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유한요소 해석 기반 자동차 공조용 DC모터 토크 리플과 소음 저감에 관한 연구

FEA-based Torque Ripple and Noise Reduction of DC Motor for Automotive Air-Conditioning

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Abstract -This paper discusses methods for the torque ripple and noise reduction of DC motors for automotive air-conditioning based on electromagnetic field analysis. The target of the motor is a blower motor, and to reduce cogging torque and the torque ripple, the optimum model was selected by deforming the brush or commutator shape. In addition, to reduce the cogging torque, the model design was carried out by applying the skew method and the magnetization method of a magnet to the rotor. For optimization, the shape, material, and drive system of the motor were selected using an electromagnetic field as the analysis tool, and the method of reducing the cogging torque was applied to 4-pole, 12- and 13-slot motors considering the mechanical part . Lastly, this paper confirmed thatthemethod, which proposed how much noise, cogging torque, and vibration are reduced, improves through practical analysis.

Key Words : DC motor, Torque ripple, Cogging Torque, Skew method

1. Introduction

Recently, in the automobile industry, to provide convenience and comfort for automobiles, there have been used to many applications of motors as automobile parts, and studies on the motors have been increasing. The environmental friendliness of blower motors applied to automobiles' interior is also important, but most of all, since motors are required to be quiet inside automobiles, various methods for noise reduction are being discussed. The structure of a DC motor is mechanically contacted by the brush and the commutator, resulting in noise in the DC motor[1-7]. Therefore, the aim of this paper is to propose a method of reducing the noise and vibration of DC motors by analyzing the factors affecting the mechanical noise of the DC motor[7-9]. Typical elements include the brush width, commutator width, and magnet shape (eccentricity), and this paper attempts to analyze these noise factors through the analysis of the electromagnetic field. Therefore, the design was intended to minimize the cogging torque and torque ripple of 4-pole, 12-and13-slot blower motors for automotive air-conditioning, and the results of analyzing the cogging torque and torque ripple were compared and analyzed through the finite element method[3-5].

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2. Blower Motor Torque Ripple and Noise for Automotive Air-Conditioning

2.1 DC motor analysis model

The design model specifications are 4-pole, 12- and 13-slot blower motors for automotive air-conditioning, providing information on the design specifications and

Table 1 Blower motor analysis model specifications

Item	Unit	Specifications
Pole	Pole	4
Slot	EA	12, 13
Speed	RPM	2300~2800
Cogging Torque	Nm	0.22~0.023(12 slot), 0.004~0.005(13 slot)
rated current	A	17.9(12 slot), 19.3(13 slot)
winding patten	12slot	0.85ø * 1 Reel * 12 Tc
	1slot	0.85ø * 1 Reel * 12 Tc
brush position		90°, 4° ~ -4°
skew	mm	1 pich

models. The motor models were analyzed and optimized using the analysis of electromagnetic field. Table 1 shows the design specifications.

2.2 Blower Motor torque ripple analysis

A DC motor magnet is ferrite, and the rotor is a motor that uses a coil on an electric steel plate to change the direction of the current flowing in the electric field to generate a rotational force by the repulsion or attractive force of the magnetic force. The DC motor uses a brush and commutator for rotation, so a mechanical contact occurs in the commutator. DC motors' noise has both electromagnetic and mechanical causes. In this paper, vibration noise is analyzed with mechanical factors.

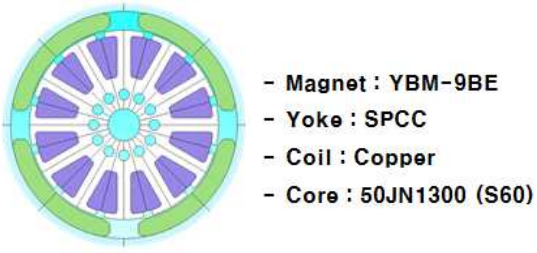
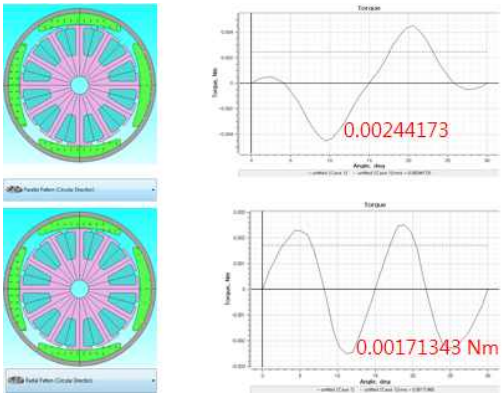
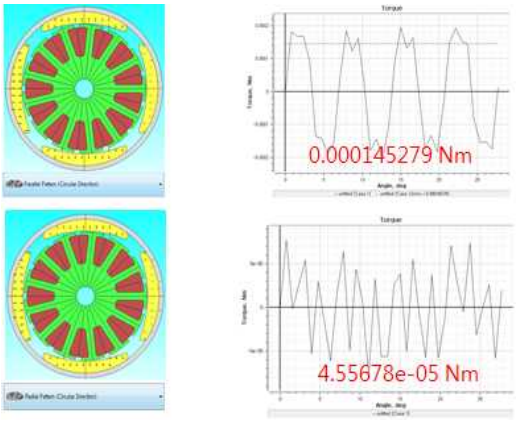


