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Analysis of Tin Grade and Recovery in Monazite Retreatment with Three Disc Magnetic Separator

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Abstract

Retreatment is conducted to obtain tin that remains in the monazite tailings (2-3% Sn) from the processing that has been carried out by PT. Timah. The purpose of this study is to analyse the presence of tin in monazite as well as the effect of magnetic intensity and opening feed on recovery and tin grade by employing a quantitative method of experimentation with three disc magnetic separator. In this study, magnetic intensity was used with disc 1, 2, and 3 respectively is 1.1 T, 1.3 T, 1.5 T (A); 1.3 T, 1.5 T, 1.7 T (B); and 1.5 T, 1.7 T, 1.9 T (C) with opening feed 0.4 cm and 0.8 cm. Based on the experiment, the highest tin grade is 7.33% with the largest combination of magnetic intensity, variation C, and opening feed 0.4 cm. Meanwhile, the highest recovery of 73.64% was obtained at the lowest magnetic intensity, variation A, with the same opening feed. It can be seen that by increasing the magnetic intensity, the tin content will be higher. Meanwhile based on some related experiment, the larger the opening feed, the higher the recovery. However, it should be noted that the opening feed used must not exceed 0.8 cm. If the opening feed used is equal or wider than 0.8 cm, it requires a strong magnetic intensity or the grade and recovery produced will not change significantly.

Keywords: Magnetic Intensity; Mineral Processing; Recovery; Three Disc Magnetic Separator; Tin Grade

Introduction

Tin is one of many metals that are widely utilised in industries such as automotive, electronics, construction, and even the food industry (Salim & Munadi, 2016). Indonesia, country with the largest tin mining production after China, has reserves estimated at around 800,000 tonnes according to the United States Geological Survey (USGS, 2023). In addition, the Ministry of Energy and Mineral Resources (ESDM) noted that Indonesia produced 52,893 tonnes of tin throughout 2022. This is considered an improvement when compared to 2021, which was only able to produce 34,05 tonnes of tin.

PT. Timah, Tbk is one of the tin mining and production companies in Indonesia. Since its establishment, cassiterite (SnO_2) which is a secondary deposit has always been used as PT. Timah, Tbk's main reserve source in extracting tin due to its high grade (Louis, 1911). However, the decreasing source of reserves with easy accessibility has caused PT. Timah, Tbk to experience a decline in production starting from 2020-2022 (PT. Timah, 2022). To overcome this situation, PT. Timah Tbk began to conduct retreatment to reprocess tailings from the process that has been carried out by the Mineral Processing Division (BPM).

Mineral processing is a process used to increase the selling value of a valuable mineral by separating it from its impurities (Wills & Finch, 2016). Processing conducted at PT Timah uses a multi-unit processing method, where the first process is carried out in a jig machine, followed by shaking table and air table, high tension separation, and finally magnetic separation. Some of these processes produce tin minerals and tin-associated minerals, such as zircon (the result of the high-tension separation process), as well as ilmenite and monazite (the result of the magnetic separation process).

Monazite, as one of the tin-associated minerals (Balaram, 2019; Habashi, 1997) obtained from the magnetic separation process, has weak magnetic properties (paramagnetic), so it needs a magnet with a high enough intensity to be able to separate it from cassiterite or other minerals (Fuerstenau & Han, 2003; Tripathy, Banerjee, Suresh, Murthy, & Singh, 2017). As a result of the low magnetic susceptibility of this mineral, there is a tendency for cassiterite with a fine size and still bound to monazite to be drawn into part of the monazite as a result of magnetic separation (Tripathy & Suresh, 2017). Therefore, PT. Timah endeavours to reprocess the monazite to obtain the tin still contained therein by taking into account the magnetic intensity factor and the opening feed used.

Research Methods

In this study, experiment were conducted by using magnetic separator with monazite processed by BPM at a dominant size of -50 mesh with 2-3% Sn content of 1 tonne was used as the initial sample. The process of concentration, as shown in Figure 1.

