Robust Optimization of Electric Machine Using Response Surface Methodology

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Abstract **– This paper describes an approach to robust design of electric machine to enhance the robustness. The approach is based on the Response Surface Methodology and the estimated model is used to minimize the total sensitivity of design variables. A validity of this approach is verified through comparing the robust solution with the normal result obtained by a conventional optimization procedure.**

INTRODUCTION

An optimization of electric machine is used to obtain a most economical approach to improve the motor performance. However, a small variation of design variables in the optimization can affect the product performance, in terms of operating efficiency and reliability and so on [1]. Therefore, the design technique considering the variation of the variables is required to minimize the total sensitivity of the variables, which makes the performance unstable. In this paper, we present the robust optimization technique, which considers the variation, to find the robust optimal solution and apply to reduce a torque ripple of a BLDC Motor. Using the technique based on the RSM [2], the robust design is achieved by minimization of the total sensitivity concerning design variables.

CALCULATION METHOD AND RESULT

Three design variables are considered for the reduction of the torque ripple as shown in Fig. 1. In order to obtain the robust optimal solution, the new objective function, which considered the small variation, is defined as follows:

$$\text{Minimize: } \varphi(x) = \alpha \cdot f(x) + (1-\alpha)\cdot \Delta f(x) \quad (1)$$

$$\text{Subject to: } g_i(x_1, x_2, \ldots, x_k) = 0, \quad i = 1, 2, \ldots, m \quad (2)$$

$$x_{iL} \le x_i \le x_{iU} \qquad i = 1, 2, \ldots, k \quad (3)$$

where, α is a weighting factor determined by designer and the variation of objective is obtained by Taylor expansion.

$$\Delta f(x) = \sum_{i=1}^{k} \left| \frac{\partial f(x_1, x_2, \ldots, x_k)}{\partial x_i} \right| \times \Delta x_i \quad (4)$$

When the variation of design variable occurs, it is assumed that the system response has distributed variations and the less variance of the system response is more robust. The sequential quadratic programming method has been commonly used to minimize the objective function that satisfies the constraint in this paper.

The aim of the sensitivity analysis is to reduce deviation in the torque ripple by reducing the sensitivity of design variables. Fig. 2. shows variation and variance of torque ripple according to the weighting factor. A selection of the weighting factor controls the balance between the minimization and variation. Higher weighting factor (α) leads

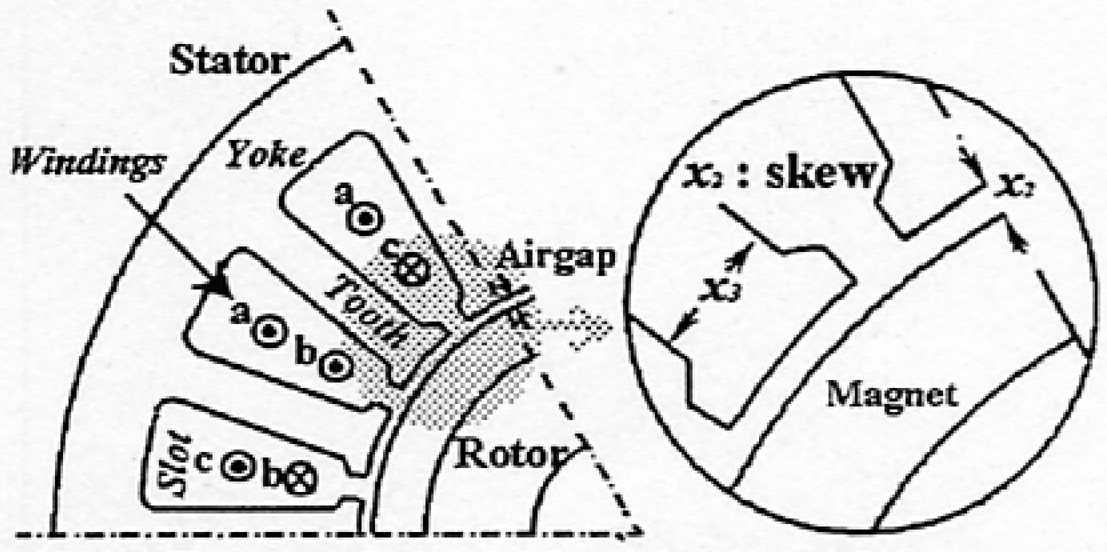

Fig. 1. Analysis model and design variables

to smaller variation while it shifts to larger torque ripple. The analysis of variance is carried out to investigate improved robustness in torque ripple. It is assumed that the variations of design variables are from 0(%) to 10(%), the analyses of variance are archived by Monte Carlo Simulation. At the results, Fig. 3. shows that the variance of the robust design point is smaller than that of the normal design point. Distributions of output variation are predicted as shown Fig. 4. In the final paper, these points plus further results and a detail of this method will be given.