Fig. 1 Analysis model and material properties



a) 12 slot cogging torque analysis



b) 13 slot cogging torque analysis

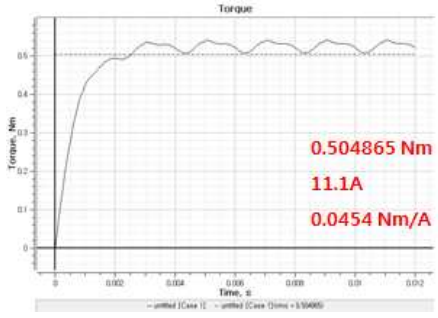
Fig. 2 12 and 13 slot cogging torque analysis

2.3 Analysis and design of noise factors through Finite Elements Analysis

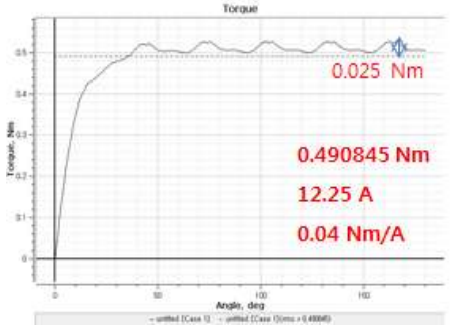
This part analyzed blower motors for automotive air-conditioning. Fig. 2 compares the cogging torque through the FEA of 4-pole,12-and13-slot motors.

This paper analyzed the electromagnetic field in a parallel magnetization pattern and a radical magnetization pattern as the magnetization direction of the permanent magnet. As a result, it was confirmed that the cogging torque in the radical magnetization pattern was lower than the parallel magnetization pattern.

Figures 3 and 4 compared the torque ripple according to the brush width. The brush width is also important, but the contact area of the brush initially contacts the corner point, and if the brush is worn afterward, the entire area of the brush will be in contact. The electromagnetic field was analyzed by 4-pole 12-and 13-slot motors, and its analysis

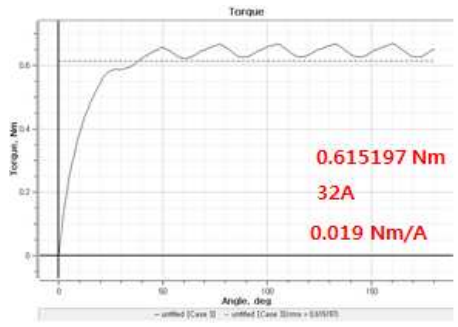


a) Radical magnetization pattern of 12 slot torque ripple

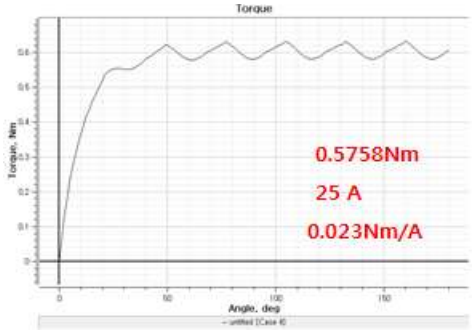


b) Parallel magnetization pattern of 12 slot torque ripple

Fig. 3 20° radical and parallel magnetization patterns of 4 pole 12 slot torque ripple



a) Radical magnetization pattern of 13 slot torque ripple



b) Parallel magnetization pattern of 13 slot torque ripple

Fig. 4 20° radical and parallel magnetization patterns of 4 pole 13 slot torque ripple

Table 2 Vibration measurement results(Skew method)

	12 slot(mm/s^2)	13 slot(mm/s^2)
General	246	195
Skew	121	111

was performed according to the direction of magnetization.

