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Investigation of NdFeB N52 magnet field as advanced material at air gap of axial electrical generator

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Investigation of NdFeB N52 magnet field as advanced material at air gap of axial electrical generator

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Abstract. The aim of this study is to investigate and analyze the NdFeB N52 type magnetic field distribution on a Trapezoidal type coil in an axial type generator. The main problems addressed by this study are how the distribution of magnetic field type NdFeB N52 to the trapezoidal type coil and how the influence of air gap between NdFeB N52 magnets and the coil to the output electric voltage generated from the coil at the speed of rotation. In order to answer the problems, we moved a rectangular type magnet axially towards the trapezoidal type coil with a specified distance, so that we could identify the change of the output voltage. The description of the magnetic field distribution in the stator was simulated by using the Maxwell 3D Design application ran in ANSYS software 16.0. The result of this study shows that the magnet was distributed evenly on the coil. It is also known that based on experiments with 2mm to 6mm of magnet to coils of gaps, the highest output voltage is at 2mm gaps at 750rpm.

1. Introduction

Energy is a major requirement for communication [1-2], transportation and many more, so it requires high efficiency energy sources, one of which is the generation of energy from advanced materials, for example permanent magnets. A neodymium magnet is strong magnet [3] which is also known as NdFeB, NIB or Neo magnet. It is the most widely used type of rare-earth magnet. It is a permanent magnet made from an alloy of neodymium, iron, and boron to form the Nd2Fe14B tetragonal crystalline structure [4]. NdFeB magnets are used in applications such as hard-disk drives and permanent magnet motors [5]. NdFeB magnet made from a combination of an alloy of neodymium, iron and boron, therefore, it is shortened by Nd2Fe14B. Developed in 1982 by General Motors and Sumitomo Special Metals, neodymium magnets are the strongest type of permanent magnet commercially [6] and very useful for energy production need [1, 2, 7].

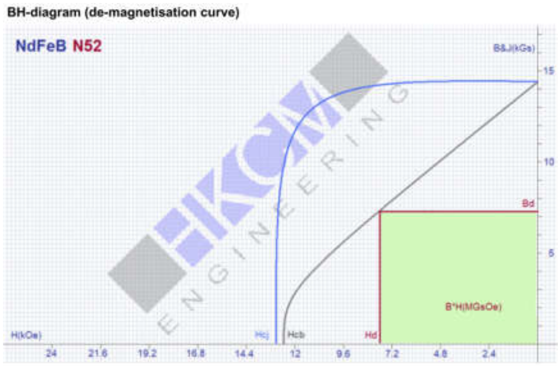
Even the hybrid bonded magnet, such as NdFeB with ferrites and NdFeB with SmFeN, was reached in many research, but (BH) is not more than 20 MGOe [8]. With the particle size of NdFeB powders 80 – 100 µm, prepared by Hydrogenation Disproportionation Desorption Recombination (HDDR), it was found that the gaps among the particles are 4–10 µm which are mainly filled by an organic binder. The characteristic of NdFeB N52 (figure 1) shows that it has Maximum Energy Product (Bhmax) that is 50-53 MGOe (398-422 MGO (KJ/m3) [9-10]. With this unique nature energy, NdFeB magnets are a favorite in many purposes, from home-based needs to the the healthcare needs. NdFeB permanent magnets contain about 31–32 wt% of rare-earth elements (REEs) [3].

This paper scope is imulation of generator axial involve of NdFeB class N52 implementation on axial generators using analytical methods using Maxwell simulation from Ansys Application. We test focus on the simulation to find the fact of voltage produced in coils that coused of gaps of NdFeB to coils.

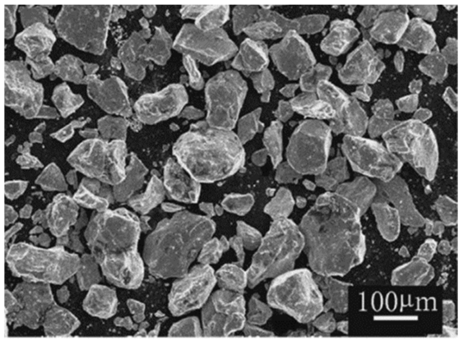
Tests were conducted on simulations with Maxwell and Ansys applications with NdFeB N52 permanent magnet 8 coils and 8 pole.

