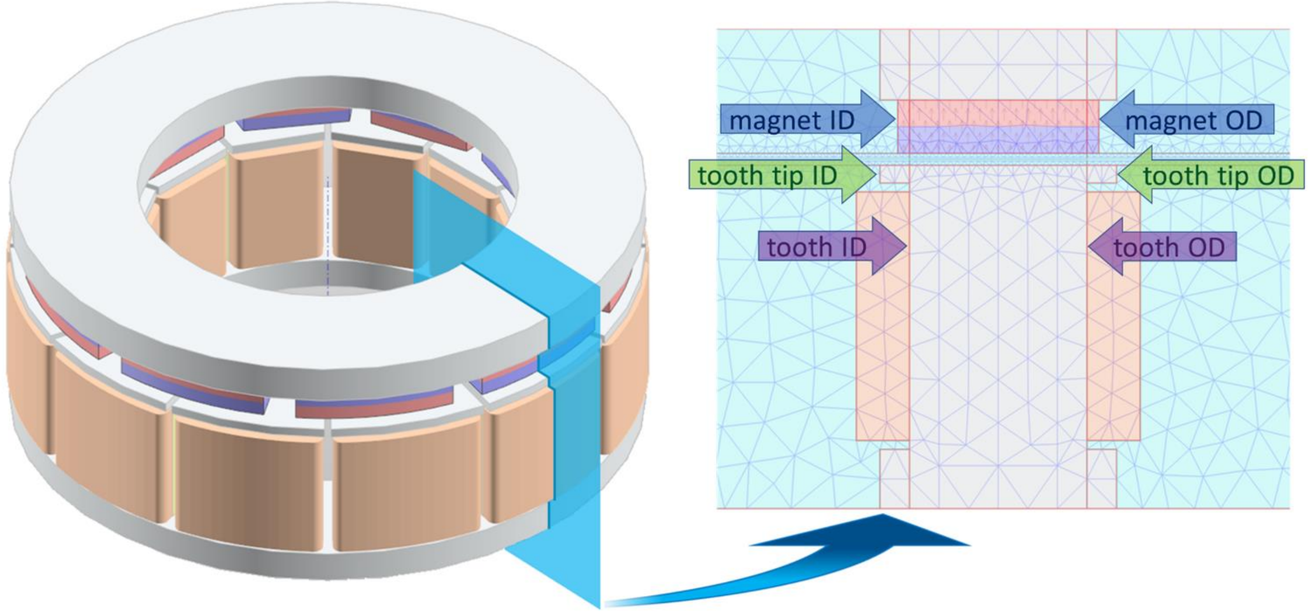
- **Plots exported into CSV and MAT files**

Quasi-3D FEA of an axial flux machine: summary

- Around 50 times higher computational speed compared to full 3D FEA
- The magnetic field is simultaneously solved in cylindrical and radial cross-sections of the AFM
- The leakage flux alone the radial cross-section plane is taken into account
- The variation of the inner and outer diameters of different parts of the AFM is considered
- Specific 3D geometry details are taken into account via geometry correction coefficients

