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Beneficiation Study of Iron Ore from Pakke area of Bontocani Subdistrict, Bone Regency of South Sulawesi, Indonesia Using Roasting and Magnetic Separation Methods

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ABSTRACT

This study aims to examine the characteristics and analyze the magnetic beneficiation process of iron ore from Pakke area of Bontocani subdistrict, Bone regency. Mineralogical analysis using Microscopic and XRD (X-Ray Diffraction) methods indicate that iron ore sample is composed of quartz (SiO_2), calcite ($CaCO_3$), goetite (FeO.OH), hematite (Fe_2O_3) and magnetite (Fe_3O_4). The results of chemical analysis by means of XRF (X-Ray Fluorescence) method showed that sample consists of 30.49% Fe_2O_3, 42.39% SiO_2, 10.03% MnO and 1.19% As_2O_3. Each feed fraction was separated using a low-intensity drum magnetic separator. The higherst Fe_2O_3 content of concentrate product was 54.21% and recovery of 75.31% which was achieved at the size fraction of (-180 + 150) µm. The addition of wood charcoal as reducing agent by 3% during roasting process at the temperature of 950°C for 90 minutes has led to increase the Fe_2O_3 content in concentrate product about 63.791% but recovery was slightly recerease to about 65.20%. It was shown that the size fraction of (-180 + 150) µm is better feed in this experiment.

Keywords: Iron ore; goethite, hematite, magnetic separator; recovery

1. INTRODUCTION

National steel demand is currently still being met with imports. Even though the iron ore resources in Indonesia are very large, but they generally have still low grade so that those ores do not meet the requirement as raw materials in steel production which is the minimum iron content of 65%. National steel consumption is currently estimated to have reached 6.3 million tons while production is only 3.8 million tons, of which a shortfall of 2.5 million tons is still supplied from imports. This is what causes iron ore has not met the requirements because it still contains many impurities so that it inhibits the utilization of iron ore [1-3].

Low grade iron ore in Indonesia has not yet fully utilized. One of the step after mining of the iron ore is beneficiation, namely the process of increasing the iron content so that it meets the requirements with added value of raw materials. Iron ores generally contain many impurities such as quartz, calcite, feldspar, amphibole, pyroxene, biotite and tourmaline. This type of ore can be upgraded its quality by increasing iron content using reduction roasting followed by magnetic separation [4]. Study conducted by Rath et al. [5] utilizing a magnetic separator and reduction roasting for a low grade iron ore with the grade of 45.23% Fe obtained a concentrate product with the grade of 59.6% Fe.

Roasting method is a heating process of an iron ore to reduce moisture content thereby increase Fe content and particle size separation can be done to match what is needed in the next processing using magnetic separator. The principle aim of this study was to characterize the mineralogy and chemistry of the iron ore and subsequenty to analyze the beneficiation process of such ore using roasting and magnetic separation method.

2. METHODS

Sample used in this study was taken from Pakke area of Bone Regency, South Sulawesi Province (Fig. 1).

Fig. 1 Sample location map

Prior to separation experiment, sample was initially characterized in order to fine out mineralogical and chemical composition. Mineralogical analysis was conducted by means of optical microscopy (Nikon ECLIPSE LV-100) and X-ray diffraction (Shimadzu, Maxima X-7000). Chemical composition of sample was determined by using X-ray fluorescence (XRF) spectrometer (Shimadzu, EDX-720).

Before undertaking magnetic separation experiment, the ore sample was crushed and ground then sieved into five different size fractions namely: +180; -180+150; -150+125; -125+106 and -106 microns. Each size fraction was furher separated using a low-intensity drum magnetic separator. Another subsample was mixed with charcoal and then heated in muffle furnace at 950^{o}C for 90 minutes. The roasted sample was submitted to magnetic separator. All separation products were chemically analyzed using XRF and mineralogical composition of selected products were determined by XRD. product acquisition. The products of magnetic materials here is referred to as concentrates and non-magnetic materials called tailing.

Magnetic process is one of the stages of operation in the processing of mineral materials whose operations use the magnetic properties of the minerals to be separated [6]. This technique is based on the differential deposition speed of the ore constituent particles [7]. The advantages of using magnetic separation are high capacity, durability, and easy to operate and reagent-free process [8].

