Characteristic Research on Dual-rotor Magnetic Field Modulation Motor with Halbach Array and HTS Bulks

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Background

In order to ensure the stability of the dual-rotor permanent magnet motor, it is necessary to design the permanent magnet structure of the motor, or to improve the material and processing technology. Although the research and improvement in this aspect have played a certain role, in terms of its own magnetic field coupling transmission constraints, the improvement result is very limited. So far, the topological structures of various motor have been proposed successively. However, these structures of motor are relatively complex, a large cogging torque and torque ripple to meet the growing demands of the industry. Therefore, it is necessary to research on dual-rotor permanent magnet motor with simple structure and high stability.

Objectives

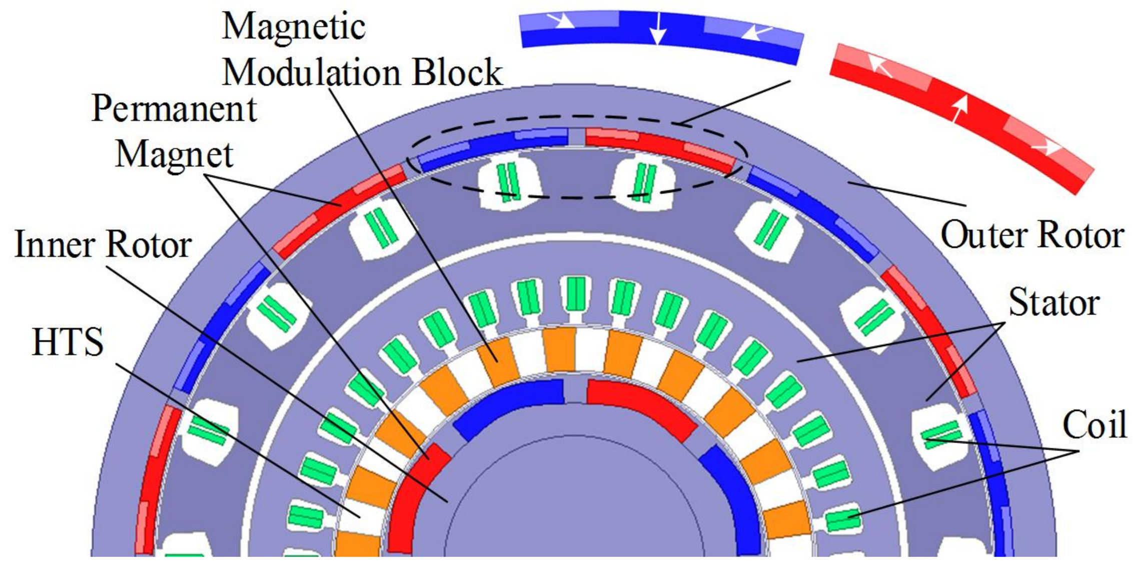
- ❖ A novel dual-rotor MFMM with HTS and Halbach array is proposed, which has 4 pole pairs inner rotor and 8 pole pairs outer rotor, respectively.
- ❖ There are two types of PMs, one is an eccentric structure on the inner rotor and the other one is Halbach arrays on the outer rotor.

Conclusion

- ❖ A novel dual-rotor magnetic field modulation motor with HTS bulks, which has a good flux modulation effect, and also can suppress magnetic flux leakage.
- ❖ The eccentric structure of PMs on the inner rotor can make the irregular air gap, so it is easy to get sinusoidal magnetic flux waveform.
- ❖ The PMs on the outer rotor adopted Halbach arrays, which can augment more harmonics into torque production.