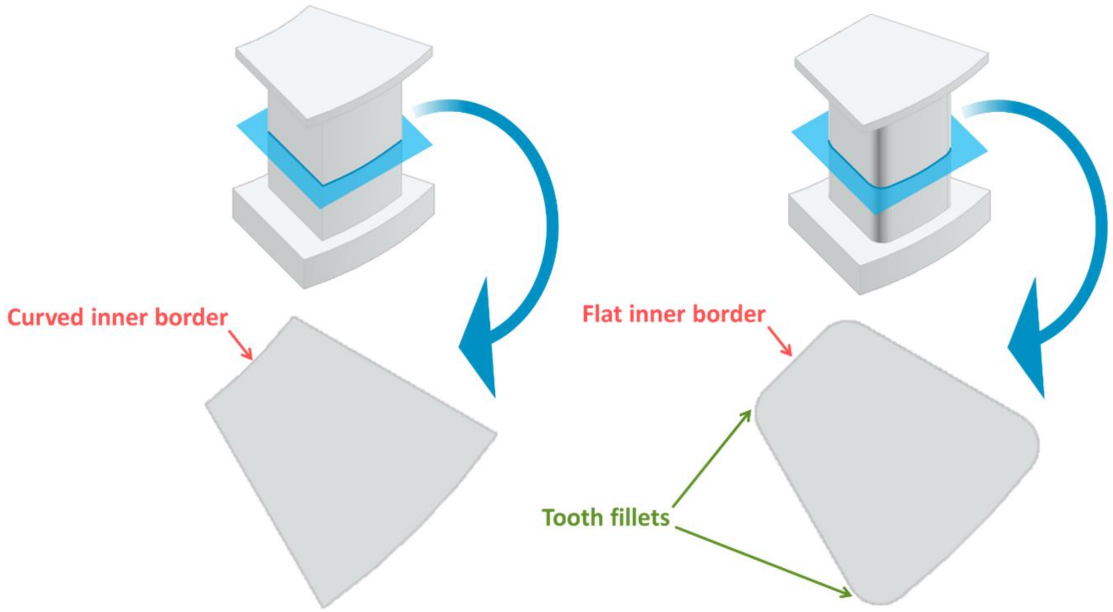


Cylindrical mesh slices



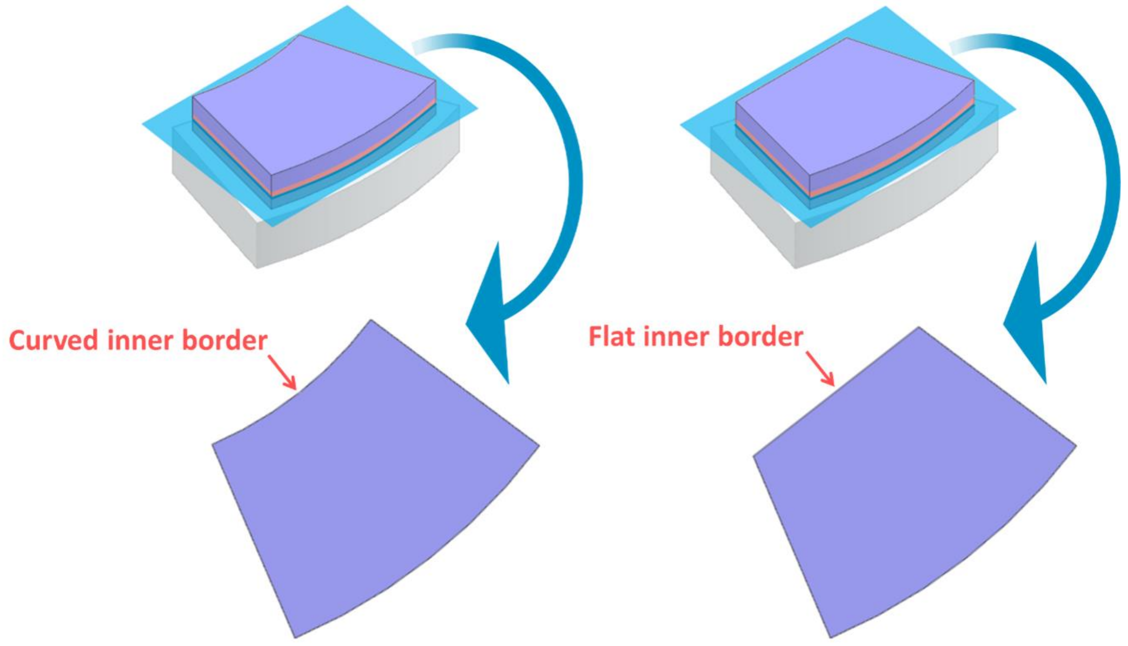
Radial cross-section mesh

Quasi-3D FEA of AFM: geometry correction coefficients

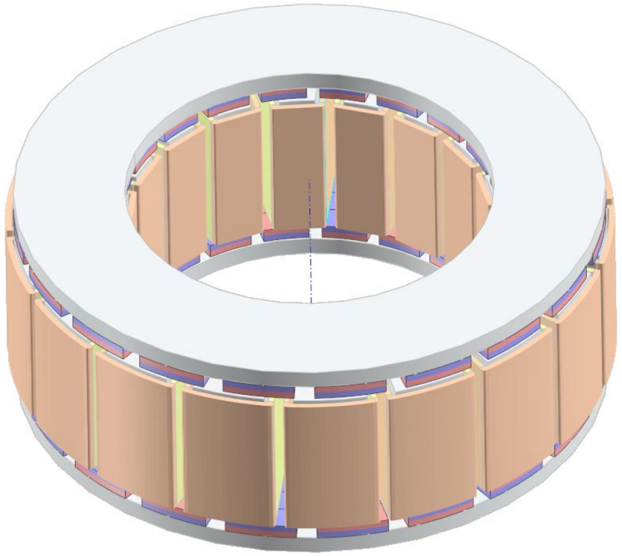


Examples of two stator tooth shapes which are taken into account using geometry correction coefficients

