EFFECT OF FERRITE COMPOSITED IN POLYAMIDE6 ON THE MAGNATIC FIELD OF INDUCTIVE SPECIMEN PREPARED BY INJECTION MOLDING PROCESS

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ABSTRACT

The aims of this research are to design and make a plastic injection mold for manufacturing a plastic magnet. The dimension of a workpiece was created on a scale of 5 × 11 × 2 mm. Mold making was firstly designed by CATIA software before subjecting to computer numerical control (CNC) milling machine. To clarify an effect of ferrite content on the magnetic field of composites, quantity of ferrite in the polyamide 6 matrixes was diluted from 85 to 20%. Polymer composite was mixed on a two rolls mill machine at 220ºC for 20 min. To activate the ferrite in a polymer matrix, workpiece was injected in a special mold which was attached with a part of magnet. Gauss meter proved that magnetic field of the workpiece suddenly decreased with the major reduction of ferrite composition. In addition, density, Shore D hardness, tensile properties and impact strength of the composites were also reported.

KEYWORDS: Ferrite, Plastic magnet, Polyamide6

1. Introduction

Injection molded plastic magnet is an essentially occurring material, which have been developed for widely used in an industrial application .At present, there are only a few of groups in Thailand that are involved in this process. [1] Mostly products were operated in the manufacturing of small electronic components for example camera part, printer part, etc. [1] Because of numerous advantages of the plastic magnet such as light in weight and practically produced a complex specimen, the special injection molding technique is very interesting.

Plastic magnet is a magnet made by mixing magnetic ferrite powder with plastic polymers. Injection mold process can be used to produce small workpieces or complex geometric shapes with high accuracy. The properties of plastic magnets are depended on the type of ferrite magnetic material and binder [2-4]. Thus, it can be used as a different mixture of magnetic materials to create the desired properties.

The scope of this research will be divided into three parts such as; 1) to design and make a special injection molding, 2) to mix ferrite compound in a polymer matrix and 3) to perform a plastic magnet by special injection molding and characterize.

2. Research Objectives

To study the effect of ferrite composition on the properties of polyamide6 composite performed by a special injection molding technique.

