THE POTENTIAL OF IRON SAND FROM THE COAST SOUTH OF BANTUL YOGYAKARTA AS RAW CERAMIC MAGNET MATERIALS

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INTISARI

Magnet merupakan bahan teknik yang kebutuhannya meningkat seiring dengan meningkatnya perkembangan industri elektronika di Indonesia, akan tetapi kebutuhan magnet di Indonesia masih diimpor dari luar negeri. Sementara bahan baku magnet berupa besi oksida tersedia cukup banyak di Indonesia, salah satunya pasir besi di pantai Selatan Yogyakarta. Pasir besi mengandung sifat magnetik karena adanya mineral magnetite (Fe_3O_4) berwarna hitam, maghemite (γ-Fe_2O_3), Rutil ($FeTiO_3$), yang besifat magnetik. Mineral magnetit dapat dikembangkan menjadi bahan magnet contohnya untuk pita magnetik, magnet speaker, magnet motor listrik dan lain-lain. Pasir besi di pantai selatan Bantul Yogyakarta berwarna abu-abu kehitaman menunjukan adanya kandungan material magnetik dalam jumlah besar. Hasil pengujian dengan menggunakan magnet, rata-rata 66.32% berat menempel pada magnet, dari hasil tersebut dilakukan pemisahan dengan metode *sieving* persentase jumlah terbesar sebanyak 32% pada ukuran bukaan <+212 μm. Pengujian dilakukan pada pasir yang menempel pada magnet dan hasil sieving pada jumlah terbesar. Hasil karakteristik material magnetik menggunakan *Vibrating Sample Magnetometer* (VSM), menunjukan saturation magnetisation (Ms) adalah 13,18 emu/gr dan 36,49 emu/gr, magnetik remanen (Mr) 4,15 emu/gr dan 7,95 emu/gr, koersivitas (Hc) 230 Oe dan 186 Oe, suseptibilitas massa (χ_m).1,45 $\times 10^{-4}$ m^3/kg dan 4,31 $\times 10^{-4}$ m^3/kg. Hasil uji XRD menunjukan dominasi magnetite dan maghemite pada pasir besi. Berdasarkan kajian tersebut, bahwa pasir pantai Selatan Bantul Yogyakarta merupakan material magnetik. Material mangetik yang terkandung pada pasir pantai memiliki potensi sebagai bahan keramik magnet (MO.xFe_2O_3).
Kata kunci: magnet, magnetite, magnetisasi saturasi, suseptibilitas, pasir besi

ABSTRACT

The demand of magnets increases with the increasing development of electronic industry in Indonesia, but it was still imported from abroad. While the magnetic materials as iron oxide are quite a lot in Indonesia, one of deposits area of iron sand is Southern coast of Bantul Yogyakarta. The sand contained of the mineral magnetic, these minerals were magnetite (Fe_3O_4) is black color, maghemite (γ-Fe_2O_3). Mineral magnetite can be developed as a magnet, example of magnetic material for magnetic tape, magnetic speaker, magnet electric motors and others. Iron sand at southern coast of Bantul Yogyakarta is blackish gray color indicates that it contains large amounts of magnetic material. The results of research by using a magnet, average 66.32% of weight attracted to magnet permanent. The results of the separation is carried out by sieving method the largest percentage of 32% at opening size <+212 μm. Characterizations of magnetic materials using Vibrating Sample Magnetometer (VSM) and XRD have done on the sand that attracted to the magnet and sieving result. The result by VSM showed that saturation magnetization (Ms) are 13.18 emu/g and 36.49 emu/g, remanent magnetic (Mr) 4.15 emu/g and 7.95 emu/g, coercivity magnetic (Hc) 230 Oe and 186 Oe, susceptibility mass (χ_m) 1.45 $\times 10^{-4}$ m^3/kg and 4.31 $\times 10^{-4}$ m^3/kg. XRD analysis indicates that the iron sand were dominated magnetite and maghemite minerals. Based on this analysis, the sands of Southern coast in Bantul Yogyakarta can be used as magnetic material. Magnetic material contained on the coast sand has potential as ceramic magnet permanent materials (MO.xFe_2O_3).
Keywords: magnet, magnetite, saturation magnetization, susceptibility, iron sand

