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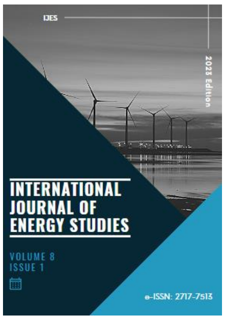

Research Article

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Effect of material on efficiency in alternators used in wind energy

Kadir Yılmaz[a*], Taner Dindar[b]

[a] *Department of Energy Systems Engineering, Kocaeli University, Kocaeli, Turkey, ORCID: 0000-0002-0819-3420*

[b]*Department of Electronics and Automation, Nallıhan Vocational School, Ankara University, Ankara, Turkey, ORCID: 0000-0002-4112-2114*

*(*Corresponding Author:kayel@kocaeli.edu.tr)*

Highlights

- The nominal power of the designed brushless permanent magnet alternator as reference is 750 watts.
- The analyzes of the radial flux permanent magnet alternators designed in the study were carried out using the Ansys_maxwell program
- The effect on efficiency was investigated when the stator and rotor materials were changed
- Torque concept is one of the important parameters affecting the power of the alternator.

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ABSTRACT

It is seen that the use of wind energy as a renewable energy source in the world has increased recently. In addition to this, power plants are established for the production of high power electricity and the energy produced is given to the grid. However, in a region far from the urban area, electrical energy can be produced at small power levels. Radial flux permanent magnet alternators are the most widely used to generate electrical energy at small powers. Therefore, in this study, the effect on the efficiency of the materials used in radial flux permanent magnet alternators was investigated. Time savings can be achieved by analyzing the alternators used for the energy to be produced. The analyzes taken from the program contribute to the studies and may cause small deviations in real applications. In our study, considering the B-H characteristics of ferromagnetic materials, the effects of variable stator, rotor and magnet materials on the output performance were examined and comparisons were made by choosing the configuration with the best efficiency as a result of the optimization made. According to the graphical results obtained, time and cost savings were achieved.

Keywords: Radial flux permanent magnet alternators, renewable energy, ferromagnetic material

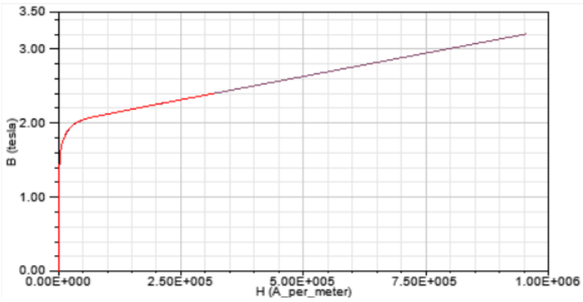
1. INTRODUCTION

Due to the increase in energy consumption in the world and the need for clean energy, the need for renewable energy sources has started to increase. In addition, the value of renewable energy increases in places where it is difficult to reach. There are multiple renewable energy sources, among which solar and wind energy have an important place. Obtaining electrical energy from renewable energy in places far from urban areas provides many advantages. There are alternators that must be used in these power plants while obtaining energy [1]. H. Tejas, et all. presents efficiency improvement of PMBLDC motor with usage of Hiperco magnetic material for the stator core [6]. H. Toda, et al. have shown that use of newly developed non-oriented electrical Steel sheet material (JNP Core) for laminated core improves efficiency of PMBLDC motors [7]. These materials offers high flux density and relatively low iron loss. R. Kolano et al. developed production technology of amorphous soft magnetic materials (ASMM) used to build stator cores of high speed PMBLDC motors [8]. They demonstrated that the replacement of FeSi Steel based stator core with ASMM in high speed PMBLDC motor resulted in substantial reduction in stator iron losses. Hence, the operating efficiency of PMBLDC motor is increased. T. Ishikawa et al. analyzed a brushless dc motor, the stator and rotor core of which are made of soft magnetic composite (SMC) material. [9]. SMC material has low eddy current loss, reduced production cost and good recyclability. It is analyzed that when rotating at high speed, motor efficiency made from SMC core is higher than core made of standard Steel laminations.

