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IMPROVEMENT OF CASSITERITE LEVELS WITH VARIATION OF FEED ROLL AND SEPARATION ROLL SPEED IN HIGH TENSION ROLL SEPARATOR (HTRS)

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Abstract

The separation of cassiterite mineral as a concentrate from tin ore was carried out by various gravity separation methods, one of which is using an electrostatic separator with the type of High-Tension Roll Separator (HTRS). This separation is often an obstacle because the level of cassiterite (SnO2), which is a HTRS product, does not meet the requirements for smelting tin ore. The purpose of this study was to obtain cassiterite levels that meet the requirements of the melting unit, namely Sn ≥ 70%. The method used in this research is research and development, where the research variable was carried out from the current condition and developing the research results obtained by optimization experiments. In addition, this study contributes to the process parameters of the HTRS separation. Feed was obtained from the jig with the cassiterite (SnO2) level of 56.97%. Furthermore, the HTRS experimental variable was the feed roll speed varied from 20, 25 and 30 Hz, while the separation roll speed varied from 10, 15, 20, 25 and 30 Hz. As for the results of the research at the initial stage, the cassiterite (SnO2) concentrate product ≥ 70% was produce at a variation of the feed roll speed of 20 Hz and 15 Hz separation roll speed. The results of this study are expected to be use in the processing unit to obtain cassiterite (SnO2) level that meets the requirements of the smelting unit.

Keywords: Cassiterite, Feed roll speed, High tension roll separator, Optimization, Separation roll speed.

1. Introduction

An electrostatic separator is a high voltage actuation device for sorting two or more substances with different electrical conductivity. Typically, the roll type separator consists of a rotating roller, a feeder, a corona and electrostatic electrodes and a DC high-voltage power supply. The separation of cassiterite mineral as a concentrate from tin ore is carried out by various gravity separation methods, one of which is using an electrostatic separator with the type of High-Tension Roll Separator (HTRS). This separation is often an obstacle because the levels of cassiterite which is a HTRS product do not meet the requirements for tin smelting. Several ways have been done to obtain the variable of the tool that produces the desired product [1, 2]. Based on field data, the need for cassiterite products has not met the requirements for smelting, so it is necessary to conduct research on the HTRS variable current conditions.

In some cases, a mathematical model of a multifactor electrostatic separation process can be used to estimate the value of input variable which tends to optimize the response [3, 4]. The optimal process is usually obtained only after a number of tests have been performed to produce the desired recovery (up to several hundred, in the case of electrostatic separation of complex minerals [5, 6]. Recovery assessment is also carried out with a Box-Behnken factorial design and the results are analysed using the response surface methodology (RSM) [7, 8] A new term has been obtained called the Operational Quality Index (OQI) [9]. Recovery assessment uses the Grade Recovery curve with the Tromp Curva Method, and the Gravity Separation Index has the advantage that it is a fast and simple method for evaluating separation performance [10, 11]. A numerical approach was also used to look for variables that resulted in high cassiterite level [4, 12, 13].

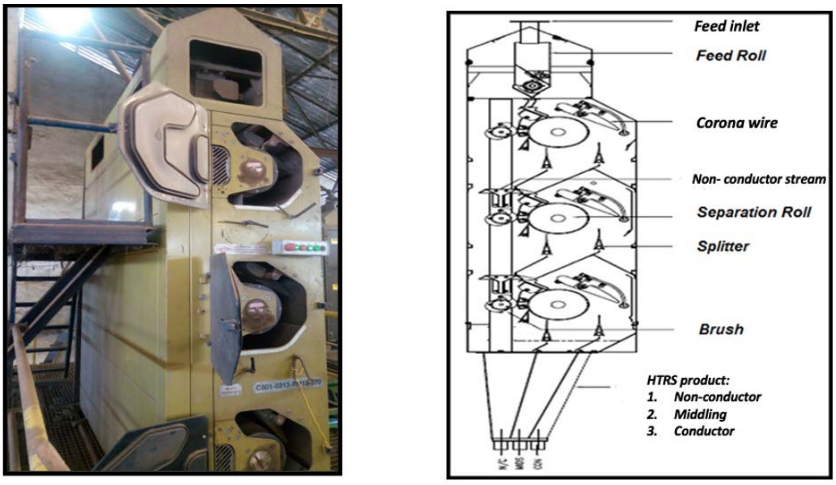
Many other methods are presented to increase cassiterite level. Basically, various ways to increase cassiterite level still have to pay attention to feed conditions. Previous studies have concluded that the results of the study (modelling or other methods) were the optimization values generated from several variables [14, 15]. The results of the optimization of these variables have not been tested in the field to test the modelling result variables. This research was also conducted based on the need that the products from HTRS had not reached the level of cassiterite desired by the smelter and tried to validate the selected variables with optimization experiments. Thus, final results can be considered for the method used to perform the optimization stage. In addition, there is still a need for a practical approach in the field to describe the interactions between process parameters that affect the output variables. These two facts motivated this study, so that experimental data were not only reported, but contributed to a better understanding of the effect of process parameters on HTRS separation.

