Optimal Stator Design of Synchronous Reluctance Motors by Loss & Efficiency Evaluations Related to Slot Number using Response Surface Methodology

Seong June Park (*), Jung Ho Lee (*), Sung Il Kim(**), Jung Pyo Hong (**)

(*)Dept. of Electrical Engineering,
Hanbat National University,
Dukmyung-Dong, Yuseong-Gu, Daejeon,
305-719, KOREA
E-mail: limotor@hanbat.ac.kr

(**)Dept. of Electrical Eng.,
Changwon National University,
Sarim-Dong, Changwon,
641-773, KOREA
E-mail: jphong@sarim.changwon.ac.kr

Abstract : This paper deals with the optimal stator design of synchronous reluctance motors (SynRMs) with concentrated winding by response surface methodology (RSM). The motors, based on finite element analysis (FEA) and Preisach modeling, have different slot number respectively. The focus of this paper is to compare with torque ripple and efficiency between a distributed winding SynRM and optimized SynRMs by RSM with changing slot open width. The coupled FEA and Preisach model have been used to evaluate the nonlinear solution. In the end, this paper verifies the usefulness of RSM in optimizing SynRM and presents characteristic comparison between the distributed winding SnyRM and optimized SynRMs.

Key words : SynRM, Optimal Stator Design, RSM, FEA, Loss & Efficiency Evaluation, Slot Number, Slot Open Width

I. INTRODUCTION

If stator winding of a Synchronous reluctance motor (SynRM) is not a conventional distributed winding but a concentrated winding, the decreasing of copper loss and production cost due to the simplification of winding in factory are obtained. However, it is difficult to expect a good performance from the SynRMs of concentrated winding without considering torque ripple, inductance ratio and difference (efficiency, power factor) [1]-[3].

This paper deals with the optimal stator design of the SynRMs with concentrated winding by loss & efficiency evaluations using response surface methodology (RSM), one of the optimization methods [4]. In other words, the purpose of this paper is to optimize configuration of the stator related to torque ripple and efficiency changed by variations of stator slot number and slot open width in order to improve performance and production cost problem of the SynRM. The coupled Finite Elements Analysis (FEA) & Preisach model have been used to evaluate the nonlinear solution [5]-[6].

In this paper, the characteristics of normal distributed winding SynRM(24 slots) and concentrated winding SynRMs (12, 6 slots) are compared, and anisotropy ratios up to 8 or more are obtained by means of these structures. The consequent torque performance approaches that of state of the art (distributed winding SynRM : 24 slots).

II. DESIGN STRATEGY

II.1. Design Algorithm And Model

The process of optimization design is shown in Fig.1. Fig. 2 shows the d-axis flux plots of distributed and concentrated winding SynRM, respectively. In this paper, the slot number of each SynRM is considered 24 (distributed winding: 36 turns/slot), 12 and 6 (concentrated winding: 144 turns/ slot). The slot number and slot open width are variables, which is related to torque ripple and efficiency together with the number of flux barrier in a SynRM.

RSM is applied to design the stator configuration minimizing loss and torque ripple from each SynRM, which is different from slot number. This optimization method not only can predict the loss of each model on all variations of slot open width from several sample points but also search optimal point, and experimental frequency of the method is relatively few, too. In Fig. 1, design area of the slot open width is determined to reduce torque ripple and increase efficiency of the concentrated winding SynRMs. And then, analysis data is obtained through finite element method (FEM) and Preisach model based on central composite design (CCD) mostly used in RSM, and optimal point is determined through analysis of the data. In the end, the characteristic of the SynRMs is estimated through comparisons between SynRM of distributed winding and optimized SynRMs of concentrated winding considering variations of slot number and slot open width.

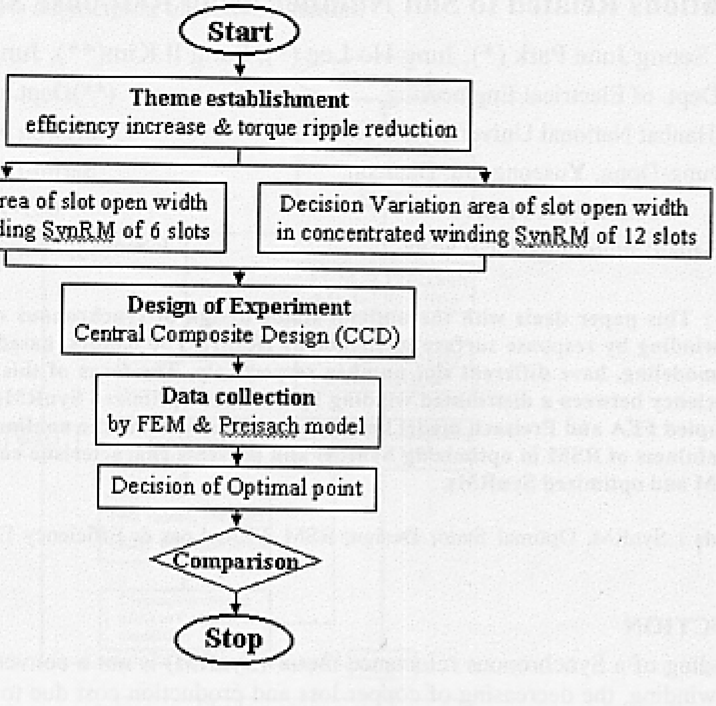
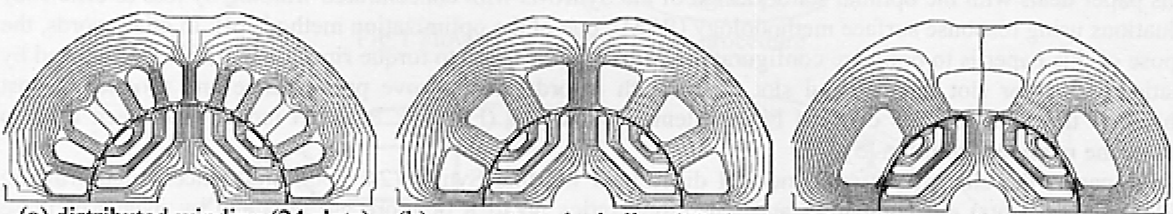


Fig. 1 flow chart of design procedure



(a) distributed winding (24 slots) (b) concentrated winding (12 slots) (c) concentrated winding (6 slots)

Fig. 2 d-axis flux plots of distributed and concentrated winding SynRM

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