3. RESULT AND DISCUSSION

The iron ore sample studied is in the form of lumps. A total of 14,000 grams of iron ore sample has been prepared with a multilevel sieve using a sieve shaker. The grain size distributions of the sifted iron ore sample are shown in Table 1.

The result of microscopic analysis of the initial iron ore sample is depicted in Figure 1. It was shown that minerals found within ore sample are goethite, hematite, magnetite with the gangue minerals are mainly calcite and quartz.

No	Size (µm)	Mass (grams)
1	(+180)	11,345
2	(-180+150)	1,196
3	(-150+125)	912
4	(-125+106)	268
5	(-106)	224
6	Total	13,946

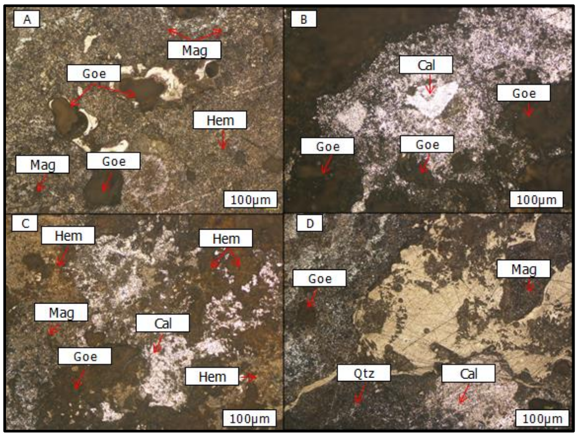

Figure 1 Microscopic appearance of iron ore sample: (Goe: goetite); (Cal : calcite); (Qtz: quartz); (Hem : hematite); and (Mag: magnetite).

The goethite mineral under microscope exhibits light brown in color with a relatively fine grain size and irregular texture. The size of the mineral varies between 0.2-0.5 mm. Goethite crystals are generally in the form of acicular, irregular crystalline shapes with finer grained sizes indicating that the mineral has undergone a weathering process. The optical appearance of undefined mineral (porbably manganese oxide) shows black, metallic luster and irregular texture. Magnetite is black and hematite is blackish gray.

Results of XRD analysis of the raw ore sample are shown in Figure 2. It was shown that initial iron ore sample was composed of calcite, quartz, goethite, and hematite. Calcite was idenfied with the occurrence of peak with d value of 3.03Å and quartz (3.34Å and 4.25Å). The presence of goethite is assigned to reflection intensities with diffraction peaks of 4.18Å; 2.44Å (36.78^{o}); 2.30Å (39.02^{o}), and 1.5Å (57.62^{o}). In addition, a small amount of hematite was also seen at the diffraction peak of 2.6Å (33.42^{o}).

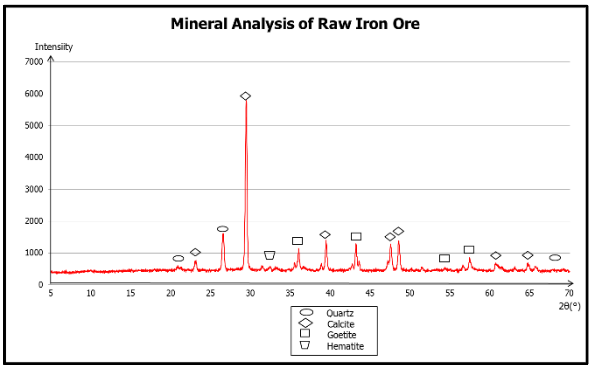

Figure 2 Diffractogram of raw ore sample

Beneficiation is defined as the process of increasing grade by separating valuable materials /minerals contained in ores [9]. Based on mineralogical analysis of concentrated product and tailing, there are differences in the form of diffractograms that indicate differences in the constituent minerals. Figure 3 shows the comparison of diffractogram results of mineralogical analysis using the X-ray diffraction method.

