Equivalent magnetic circuit analysis of doubly salient permanent magnet motor with Π-shaped stator iron core segments

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Tue-Af-Po2.21-03[67]

Session: Sep. 24, 14:00 - 16:00

Posters Area :Motors VIII, Level 2 Posters 2

MT 26 International Conference on Magnet Technology

Vancouver, Canada | 2019

Abstract

Traditional three-phase DSPM motors usually suffer from high torque ripple due to the unbalanced PM flux linkage. Then, a three-phase 12/7-pole DSPM motor with Π-shaped stator cores (Π-core DSPM) was presented to achieve a smooth torque output. In this paper, an equivalent magnetic circuit (EMC) analytical method of Π-core DSPM motor is established in the perspective of the general airgap magnetic field modulation theory (AFMT), so that the performances can be calculated analytically.

Conclusion

An EMC analytical method is established to analyze the performances of Π-core DSPM motor in this paper. The airgap permeance formula of doubly salient motor is deduced firstly, so that the influence of slotting on the modulation is analyzed. Then, an EMC model of the Π-core DSPM motor is established, so the airgap magnetic field density can be obtained, based on which the no-load EMF and the torque can also be calculated. Finally, the 2-D FEA and experimental results of the prototype motor are given to verify the analyses.

Topology and Operation Principle

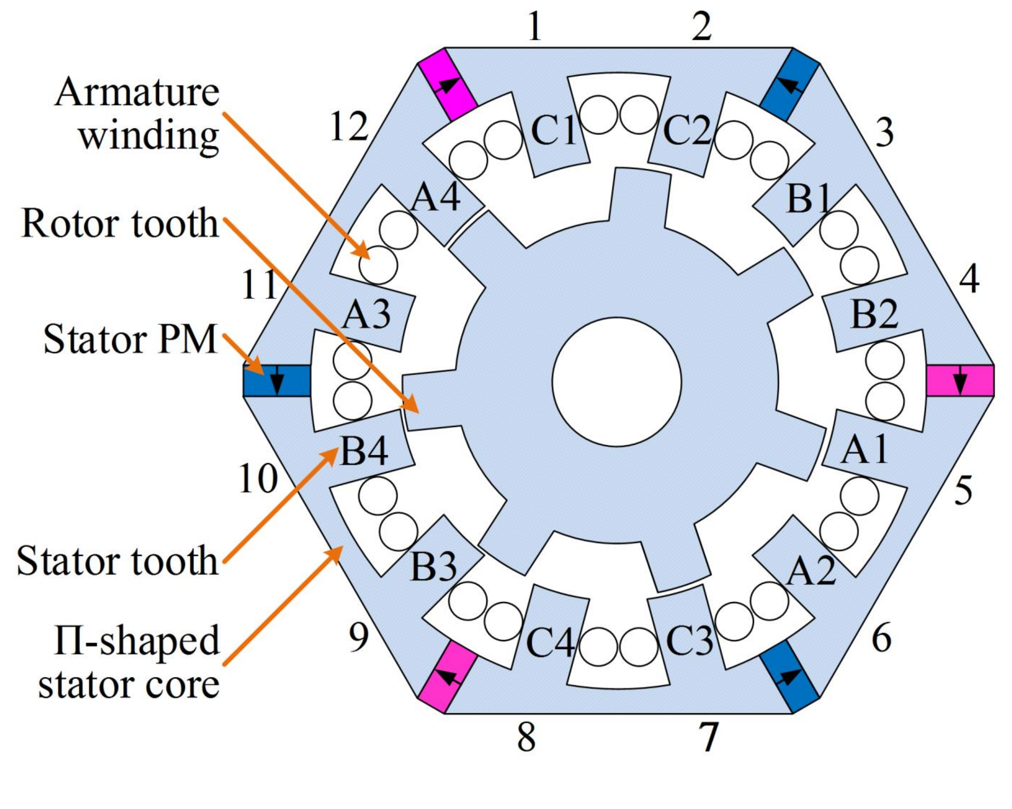

Fig. 1. Configuration of 12/7-pole Π-core DSPM motor.

The Π-core DSPM motor operates based on the AFMT considering both stator teeth and rotor teeth as modulators to airgap magnetic field.

Considering one of the stator and the rotor is slotted and the other one is a smooth core, the airgap flux density will vary with circumferential position θ due to the different permeance of slot-tooth structure, as shown in Fig. 2.