2.4 Evaluation of automotive air-conditioning motors

As shown in Table 2, the result of carrying out the experiment of vibration by applying skew in 12 and 13 slots. It was found that the vibration was reduced. Through this study, it was confirmed that applying the skew to blower motors can produce and good performance results in the vibration area.

The cogging torque was measured by applying the skew, and 12 and 13 slots were compared with the measurement condition of 1rpm.

As a result of comparing the cogging torque by applying the skew, 12 slots had a 0.05Nm-lower result; on the other hand, 13 slots showed a 0.001Nm-lower result.

Table 3 12 and 13 slot cogging torque measurement

	12 slot		13 slot	
	General	Skew	General	Skew
Coggingtorque (Nm)	0.023	0.018	0.006	0.005

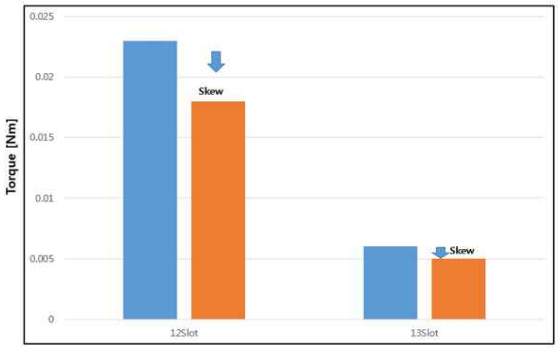


Fig. 5 Cogging torque reduction effect of Skew method

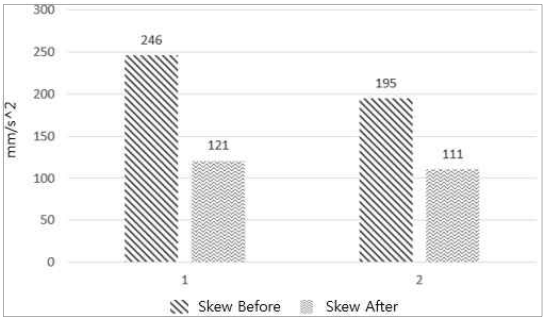


Fig. 6 Vibration test result of Skew method

3. Simulation Result

In this paper, the cogging torque was compared by applying the skew to the core to reduce the noise and torque ripple in 12 and 13 slots from the proposed method.

Figure 5 shows the results obtained by applying the proposed method. As illustrated, the cogging torque is reduced to 0.005Nm at 12 slots and 0.001Nm at 13 slots in the skew method.

Figure 6 shows the results obtained by conducting the vibration test by applying the skew method. It can be confirmed that when the skew method is applied, the vibration is remarkably reduced.

4. Conclusion

This paper described a study conducted on the torque ripple and noise reduction of blower motors for automotive

air-conditioning. Based on the results of analyzing the torque ripple factors for the blower motor and the analysis and design of motor noise factors in terms of parallel and radical magnetization patterns for 4-pole, 12- or 13-slot motors as the electromagnetic field analysis, the cogging torque of the radical magnetization pattern was lower than parallel magnetization pattern. In addition, the skew method was applied to reduce the cogging torque of the motor. Therefore, the method applied to this study was confirmed to be effective, In the future, a motor will be made using the proposed method, and its performance will be verified.

References

[1] Paresh C. Sen, “Principle of Electric Machines an d Power Electronics (2nd ed), 1998

[2] J.R. Hendershot, T.J.E. Miller, “Design of Brushless Permanent Magnet Machines”, Motor Design Books LLC, 2010

[3] EMDYNE, “JMAG”, Jmag Application Note Analysis of a Permanent Magnet Brush Motor

[4] EMDYNE, “JMAG”, Jmag Application Note Basic Characteristic Analysis of a Motor with 2 Brushes, 6 Poles, and 19 Slots

[5] EMDYNE, “JMAG”, Jmag Application Note Iron Loss Analysis of a Brush Motor

[6] Agency for Technology and Standards, 2009, "Blower motor for Automobiles", Reliability Standard, RS R 0010.

[7] F. C. McQuiston and J. D. Parker, "Heating, Ventilating, and Air Conditioning Analysis and Design", John Wiley & Sons, Inc, 1994.

[8] Jeong Yong Wook, Jeong Ku Sup, and Kim Seong Hoe, "Study of over current protecting apparatus for automobile blower motor", ICROS, Mar. 2010.

[9] Agency for Technology and Standards, 2009, "Blower motor for Automobiles", Reliability Standard, RS R 0010.

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