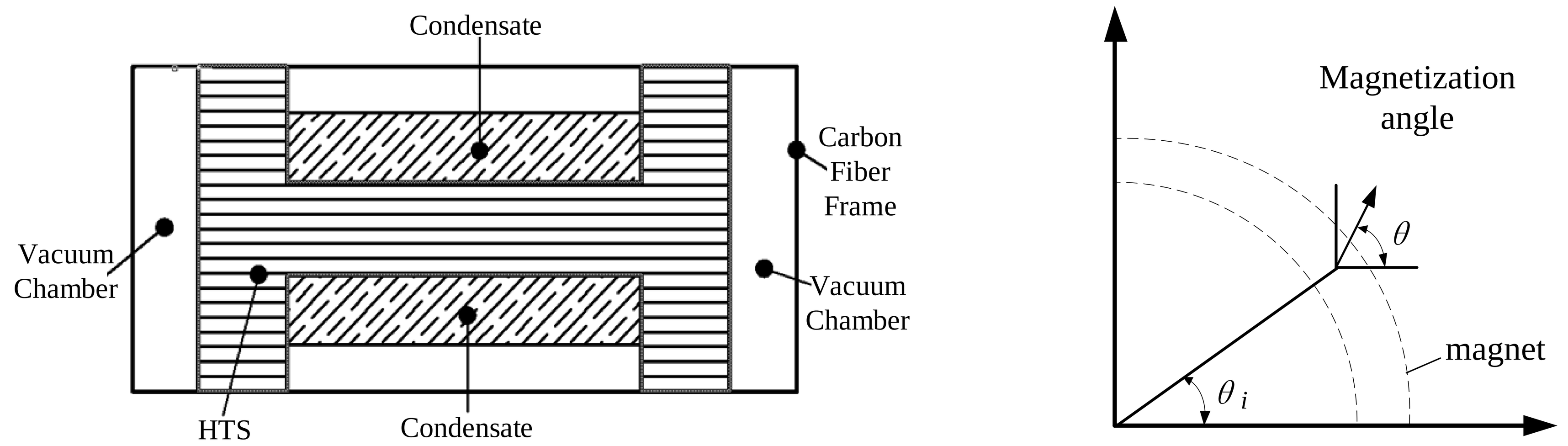
Structure

model and magnet pole geometry



Substitute bulk HTS for epoxy resin; the eccentric structure of PMs has different arc centers on the inner rotor; Halbach arrays on the outer rotor, each PM pole is divided into 3 segments.

Structure of HTS bulks and magnetization direction

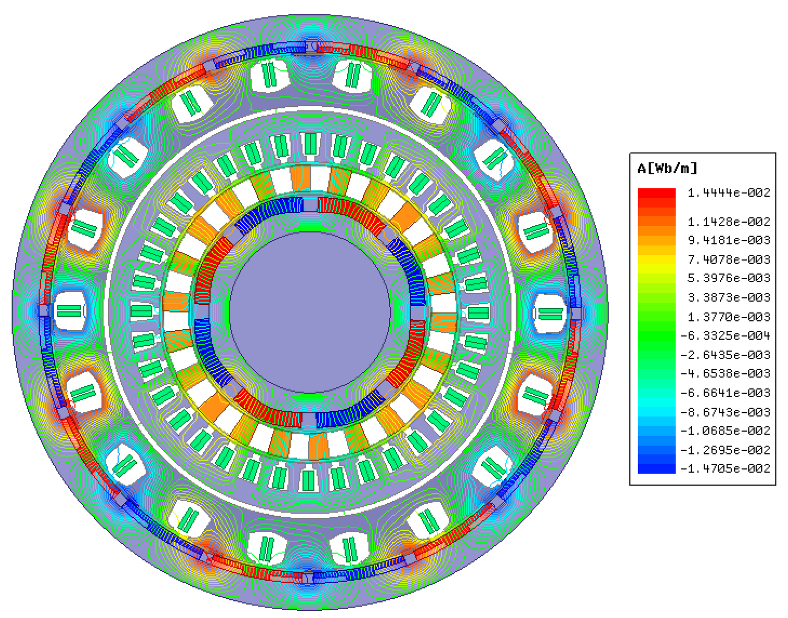


The bulk HTS is mainly composed of carbon fibers frame, superconducting material, condensate and vacuum chamber. θ is the magnetization angle of the ith block permanent magnet. θ_i is the angle between the geometric centerline of the ith block permanent magnet and the transverse coordinate. p is the pole number of the motor, '+' represents inner rotor.