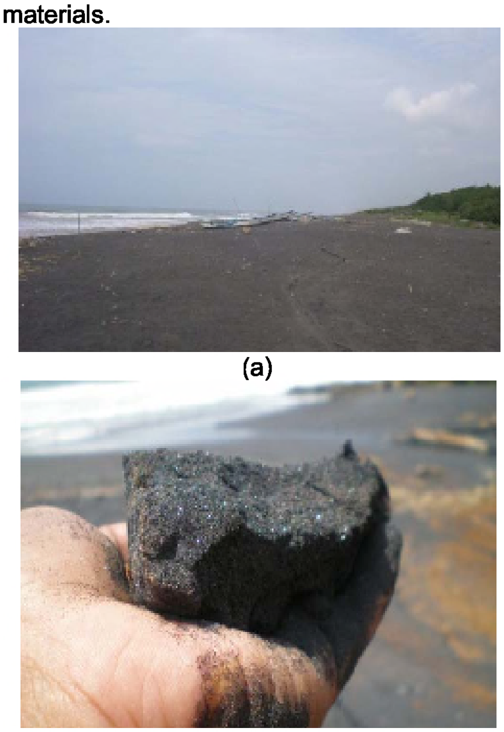
INTRODUCTION

Permanent magnets have been used in electrical machinery for over 100 years, but because of recent dramatic improvements in their properties and availability, their application in electro-mechanical and electronic devices is now rapidly growing, [Strnat, 1990]. Permanent magnet is a major parts of the electronic equipment such as speaker, electric motors, electrical generators and so on. The demands of magnet increase from year to year in Indonesia, it is estimated the demand about 1800 magnets ton/year (Pramono, 2009). Indonesia have the basic raw magnetic materials in enormous amount, such as iron sand. Expectation, iron sand can be used as magnetic materials, and it can supply for local industry.

The spread of iron sand in Indonesia are in a particular area, which is a mineral deposit, all of which have not been carried out exploration, Figure 1 shows the distribution of mineral deposit iron sand in Indonesia. Regions in Indonesia with the iron sand deposit is large enough that spread on the island of Java in the Southern coast, such as the three provinces, namely the Southern coast of the province of East Java, Central Java and Yogyakarta.

Figure 1. The spread of iron sand in Indonesia [Tekmira, 2011]

Southern coast of Yogyakarta from Parangtritis area in Bantul district to Glagah coast in Kulonprogo district is rich in mineral deposits of iron sand. Kulonprogo district has been targeted to areas of the iron sand mining. The planned mine area will be carried out on the coast along the 22 kilometers, from the Bongowonto river to Progo river go to the mainland entered the residential areas as far as 1.8 kilometers and 14.5 meters deep grind [Syaifullah, 2007], with the iron sand deposits reach approximately 33.6 million tones [Yunianto, 2009]. The activity of mining was confronted by indigenous, because of coastal land becomes damaged. The Damages will occur include the loss of agricultural land surrounding residents, the loss of conservation land in the form of land that withstand interruptions sea water to the mainland, and destruction of coastal environment conservation. Figure 2 show the photograph Southern coast of Bantul Yogyakarta and iron sand that contain in the coast. The aim of this research was to characterization of iron sand from Southern coast of Bantul Yogyakarta as magnetic materials.



(a)

(b)

Figure 2. (a) The Southern Coast of Bantul Yogyakarta (b) black sand contains iron oxide.

Iron mineral sands contain magnetite and maghemite that has properties of high magnetic susceptibility [Mufit, 2006]. High magnetite ingredients are certainly encouraging the utilization of iron sand for magnetic materials. Iron sands has high economic value, if it can be processed as magnetic materials. Which, indigenous communities could be involved in the management of the processing and mining iron sands so as to increase their revenues, Iron sands can be processed as a magnetic materials. Certainly the processing does not need a large scale mining, that the mining and processing can be done selectively.

The separation technique by magnetic separator can separate iron sands between magnetic materials and nonmagnetic materials. The high purity of magnetic materials can be used crushing and sieving method. Magnetic materials have an associated non-magnetic materials that bonded in it and it can be separated by crushing. After crushing, magnetic separator was used to separate magnetic materials again.