Examples of two rotor magnet shapes which are taken into account using geometry correction coefficients



MotorXP-AFM vs. Ansys Maxwell 3D: Magnetostatic FEA (motor 1)



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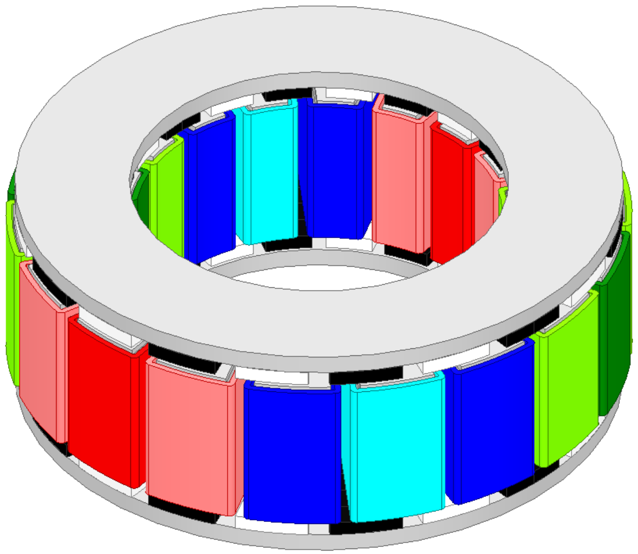


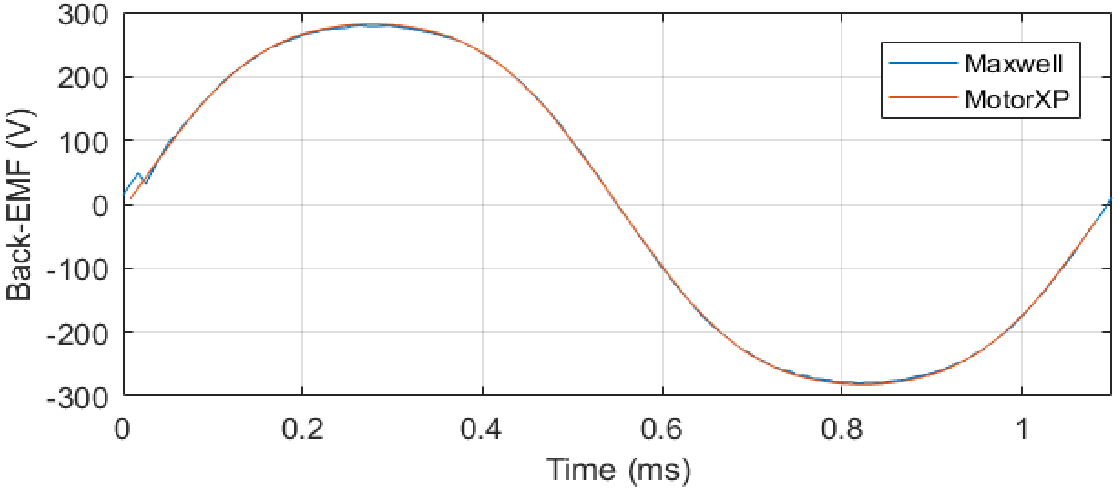
Ansys Maxwell 3D

EMRAX-228*, 5500RPM (zero current)			
	Maxwell	MotorXP	Discrepancy, %
Back EMF peak (V)	279.0	282.0	1.08
Total iron losses (W)	486.3	474.3	2.47

