A Study on Design of Magnetization Yoke of Ferrite Spoke-Type Permanent Magnet Synchronous Motor considering Demagnetization

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The study proposed a design of magnetization yoke of ferrite spoke-type permanent magnet synchronous motor. A high magnetic field intensity(H) is required for the magnetization of permanent magnet, meaning that the analysis of nonlinear finite elements methods is needed considering saturation of core. The permanent magnet is placed deeply to the shaft especially in spoke-type motor. The high H, however, may cause demagnetization of surrounding permanent magnets, making the design of spoke-type magnetization yoke to be difficult. This study proposes the interpole winding to reduce the demagnetization of surrounding permanent magnets and analysis of power supply source considering magnetizer, derives the structure of optimized magnetization yoke to meeting the criteria of magnetization and demagnetization by analyzing field, and finally verifies the results of this study by manufacturing and testing.

***Index Terms*— Permanent magnet motors, Magnetization**

I. Introduction

The rare earth free permanent magnet motor has been developed, in recently, capable of reaching the torque density almost identical to that of rare earth permanent magnet by using ferrite magnet, because of price instability of rare earths. The ferrite magnets have advantages that it, unlikely to rare earth magnet, causes no eddy current loss because of absence of conductivity and is cheaper than rare earth magnet by five times. The ferrite magnet, however, have problems in meeting requirements of high output because of lower residual magnetic flux density and coercive force than rare earth magnet by four times. The application of spoke-type structure as shown in Fig. 1, the magnetic flux is concentrated and become effective structure for demagnetization. For the mass production, the permanent magnet should be inserted into rotor before magnetization. The existing bar-type permanent magnet is easy for magnetization while the spoke-type one is difficult for magnetization. because the permanent magnet placed deeply to the shaft. The demagnetization phenomenon of surrounding permanent magnet due to high magnetic field intensity(H) should be considered also. The purpose of this study was, therefore, to present a design method of ferrite spoke-type permanent magnet motor fulfilling those conditions mentioned above.[1][2]

II. Body(Magnetization Yoke Design)

Fig. 2 shows the structure of ferrite spoke-type motor of 10 pole and 12 slot. The method for magnetizing rotor is determined by the number of magnetization as shown in Fig. 3. Table 1 shows the specification of power supply for magnetizer and material of permanent magnet. The determination of achievement of magnetization is performed by using I_{hc} values appeared in initial magnetization curve of permanent magnet. The analysis of current source was also performed in review of basic design. The review of basic magnetization yoke showed that the appropriate number of magnetization is five. It is decided, however, that the number is too high for mass production, therefore a structure of minimize times magnetization yoke capable of magnetizing four permanent magnets, as shown in Fig. 3. The required total H, however, increases as the decrease of the number of magnetization, resulting in significant demagnetization of permanent magnets other than target one, leading to the needs for interpole core structure capable of changing the direction of magnetic flux. The interpole core structure is referred in many studies and used actually. The permanent magnet is demagnetized significantly, however, in existing three-times magnetization yoke despite the installation of interpole core because of high magneto motive force(MMF) as shown in Fig. 4(a). The installation of the interpole winding is proposed, therefor, to counterbalance the magnetic flux. The interpole winding reduced the phenomenon of demagnetization significantly as shown in Fig. 4(b), therefore, the design of minimized magnetization yoke was performed as considered above. The power supply specification of magnetizer was considered in designing by analyzing power supply source. The structure in Fig. 5 is the resulting detail design to maximize the capacities of magnetization and demagnetization. Table 2 is the performance did not decreased much even in comparison with finite element analysis excepting for demagnetized parts. The magnetization of rotor was performed by using manufactured magnetization yoke according to the design. The Table 3 shows the results of noload back emf test of magnetized rotor, indicating that the 97% and more of permanent magnet is magnetized with the decrease of back emf by under 3%.[3]

III. Conclusion

The rotor magnetization yoke electromagnetic field of ferrite spoke-type permanent magnet synchronous motor was designed and manufactured. The structure of interpole core and compensating winding were proposed in order to maximize the low magnetization and demagnetization performance, a shortage of spoke-type ones. The structure of magnetization yoke capable of minimizing the number of magnetization is also presented.

