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Finite Element Analysis of Two Dimensional Permanent Magnets

F. KASSID[1], L. BOUSSHINE[2]
[1]*(Mechanical engineering ,Ecole National d'electricité et de mécanique, Morocco)*
[2]*(Mechanical engineering ,Ecole National d'electricité et de mécanique, Morocco)*

Abstract:
Background*: Magnetic separation devices are widely used to separate tramp of iron from a specific feed of materials. These devices for separation employ a variety of mechanical designs.those designs are mainly chosen based on the application and the feed of materials.low intensity magnetic separation devices extend the application of magnetic separation by usingpermanent magnets for dry or wet feed.*
Materials and Methods*: In thispaper,a study of the electromagnetic behavior ofparallelepipeds permanent magnet is presented. Based on magnetic vectorial approach and finit element method,Performance ofAlnico and NdFeBis put under comparaison.*
Results*: Flux density was comparable and the gap between both magnets curvs is significant.*
Conclusion:*the desired tramp ironto be removed is influencing the choice of permanent magnet to build up magnetic separator.*
Key Word*: Magnetic separation; Permanent magnet; Finite element Method; Vector potential.*

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I. Introduction

Permanent magnets are widely used in magnetic separation .where many shape can be found based on the application itself. Two great kinds of applications can be identified; The first one use parallelepiped permanent magnets (ex:suspended magnets separator) while the second one use arc-shaped permanent magnets (drum magnetic separator). In this paper, the electromagnetic behavior of 2 dimensional parallelepipeds permanent magnet is discussed by comparing the Alnico and NdFeB and their performances in low intensity. Recently developed low intensity magnetic separation devices extend the useful application of magnetic separation of permanent magnets for the three dimensional simulation, it can be found in[1].

II. Material And Methods

Theoretical background

Magnetic field vectors can be expressed in terms of either the magnetic field strength H or the magnetic induction B[2.] The field vectors are related by:

$B = \mu m.H$(1)

With the magnetic permeability µm ,the proportionality constant. In a vacuum, the permeability has the value of:

$$\mu m = \mu 0 \qquad (2)$$

When a magnetic field passes through a material, the material acquires an induced magnetization M given by:

$H.\chi m=M$ (3)

Where χm is the magnetic susceptibility of the material. The magnetic induction can also be expressed as:

$B = \mu 0.(H+M)$ (4)

Equations (1), (3) and (4) show that:

$\mu m= \mu 0.(1+ \chi m$(5)

Which relates the permeability to the susceptibility.

Following Maxwell 's equation for magnetostaic.magnetic field is expressed as follow:

$\nabla \mathrm{x} H = J$ (6)

$$\nabla . B = 0 \quad (7)$$

Where j is the density charge.

via a magnetic vector potential approach. The flux density may be written in terms of the vector potential, A as:

$Bx\nabla = A$(8)
As A is the vector potential

By using Lorentz gauge ,we found the Alembert equation as follow:

$$\text{?}J = \Delta A - \text{?}\frac{\mathcal{E}\partial^2 A}{\partial t^2} \quad (9)$$

inquasistaionary terms:
$\text{?}J = \Delta A$(10)

And finally we get the formulation of Poisson’s equation.

Boundary conditions
The permanent magnet is a suspended one in the air,it’s flux lines are parallel to the boundary edge .Hence the dirichlet conditions are the best to express this problem. Below the formulation:
A=0 at the boundary of the space of study of the permanent magnet.

Finite element analysis
The boundary value problem under consideration is defined by the second order PDE :

$$\text{?}J = \Delta A \quad (11)$$

Triangular elements are used in this case ,with the following interpolation equation :

$$\emptyset^e(x, y) = \sum_{j=1}^{3} N_j^e(x, y)\emptyset_j^e \quad (12)$$

By using variation formulation we get the expressions of the matrices

Final formulation:

