자동차 쿨링팬용 분절회전자를 가지는 SRM의 특성해석 비교

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Comparative Analysis of SRM with Segmental Rotors for Vehicle Cooling Fan

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ABSTRACT

In this paper, two types of switched reluctance motors (SRMs) with segmental rotors are presented in detail. One is 6/5 segmental rotor type; the other is 12/8 segmental rotor type. Both motors have the same stator, rotor and winding configurations. The stator is constructed with special stator poles in which the exciting and auxiliary poles are designed exclusively. The rotor is constructed from a series of discrete segments, each of which is embedded in the magnetic isolator. The windings are only wound on the exciting poles, and no windings are wound on the auxiliary poles. These structures result in short flux path and high flux linkage utilization in the proposed motors, which may reduce the magneto motive force (MMF) requirement and increase the electrical utilization of the machine. To verify the proposed two structures, the characteristics of the proposed two types are analyzed and compared with that of conventional 12/8 SRM.

1. Introduction

Since the development of the power electronics and high price of permanent magnet (PM), switched reluctance motor (SRM) is gaining more attentions. In particular good fault tolerance, simple manufacture, robustness, low cost and applicability in harsh environments properties [1] make it a powerful candidate for many automotive and aerospace products.

In this paper, two segmental rotor type SRMs, 6/5 and 12/8 types, are proposed for vehicle cooling fan application. The characteristics of the two types, including magnetic flux distribution, flux linkage, torque, and radial force, are analyzed and compared to that of conventional 12/8 SRM to verify their validity.

2. Two Novel SRMs with Segmental Rotors

2.1 6/5 Segmental Rotor Type SRM

A novel 6/5 SRM with segmental rotors is proposed in Fig. 1. The motor has six stator poles and five rotor poles. The stator poles are divided into exciting and auxiliary poles. The phase windings are only wound on the exciting poles of the stator. There are no windings wound on the auxiliary pole, so the auxiliary poles only act as the flux return path. The rotor is comprised of series of discrete segments and nonmagnetic isolator. The rotor segments are embedded in the nonmagnetic isolator and magnetically isolated from each other segments. The 0° rotor angular position of this motor is defined at the aligned position of phase A, as the rotor position shown in Fig. 1.

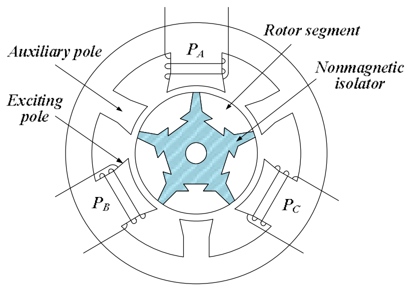


Fig. 1 Structure of 6/5 segmental rotor type SRM.

2.2 12/8 Segmental Rotor Type SRM

Fig. 2 shows the proposed 12/8 segmental rotor type SRM. The structure of the 12/8 type is the same with that of the proposed 6/5 type except the number of the stator and rotor poles. Furthermore, the proposed 12/8 type is also a three phase motor. The detailed winding connections of the three phases are shown in Fig. 2.

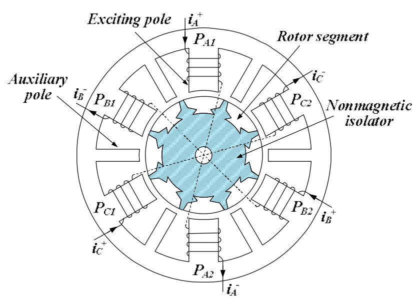


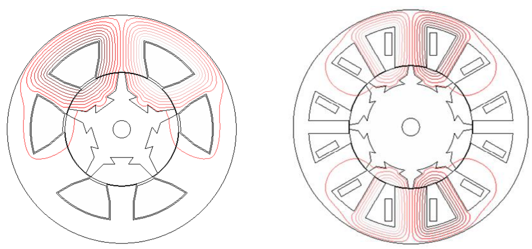
Fig. 2 Structure of 12/8 segmental rotor type SRM.

