The tin ore separation process and optimizing the rare earth mineral (monazite) as a by-product of tin mining in East Belitung Regency

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Abstract. Characteristics of granitic igneous rocks as a source of tin mineralization in the study area are generally ilmenite granite series or commonly called Granitic S type. The occurrence of rare earth elements is relatively common in the earth’s crust. Based on its chemical properties, the occurrence of REEs (Rare Earth Element) is rarely scattered and not concentrated in one place, so it is often stated that it is not economical to be mined. However some rare earth mineral deposits such as monazite can be processed economically. Rare earth element like monazite is discovered as by-product from mining process and extracting tin mineral. The purpose of this study is to examine the separation process of tin ore that could affect the grades of tin ore produced. The highest grade of pure tin obtained rare earth element and will be optimal to the ore extraction. The methods of concentrating monazite use wet processing followed by dry concentration techniques, then extraction and refining are required. This method was observed during the study. The result showed that extraction involved sulphuric acid routes and the acidic route is the most common, dominating at least 90% of the current extraction methods.

1. Introduction

Tin is a white silvery metal which is easily formed and flexible, crystalline structured, but easily broken if in cold condition. Tin is formed as the primary deposit in the granite rock and at the touching area of metamorphic rock (associated with tourmaline and quartz tin veins), as well as a secondary deposit in it, consisting of alluvium, alluvial, and colluvium sediment. The research location is in the eastern part of the Southeast Asian granites tin belt zone so that it is expected as a potential area for the occurrence of the ore deposit such as iron and cassiterite associated with monazite and other accessory minerals.

The occurrence of rare earth elements is relatively common in the earth’s crust. Based on its chemical properties, the occurrence of REEs is rarely scattered and not concentrated in one place, so it is often stated that it is not economical to be exploited. However some rare earth elements like bastnasite, monazite, and xenotime will be processed economically [1] [2]. Based on the geological setting of Bangka Belitung Island and around, this area is located on the Sunda Shelf and the edge of the Asian Continent Crust (figure 1). Therefore, the bedrock constituent of this area is an addition to metamorphic rock and it is the continental core rock in the form of acidic igneous rock or granitic, trias-yura (230 –
135 million years ago). The research area is in East Belitung Regency with the -Carbon Kelapakampit Formation (PCks) with Diorite Quartz Batubesi (Kbd) aged Cretaceous and there are fault structure and/or fractures. The Characteristics of granitic igneous rocks as a source of primary tin mineralization in the study area are generally ilmenite granite series or commonly called Granitic S type [3]. This granite is formed by the fusion of continental crust.

![Figure 1](image.png)

Figure 1. Local geological map of the research area

LREE (Light Rare Earth Element). Minerals containing predominantly yttrium and the HREE include gadolinite, xenotime, samarskite, euxenite, fergusonite, yttrotantalite, yttrotungstite, yttrialite. Minerals containing predominantly LREE include bastnasite, monazite, allanite, oparite, ancylite, parasite, lanthanite, chevinitie, cerite, stillwillite, britholite, fluocerite and cerianite. However, commercially operating mines around the world mainly extract bastnasite, monazite and xenotime ores [1].

Rare earth elements mining can be open pit, underground or leached in-situ. For a typical open-pit mine, like in the research area, the approach is very similar to other mining operations which involves removal of overburden, mining, milling, crushing and grinding, separation or concentration. The product of the enriched concentrate after separation may contain around 30% - 70% of rare earth bearing ore. Therefore the aim of this study is to examine the separation process of tin ore that could affect the grades of tin ore produced.

2. **Method**

Flotation and magnetic separation are the usual techniques used for processing rare earth ores to produce monazite concentrate [4] [5]. The REE mineral concentrate contains between 60% - 70 % of rare earth oxides (REO). The recovery of REO in concentrate varies between 40% to 80% depending on the nature [4] [6]. In addition, the concentrates of REE minerals consist of various processing routes that lead to extraction of the REEs into an aqueous solution [7]. Flotation and magnetic separation are the usual techniques used for rare earth ores processing to produce concentrate.

The field observation was conducted to obtain the data associated with tin production. Some processes were observed including tin ore separation process both using jig and magnetic method.

3. **Result and Discussion**

3.1 Tin ore separation of gangue minerals
Tin ore processing activities are carried out directly in the field because the process of separating tin ore with gangue minerals is easy and does not require chemical liquids (figure 2). It is only using gravitational process. Tin density of 7.31 g/cm³, is heavier than other gangue minerals.

