Power efficiency analysis in various types of coil design

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Abstract. The efficiency of power produced by magnetic flux in the coil has been analysed using various forms of coil section. Magnetic flux was produced by magnets which were moved radially with a certain rotational speed. Meanwhile, a coil placed close to the magnets will produce an electromotive force (emf) according to Faraday's law. Besides affecting the magnitude of emf, the shape of coils also affected the power loss due to partial of magnetic field radially dispersed or didn't go through a coil cross-section. It caused only a portion of the magnetic field would be converted. Therefore, this study aims to reduce the power loss by various type of coil design i.e. round-shaped coil, square-shaped coil, and cone-shaped coil. The coil was formed by the same wire with a length of 60 m to produce the same resistance. The results showed that at a speed of 1100 rpm, the voltage which obtained using round-shaped coil, square-shaped coil, and cone-shaped coil respectively of 1.26 V and 1.01 V and 1.5 V and 1.88 V.

1. Introduction

Eddy currents are electric currents that circulate in conductor induced by changing the magnetic field, flow in closed loops and perpendicular to the magnetic field. It can be produced either when the conductor moved in a fixed magnetic field or when changed magnetic field induced the conductor. It is corresponding to law of Lens. The currents can cause repulsion, traction, impulses, and a warming effect. Eddy currents are also known as the main cause of energy loss in transformers and electric motors [1]. It due to Eddy's tendency that against the cause.

Many researchers have been worked to reduce the loss of energy. The effect of eddy currents had been reduced both in simulation and experiment [2-4] by designing the place of permanent magnets in the rotor, substituting the material of magnets and varying thickness of the rotor [3]. Varying shape of the coil also have potential to reduce the eddy current effect. Coil shape had been analysed in many previous studies [5-9]. The analysis is carried out using coils in many shapes such as circles, rectangular and triangular. However, conical shaped coils have not ever been analysed. In this paper, varied coil's shape which is circular shaped coil, a rectangular shaped coil and conical coil shape was analysed to reducing Eddy current effect and improving power efficiency. The efficiency can observe from the value of voltage obtained in each shaped of coil. The shape of coil that obtain highest voltage and longest retardation time potentially used in permanent axial magnetic flux generator applications.
2. Experiment

2.1 Materials and design
Experimental of this study was made using some equipment such as power supply, speed control devices, motors, rotors, coils, and multimeters. The rotor in this study is similar to the rotor on a disc-shaped axial flux permanent magnet synchronous generator. The rotor was contained ten neodymium (NdFeB) permanent magnets implanted on the disc. The magnets are coin-shaped with dimensions of 20 x 10 mm. The magnets are arranged symmetrically with the poles in the opposite direction to provide N-S magnetization as shown in Figure 1. The disk of rotor was made of acrylic material with a diameter of 24 cm.

![Figure 1. Magnet arrangement in disk of rotor](image)

The coils were made from copper wire (Polyurethane Email wire - UEW type) with a diameter of 0.5 mm and length of 60 m. Email type of wire is chosen due to more flexible, resistant to repeated loops, and the protective layer which easier to peel and clean. The emf was analyzed in varied shaped coils i.e. circular coil, square coil and conical coil as shown in figure 2. The rectangular coil has a size of 5 x 5 cm. Diameter and depth of the circular coil are 5 cm and 5 cm respectively. The cone-shaped coil has two face sections which are front face and back face with diameter of 5 cm and 2.5 cm respectively. It has effective depth of 5 cm.

![Figure 2. Circular coil (left), square coil (center) and conical coil (right)](image)

2.2 Method
While the rotor rotated, the coil was placed close to the outer side of the rotor and parallel with the section of magnet. Experiment had been done using the equipment scheme as shown in Figure 3. The wire at the end of coil is connected to multimeter to measure the generated voltage. In this study, measurement of voltage was obtained in the range of rotor’s speed from 200 rpm to 1100 rpm. The deceleration data was recorded after the voltage had stabilized and the power supply was turned off. the deceleration data is the required time when the power supply was turned off until the rotor stops.
3. Results and Discussion
Coils with round-shaped coil, square-shaped coil, and cone-shaped coil made of wire of the same diameter and length have the same resistance value in each coil. In general, the voltage increases when the rotation speed value on the rotor is getting bigger. At the same rotation velocity value, the voltage value from the smallest to the largest is obtained sequentially provided by square-shaped coil, round-shaped coil, a wider section coil and a smaller section cone coil (Figure 4). The results showed that at a speed of 1100 rpm, the voltage which obtained using round-shaped coil, square-shaped coil, a wider section coil and a smaller section cone coil respectively of 1.26 V and 1.01 V and 1.5 V and 1.88 V. The voltage represents changed flux corresponded to change rotation velocity in each shaped of coils. Higher voltage indicated higher efficiency.

![Figure 4. Voltage as measurement results corresponding to rotation velocity](image)

The retardation data obtained from the experiment shows that with the same voltage value the small face cone coil has a greater retardation value. (Figure 5). This is due to the magnetic flux produced by magnets can generate current eddy. Meanwhile, the coil placed near the magnet will produce an electromotive force (emf) according to Faraday’s law. In addition to influencing the magnitude of the emf, the shape of the coil also affects power loss because some magnetic fields are radially dispersed or not through the cross section of the coil. That causes only a portion of the magnetic field to be converted. In the smaller section of cone-shaped, magnetic flux entering the coil is more focus. The statistical and dynamic nature of magnetic topology systems can provide a tight
relationship with geometric structures [10] and field strength depends on the length, dimensions, and placement of the source coil [11]

![Graph](image)

**Figure 5.** Retardation time corresponding to rotation velocity using short circuit

5. Conclusion

Magnetic flux generating electric motion force can be dependent by shape of coils. Cone-shaped coil can obtain higher electric motion force. However, if the smaller section placed near magnet, electric motion force would be higher due to the magnetic flux passed coils is more focus. When short circuit had connected to coils, the magnetic flux can generate current eddy that can also affected retardation of rotation. Therefore, the slowest rotation had been also obtained using cone-shaped coil with smaller-section placed near magnet.

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