2. Related works

NdFeB permanent magnet production growth is projected to increase significantly, especially between 2015 and 2020 which will reach more than 120 (kt), especially in China. In addition to the NdFeB type permanent magnet, the ferrite type also has the same role, but based on the economic value of the energy produced, the generator with NdFeB is cheaper than the ferrite type magnet [11]. Figure 1, a and b shows the characteristic of NdFeB N52.



(a)



(b)

Figure 1. (a) Characteristic of NdFeB N52 [9], (b) SEM images of the magnetic powder of NdFeB. [8].

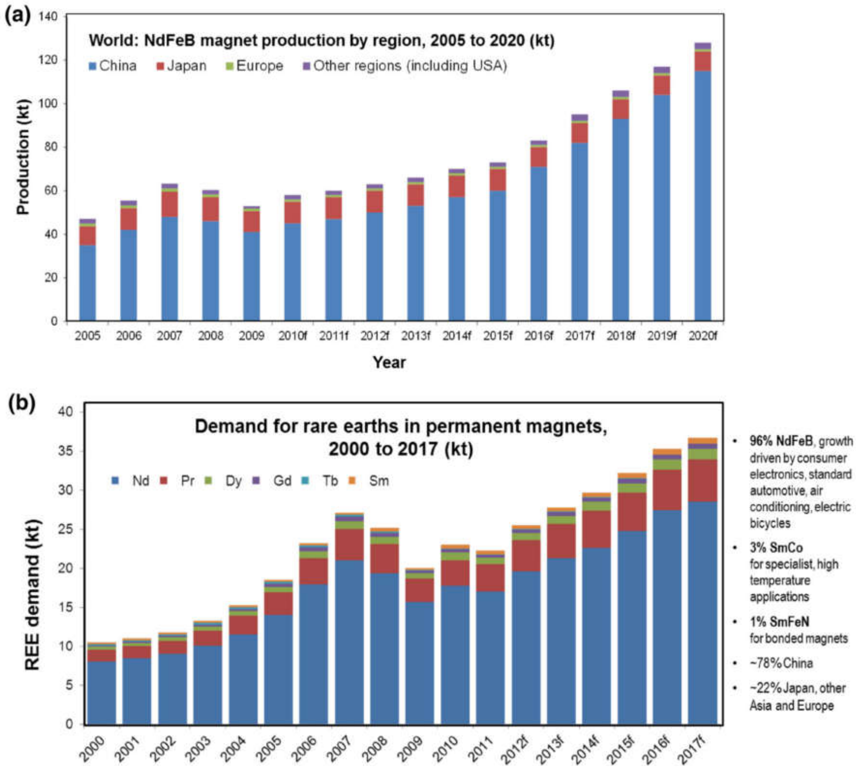


Figure 2. Global production of NdFeB permanent magnets and the demand for the REEs [12], [3]. (a) Total global NdFeB magnet production and prediction: 2005–2020, (b) Total global REE demands for permanent magnets [3].

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In industrial scale, China is the largest producer of permanent magnets compared to Japan, Europe and other countries including USA (figure 1). While the world's need for permanent magnets is dominated by the Nd type of permanent magnet (figure 2).

The implementation of NdFeB on generators has been widely used for low speed generators research. This paper is part of the research. N. Georgiev (2017) has succeeded in simulating a 3 phase 16 pole generator using NdFeB magnets [13] and DC generator [14], While axial generators with trapezoidal-shaped coil have been studied in [15]. The differences that come up in those papers, it is not explained the type of class of NdFeB that is used, so that the potential energy value in the magnet cannot be known, Nevertheless NdFeB N52 with MGOe is (398-422 MGO (KJ / m3) is used in the design generator [16]. In N. Georgiev (2017) [13] found the fact that the closer the gap between the magnet and coils, the greater the voltage and power of the generator produced, and this is also affected by the rotor speed.

