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Effect of Core Manufacture Process for Electric Motor Efficiency

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Abstract. In this study, radial BLDC motor is the object of research. The study focused on stator core material to improve electric motor performance by replacing the laminate material with a composite material powder. The use of composite material powder for wound core material is to simplify the manufacturing process with efficiency equal or close. Wound core material was tested by using VSM, the test is intended to determine electromagnetic properties of materials. The process of preparation of the sample is done by using pressure variations. The result of electromagnetic properties of the material is in the form of remanence, permeability, and coercivity. The result of the electromagnetic character of the material is then used as input material properties of the core windings for simulation. From the simulation results obtained performance electric motors. The effect of using different wound core to the efficiency of the motor is then compared. From the study, it can be concluded that by replacing the core material obtained efficiency of the motor windings are nearing a conventional motor. Excellence wound core materials that use composite powder is the ease in the manufacturing process.

INTRODUCTION

The electric motor is the component that is most widely used in everyday life. Ideally, the electric motor has a high efficiency and have a small loss. In fact, the losses in the electric motor are still high, one of which is the loss contained in the stator. Losses contained in the stator consists of hysteresis loss and eddy current loss. In general, the core windings on the stator using the laminate material. The laminate material has eddy current loss is relatively high, so the losses contained in the stator is still high. The new material can replace the laminate material is Soft magnetic materials iron powder.

Soft magnetic materials are widely used for various applications of electromagnetic. Soft magnetic materials are widely used in the electronics industry and the manufacture of core components in electric motors. Various studies conducted to obtain new materials or developing existing research by changing the composition, structure or manufacturing technology. Research on the magnet both theoretically and experimentally continues until today, ranging from magnetic properties to study the microstructure. With the exact chemical composition will be produced magnetic material has magnetic properties are optimal with minimal weight and size [1]. In general, the soft-magnetic material primarily made from iron powder (Fe). Purity and Fe content affect the magnetic properties, such as the value of coercivity field and magnetic permeability values. The higher the value of purity and content of the womb, then the value of the magnetic permeability will also be higher [2]. The soft-magnetic material has a permeability value saturation induction higher than the hard magnetic materials, but it has a coercivity value which is comparatively lower than the hard-magnetic material [3].

EXPERIMENTAL METHOD

This study was conducted to simulate the effect of changing the material of the core windings using the software Ansys Maxwell RMxprt. The core windings are manufactured from iron powder materials and laminate materials.

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Then determine the effect the efficiency of the electric motor after simulated using wound core manufactured from iron powder material. The materials used were the results of previous studies. Iron powder compacting material with 4, 5 and 6 tons treated by the annealing temperature of 600ºC. Soft magnetic materials made using iron powder and epoxy binder. The ratio of iron powder and epoxy is 5% by volume epoxy. VSM testing conducted to determine the magnetic properties of a soft magnetic composite material. The test results in the form VSM hysteresis curve. The curve of hysteresis is the curve of the ratio between B (grades induction generated) and H (rated induction given to induce B) [4]. Data from hysteresis curve is used as input data on the properties of materials stator on the simulation efficiency of electric motors in Ansys Maxwell Rmxprt. Results simulation efficiency of electric motors with wound core of soft magnetic composite then compared with the value of the motor efficiency with a wound core laminate.

ELECTRIC MOTOR SIMULATION

Parameters that affect the efficiency of electric motors is the geometric shapes of the stator and stator materials properties. The stator and rotor each have a geometry that includes property outside diameter, inside diameter, and height as shown in Fig. 1 and Table 1.

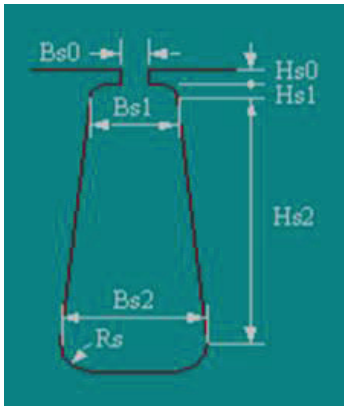

FIGURE 1. Stator slot

TABLE 1. parameters for the simulation of electric motors

Parameter	Value	parameter	Value
Output power (kW)	3	Bs0 (mm)	3
Voltage (V)	72	Bs1 (mm)	12
Number of poles	22	Bs2 (mm)	12
Stator slot number	12	Hs0 (mm)	2,5
Stator outside diameter (mm)	150	Hs1 (mm)	4,5
The inner diameter of the stator (mm)	70	Hs2 (mm)	25
Stator core length (mm)	48	Rs (mm)	3
Stacking factor	0.95		

