A Double-Stator Single-Rotor Field Modulated Motor with HTS Bulks

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WED-PO2-507-01

27th International Conference on MAGNET TECHNOLOGY
November 15-19, 2021, Fukuoka, Japan
Hybrid Conference: On-site and On-line

Background

In order to improve the electromagnetic performance of the motor, it is necessary to design the structure of a double stator single rotor magnetic field modulation motor with high-temperature superconducting (HTS) bulks. So far, the topological structures of various double stator single rotor permanent magnet motors have been proposed successively. However, the back EMF harmonics of these double stator single rotor permanent magnet motors are rich, the torque fluctuation is large, or the torque density is not high enough to meet the needs of industry growth. Therefore, it is necessary to study the HTS bulks double stator single rotor magnetic field modulation motor with small torque ripple and high torque density.

Objectives

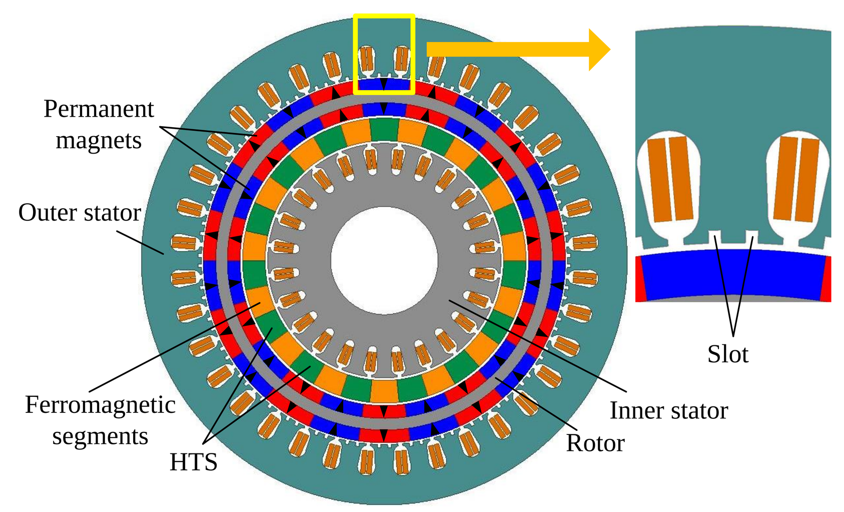
- A double stator single rotor magnetic field modulated motor with HTS Bulks is proposed, which has HTS bulks in magnetic modulation ring and auxiliary slot structure in the outer stator, respectively.
- The genetic algorithm (GA) is used to optimize the motor and the outer stator of the motor adopts auxiliary slot structure to reduce torque ripple.

Conclusion

- A double stator single rotor magnetic field modulated motor with HTS Bulks bas been proposed and analyzed, which has a good flux modulation effect, and also can suppress magnetic flux leakage.
- The GA is used to optimize the motor and the outer stator of the motor adopts auxiliary slot structure to reduce torque ripple.