Parameters

Parameter	Value	
	Inner rotor	Outer rotor
Number of pole-pairs	4	8
Slot number	36	18
Stator inner radius	56mm	77mm
Stator outer radius	75mm	96mm
Rotor inner radius	30mm	101mm
Rotor outer radius	38.5mm	111mm
Permanent magnet inner radius	38.5mm	97mm
Permanent magnet outer radius	44mm	101mm
Motor length	50	50
Pole-arc factor	0.822	0.889
Inner diameter of magnet block	45mm	-
Outer diameter of magnet block	55mm	-
Number of magnet blocks	22	-

Results



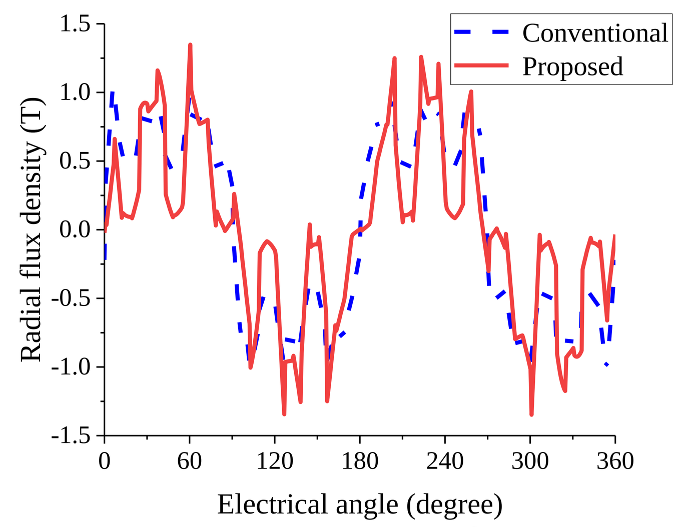
The flux distribution.

According to the Maxwell Stress tensor, the motor cogging torque is expressed as follows,

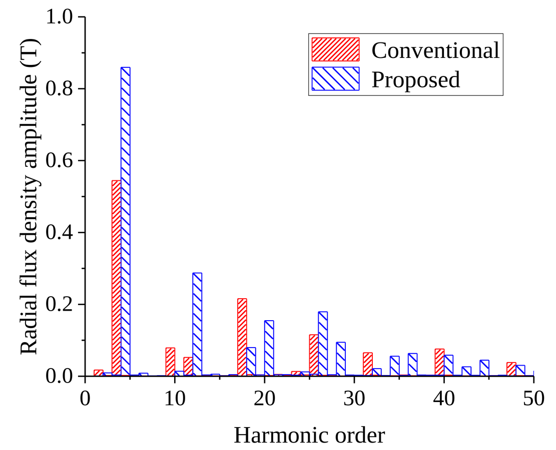
$$T_{cog} = -p\frac{W(\alpha)}{\partial\alpha}$$

the torque fluctuation coefficient k_T is,

$$k_T = \frac{T_{\max} - T_{\min}}{T_{\max} + T_{\min}} \times 100\%$$

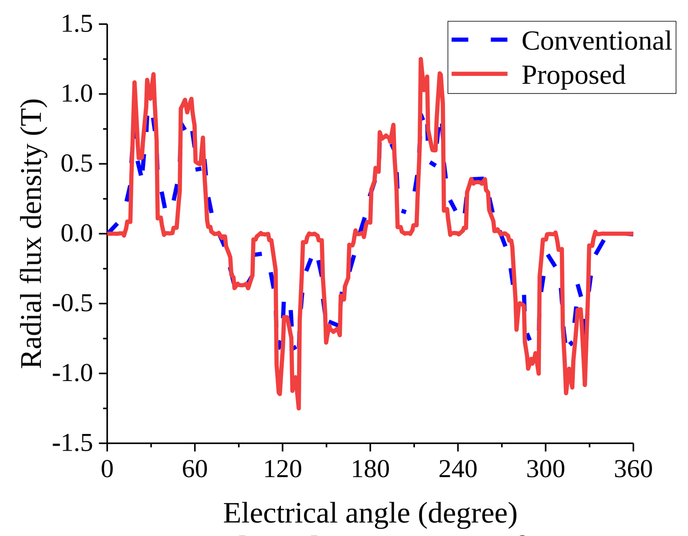


(a) Flux density waveform.