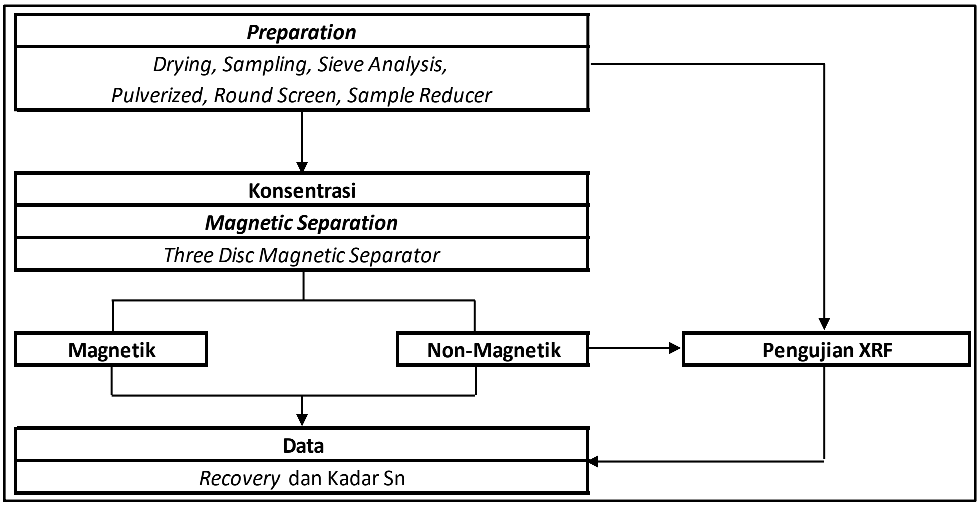

Figure 1 Concentration Process

1. Preparation

Preparation was conducted to prep the monazite before the experiment began with a magnetic separator. This stage consists of drying, sampling, sieve shaker, pulverised, round screen, and sample reducer.

a. Drying

Drying is performed to remove the moisture content contained in monazite by using a rotary dryer at a temperature of 250°C.

b. Sampling

At this stage, sampling was performed by using a thief sampler by inserting the thief into the container, this equipment consists of a hollow tube with a rod inside and has an output with a sharp tip (World Health Organization. & WHO Expert Committee on Specifications for Pharmaceutical Preparations (39th : 2004 : Geneva, 2005). Samples were taken as much as 3 kg and then split up using a riffle splitter, so as to obtain a sample that consisted of 1.5 kg for sieve analysis and 15 gr as XRF testing material, the rest of the sample was kept as an initial sample.

c. Sieve Shaker

Sieving is done to determine the percent distribution of tin from each fraction, thus making the magnetic separator adjustment process more efficient. The sieve sizes used are 20 mesh, 50 mesh, 70 mesh, 100 mesh, 140 mesh, and 200 mesh. At this stage a sample of 1500 gr was used with a vibration amplitude of 8 m/s for 25 minutes. The results of each fraction were divided with a riffle splitter, so that 15 gr of each fraction was obtained which was used as XRF testing material.

d. Pulverized

This stage is used to grind the sample into fine powder as XRF testing material. This pulverisation is intended to ensure that the X-rays fired by the XRF can penetrate the sample properly, so a more accurate analysis can be produced. Before pulverising, the bowl as a sample container needs to be cleaned first, either by vacuum or wipe so that the previous sample is not mixed with the sample to be pulverised. The bowl that had been cleaned and filled with samples was placed into the manual pulveriser and locked. Pulverisation was carried out for 1 minute for each sample. The pulverised samples were put into a holder that would be used for XRF analysis.

e. Vibrating Round Screen

Once the distribution percentage of tin from the sieving process is determined, screening of the feed is conducted by using a production-scale vibro screen. The sieve sizes used are 20 mesh and 50 mesh, resulting in material at sizes +20 mesh, +50 mesh, and -50 mesh which will be used as magnetic separator feed.

f. Sample Reducer

At this stage, the feed is allocated to 12 tests with each test amounting to 50 kg. The feed that has gone through screening is split and then homogenised by using a 1/16 sample reducer. The results of the process obtained 50 kg of feed and about 1 kg of samples which will be analysed by XRF to determine the contained tin grade.

2. X-Ray Fluorescence

Samples that have been ground using a manual pulveriser are analysed with a Portable XRF Vanta Olympus. This tool consisted of an analyser, battery, adapter charger, USB, and laptop. Samples have been pulverised, put into a small cup and compacted to achieve more accurate analysis results. The analysis is arranged in such a way that the analysis is carried out 3 times, and then the results are obtained in the form of an average of the three analyses.