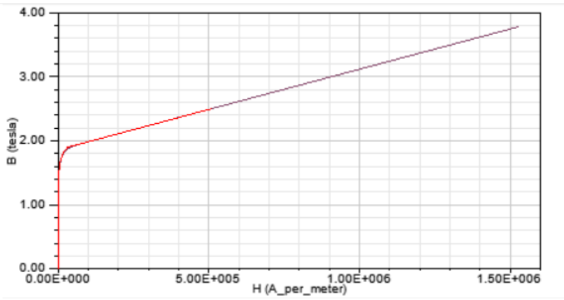
Permanent magnet alternators are examined in two groups as radial and axial flux. They have advantages and disadvantages relative to each other. When evaluated in terms of efficiency, while the axial flux alternator is advantageous, its high cogging torque creates a disadvantage [2,4]. Many new methods are applied to reduce the high cogging torque. Some of these are making auxiliary slots on the stator teeth, adjusting the ratio of magnet pitch to magnet pole [3,5]. The use of radial flux permanent magnet alternators seems to be more advantageous in small power wind turbines. There are many parameters that affect the efficiency of alternators. It is important both in terms of cost and time to choose the efficient programs by making certain changes in these parameters with high-reliability programs before proceeding to the implementation stage. In this study, the materials used in the alternators were changed in the program before the electricity was produced by wind power in the regions far from the city center and the appropriate one was selected. Different parts of the materials related to alternators were examined and the most efficient one was tried to be preferred. The feature that distinguishes it from other studies is that three different materials were compared for the stator and rotor. Thus, the analyzes were made by comparing the efficiency and torque parameters originating from the materials.

2. FERROMAGNETIC MATERIAL SELECTION

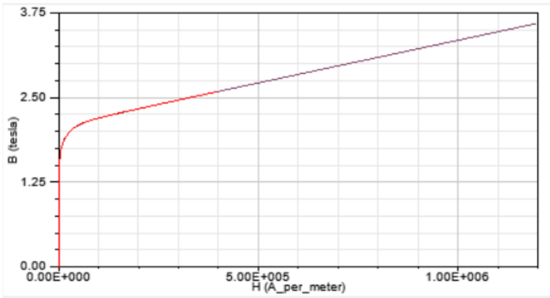
It is the concept that is defined as the highest torque per current (MTPA - Maximum Torque Per Ampere) for good efficiency in electric motors and expresses the production of the highest torque with the lowest current. A high MTPA value means lower copper losses and lower motor temperature. In order to have a high MTPA value, it is necessary to choose a high quality ferromagnetic material. However, high magnet specific values also increase the MTPA value. In our study, comparisons were made by choosing stator, rotor and permanent magnet materials [3].



a) Steel-1010 material



b) M19-24G material



c) Steel-1008 material

Figure 1. B-H characteristics of the materials used in the stator and rotor

The B-H graphs used for the stator and rotor of the alternators are given in Figure 1. Material selection is important for optimum design. For optimum design, magnetic field densities should be between 1.5-2 Tesla in the turning regions. Choosing a smaller rotor volume increases the rotor volume, if a large one is selected, iron losses increase. When the curve of the Steel-1008 material is examined, it is seen that the turning zone is suitable for optimum design.

3. MATERIAL AND METHOD

The analyzes of the radial flux permanent magnet alternators designed in the study were carried out using the ANSYS_Maxwell program. It is more appropriate to use the Rmxprt module, which is suitable for the material we want in the program, which includes different modules. In addition, the analysis time is shortened with the help of modules. In this process, application in machine design also saves time. Parameters of radial flux permanent magnet alternators made of three different materials are given in Table 1, below.

Table 1. Electrical and mechanical parameters of radial flux permanent magnet alternators (M19-24G, Steel 1010 and Steel 1008)

General Machine Parameters	**Slot Values**
Machine type (RASM alternatör)	Hso: 0.8 mm
Number of poles: 8	Hs2: 8.4 mm
Rotor position (Internal rotor)	Bs0: 1.3 mm
Reference speed: 1800 rpm	Bs1: 4 mm
Connection type: Star	Bs2: 6 mm
Power: 0.75 kW	**Rotor Values**
Voltage: 21 V	Outer diameter: 31.1 mm
Operating temperature 100 C^0	Inner diameter: 11.1 mm
Friction losses: 10 W	Length 37.4 mm
	Stator values Pole spring ratio: 0.8
Outside diameter: 63.5 mm	Magnet Type: NdFe35
Inner diameter: 32.6 mm	Sheet Type 1: M19-24G
	Sheet Type 2: Steel 1010
	Sheet Type 3: Steel 1008

