Optimized Design of Permanent magnet Considering Thermal Demagnetization Analysis of Synchronus Motor

Ju-Hyeong Moon*, Byung-Chan Kim*, Jong-Hun Lee*, Dong-Hwan Kim * * , Dong-Woo Kang*

Department of Electrical Energy Engineering, Keimyung University, Daegu 42601, Republic of Korea *

STARGROUPIND.CO.LTD, Daegu 42714, Republic of Korea * *

Abstract - Currently, In many fields of research for miniaturization and high efficiency of electronic parts are being conducted in order to reduce the weight and improve efficiency of electric vehicles. therefore, In this paper, the research was conducted for the purpose of optimal design to improve the efficiency of the motor and further reduce its size. We redesigned the distributed winding model into the concentrated winding model as an optimal design process by changing the winding method. The goal was to reduce the specific gravity of the motor by reducing the end coil, improve the operation efficiency of the low speed section, and increase the output by changing the winding method. However, due to the concentration of the magnetic force and the increase of the leakage magnetic flux due to the change of the winding method, the problem of the irreversible demagnetization of the magnet has occurred. In order to solve these problems, this paper analyzes the rotor design parameters that are a major factor in the irreversible demagnetization and designs the structure to improve them. Since then, we have implemented the loss reduction and efficiency improvement design through the optimization of the Stator design parameters. Through this, it was possible to design the optimum motor that has high reliability and high efficiency and miniaturization. Finally, to verify the reliability of the simulation results, load tests using dynamos were conducted and analyzed.

1. Introduction

- In this paper, the research was conducted for the purpose of optimal design to improve the efficiency of the motor and further reduce its size.
- In order to verify the sensitivity, a simulation using finite element method was performed, and an improved design was performed to find the optimal point between the required output and the demagnetization phenomenon based on the basic model of the concentrated winding with irreversible demagnetization characteristics.

2. Improvement design

A. Characteristics by the winding method

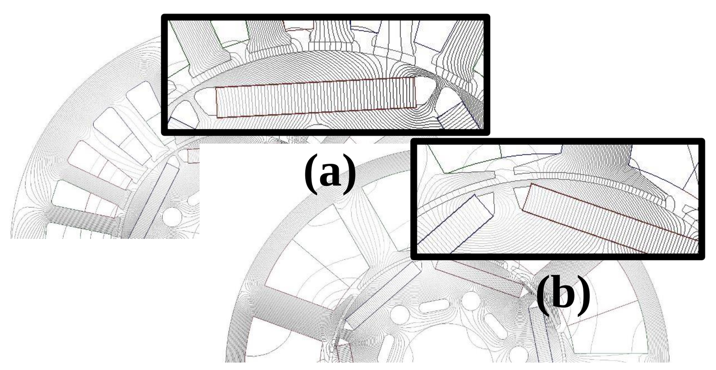

Fig. 1. Lines of magnetic force distribution in the winding method. (a) Distributed winding. (b) Concentrated winding.

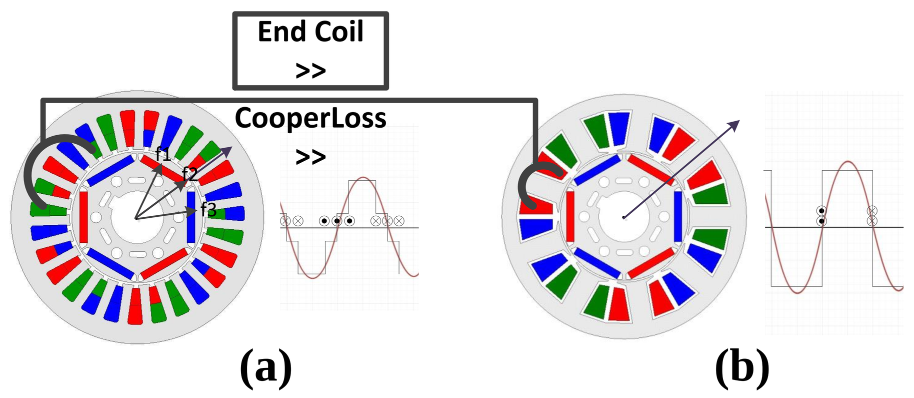

Fig. 2. Magnetic force distribution and copper loss by winding method. (a) Distributed winding. (b) Concentrated winding.