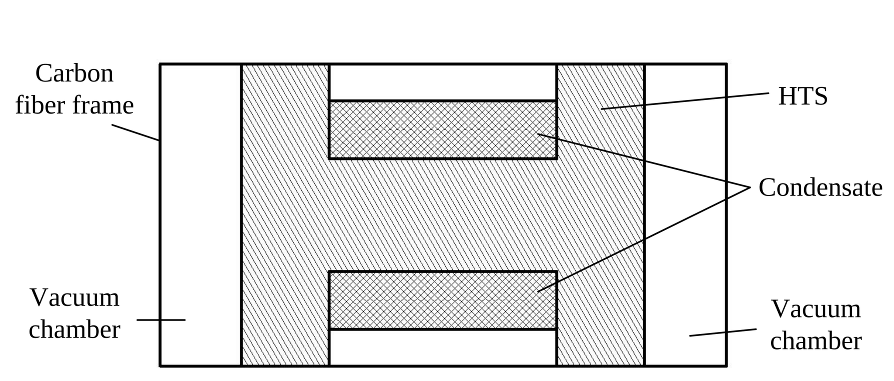
Structure

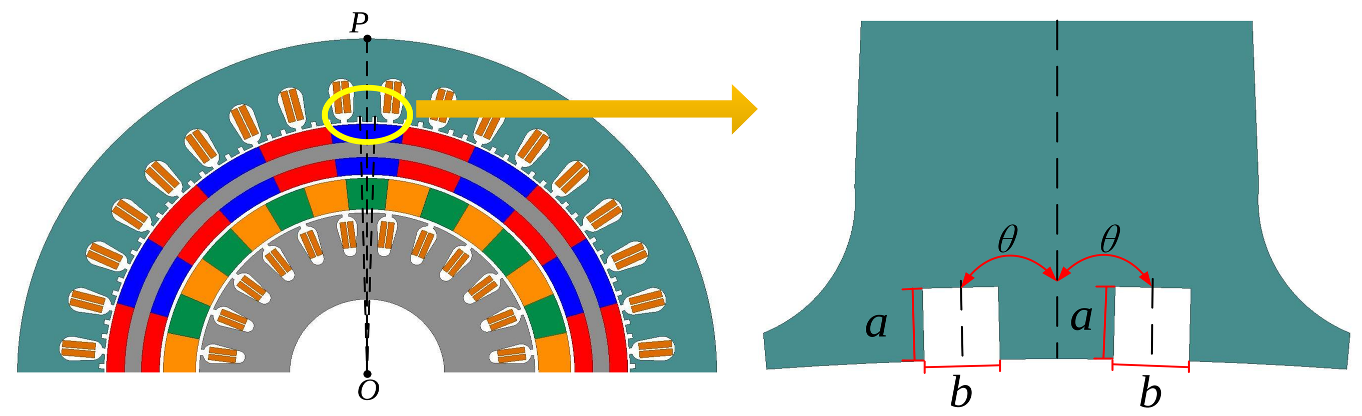
Motor model with HTS Bulks



The motor has three layers of air gap, including an outer stator with auxiliary slots, a rotor, an inner stator and magnetic modulation ring with HTS bulks and magnetic blocks.

Structure of HTS bulks and auxiliary slot model

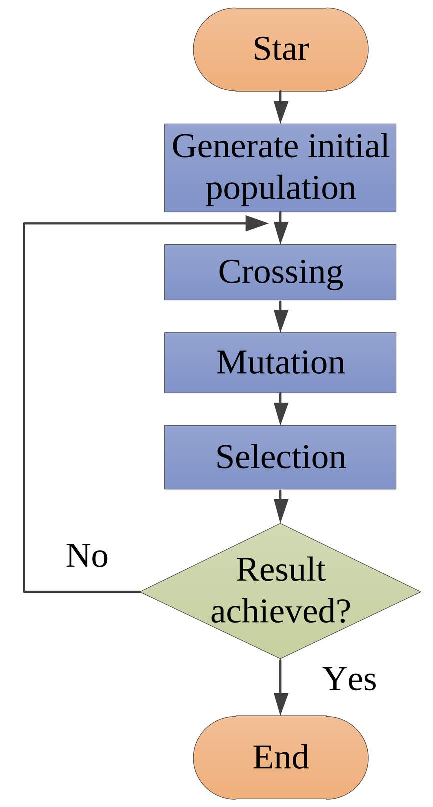




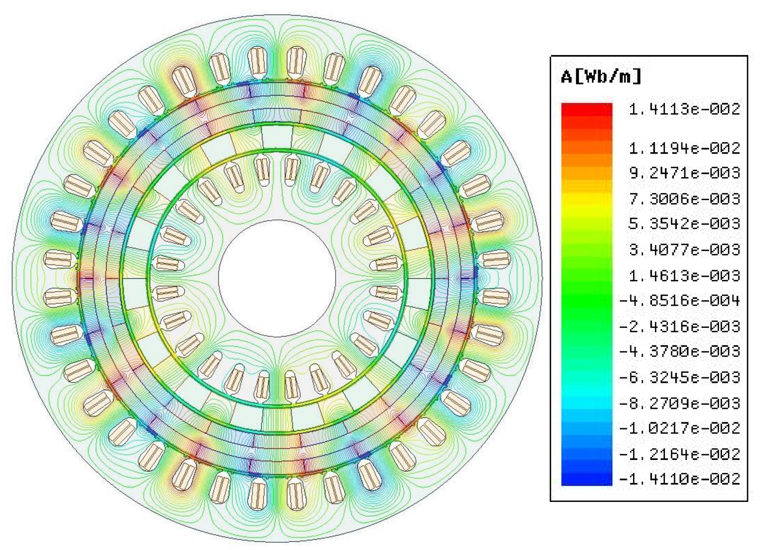
The HTS bulks is mainly composed of carbon fibers frame, superconducting material, condensate and vacuum chamber. The auxiliary slot model of outer stator, *O* is the center of the circle; *OP* is the centerline of the motor. Obviously, the auxiliary slot position is θ, The three parameters of auxiliary slot depth a and auxiliary slot width b directly affect the distribution of air gap magnetic conductivity, and then affect the back EMF waveform and torque ripple.