3. Methodology

In this study, the magnet used was NdFeB N52 type with Energy Product Bhmax 398-422 (KJ/m^3). Figure 3 shows the steps of the simulation process. The ANSYS software version 16.0 was used as the main application to be running the simulation. Then, the process steps consisted of determining the material which will be used which in this case was winding coil made of copper material and formed into trapezoidal (figure 4).

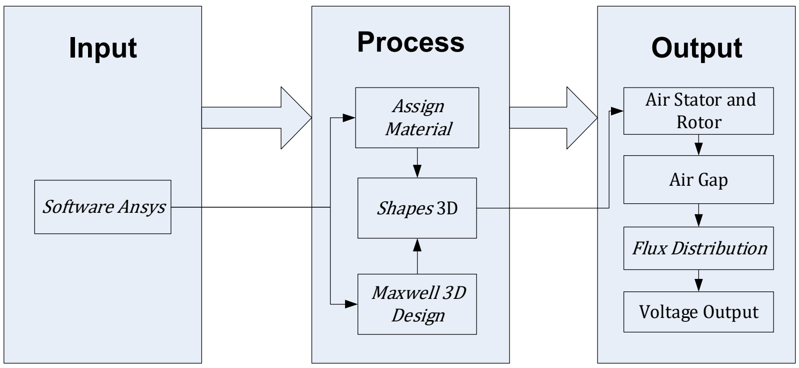
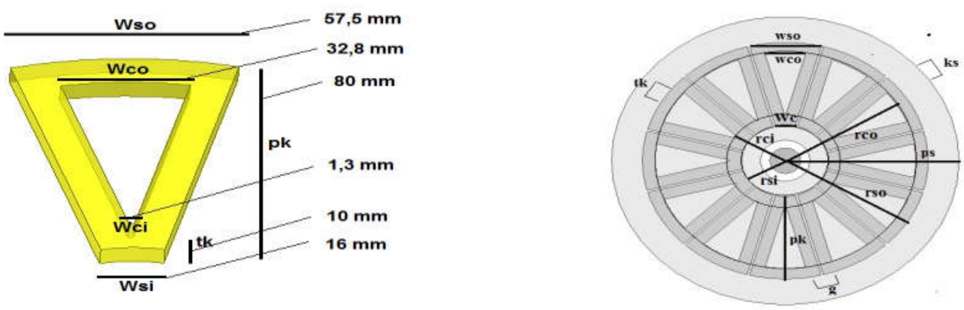


Figure 3. Process of simulation.

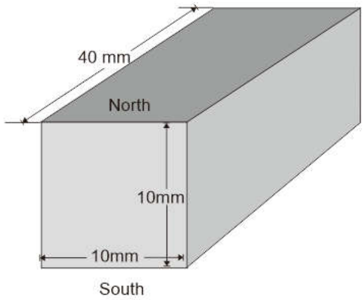
The model of winding coil design was trapezoidal (figure 4.a). The winding coil then was placed on the stator and arranged in a row. The number of winding coil, arranged in parallel on the casing of the stator, was total 12 units (figure 4.b).

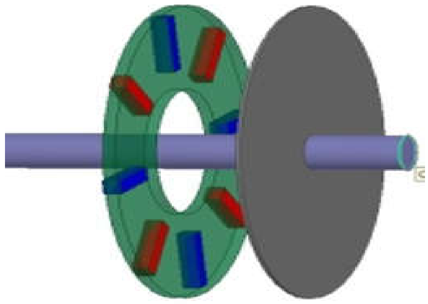
The chasing of the winding coil was designed in the form of cylinder (figure 5) with the length (ps) was 140 mm, the thickness (ks) was 25mm, the distance between winding coil (g) was 2mm, the outer width (wso) was 57,5 mm, inner width (wsi) was 16mm, stator foot width (wc) was 2mm, the length of the coil (pk) was 80mm, the coil thickness (tk) was 10mm. Coil wire density was 6.36 A /mm^2, diameter 1mm, with turn of coil was 38 turns.



