Analysis of Physical, Mechanical, Magnetic Properties and Corrosion Resistance on Composite Magnet NdFeB With Bakelite Binder

Ramlan[1*], Dedi Setiabudidaya[1], Suprapedi[2], Priyo Sardjono and Muljadi[2]

Abstract—The composite magnet NdFeB has been made by using raw materials such as: jet milled NdFeB powder (type MQP-B) and bakelite powder as binder. The mixing process was carried out with variations of bakelite composition used were 3 % wt, and 8 wt. The mixtured raw materials were formed by using hot press at 10ton force and at temperature: 120, 140, 160, and 180 °C. The examination of physical, mechanical, magnetic properties, and corrosion resistance of pellet samples were done. According the characterization results show that the composition of bakelite and hot press temperature can siqnificantly influence the bulk density value and compressive strength. The optimun value of binder composition based on the magnetic properties is 3 % wt of bakelite at hot press temperature of 180°C. This sample has remanence value Br = 5580 Gauss, coercivity value Hc = 7950 Oe, bulk density = 5.62 gram/cm^3, and compressive strength value= 1285 kgf/cm^2. The corrosion test results show that NdFeB magnetic composite remains easily corroded, therefore surface coatings are required to prevent corrosion

Index Terms— bakelite, composite magnet, compressive strength, corrosion resistance, magnetic properties, NdFeB, physical properties

1 Introduction

The development of today's permanent magnets is highly focused for high-energy permanent magnets. One of the permanent magnet materials that can produce such high energy is of the type RE-Fe-B (RE = Nd, Pr) [1]. There are several types of permanent magnetic material, but only permanent magnet based on Nd-Fe-B, are classified as hard magnetic materials that have a highest coercive force and energy product, but have a low corrosion resistance [1],[2]. There are two type of permanent magnet product namely a sintered permanent magnet dan a bonded permanent magnet [3]. It's been more than half a century since the bonded magnet was first developed by Baermann in 1934.[4]

The bonded magnet was made from mixture of particle magnetic and polymeric binder, and it is called as composite magnet. Currently, a composite magnets with different properties are used in various applications, sucha as : small motor componets, generators, and hard-disk electromagnetic and radio-frequency interference shielding for electronic devices and electrostatic dissipation[4],[5]. The composite of permanent magnet NdFeB has many advantages: a simple manufacturing technology, its properties can be varied, and it has lower manufacturing costs because of its inexpensive finishing and ability to form as any shape [6],[7].

There are many types of polymer materials that are generally used for the manufacture of a composite magnet NdFeB, and many authors have conducted research on permanent magnet composites using polymers such as rubber, epoxy resin, nylon, and polyvinyl butiral [8], [9].

In this study, bakelite polymer was used for the manufacture of NdFeB magnetic composites. Bakelite has been widely used for electrical components and automotive accessories, it can be used as an adhesive in the manufacturing of magnets. Bakelite is the synthetic plastic form of polyoxy benzyl methylen glycolanhydride. It is a thermosetting phenol formaldehyde resin. The molding temperature of bakelite is 160°–180 °C and it has a density value of approximately 1.4 g/cm^3 [10].

The application of various process techniques in the production process of composite magnets, provides the possibility for the utilization of various magnetic powders in combination with different polymeric materials as binders. The development of composite technology, The composites magnet can be produced using conventional techniques and modern techniques. Conventional techniques generally involve extrusion and compression, the improvement of such techniques generally depends on the selection of the polymer type and increased loading of the magnetic particles [11]. Conversely, modern techniques are being developed by researchers, which include improvements such as the development of surface modification by adding surface agents, using selective laser melting methods, and using advanced 3D printing [11],[12].

In this study discussed the manufacture and characterization of composite permanent magnet NdFeB with a bakleite binder . The purpose of this study was to determine the effect of bakelite composition on the physical, mechanical, magnetic and corrosion properties of NdFeB magnetic composite made.

