Minimization of Iron Loss of 600W IPMSM by Quasi-Newton Method

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In this paper, the design of iron loss minimization of 600W was performed by using Quasi-Newton method. Stator shoe, the width of stator teeth and yoke, and the length of d-axis flux path were selected as design parameters, and the output characteristics according to each design variable were considered. The objective function was set to minimize iron loss.

Index Terms*—*Newton method, Cost function, Design optimization, Magnetic losses, Minimization methods

I. Introduction

These days, it is possible to perform electromagnetic analysis very quickly with the developement of high-performance CPU, so that the importance and necessity of designing motors by fast and efficient optimization algorithm are increasing more rapidly [1].

The IPMSM has the advantage that it is structurally possible to operate at high speed by inserting the permanent magnet into the rotor [2]. However, high iron loss occurs due to high driving frequencies at high speed, and the risk of efficiency reduction is high because of permanent magnet demagnetization by rising temperature. Since the loss in electric machinery is an important factor determining the operating conditions and efficiency of equipment, it is very important to design with predicting these losses precisely [3].

In this paper, the change of characteristics was considered according to design variables defined using the Quasi-Newton method which is one of optimization methods based on numerical analysis. Also, the process of optimization algorithm was considered by analyzing the behavior of design variables, and this is compared with losses and aspect of efficiency changes.

II. Design variables and objective function

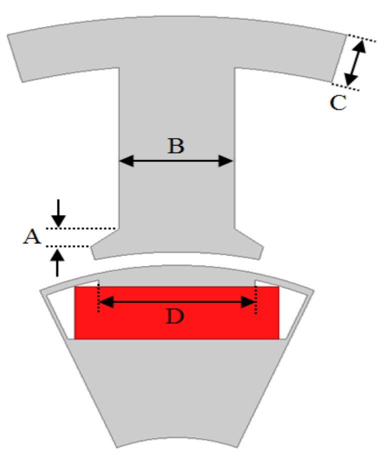


Fig. 1. The design parameters

The design parameters for the optimization of magnetic circuit are shown in Fig. 1. A is the width of stator shoe, B is the width of stator teeth, C is the width of stator yoke and D is the length of the d-axis flux path. Table I shows the minimum and maximum variable value of each design parameter for optimization.

TABLE I

Design Variables and Variable Range

Items	A	B	C	D
Minimum value [mm]	0.5	4.3	3.5	10
Maximum value [mm]	1.21	7.4	4.3	13
Nominal value [mm]	1.21	4.3	4.3	0

III. Optimization result

The result of the design using the optimization algorithm is shown in Fig. 1. The cost was set to converge at less than 0.0001, and the final convergence was 0.0003 after 77 times of optimizations progressed.

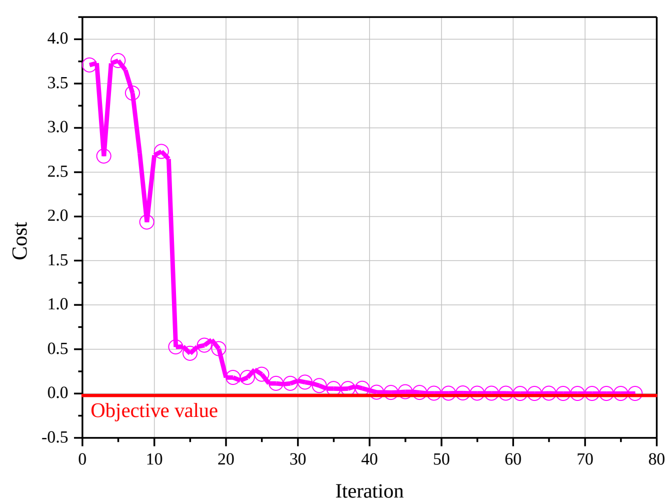


Fig. 2. Cost convergence result of optimization algorithm

Fig .3 shows the behavior of loss and efficiency with the progress of optimization, and Fig. 4 shows the behavior of the variable due to the progress of optimization.