(a) (b)

Figure 4. (a) Design of winding coil with trapeziodal shape, (b) design of winding stator casing.





(a) (b)

Figure 5. (a) Dimension of permanent magnet, (b) placing the magnets on the rotor casing.

The permanent magnet used was in rectangular form with a length of 40mm, 10mm wide and 10mm thick (figure 5.a). Nine magnets were arranged in rows on the rotor casing with crossed positions, ie the north pole of the magnets was adjacent to the south pole of the magnet (figure 5.b).

Finally, the stator and rotor designs had been successfully designed based on the design. The stator consists of 12 winding coils, while the rotor consists of 9 permanent magnets. The combination of rotor and stator was arranged axially. The position of the rotor was independent of the stator, so that the rotor could rotate axially while the stator remained stationary (figure 6.).

The fact that the NdFeB N52 magnet was rotated axially resulted in the outer electric voltage of the winding coil which was proportional to the distance between the stator and the rotor.

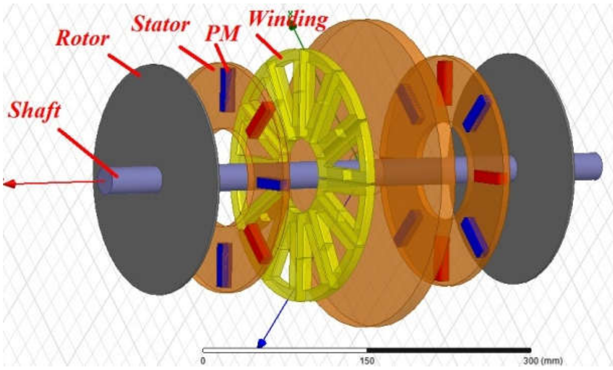


Figure 6. The result of combination of the stator and the rotor on the shaft by software Ansys.

4. Result and discussion

The simulation carried out by using Maxwell 3D Design ran on ANSYS software showed that the distribution of magnetic flux density (B) of NdFeB N52 magnet on winding coil was evenly distributed with the middle of winding coil had the highest magnetic flux density (B) that is 1.2 Tesla, while the lowest magnetic flux density was the outer part, ie 3.26e-5 Tesla. Further result shows that the distribution of magnetic flux density showed arose in all winding coils on the stator casing (figure 7).

Figure 7 shows the value variation of the magnetic flux density (B) on winding coil. There was an air gap between the stator and the rotor with the highest value was 1.23 Tesla at a distance of 2mm and the lowest magnetic flux density was 0.7 Tesla. In the 6mm air gap (figure 8). It proves that the farther the air gap, the smaller the magnetic flux density occurs.

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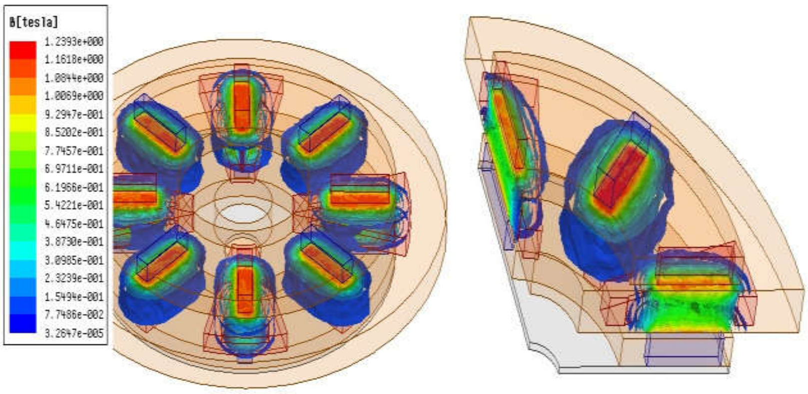

Figure 7. The magnetic flux distribution (B) of the stator to the winding coil.