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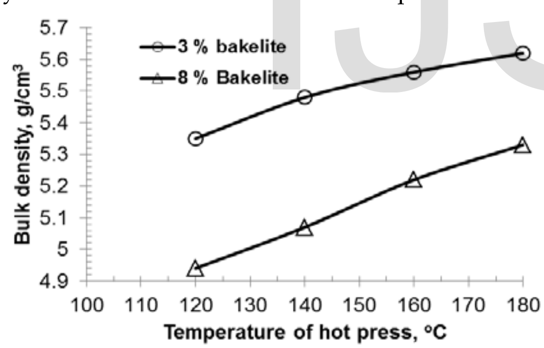
2 EXPERIMEN

The raw materials of the composite magnet NdFeB were a jet milled rapidly quenched Nd-Fe-B (MQP-B) and a powder of bakelite polymers. The average particle diameter of jet milled NdFeB was 22.42 μm and that of the bakelite polymer was 26.64 μm. The amount of the polymer was varied to be 3 %, and 8 wt.%. Both raw materials were weighed and mixed to obtain various compositions of the bakelite polymer using a pestle and mortar, and the total weight for each composition was 30 g. The mixed powders were inserted into mold then compacted with hydraulic press with load force 10 ton force and hold for 20 minutes at temperature of 120, 140, 160, and 180 °C. This pellet samples were then magnetized using Magnet-Physic Dr. Steingroever GmbH Impulse Magnetizer K-Series. The samples were given a shock voltage of 1.8 kV and with an average current of 6 kA. Characterization conducted in this study include physical properties (bulk density), compressive strength, magnetic properties by using Permeagraph Dr. Steingroever GmbH and corrosion resistance (immersion in water test).

3 RESULTS AND DISCUSSION

The first physical properties test is bulk density. This test is performed for all samples with different polymer compositions. The result of measurement of bulk density can be seen at Figure 1. From the graph below shows that the addition of bakelite polymer binder composition increases, the value of density tends to dercrease. Also the temperature of hot press



increses, the value of bulk density tends to increasing. This is because that the density of bakelite is lower than the density of magnetic powder NdFeB and also more higher temperature of hot press, the samples become dense, because the higher the temperature of the hot press, the melting of the bakelit polymer is easier to flow and enter the cavity between the grain.

Fig 1. Curve of the relationship between the variation of hot press temperature and the bulk density at different of polymer composition.

The result shows that the highest density value is achieved 5.62 g/cm³ for sample with 3 % bakelite and 5.33 g/cm³ for sample with 8 % bakelite at temperature of hot press about 180°C . When compared to the theoretical density value of composite NdFeB that is about 6 g/cm³ with experimental results, then the densification achievement of this research is only about 94 % for sample with 3 % bakelite. Furthermore, for measurement of mechanical properties, magnet, corrosion resistance test and microstructure are done for samples with hot press temperature 180°C. The result of measurement of compressive strength is seen at Figure 2. The Figure 2 shows that the bakelite binder composition increases , the compressive strength value tends to increase. If the hot press temperature increases so the value of compressive strength tends increasing.

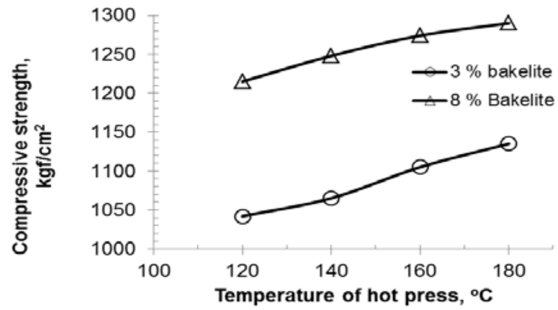


Figure 2. Curve of compressive strength as function of temperature hot pressat sample with 3 % and 8 % bakelite.

This suggests that the greater the addition of bakleite composition shows the ability of test samples to better defend themselves. This happens because the function of the binder it self is as a binder. So the more polymer binder the test sample will be more hardened. It also happens because the process of compaction between polymer binder and magnetic powder interact well.