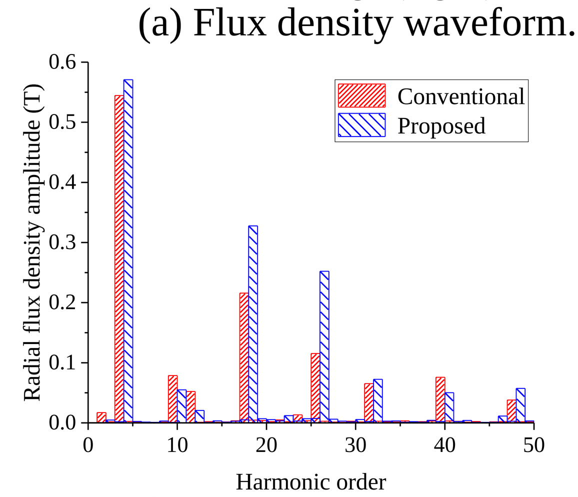


(b) Harmonic spectra.

Inner radial flux density distribution.

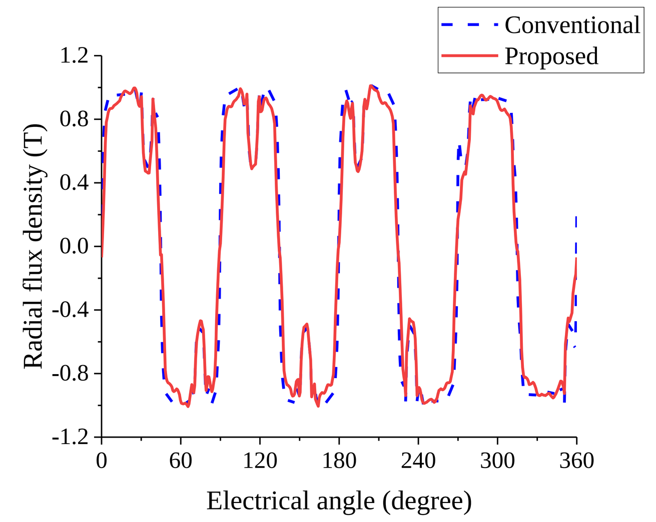


(a) Flux density waveform.

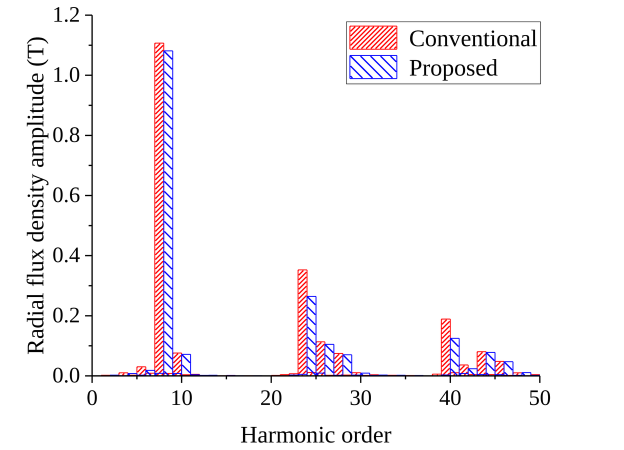


(b) Harmonic spectra.

Middle radial flux density distribution.