3. Concentration

In this process, magnetic separation will be carried out using a three-disc magnetic separator. The fixed parameters in this process are the gap between the magnet and the conveyor belt of 0.5 cm, the feed weight of each test of 50 kg, and the grain size used is -50 mesh. Meanwhile, two parameters are used as independent variables in this process, namely magnetic intensity and opening feed. The magnetic intensities used were 1.1 T, 1.3 T, and 1.5 T (variation A); 1.3 T, 1.5 T, and 1.7 T (variation B); and 1.5 T, 1.7 T, and 1.9 T (variation B). The opening feeds used were 0.4 cm and 0.8 cm.

Setting the magnetic intensity is done by adjusting the current strength of each coil. Magnetic intensity is measured using a gaussmeter, where 1 Tesla = 10,000 Gauss. The opening feed is adjusted by turning the bolt located under the hopper, and the width of the opening is measured using a ruler. Every 1 turn of the bolt, the width of the opening feed shifts by 0.2 cm.

Samples that have passed the screening process with a round screen and have been divided by a sample reducer will be put into a magnetic separator that has been adjusted according to the parameters so that magnetic and non-magnetic minerals are obtained which will later be weighed and XRF testing (non-magnetic) for the calculation of recovery and tin content.

Results and Discussion

1. Tin Availability in Monazite

The presence of tin in materials is important to determine whether or not a beneficiation process is feasible. This can be determined by performing a sieve analysis on the monazite used as feed. The result of this process is tin distribution data, as can be seen in Figure 2 and Figure 3.

Figure 2 shows the tin content in each size fraction. Based on the data, it can be seen that there is a decrease in tin grade as the particle size increases. This happens because, with the larger particle size, the tendency of a valuable mineral that has not been liberated with impurities is also greater, so the Sn content obtained also decreases

(Lottermoser, 2010). However, different things happen at sizes 210 to 2000 microns where there is an increase in tin grade. In this case, the increase in tin grade occurred due to the processing of 297 to 2000 microns by the Mineral Processing Division (BPM) of PT. Timah, leaving tin with a grade of about 2-4%.

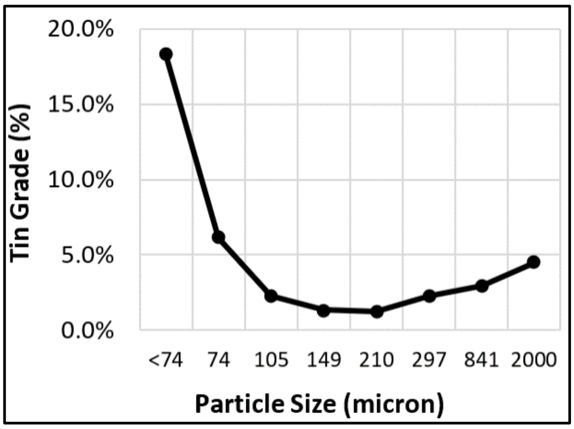

Figure 2 Tin Grade in Monazite for each Size Fraction

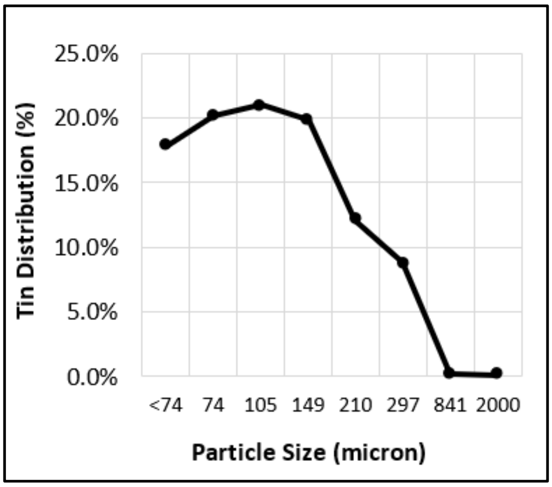

Figure 3 Tin Distribution in Monazite for each Size Fraction

This happened due to the initial grade of PT. Timah's mineral beneficiation process, which can be said to be quite high in particle sizes of 297 microns to 2000 microns. Therefore, PT. Timah conducts mineral processing at that particle size. However, it does not deny that there is tin at that size that escapes the BPM processing process. Therefore, in the XRF test carried out to analyse the tin content in this monazite mineral, tin levels of up to 4% were still obtained, but in very small amounts when compared to smaller particle sizes. In addition, pulverization was not performed for the particle size 841 and 2000 microns due to the small amount of material. As there are many things that can affect XRF performance, such as the area that can be analyzed and the sensitivity of the instrument (Goodman, Skipper, & Aitken, 2015). Thus the resulting x-ray intensity to be lower so that the analysis results given are less precise (Morikawa, 2014).