3. Characteristics Analysis

To verify the proposed structures, the proposed 6/5 and 12/8 types are designed to compare with a conventional 12/8 SRM. For accurate comparison between conventional 12/8 and proposed SRMs, both the proposed structures are deliberately made with exactly the same outside diameter, core axial length, air gap and wire gauge as a previous constructed 12/8 motors. Meanwhile, the slot factor of the proposed types is kept lower than or same with that of the conventional 12/8 SRM.

3.1 Magnetic Flux Distribution

Fig. 3 shows the magnetic flux distributions of the proposed 6/5 and 12/8 SRM with phase A excited at aligned position. As shown in the figures, the magnetic flux flows down from the wound stator poles and returns via the adjacent auxiliary poles. All the conductors in each plot slot only couple with the flux driven by their own magneto motive force (MMF) with very little mutual coupling between one slot and another. Therefore, the proposed structures may increase the electrical utilization of the machine and reduce the MMF requirement. However, with one phase excited, the magnetic flux only flows on one side in the 6/5 type. This may result in unbalanced force in the machine which can increase the acoustic noise and vibration as the motor operates.



(a) 6/5 type (b) 12/8 type

Fig. 3 Magnetic flux distribution of proposed 6/5 and 12/8 segmental rotor type SRMs.

3.2 Flux-linkage, Torque and Force Characteristics

Fig. 4 shows the finite element predictions of the flux linkage per turn for the conventional and proposed SRMs. Fig. 5 shows the average torque per turn for the conventional and proposed SRMs. As seen in Fig. 9, the average torque produced by the proposed types is higher than that of the conventional 12/8 type, especially for the 6/5 type, it is about two times that of conventional 12/8 type. Therefore, to produce the same torque, the proposed types require lower current or less winding turns. That is, compared with conventional 12/8 type, the MMF requirement is reduced and the electrical utilization of the machine is increased in the proposed types.

Fig. 6 shows the radial force magnitude profiles of all the three machines with constant current 110A. Due to the asymmetry of inherent magnetic flux paths, unbalanced force is produced in the proposed 6/5 type, while the force is very balanced in the conventional and proposed 12/8 SRMs.

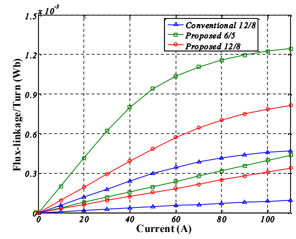


Fig. 4 Flux-linkage per turn for all three machines.

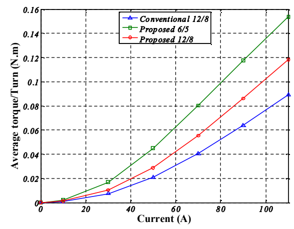


Fig. 5 Average torque per turn for all three machines.

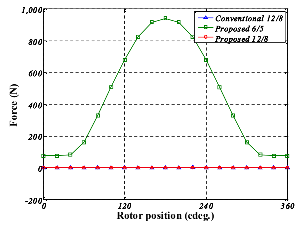


Fig. 6 Radial force profiles of all three machines.

4. Conclusions

In this paper, two segmental rotor type SRMs are presented and compared with a conventional 12/8 SRM. From the comparison results, it can be concluded that the proposed SRMs has better torque output capacity than the conventional 12/8 SRM, and the MMF can be reduced about 40% and 20% in 6/5 and 12/8 type, respectively. However, there is unbalance force in the 6/5 type. The unbalance force not only increases the acoustic noise and vibration of the machine, but also increases burden of the bearing, which may reduce the life of the bearing. For this reason, the proposed 12/8 type is researched even though the torque output capacity is lower than that of the 6/5 type.

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참 고 문 헌

[1] D. H. Lee and J. W. Ahn, “Design and analysis of hybrid stator bearingless SRM,” J. Elect. Eng. Technol., vol. 6, no. 1, pp. 94 103, Jan. 2011.