Parameters and GA flow

Quantity	Value
Number of inner stator slots	24
Number of outer stator slots	36
Number of ferromagnetic pieces	15
Number of HTS bulks	15
Thickness of PMs	7mm
Thickness of ferromagnetic pieces	12.5mm
Inner radius of outer stator core	204mm
Outer radius of outer stator core	271mm
Inner radius of rotor core	161mm
Outer radius of rotor core	202mm
Inner radius of inner stator core	60mm
Outer radius of inner stator core	130mm
Pole-pairs of inner layer PMs	11
Pole-pairs of outer layer PMs	11
Axial length	100mm
Auxiliary slot position (θ)	2.78°
Auxiliary slot depth (a)	1.12mm
Auxiliary slot width (b)	2.56mm



Results



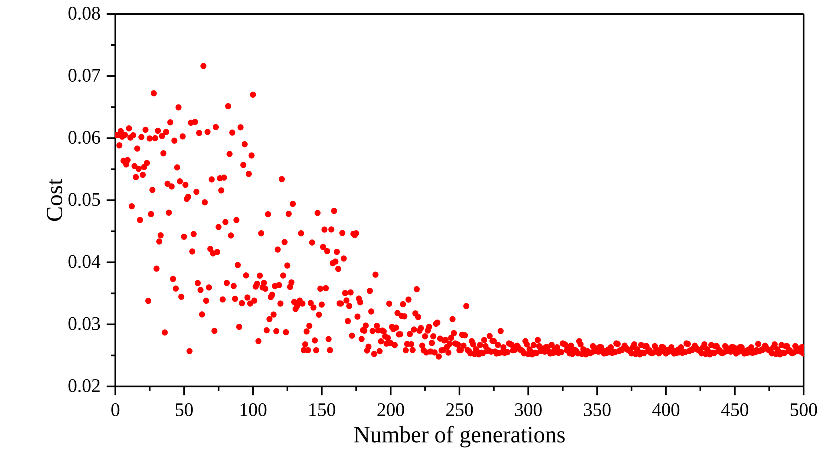
The flux distribution.

The pole logarithm of spatial harmonic contained in the air gap magnetic field is expressed as,

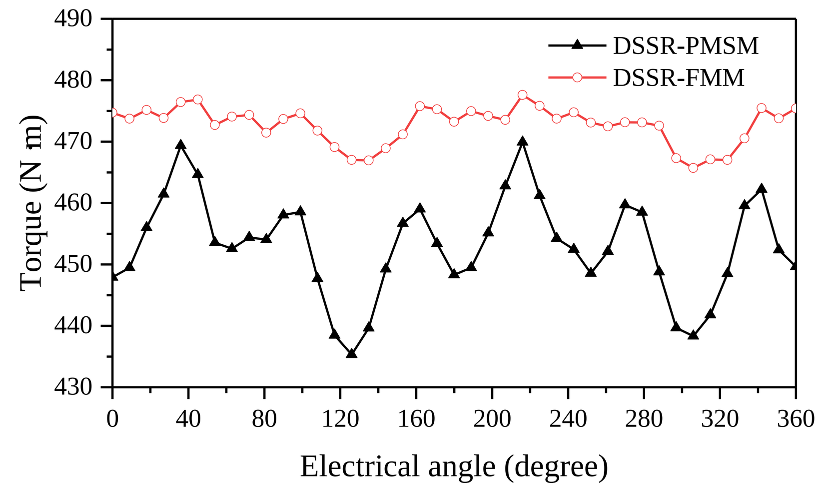
$$p_{m,k} = | mp + kn_s |$$

The angular velocity of the spatial harmonic component in the inner and outer air gaps is expressed as,