$$B_{g1} = B_m \sin(\theta - \omega t) \quad \Rightarrow \quad B_m = \frac{6\sqrt{2}}{\pi}\frac{\mu_0}{l_g}\frac{NI}{P}k_\mu, \quad (k_\omega = k_p \cdot k_d) \tag{1}$$

$$k_p = \sin\frac{\beta\pi}{2}, \qquad k_d = \frac{\sin(\pi/2m)}{q\sin(\pi/2mq)} \tag{2}$$

$$T = P_n(\psi_a i_a \cos\beta + \frac{1}{2}(L_q - L_d)i_a^2 \sin 2\beta) \tag{3}$$

B. Model improvement

- Specifications of distributed winding model

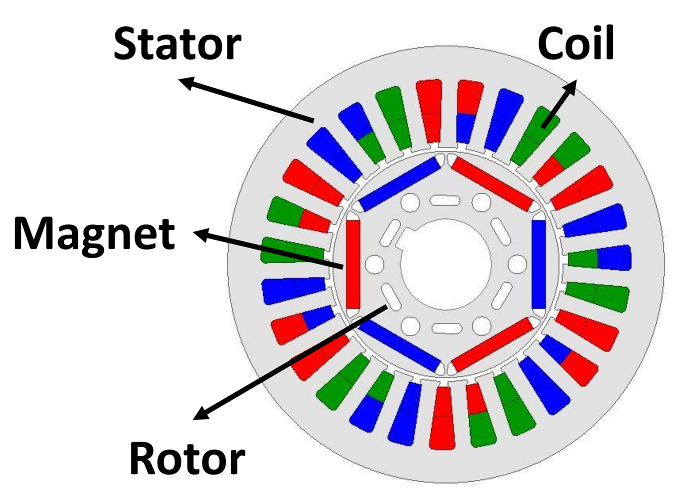

Fig. 3. Distributed winding model.

TABLE 1
SPECIFICATIONS OF DISTRIBUTED MODEL

	Value	Unit
Pole/Slot	6/27	-
Stator outer diameter	59.9	mm
Rotor outer diameter	50	mm
Stack length	50.5	mm
Total length	84.5	mm
Rated speed	6000	RPM
Magnet	NdFeB(40UH)	-
Stator/Rotor	POSCO steel (35PN250)	-

- The Stator and Rotor specifications of Table 1 should be the same, but the distributed winding model is changed to the concentrated winding model and improvement design is aimed at improving efficiency and miniaturizing the motor.

