Effect of composition polymeric PVB binder on physical, magnetic properties and microstructure of bonded magnet NdFeB

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Abstract. The bonded magnet NdFeB has been made by using the hot press method and using Poly Vinyl Butiral (PVB) as a binder. The composition of polymeric binder was varied: 0, 2, 4, 6 and 7 % of weight. Both raw materials are weighed and mixed according to the composition of PVB, then formed by hot press with a pressure 30 MPa, a temperature of 160 ° C and holding time for 30 minutes. The bulk density was measured by using Archimedes method. SEM observation was done to determine the microstructure of bonded magnet NdFeB. The flux magnetic value was measured by using a Gauss meter and the measurement of hysteresis curves was done to know value of remanence Br, coercivity Hc and energy product BHmax by using VSM. According to the characterization results show that the best composition of PVB is 2 of weight. The properties of bonded magnet NdFeB of those compositions are the bulk density around 5.66 g/cm³. Flux Magnetic value: 1862 Gauss, Br value: 5000 kGauss, Hc value: 8.49 kOe and BHmax value : 5.10 MGOe. According of SEM observation results show that the polymer matrix of PVB appears to have covered on all surface grain and filled grain boundary.

1. Introduction

Permanent magnets are distinguished in two different categories: ferrite and rare earth. Ferrite magnets are classified as oxide magnets and mainly composed of ferric oxide. In the case of rare earth magnets, they retain a higher level of strength than ferrite magnets by approximately 10-fold which are also more expensive [1]. There are two types of rare earth magnets: SmCo-type and NdFeB-type. Currently, more than 98% of rare earth magnets produced are NdFeB ones. There are two types of Nd magnets: sintered and bonded [2]. An Alloy Neodymium Iron Boron (NdFeB) is made from metal elements to form Nd2Fe14B with a tetragonal crystal structure [3]. Bonded magnets are mixtures of permanent magnetic powder and a binder. The powder may be Ferrites, NdFeB, SmCo, AlNiCo and mixtures (hybrides) and the binder will bind the magnetic particles and can produce flexible bonded magnets or rigid bonded magnets. Typical binders for flexible magnets are nitrile rubber and silicon rubber. Binders for rigid magnets include Nylon, Epoxy Resin, Polyphenylene Sulfide, Polyester and Poly Vinyl Butiral[4]. The amount of the NdFeB powder in the bonded magnet is directly correlated with the magnetic and mechanic behaviour of the bonded magnets [5]. A higher content of Nd-Fe-B powder usually results in a higher remanence magnetization (Mr) and maximum energy density.
and therefore, it is desirable from the magnetic perspectives [6]. The applications of bonded magnets are for motors and sensors for the media storage, consumer electronics, automotive, office automation and appliance markets [1,7]. This paper will discuss the synthesis of bonded magnet NdFeB using Poly Vynil Butiral (PVB) as binder. The objective of this study was to determine the bulk density, the magnetic properties (flux magnetic density, coercivity, remanence and energy product) and micro structure by using Scanning Electron Microscope (SEM).

2. Methodology
NdFeB powder type MQP-B was used for preparing bonded magnet NdFeB by using hot press method and Poly Vynil Butiral (PVB) powder was used as binder. The composition of polymeric binder was varied: 0, 2, 4, 6 and 7 % of weight. Both raw materials are weighed and mixed according to the composition of PVB, then formed by hot press with a pressure of 30 MPa, a temperature of 160 °C and holding time for 30 minutes. The disc samples were measured its bulk density by using the Archimedes method. SEM observation was done to determine the microstructure of bonded magnet NdFeB. The flux magnetic value was measured by using a Gauss meter and the measurement of hysteresis curves was done to know the value of remanence Br, coercivity Hc and energy product BHmax by using Permeagraph.

3. Results and Discussion
The bulk density values of bonded magnet NdFeB with different composition of binder (PVB) are shown in figure 1.

The bulk density curve shows that the value of bulk density decreases with increasing of PVB composition. It is because the different density value between NdFeB particle and binder (PVB) particle. The theoretical density of NdFeB particle is higher (about 6 - 7 g/cm³) compared with the density of PVB (about 1-2 g/cm³). The highest density value is achieved at 5.66 g/cm³ (87 % from theoretical density for sample with 2 % PVB) and the lowest density value is achieved at 4.97 g/cm³ (76.50 % from theoretical density for sample with 7 % PVB). The flux magnetic curve as function of PVB composition is seen in figure 2.
Figure 2. Flux magnetic value of bonded magnet NdFeB with variation of PVB composition.

Figure 2 shows the correlation between flux density with PVB composition. Generally, value of flux magnetic decreases with increasing of PVB concentration, this is due to the properties of both materials, the PVB is nonmagnetic materials. When the amount of nonmagnetic materials in bonded magnet materials, so the magnetic properties of bonded magnet will decrease. According to the application, this material is a magnetic one, so that it becomes a magnetic property is the main consideration. Samples with 2 % and 4 % PVB have the enough high value of flux magnetic, and also they have enough high bulk density as seen in figure 1.

In figure 3, the hysteresis cycles of the samples with 2 % PVB and 4 % PVB are presented. It was found that their shapes are similar, this is due to the small contents of PVB as a binder, hysteresis cycle depends on the content of NdFeB particles, in this case that the content of NdFeB particles are dominant.

Figure 3. Hysteresis cycles of sample with 2 PVB and sample with 4 % PVB.
Based on figure 3, the value of the remanence (Mr), the magnetic saturation (Ms), the coercivity (Hc) and the maximum energy product (BHmax) can be obtained and the results are shown in table 1. The value of magnetic properties of bonded magnets with 2 % and 4 % PVB are similar.

Table 1. Value of Mr, Ms, Hc and BHmax of samples bonded magnet NdFeB

| % wt. | Mr (emu/g) | Ms (emu/g) | Hc (kOe) | BHmax (MGOe) |
|-------|------------|------------|----------|-------------|
| PVB   |            |            |          |             |
| 2%    | 72.86 [5000 Gauss] | 103 [7300 Gauss] | 8.490    | 5.1         |
| 4%    | 73.84 [4000 Gauss] | 102 [5700 Gauss] | 8.647    | 5.2         |

Figure 4 shows structure of a composite bonded magnet with 2 % PVB and 4 % PVB observed in scanning electron microscopy. Their grains are irregularly shaped and occurrence of the small portion of pores was observed in the materials. During the hot pressing at temperature 160 °C, the binder PVB melted. The melted PVB enveloped surface of gains and bind together with each other. As in the figure 4 (a) and (b) that the PVB binder can be found between grains and it was clear that the polymer binder (PVB) has bonded well the whole NdFeB grain.

(a). Sample with 2 % PVB  
(b) Sample with 4 % PVB

Figure 4. The SEM microstructure of bonded magnet with 2 % PVB and 4 % PVB.

4. Conclusion
The bonded NdFeB magnet has been made using a Poly Vinyl Butyral (PVB) binder by a hot press method. The composition of PVB binder gives significant effects on the bulk density and flux magnetic value, but it does not influence performance of hysteresis loops and micro structure. The optimum PVB binder is achieved at 2 % wt. of PVB, the bonded magnet, NdFeB with 2 % wt. of PVB has bulk density value about 5.66 g/cm3, flux magnetic value 1862 Gauss, remanence value about 72.86 emu/g [5000 Gauss], coercivity about 8.49 kOe and energy product about 5.1 MGOe.

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