The calculation of the efficiency of the electric motor can be done by comparing the input electrical power used compared with the mechanical energy output that can be produced. Or can also be calculated from the total loss of the motor as in the following formula.

$$\text{eff} = (\text{Pin} / \text{Pout}) \times 100\% \quad (1)$$

$$\text{Pout} = \text{Pin} - (\text{power loss}) \quad (2)$$

Where, Pin (Watts) is the input power and Pout (Watts) is the output power of the electric motor. Power loss is the total power loss found in electric motors.

RESULTS AND DISCUSSION

VSM testing was done at the Center for Science and Technology of Advanced Materials - BATAN. Tests performed at the workstation -800 kA / m to 800 kA / m. Comparison of material characteristics in terms of the magnetic properties of the material, the value obtained was applied to the manufacture of wound core material on the electric motor. The test results will produce data BH VSM diagram as shown in Fig. 2.

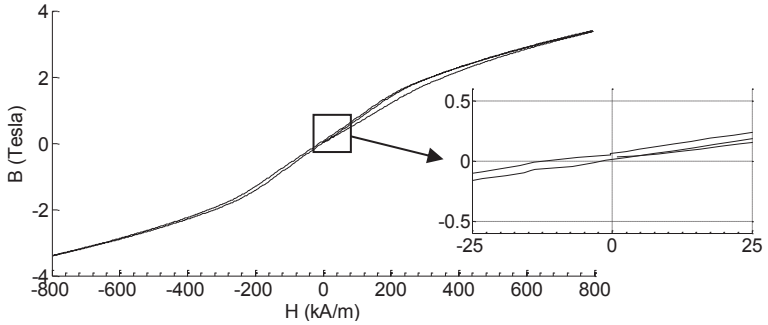

FIGURE 2. Hysteresis curve laminate sample

TABLE 2. Magnetic properties Test results for the VSM Laminate Specimens and SMC-s

Test specimens	Br (T)	Hc (kA/m)	μr (Wb/Am)
Laminate	0,068	-2,70	4,09
SMC-s compacting 4 ton	0,026	-4,56	1,81
SMC-s compacting 5 ton	0,029	-6,25	1,91
SMC-s compacting 6 ton	0,041	-6,28	2,37

BH diagram data can be processed to determine the magnetic properties of materials as shown in Table 2. Based on the theory, the most optimal material applied to the manufacture of wound core to the electric motor is a material that has a value of remanent induction and low coercivity value, while the value of high-value magnetic permeability [5,6]. Coercivity is the magnitude of the magnetic field required to remove remanent induction after going through the process of electromagnetic induction. Terrain coercivity material to be magnetized magnetic induction greater than the amount required to generate the magnetic properties of the material is also great. So that the energy released was also getting bigger. When applied to the electric motor, the power output becomes larger [7]. To value the most optimal coercivity terrain found on the SMC-s specimen compacting pressure of 6 tons is equal to -6.28 kA / m. This specimen has a coercivity field value is the smallest compared with other specimens.

Remanence induction value affects the response of the electric motor's rotational movement. Remanence magnetic induction that is left behind in the soft-magnetic material at the time eliminated the magnetic properties (demagnetization). If the value of the induction remanent smaller then the resulting response will be faster, this phenomenon is caused by the return of the orientation of the magnetic field is small. Remanence value will make a material can be demagnetization in a short time [5].

The ratio of the flux density magnetic field strength magnet is called the permeability, the value ratio between the meetings of the magnetic flux with the magnetic field strength is high on the curve hysteresis showed that the magnetization easily happens because of required magnetic field is small to generate a flux density of high value for the induction. The value of SMC-s permeability compacting pressure of 6 tons has the highest permeability values in comparison with another SMC-s has a permeability of 2.37 Wb/Am, but when compared to the laminate specimen permeability values are still less high, which has a value permeability of 4.09 Wb/Am. The value of the permeability of the SMC-s smaller than the laminate specimen is in conformity with the theory, which can be explained as follows. In the manufacture of SMC-s specimen binder powders used are an epoxy resin and epoxy hardener. Epoxy classified into types of diamagnetic materials, ie materials that reject lines of magnetic force, while the laminate specimen had

higher levels (Fe) is high because it is still pure, which makes laminate specimen susceptible to magnetization. [5] & [6]. Data comparison of the relationship between the value of B and H are used as input data on the properties of materials at Maxwell Ansys simulation.

