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EX-10. Characteristic Analysis & Optimum Design of Permanent Magnet Assisted Synchronous Reluctance Motor for Premium Efficiency Performance. J. Lee[1], *M. Jun* [1] and B. Lee[1] *1. Electrical Engineering, Hanbat National University, Daejoen, Korea, Republic of*

EX-11. Quantitative Comparison and Experimental Evaluations of Two Novel Permanent-Magnet Vernier Machines. *J. Li* [1] and K. Chau[1] *1. Department of Electrical & Electronic Engineering, The University of Hong Kong, Hong Kong, Hong Kong*

EX-12. Optimum Shape Design of Single-sided Linear Induction Motor Using Response Surface Method and Finite Element Method. J. Lee[1], *S. Jang* [1] and S. Lee[1] *1. Electrical Engineering, Hanbat National University, Daejeon, Korea, Republic of*

EX-13. 3D Analytical modeling of a double skewed linear magnet array. *M. Kremers* [1], J. Janssen[1], J. Paulides[1] and E. Lomonova[1] *1. Electromechanics and Power electronics, Eindhoven University of Technology, Eindhoven, Netherlands*

EX-14. PM Magnetization Characteristics Analysis of a Post-Assembly Line Start Permanent Magnet Motor Using Coupled Preisach Modeling and FEM. J. Lee[1], *K. Kim* [1] and S. Lee[1] *1. Electrical Engineering, Hanbat National University, Daejeon, Korea, Republic of*

THURSDAY MORNING 9:30 — EXHIBIT HALL TWTC

Session EY
DESIGN AND ANALYSIS OF ELECTRIC MACHINE AND ACTUATOR II (Poster Session)

Min-Fu Hsieh, Session Chair
National Cheng Kung University

EY-01. Experimental Verification and Effects of Step Skewed Rotor type IPMSM on Vibration and Noise. *J. Jung* [1], D. Kim[1], J. Hong[1] and D. Lee[2] *1. Department of Automotive Engineering, Hanyang University, Seoul, Korea, Republic of; 2. Motor R&D Center, S&T Daewoo, Busan, Korea, Republic of*

EY-01

Experimental Verification and Effects of Step Skewed Rotor type IPMSM on Vibration and Noise.

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1. Introduction

Integrated starter and generator (ISG) is operated as a motor that starts engine when vehicle moves on the city road where engine power on-and-off is repeatedly required due to signal change. During this operation, acoustic noise of ISG can be detected by driver inside the vehicle. The acoustic noise is caused by electro-magnetic exciting force such as radial and tangential force, which deforms the stator core [1].

The electro-magnetic exciting force can be minimized by optimization of control algorithm for objective motor [2]. On the other hand, some of researchers optimize shape of flux barrier in the rotor core and shape of stator tooth to reduce vibration and noise of the motor [3]. However, this method has a limitation as it applies to the motor, which originally has high exciting force due to its geometry. Therefore, minimization of exciting force by skewing the rotor is studied so that vibration and noise of the motor can be ultimately improved regardless of original state of exciting force in this paper. Furthermore, the mechanism of reduction of vibration and noise by skewing the rotor are investigated by electro-magnetic analysis coupled with deformation of stator core.

2. Analysis model

The specifications of prototype, interior permanent magnet synchronous motor (IPMSM), are shown in Table I. Prototype consist of 6-pole and 36-slot, and is wound by distributed winding as shown in Fig. 1. Slot pitch of armature winding is set to 5 to obtain sinusoidal back electro-motive force (EMF). In order to increase power density, permanent magnet of Nd-Fe-B type is inserted in the rotor and divided by two segments per pole in axial direction to make assemblage more easily. Moreover, segmented PM helps to achieve two-step skewed rotor more easily. The rotor core below the permanent magnet is punched to reduce total weight of the rotor.

3. Calculation method and experimental verification

In this paper, three-dimensional finite element analysis (3-D FEA) is used to consider leakage flux in axial direction and overhang effect. Furthermore, deformation of stator, which resulted from electro-magnetic exciting force, is calculated by 2-D FEA with overhang coefficient. Lastly, in terms of deformation quantity of stator core, its tendency, and experimental result of vibration, prototype and step skewed model are compared to verify the calculation method. ‘Vehicle-level’ experiment result of prototype is shown in Fig. 2. Because the trend of vibration result is almost same with noise so that exciting force which deform stator core should be minimized in order to decrease the noise.

Step skewed rotor is applied to minimize exciting force. Fig. 3 shows 3-D model of step skewed rotor type IPMSM. In order to compensate leakage flux in axial direction where attached side of two rotor body, overhang is applied in the rotor. Overhang coefficient for PM can be calculated by using 3-D FEA [4]. Then we can calculate exciting force such radial force and tangential force easily by using 2-D FEA. Using the exciting force, deformation of stator core can be calculated and its tendency of deformation is studied with comparison of experimental result of vibration and noise. Accordingly, effect on noise and vibration of skewed rotor type IPMSM can be proved in this paper.

[1] Se-hee Lee, Il-han Park, and Ki-sik Lee, “Comparison of Mechanical Deformations Due to Different Force Distributions of Two Equivalent Magnetization Models,” IEEE Trans. Magn., vol. 34, no. 4, pp.1368-1372, July. 2000.

[2] Kyung-Ho Ha, Young-Kyoun Kim, Geun-Ho Lee, and Jung-Pyo Hong, “Vibration Reduction of Switched Reluctance Motor by Experimental Transfer Function and Response Surface Methodology,” IEEE Trans. Magn,, vol. 40, no. 2, pp.577-580, March. 2004.

[3] Kasper, K.A. Fiedler, J.O. Schmitz, D., and De Doncker, R.W, “Noise Reduction Control Strategies for Switched Reluctance Drives,” VPPC ‘06. IEEE, Sep. 2006.

[4] Ki-Chan Kim, Dae-Hyun Koo, and Ju Lee, “The Study on the Over Coefficient for Permanent Magnet Machine by Experimental Design Method,” IEEE Trans. Magn., Vol. 43, No. 6, pp. 2483-2485, June 2007.

List	Values	Note
Number of pole and slots	6 / 36	-
Operating speed range	4000 rpm	Motoring mode
Maximum power	6.4 kW	-
Winding method	Distributed winding	Short pitch (5/6)
Driving method	Sinusoidal wave	SV PWM

Table 1. Specification of prototype

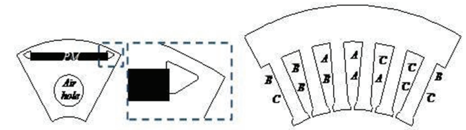

Fig. 1. Configuration of prototype

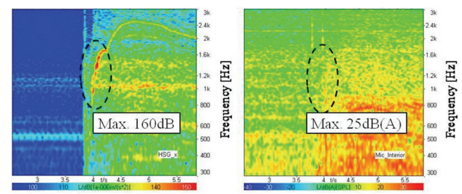

Fig. 2. ‘Vehicle-level’ experiment result of prototype

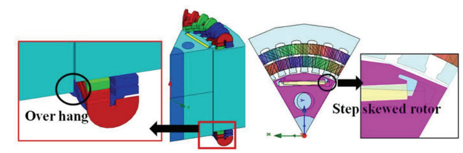

Fig. 3. 3-D model of step skewed IPMSM with rotor overhang