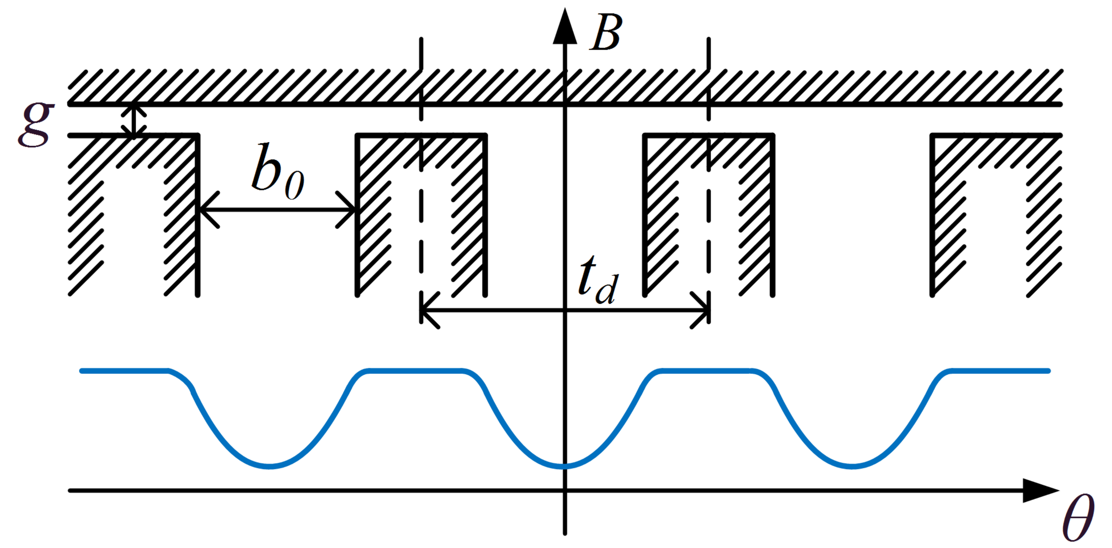

Fig. 2. Modulation effect of salient teeth.

