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A study of bauxite tailing quality improvement by reverse flotation

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Abstract. The pre-treatment of bauxite ore from Tayan, West Kalimantan includes washing and screening fine bauxite particles (-2mm) prior as the feed to the Bayer process for producing alumina. These fine particles are believed to have high content of silica which is detrimental to the process. This washed bauxite tailing still has a significant amount of alumina content. Previous research has indicated that bauxite ore can be upgraded by applying reverse flotation method to reduce its silica content in the ore. Therefore, this study is aimed to utilize reverse flotation method to recover alumina content from washed bauxite tailing. The reverse flotation experiments were carried out at pH of 6 and 8; while the particle sizes were varied at -140+270 mesh and -270 mesh, using a batch and circuit configuration. The result of this study shows that the batch reverse flotation can recover alumina in the tailing up to 81.4%, however the silica content is still significant. The complexity of silica-alumina minerals in the tailing prevents a complete separation of the ores by only using reverse flotation.

1. Introduction

Bauxite is the raw material for producing alumina, both as Metallurgical Grade or Chemical Grade via the Bayer process. West Kalimantan has large amount of bauxite reserve, and has been mined by PT Aneka Tambang to be processed by PT Indonesia Chemical Alumina. Bauxite from West Kalimantan is categorized as lateritic bauxite. Typical bauxite from Tayan area has alumina content ranging from 41 to 46%, with silica content of 5 % to 17%, giving alumina to silica ratio of 5 to 9 [1].

Silica in bauxite comprises of two types, reactive silica and nonreactive silica [2]. Reactive silica is the clay type minerals, including kaolinite ($Al_2[Si_2O_5](OH)_4$), haloisite ($Al_2[Si_2O_5](OH)_4.2H_2O$), and zussmanite ($K(Fe^{2+},Mg,Mn)_{13}[AlSi_{17}O_{42}]$, while non-reactive silica includes quartz (SiO_2). Silica combined as clay and other silicates dissolves in the digestion process and forms sodium aluminium silicate, which precipitates as Desilication Precipitates (DSP), and therefore responsible for the loss of caustic soda as well as reduces the alumina recovery from the ore [3]. Silica in the form of quartz is not attacked during the digestion process, but it reduces the production capacity of bauxite processing.

The current practice to process bauxite ore from Tayan, West Kalimantan, by PT Aneka Tambang is to wash and screen bauxite ore. The washed bauxite that has particle size +2 mm is believed to have low silica content and suitable for processing in the next process step, which is the digestion in the Bayer process. The bauxite that has particle size -2+1 mm also can be processed to the Bayer process as the alumina content for this fraction is about 40%. The washed bauxite tailings that have particle size less than 1 mm has not been utilized yet. This results in a big dump of washed bauxite tailings. The alumina content in the washed bauxite tailing is still significant, at about 36.3 wt%.

One of the methods to physically separate gangue materials is reverse flotation. The term “reverse flotation” refers to flotation that collects unwanted material at the froth phase, while the economic material is collected in the base phase. This is beneficial for high silica bauxite as the collector chemicals collect rich silica phase in the froth phase and the upgraded bauxite can be utilized for further process.

Reverse flotation has been applied to process high silica bauxite in order to increase the bauxite quality, particularly for Chinese diaspore [4]. Xia *et al* [5] used Gemini cationic surfactant, BDDA, as a collector for reverse flotation to separate illite, pyrophyllite and kaolinite from diaspore bauxite. The bench-scale separation was reported to obtain Al to Si ratio of 9.72 with 81.25% of Alumina recovery. Wang *et al* [6] used quartenary ammonium salt (DTAL) to obtain good separation from similar diasporic bauxite with Al to Si recovery ratio of 10 and alumina recovery of 86%. Recent research by the authors reported that reverse flotation can be applied to separate silica from bauxite ores from Tayan. The ratio Al to Si can be increased from 7 up to 14, by using dodecylamine as the collector [7].

While reverse flotation has been successfully applied to separate major silica from bauxite ores, no literature is available for reverse flotation method that applied to the tailing. This paper aims to understand the reverse flotation of washed bauxite tailing, thus attempts to increase the quality of washed bauxite tailing by such method. In particular, the operating conditions that is suitable for the reverse flotation is examined, and the product from the concentrate and tailing are characterized in order to study the phenomena for better understanding.