IV. References

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V. Tables & Figures

TABLE I
MAGNETIZATION SPECIFICATIONS

Specification	Value	Unit
Input Current	10k	A
Magnetizer Voltage	4500	V
Magnetizer Capacitance	5000	uF
Magnetizer Yoke Core	S20C	
Magnet Type	Ferrite (12grade)	0.45T(20deg)
Magnetizing I_{hc}	340k	A/m
Demagnetization H	-290k	A/m

TABLE II
COMPARISON FEM OF YOKE DESIGN AND NON YOKE DESIGN

Efficiency / Temp	-20ºC	20ºC	50ºC	80ºC	110ºC	130ºC
Non Design Magnetization Yoke[%]	97.3	97.0	96.7	96.2	95.52	94.9
Final Design Magnetization Yoke[%]	97.44	96.98	96.67	96.05	95.3	94.66
VS Efficiency [%]	**-0.06**	**-0.02**	**-0.03**	**-0.15**	**-0.22**	**-0.34**

TABLE III
COMPARISON TEST OF BACK-EMF

No.	EMF			
	Phase Emf		L-L EMF	
	EMF	Magnetization	EMF	Magnetization
Standard Rotor (Non Yoke)	35.10	100% (Standard)	60.78	100% (Standard)
Rotor 1 (Final Yoke)	34.80	99.16%	59.80	98.39%
Rotor 2 (Final Yoke)	33.82	96.37%	58.73	96.61%

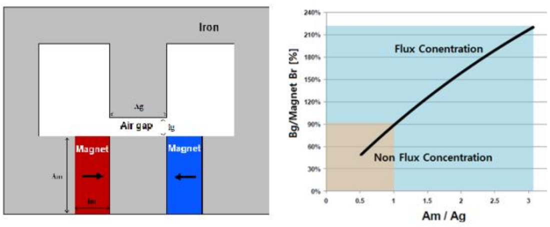


Fig. 1 Characteristics of Flux Concentration Magnet Flux

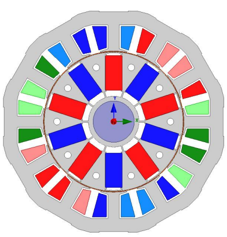


Fig. 2 10p12s Ferrite Spoke-Type Permanent Magnet Motor

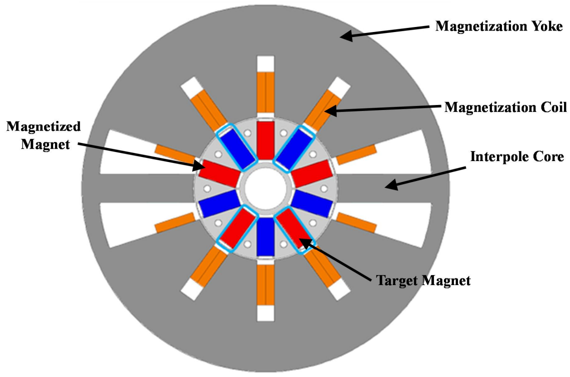
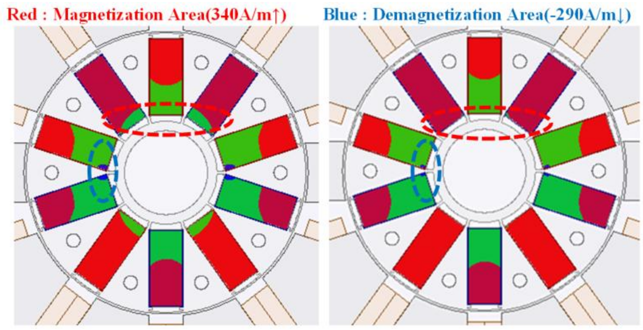
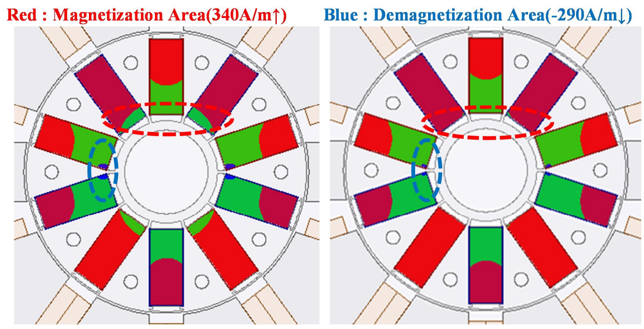


Fig 3. Basic Yoke Model of Minimized Magnetizatization



(a) Non Interpole winding (b) Interpole winding

Fig 4. Rotor Magnet Magnetizaion Area



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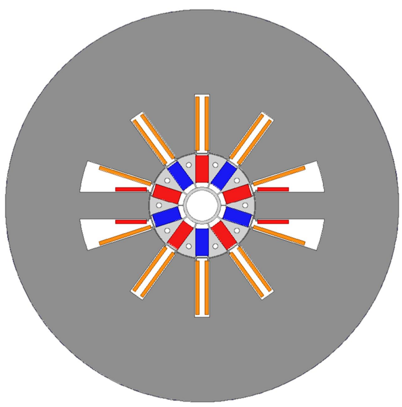

Fig 5. Final Model of Magnetization Yoke