APPLICATION OF REVERSE FLOTATION METHOD FOR THE UPGRADING OF IRON OXIDE CONTAINED IN CALCINE LATERITE ORE

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Received : 24 September 2007, first revision : 05 January 2008, second revision : 03 February 2008, accepted : 24 February 2008

ABSTRACT

Reverse flotation was adopted for Indonesian iron-rich laterite ore from Pomalaa to float siliceous minerals in the separation of iron mineral. Nickel siliceous mineral such as garnierite is one of the silicate minerals containing in laterite ore that are undesirable and must be eliminated from the ore before used as raw material for iron making industry. Calcine laterite product was obtained from reduction process in rotary kiln for 3 hours at 900 °C by transforming limonite/goethite to magnetite containing Fe 45.6 % and Ni 1.16 %. The reverse flotation tests were focused on the separation of iron mineral from nickel mineral using amine complex, ARMAC-C, a commercially available amine thioacetate as collector.

Influences of pulp pH, dosages of collector amine complex and frother, and also solid percent of pulp on the reverse flotation of calcine laterite ore were investigated. The optimal condition was obtained at pH 10, collector 1000 g/t and frother 25 g/t at solid percent of 30%. The test results show that after one-stage rough reverse flotation the concentrate had Fe and Ni grades of 77.5% and 0.5% with recoveries of 57.3% and 33.7%, respectively. Therefore, it is possible to use iron-rich lateritic ore to produce magnetic concentrates by using magnetizing roasting followed by reverse iron flotation.

Keywords: reverse flotation, iron laterite, transforms limonite/goethite, amine thioacetate

1. INTRODUCTION

Import of raw materials of iron ore by Indonesia iron and steel industry in the form of pellets is estimated to increase double up to four million tons annually. Instead of using imported raw material, there are some unexploited deposits of iron ore scattered throughout the country. One of these resources is lateritic iron ore which can be found in South Kalimantan, Sulawesi and Western Papua, which is estimated amounted up to one billion tons. The biggest resources are distributed in Sebuku Island, Kukusan Mountain, Geronggang (South Kalimantan), Pomalaa (Southeast Sulawesi) and Halmahera. Geological reports estimated that iron ore resources reaches 950 million tons with Fe contents range between 39.8 up to 55.2 % (Direktorat Industri Logam, 2007)). Another review stated that the potency of lateritic iron ore resource of Indonesia is more than 1.1 billion tons, and calculated reserves reaches 215,160,000 tons (Setiawan *et al*, 2004).

Lateritic iron ore can be found on the top layers of nickel lateritic deposits as *iron cap* with iron content range from 40 to 59 %. In order to be used as suitable raw material feed for the local iron and steelmaking industry, it is necessary to upgrade the iron content to minimum 65 %. Intensive study on the utilization of lateritic iron ore as raw material for iron and steel industry with emphasizes on increasing the iron content by lowering the metal impurities will be essential.

Until recently, there is no effective and economic technology to upgrade the iron content in lateritic iron ore which is suitable as raw materials for steel industries. However, there are many technologies successfully applied for enhancement of hematite and magnetite ores (Song *et al*., 2002) as well as ilmenite ore (Cui *et al*., 2002). It is also reported that India has developed technology to process of fines and low content hematite iron ore by using column flotation method to increase the iron content from 55.9 %, as a product of high gradient magnetic separator pre-concentration method up to 67.4 % (Kumar, 2005). Furthermore, there are alternative iron and steelmaking processes that have been reviewed (Pearson and Thambimuthu, 2007), by using different resources of energy and raw materials being developed, including the use of fines ore and non-coking coal indicated by asterisks (*) as shown in Figure 1. Some abbreviations commonly use by iron and steelmaking industry such as basic oxygen furnace (BOF), electric arc furnace (EAF), direct reduced (DR) pellets, etc., can be found further in Pearson and Thambimuthu (2007) report.

