Superconducting Motor Design using 3D Analysis Model and Response Surface Methodology

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***Abstract*-- This paper proposes an effective design process for superconducting motor with a simplified 3D analysis model and an optimization algorithm. Response surface methodology (RSM) is used as the optimization method in whole design process from selecting main design parameters to optimizing them. During the process, the simplified 3D analysis model is used to get electric parameters by 3D equivalent magnetic circuit network method (EMCN). The utility of this method is verified through the comparison of the performances of the optimal geometry and those of the initial geometry.**

I. INTRODUCTION

Design of superconducting machines using high temperature superconducting (HTS) tapes as field coil has been an object of concern for high efficiency and high power density. In general cases, there is no magnetic core in both stator and rotor in order to contribute to lighter weight, remove a signification source of motor noise, and lessen core losses, so the magnetic air-gap can be too large to consider the flux path as two-dimensional problem [1, 2]. Moreover, in designing a superconducting motor, an analytical prediction of performances such as output power and efficiency is so important that accurate electrical parameters should be calculated previously. Accordingly, the authors considered three-dimensional (3D) flux path in design process with commercial program in [3]. However, in overall design process from initial dimension decision to optimization, calculating parameters from each detailed 3D model can be troublesome or time-consuming.

Therefore, this paper proposes an effective design process for HTS superconducting motor with a simplified 3D analysis model and an optimization algorithm. Response surface methodology (RSM) [4] is used as the optimization method in whole design process from selecting main design parameters to optimizing them. During the process, the simplified 3D analysis model is used to get electric parameters by 3D equivalent magnetic circuit network method (EMCN) [5]. The utility of this method is verified through the comparison of the performances of the optimal geometry and those of the initial geometry.

II. DESIGN AND ANALYSIS MODEL

Fig. 1 shows a schematic cross sectional view of the superconducting motor which is designed as a HTS synchronous motor in the 21st Century Frontier R&D Program, Korea. The motor is composed of HTS field winding, cold damper shield, air-gap, armature winding made by cooper wire, and laminated magnetic shield. The field winding consists of racetrack type double pancake coils wound with Bi-2223 HTS tapes operated at about 35K.

Fig. 2 shows the analysis models of 3D EMCN in left side and commercial program in right side respectively. The simplified analysis model for using 3D EMCN is useful in design process because of rapid calculation time, and relatively accurate analysis results. Table 1 presents the comparison of inductance calculation using 3D EMCN and a commercial program. Even though one is simplified model and the other is detailed, the calculated inductances are almost identical. In the case of coils of which length are similar, the error of inductance values are under 5%.

Fig. 3 shows the axially flux distribution in the middle of the armature coil. The radial direction flux density, Br, in the end of straight part decreases by 32% in comparison with Br in the center part. Accordingly, 3D flux path should be considered in design process where the parameters such as inductance and EMF relating flux are needed to do reliable design.

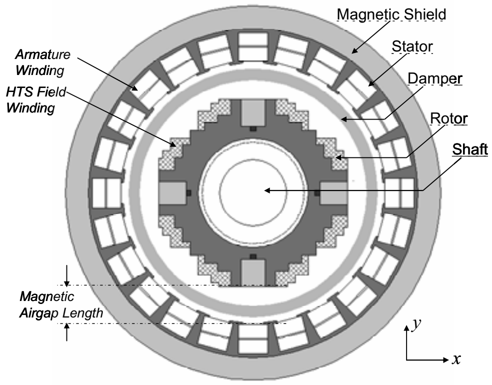

Fig.1. The cross-section view of superconducting motor

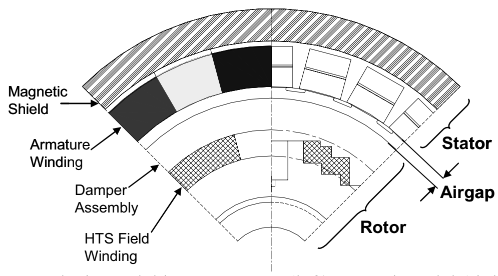

Fig.2. Analysis model by 3D EMCN (left) vs. real model (right)

TABLE I
THE COMPARISON OF INDUCTANCE CALCULATION

	Coil Length (mm)		Inductance (mH)
	Straight-coil part	End-coil Part	
3D EMCN	212.5	50	2.91
	212.5	201	3.78
Flux 3D	212.5	46	2.89
	212.5	200	3.94

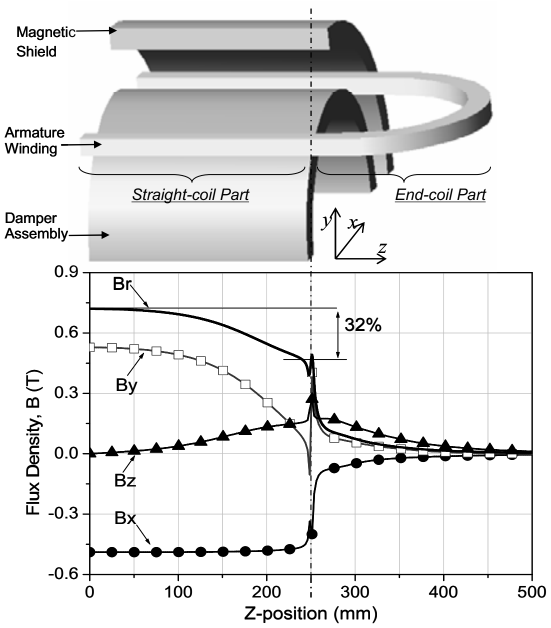

Fig.3. Axially irregular flux distribution in superconducting motor with large air-gap

III. DESIGN PROCESS

Fig. 4 shows the proposed design process with response surface methodology. The detail analysis process for collection of samples with 3D EMCN in the middle of the design process is shown in Fig. 5.

