

Study on the Characteristics for A Novel Segmental Switched Reluctance Motor

Tao Sun¹, Ji-Young Lee², Jung-Pyo Hong³

¹ Changwon Nation University, ² Korea Electrical Research Institute, ³ Hanyang University

¹ Changwon, 641-773, Korea

² Changwon, 641-120, Korea

³ Seoul, 133-791, Korea

¹ laplace_sun@hotmail.com, ² jyecad@korea.com, ³ hongjp@hanyang.ac.kr

Abstract — This paper deals with the study of a novel SRM with the embedded segment core type rotor. First, the static characteristics of this motor are investigated by finite elements analysis. And then, according to voltage equations and motor parameters including inductance profiles generated in the last step, the dynamic characteristics are calculated. Finally, the total characteristics are compared with those of conventional SRM which are already examined for verification of the analysis method.

I. INTRODUCTION

Switched Reluctance Motor (SRM) has been used in various fields for many years, which is due to its a few benefits such as simple structure, low cost, extremely high speed, high starting torque and running under fault condition and dash environment. However, the high torque ripple and wind resistance seriously weaken its performance and reduce using life. For conventional SRM (CSRM), these drawbacks are inherent because of the toothed rotor and stator structure. Although many papers have presented some solutions to improve them, the complex operations and control algorithms still did not change the essential performances of motor. The author of [1] proposed a novel SRM structure with segmental rotor (SSRM). And in [2], based on [1] the author proposed an improved structure which has simpler and stronger rotor. However, [2] only gave a few comparisons of the general performances of CSRM and SSRM by experimental results. In spite that some merits of SSRM have been proved in theory, the specific results have not been analyzed and presented yet [3]. According on the electromagnetic field computation theories, this paper will concentrate on static and dynamic analysis for SSRM proposed in [2]. First, in the static analysis, the inductance profiles are calculated in Finite Elements Analysis (FEA). And then, according to the voltage equation considering drive topology, the dynamic characteristics will be compared with those of conventional SRM which are already examined for verification of the analysis method.

II. THE NOVEL SEGMENTAL SRM

In this paper, the analyzed novel SSRM has 6 slots and 4 segment cores embedded in the aluminum rotor block as shown in Fig. 1(b). Compared with the CSRM shown in Fig. 1(a), it is obvious that the other big difference of these two models is the winding strategy except rotor structure.

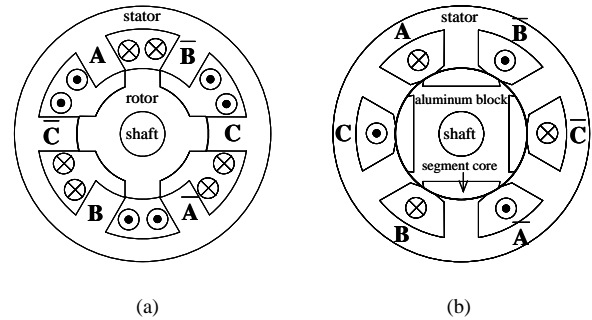


Fig. 1. (a) the model of CSRM; (b) the model of SSRM

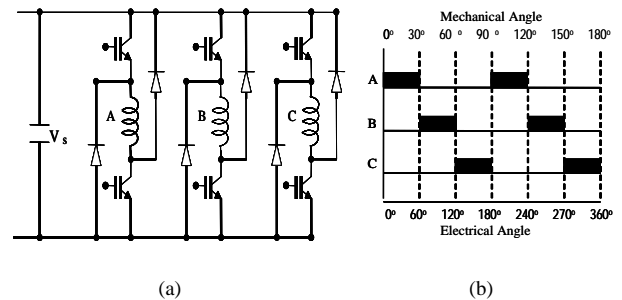


Fig. 2 (a) the asymmetric converter for driving the 2 SRMs; (b) the switching sequence of the converter

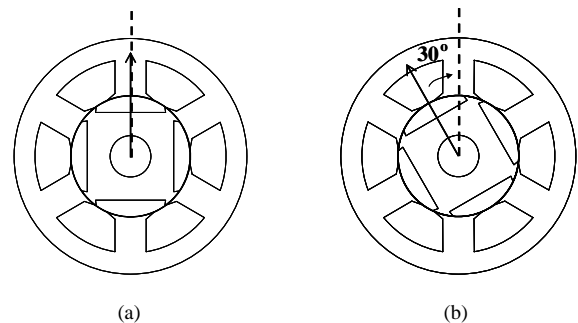


Fig. 3. (a) the aligned position of SSRM; (b) the unaligned position of SSRM

Although there are such big differences, the both kinds of SRM can be driven by same asymmetric converter and switching sequence as shown in Fig. 2. The Fig. 3 shows the aligned position and unaligned position of the SSRM. In theory, because of four magnetized stator poles in each stroke, short flux path in each phase and the more horizontal magnetization direction in rotor core, the SSRM has high average torque, lower iron-loss and lower vertical

force than those of CSRSM. The detail discussion and results will be presented in the extended paper.