The separations of the iron sands by crushing and separating have given good method to get high purity magnetic materials. The sand that does not contain the magnetic mineral can be restored to the site of coast. Using this method, the conservation of coastal can be maintained. Sand beach as a land withstand of interruptions sea water to the mainland can be sustained as environmentally friendly area. Amount of iron sands was mined for ceramic magnetic material much smaller than it was processed to pellet of iron ores to make steel. Magnets have a higher economic value than that steel.

Magnetic nano particle technology is now growing rapidly. There are several techniques to make of powder materials with nanometer size. Raw materials with nanometer size materials can give the product very satisfying magnetic properties, such as compact disc, and hard disk drives, magnetic random access memory/MRAM. Magnetic nanoparticles as superparamagnetic material is widely used in medicine as biomaterials now, such as drug deliver, contras agent in Magnetic Resonance Spectroscopy (MRS), Magnetic Resonance Imaging (MRI) and magnetic fluids. Magnetite and maghemite in iron sands can be crushed into the nanometer size, so that it would obtain high concentrate magnetic materials, which it was highly qualified to serve as raw material for making magnets

Mufit (2006), conducted a study on the magnetic properties of iron sand from the coast of West Sumatra Sunur Pariaman, that the main mineral constituent of iron sand is magnetite (Fe_3O_4), as indicated by high magnetic susceptibility up to 2.58×10^{-4} m^3/kg and field of saturation IRM (isothermal remanent magnetization) is relatively low.

The other measurement indicated not only magnetite minerals, but also there were other magnetic minerals such as maghemite (γ-Fe_2O_3) and ilmenite ($FeTiO_3$). Characterization of magnetic iron sands on natural ingredients Cilacap showed that the magnetic material contained by a family of iron sands titanomagnetit ($xFe_2TiO_4.(1-x)Fe_3O_4$) with the main mineral magnetite (Fe_3O_4), [Yulianto, 2002]. Southern coast of Yogyakarta iron sands contains maghemite and magnetite minerals, it can detected by using a magnet. The sand attached to magnet. Chemical analysis was applied to iron sands composition of minerals contained such as magnetite, hematite, maghemite, ilmenite and so on [Katim, 1994]:

Table 1. Chemical composition in iron sand [Katim, 1994].

Fe_3O_4	59,97 %	Al_2O_3	4,34 %
SiO_2	11,71 %	MgO	3,72 %
TiO_2	6,48 %	V_2O_3	0,54%
CaO	4,66 %	MnO	0,48%

Iron sand has a high specific gravity about 4.2 to 5.2, generaly, iron sand consists of an opaque mineral grains mixed with non-metals such as quartz, calcite, feldspar, ampibol, pyroxene, biotite and tourmaline. Minerals consist of magnetic materials such as titaniferrous, magnetite, ilmenite, limonite, maghemite. The ferrous content was found in the main iron sand deposits as mineral tetanomagnetic, while its composition 60% Fe, 3.3% Al_2O_3, 0.26% SiO_2, 0.55% P_2O_5, 9.2% TiO_2, and 0.6% MgO. Iron ores in the form of iron sand deposits with Fe content is about 38 to 59%. The aggregate particles were widely available in the beach district Congot Kulonprogo Yogyakarta [Putra, 2008].

During the past decade, great efforts have been devoted to the preparation of Magnetic Nano Particles/MNPs due to their potential applications in many diverse fields. During the last few years, a large portion of the published articles about MNPs have described efficient routes to attain shape-controlled, highly stable, and narrow size distribution MNPs. MNPs have been synthesized with a number of different compositions and phases, metal oxides such as Fe_3O_4 and γ-Fe_2O_3, ferrites such as MFe_2O_4, and metal alloys such as FePt, CoPt. Up to date, several popular methods including co-precipitation, microemulsion, thermal decomposition, solvothermal, sonochemical, microwave assisted, chemical vapour deposition, combustion synthesis, carbon arc, laser pyrolysis synthesis have been reported for synthesis of MNPs [Faraji, 2010].