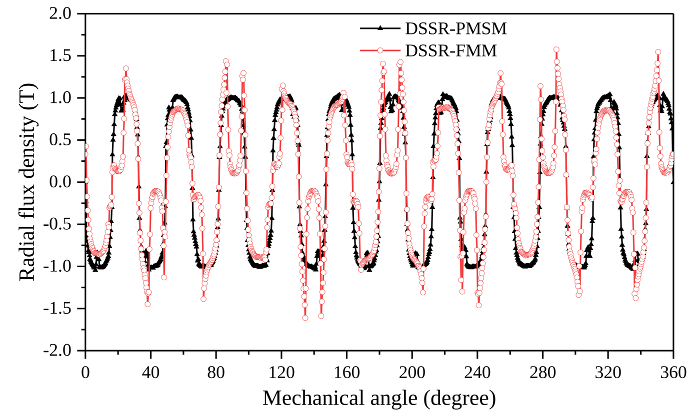
$$\Omega_{m,k} = \frac{mp}{mp+kn_s}\Omega_r + \frac{kn_s}{mp+kn_s}\Omega_s$$



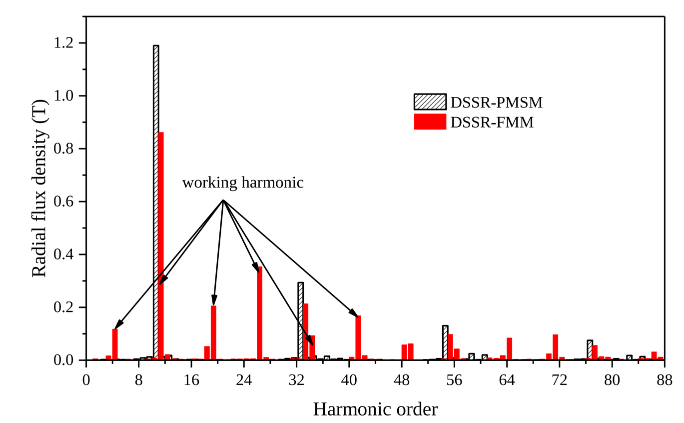
Objective function value change of GA optimization.



Electromagnetic torque.

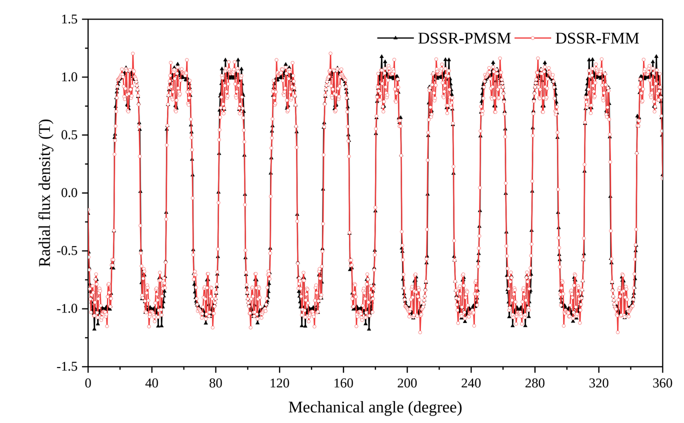


(a) Waveform.

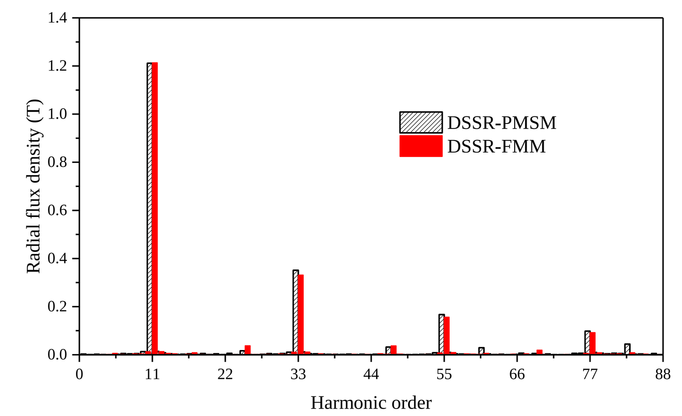


(b) Harmonic spectra.