3. Methodology

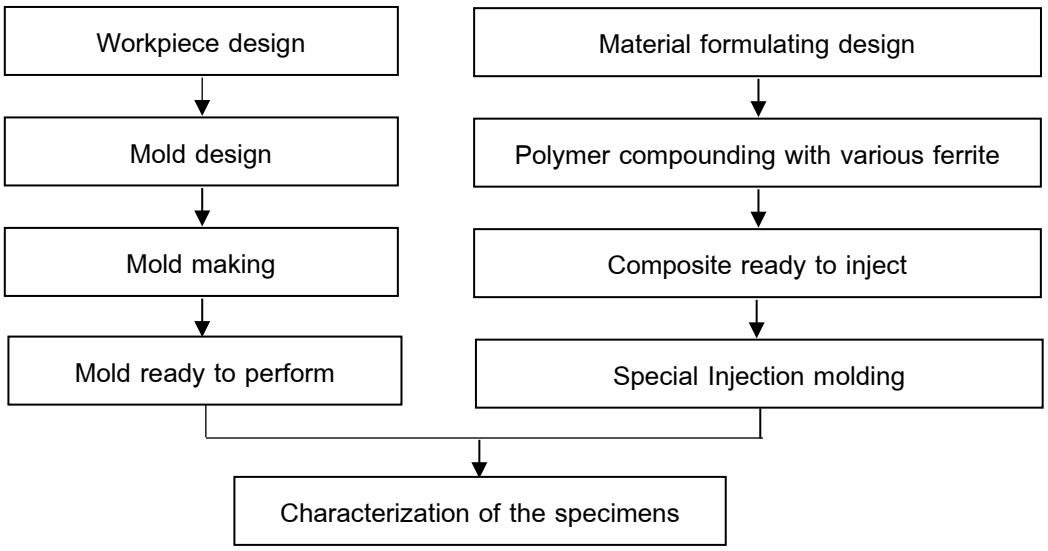


Figure 1 Overview of the research

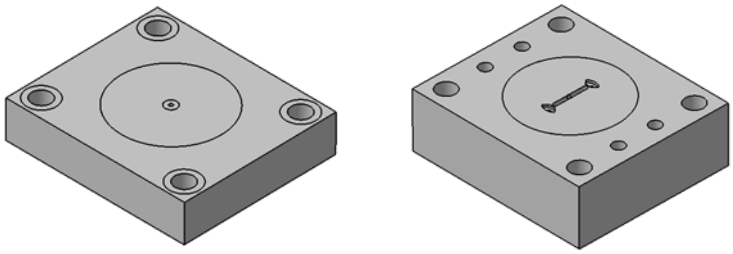
3.1 Designing and making an injection mold

The overview of this research is presented in Figure 1. CATIA V5R20 software was used for drafting both of product and injection mold. Dimension of the workpiece was

approximately 5.5 × 11 × 2 mm (see Figure 2) by laying together with 2 cavities in a mold . Two plate mold was chosen to design for the experiment by dividing the parting line into the product contact surface as shown in figure 3.

(a) (b)

Figure 2 Workpieces from the CATIA design; front (a) and rear (b)



(a) (b)

Figure 3 Two plates of molded design; core plate (a) and ccavities plate (b)

After finished the designing, cutting toolpath prepared by CATIA V5R 20software was converted to G-Code in order to control CNC milling machine to make an injection mold. Although mold making consists of many parts, there are only 2 steels used in this work. Namely, S50c steel was chosen for making a mold base while brass with non-magnetic grade was used for making an insert part. Because the workpieces must have a magnetic property after injection molding process, special mold was carried out by inserting a 400 mT cylindrical magnet with a dimension of 15 × 5 × 10 mm (outside diameter × inside diameter × thickness) as given in Figure 4.

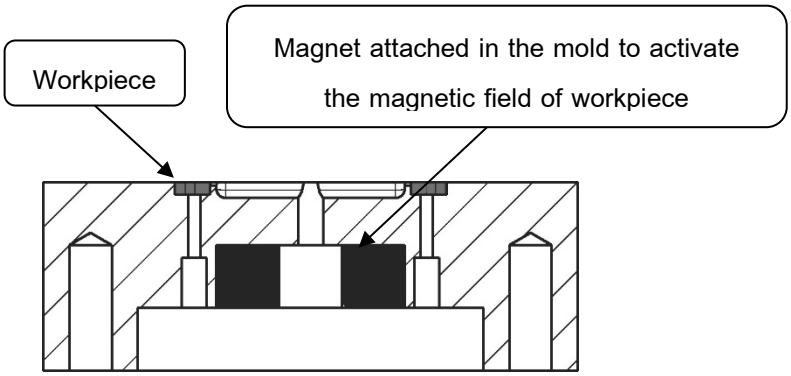


Figure 4 Side view of injected mold attached with a cylindrical magnet

3.2 Plastic compounding with various amount of ferrite

Ferrite bonded magnet compound (FBMC) for injection molding donated from MATE Co., Ltd. was mainly employed for the experiment. FBMC was consisted of about 85% ferrite in the polyamide6 matrix. So as to study the effect of ferrite content on the magnetic properties of the injected workpiece, it is necessary to vary the amount of FBMC in the polyamide6. In this paper, FBMC was diluted to perform the percentage of ferrite from 85 to 20% by using polyamide6 purchased from UBE Industrials, Ltd. The formulations of dilution are presented in Table 1. Polymide6 was mixed with FBMC on a two-roll mill at 220ºC for 20 min prior to crushing for injection molding process.