Magnetite is a natural magnet, hence the name, giving it a very nice distinguishing characteristic. Magnetite is a member of the spinel group which has the standard formula $A(B)_2O_4$. The A and B represent usually different metal ions that occupy specific sites in the crystal structure. In the case of magnetite, Fe_3O_4, the A metal is Fe^{+2} and the B metal is Fe^{+3}, two different metal ions in two specific sites. This arrangement causes a transfer of electrons between the different irons in a structured path or vector. This electric vector generates the magnetic field. Explanation of the magnetism is not easy, but by adopting the laws of quantum mechanics and electromagnetism, it can be solved. Remember, electricity produces magnetic fields same as magnetism produces electric fields. The orbital electrons and electrons spin in atom generate fields magnetic flux.

Physical characteristics of magnetite such as, black color, transparency of crystals is opaque. Crystal habits are typically octahedrons but rarely rhombododecahedron and other isometric forms, most commonly found massive or granular. Hardness is 5.5 - 6.5 (Mohs scale), specific gravity is 5.1 (average for metallic minerals). Associated Minerals are talc and chlorite (schist), pyrite and maghemite. Other Characteristics: Magnetism stronger in massive examples than in crystals, striations on crystal faces (not always seen). Best Field Indicators are magnetism, crystal habit and streak.

The magnetite mineral can be processed into a magnet (hard magnet $MO.F_2O_3/FeO$. F_2O_3/Fe_3O_4). MO (metal oxide) should be added that the magnetic elements forming BaO and SrO. The manufacturing of magnetic components use a technique of powder metallurgy process [Ridwan, 2009]. Barium hexaferrite powders can also be obtained by the sol-gel citrate precursor [Mazaleyrat, 2011]. For the formation of metal oxide-hexaferriet, M_xCO_3 and F_2O_3/Fe_3O_4 were mixed and then calcination at high temperature 1000 °C.

Ferromagnetism is the basic mechanism of certain materials (such as iron/Fe) shaped permanent magnet, or attracted to a magnet. Ferromagnetism (including ferrimagnetism) is a powerful magnet type; it is the only kind of power strong enough to be felt in the general phenomena of the magnet. This interaction forces are produced by the exchanges electrons and produce parallel or antiparallel alignment of atomic moments. Enormous power is equivalent to a magnetic field on the order of 1 tesla. The power exchange is a quantum mechanical phenomenon due to the relative orientation of the spin of two electrons. Ferromagnetic materials show a parallel alignment of the magnetization current yield in the absence of a magnetic field. The effect then is equal to the magnetic field. The elements Fe, Ni, and Co and its alloys are typical ferromagnetic materials [Gignoux, 2005].

The property of magnetic materials is expressed by magnetic susceptibility symbolized χ_v. Susceptibility is relationship between the magnetization and the field magnetic, susceptibility is a gradient curve of the nature of the magnetization (M) of the material due to the influence of magnetic field H, which is expressed in:

$$\mathbf{M} = \chi_v \mathbf{H}$$

Magnetization is the magnetic dipole moment per unit volume in (emu/gr). H is magnetic field in unit tesla (T) = 10^4 gauss. Magnetic susceptibility is basically measuring the total attraction of the first two groups of minerals to a magnet, in other words the rock's magnetic ability. Rocks with relatively high concentrations of magnetite, like basalt have much higher magnetic susceptibility values than rocks such as limestone which usually have no magnetite crystals at all.

In materials science, the coercivity, also called the coercive field or coercive force, of a ferromagnetic material is the intensity of the applied magnetic field required to reduce the magnetization of that material to zero after the magnetization of the sample has been driven to saturation. Thus coercivity measures the resistance of a ferromagnetic material to becoming demagnetized. Coercivity is usually measured in oersted or ampere/meter units and is denoted H_C. Remanence (M_r) or remanent magnetization is the magnetization left behind in a ferromagnetic materials, after an external magnetic field was removed. A good permanent magnet should produce a high magnetic field with a low mass. It should be stable against the influences which would demagnetize. The desirable properties of such magnets are typically stated in terms of the remanence and coercivity of the magnet materials. Saturation magnetic was the state reached when an increase in applied external magnetizing field H cannot increase the magnetization of the material further, It is a characteristic particularly of ferromagnetic materials. The caracterization of magnetic material was indicated by **Hysteresis loops** (fig.3).