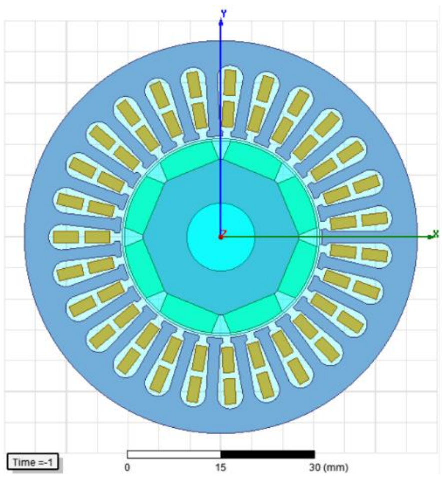
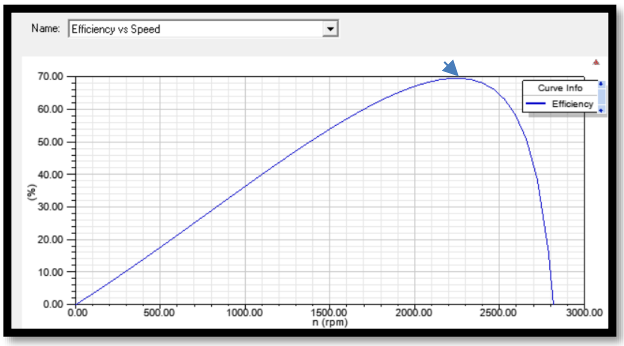


Figure 2. Modeling of machine design in AnsysMaxwell program

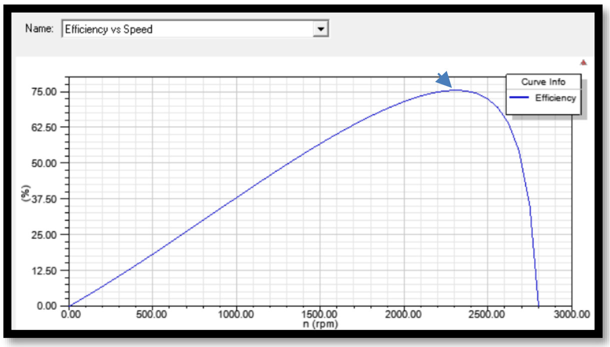
In table 1, the design parameters of the radial flux permanent magnet alternator are given in general. In the design, the inner stator diameter is determined as 32.6. The winding structure, number of poles, nominal electrical sizes and rotor structure have been redesigned. In Figure 2, a 2D view of the RASM synchronous alternator designed in the ANSYS Maxwell RMXPRT module is given. If desired, it can be done in 3D design in the program, but it takes more time. Drawings can be added to the program by using other software from outside.

4. CONCLUSION

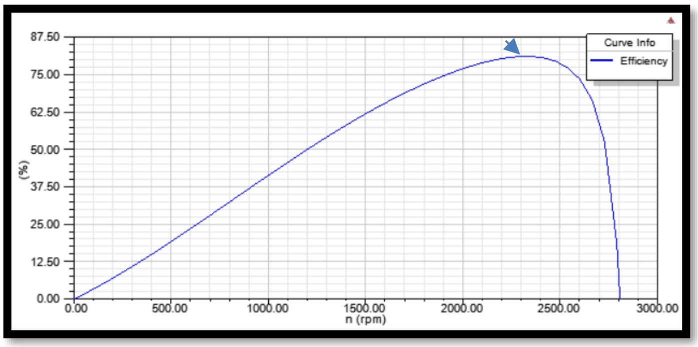
Parameter values of the designed radial flux permanent magnet alternator are entered directly in the program as given in table 1. The obtained values and results were analyzed in the form of graphs. The effect on efficiency was investigated when the stator and rotor materials were changed. The efficiency of the materials given in Figure 3a is around 70 percent. In Figure 3b, it is understood that it is around 75 percent. When we apply the Steel 1008 material in the program, it is clearly seen that the efficiency is around 82 percent and it gives better results than the others.



a.) Stator and its rotor M19-24G as magnet material NdFe35 data



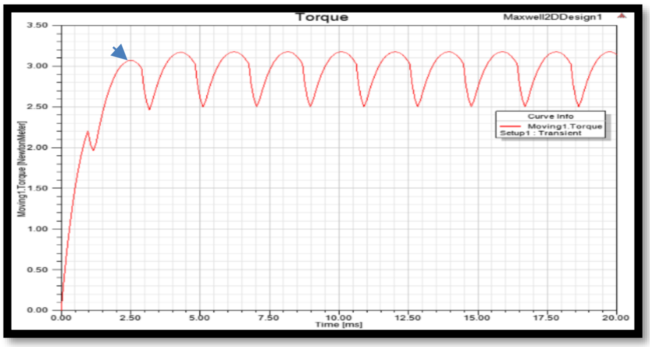
b.) Stator and rotor STEEL-1010, magnet material NdFe35 data