Flux density distribution in the air gap.

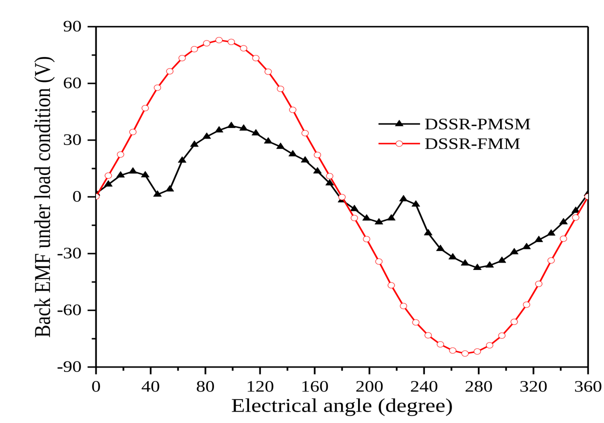


(a) Waveform.

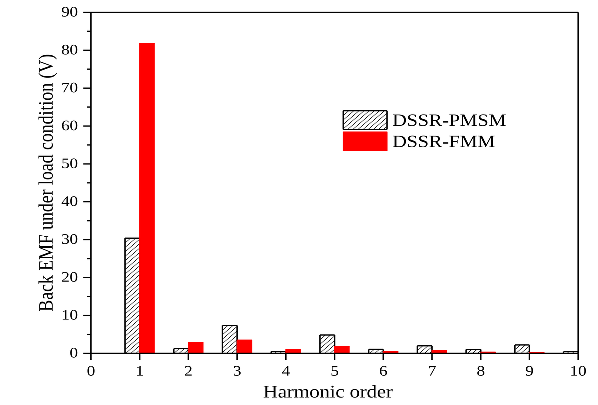


(b) Harmonic spectra.

Flux density distribution in the outer air gap.

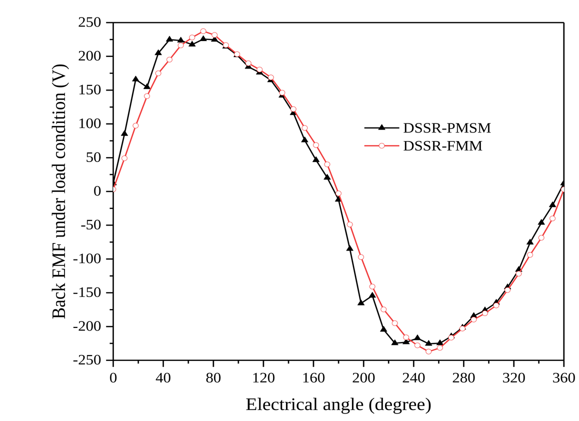


(a) Waveform.

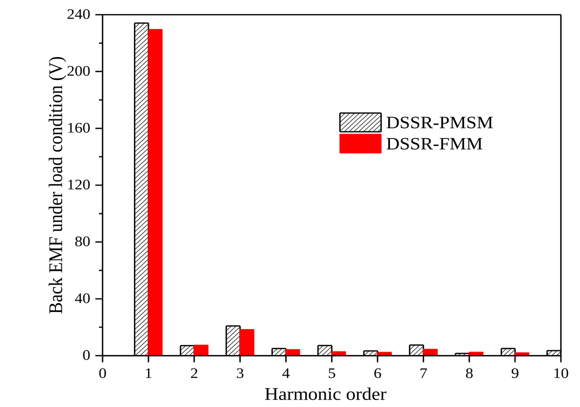


(b) Harmonic spectra.

Back EMF of inner stator.



(a) Waveform.



(b) Harmonic spectra.

Back EMF of outer stator.

Presented at the MT 27, Nov. 15 – 19, 2021, Fukuoka, Japan.