Design and Analysis of a Multi-Flux-Modulated Permanent Magnet Motor

Weiling Pu, Xiaoyong Zhu, Li Quan, Zixuan Xiang, and Deyang Fan

School of Electrical and Information Engineering, Jiangsu University, Zhenjiang 212013, Jiangsu, China

Email: alivia.wlpu@gmail.com

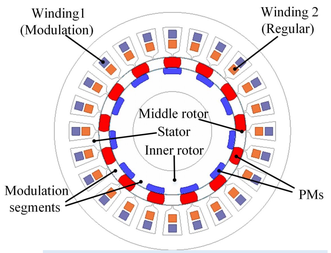
Mon-Af-Po1.21-05[92]
Session: September 23rd 14:30
Posters Area : Motors III – level 3 Posters

MT 26 International Conference on Magnet Technology
Vancouver, Canada | 2019

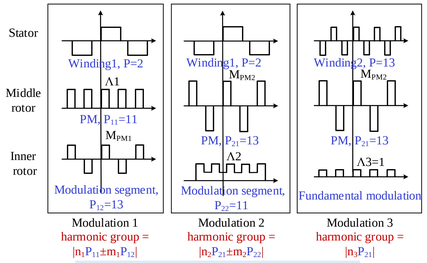
I. Abstract

A new multi-flux-modulated flux-modulated permanent magnet (MFM-FMPM) motor is proposed in this paper. The keys are the diversification of modulation forms and the PM shape design considering torque performances. With the unique MFM effect and PM shape design, the torque density can be improved significantly. The topologies and the operation principle of the proposed motor are introduced first. Then, the PM shape design considering torque performances is described in detail. Finally, the basic electromagnetic performances are analyzed by finite-element method. Both the theoretical analysis and simulation results indicate that the proposed motor not only can own the high torque density but also can improve the PM utilization significantly.

II. Machine Topology and principle



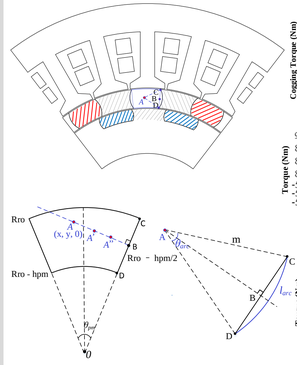
The topology of the MFM-FMPM motor



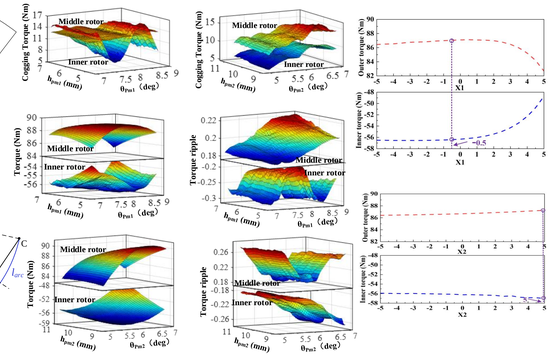
Multi-flux-modulation diagram

The MFM-FMPM motor consists of a stator and two internal concentric rotors, which can be regarded as the combination of three modulation motors. With the introduction of double layer PMs and two sets of windings, the motor structure is relatively compact.

III. PM Shape Design



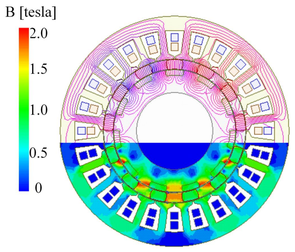
PM shape design



PM shape optimization

Since the PMs and modulation segments are placed adjacent, the PMs in the middle rotor and inner rotor are convex, while the modulating segments in the two rotors are concave and share the same arc with the PMs.

IV. Performance analysis



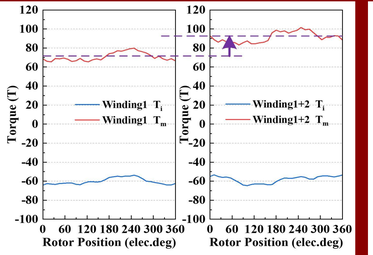
Flux distributions

The distribution of magnetic field is calculated to verify the correctness of the theoretical analysis.

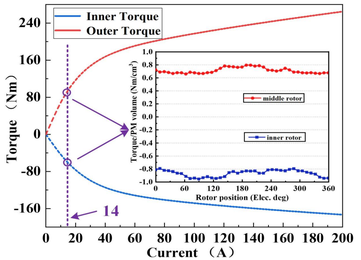
TABLE I
THE COMPARATIVE RESULT BETWEEN THE MOTOR WITH SINGLE/DOUBLE LAYER PMS

PM condition ()	T_{mid} (Nm)	T_{in} (Nm)
PMs in the inner rotor	53.88	26.71
PMs in the middle rotor	41.15	35.81
PMs in the inner and middle rotor	90.39	58.22

In order to display the improvement in torque density, two cases are modeled for comparative study: motor with single layer PM (PMs in the inner rotor or middle rotor) or with double layer PMs (PMs in the inner rotor and middle rotor) (case 1), and motor only with modulation winding(winding1) or added with regular winding(winding1+2) (case 2).



Torque waveforms with winding1 or winding1+2



Torque-current characteristic and torque in per unit PM volume

The torque performance at rated current is analyzed.

V. Conclusion

In this paper, a novel MFM-FMPM motor is proposed and analyzed. Its operating principle lies in the so-called multi-flux modulation (MFM) effect, which guarantees the diversification of modulation forms to effectively improve the torque density. Meanwhile, the PM shape considering torque performances is designed. Comparative analysis by using FEM demonstrates that the proposed MFM-FMPM motor can offer much higher torque capability with the special PM and winding configurations, which allows it a strong competitor for the area of low-speed large-torque applications.