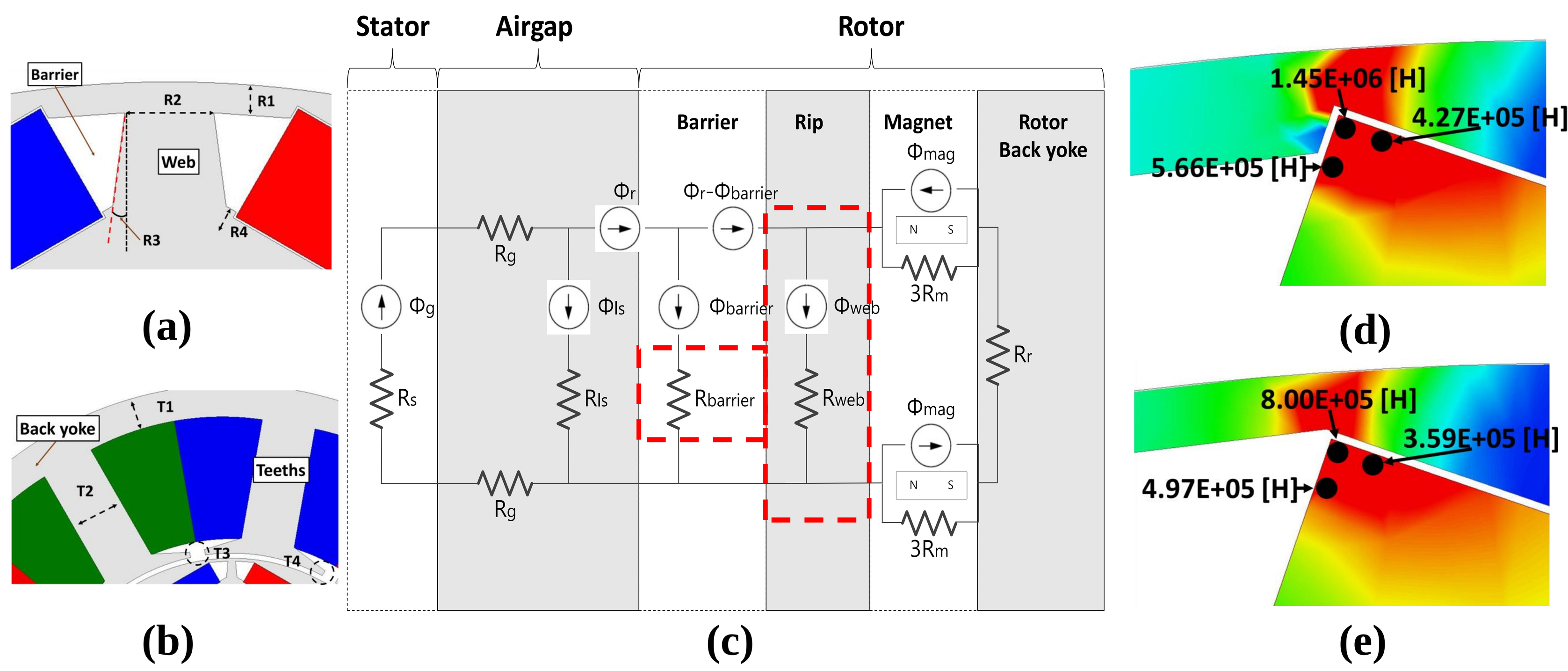

Fig. 4. Basic model of teeth concentrated winding. [Rotor] (a) Basic model. (b) Rotor shape and parameters. (c) Magnetic equivalent circuit of IPMSM type. (d) Magnetic field of Basic model. (e) Magnetic field of improvement model.

- Web and barrier are represented through magnetic equivalent circuit, and structural design that is strong against irreversible demagnetization through variation of magnetic resistance is performed.
- As the result of analysis, the smaller the size of R1 and R2, the higher the magnetoresistance of the Barrier and the less the leakage flux to the Barrier.