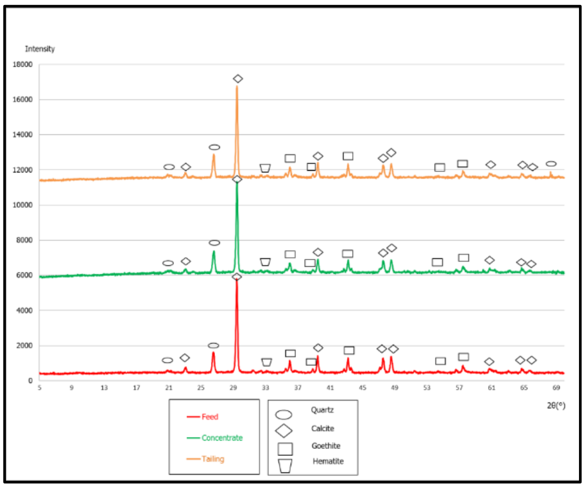

Figure 3 Comparison of diffractogram between feed, concentrate and tailing products.

Mineralogical analysis based on Figure 3 shows the different diffractogram forms between initial sample, concentrate product and tailings. This can be interpreted that concentrate has a poor crystallinity as indicated at the diffraction peaks of 4.2Å (21.02^{o}), 3.01Å (29.6^{o}), and 1.9Å (47.74^{o}) with a wide diffraction peak shape.

Recovery is defined as the amount of valuable minerals or metals that can be extracted or obtained, expressed in percent by weight, from a mineral processing operation carried out. The recovery can be formulated as follows:

$$R = \frac{K.k}{F.f} x100\%$$

where :
R = Recovery (%
K = Concentrate mass (gr)
k = Concentrate content (%)
F = Feed mass (g)
f = Feed content (%)

Table 2 shows the results of Fe_2O_3 recovery of magnetic separation.

Table 2 *Recovery* Fe_2O_3 of different size fractions

Fraction (μm)	Concentrate		Feed		*Recovery* (%)
	% Fe_2O_3	Mass (gr)	% Fe_2O_3	Mass (gr)	
(+180)	54,208	3.102	30,487	11.345,5	48,61
(-180+150)	32,394	847,7	30,487	1.196	75,31
(-150+125)	27,197	753,2	30,487	912,5	73,63
(-125+106)	26,500	206,5	30,487	267,7	67,05
(-106)	26,709	137,8	30,487	224,5	53,77

The highest recovery value of Fe_2O_3 is in the fraction (-180 + 150) μm with a value of 75.31% while the lowest recovery value is in the fraction (+180) μm which is 48.61%. The effect of the mass of the concentrate is very significant effect on recovery, while the level of Fe_2O_3 on the results of the separation of concentrates has a small range. Here is Figure 4 which shows a graph of the relationship between Fe_2O_3 grade and recovery:

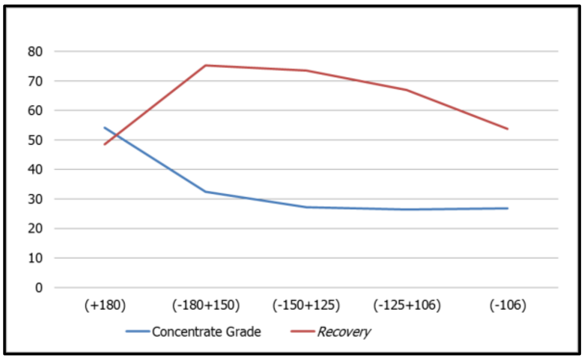

Figure 4 Graph of the relation of Fe_2O_3 concentrations and recovery to the size fractions

Roasting method can be done by using orange wood charcoal as a reducing agent, because it is easy to obtain and its reserves are quite large when compared with the reducing agent in the form of natural gas whose reserves are known to start to thin. Following is Table 3 which shows the composition of orange wood charcoal through proximate analysis.