This paper deals with the implementation of roasting reduction followed by reversed flotation, in attempt to increase the iron content of Pomalaa laterite ore, Southeast Sulawesi. Roasting magnetizing method generally utilizes natural gas as reducing agent (Youssef and Morsi, 1998; Purwanto *et al.*, 2003). The gas is converted to CO and CO_2 gases inside the reformer and injected into the reduction incinerator (Purwanto, 2003; Pramusanto and Saleh, 2006). The reduction condition should be adjusted to prevent the exhibition of metallic phase. The expected phase is magnetite phase, which can be separated using magnetic separator. Unlike of floating the valuable minerals in the common flotation process, in the reversed flotation method, mineral impurities, like silicate minerals is recovered in the float concentrate and the iron minerals as the valuable minerals in the sink product (Castro *et al*., 1985; Wills, 1992; Rianes, 2008).

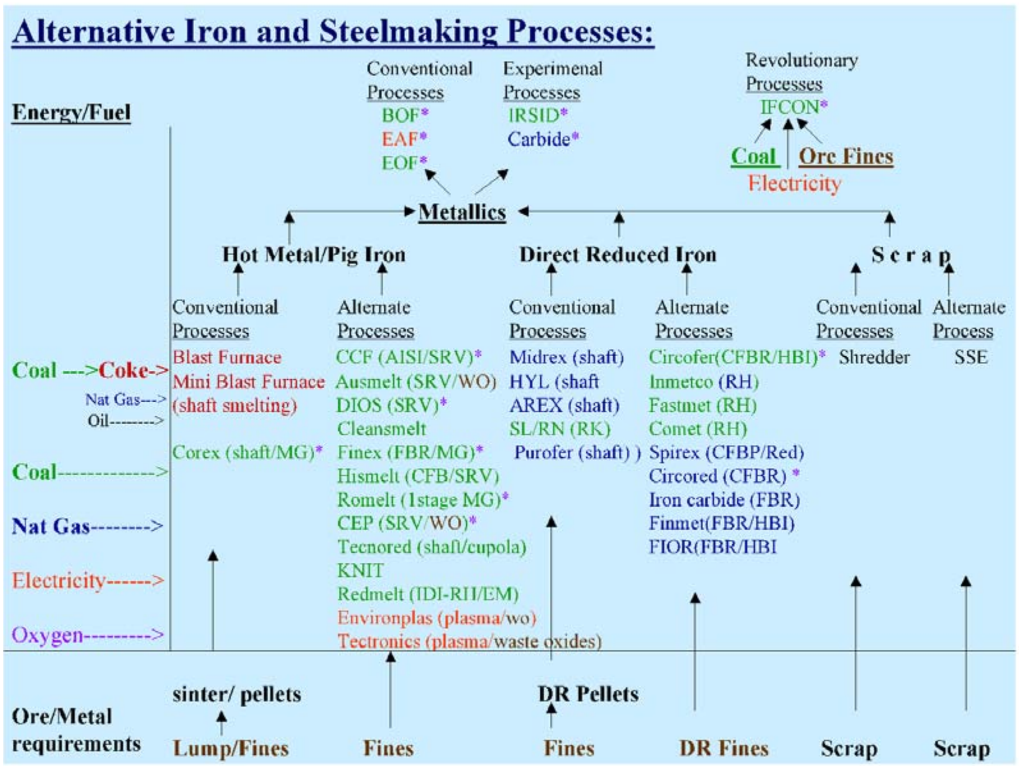

Figure 1. Ore/metal requirement for the iron and steelmaking processes

Table of Contents

2. MATERIALS AND METHODS

Reversed flotation was carried out to the Pomalaa iron ore laterite resulted from reduction roasting. Raw material studies on the fresh and reduced ores were conducted. An optimum conditions, including pH influence, collectors amount and solid percent were tested.

Raw material used in this study is calcine laterite iron ore of Pomalaa, Southeast Sulawesi resulted from roasting reduction. Roasting reduction was performed in laboratory rotating kiln at 900 °C for 3 hours to produce calcine laterite. Raw material characterization was done by chemical analyses for Fe and Ni determination, x-ray diffraction and mineralogical analyses for mineral components identification.

The reversed flotation was performed in Denver laboratory flotation machine by floating of mineral impurities in concentrate, while the valuable minerals are collected in tailing. Calcine laterite iron ore resulted from roasting reduction was used as feed of flotation tests by floating of silicate minerals as impurities and iron minerals in the sink product. The flotation parameters investigated were the influence of pH, dose of collector and frother, solid percent of pulp and the recovery of Fe as well as Ni.