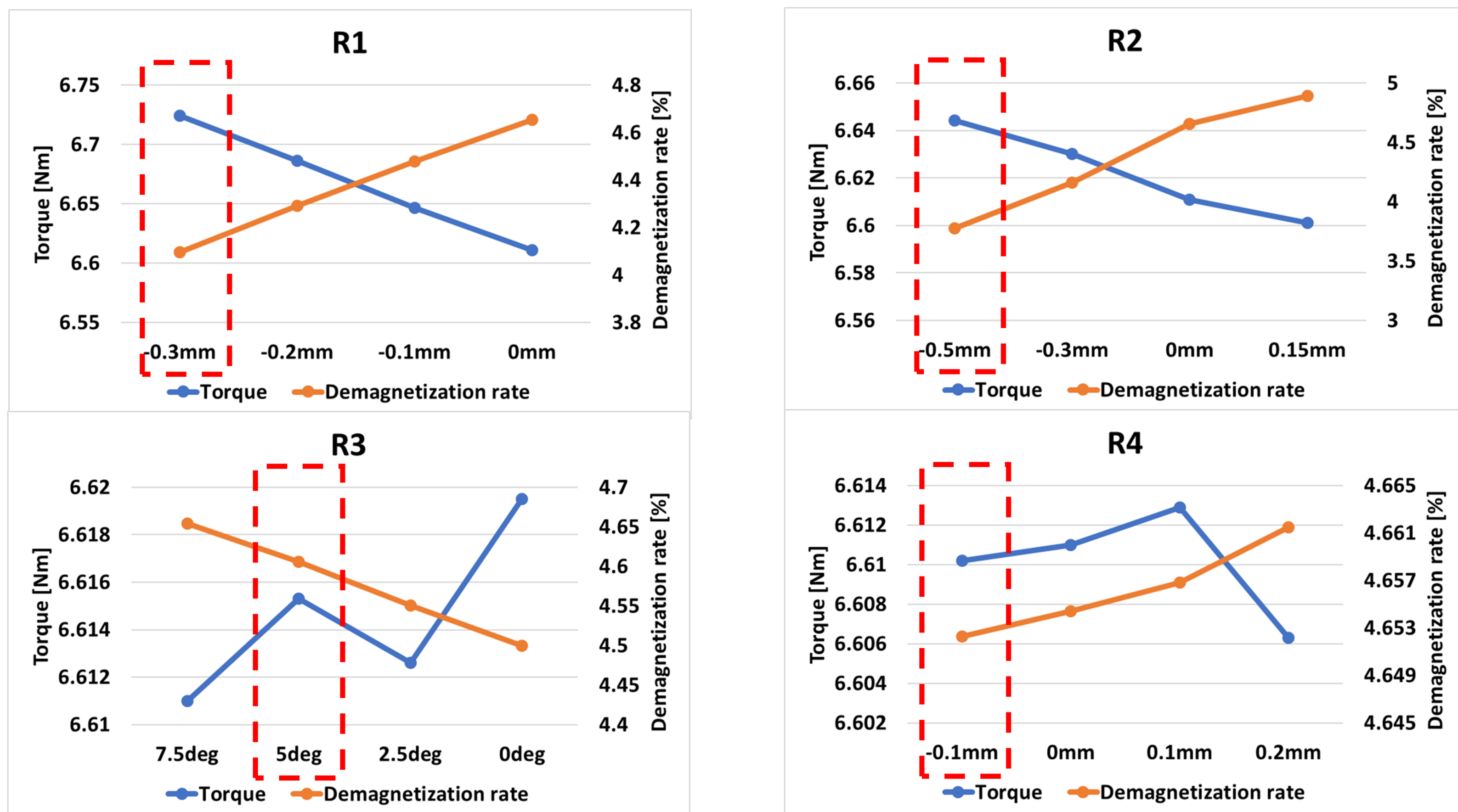

Fig. 5. Basic model of teeth concentrated winding. [Rotor] Simulation results according to the design of experiment.

- After the rotor design, the stator's output improvement design was carried out.
- As a result of analysis, T1 and T2 affect the loss due to slot fill factor and saturation, and model characteristics deteriorate when designing without understanding the characteristics.