III. ANALYSIS METHOD

A. Inductance Calculation

Owing to the domination of the inductance in SRM, the FEA is employed to get the inductance profiles considering magnetic nonlinearity. The analyzed SSRM model with flux pattern is shown in Fig. 4. The inductance profiles and flux linkage vs. current profiles of the CSRSM and SSRM are shown in Fig. 5, respectively. It is obvious that the SSRM has bigger area of field energy and sharper inductance shape when the two motors have same dimensions and low excited current.

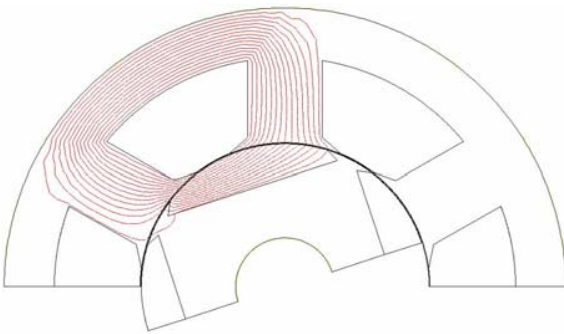


Fig. 4 the flux pattern of the SSRM

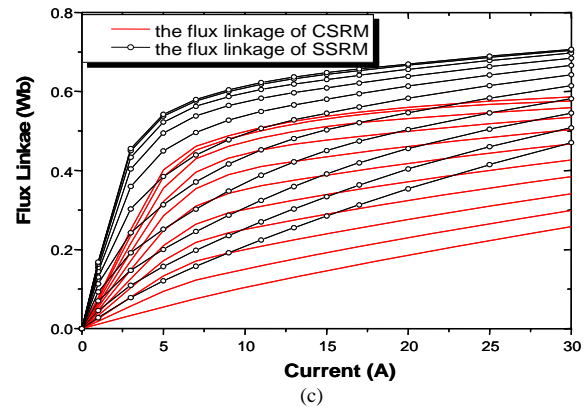
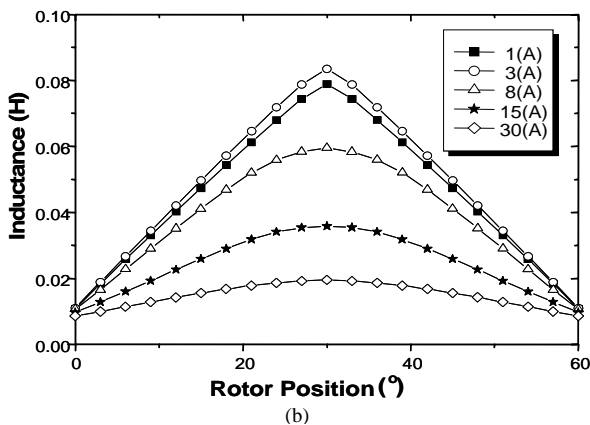
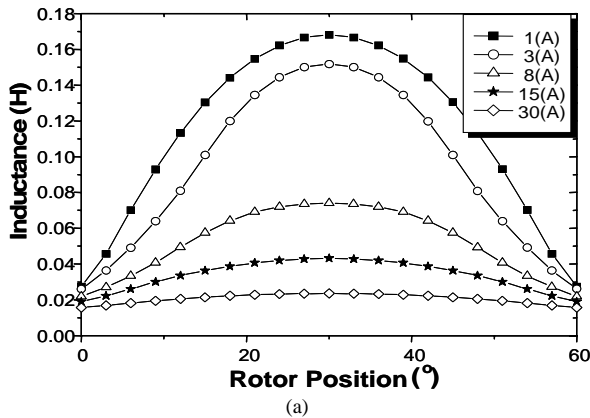


Fig. 5. (a) the inductance profile of the SSRM; (b) the inductance profile of the CSRSM; (c) the flux linkages of the SSRM and CSRSM