3. RESULTS AND DISCUSSION

3.1. Characterization

3.1.1 Chemical Composition

Chemical composition analyses show, that the raw material contained 41.44% of Fe and 0.50% of Ni. In the magnetic concentrate product resulted from roasting reduction, the Fe and Ni contents had increased to 66% of Fe and 1.03% Ni as previously reported (Pramusanto and Saleh, 2006). In the calcine laterite product, the iron content increased due to changes of phases from hematite to magnetite, as well as to elemental iron resulted from roasting reduction.

3.1.2 X-ray Diffraction

Before reduction, the raw material of laterite iron ore contained hematite, magnetite, and nickel-chrome iron oxide, and also aluminum hydroxide as revealed from x-ray diffraction results of Pomalaa laterite (Figure 2). X-ray diffraction analyses of calcine laterite obtained from roasting reduction product reveals the occurrence of magnetite and elemental iron as shown in Figure 3. There was no iron compound detected in this result, showing that excessive reduction was prevented by introducing air into the reduction kiln.

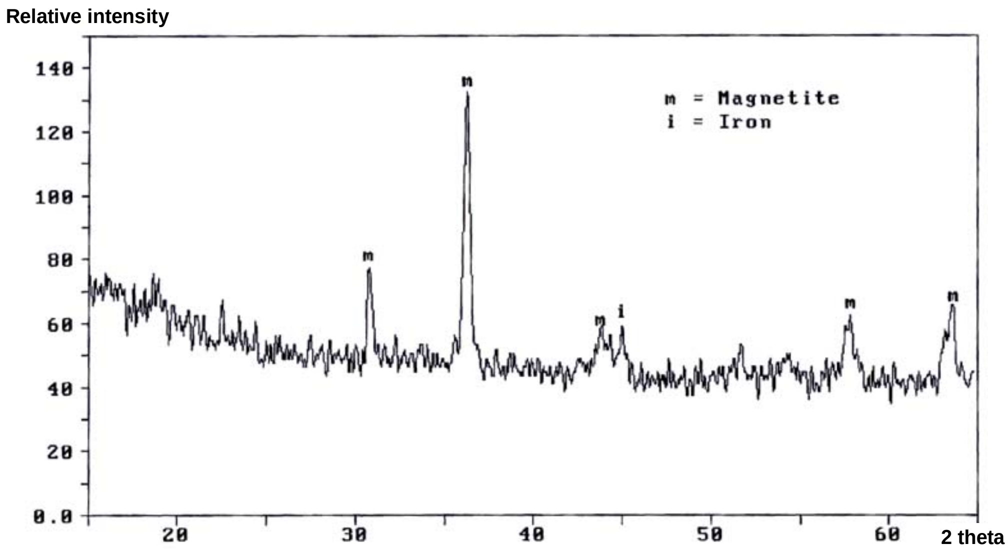

Figure 2. X-ray diffraction analyses of calcine laterite resulted from roasting reduction

However, as nickel contained in the ore was much less than iron, during reduction, most of nickel will reduced to elemental nickel in the presence of elemental iron to produce ferronickel. The formation of ferronickel during reduction of lateritic ore was also reported (Yusuf *et al*., 2003) in attempt to produce high iron content in magnetic product.

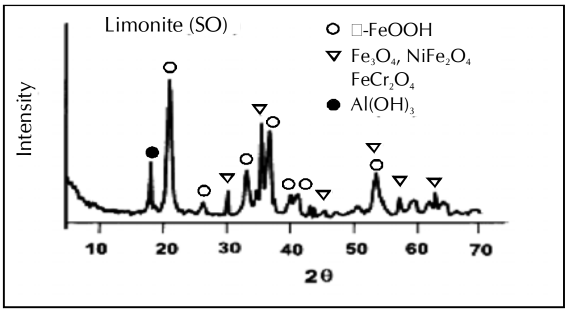

Figure 3. X-ray diffraction analyses of laterite iron ore Pomalaa

3.1.3 Mineralogy

The optical mineralogical observations of both fresh iron ore and calcine ore resulted from roasting reduction, are shown in Figure 4 and 5, respectively. Typically in the calcine product as shown in Figure 5, the layer of metallic iron is exhibited at the outer surface of magnetite, indicated that some excessive reduction was occurred.