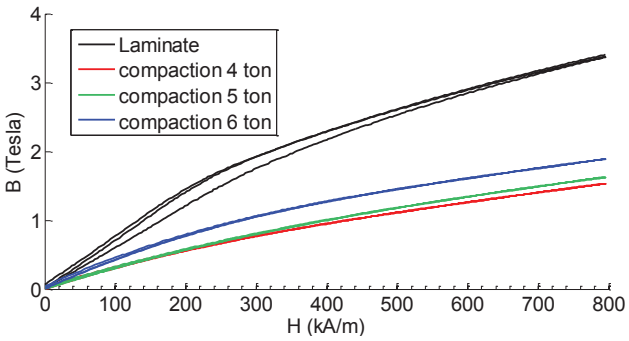

FIGURE 3. Relationship between B and H in the specimen

BH diagrams data was modified and then taken to a positive force for the purposes of the simulation, as shown in Fig. 3. Each additional compaction values on soft magnetic composite specimens can increase the value of magnetic induction (B). This is due to the higher compression force or compaction is given on the powder granules bonding material particles becomes stronger so that the distance between the particles become more tightly or less. The more dense spacing between the particles due to voids contained in the specimen on the wane. As the more dense spacing between the particles then the specimen easier to accept induction [8]. Magnetic induction (B) specimen laminate value is higher than the value of magnetic induction soft magnetic composite specimens. The content of the resin contained in the soft magnetic composite specimens can hinder the process of magnetic induction. The resin can inhibit magnetic induction because the resin included in the insulator material. Insulators are materials that can prevent the conduction of electrical charge [7].

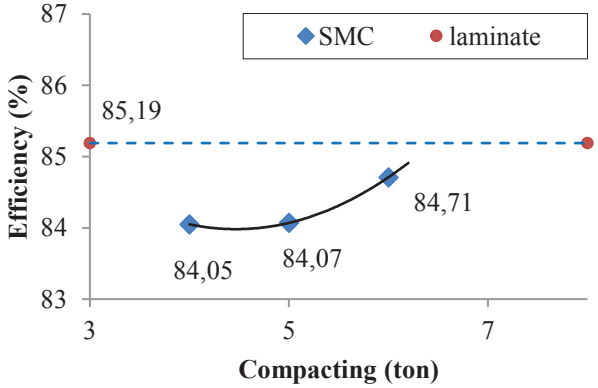

FIGURE 4. The effect of compacting pressure on the efficiency of electric motors

The results obtained from electromagnetic simulation efficiency of electric motors with an upward trend every additional compacting the soft magnetic composite material. The results of the electromagnetic simulation can be seen in Fig. 4.

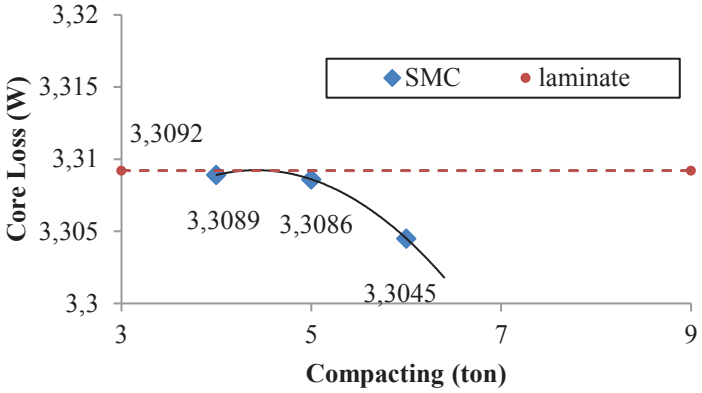

FIGURE 5. The effect of compacting pressure on core loss

Increased efficiency due to the addition of compacting pressure on any soft material magnetic composite caused by the narrower core loss in the electric motor [6]. Core loss is a loss that is contained in the core windings of electric motors. Core loss consists of eddy current loss, hysteresis loss, and winding loss. Core loss on the electric motor decreased with increasing compacting pressure value on the specimen and electric motor efficiency will increase with decreasing core loss. It can be concluded by the reduced value of core loss on the electric motor causes the value of electric motor efficiency will increase as shown in Fig. 5.