REFERENCES

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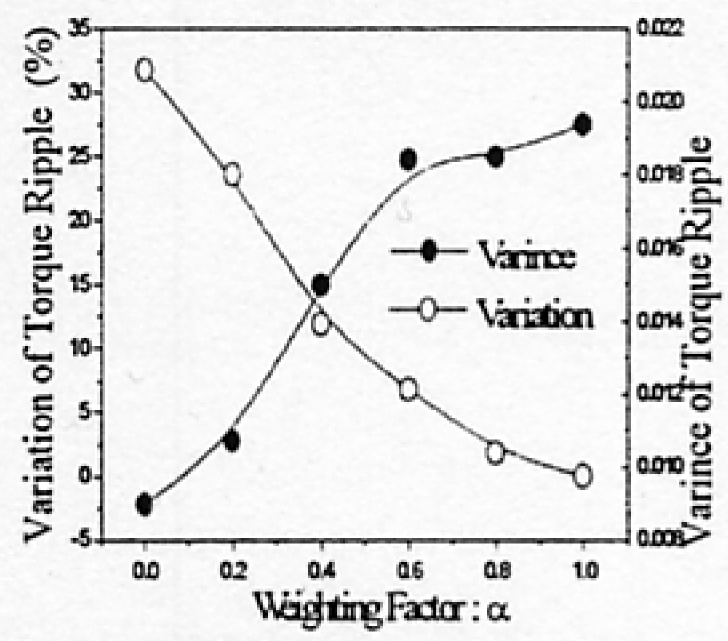

Fig. 2. Statistical properties of torque ripple according to weighting factor

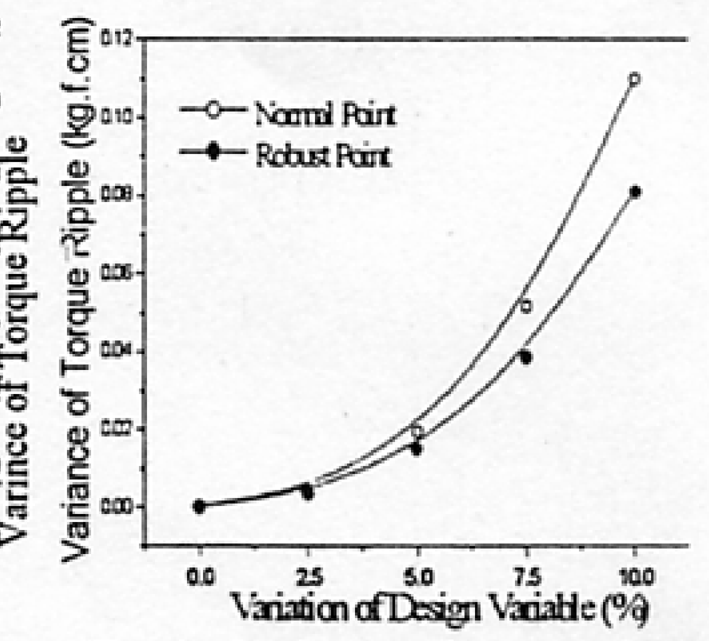

Fig. 3. Variance of torque ripple according to variables variation

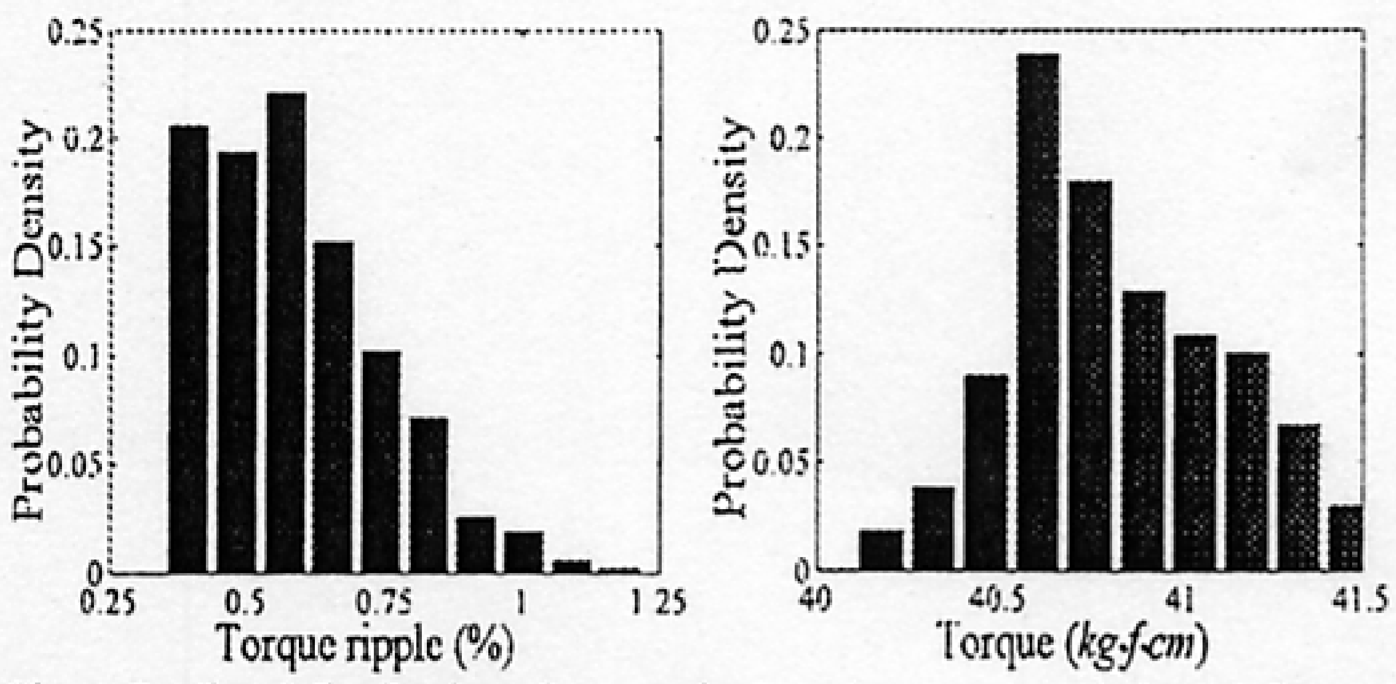

Fig. 4. Predicted distribution of torque ripple and torque at variation 10 (%)