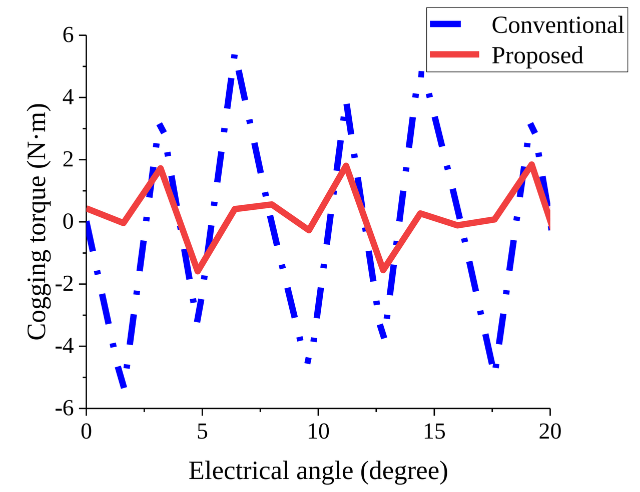


(a) Flux density waveform.

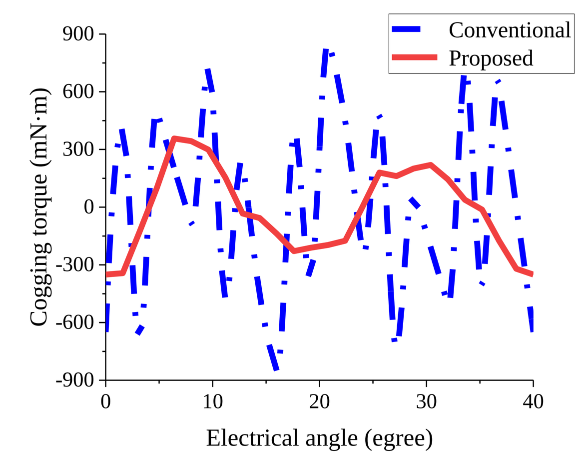


(b) Harmonic spectra.

Outer radial flux density distribution.

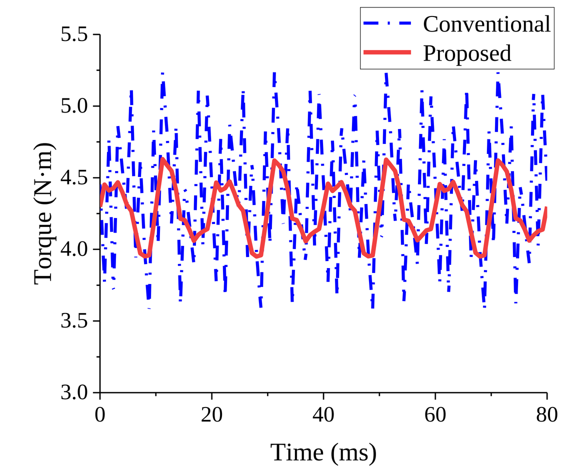


(a) Inner rotor.

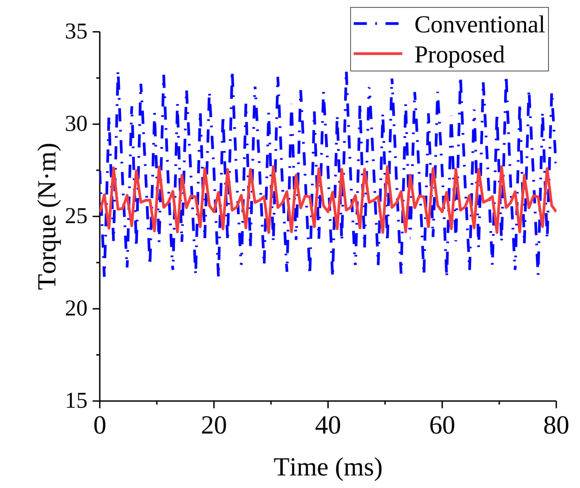


(b) Outer rotor.

Cogging torque.



(a) Inner rotor.



(b) Outer rotor.

Electromagnetic torque.

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