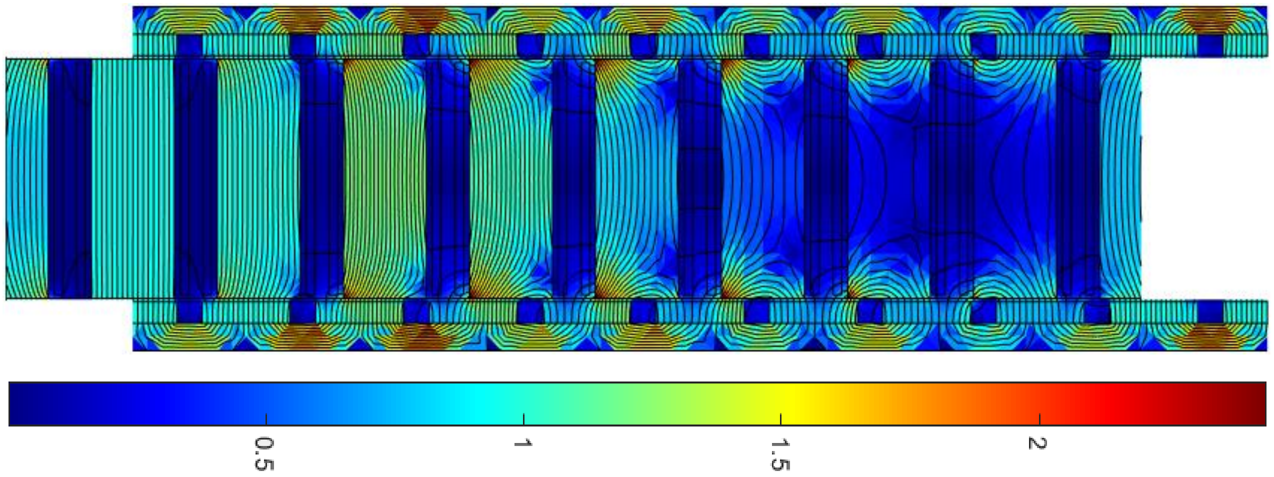
EMRAX-228*, 5500RPM, 57.5Arms			
	Maxwell	MotorXP	Discrepancy, %
Torque (Nm)	63.1	63.3	0.43
Induced voltage peak, Rs=0 (V)	320.2	317.1	0.97
Total iron losses (W)	562.9	536.6	4.67

EMRAX-228*, 5500RPM, 115Arms (rated conditions)			
	Maxwell	MotorXP	Discrepancy, %
Torque (Nm)	125.8	126.2	0.38
Induced voltage peak, Rs=0 (V)	398.0	387.8	2.56
Total iron losses (W)	780.7	724.9	7.15

Comparison of no-load back-EMF waveforms

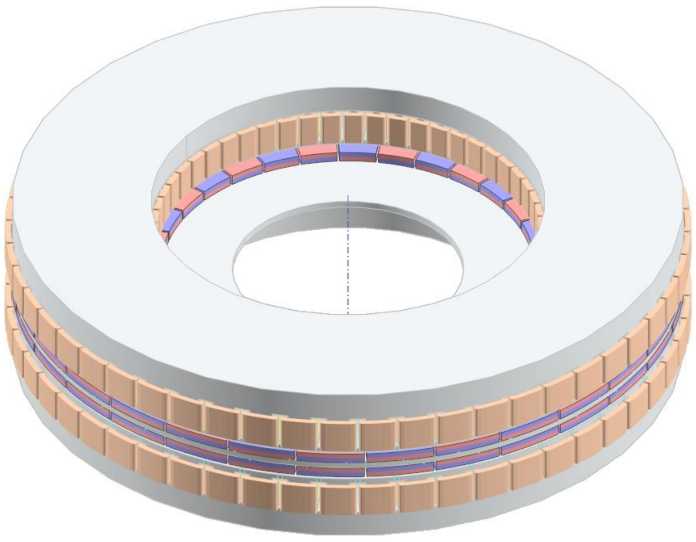


Flux density distribution at rated conditions (MotorXP-AFM)