Based on the measurement of bulk density and compressive strength, the highest values of bulk density and compressive strength were obtained for samples with 3% and 8% bakelite and hot press temperature of 180°C. Then the two samples were measured the magnetic properties by using permeagraph Physic Dr Steingroever GmbH. The result of the hysteresis curve in quadrant II is shown in Figure 3. Samples with 3% bakelit have higher magnetic properties compared to 8% bakelit samples. because bakelit is non -magnetic, if the fraction of the polymer bakelit

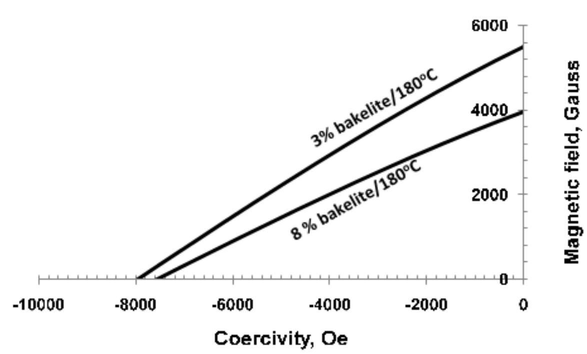


Figure 3. Hysteresis curve at quadrant II for sample with 3% and 8 % bakelite and with hot press temperature 180°C.

increases, it will affect the movement of the particle direction of the domain. Based on the results shown in Figure 3, it can be obtained the remanence and coercivity values of each sample as shown in Table 1.

Tabel 1.
Value of remanence (Br) and Coercivity of sample with hot press temperature 180^{o}C.

% Bakelite	Remanence (Br) Gauss	Coercivity (Hc) Oe
3	5580	7950
8	3990	7600

In Table 1, it can be seen that the sample with 3% bakelite has a greater remanence and coercivity value compared to the sample with 8% bakelit. This is because the nature of bakelit is non-magnetic. This shows that the test sample with the addition of a bakelit polymer binder is included into the hard magnet, since its coercivity value is more than 200 Oe.

The corrosion resistance test is conducted by soaking the test sample in water with temperature according to the temperature of the room that is 29 °C. The test is performed by looking at the flux magnetic value changes from the test samples. The corrosion test result can be seen at Figure 4. From the Figure 4 can be seen the test sample with the addition of bakelit polymer undergoes a flux magnetic value change during this test. The flux magnetic value of the sample decreases as the sample immersion time increases. The sharp decline in flux magnetic value is due to corrosion test samples. In this test the sample was corroded because it was immersed in water. Therefore the corroded sample will experience a decrease in flux magnetic value from its original state. It can be concluded that corrosion resistance test with indicator of flux magnetic value change for bakelit polymer binder, the more the addition of polymer binder composition the better the sample is to defend it self from corrosion.

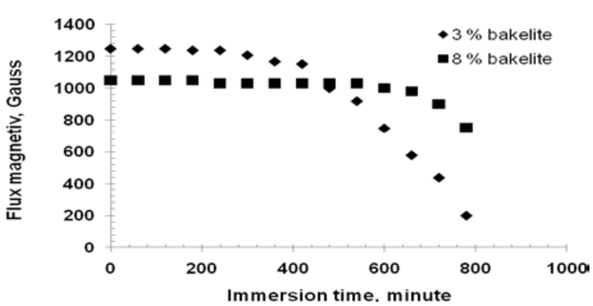


Figure 4. Graph of immersion time relationship with flux magnetic value.

According the corrosion results, the sample with 3 % bakelite can be easy corroded and starts to corrode after 400 minute immersion in water, but a sample with 8% bakelite begins to corrode after 800 minutes immersion in water.

4 CONCLUSION

According the characterization results show that the composition of bakelite and hot press temperature can siqnificantly influence the bulk density value and compressive strength. The optimun value of binder composition based on the magnetic properties is 3 % wt of bakelite at hot press temperature of 180^{o}C. This sample has remanence value Br = 5580 Gauss, coercivity value Hc = 7950 Oe, bulk density = 5.62 gram/cm^{3}, and compressive strength value= 1285 kgf/cm^{2}. The corrosion test results show that NdFeB magnetic composite remains easily corroded, therefore surface coatings are required to prevent corrosion.

ACKNOWLEDGMENT

The authors would like to thank Joint Research Program UNSRI - PPF-LIPI on "Riset Unggulan Kompetitif Program 2016-2018" for financial support.

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