EMC Model Establishment

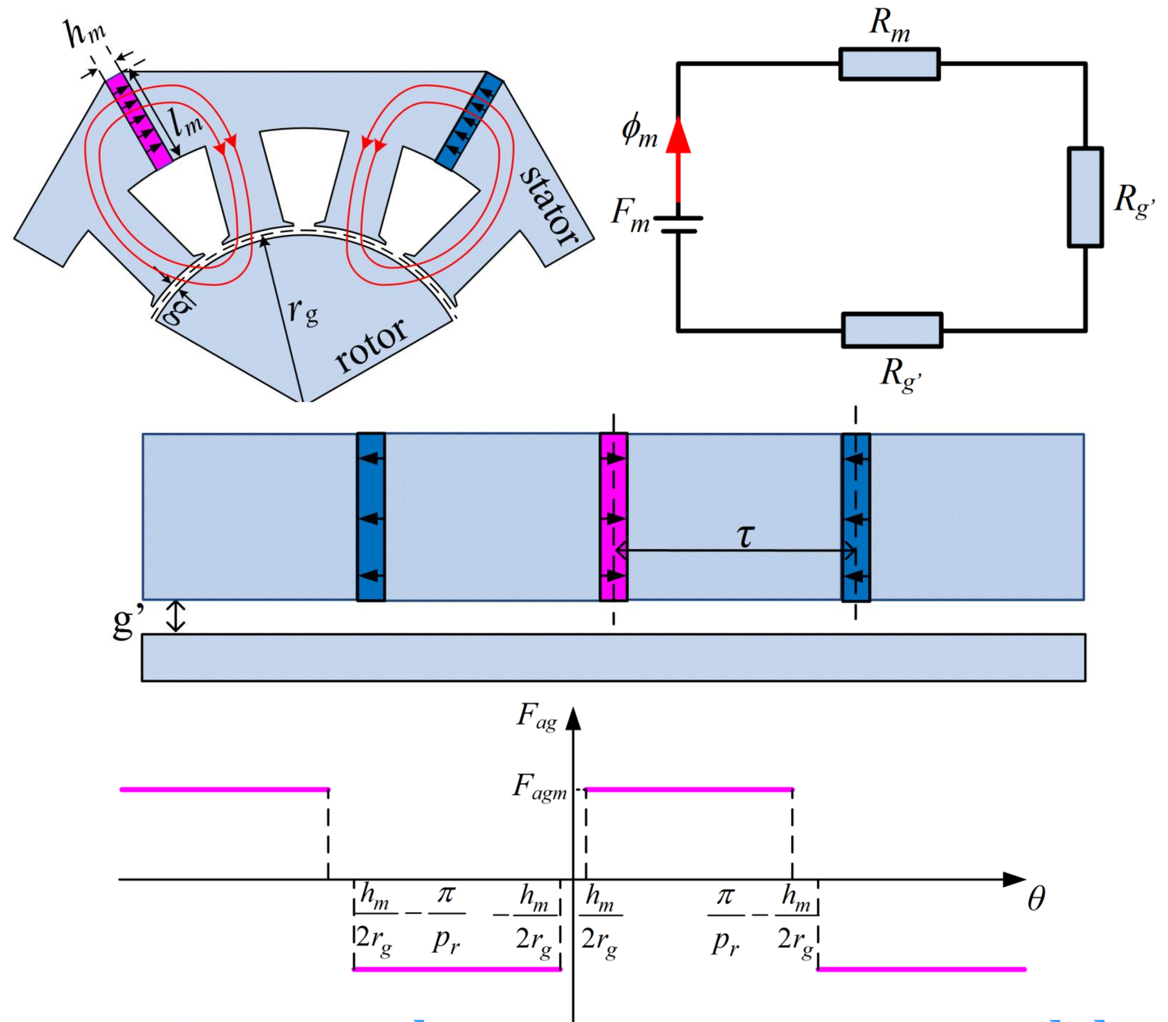

Fig. 3. Equivalent magnetic circuit model.

The airgap MMF waveform of the Π-core DSPM motor can be equivalent to the square wave, and be expressed as

$$F_{ag}(\theta) = \sum_{j=1,3}^{\infty} F_{agj} \cdot \sin(j p_r \theta)$$

For doubly salient structure, the airgap permeance distribution or the flux density under the unit MMF difference can be calculated as

$$\Lambda(\theta,t) = \frac{\Lambda_s(\theta)\Lambda_r(\theta-\omega t)}{\Lambda_s(\theta)+\Lambda_r(\theta-\omega t)-\frac{g}{\mu_0}\Lambda_s(\theta)\Lambda_r(\theta-\omega t)}$$

Then, the airgap magnetic flux density can be obtained by

$$B(\theta,t) = F_{ag}(\theta)\cdot\Lambda(\theta,t)$$

Performance Analysis and Comparison

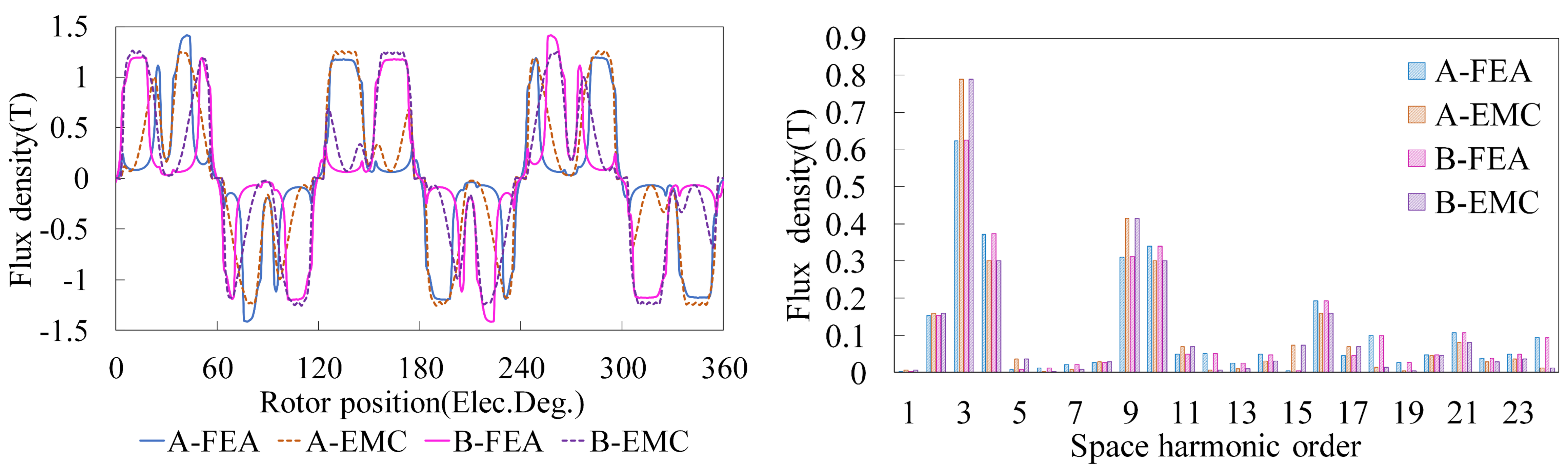

Fig. 4. Comparison of airgap flux density at two difference rotor positions.