2. Material and Methods

The mined tin ore generally comes from a type of alluvial tin sediment and is often referred to as secondary tin sediment or called placer tin. Tin ore mining is carried out in Bangka Regency, Bangka Belitung Province, Indonesia. The mining method applied by PT Timah at the mining site is a dry system, where soil containing tin (kaksa) is excavated using excavator (backhoe) and transported to the stockpile using an articulate dump truck (ADT), then sprayed using high pressure water to flow to the washing facility. By doing total mining, the perfection of washing activities is absolutely necessary.

In the processing of tin ore, there are wet and dry processes. The dry process of tin ore is usually obtained from onshore mining, and the wet process is usually obtained from marine mining. The tin ore to be separated will come from onshore mining. At the time of receipt of tin ore from mining results, sampling is carried out to determine the level of Sn and the content of associated minerals, this activity is carried out with the aim of knowing the tin processing process using tools that are in accordance with the Sn content and associated mineral content.

Currently, the tin ore washing system uses a multilevel jig operation structure with a closed circulation system. Ore Bin as a place for washing tin from mining products is carried out by inserting tin ore into an Ore Bin with a capacity of 25 drums/unit and capable of washing 15 tons/hour. In the Ore Bin, the ore is washed with pressure and water discharge according to the feed, the washed feed is then streamed to the Jig tool. The applied jig consists of two, namely the harz jig and the yuba jig. This tin ore processing produces a dry final product. Drying using a Rotary Dryer with a temperature of 400-900^{o}F, this drying aims to facilitate processing to separate the concentrate from its associated minerals. Then the feed will be streamed to a round screen which functions as a filter. The lead ore feed will then carry out a further separation/classification process, namely: classification based on grain size with screening, classification based on its conductivity properties with High Tension Roll Separator (HTRS) (see Fig. 1), classification based on magnetic properties with magnetic separator, classification based on specific gravity by using tools such as a shaking table, air table and multi gravity separator.



(a) (b)

Fig. 1. (a) HTRS tool and (b) HTRS tool components diagram.

Sampling was done after exiting the round screen, with size fraction +20#, size fraction -20#+50#, and size fraction -50#. Before the sample is inserted into the HTRS, the sample is first put into a splitter to divide 2. One part is taken for laboratory analysis and the other part is used as HTRS feed. The sample size to be used is a maximum

HTRS of 20#. Sampling of the HTRS concentrate was carried out using a plastic bag, namely by accommodating the concentrate that came out of each hole (compartment) for 7 seconds. Sample of the splitter hole is made in 1 sample, then the total is 15 samples for primary concentrate, 15 samples for middling and 15 samples for tailings. After the sample is obtained, then weighing is done.

High Tension Roll Separator (HTRS) is a type of device that is widely used to separate conductor and non-conducting minerals. In this separation, the cassiterite mineral to be separated from the impurity minerals is 20 mesh in size. The mineral content of cassiterite contained in tin ore has not met the requirements as a raw material for smelting tin ore. Therefore, it is necessary to increase the cassiterite mineral content with the HTRS tool. The products of separation with HTRS are cassiterite minerals (conductor minerals), middling and tailings (non-conductor minerals).

This tin ore deposit in the form of mud will be processed immediately. The results of the chemical analysis of tin ore describe the minerals in tin ore, consisting of 56.97% cassiterite content, 1.22% ilmenite content, 3.92% monazite, 16.86% pyrite, 8.76% zircon, and 12.27% quartz. Cassiterite mineral in tin ore as the main mineral has magnetic and conducting properties. The experimental design was carried out in 2 stages. The first stage was testing several values of the variable feed roll speed and separation roll speed. The second stage of the design is an optimization experiment.

HTRS typically operates with a feed roll speed of 30 Hz and a separation roll speed of 20 Hz, the electrode voltage is 26 kV, the splitter positions are 29.2 cm (upper separation roll), 28.9 cm (middle separation roll), 26 cm (bottom separation roll), the distance between the electrode and the roll is 5 cm, the temperature on the feed roll is 100ºC, and the temperature at heater 350 ºC. With this condition, it turns out that the resulting Sn concentrate is ≤ 70%. Furthermore, the experiment was carried out by testing at three speed variations on the feed roll (20 Hz, 25 Hz and 30 Hz) and five speed variations on the separation roll (10 Hz, 15 Hz, 20 Hz, 25 Hz, and 30 Hz), while the variable others were not tested. From the results of each experiment in the initial stage, obtained the data on the concentrate (mineral conductor), middling (conductor + non-conductor), and tailing (non-conductor). Furthermore, in the second stage, an optimization experiment was carried out from the initial variables which resulted in Sn levels ≥ 70%. Optimization experiments were carried out 5 times to get the best results from levels of Sn ≥ 70%.

3. Results and Discussion

The results of laboratory analysis showed that the cassiterite level did not meet the requirements to enter the smelting unit, so it was necessary to carry out further processing stages to reach a level of Sn ≥ 70%. The mineral composition in tin ore was show in detail in Fig. 2. Based on the need for cassiterite minerals as a smelting material that produces crude tin, the cassiterite content must meet the requirements for smelting. Given the physical properties of the mineral cassiterite as a conducting mineral, the next step is to increase the content by utilizing the physical properties of the mineral. The selected tool is High Tension Roll Separator (HTRS).