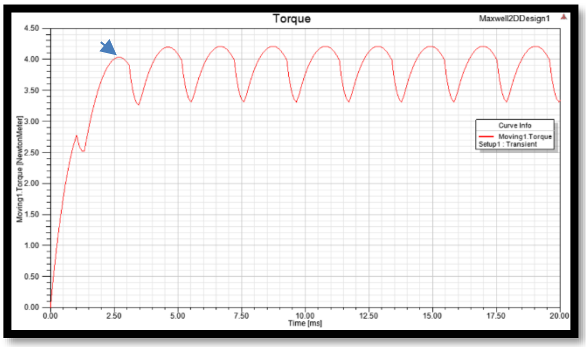
c.) Data of stator and rotor STEEL-1008, magnet material NdFe35

Figure 3. Comparison of efficiency and speed

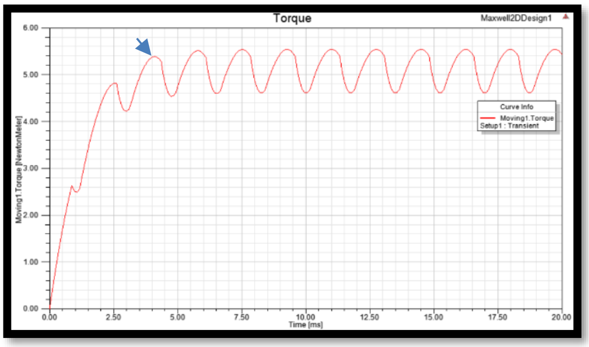
Torque concept is one of the important parameters affecting the power of the alternator. There is a direct ratio between torque and power. Therefore, good torque value is important for alternators. According to the results obtained from the parameters entered into the program in Figure 4, it is seen that approximately 3 N.m is obtained according to the graph in Figure 4a. In Figure 4b, it is seen that 4 N.m is obtained. When we apply the Steel 1008 material in the program, it is seen that 5 N.m is obtained and it is seen that better torque is produced than the others.



a.) Stator and its rotor M19-24G as magnet material NdFe35 data



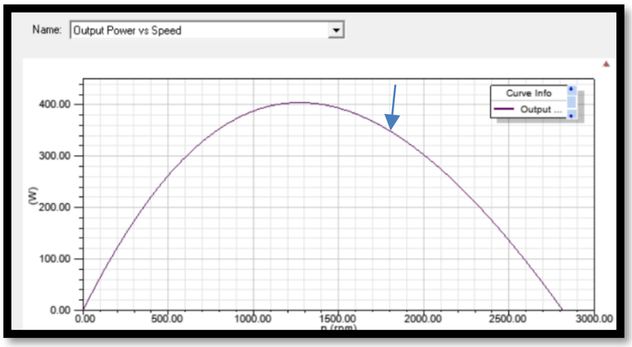
b.) Stator and rotor STEEL-1010, magnet material NdFe35 data



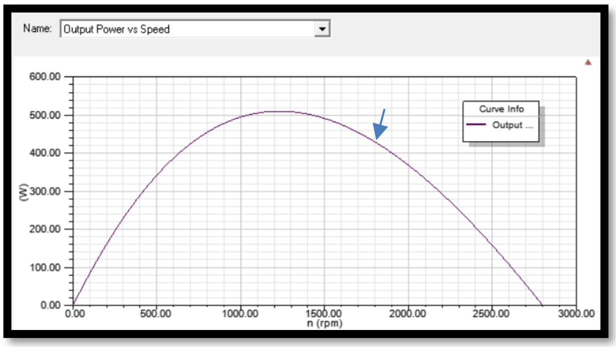
c.) Stator and rotor STEEL-1008, magnet material NdFe35 data

Figure 4. Torque comparison

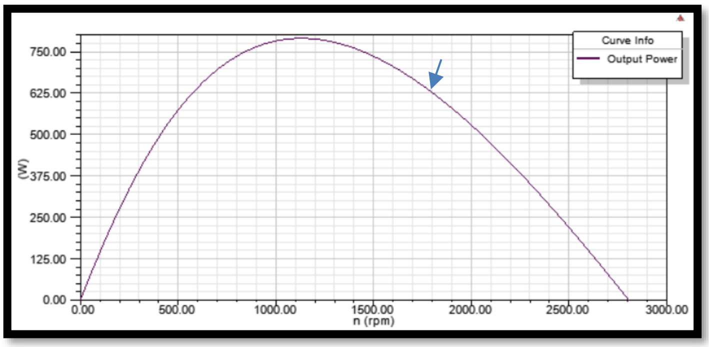
According to the parameters entered in the program in Figure 5a, when the output power is examined, it is seen that it is approximately 340 Watt at 1800 rpm. In Figure 5b, it is understood that it is around 440 Watt at 1800 rpm. It is clearly seen that the output power of Steel 1008 material is 625 Watts.