Figure 3 shows the percent distribution of tin in each size fraction. Based on the data, it can be seen that the most tin is found in the size of 105 microns, followed by the size of 74 microns, 149 microns, <74 microns, and 210 microns. This shows that tin is dominant in small particle sizes around ≤210 microns. The amount of tin contained at this size can be explained by the smaller the particle size, the more cassiterite is released from its impurities, so that the grade given is also greater. The low distribution of tin at 297-2000 microns can also be influenced by this, because the larger the particle size, the more imperfect liberation that occurs.

In addition, this may be due to the large size of the cassiterite minerals being separated in the processing process that has been carried out by BPM, leaving the finer size cassiterite (≤149 microns). Therefore, based on this and the screens available in the field, a size of <297 microns was used as the feed used in this study.

2. Effect of Magnetic Intensity on Tin Grade and Recovery

The magnetic intensity variations used in discs 1, 2, and 3 respectively are 1.1 T, 1.3 T, and 1.5 T (variation A); 1.3 T, 1.5 T, and 1.7 T (variation B); and 1.5 T, 1.7 T, and 1.9 T (variation C). The result of this process is the change in tin content and recovery at different variations. Based on the experimental data, a graph is obtained showing the changes in tin grade in the concentrate (non-magnetic) of the magnetic separation process at varying intensities A, B, and C which can be seen in Figure 4, as well as changes in recovery shown in Figure 5.

Based on Figure 4, at a fixed feed opening of 0.4 cm with different intensity variations, changes in tin grade are obtained. When looking at the data, there is an increase in tin content along with the increase in magnetic intensity used. Then at a fixed opening feed of 0.8 cm, there is also an increase in levels along with the increase in the amount of magnetic intensity used.

Based on this, it can be concluded that the stronger the magnetic intensity used, the higher the concentrate grade produced in the non-magnetic magnetic separation process. The magnitude of the magnetic intensity used makes magnetic minerals, both those with high and low magnetic strength, attracted by the magnet. Therefore, in non-magnetic it is found that the stronger the magnetic intensity used, the higher the tin grade is produced. This is consistent with other studies (Zong, Fu, & Bo, 2018) where the higher the magnetic intensity, the more magnetic minerals or impurities are separated, so that the resulting (non-magnetic) concentrate has a high tin grade.

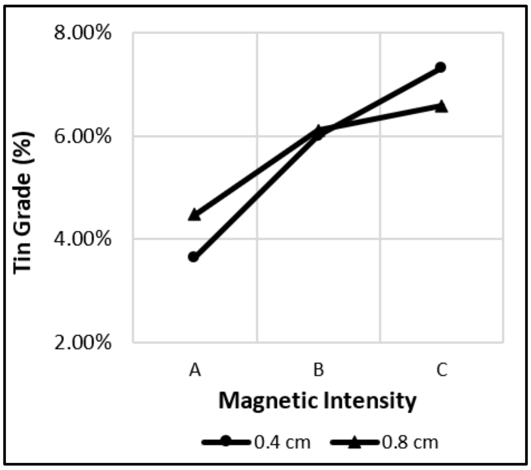

Figure 4 Effect of Magnetic Intensity on Tin Grade

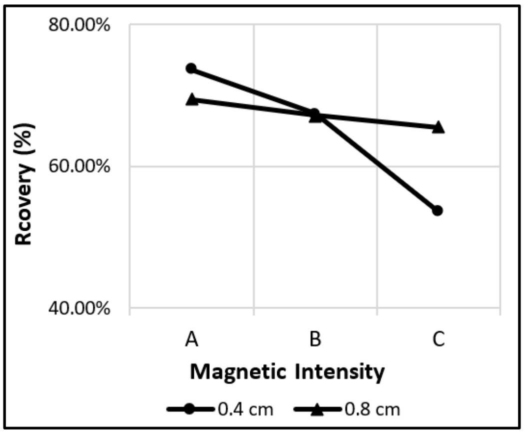

Figure 5 Effect of Magnetic Intensity on Recovery

Based on Figure 5, at a fixed opening feed variation of 0.4 cm, changes in tin recovery are obtained with varying magnetic intensity. When looking at the data obtained, it can be seen that with a fixed opening feed, the tin recovery obtained decreases as the intensity used increases. Then at a fixed opening feed of 0.8 cm, it can be noted that at different opening feeds, there is also a decrease in tin recovery.