Figure 2. The flow of separation between tin ore and by-products [8]

After carrying out mining activities, minerals containing tin ore are distributed to the stockpile area. The stockpile location is lower than their working front and close to the water source because the separation of tin ore requires a lot of water. Material that has been piled will be inserted into the grizzly in the form of slurry through a lounder (the drainage to enable the material to flow). Grizzly functions to separate the large tin ore size with the relatively smaller one, so that materials with a relatively smaller size can enter the next process sequence as seen in Figure 3.

Figure 3. Grizzly and lounder with slurry materials (left), and rotary screen (right)

The material that passes from the grizzly then through the lounder goes to the rotary screen. The rotary screen serves to filter the slurry that is passed through the grizzly and produces slurry with the tin ore size that is optimal for the next jig operation. Material with an optional size (undersize) will go directly to the primary jig. In the jiggling process, stratification will occur in separated particles. This is because the particles have different gravity. The jiggling process have two stages, i.e. primary jig and secondary jig. The primary jig consists of six jigs, each of which consists of two cells and each cell consists of four compartments. While the secondary jig consists of two jigs, each of which consists of two cells and each cell consists of three compartments as shown in Figure 4. The concentrate yielded from the secondary jig will be reprocessed in the sakhan.
Sakhan is an ore mineral concentration toll that has a flat surface and works based on specific gravity (SG). In this process, it is expected that minerals that have a high SG will settle while those with lower SG can be carried by water flow to the settling pond. The deposited mineral will be taken and will be inserted into the lobi for the next stage of separation. The working principle of the lobi is the same as the sakhan, only that the lobi has more water pressure to allow the material to be separated optimally. Pressurized water is released from the bottom with a certain speed. The tailings from the lobi will be accommodated in a tub and will be reprocessed until it is separated optimally, while the material deposited at the base of the lobi will be directly inserted into the feed and then into the rotary dryer as presented in Figure 5.

Rotary dryer is working by using heat flow from LPG (Liquid Petroleum Gas) combustion. The temperature of the heat flow released from the combustion is 300°C and drying is performed repeatedly to allow all parts undergo drying process so that the process may be performed more evenly. Magnetic separation is a separator of one mineral and other minerals that utilizes different magnetic properties from the minerals to be separated. The minerals of tin and some associated minerals (especially iron) will be separated. Concentrate generated from the separation process in the field usually have a grade of ± 65% as already to sending the product to Central Processing of Tin Ore for checking grade more accurately (see Figure 6).
3.2 Rare earth element processing steps

The principal rare earth mineral exploited is monazite, which typically has associated radioactive due to thorium content. The process involved monazite concentrate using wet processing followed by dry concentration techniques. Wet concentration separates the heavy minerals from gangue minerals. Dry concentration such as magnetic, electrostatic and gravity separation steps are used to separate monazite from the other heavy minerals. The rare earth element may be dissolved from monazite by high-temperature leaching in concentrated sulphuric acid.

The following description of rare earth processing is very general and represents a limited range of options that could be used in the industry. To extract rare earth, further processing or extraction and refining are required. The extraction process may involve sulphuric acid routes because the mineralogy of the REE contents has phases and reactivity of sulphuric acid. Typically, the acidic route is the most common, dominating at least 90% of the extraction methods. The extraction step often involves roasting of the rare earth ore at 400°C – 500°C in concentrated sulphuric acid to remove fluoride and CO₂, and to change the mineral phase to make it more water-soluble. The generated ore is washed (usually using water) and filtered or decanted to remove fine solid impurities. The REEs are then further leached using extraction agent (hydrochloric acid) and precipitating agents (ammonium bicarbonate (NH₄)HCO₃). The precipitate is heated to get rare earth oxides (REO). LREEs may be extracted by molten salt electrolysis based on chlorides or oxides. Metallothermic reduction processes are used to extract the middle and heavy rare metals such as Sm, Eu, Tb and Dy in near-vacuum conditions with inert gas at high temperatures (>1000°C).

4. Conclusion

Tin ore processing activities are carried out directly in the field because the process of separating tin ore with gangue minerals is easy and does not require chemical liquids. It is only using gravitational involve. The main processing are jigging, sakhan, lobi, rotary dryer, and magnetic separation. Concentrate generated from the separation process in the field usually has ± 65% grade, which is ready to be sent to Central Processing of Tin Ore for grade checking in a more accurate way.

The process involved concentrating monazite using wet processing followed by dry concentration techniques, and then followed by extraction and refining. The extraction may involve sulphuric acid routes because the mineralogy of the REE contents has phases and reactivity of sulphuric acid and ammonium bicarbonate. The acidic route is the most common, dominating at least 90% of the extraction methods.

Acknowledgement

The authors would like to thank PT. Timah Tbk, ITSB and LAPI ITB for discussions, suggestions and financial assistance in this research and publication.

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