Optimum Shape Design of Single-sided Linear Induction Motor Using Response Surface Method and Finite Element Method

Jung Ho Lee, Soon Myung Jang, Seung Chul Lee
Dept. of Electrical Engineering, Hanbat National University, Dukmyung-Dong, Yuseong-Gu, Daejeon,
E-mail: smjtown@naver.com

Abstract — This paper describes the optimization of the design variables of a single-sided linear induction motor (SLIM) using finite element method (FEM) and Response Surface Method (RSM) The thrust is taken as an objective function in order to maximize the thrust and minimum thrust ripple under a various current drive, and various shape.

As a result, Parameter of SLIM as the best design for the servo system is determinded.

I. Introduction

Single-Sided Linear Induction Motor (SLIM) has been developed for use in the industry, transportations, OA, FA, because of the merits of direct drive and simple structure.

The Single-Sided linear induction motor (SLIM) is very useful at places requiring linear motion since it produces thrust directly So the necessity for industry application is increasing. It is possible to divide linear motors into the following categories from the application (1) force machine (2) power machine, and (3) energy machine. Force machine are short duty machines operating at very low speed, and efficiency is not major consideration with regard to overall performance. Power machines are often operated at medium or high speed and are continuous-duty machine, they must have high efficiency. Energy machines are short-duty machines and have found applications as an accelerator. At present most of the linear machines are applied to low speeds and standstill.

The optimum design of SLIM subject to constraints has to performed because the design is very different according to its application. In this Paper the variables of the SLIM for Servo system are optimized by using finite element analysis and Response Surface Method.

The RSM has been achieved to use the experimental RSM seeks the relationship between design variables and response in interest area through statistical fitting methods, which is based on the observed data from system. The response is generally obtained from real experiments or computer simulations.

There are many experimental designs for creation of a response surface. In this paper the central composite design (CCD) is chosen to estimate interactions of design variables and curvature properties of response surface in repeated experiments.

The CCD has been widely used for fitting a second-order response surface.

Much of the CCD evolves from its use in sequential experimentation. It involves the use of a two-level factorial or fraction, combined with 2k axial or star point.

The proposed optimum design procedure (RSM) & characteristics analysis allow to define the shape geometric dimensions performed high efficiency starting from an existing motor or a preliminary design.

II. Analysis Model

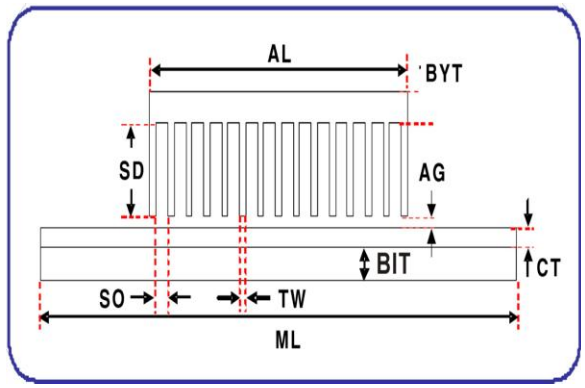

Fig.1 The design variables of the initial model LIM

TABLE I
Parameters of LIM

Parameters	Descriptions	Parameters	Descriptions
AG	Air-Gap length	SO	Slot Opening
BYT	Back Yoke Thickness	TW	Tooth Width
CT	Conductor Thickness	ML	Mover Length
BIT	Back iron Thickness	AL	Axial Length
SD	Slot Depth		

The variables of optimization design is shown in Fig.1. The shape coordinates of the parameter have been drawn according to the variation of parameter width.

Design variables of parameter are determined to maximize thrust density and to minimize thrust ripple of the SLIM. And then, analysis data is obtained through finite element method based on central composite design mostly used in RSM. And optimum point is determined through analysis of the data.