Fraction (μm)	Concentrate		Feed		*Recovery* (%)
	Fe_2O_3(%)	Mass (gr)	Fe_2O_3(%)	Mass (gr)	
(+180)	63.791	30.7	30.487	212.2	30.27
(-180+150)	33.991	124.1	30.487	212.2	65.20
(-150+125)	33.791	50.0	30.487	212.2	26.12
(-125+106)	27.819	73.1	30.487	212.2	31.43
(-106)	17.768	44.1	30.487	132.1	19.46

Table 3 The composition of orange wood charcoal as a reducing agent

Component	Composition (%)
Ash	5,1
Moisture Content	5
Volatile Matter	17,3
Fixed Carbon	72,7

To determine the effect of temperature on the iron ore phase change, the resulting reduction resulting from the roasting reduction process at 950°C, for 90 minutes was analyzed using XRD, the results are shown in Figure 5 as follows:

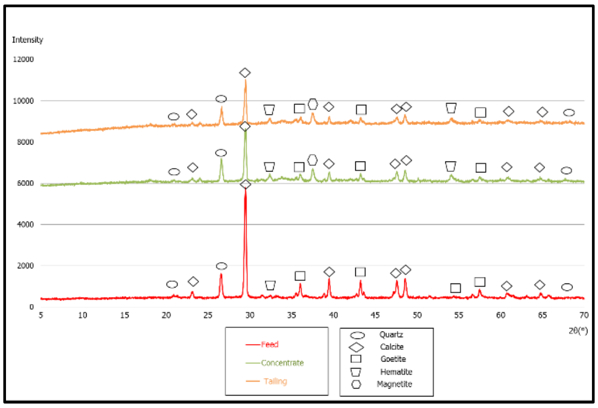

Figure 5 X-ray diffraction pattern results in a reduction in temperature 950°C for 90 minutes

The highest recovery value of Fe_2O_3 is in the fraction (-180 + 150) μm with a value of 65.2% while the lowest recovery value is in the fraction (-106) μm which is 19.46%. The effect of the mass of the concentrate is very significant effect on recovery, while the level of Fe_2O_3 on the results of the separation of concentrates has a small range. Following is Table 4 which shows the results of Fe_2O_3 recovery.

Table 4 Recovery of Fe_2O_3 after roasting of sample

The following is Figure 6 which shows the relationship between concentrate on recovery recovery, namely:

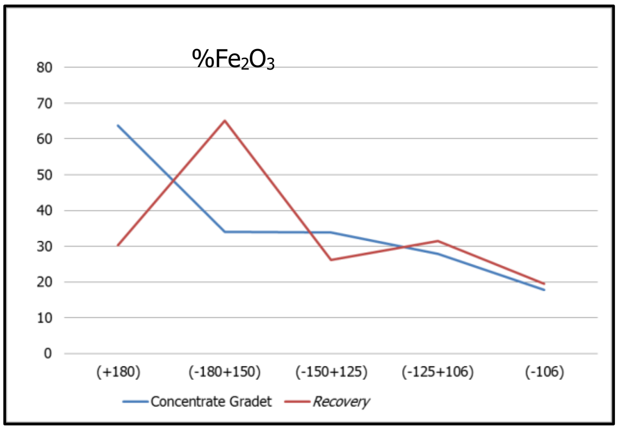

Figure 6 Graph of the relation between recovery of Fe2O3 and concentrate grade to the size distribution after heating sample.

4. CONCLUSIONS

Iron ore from Bone Regency based on XRD analysis results containing quartz minerals (SiO_2), calcite ($CaCO_3$), goetite (FeO.OH), hematite (Fe_2O_3) and magnetite (Fe_3O_4). The mineral that dominates the iron ore sample the most is goetite.

Magnetic beneficiation results in increasing concentrates as the coarse grain size fraction increases. Thus, the highest Fe_2O_3 recovery was in the fraction (+180) µm with an acquisition rate of 48.615%, while the lowest Fe_2O_3 in the fraction (-125 + 106) µm was 26.5% and the recovery rate was 53.7774%.

The selective reduction process time affects the increase in iron ore grade. The longer the reduction process, the intensity of the peak metal will also increase and the intensity of impurities will decrease. The highest iron ore content obtained from the roasting process and magnetic separation is 63.791% with a percentage gain of 30.272% in the grain size fraction (+180) µm. The level of Fe_2O_3 in the fine grain size fraction was (-106) µm 17.768% with the lowest acquisition rate of 19.456%.

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