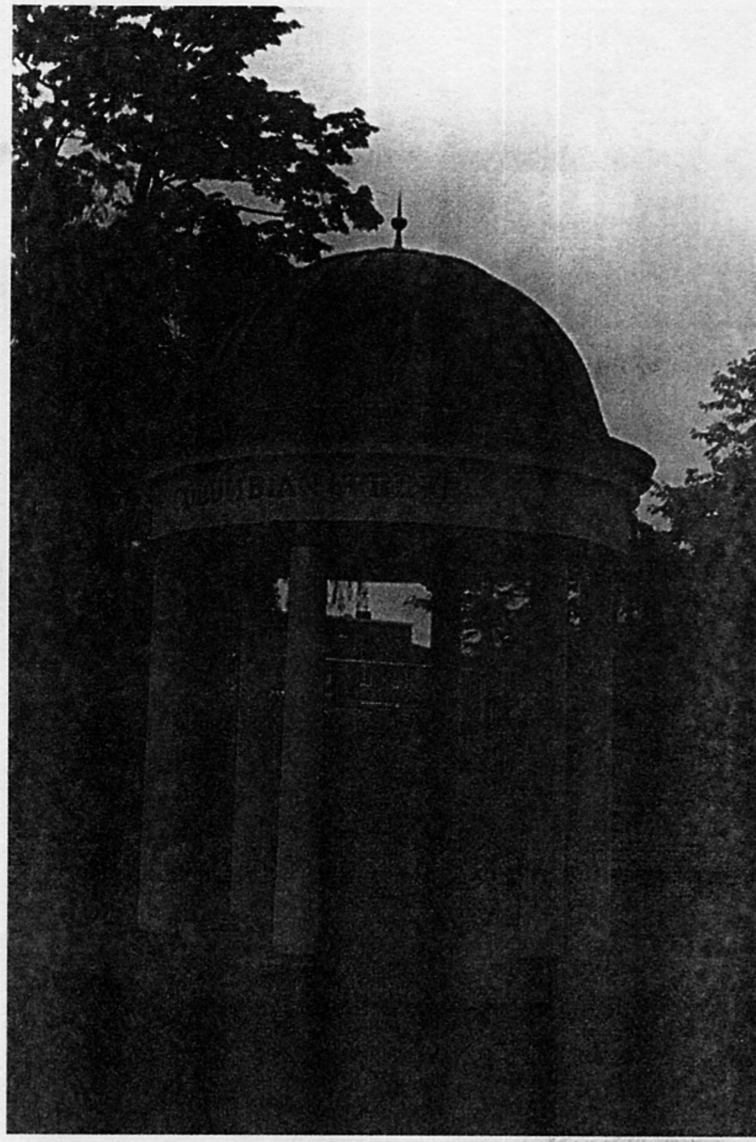

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Prediction of Torque Characteristic on Barrier Type SRM Using Stochastic Response Surface Methodology Combined with Moving Least Square

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***Abstract*—This paper describes a design of switched reluctance motor with rotor poles having inserted barriers. A shape of the rotor barrier leads to improvement of torque characteristics. As well, dimensional tolerances of the barrier directly affect electrical performances of the motor. Therefore, the torque characteristic prediction of the motor is accomplished by a combination technique employing Stochastic Response Surface Methodology and Moving Least Square Method.**

INTRODUCTION

Switched Reluctance Motor (SRM) has some advantages, such as, a high speed, efficient variable speed and a high reliability. Therefore, an application of switched reluctance motors is recently received attention in various industrial fields. However, a SRM is strongly nonlinear and suffer from high torque ripple. Also, the torque per volume of SRM strongly depends on the designed shape of salient poles. This paper proposed a barrier type SRM, which is designed by inserting separated barriers in the rotor. Separated barriers lead the reduction of a torque ripple and the improvement of torque performances. What is more describing in this paper, dimensional tolerances of electric machines can effect on electrical performances, and besides, the larger tolerance in manufacturing processes, the lower it is to cost of manufacturing electric machines [1]. A design of the barrier type SRM needs allowance for dimensional tolerances on especially barrier part of the SRM, beacuse of limitations on the manufacturing , measuring precision and so on.

Therefore, the design techniques are required to find the tolerance band of design variables in order to minimize the cost and satisfy required performance. The torque charectristic, according to tolerances of the dimensional barrier, of barrier type SRM is predicted by using Stochastic Response Surface Methodology (SRSM). SRSM can be illustrated as an extension of Response Surface Methodology (RSM), and it is then combined with Moving Least Square (MLS) to ehance the accuracy of stochastic response modeling in SRSM.

STRUCTURE OF BARRIER TYPE SWITCHED RELECTANCE MOTOR

Fig. 1 shows the proposed barrier type 8/6 SRM, which is designed to improve torque characteristics. With a proposed rotor inserted the flux barrier, the motor characteristics seriously vary according to the shape of flux barrier. Therefore, the geometric shape design of the barrier is required to find the design variables that consider manufacturing tolerance as well as improve the performance and exactly predict the torque characteristics. These tolerances can affect the machine performance, such as operating efficiency.

FRAMEWORK FOR TOLERANCE ANALYSIS

Stochastic Response Surface Methodology

In the SRSM, a relationship of the uncertainty between the outputs and inputs is addressed by the series expansion of standard normal variables in terms of Hermite polynomials. The output function can be approximated by an polynomial chaos expansion and the approximation is sampled to calculate a statistical distribution of outputs as described in [1].