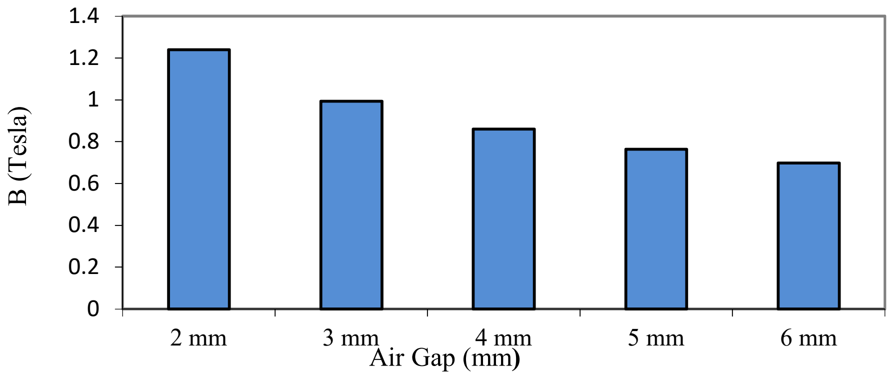

Figure 8. Magnetic flux density on the variation of air gap distance between the stator and the rotor.

Magnetic flux density, winding coil and air gap affected the value of output voltage generated from winding coil, figure 9 shows the relationship between the output voltage with rotation speed of rotor or permanent magnet, it demonstrates that the created model produced maximum voltage at 750 rpm axial speed. After 750 rpm, there was a reduction in the output voltage. This condition is in accordance with what has been done inside [13, 15-17], that the number of magnetic poles, magnetic strength and magnetic gap distance to the coil affect the voltage generated from the axial generator.

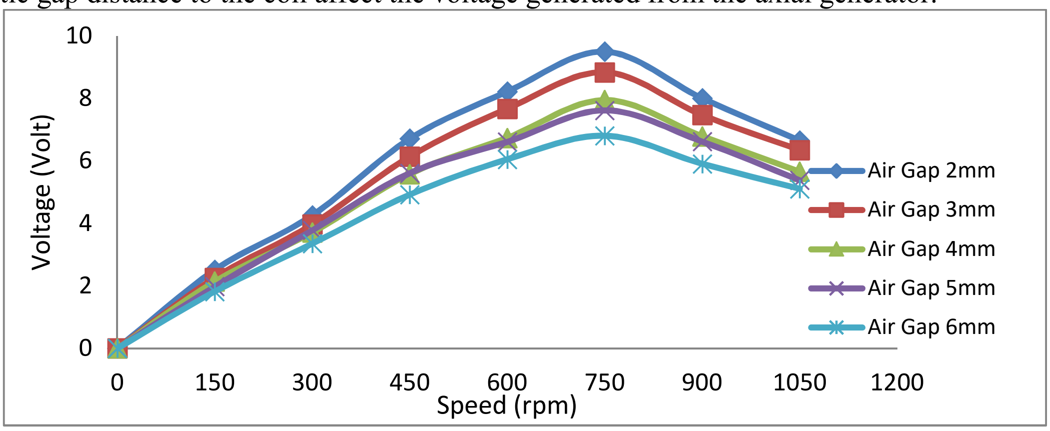

Figure 9. Relationship between output voltage and speed (rmp).

5. Conclusion

The evidence from this study suggests that magnetic flux density of NdFeB N52 on 1 mm of diameter trapezoidal shaped coil and coil wire density of 6.36 A /mm2, has a linear relationship to the air gap,

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which indicates that the bigger the gap the lower the magnetic flux density in the winding coil. However, the NdFeB N52 magnet has an equitable distribution of magnetic flux density on the winding coil. The uniform distribution will provide good quality outcome, however, it should be noted that the distance of permanent magnet placement on the rotor side and also the distance between the coils on the stator side must be precise, so that the magnetic distribution in the coil will be evenly distributed. Based on experiments with 2mm to 6mm of magnet to coils of gaps, the highest output voltage is at 2mm gaps at 750rpm. This condition is in accordance with what has been done inside, that the number of magnetic poles, magnetic strength and magnetic gap distance to the coil affect the voltage generated from the axial generator.

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