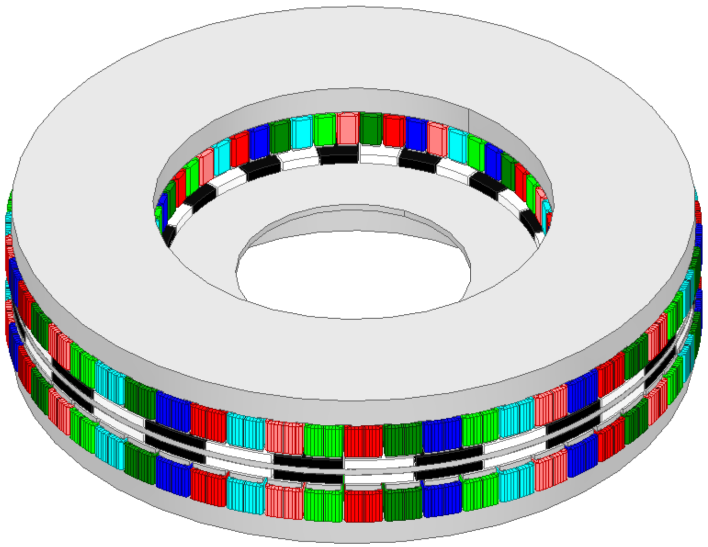


*source: https://emrax.com/e-motors/emrax-228/

MotorXP-AFM vs. Ansys Maxwell 3D: Magnetostatic FEA (motor 2)