a.) Stator and its rotor M19-24G as magnet material NdFe35 data



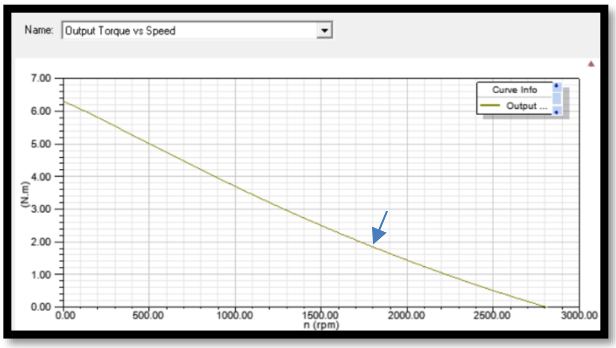
b.) Stator and rotor STEEL-1010, magnet material NdFe35 data



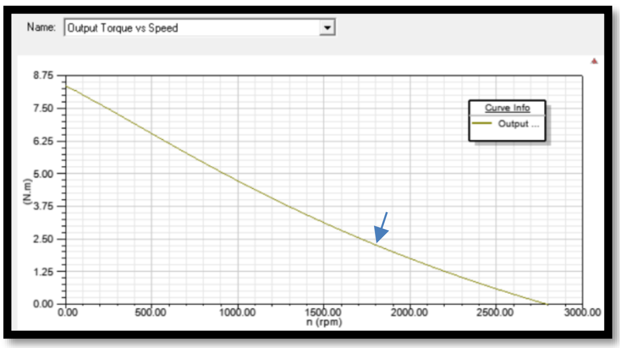
c.) Data of stator and rotor STEEL-1008, magnet material NdFe35

Figure 5. Output power and speed comparison

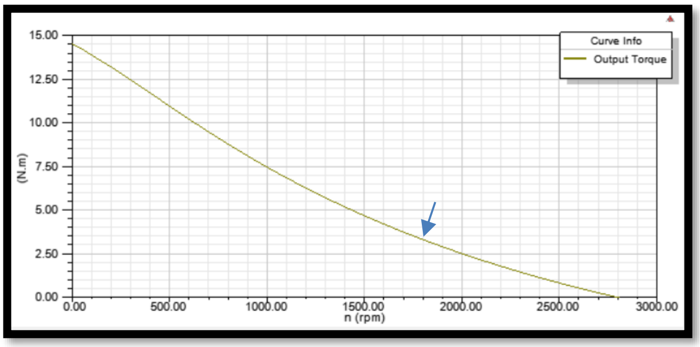
Considering the output torque at 1800 rpm according to the parameter values entered in Figure 6a, it is approximately 2 N.m. is seen as. In Figure 6b, 2.5 N.m. appears to have been around. In Steel 1008 material, approximately 3.5 N.m. appears to be out. It is important that it reaches the highest moment value with the effect of the material used.



a.) Stator and its rotor M19-24G as magnet material NdFe35 data



b.) Stator and rotor STEEL-1010, magnet material NdFe35 data



c.) Data of stator and rotor STEEL-1008, magnet material NdFe35

Figure 6. Output torque and speed comparison

5. RESULTS

In this study, the analysis of radial flux permanent magnet alternators was carried out using the modules of the ANSYS_Maxwell program. The reason for using modules here is to shorten the analysis time. It is aimed to produce small power electricity with radial flux permanent magnet alternators. The nominal power of the designed brushless permanent magnet alternator as reference is 750 watts, its nominal speed is 1800 rpm and the number of poles is 8 and entered into the program. In the values given in the table, the stator and rotor materials were changed and the effect on the efficiency was examined and the best material was selected. From the analysis results, it was seen that the efficiency of the radial flux permanent magnet alternators whose stator and rotor were selected as STEEL-1008 material was higher. It is more suitable to use STEEL-1008 material in application areas.

ACKNOWLEDGMENT

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DECLARATION OF ETHICAL STANDARDS

The authors of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

CONTRIBUTION OF THE AUTHORS

Taner Dindar: Perofrmed the experiments and analyse the results.

Kadir Yılmaz: Wrote the manuscript.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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