Design and Analysis of a Novel Inductor Motor with Auxiliary Permanent Magnet Excitation

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A novel inductor machine with auxiliary PM excitation on the rotor is presented to reduce noise and loss as well as strengthen the air-gap magnetic field. A simplified method by using 2D model is presented in order to investigate the influences of the structures parameters of PM on the performance of the presented machine. The magnetic field of the equivalent 2D model is calculated. The air-gap flux density under different cases are obtained. The variations of harmonic components of the air-gap flux density are discovered. The optimal geometry parameters of PM and rotor are found. An inductor machine with 8 poles and 9 slots is designed. The magnetic field of the designed machine is computed and analyzed. The air-gap flux density and back-emf of the designed machine are compared with the conventional inductor machine without PM. The calculated results show that the alternative component of the air-gap flux density and back-emf of inductor machine with auxiliary PM increase and the constant component decreases largely. It can be inferred that the iron loss and viscous drag loss as well as noise would reduce and the efficiency would rise for the presented inductor machine.

***Index Terms*—Homopolar inductor motor, 2D simplified model, Auxiliary permanent magnet, numerical computation**

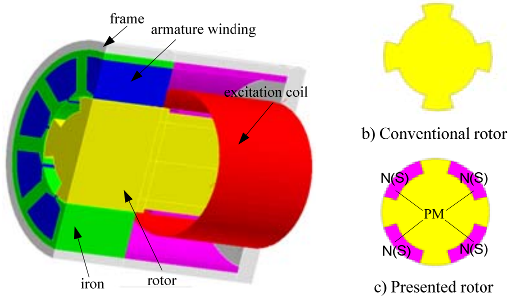
I. INTRODUCTION

Homopolar Inductor Machine (HIM) is mainly used as intermediate frequency generator or in flywheel energy storage system thanks to the high rotor-space utilization rate and compact structure [1]. The structure with teeth and slots on the rotor is essential to generate an alternating magnetic field in HIM. The viscous drag loss and noise of HIM are fatally flaw owing to slotted rotor, especially in high speed. There is some other weakness such as homopolar air-gap magnetic field and DC component in air-gap flux density. A novel construction of inductor machine with auxiliary PM excitation is presented in this paper. An equivalent 2D model is also presented to compute the air-gap magnetic field and analyze the influences of PM parameters on flux density. An inductor machine is designed. The magnetic field of the designed machine is computed to validate the performance and effectiveness of presented 2D model. The research results show that the presented solution is helpful to improve the alternative component of air-gap flux density, back-emf and other performance, as well as decrease the constant component, iron loss, noise.

II. CONSTRUCTION AND OPERATION PRINCIPLE

The basic construction of conventional HIM is shown in Fig. 1 a). The stator core consists of laminated silicon steel sheets. The excitation coil is placed between the end and the armature windings. The rotor is made from solid steel. There are some salients and slots on the effective part of the rotor. The radial length of the effective air-gap is not uniform owing to the unsmooth rotor surface. The radial cross section of the effective rotor in the conventional HIM is shown in Fig. 1 b).

A novel inductor machine is presented in this paper. The stator of the presented machine is same with the conventional HIM. The radial cross section of effective rotor is shown in Fig. 1 c). The PMs inserted into the rotor slots are same polarity, which can change according to the direction of excitation current under the condition of guarantying the same direction of air-gap magnetic fields generated by PMs and excitation current at the minimum air-gap in the machine.



b) Conventional rotor

c) Presented rotor

a) Cut cross section of conventional HIM

Fig. 1. Construction of conventional and presented inductor machine

III. NUMERICAL COMPUTATION AND ANALYSIS

The air-gap flux density of the presented machine depends on the structure parameters of the slotted rotor and the PM. The optimal parameters of the slotted rotor in general HIM have been discovered in [2]. The PM optimal parameters are discussed in this paper using FEM. The magnetic field computation of inductor machine is time consuming and high-demanding because of 3D field. To save time and sources, a novel simplified 2D model is presented and shown in Fig. 2.

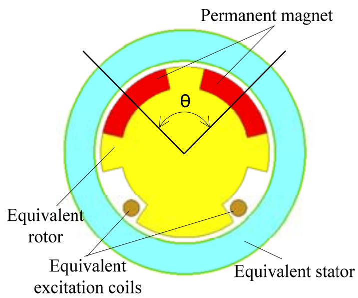
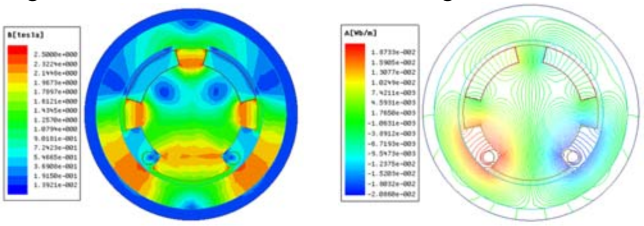


Fig. 2. Novel simplified 2D model.