III. RESPONSE SURFACE METHODOLOGY

TABLE II
Analysis of variance

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	F_0
Regression	k	SS_R	SS_R / k = MS_R	MS_R/MS_E
Residual	n-k-1	SS_E	SS_E /(n-k-1)= MS_E	
Total	n-1	S_{yy}		

It is always necessary to examine the fitted model to ensure that it provides an adequate approximation to the true response, and to verify that none of the least squares regression assumptions are violated. In order to confirm adequacy of the fitted model, an analysis-of-variance (ANOVA) table, shown in Table 1, is used in this paper.

In Table 2, n is the total number of experiments and k is the number of parameters in the fitted model.

IV. OPTIMIZATION PROCEDURE

Fig. 2 shows the process of optimization design.

The shape coordinates have been drawn according to the variation of parameter

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 pole=3, slot=12.

Step2. : variables Air-Gap length (AG) , Back Yoke Thickness (BYT),Conductor Thickness(CT) and Back Iron Thickness(BIT) in shape are adopted the design variables related to thrust density in the LIM

Step3. : The range of design variables and experiment frequency is established by using the central composite design (CCD). The experiment frequency (N) is 25.

Step4. : Finite element analysis (FEA) is performed and thrust density and thrust ripple is calculated.

Step5. : The thrust density and ripple obtained from FEA, are stored.

Step6. : The experiment frequency N >25?

▶ Yes: Search an optimum thrust density and ripple.

▶ No: N=N+1

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

When the shape according to variables Air-Gap length (AG), Back Yoke Thickness (BYT),Conductor Thickness (CT) and Back Iron Thickness(BIT) is varied, 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 this way, this procedure goes on until N.

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

The RSM seeks to find the relationship between design variable and response through statistical fitting methods, which are based on the observed data from system [1]- [3].

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

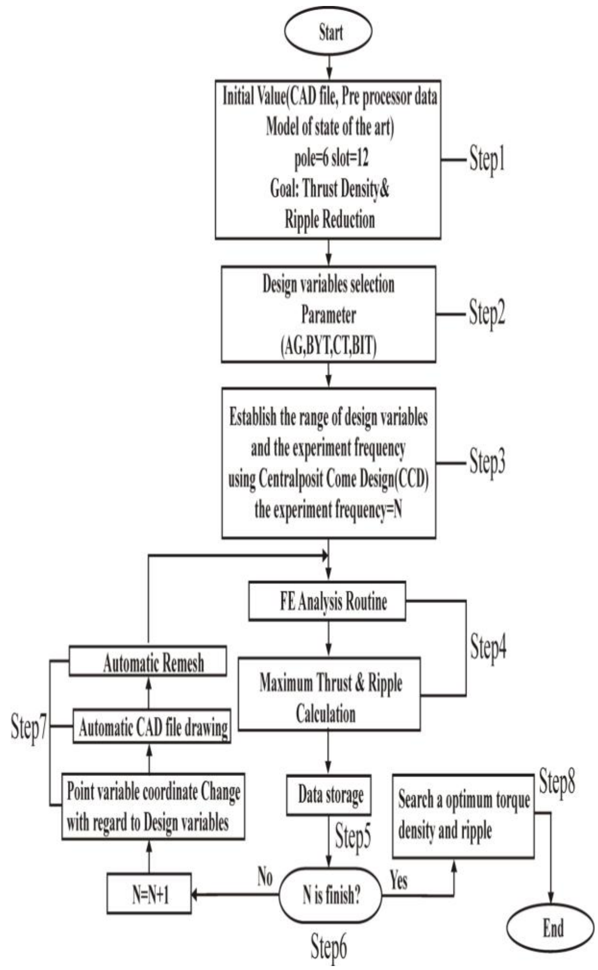

Fig.2 The design variables of the initial model LIM

V. REFERENCES

[1] Raymond H. Myers and Douglas C. Montgomery, Response Surface Methodology Process and Product and Optimization Using Design Experiments, JOHN WILEY & SONS, 1995.

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

[3] Y. C. Choi, H. S. Kim, J. H. Lee, "Design Criteria for Maximum Torque Density & Minimum Torque Ripple of SynRM according to the Rated Wattage using Response Surface Methodology", IEEE Transactions on Magnetics, Vol., 44, No. 11, pp.4135-4138.