Several design parameters such as number of slots, number of field-turn, axial length of field coil, width of field-pole, etc. are investigated in the screen activity. After selecting main parameters through the design process, the motor can be optimized with a few design parameters which have great effects to the characteristics which can improve efficiency and power density.

IV. CONCLUSION

In this paper, a design process is introduced to design superconducting motor having improved efficiency and power density. With analysis using a simplified 3D analysis model and 3D EMCN, more reliable and rapid design can be performed considering unique characteristic of superconducting motor such as large air-gap.

With proposed design process, detail results and explanation will be presented and discussed in full paper.

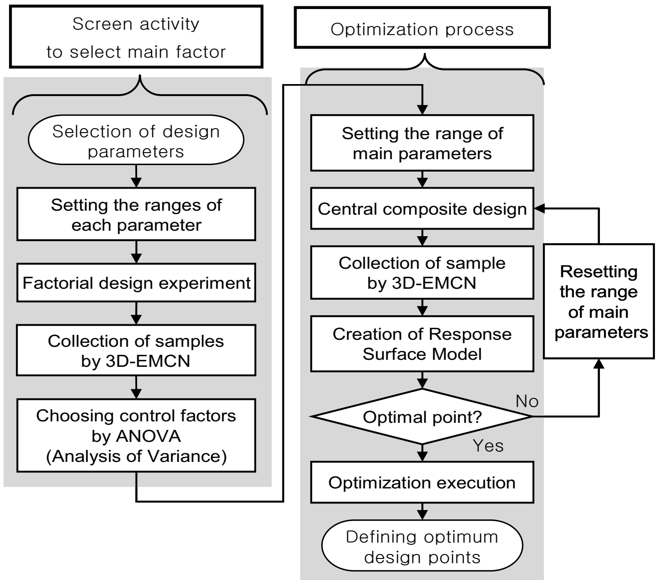

Fig.4. Proposed design process by response surface methodology

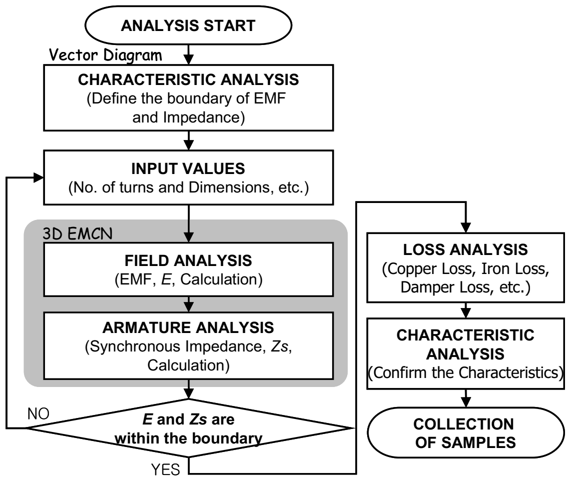

Fig.5. Analysis process for collection of samples by 3D EMCN

REFERENCES

[1] Young-Sik Jo, Young-Kil Kwon, Young-Kyoun Kim, Jung-Pyo Hong, "Design of High Temperature Superconducting Magnet", *IEEE Trans. on Applied Superconductivity*, vol.12, No.1, pp.721-724, 3, 2002.

[2] Jung-Jong Lee, Young-Sik Jo, Jung-Pyo Hong, Young-Kil Kwon, "Design of Field Coil for 100 HP Class HTS Motor Considering Operating Current" *IEEE Trans. on Applied Superconductivity*, vol. 13, No.2, pp.2214-2217, 6, 2003.

[3] Young-Sik Jo, Taketsune Nakamura, Tsutomu Hoshino, Yoon-Do Chung, Jung-Pyo Hong, and Young-Kil Kwon, "Characteristic study and three dimensional magnetic field analysis of the superconducting synchronous mahcine," Physica C: Superconductivity, vol.416, pp. 108-114, Issues 3-4 , 1 December 2004

[4] Young-Kyoun Kim, Jung-Pyo Hong, Geun-Ho Lee, Young-Sik Jo, "Application of Response Surface Methodology to Robust Design for High Temperature Superconducting Magnet", *IEEE Trans. on Applied Superconductivity*, vol12, No1, pp.1434-1437, 3, 2002.

[5] Jin Hur, Sang-Baeck Yoon, Dong-Yun Hwang, and Dong-Seok Hyun, " Analysis of PMLSM using three dimensional equivalent magnetic circuit network method," *IEEE Trans. Magn*, vol. 33, No. 5, Sept. 1997

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