Set of matrices are represented as follow:

$$K_{i,j}^e = \int \left(\left(\frac{\alpha d N_i^e}{dx} \frac{dN_j^e}{dx} \right) + \beta N_i^e N_j^e \right) dx \quad (13)$$

$$b_i^e = \int N_i^e f dx \quad (14)$$

$$g_i^e = \alpha N_i^e d\emptyset/dx \quad (15)$$

$$(\emptyset^e) = \begin{pmatrix} \emptyset_1^e \\ \emptyset_2^e \end{pmatrix} \quad (16)$$

$$(K)(\emptyset) = (b) + (g) \quad (17)$$

III. Result

Distribution of magnitude of flux density obtained for both materials using simulation software based on the finite element method [3] is presented in the Figure 1 and 2. The values of the geometrical parameters used in the numerical computation are: w=1mm, L=0.5mm, triangle mesh were used for the simulation of both materials [4.]

The flux lines in Alnico magnets leave the magnet limb perpendicularly, on the other hand, in ferrite magnets the flux lines tend to reach the terminal and the pole spacing. The resultant flux density according to coordinate axis have been given in Figure 3. It is observed that BmaxNdF eB32 is more important than BmaxAlnico5 as the magnitude of maxNdF eB32 can achieve 1.4 T.

Figure no 1 : Flux line and density of ALnico 5

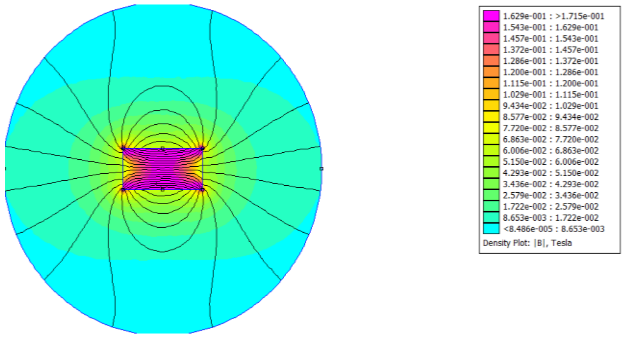


Figure no 2 : Flux line and density of NdFeB 35

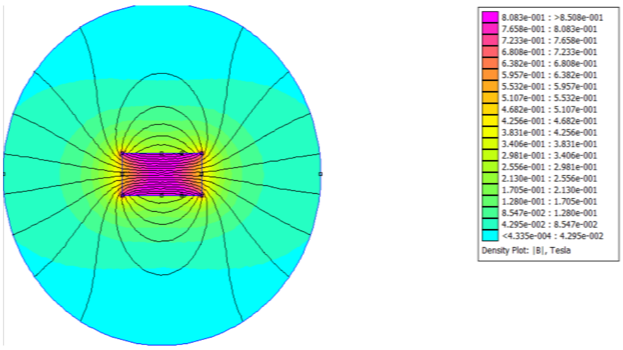
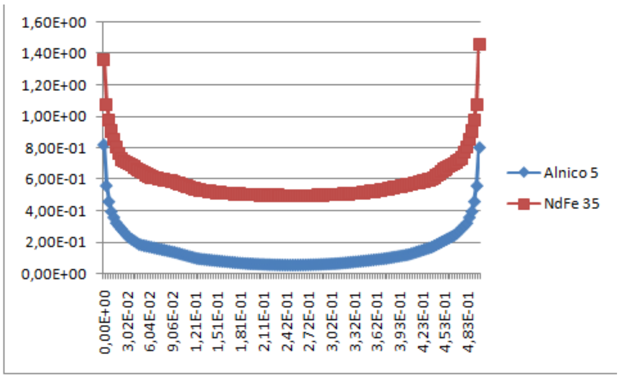


Figure no 3 : distribution of flux density of both materials according to the coordinate axis



IV. Discussion

Alnico have good residual magnetization, good thermal stability, but their coercive is relatively low, on the other hand even if NdFeB permanent magnets possess exceptional magnetic properties, they have insufficient level of thermal and environmental stability [2.] Therefore, each material is used under special circumstances.

V. Conclusion

In this work, an analytical expression for the magnetic induction of a parallelepiped permanent magnet was given .Using finite element method,expressions of matrixes was given in order to develop the study. And as a final step,by using software simulation , behaviors of the Alnico and NdFeB permanent magnet were compared as an application to discuss electromagnetic behavior of both magnets.

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