In another research (Kim & Jeong, 2019), it was found that monazite was recovered at magnetic intensities above 1.2 T. Then, in the research (Blankson Abaka-Wood, Addai-Mensah, & Skinner, 2016), it was found that monazite was recovered at intensities of 0.29 T - 1.08 T and recovery increased as the intensity used increased. In another study (Dieye, Thiam, Geneyton, & Gueye, 2021), monazite was recovered at a magnetic intensity of 1.5 T with a recovery of 94%.

Based on these three studies, it can be seen that the stronger the magnetic intensity used, the more monazite which is a magnetic mineral will be recovered. When it comes to this study, the more monazite recovered, the less non-magnetic products will be obtained. This can happen because when the magnetic intensity increases, more magnetic minerals are separated from non-magnetic minerals. Therefore, when the intensity used increases, the recovery of non-magnetic concentrate decreases.

3. Effect of Opening Feed on Tin Grade and Recovery

The opening feed variations used are 0.4 and 0.8 cm. The results of this process are changes in tin grade and recovery at different variations. Based on the experimental data, a graph is obtained showing changes in tin grade in the concentrate (non-magnetic) of the magnetic separation process at opening feeds of 0.4 and 0.8 cm which can be seen in Figure 6 as well as changes in recovery shown in Figure 8.

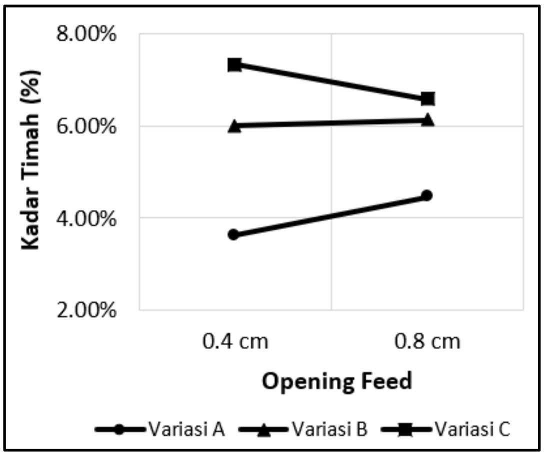

Figure 6 Effect of Opening Feed on Tin Grade

Based on Figure 6, at fixed intensity variations A of 1.1 T, 1.3 T, and 1.5 T with different opening feed variations, an increase in tin grade is obtained. Then at fixed intensity variation B, the same thing happened with variation A where at 0.8 cm opening feed, the tin grade increased. However, the opposite occurs in the fixed intensity variation C, where when the opening feed is used the larger the grade obtained decreases.

According to research (Fadhil, Yusuf, & Ningsih, 2021), the larger the feed opening used, the less grade will be obtained. In this case, it can be seen that only in variation C there is a decrease in tin grade. Meanwhile, in intensity variations A and B, there is an increase in tin grade when the opening feed used gets bigger. This can occur because the opening feed used is too large causing the feed rate to accelerate and the layer formed on the conveyor belt is also thicker, as written in the study (Zong et al., 2018).

The thicker the layer formed, the more likely it is for the feed to be swept away by the magnet regardless of the separation of magnetic and non-magnetic minerals. This is due to the small distance between the magnet and the conveyor belt, which is only about 0.5 cm. The thick layer on the conveyor belt also causes the magnetic field formed to not reach the bottom of the layer. An illustration of this can be seen in Figure 7.

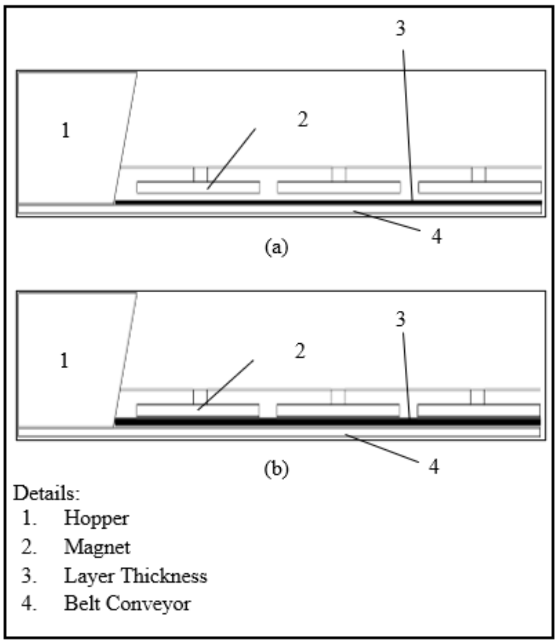

Figure 7 Layer Thickness of Feed on Belt Conveyor at
opening feed: (a) 0.4 cm, (b) 0.8 cm