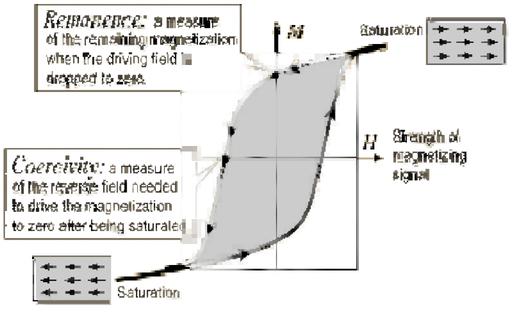


Figure 3. Hysteresis loops of ferromagnetic materials [Nave, 2012]

Experimental Method

The iron sand of coast was separated by permanent magnet, a large amount of sand coast attracted to magnet, It was phenomena that indicates magnetic materials. The balanced technique used to knew percentage of magnetic materials. Then, the iron sand was separated by sieving method. The sieve analysis (gradation test) is a practice or procedure, where used to assess the particle size distribution of a granular materials.The size distribution is often of critical importance as the way the material performances before used.

The sieve analysis can be performed on any type of non-organic or organic granular materials, such as sands, crushed rock, clays, granite, feldspars, coal, soil, a wide range of manufactured powders, grain and seeds.The sieving is a simple technique of particle sizing, it is probably the most common. A mechanical shaker was used for sieve analysis with the pan. the most common mesh opening sizes for these scales are given pan number 3 to 400 mesh (particle sizes or opening number +3 mm to 37 μm).

The iron sand attracted to magnet as magnetic materials (sample A). Convincing of magnetic material, it was examined by using Vibrating Sample Magnetometer (VSM) tipe OXFORD VSM 1.2H (maximum ± 1,2 tesla). The highest precentage weigth of meshing was separated by sieving method also examined by VSM (sample B). The dominated grain size of particle magnetic minerals showed characteristic of minerals specification, in this case was magnetite minerals. The standard for characterization magnetic material used ASTM A977 / A977M - 07 Standard Test Method for Magnetic Properties of High-Coercivity Permanent Magnet Materials Using Hysteresigraphs.

X-ray diffraction (XRD) patterns were recorded on the fine-grained powders in order to identify the crystalline phases obtained using a Philips diffractometer
and Cu Kα radiation. Diffraction patterns were recorded from 5° to 85° with a step of 0.02°, and a scanning rate of 7.15 s per step.

RESULTS AND DISCUSSION

The research have conducted the observation of iron sand from Southern coast of Bantul Yogyakarta. Observations included a magnetic material content of the sand beach with a separation method using a permanent magnet. The result of research showed the compound materials attracted to the permanent magnet. The 100 gram sample of sand was the average weight of 66.32% attracted to permanent magnet (Fig. 4 and 5).

Figure 4. iron sands attracted to permanent magnet.

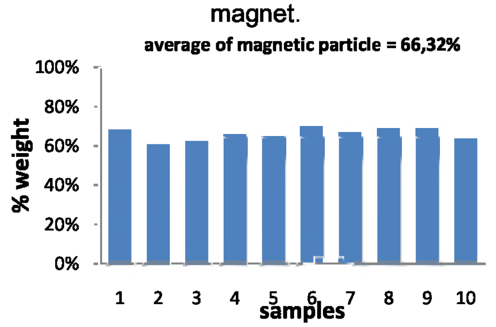


Figure 5. The graphic of contained magnetic particles in sand coast of Bantul Yogyakarta

The iron sand was purified again to obtain a magnetic material that is really pure, so it could produce a strong permanent magnet. The purification process can be done with the mechanical process, sieving method is one of method purification, because formation of minerals sedimanted at the same condition and in long time. Sediment is transported based on the strength of the flow that carries it and its own size, volume, density, and shape

Sedimentation is the tendency for particles in suspension to settle out of the fluid in which they are entrained, and come to rest against a barrier. This is due to their motion through the fluid in response to the forces acting on them, these forces can be due to gravity, centrifugal acceleration or electromagnetism. The magnetic sand also observed the shape and size of magnetic grains sand, it can be seen in Fig. 6 and 7.