Moving Least Square Method

Unknown coefficients of the Stochastic response modeling are estmated by MLS method. The main idea of the MLS method is that a whole approximation $U^h(x)$ of a sampling space can be accomplished by going through a moving proess and written as follows [2]:

$$U^h(x) = \sum_{j=1}^{N} \mathbf{P}(0)^T \mathbf{M}(x)^{-1} \mathbf{P}(x - x_1) \mathbf{W}(\bar{x} - x_1) \mathbf{U}_1 \quad (1)$$

$$\mathbf{M}(\bar{x}) = \mathbf{P}\,\mathbf{W}(\bar{x})\,\mathbf{P}^T \quad (2)$$

where **W** is weight function having form of a quartic spline, **P** and **U** are composed with a set of sample point regarding design variables and outputs, respectively.

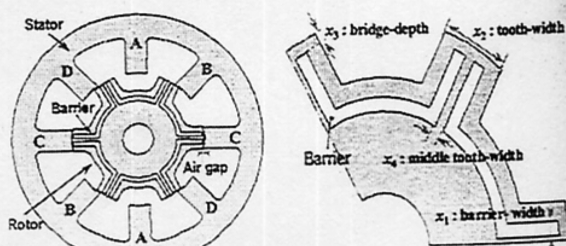

Fig. 1. Analysis model and design variables

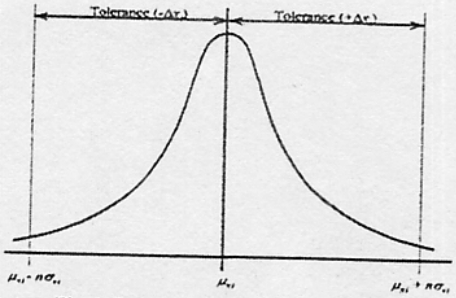

Fig. 2. Tolerance band of design variables

Introductory Statistics for tolerance Analysis

A variation band of design variables with assuming the distribution of a normal distribution is show in Fig. 2. In this symmetrical distribution, the tolerance band of design variables is easy to quantify in terms of the percentage of the area that will occur between one, two and more standard deviation from the mean μ as follows [1];

$$\Delta x = \quad n\sigma \quad (n = 1, 2, 3, \cdots) \tag{2}$$

Modeling variation of outputs according to tolerance of design variables is built by the SRSM. From a set of N samples, the basic moments of the distribution of an output y_i can be calculated as follows;

$$\mu_{y_i} = \mathrm{E}\{y_i\} = \frac{1}{N}\sum_{j=1}^{N} y_{i,j} \tag{3}$$

$$\sigma_{y_i}^2 = \mathrm{E}\{(y_i - \mu_{y_i})^2\} = \frac{1}{N-1}\sum_{j=1}^{N}(y_{i,j} - \mu_{y_i})^2 \tag{4}$$

$$\sigma_{y_i} = \sqrt{\sigma_{y_i}^2} \tag{5}$$

where, μ_{yi} is a mean, σ_{yi}^2 is a variance and σ_{yi} is a standard deviation, respectively.

RESULTS AND DISCUSSION

Fig. 3 shows the torque profile of one stroke of the proposed motor, the electromagnet field within the motor is computed by using the two-dimensional finite element method (2D-FEM). And then the manufacturing process is running at the design variable tolerance of 10 (%) based on the six-sigma level. The variation of the outputs is distributed as shown in both Fig. 4 and Fig. 5, which are concerned about both the average torque and the torque ripple, respectively. In order to reduce the scatter of outputs from their population, design variables need to be regulated at a tighter tolerance than 10 (%).

CONCLUSIONS

In this paper, the barrier sailent pole applied to the rotor of conventional SRM to a enhancement of the torque performance, and it is then accomplished by tolerance analysis to predicte torque variations according to the geometric shape of the barrier. Tolerance analysis is achieved by SRSM combined with MLS method. From the result, proposed approach will provide a great potential for improving robustness of production and reducing production cost. In full paper, more detailed descritions of tolerance analysis will be presented.

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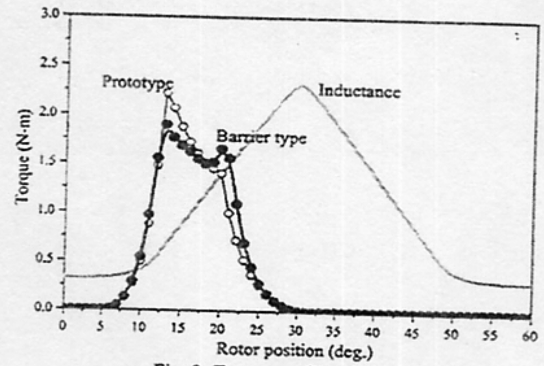

Fig. 3. Torque profile of one stroke

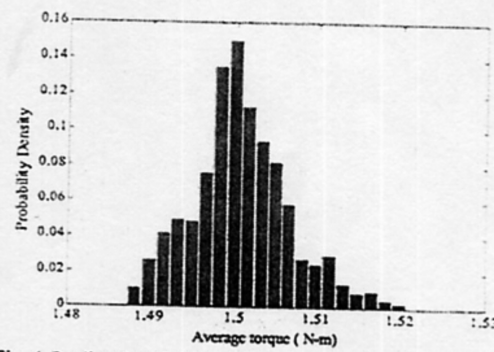

Fig. 4. Predicted probability distribution for the average torque.

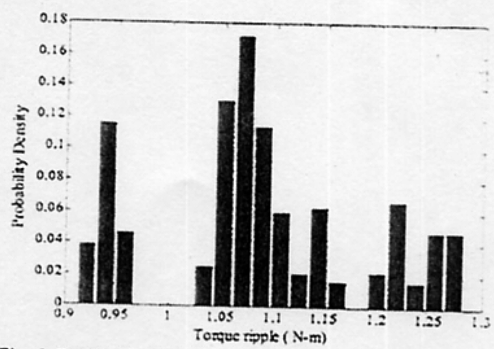

Fig. 5. Predicted probability distribution for the torque ripple.