Physics

Electricity & Magnetism fields

Okayama University *Year* 2005

Optimal design of efficient IPM motor using finite element method

Takuma Ohnishi
Okayama University

N. Takahashi
Okayama University

OPTIMAL DESIGN OF EFFICIENT IPM MOTOR USING FINITE ELEMENT METHOD

T.Ohnishi and N.Takahashi
Dept. Electrical and Electronic Eng., Okayama Univ., Okayama 700-8530, Japan

Introduction

The interior permanent magnet (IPM) motor has many advantages, such as high efficiency etc., then this motor is becoming widely used not only in home application like air conditioner but also electric vehicle. Although the investigation of optimal design of IPM motor is important, the analysis of IPM motor using the finite element method and the optimization method is very few. Because the mesh generation at each step of rotation is troublesome and the practical optimization technique with small number of iterations is not demonstrated for the design of such a motor.

In the paper, techniques for the optimal design of permanent magnet motor considering rotation are investigated. The nonconforming mesh[1], the combined experimental design method and Rosenbrock method[2] are introduced for practical design. The usefulness of the optimal design method is illustrated by applying it to the design of IPM motor with small volume of permanent magnet and with low torque ripple.

Model of IPM Motor

Fig.1 shows the model of IPM motor. The core is made of non-oriented silicon steel, and the NdFeB magnet (Br=1.25T) is inserted in the rotor. the number of turns of the winding per phase is 140 and the rated current is 3A (rms).

The length d, the width L, the depth h of permanent magnet and the phase angle θ of current are chosen as design variables.

Techniques for Optimal Design

The meshes of stator and rotor are generated separately, then both meshes are combined at the respective rotor position using the nonconforming mesh technique[1]. Fig.2 shows the whole mesh and enlarged mesh near air gap. The white and black circles are nonconforming nodes. The nodal force method [3] is used in the calculation of torque. In order to speed up the search of optimal value, the experimental design method (EDM) is combined with the Rosenbrock's method (RBM)[2]. The optimization is carried out so that the volume V of permanent magnet or torque ripple becomes minimum under the constraint that the torque is not less than 1.9 N¥m. The objective functions W are chosen as follows:

[minimum volume of magnet]

$$W = V / V_0 + P \tag{1}$$

$$P = \begin{cases} 0 & (T \geq 1.9) \\ 10 \times (1.9 - T) & (T < 1.9) \end{cases} \tag{2}$$

[minimum torque ripple]

$$W = T_{max} - T_{ave} + P \tag{3}$$

where subscript (0) denotes the value at initial shape. P is the penalty function defined in (2).

Optimization and Discussion

The optimization using only RBM and that using the combined method of EDM+RBM are examined. Table I shows the results of both technique. The table denotes that the combined method of EDM and RBM (caseB) is effective from the viewpoint of shorter CPU time. About 40% of volume permanent magnet can be reduced (caseB). Fig.3 shows the flux distribution at final shape (caseB).

About 20% of torque ripple can be reduced. The detailed result of low torque ripple will be shown in the full paper.

References

[1] K.Muramatsu, T.Nakata, N.Takahashi and K.Fujiwara, *IEEE Trans. magn.*, vol.27, no.6, pp.5211-5213, 1991.
[2] N.Takahashi, et al., *ibid.*, vol.34, no.5, pp.2996-2999, 1998.
[3] A.Kameari, *Int. Jour. Applied Electromagnetics in Materials*, vol.3, pp.231-240, 1993.

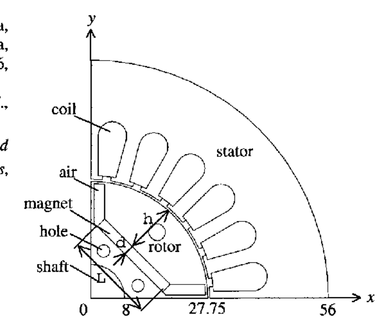
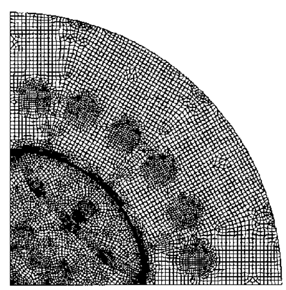
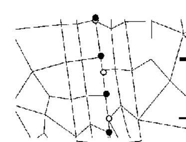


Fig.1 Model.



(a) whole view



(b) enlarged

Fig.2 Meshes (final shape).

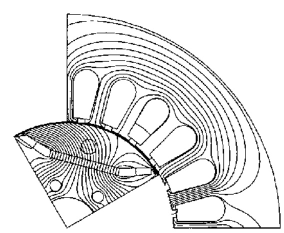


Fig.3 Flux distribution (final shape).

TABLE I
COMPARISON OF OBTAINED RESULT

case	d (mm)	L (mm)	h (mm)	- (deg.)	volume (-10^3mm^3)	torque (N¥m)	number of iterations	CPU time (h)
initial	2.50	20.5	12.0	30.0	3.33	2.09	-	-
A	1.92	18.6	8.89	32.3	2.31	1.90	93	27.8
B	1.54	20.2	8.50	33.5	2.02	1.90	56	17.2

computer used VT-Alpha533(SPECfp95:22.5)
case A: only RBM
case B: EDM + RBM