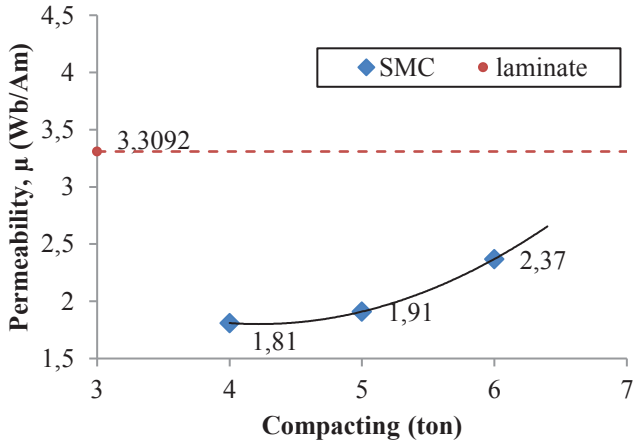

FIGURE 6. The effect of compacting pressure on the permeability

Another factor influencing the increase in the efficiency of electric motors is the permeability of a magnetic material. Permeability is the ability of a material to conduct magnetic magnet. Magnetic material having high permeability will easily magnetize [7]. Figure 6 shows that the increase in the value of compacting pressure will affect the increase in the value of permeability. The greater the value of the permeability compacting pressure generated will be greater. It can be concluded that the compacting pressure is directly proportional to the permeability. The magnetic permeability of the soft magnetic composite specimens with compacting pressure 4, 5, and 6 tons of permeability values obtained successively as follows: 1.81 , 1.91, and 2.37 Wb / Am.

Laminate material permeability value higher than the value of the permeability of soft magnetic composite materials. It is caused by the presence of resin in the soft magnetic composite material. The resin may reduce the permeability of a magnetic material. As with the previous explanation, the resin can inhibit magnetic induction because the resin is included in the insulator material. Insulators are materials that can prevent the conduction of electrical charge. Therefore, the value of a magnetic induction laminate material is higher than the magnetic induction soft magnetic

composite materials because the materials do not contain resin laminate Therefore permeability soft magnetic composite materials by compacting pressure 4, 5 and 6 ton was lower than laminate material.

From the test results and the discussion that has been done, it can be compared the efficiency of electric motors laminate specimen with soft magnetic composite specimens that have been made. The efficiency of electric motors for a laminate specimen is 85.19%. The efficiency of electric motors for soft magnetic composite specimens with a compacting pressure of 4, 5 and 6 tons amounted to 84.05%, 84.07%, and 84.71%.

Based on research that has been done, the effect of the process of making the core windings on the efficiency of electric motors is successfully simulated on Ansys Maxwell. Values efficiency of electric motors by using laminate materials and soft magnetic composite materials by compacting pressure 4, 5 and 6 tons were found. Soft magnetic composite specimens with a compacting pressure of 4, 5 and 6 tons have a value of electric motor efficiency approaching laminate specimen. It can be concluded that the specimens with the same material but different ways of making the electric motor efficiency values do not differ much. The efficiency of the electric motor is directly proportional to the increase in the value of compacting pressure on the soft magnetic composite specimens. The greater the value of compacting pressure on the soft magnetic composite specimens, the value will increase the efficiency of electric motors. Therefore, in order to obtain the efficiency of electric motors are better than the laminate material iron powder material to be compacted more than 6 tons.

CONCLUSION

Compacting pressure is directly proportional to the magnitude of the remanence and magnetic permeability but is inversely proportional to the magnitude of the coercivity field based on simulation data and discussion of comparative efficiency of electric motors with winding core laminate materials and composites using powder. In the motor with winding core composite, the pressure in the process of making the efficiency tends to increase. This is supported by the reduced value of core loss and an increase in the permeability of the material. Electric motors using iron powder core material winding efficiency is still below the laminate material due to content on the resin material can hinder the process of magnetic induction.

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