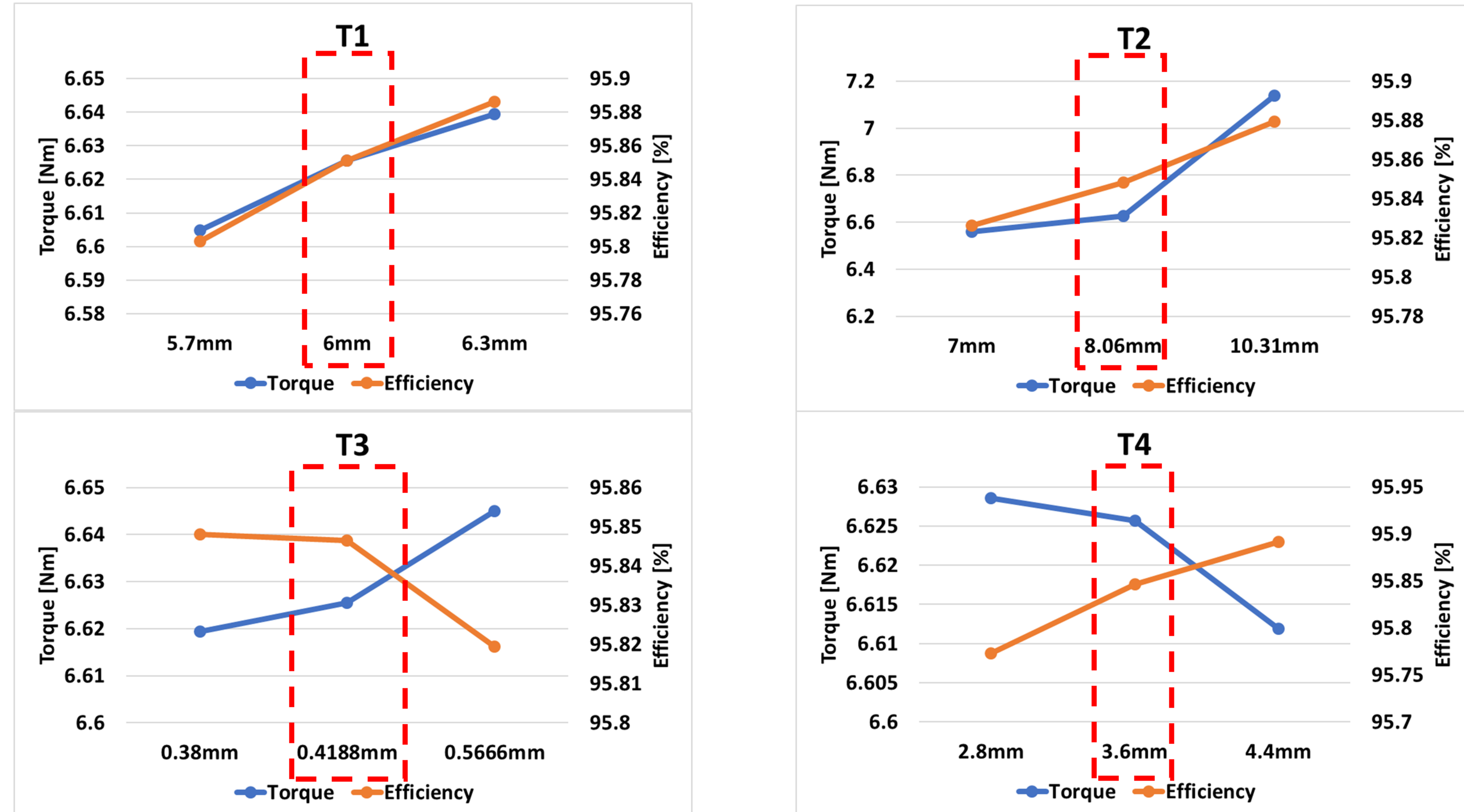

Fig. 6. Basic model of teeth concentrated winding. [Stator] Simulation results according to the design of experiment.

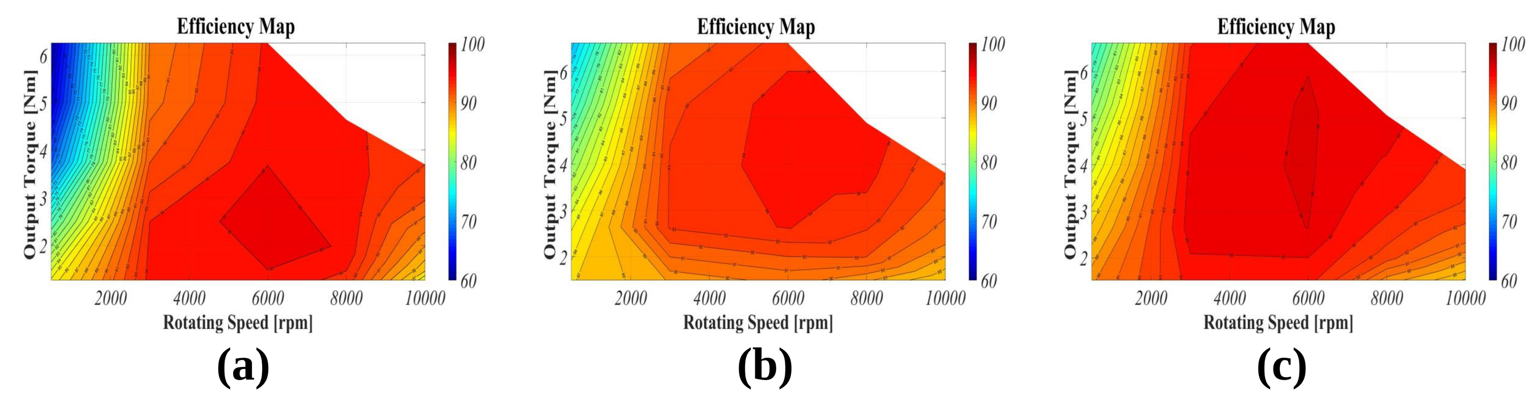

Fig. 7. Efficiency map (a) Distributed. (b) Basic model. (c) Improvement model

3. Experiment

TABLE 2
SIMULATION RESULTS OF THE IMPROVEMENT DESIGN MODEL

	Target (simulation/experiment)	Simulation	Experiment	Unit
Torque	6.6/6.1	6.61	6.33	Nm
Output power	4.0/3.8	4.08	3.99	KW
Efficiency	95/91	95.81	94.9	%
Output power density	0.01	0.012	0.0113	W/mm^3
Rated speed	6000	6000	6000	RPM
Stack length(total length)	50.5(84.5)	48.8	49(71)	mm
Coil resistance	-	0.0777	0.077	Ω

Conclusion

Through this paper, it is possible to improve the efficiency by reducing the copper loss by changing the winding method of the motor having the wide range of low speed operation, and to confirm the model size reduction by the improved output. In addition, when designing the concentrated winding model, attention should be paid to the irreversible demagnetization due to the concentration of magnetic flux, and the method for reliable design could be suggested by suggesting the method to improve this.