Table 1 Formulations of polyamide6 mixed with FBMC

Batch No.	Composition	Ferrite content (%) (by calculation)
1	Control FBMC	85
2	FBMC diluted with Polyamide6	70
3		55
4		20

3.3 Injection molding and characterizations of the specimens

3.3.1 Preparations of workpiece and specimen

Injection molding machine used to create specimens is ENGEL 50 tons' series ES 200/50HL and the technical parameters of the injection is given in Table 2. In this work, there are two types of injection molding process which are mold with and without inductive cylindrical magnet attachment. Workpiece was necessary to activate the magnetic properties under injection molding process in order to study the effect of ferrite dilution. However, tensile and impact's specimens were performed by a normal injection molding to clarify only their mechanical properties.

Table 2 Experimental parameters of injection molding

Parameters	Injection Conditions
Injection Time (s)	0.094
Packing Time (s)	7.765
Cycle Time (s)	15
Pressure (bar)	1500
Clamping (kN)	450
Injection Flow (cm^3/s)	133
Melt temperature (ºC)	280

3.3.2 Characterizations of workpiece and specimen

Measurement of the magnetic field quickly and easily carried out by Gauss or Tesla Meter (LEYBOLD DIDACTIC GMBH) .The experiment reported the maximum magnetic field both in north and south poles of the workpiece because of unstable of the magnitude of the electromagnetic wave around the workpiece. In addition, hardness, tensile and impact properties of the polyamide6 mixed with FBMC's specimens were also investigated. Shore durometer type D (regarding to ASTM D256) is one of several equipments to monitor the hardness of a material. Repeated test in other areas of workpiece for at least 10 points to find an average data was done. Tensile Test Metric Tester model M500-25AT was used for the experiment to evaluate the tensile strength and percentage of elongation at break,

according to ISO 8256 with sample TYPE 3 standard. The test is performed using a stretching speed of 10 mm/min and the samples were tested at least 5 piece a batch. Finally, impact test operated by CEAST brand series Resil Impactor with an Izod type for the polyamide6 mixed with FBMC's specimens was carried out according to ASTM D6110. Surely, 10 pieces for each batch were tested to get an average result.

4. Results and Discussion

Designing and making of the special mold have been completely carried out. Preferences of workpieces and specimens created by injection molding process were presented in Figure 5. Although the specification of the FBMC from the supplier has been reported, it should be investigated again by thermal gravimetric analysis (METTLER TOLEDO – TGA/DSC 3+). Example of the TGA thermograms for both control FBMC and FBMC diluted with polyamide6 as 20% of ferrite by calculation was shown in Figure 6. It is clear tendency that after mixing the batch of 20% ferrite polyamide6 composite, the composition of the existing ferrite was found to be 18.21%.

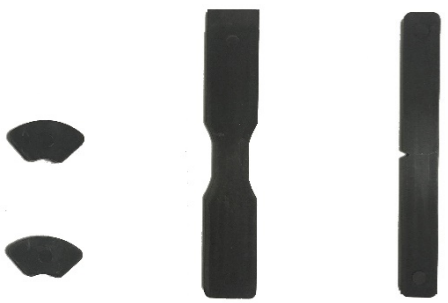


Figure 5 Workpiece (a), Tensile's specimen (b) and Impact's specimen (c) prepared by injection molding

In order to prove the effect of existing percentage of ferrite on magnetic properties of the FBMC composite prepared with a special mold, two poles of the workpiece, north and south poles, should be considered. The results of magnetic field and all mechanical properties were reported in Table 3. It was found that control FBMC, 70% and 55% ferrite

of FBMC composites presented the magnetic field by about 20 and 15 mT at the north and south poles, respectively. However, a great reduction in the magnetic field has been found after the percentage of ferrite was decreased to 20 (by calculation). It might be suspected by about the special characteristic of the magnetic induction performed by the new technique of mold making. In addition, Shore D hardness and impact strength of the FBMC composite, as shown in Figure 7, gradually decreased with the decreasing of the existing percentage of ferrite. Although the compatibilizer has not been used in the experiment, ferrite in the FBMC seems to be a good reinforcing agent in the polyaminde6 matrix. However, tensile properties of the FBMC composite normally increased with the decreasing percentage of ferrite, excepting for 55% of ferrite.