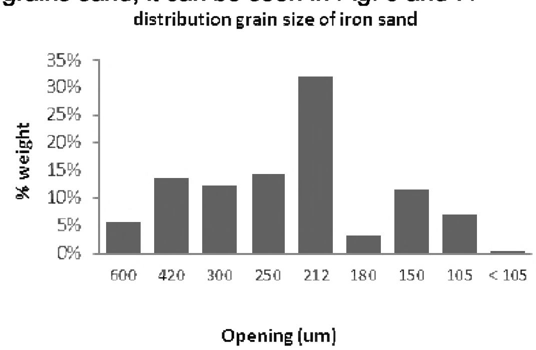
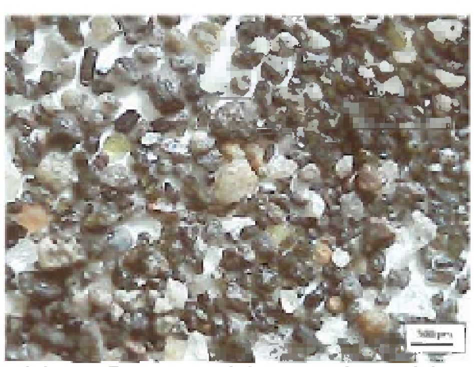
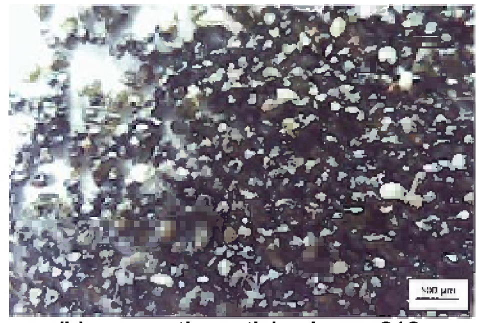


Figure 6. The average distribution of sand grain size of magnetic sand

Magnetic grains sand can be classified based on its grain size or its composition. Sediment size is measured on a log base 2 scale, called the "Phi (φ) scale", which classifies particles by size from "colloid" to "boulder". Magnetic grains sand in "φ scale" are 0 (0.5–1 mm is coarse sand) to 4 (62.5–125 μm is very fine sand) by Classification of Soils for Engineering Purposes: Annual Book of ASTM Standards, D 2487-83, 04.08, American Society for Testing and Materials, 1985, pp. 395–408.



(a) Raw material magnetic particle attracted to permanent magnet



(b) magnetic particle size <+212 μm, The highest percentage dominated by magnetite (black)

Figure 7. macrosphotographic of the magnetic grains of iron sand and follow-up to the size of selected minerals.

The result of researched used Vibrating Sample Magnetometer. It was magnatic hysteresis loops taken at room temperature are shown in Figure 8. The hysteresis loop of specimen indicated contains the mineral magnetic such as magnetite mineral.

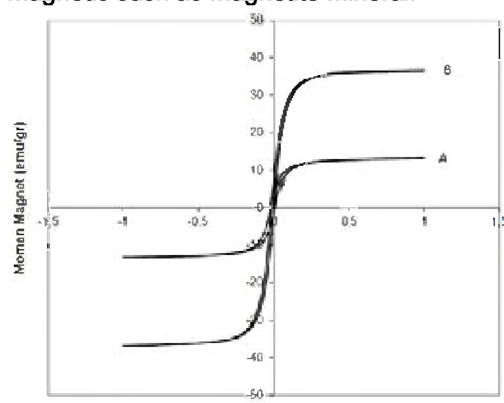


Figure 8. Magnetic hysteresis loops taken at room temperature of iron sand coast
(A) Raw material magnetic particle attracted to permanent magnet,
(B) magnetic particle size <+212 μm, The highest percentage dominated by magnetite (black)

The hysteresis loop shape of iron sand particles corresponds well to an assembly of individual magnetic particles with mutual dipolar interaction. The value of magnetic moment maximum (saturation maximum Ms), Coercivity (Hc) remanent magnetization (Mr) and susceptibility magnetic (χ_{mass}), susceptibility was measured as mass susceptibility rather than dimensionless volume susceptibility, the result magnetic characterization for sample A and sample B are tabulated in Table 1.