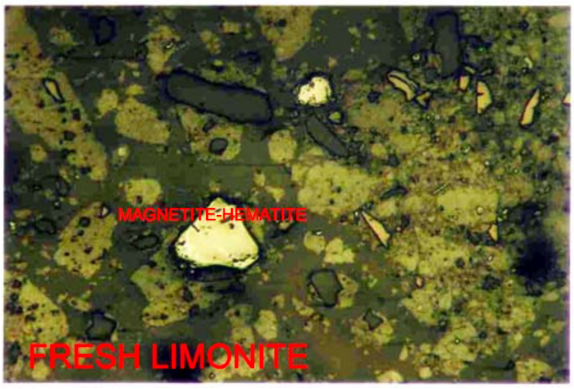

Figure 4. Microscopical observation of fresh Pomalaa ore

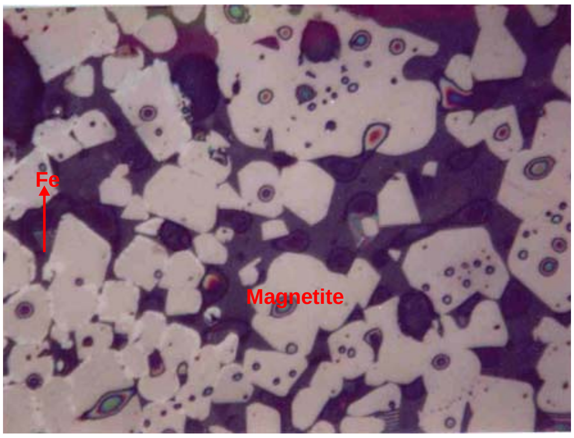

Figure 5. Microscopical observation of calcine laterite resulted from roasting reduction

3.2. Flotation

Results of reversed flotation of calcine laterite was observed through the influences of pH, doses of both collector and frother, percent solid of pulp, and iron as well as nickel recovery. Flotation time was determined at one stage rougher to exhaustion until the froth completely barren. The addition of calcium chloride to activated silicate minerals was applied, and also starch to prevent iron minerals into the float product.

3.2.1 pH

The influence of pH to the recovery of both iron and nickel is shown in Figure 6. The results reveal that grades as well as recovery of Fe significantly increased from pH 8 to pH 10, however, but it slightly decreased at pH 12. The maximum recovery for Fe and Ni were 65% and 28% with grade of 48% and 0.37%, respectively. This result due to silicate minerals behavior as water repellent material generated by collector amine acid compound which performed perfectly at pH 10 and causing more silicate mineral as impurities being removed. While at less alkaline conditions, the hydrophobic behavior of silicate minerals generated from the collector was insufficient causing less silicate minerals can be removed by raising air bubbles. On another side, as most of the nickel was associated with the silicate minerals, both the grades and recovery of Ni had expectedly followed the trend of silicate removal which was inverse of iron.

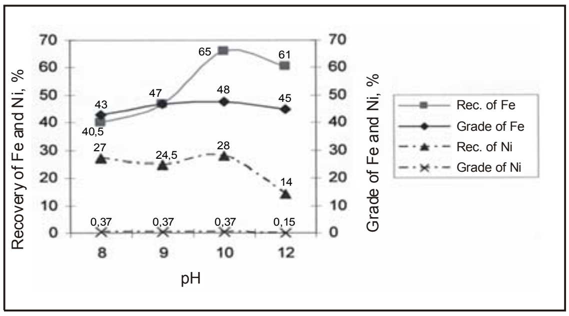

Figure 6. **Effect of pH on grades and recovery of Fe and Ni**

3.2.2 Collector

Doses of collector *i.e*. amine acetate compound used in reversed flotation process influenced the content and recovery of both Fe and Ni (Figure 7). The result shows that Fe content and its recovery increased at collector usage from 500 up to 1500 g/ton, and then decreased with increase of collector usage to 2000 g/ton. The addition more collectors beyond 1500 g/t causing the pulp in less alkaline condition, gave an effect in lowering selectivity of the silicates and iron minerals. The results show that at 1000 g/t of collector, the grades of Fe and Ni obtained were 46.5% and 0.37% with recoveries of 63.1% and 25.1% respectively.