2. Experimental

This study used washed bauxite tailing obtained from PT Aneka Tambang. About 68 kg of these tailings with particle sizes of -2 mm were dried and were reduced to 17 kg and 2 kg by using coning and quartering sampling technique (ASTM D346). The tailings were then screened to obtain 3 kg of -2+1 mm fraction, while the latter was further milled using ball mill to obtain a fraction of -140+270 mesh (-0.105+0.053 mm) and -270 mesh (-0.053 mm).

The experiments were carried out in two configurations, batch and circuit. For batch configuration, every experiment used 455 gram of fine sample which has been obtained by using sampling splitting method (ASTM D2013). The reverse flotation experiments were conducted in a 1.5 liter of Denver flotation equipment with 1 liter of aqua dm. It used 2 ml of dodecylamine 98% as the collector agent, 9 gram of sodium hexametaphosphate (SHMP) as the dispersant, food grade starch as the depressant, and Dowfroth 1016 as the frothers. To adjust the acidity/basicity, sulfuric acid and sodium carbonate was used. During the flotation process, the concentrate (at the froth) was scrapped and collected from the top, while the tailing was collected at the end of experiment. Both products were dried by using oven at temperature of 110 °C for 16 hours. The products were characterized by using X-Ray Fluorescence (XRF) to determine the oxide content and XRD to determine the major phase.

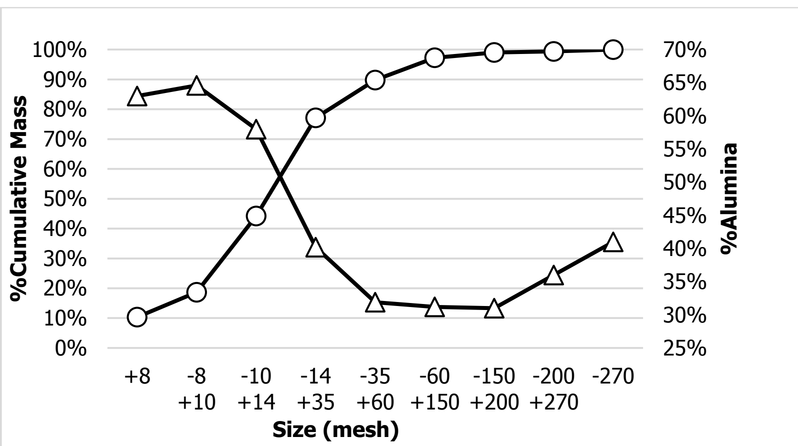

Figure 1. Mass cumulative of washed bauxite tailing particle distribution

3. Result and Discussion

3.1. Feed Characterization

About 2 kg of feed was characterized by using sieving analysis and XRF analysis. Figure 1 shows the mass cumulative of washed bauxite tailing and its particle size distributions. It is obtained that the bauxite feed with particle size of +8 mesh (+1 mm) has cumulative mass of 45% while the particle size -14 mesh (- 1mm) has cumulative mass of 55%, respectively. Figure 1 also shows alumina content of each fraction by using XRF analysis. As the particle size of bauxite is smaller, the alumina content is also decreased. For typical fraction size of -1mm, XRF analysis of the feed shows that washed bauxite tailing comprises of 36.80 wt% of Al_2O_3, 24.05 wt% of SiO_2, 34.15 wt% of Fe_2O_3, 3.47 wt% of TiO_2, 0.76wt% of SO_3, 0.25 wt% of V_2O_5, and others.

Figure 2 shows the mineralogy of washed bauxite tailing. It is shown that the washed bauxite tailing consists of Gibbsite, quartz, hematite, kaolinite, zussmanite, and pyrophyllite. Overall, the washed bauxite tailing still contains gibbsite as the source of alumina, quartz as the non-reactive silica, and kaolinite, zussmanite and pyrophyllite as the reactive silica minerals. Hematite also presents as the impurities, with the XRF indicates the presence of hematite as high as 34.15%.

