Optimum Design Criteria of 250 kW Premium Efficiency Traction Induction Motor Using RSM & FEM

Jung Ho Lee *Member IEEE*, Soon Myung Jang, Byeong Du Lee
Dept.of Electrical Engineering, Hanbat National University
Dukmyung-Dong Yuseong-Gu, Daejeon, 305-719, KOREA
E-mail: smjtown@naver.com

Abstract — This paper deals with the optimum design criteria for the premium efficiency of 250kW traction induction motor, using response surface methodology (RSM) & finite element method (FEM). The focus of this paper is found firstly a design solution through the comparison of torque according to rotor bar shape, rotor dimensions variations and, secondly, a mixed resolution with central composite design (CCD) is introduced and analysis of variance (ANOVA) is conducted to determine the significance of the fitted regression model. The proposed procedure allows to be optimized the rotor copper bar shape, rotor slot, rotor dimensions starting from an existing motor or a preliminary design.

I. INTRODUCTION

Recently, saving energy is a most important task in the world. Thus, obtaining high efficiency electrical machines and apparatus is a very important task.

Induction Motors are very important in industry. For many years, the efficiency of three-phase induction motors has been the subject of numerous investigations aimed at increasing efficiency values by minimizing losses during the operation.

Induction motor design principles have not changed dramatically over the years, whereas the tools and the knowledge of engineers have improved considerably.

This better understanding has led to continuous improvements for reducing losses in electric motors.

Systematically analyzing the root causes of losses and the possibilities for improvements requires a complete and new approach, looking into not only the electrical area but also mechanical areas such as cooling, temperature levels, and outer diameter (OD) versus length ratio, etc. In this article, we apply a systematic and optimized new design approach for 250 kW Traction Induction Motor.

The electromagnetic factors for improving efficiency are as follows:

1) increase the amount of active material
2) utilize high-performance lamination materials
3) optimize the rotor geometries
4) optimize the air gap dimensions

All the factors have to be carefully looked at and investigated, because most of them are not independent from each other and may negatively influence the efficiency gains in one case or the other. Secondly, the commercial impacts have to be strongly considered, since with higher efficiency the premium paid may limit the savings seen.

The RSM has been achieved to use the experimental design method in combination with Finite Element Method and well adapted to make analytical model for a complex problem considering a lot of interaction of design variables [1]-[3].

The focus of this paper is found firstly a design solution through the comparison of torque and losses according to rotor bar shape rotor dimensions variations and, secondly, a mixed resolution with central composite design (CCD) is introduced and analysis of variance (ANOVA) is conducted to determine the significance of the fitted regression model.

II. DESIGN MODEL AND ALGORITHM

TABLE I show the initial model specifications, which is T company model. The variables for optimization design are shown in Fig.1.

In Fig. 1, design variables which are P1(slot depth) and P2(slot width) of rotor and air gap length, are determined to improve torque performance of 250kW traction induction motor. Analysis data is obtained by FEM based on central composite design mostly used in RSM, and optimum point is determined by analysis of the data.

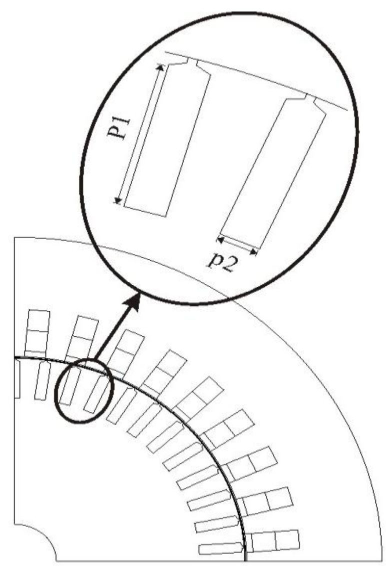

Fig. 1. The initial model, design variables and variation direction of 250kW traction induction motor

III. OPTIMIZATION PROCEDURE

Fig. 2 shows the Flow chart of design procedure.

Design procedure according to the flow chart is as follows;

Step1 : Set the initial value (CAD file, Pre-processor data). And the initial model is assigned to rotor slot=46, stator slot=36.

Step2 : Width and depth in rotor and are adopted the design variables related to torque density in 250kW traction induction motor.

Step3 : The range of design variables and experiment frequency is established by using the central composite design (CCD) shown Table I and II. The experiment frequency (N) is 12th.

Step4 : Finite element analysis (FEA) is performed and torque is calculated.

Step5 : The torque obtained from FEA, are stored.

Step6 : The experiment frequency (N) > 12?.

▶ Yes : Search an optimum torque density.

▶ No : N=N+1.

Step7 : The example of the point variables and variation direction of rotor is well shown in Fig. 1.

When the rotor and stator shape according to variables is varied, they have a difficulty in performing a lot of the pre-processor for FEA. For this reason, the new CAD file is redrawn with regard to the change of the design variables automatically.