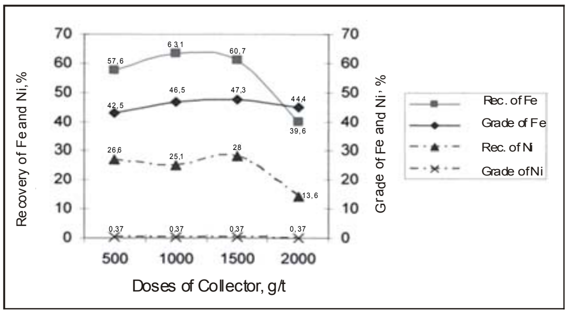

Figure 7. **Effect of collector on grades and recovery of Fe and Ni**

3.2.3 Frother

Frother addition has much influence to the air bubbles formation which enable to lift up the unwanted minerals. At this study, the influence of frother addition to the Fe content and recovery is shown in Figure 8. The result shows that Fe content and recovery increased at frother usage of 25 g/ton up to 175 g/ton as optimum condition. While by further frother addition of 250 g/ton, both of Fe and Ni content and recoveries, decreased. However, at lower dosage of frother, Ni content and recovery were remained stable. This was due to more usage of frother tends to produce larger size bubbles which can easily broken, then silicate mineral attached to the bubbles will be released again as it broken, and resulted in less silicate mineral floated which further decreasing Fe content and recovery.

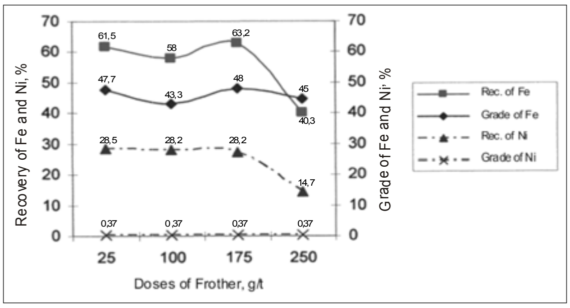

Figure 8. **Effect of frother on grades and recovery of Fe and Ni**

3.2.4 Solid percent

Solid percent of pulp at flotation process was influenced by concentrate amount obtained. The influence of percent solid to the Fe content and recovery can be seen in Figure 9. The results show that Fe content and recovery increased from 20% solid, after reach an optimum condition at 30% solid, then it slightly decreased at 40% solid. The decreased at higher pulp was resulted from less freely movement of minerals in the pulp and causing lessen capability of collector to change surface behavior of silicate mineral, thus less sili-

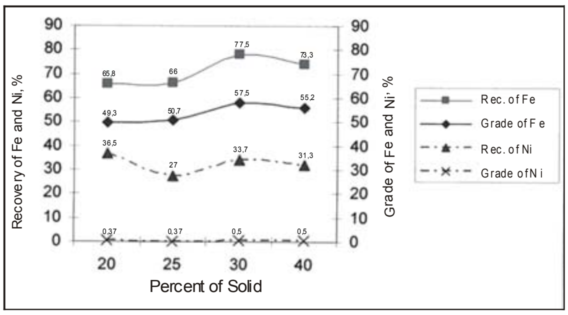

Figure 9. **Effect of percent solid on grades and recovery of Fe and Ni**

cate surface unattached to the air bubbles. In overall, this conditions cause less floated silicate mineral and remain in tailing which lowering the Fe content and recovery.

4. CONCLUSIONS

It can be concluded that reversed flotation can be adapted to the iron-rich laterite ore of Pomalaa, Southeast Sulawesi after roasting reduction. The iron content in concentrate increased from 66% to 77.5% with recovery 57.3%, and nickel content decreased from 1.03% to 0.5% with recovery of 33.7%, at optimum conditions of pH 10, collector of 1000 g/ton, frother of 25 g/ton and 10% solids.

ACKNOWLEDGEMENT

The authors would like to thank Dessy Amalia for her painstaking during laboratory preparation and manuscript writing.

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