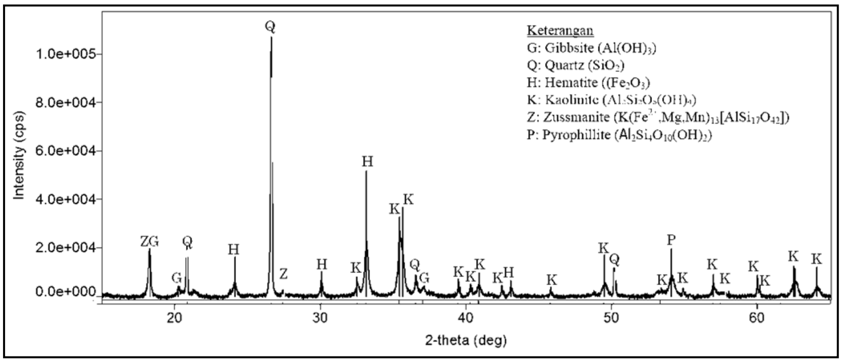

Figure 2. XRD analysis of washed bauxite tailing feed

3.2. Effect of Operating Condition to Reverse Flotation

Batch reverse flotation was carried out at pH 6 and 8 at two different particle sizes: -140+270 mesh and -270 mesh. Figure 3 shows the alumina recovery at the concentrate (the depressed section) from the reverse flotation. For the particle sizes -140+270 mesh, the alumina recovery obtained was 81.4% at pH 6 condition, and 80.6% at pH condition. The recovery is similar with other work reported in the literatures, such as Wang *et al* reported alumina recovery of 78% from reverse flotation of diaspore bauxite (6) .

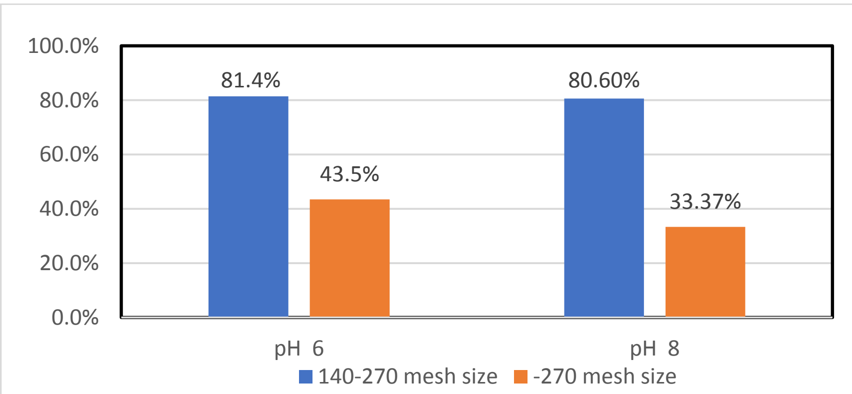

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Figure 3. Alumina recovery at pH 6 and 8 for different particle sizes

The reverse flotation has been found not effective in recover alumina, as in Figure 3, the alumina recovery of alumina in at the concentrate is only 43.5% at pH 6 and 33.37% at pH 8. This can be explained by the settlement phenomena that may happen very fast as well as the probability of entrainment of very small particles for those -270 mesh particles to the froth phase, thus reduce alumina recovery at the concentrate.

3.3. Mineralogy analysis of Reverse Flotation

Figure 4 shows the XRD pattern of (a) concentrate and (b) tailings of batch reverse flotation of washed bauxite tailings. Overall, both of concentrate and tailings contain similar minerals, including gibbsite, quartz, kaolinite, haloisite, and zussmanite. Pyrophillite is present at the tailing but not at the concenrtate, The absence of pyrophillite at the concentrate shows that the pyrophillite at the feed has been completely liberated at the experiment.

The similar minerals at the concentrate and tailings was caused by the silica and alumina are bounded and not completely liberated. In addition, as the clay minerals also contains alumina, such as kaolinite, pyrophillite, the tailings at the experiments still contains alumina with fraction of 35%. Table 1 shows XRF analysis of concentrate and tailing from washed bauxite tailing reverse flotation. From all 8 runs, it is shown that the alumina and silica content in the concentrate is similar, ranging from 34-36 % for alumina and 23-26% for silica. This composition is similar to the feed composition, thus implying that the reverse flotation is not effective enough to be applied to the tailings of washed bauxite.

4. Summary

Reverse flotation method has been applied to increase to separate silica from washed bauxite tailings. While reverse flotation method has been successfully applied to raw bauxite ore from Tayan, Kalimantan, this method is not effectively separate silica and increases the quality of its washed bauxite tailing. The good condition of reverse flotation is obtained at pH 6 condition, with particle size of -140+270 mesh, with alumina recovery of 86.20%. However, the alumina content in the concentrate is still similar, only 35.78% from 36.80% from the feed. The silica content in the concentrate is also similar at 25% from 24.05 % from the feed. The complexity of silica-alumina minerals in the tailing prevents a complete separation of the ores by only using reverse flotation.