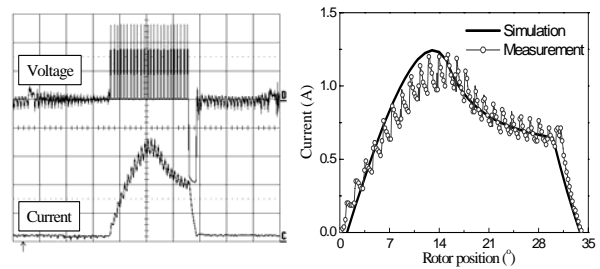


Fig. 6. the comparison of experimental current and simulated current

B. Characteristics Analysis

The characteristics analysis is performed in constant current source and constant voltage source. Particularly, in the constant voltage source case, the output torque and torque ripple will be analysis and compared in different fire on and off angle. The coupled field circuit modeling method which considers both motor flux patterns and the terminal equations is used for the characteristics analysis. The analyzed CSRSM has been manufactured and experimented. The experimental current waveform and the simulated current waveform are shown and compared in Fig. 6, which shows the validity and accuracy of the proposed method.

IV. ANALYSIS RESULTS

As mention before, the torque and torque ripple will be calculated considering different fire on and off angle. In addition, by means of the proposed method, the results of the dynamic characteristics such as current, voltage, output power and efficiency will be shown in the extended paper.

V. REFERENCES

- [1] B. C. Mecrow, J. W. Finch, E. A. El-Kharashi and A. G. Jack: "Switched Reluctance Motors with Segmental Rotors" IEE Proc. of Electrical. Power Application., Vol. 149, No. 4, pp. 245-254 (2002)
- [2] Oyama. J.; Higuchi. T.; Abe. T.; Tanaka. K. "The fundamental characteristics of novel switched reluctance motor with segment core embedded in aluminum rotor block". Electrical Machines and Systems, 2005. ICEMS. Volume 1, Issue , 27-29 Sept. 2005
- [3] T. J. E. Miller, Ed., *Switched Reluctance Motors and their Control*, Lebanon, OH: Magna Physics/Oxford University Press (1993)



**Proceedings
of the**

**16th Conference on the Computation of
Electromagnetic Fields**

COMPUMAG 2007

June 24th - 28th

Aachen, Germany

Wednesday, June 27th

OC1 – Optimisation - Software Methodology

EUROPA SAAL

08:30–10:10 Session chair: **Gabriela Ciuprina, Jan Sykulski**

IPC-1	<i>Parallel Computers Everywhere</i> Prof. Dr. Christian Bischof, GERMANY	693
*OC1-1	<i>A New Strategy for Reducing Communication Latency in Parallel 3-D Finite Element Tetrahedral Mesh Refinement</i> Da Qi Ren, Steve Mcfee, Dennis Giannacopoulos, CANADA	701
*OC1-2	<i>Analysis of the Computational Cost of Approximation-based Hybrid Evolutionary Algorithms in Electromagnetic Design</i> Frederico Gadelha Guimaraes, David Alister Lowther, Jaime Arturo Ramirez, BRAZIL	703
OC1-3	<i>Dynamic Multiobjective Optimization: a Way to the Shape Design with Transient Fields</i> Paolo Di Barba, ITALY	705

PC1 – Electrical Machines and Drives

BALUSTRADE

10:30–12:10 Session chair: **Erich Schmidt, Yoshihiro Kawase**

PC1-1	<i>An Improved Design for Steady-Static Characteristic of Permanent Magnet Type Step Motor with Claw Poles by 3D FEM</i> Dae-Sung Jung, Seung-Bin Lim, Ju Lee, SOUTH KOREA	707
PC1-2	<i>Holding Torque Characteristics Analysis of Permanent magnet Spherical Motor</i> Sung Hong Won, Tae Heoung Kim and Ju Lee, SOUTH KOREA	709
PC1-3	<i>Characteristic Analysis of Claw-pole Generator using Equivalent Magnetic Circuits</i> Sang-Ho Lee, Soon-O Kwon, Jung-Pyo Hong, Yang-Soo Lim, Yoon Hur, SOUTH KOREA	711
PC1-4	<i>Design and Analysis of Switched Reluctance Motor Working at Optimum Operating Point</i> Jian Li, In-Jae Lee, Yunhyun Cho, SOUTH KOREA	713