In the simplified 2D model, the equivalent excitation coils are putted into the rotor slots. And the area within a pole pitch (shown as the angle θ) on the opposite position of the coiling tooth can be considered as an effective area. The magnetization direction of PM in Fig. 2 is negative radial (point to the center). The direction of magnetic flux generated by the excitation current is from equivalent rotor to stator in the effective area. Based on the simplified 2D model, the magnetic field was calculated under the certain excitation current and the magnetic flux distributions are shown in Fig. 3.



a) magnetic field b) magnetic flux

Fig. 3. Calculated results of the novel 2D simplified model.

The fluxes generated by both the PM and excitation current go through the effective air-gap. The air-gap flux densities of simplified 2D model with and without PM are compared and shown in Fig. 4.

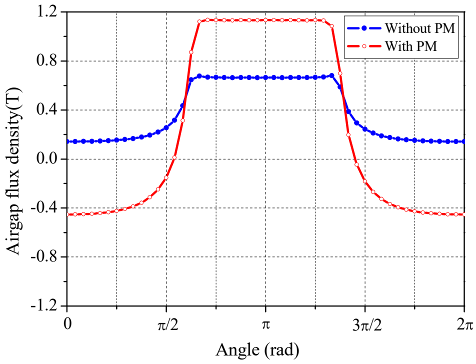


Fig. 4. Airgap flux densities of simplified 2D model with and without PM

Fig. 4 shows that the waveform of air-gap flux density changes from homopolar to bipolar. The peak value of air-gap flux density increase from about 0.63T to 1.15T at positive direction and from 0.15T to -0.42T at negative direction. The constant component of flux density has decrease largely, although the waveform is still unsymmetrical completely. Fig. 4 indicated that the amplitude of the alternative component bursts drastically. There are lots of harmonics in the waveform of air-gap flux density. The harmonic analysis results of air-gap flux density with different PM height are shown in Fig. 5.

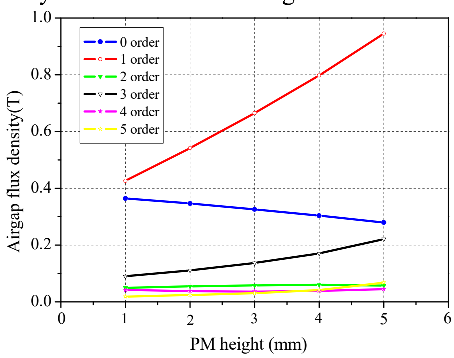


Fig. 5 Result of harmonic FFT of air-gap flux density

Fig.5 shows that the harmonic amplitude of the air-gap flux density has concern with the PM height. The calculated and analytical results of the air-gap flux density with different PM width, location, and segments will be discussed on full paper.

IV. Performance Analysis of Presented Machine

An inductor machine is designed and the 3D model with 4 teeth and 4 slots on the rotor and 9 slots on the stator has been created. The air-gap flux density is compared with that without PM and shown in Fig. 6.

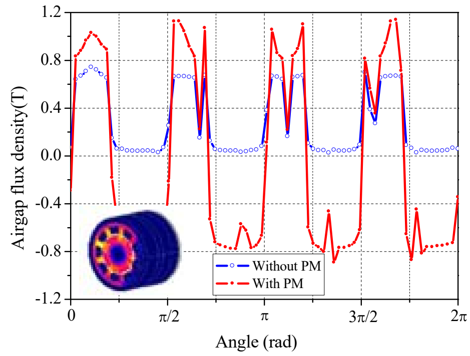


Fig. 6. Calculated results of the air-gap flux density using 3D model

The back-emf of the designed inductor machine is calculated and shown in Fig. 7. The amplitude of the back-emf is about 18V, which is about 7 V in conventional structure. Therefore, for the same volume of machine, the performance of novel machine improves largely.

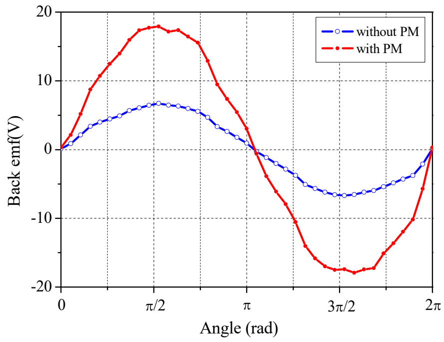


Fig. 7. Calculated results of the designed inductor machine back-emf.

The back-emf of the designed novel HIM is calculated and shown in Fig. 6. The amplitude of the back-emf is about 18V, which is about 7V in conventional structure. Therefore, for the same volume of machine, the performance of novel machine improves largely. The full paper will reveal more findings, prototype and experimental results.

V. Conclusions

The presented inductor machine has the following advantages of higher fundamental component of air-gap flux density and output voltage compared with conventional inductor machine without auxiliary PM excitation. The equivalent 2D model is convenient and valid to find the optimal geometry parameters of the PM and rotor.

VI. References

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