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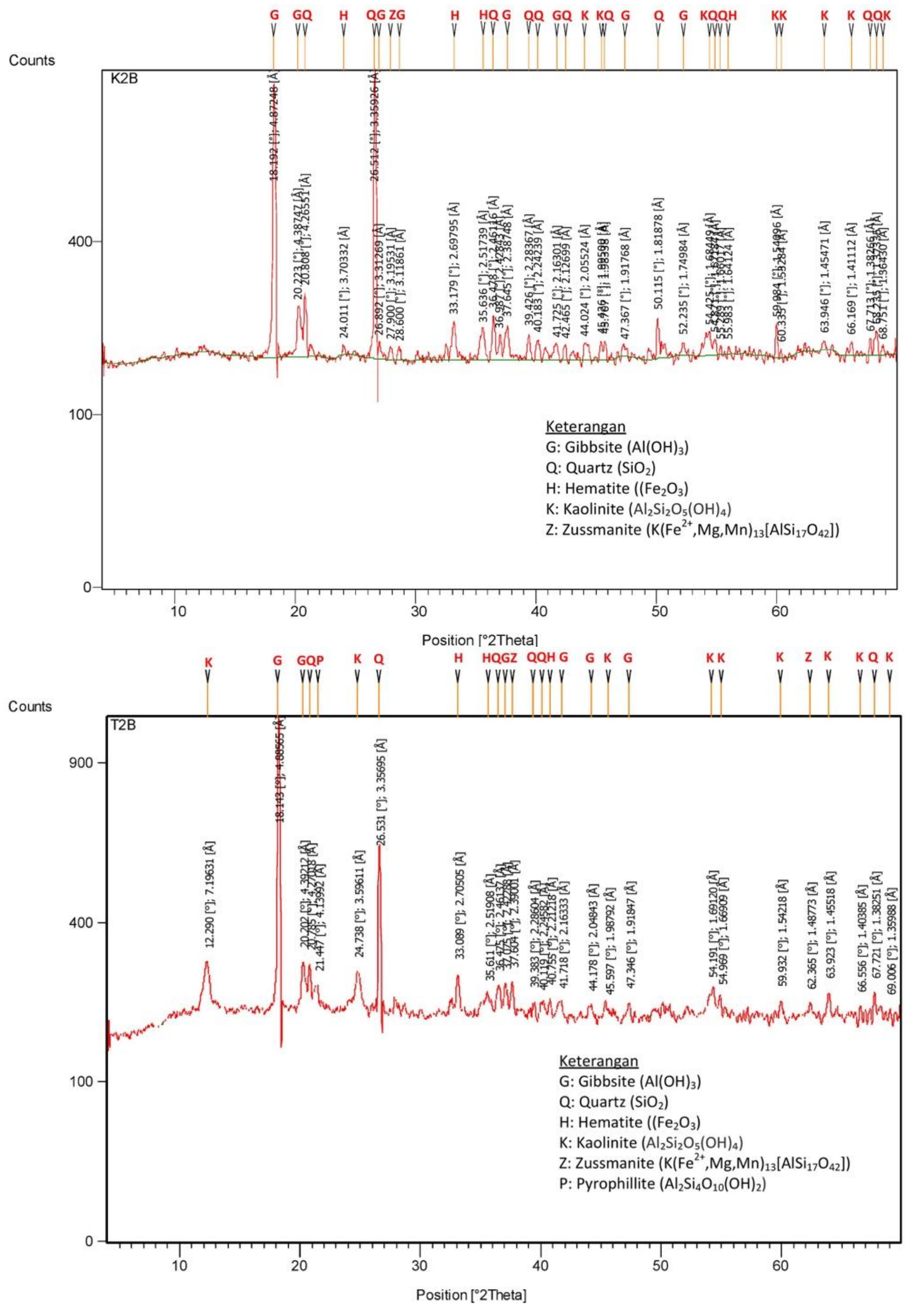

(a)

(b)

Figure 4. XRD Analysis of (a) Concentrate and (b) Tailings of Batch Reverse Flotation of Washed Bauxite Tailing

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Table 1. XRF Analysis of Washed Bauxite Tailing Reverse Flotation

Run	Condition	Concentrate		Tailings	
		Al_2O_3	SiO_2	Al_2O_3	SiO_2
1	-140+270 mesh particle size pH =8	35.72%	25.13%	43.71%	17.14%
2		35.57%	25.28%	41.68%	19.17%
3	-140+270 mesh particle size pH =6	35.58%	25.27%	43.61%	17.24%
4		35.78%	25.07%	41.81%	19.04%
5	-270 mesh particle size pH =8	36.93%	23.92%	36.75%	24.10%
6		35.65%	25.20%	37.62%	23.23%
7	-270 mesh particle size pH =6	34.20%	26.65%	39.44%	21.41%
8		34.08%	26.77%	38.89%	21.96%

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