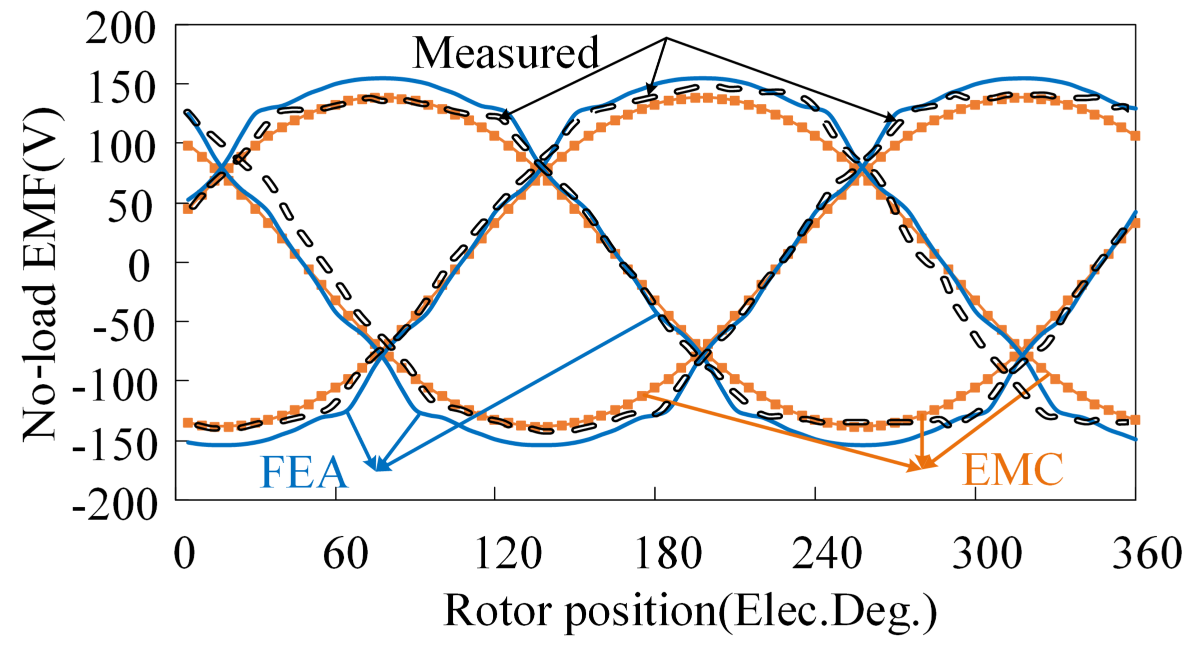

Fig. 5. No-load EMF comparison.

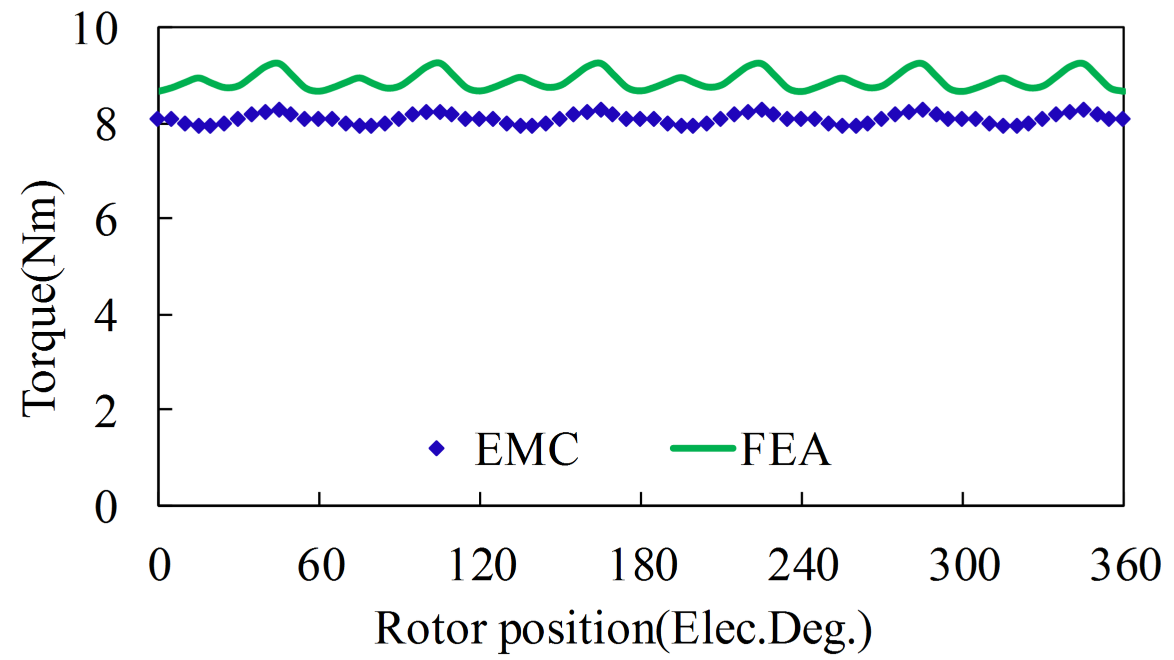

Fig. 6. Torque comparison.

Prototype