Table 1. Magnetic characterization of iron sand at room temperature by VSM

Magnetic unit	Sample A	Sample B
Ms (emu/gr)	13,18	36,49
Mr (emu/gr)	4,15	7,95
Hc (Oe)	230	186
χ_m(emu/gr.T) cgs	145,47	431.33
χ_m (m^3/kg) mks	1,45 ×10^{-4}	4,31 ×10^{-4}

Sample B has magnetic properties higher than sample A. sample B showed homogen composition of mineral magnetite in figure 7b, it is dominated by black mineral. Sample A slight loss of saturation magnetization was compared magnetite. It is cause the sample has many contains non-magnetic material, it was indicated by macrophotography (figure 7a.) of grains sand, there were white and bright minerals, such as quartz, calcite, feldspar, amphibole, pyroxene, biotite and tourmaline, it were non-magnetic minerals. The values of saturation magnetization Sample B was 36.49 emu/gr. Compared, The value of magnetic moment saturation on the γ-Fe_2O_3 nanoparticles was about 35 emu/gr in prepare Fe_2O_3/SiO_2 nanoparticles, that employed an easy co-precipitation method by Drbohlavova, (2009).

Magnetic susceptibilities mass of sample has relative same with Yulianto's report (2003). He had report the magnetic susceptibilities of the iron sand in Central Java, It were 1.01 × 10^{-4} m^3/kg for Munggangharjo Kutoarjo sample and 3.34 × 10^{-4} m^3/kg for Bayuran Jepara sample. Magnetic susceptibilities samples A and B were 1.4×10^{-4} m^3/kg and 4,31×10^{-4} m^3/kg, it could indicated the same of conclusion that material was magnetite mineral.

Figure 9, shows the XRD spectra of the sample A (Raw material magnetic particle attracted to permanent magnet) and B (magnetic particle size < +212 μm, the highest percentage dominated by magnetite (black)). The presence of magnetite (F_3O_4) and maghemite (γ-Fe_2O_3) phases was observed for samples A and B.

The sample B has higher intensity than sample A, it indicated amount particles magnetic sample B higher than sample A. the result of research showed there high correlation with by VSM, that sample B has high saturation magnetization.

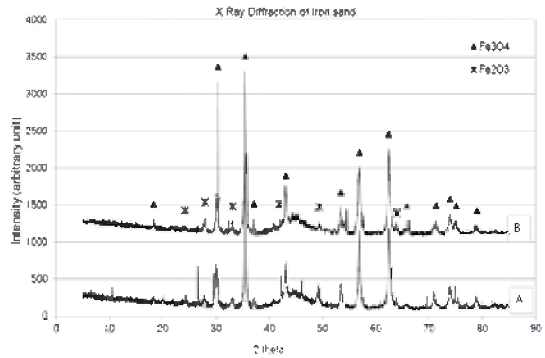


Figure 9. XRD pattern indicate that Fe3O4 (magnetite) and γ–Fe2O3 (maghemite)

The magnetite and maghemite mineral can be processed as ceramic magnet permanent (hard magnet) with composition such as $BaO.6F_2O_3$, $SrO.6F_2O_3$, $PbO.6F_2O_3$. Material magnetic processed through calsination at high temperature and the manufacture of magnetic components use powder metallurgy technique, under compacting pressure and sintering. The magnetization sintered product magnetic materials use magnetizer to formation hard magnet. Their magnetic strength is enhanced by aligning the powder particles with a strong magnetic field during forming.

CONCLUSIONS

Characterization using magnet permanent, macrophotography, Vibrating Sample Magnetometer (VSM) and XRD analysis indicates that the iron sand from coast Bantul of Southern Yogyakarta were dominated magnetite and maghemite minerals. Minerals magnetic with size opening under +212 μm have higher saturation magnetization than raw material. It indicated that iron sand from coast Bantul of Southern Yogyakarta can be developed as ceramic magnet permanent materials.

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