짧은 자속경로형 SRM의 설계와 특성해석

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Design and Analysis of Switched Reluctance Motor with Short Flux Path

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Abstract

A novel kind of switched reluctance motor (SRM) with short flux path is proposed in this paper. Phase excitation in the SRM gives short flux paths, hence reducing the magnetomotive force required to drive the machine, resulting in significant reduction of copper wire and core losses compared to the typical SRM with diametric circulation of magnetic flux. To verify the performance, the characteristics analysis of a double stator SRM, a 6/5 SRM with C-core structure and a 4/5 two-phase SRM which all composed of short flux path and a comparison with conventional SR motors are executed.

1. Introduction

The Switch Reluctance Motor (SRM) has been widely used in many industrial applications such as aerospace, automotive and domestic appliance manufacturing. A novel construction of short flux path is proposed in order to improve the performance and reduce the losses. The basic principle of short flux path uses short magnetic path, and the magnetic flux can flow faster than in the long magnetic path motors [1]. Fig. 1 shows the basic structure of short flux path type.

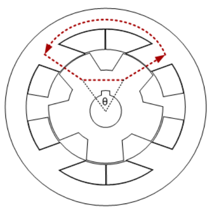


Fig. 1 Short flux path of SRM

The electromagnetic operation for this type of SRM is different from the conventional SRM. Magnetic flux travels in a short flux loop in contrast to the conventional SRM, which uses a long flux path. When a stator pole is excited, the adjacent rotor pole pair is attracted towards the excited stator pole, and alignment will be achieved between stator and rotor poles. This is due to the nature of the reluctance path. The advantage of using a short flux path is to reduce the eccentric forces between the stator and rotor poles. In addition, core losses are significantly reduced due to the short distance of the travelling magnetic fields in the short flux path design. As a result the efficiency of the SRM can be improved.

2. Short flux path SRM

2.1 Concept of SRM with short flux path

A novel double-stator SRM with short flux path is proposed in this paper, which smaller size and higher output torque is needed. The two stators of the SRM are independent and they are placed inside and outside of the rotor. There is no brush or magnet in the double stator SRM. The rotor structure employs a yokeless rotor with no connection. The rotor consists of 12 independent rotor bars with non-electrical material used to join them. The proposed rotor employs thick independent rotor poles. The stator structure is divided into three independent stator groups. Each stator group contains a pair of two connected poles [2].

In order to verify the novel idea of short flux path, a novel three-phase 6/5 SRM with C-core and a two-phase 4/5 SRM are designed and analyzed, respectively, which are shown in Fig. 2.

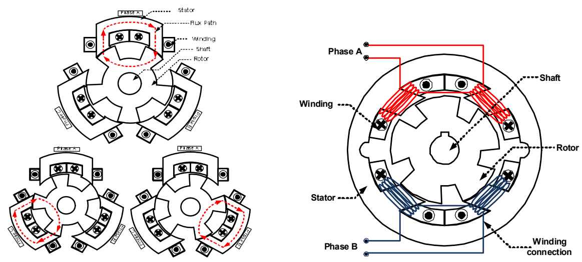


Fig. 2 Structure of 6/5 and 4/5 SRM with short flux path

The novel 6/5 SRM with short flux path has 6-stator poles, which were constructed with three independent and physically C-cores, and the rotor is compose of 5 poles. The short flux path uses a new structure where the stators are not centralizing to the origin, the three C-cores are separated by 120^0, and the rotors are separated by 72^0. The windings are in the form of concentrated wound on the stator. This odd number of rotor poles is used to deliver the magnetic flux from one stator pole to another. And the two-phase 4/5 SRM has four-stator and five-rotor pole, which employs the short flux path instead of the full long flux path in conventional SRM.

2.2 Analysis of characteristics

2.2.1 Static analysis

The FEM is usually used for steady-state performance computations. The analysis of the three-phase 6/5 SRM with short flux path is based on the software of ANSOFT-12. Fig. 3 shows that the magnetic flux path of the double-stator. The flux distribution as shown in the figure demonstrates the switching sequence of the proposed motor with double stator. 'Zero degree' represents the initial position of motor rotation. At this position, the rotor is fully aligned with phase A, while phase C is starting to overlap, and phase B is passing from the unaligned stator-rotor position. As one counter-clockwise revolution phase B and C should be alternately excited.

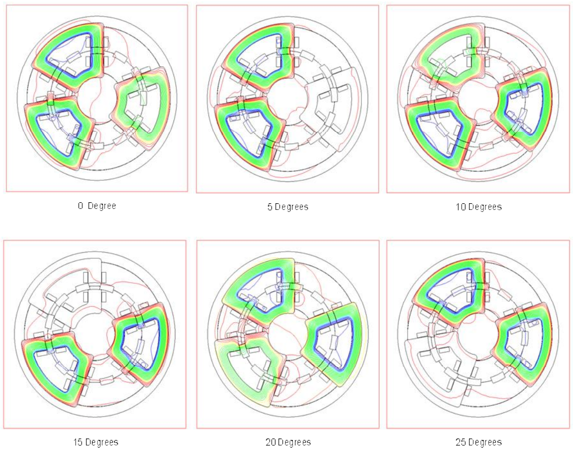


Fig. 3 Magnetic flux path of the double-stator SRM

The static analysis aimed to analyze the magnetic flux distribution between the stator and rotor. The FEM analysis demonstrates that the flux flows just pass through the pole which is excited when the phase current is excited, and there is no flux flows pass through in the other poles which are not excited. Both of static analysis of the 6/5 and 4/5 SRM are shown in Fig. 4 and Fig. 5.