PC1-5	<i>Analysis of PWM Vector Controlled Squirrel Cage Induction Motor during Eccentricity Rotor Motion Using FEM</i> Mi Jung Kim, Byung-Kuk Kim, Ji-Woo Moon, Yun-Hyun Cho, Don-Ha Hwang, Dong-Sik Kang, SOUTH KOREA	715
PC1-6	<i>Influence of Load Fluctuations upon Diagnosis of Mixed Eccentricity Fault In Induction Motors using Time Stepping Finite Element Method</i> Jawad Faiz, B.M. Ebrahimi, IRAN	717
PC1-7	<i>Synthetic Flux Linkage Identification for Interior Buried Permanent Magnet Synchronous Motor considering Cross-Magnetization</i> Sang-Yong Jung, Cheol-Gyun Lee, Sung-Chin Hahn, Sang-Yeop Kwak, Hyun-Kyo Jung, SOUTH KOREA	719
PC1-8	<i>Determination of Parameters Considering Magnetic Nonlinearity in Solid Core Transverse Flux Linear Motors for Dynamic Simulation</i> Ji-Young Lee, Ji-Won Kim, Jung-Hwan Chang, Do-Hyun Kang, and Jung-Pyo Hong, SOUTH KOREA	721
PC1-9	<i>Analysis Strategy Considering Magnetic Saturation of Interior Permanent Magnet Synchronous Motors</i> Young-Kyoun Kim, Jung-Pyo Hong, SOUTH KOREA	723
PC1-10	<i>Performance Computation of Claw-Pole Type Alternator based 3 Dimension Finite Element Method and Fourier Series</i> Seung-Bin Lim, Ki-Chan Kim, Go Sung Chul, Sang-Hwan Ham, SOUTH KOREA	725
PC1-11	<i>Flux-Weakening Performance and Output Power Capability of Permanent Magnet Synchronous Motors with Different Permanent Magnet Arrangement</i> Bojan Stumberger, Gorazd Stumberger, Miralem Hadziselimovic, Marko Jesenik, Anton Hamler, Mladen Trlep, SLOVENIA	727
PC1-12	<i>Arc models for simulation of brush motor commutations</i> Jerome Cros, Geraldo Sincero, Philippe Viarouge, CANADA	729
PC1-13	<i>Torque Ripple Reduction of Interior Permanent Magnet Synchronous Motor Using Harmonic Injected Current</i> Ji-Hyung Bahn, Sung-Il Kim, Geun-Ho Lee, Jung-Pyo Hong, SOUTH KOREA	731
PC1-14	<i>Investigation of Parameters Variation and Radial Magnetic Forces by Pole-Slot Combinations in Interior Permanent Magnet Synchronous Motor with Concentrated Winding</i> Seung-Hyoung Ha, Sang-Ho Lee, Soon-O Kwon, Jung-Pyo Hong, SOUTH KOREA	733

PC1-15	<i>Accurate induction motor estimator based on magnetic field analysis</i> Dimitrios S. Raptis, Antonios G. Kladas and John A. Tegopoulos, GREECE	735
PC1-16	<i>Power Generation Optimization from Sea Waves by using a Permanent Magnet Linear Generator Drive</i> N. M. Kimoulakis, A. G. Kladas and J. A. Tegopoulos, GREECE	737
PC1-17	<i>Study on the Characteristics for A Novel Segmental Switched Reluctance Motor</i> Tao Sun, Ji-Young Lee, Jung-Pyo Hong, SOUTH KOREA	739
PC1-18	<i>Determination of Parameters of Motor Simulation Module Employed in ADVISOR</i> Tao Sun, Suk-Hee Lee, Soon-O Kwon Jung-Pyo Hong, SOUTH KOREA	741
PC1-19	<i>Analysis of Transient Short Circuit Electromagnetic Forces in Isolated Phase Buses</i> Arash Hassanpour Isfahani, Sadegh Vaez-Zadeh, IRAN	743
PC1-20	<i>Coupling Boundary Element and Permeances Network Methods for Modeling Permanent Magnet Motors in automotive applications</i> Said Touati, J. A. Farooq, A. Djerdir, R. Ibtouen, A. Miraoui, O. Touhami, ALGERIA	745
PC1-21	<i>Optimum Design for Eddy Current Reduction in IPMSM</i> Jaewoo Jung, Soon-O Kwon, Ji-Hyung Ban, Jung Pyo Hong, SOUTH KOREA	747
PC1-22	<i>Design of a Permanent Magnet Assisted Synchronous Reluctance Motor for Integrated Starter and Generator in 42 Volt System of Vehicles</i> Yang-Su Lim, Dong-Hun Lee, Yoon Hur, Jae-Woo Jung, Jung-Pyo Hong, SOUTH KOREA	749

PC2 – Numerical Techniques

BALUSTRADE

10:30–12:10 Session chair: **Igor Tsukerman, Georg Wimmer**

PC2-1	<i>An Adaptive Remeshing Technique Insuring High Quality Meshes</i> Marcel Ebene-Ebene, Y. Marechal, D. Armand, D. Ladas, FRANCE	751
--------------	---	-----