In addition, the initial feed grade in the variation C experiment with an opening feed of 0.4 cm is quite high when compared to the feed grades of the other experiments. This may also affect the concentration grade obtained. Then, Figure 6. also shows that at a large opening feed, a large magnetic intensity is also needed to perform optimal concentration results. Therefore, it is only in the variation of magnetic intensity C that there is a decrease in grade along with the magnitude of the opening feed used by the theory that has been mentioned.

Based on Figure 8, in the fixed intensity variation A of 1.1 T, 1.3 T, and 1.5 T with different opening feed variations, there is a decrease in tin recovery. Then at fixed intensity variation B of 1.3 T, 1.5 T, and 1.7 T, the same thing happens with variation A where there is a decrease in recovery when the opening feed gets bigger. However, the opposite occurs in the fixed intensity variation C of 1.5 T, 1.7 T, and 1.9 T where when the opening feed gets bigger, the recovery obtained increases.

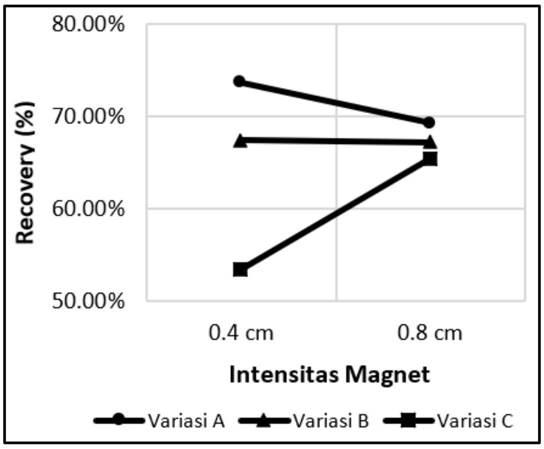

Figure 8 Effect of Opening Feed on Recovery

In the previous study (Fadhil et al., 2021; Pratama, Pitulima, & Taman Tono, 2021) it was found that the larger the feed opening used, the higher the recovery obtained. Based on the results obtained in this study, only in the variation of fixed intensity C, there is an increase in recovery when the opening feed used is getting bigger. However, the opposite occurs in the fixed intensity variations A and B where there is a decrease in recovery when the opening feed used is getting bigger.

Then it is noticed, that the recovery obtained at the opening feed of 0.8 cm does not experience a significant increase as in the opening feed of 0.4 cm. Similar to the increase in grade, the decrease in recovery in variation C occurs due to the opening feed being too large, resulting in the formation of a thick layer on the conveyor belt even though the gap between the magnet and the belt used in this study is quite small, namely 0.5 cm. The feed can be swept away by the magnet regardless of the separation of magnetic and non-magnetic minerals. As seen in Figure 7, if at the first magnet, many layers are swept away by the magnet, then at the second magnet the same thing happens, and only at the third magnet the separation process takes place, there is no doubt that the change in recovery is only due to the separation performed by the third magnet. In addition, the thick layer on the conveyor belt also causes the magnetic field formed to not reach the bottom of the layer.

Therefore, based on the results obtained in this study, the opening feed of 0.8 cm is considered too wide to perform separation using a three-disc magnetic separator. However, if it is still desired to use a wide opening feed, a high magnetic intensity is also required so that the separation process can run optimally.

Conclusion

Based on the research that has been done, it can be concluded that the presence of tin is most dominant in small particle sizes. In the magnetic separation process, the greater the magnetic intensity, the higher the grade obtained, while the recovery will decrease. Then the greater the opening feed used, the content will decrease, while the recovery obtained will increase. However, it should be noted that the opening feed used must not exceed 0.8 cm. If the opening feed used is equal to or wider than 0.8 cm, it requires a strong magnetic intensity. Thus, the size of the opening feed used must be balanced with a large magnetic intensity as well so that the separation process can run optimally. It is recommended to analyse the concentrate to know the amount of monazite that can be recovered.

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