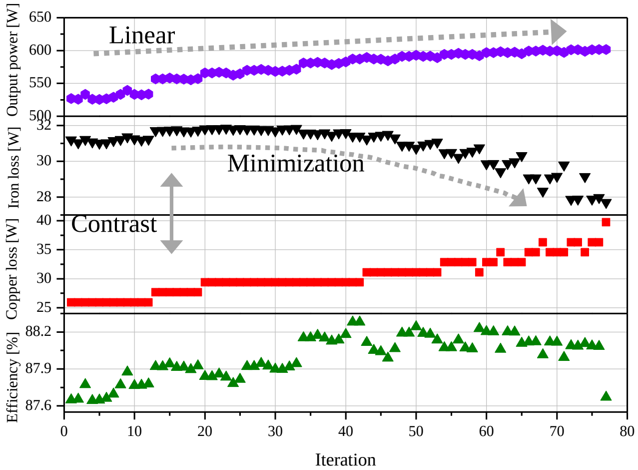


Fig. 3. Loss and efficiency according to iteration

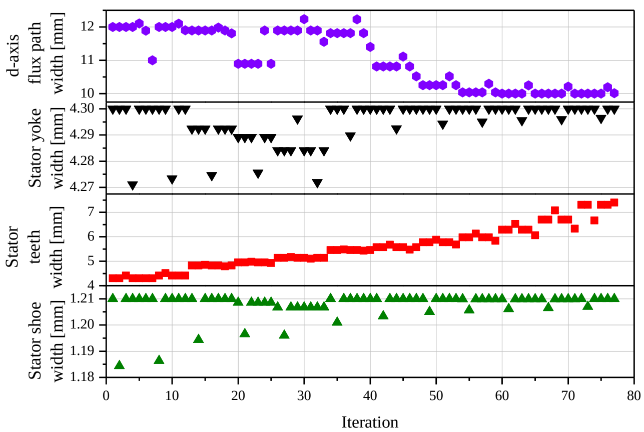


Fig. 4. Design variables according to iteration

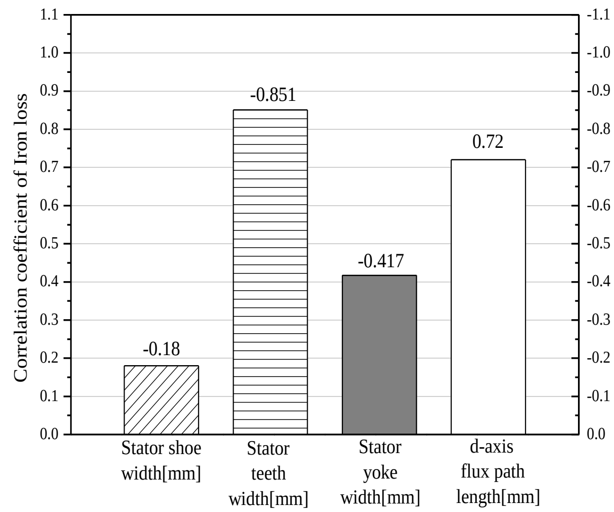
TABLE II

CORRELATION BETWEEN LOSS AND EFFICIENCY FOR EACH VARIABLE

	A	B	C	D	Copper loss	Iron loss
B	0.254 0.026					
C	0.062 0.595	0.394 0.000				
D	-0.247 0.030	-0.830 0.000	-0.427 0.000			
Copper loss	0.244 0.032	0.979 0.000	0.332 0.003	-0.845 0.000		
Iron loss	-0.180 0.118	-0.851 0.000	-0.417 0.000	0.720 0.000	-0.825 0.000	
Efficiency	0.236 0.039	0.639 0.000	0.390 0.000	-0.573 0.000	0.538 0.000	-0.262 0.021

Thus, the design has been performed with clear goals by the optimization algorithm, and it is clear that each variable were given meaning to achieve its goal under decision of the algorithm.

However, the relationship between the change in loss and the design variables is still unclear, so it is analyzed by applying the above-mentioned basic statistics. Correlation coefficient and P - value were calculated for analyzing the correlation between design variables and design results. It can be seen in Table II. The upper numerical value in each cell is a correlation coefficient as an index for indicating the relationship between two variants, and its value has $-1 \leqq r \leqq 1$. The sign indicates the direction of the relationship, and the absolute value is the size of relation. The numerical value in the lower part shows the P - value and it means the probability that the correlation coefficient is false [4].



.Fig. 5. Correlation coefficient between each variable and iron loss

Fig. 5 shows bar graph representing the correlation coefficient between each variable and the iron loss. In conclusion, the variable B has the greatest influence on iron loss and it must be sure because P-value is 0. The above results of Table II and Fig. 5 are statistically derived, which will be examined in detail and the meaning of the statistics will be described in full-paper.

A. References

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