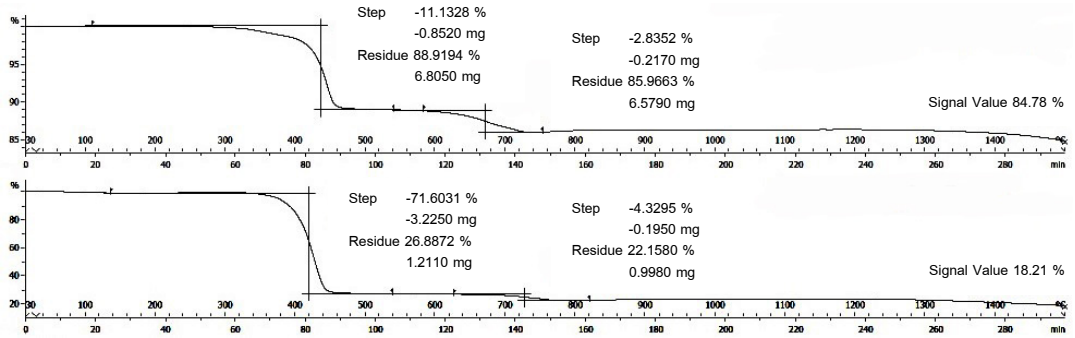


Figure 6 TGA thermograms of control FBMC (top) and FBMC diluted with polyamide6 as 20% ferrite (bottom) after mixing and injection processes

Table 3 magnetic fields of FBMC composites before and after diluted with Polyamide6

Magnetic field (mT)	Control FBMC (85% Ferrite)	FBMC diluted with Polyamide6		
		70% Ferrite	55% Ferrite	20% Ferrite
North pole	19.5 ± 0.4	20.3 ± 0.4	20.2 ± 0.9	5.8 ± 0.3
South pole	-15.1 ± 0.7	-14.3 ± 0.8	-15.7 ± 0.6	-4.8 ± 0.3

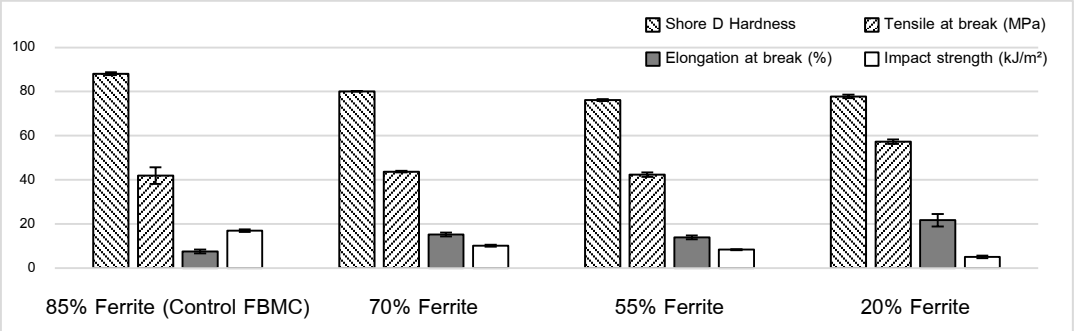


Figure 7 Mechanical properties of FBMC composites before and after diluted with Polyamide6

5. Conclusions

Special injected mold attached with cylindrical magnet to induce the magnetic field of the workpiece was successfully designed and made. Magnetic field of the workpiece produced from polyamide6 composite mixed with various amount of FBMC showed insignificantly change until the percentage of ferrite was decreased to 20. This might be concluded from the research that FBMC could be diluted with polyaminde6 up to 55% ferrite by showing the best of all properties and cost of the workpiece.

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