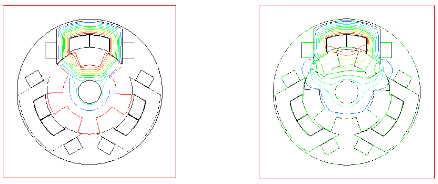

(a) (b)

Fig. 4 Flux distribution of 6/5 SRM (a) aligned (b) unaligned

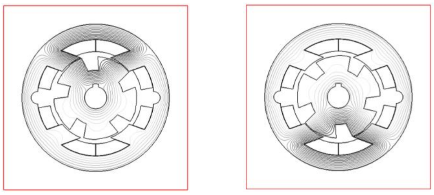

(a) (b)

Fig. 5 Flux distribution of 4/5 SRM (a) Phase A (b) Phase B

2.2.2 Dynamic analysis

There are two performance parameters which is the most important for the SRM, the flux linkages the torque.

The SRM is characterized by its flux linkage, which vary with rotor position and current. The position-dependent behavior is due to the geometry of the overlapping stator and rotor teeth. In most SRM applications, saturation occurred and results in nonlinear inductances. This nonlinear behavior explains the difficulty in modeling and controlling the SRM. The variation of flux-linkage with respect to the current for different rotor positions of the proposed motor is shown in Fig. 6 for the double stator SRM.

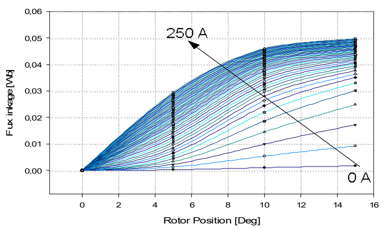
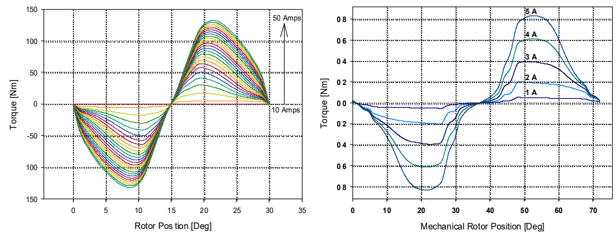
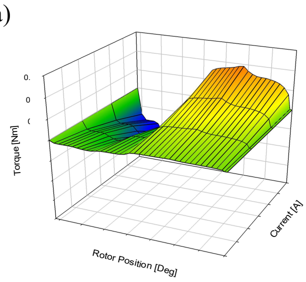


Fig. 6 Flux linkage of the double stator SRM

Torque is an important parameter to measure the motor performance. The torque of the SRM is produce by the unilateral magnetic force when the rotor poles are attracted to align with the excited stator phase, and the torque is independent of the polarity of the phase current. The torque characteristic of the double-stator SR motor is shown in Fig. 7 (a). The motor is designed to produce 117 Nm as the maximum output torque. One-phase torque of the double SRM travels through 30 mechanical degrees. The maximum torque production of the proposed motor with 250 A excited current is 130 Nm. This excessive torque production is due to the higher excited current. A 117 Nm of torque can be achieved with 230 A excitation current. Fig. 7 (b) shows the torque versus rotor position for various excited currents of the 6/5 three-phase SRM, it can be seen that the maximum torque values appear around the rotor position of 20^0 and 50^0. The 4/5 SRM employs an asymmetric air gap. The torque in this structure is not symmetric. The Fig. 7 (c) shows the torque prolife of the 4/5 SRM. It can be seen that the peak of the torque can be get about 20^0 and 50^0.



(a) (b)



(c)

Fig. 7 Torque (a) double stator type (b) 6/5 type (c) 4/5 type

3. Conclusion

A novel switched reluctance motor (SRM) with short flux path is proposed. On the basis of the special structure, a double stator SRM, a three-phase 6/5 with C-core SRM and a two-phase SRM with short flux path are designed and analyzed.

Acknowledgment

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References

[1] Krishnan R.: Switched Reluctance Motor Drives. CRC Press LLC, Boca Raton, Florida, 2001.

[2] Mohammadali Abbasian, Mehdi Moallem and Babak Fahimi, "Double-Stator Switched Reluctance Machines (DSSRM):Fundamentals and Magnetic Force Analysis," IEEE Transactions on Eenergy Conversion, vol. 25, pp.589 - 597, No.3, Sep.2010.