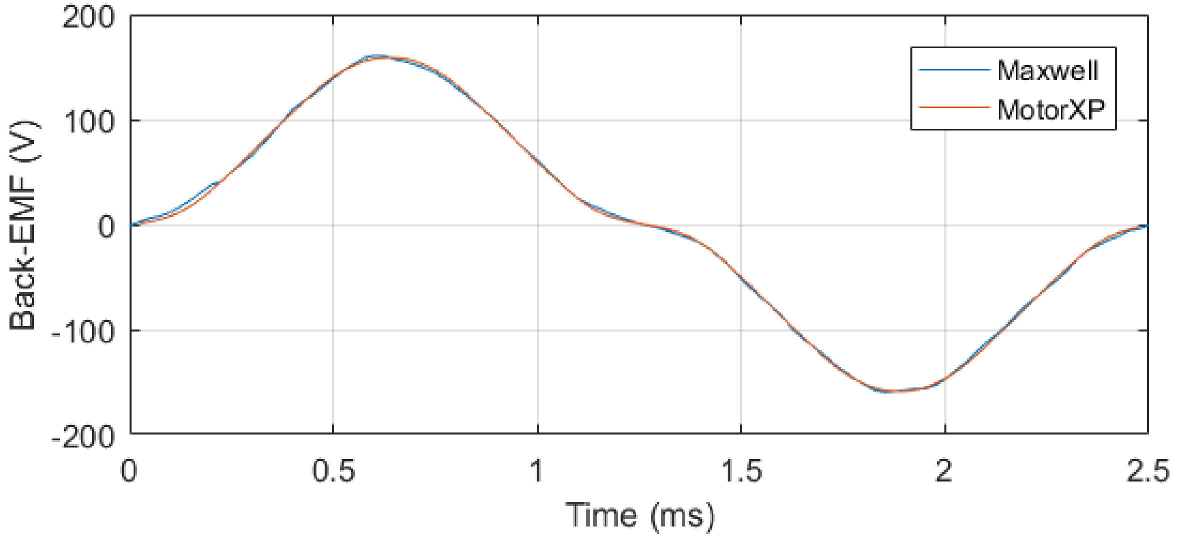
MotorXP-AFM



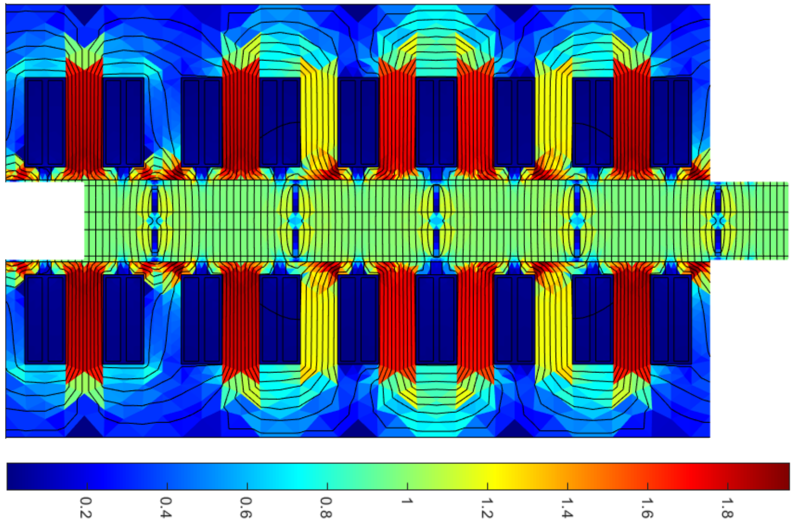
Ansys Maxwell 3D

afm_srs54_5, 1600RPM (zero current)			
	Maxwell	MotorXP	Discrepancy, %
Back EMF (V)	158.5	158.6	0.06
Total iron losses (W)	733.3	742.5	1.25
afm_srs54_5, 1600RPM, 125Arms			
	Maxwell	MotorXP	Discrepancy, %
Torque (Nm)	208.8	209.6	0.39
Induced voltage peak, Rs=0 (V)	158.0	158.4	0.25
Total iron losses (W)	750.6	758.8	1.09
afm_srs54_5, 1600RPM, 250Arms (rated conditions)			
	Maxwell	MotorXP	Discrepancy, %
Torque (Nm)	395.2	403.2	2.02
Induced voltage peak, Rs=0 (V)	160.5	159.4	0.69
Total iron losses (W)	785.9	795.1	1.17

Comparison of no-load back-EMF waveforms



Flux density distribution at rated conditions (MotorXP-AFM)



MotorXP-AFM vs. JMAG 3D: Dynamic FEA (motor 3)

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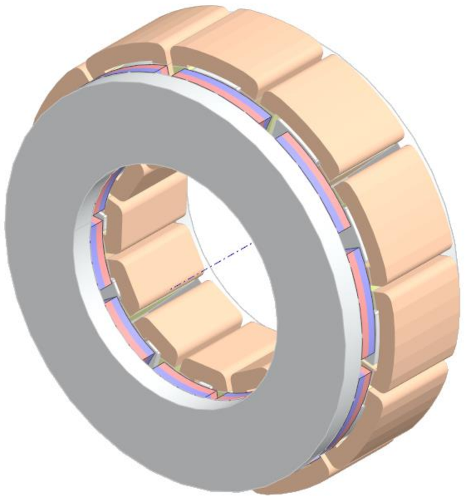

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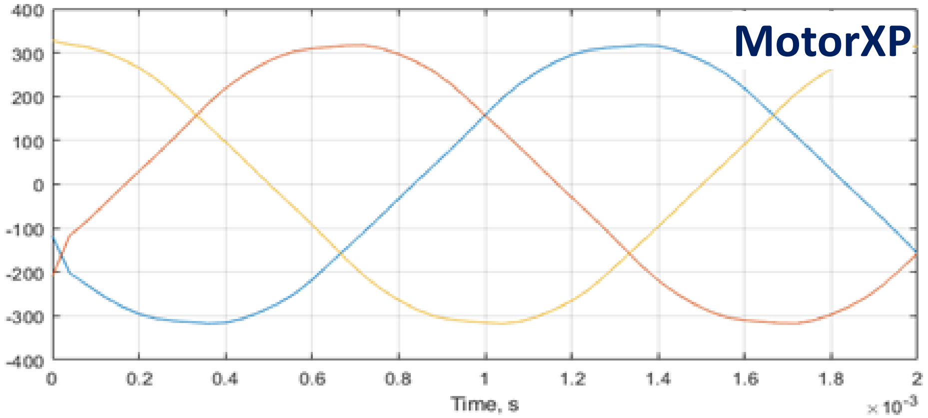
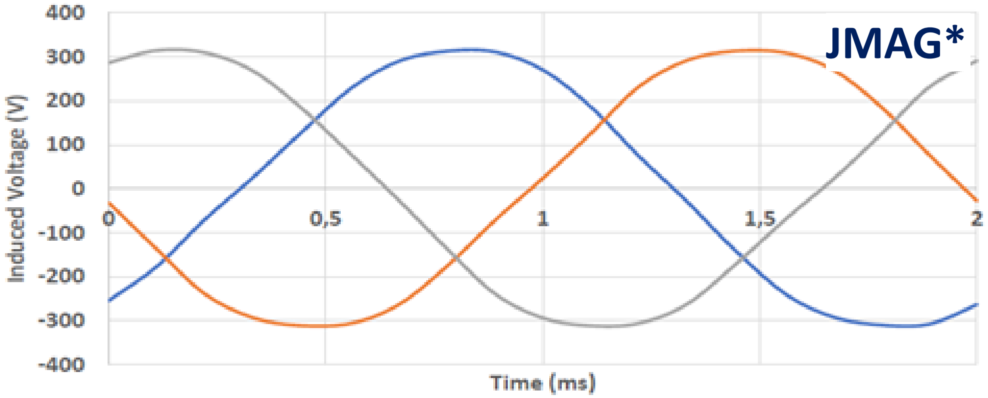
JMAG 3D

