3D Magnetic Field Analysis and Comparative Study of Circular Halbach Array

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1. Introduction

The Halbach array was first introduced by Klaus Halbach in 1979 in order to focus strong magnetic field in particle accelerators. In a Halbach array, direction of the magnetization vector is sequentially rotated to obtain the needed the magnetic field distribution. The advantages of Halbach arrays include effective magnetic shielding and less iron losses. Circular Halbach arrays or Halbach cylinders are used in brushless motors and magnetic coupling devices.

In this paper, the magnetic field of a circular Halbach array is analyzed using 3D finite element modeling. The magnetic field distribution and spatial average value is compared for two different configurations of the permanent magnets (PMs): 90 and 45 degrees difference between magnetization directions of adjacent blocks.

2. Modeling of the Circular Halbach Array

Fig. 1 shows the 3D model of the circular Halbach array. COMSOL Multiphysics software was used for finite element analysis. Two different configurations of the permanent magnets (PMs) were investigated. The first has 32 blocks with 45 degrees magnetization direction change in adjacent blocks (Fig. 2). The second model has 16 blocks with 90 degrees magnetization direction change in adjacent blocks (Fig. 3). The remanence of each PM block is 1.42 [T] in both models. The inner and outer radius of array is 30 [mm] and 50 [mm], respectively, and the height of the array is 30 [mm]. The magnetization direction is expressed by radial and azimuthal unit direction vectors.

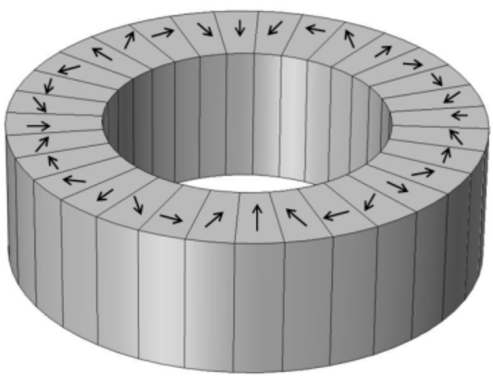

Fig. 1. 3D model of the circular Halbach array.

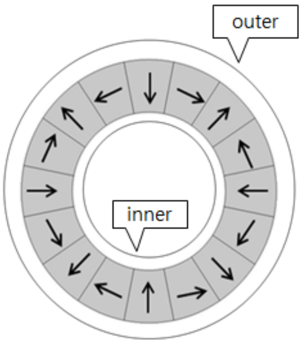

Fig. 2. 90° change of magnetization.

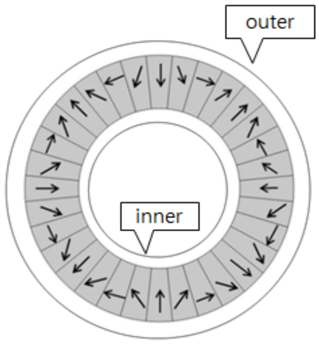

Fig. 3. 45° change in magnetization.

3. Analysis Results

Fig. 4 and 5 show magnetic field distribution according to azimuthal angle along outer circle located at r=55 [mm]. It can be observed that the peak of the flux density of 45° model has less ripple. Table 1 shows spatial average of the magnetic flux density of two models. The average flux density of 45° model is about 8.15% higher than that of the 90° model, even though the two models have the same volume of permanent magnets.

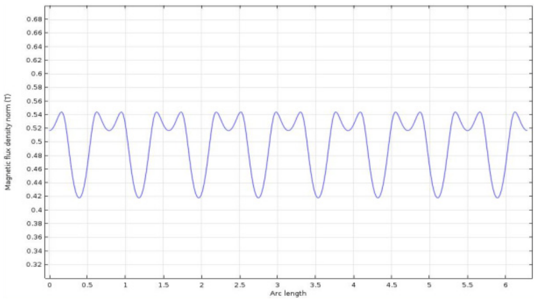

Fig. 4. Magnetic flux density along r=55 [mm] outer line (90° model).

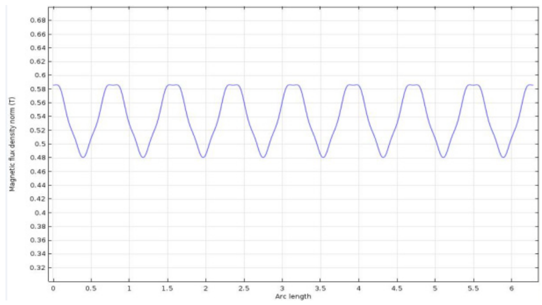

Fig. 5. Magnetic flux density along r=55 [mm] outer line (45° model).

Table 1. Average flux density of Halbach arrays.

	90° model	45° model
average flux density (r=55 [mm])	0.4982[T]	0.5388[T]
average flux density (r=25 [mm])	0.0718[T]	0.0526[T]

4. References

[1] S. M. Jang et al.,"Analysis of characteristic linear Halbach array," *Proceedings of KIEE Summer Conference*, pp. 892-894, July 2001.

[2] S. M. Jang et al.,"Characteristics analysis on the field system of Halbach array by the permanent magnet," *Proceedings of KIEE Summer Conference*, pp. 24-26, July 1997.