Next the process of automatic mesh generation follows. In mesh generation, mesh data doesn't change the node number, element number, region, boundary condition, etc., but only x, y coordinate data of the design variables.

In this way, the proposed pre-processor procedure can be performed in a short period of time. In this way, this procedure goes on until N=12.

Step8 : The response surface model is created by data obtained from FEA according to an established range.

Therefore, it is possible to get optimum torque density.

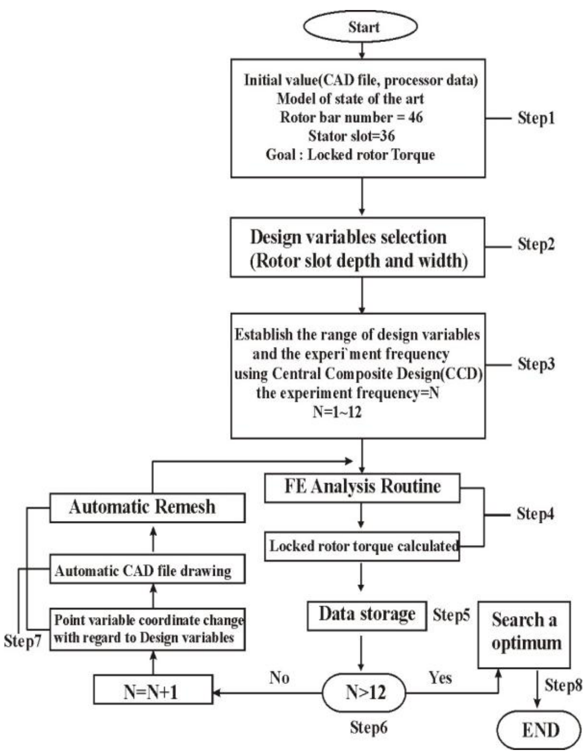

Fig. 2. Flow chart of design procedure

IV. Result & Discussion

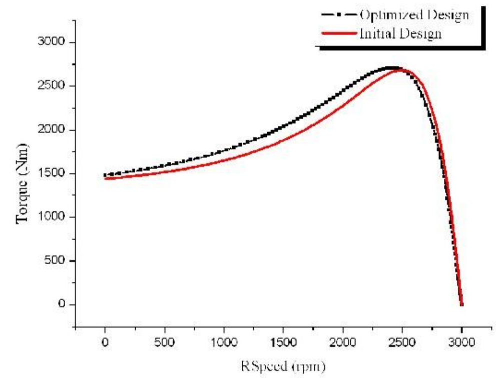

Fig. 3. Torque-Speed Curve comparisons of Optimized and T company model

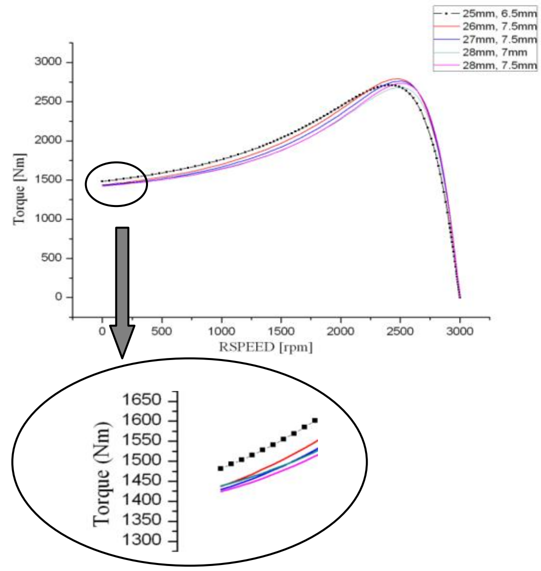

Fig. 4. Torque-Speed Curve of Optimization procedure

Fig. 3 show torque-speed curve comparisons of Optimized design model and initial model (T company model).

Fig. 4 show torque-speed curves of optimization procedure As a result, the starting torque, which is out of the traction motor' important factor, of optimized model (1482.04 Nm) is about 50 Nm higher than that of initial model.

More detailed results and discussion will be given in final paper. And the mathematical expressions for response surface methodology will be also given in extended version.

V. References

[1] J. M. Park, S. I. Kim, J. P. Hong, J. H. Lee, "Rotor design on Torque Ripple Reduction for a synchronous reluctance motor with concentrated winding using response surface methodology", *IEEE Transactions on Magnetics*, vol. 42, No.10, pp.3479-3481, Oct. 2006.

[2] F. Gillon and P. Brochet, "Shape optimization of a permanent magnet motor using the experimental design method," *IEEE Trans. Magn*, Vol.35, no. 3, pp. 1278-1281, 1999.

[3] A. I. Khuri and J. A. Cornell, *Response Surface: Designs and Analysis*. New York, NY: Marcel Dekker, Inc., 1996.