afm_sr12, 6000RPM, 7.79Apk (rated conditions)			
	JMAG*	MotorXP	Discrepancy, %
Torque (Nm)	3.20	3.19	0.31
Induced voltage peak (V)	312.87	307.50	1.72
Total iron losses	60.18	63.42	5.38

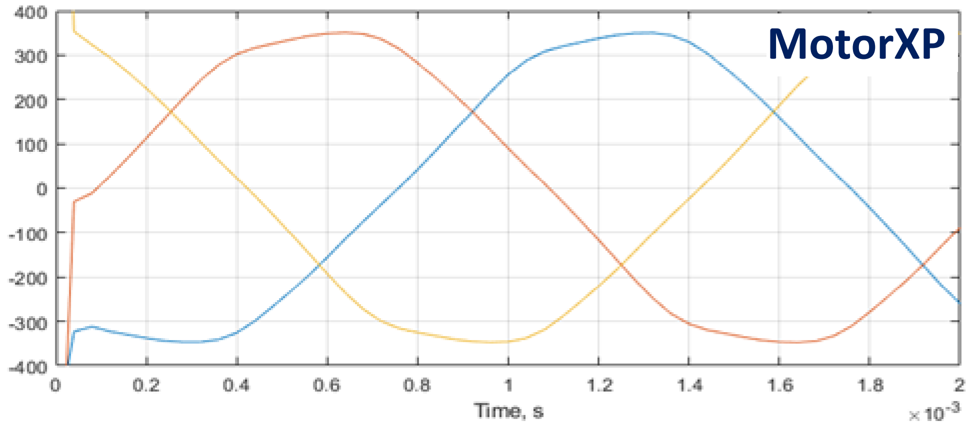
afm_sr12, 6000RPM, 20.26Apk (overload conditions)			
	JMAG*	MotorXP	Discrepancy, %
Torque (Nm)	7.94	7.86	1.01
Induced voltage peak (V)	358.40	349.0	2.62
Total iron losses (W)	73.99	78.86	6.58

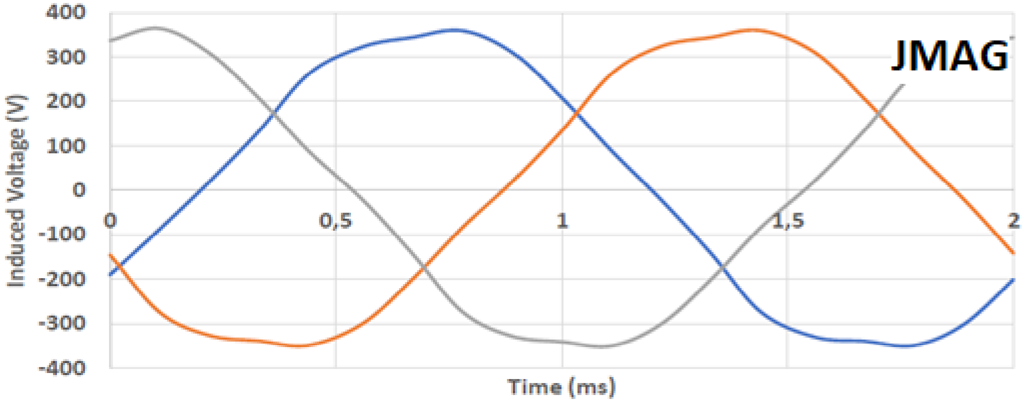
Comparison of voltage waveforms (rated conditions)





Comparison of voltage waveforms (overload conditions)





*source: https://www.jmag-international.com/motordesign-material/hoganas_001/

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Thank You!

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