This research was conducted to determine the relationship between variables that affect HTRS, namely the feed roll speed and the separation roll speed. Previous research was also carried out to observe the relationship between feed rate, roll speed and feed temperature [16, 17]. The varied parameters were the feed roll speed of 20 Hz, 25Hz, and 30 Hz and the separation roll speed of 10, 15, 20, 25 and 30 Hz. All other parameters were kept constant during the experiment, set as follows: splitter position 29.2 cm (upper separation roll), 28.9 cm (middle separation roll), 26 cm (bottom separation roll), electrode voltage 26 kV, distance between electrodes and roll 5cm, feed roll temperature 100ºC. This initial experimental design by making several variations of the experiment is displayed and the experimental results are shown in Table 1.

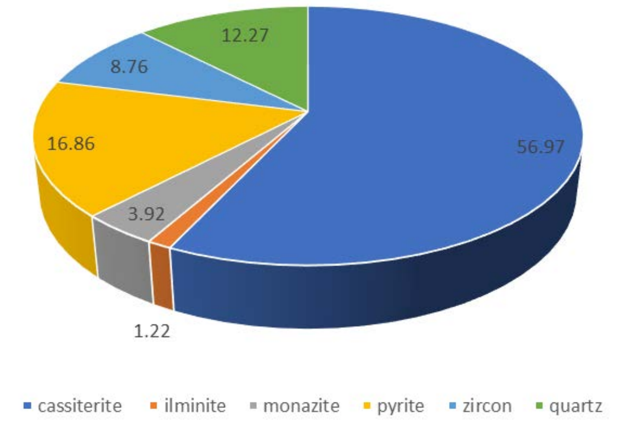


Fig. 2. Result of chemical analysis in tin ore.

Table 1. Initial test results of feed roll speed (20 Hz, 25 Hz, and 30 Hz) and separation roll speed (10 Hz, 15 Hz, 20 Hz, 25 Hz and 30 Hz).

Test no.	Variable		Product (%)		
	Feed roll speed (Hz)	Separation roll speed (Hz)	Concentrate	Middling	Tailing
1A	30	10	66,97750	52,61188	50,32764
1B		15	68,03288	51,06798	41,67192
1C		20	67,70290	36,89906	38,72629
1D		25	69,80498	42,12872	22,97429
1E		30	64,20515	38,40337	27,71564
2A	25	10	54,28926	30,70852	20,94228
2B		15	74,02652	46,75193	2,843230
2C		20	68,79686	56,10862	30,59826
2D		25	62,26765	51,71381	26,84140
2E		30	58,98460	38,44037	24,56161
3A	20	10	64,97362	33,55963	16,13972
3B		15	64,08701	42,56190	9,46659
3C		20	71,54558	37,10383	4,37118
3D		25	51,68231	59,69220	16,66516
3E		30	57,84922	35,21359	8,68723

During the experiment, two process variables namely feed roll speed and separation roll were controlled to obtain the desired results. After separation, the fraction of the concentrate (conductor), middling and accumulated non-conductor is weighed to determine the composition. The response to the separation results is the product content (concentrate, middling and tailings). Concentrate level refers to the content of cassiterite (SnO2) in % by weight in the ore. From the results of 15 times the first stage of testing, which is presented in Table 1., with the separation roll speed varying while the feed roll speed is kept 30 Hz, the concentrate product obtained has not reached the required standard for melting. Furthermore, the feed roll speed is reduced to 25 Hz, with a variable separation roll speed of concentrate product which is expected to be ≥70% seen at a separation roll speed of 15 Hz. Furthermore, to obtain the desired experimental results, the feed roll speed is lowered to 20Hz and the separation roll speed remains varied. The product is expected to be produced at a separation roll speed of 20 Hz, although the resulting product is still lower than that of the 20 Hz feed roll and the 15 Hz separation roll.

3.1. The effect of feed roll on conductor mineral recovery

Previous studies have explained the effect of feed roll speed on HTRS recovery. This effect can be explained that the feed moves through the feed roll towards separation roll. When the feed moves through the separation roll, the feed is fired with a charge coming from the electrode plate so that the lifting force caused by the feed with the conductor loses its charge, the possibility of sticking to the separator surface is smaller or not at all [18].

In electrostatic separator, the granules mixture to be separated is fed at a certain speed to the surface of the rotating ground winding electrode [19, 20]. A high intensity electric field is generated between these windings and one or more electrodes connected to a high-voltage DC supply. The insulating particles are charged in the high-voltage field zone and 'pinned' to the surface of the rotating winding electrode. The conductor particles are attracted by the high voltage electrode. Consequently, the factors affecting the electrostatic separation process must include high voltage level, electrode configuration, feed rate, grain size, and winding speed [4, 7]. Effect of temperature and feed roll speed on conductor fraction on feed rate. The grade of the conductor fraction increases as the roll speed decreases. As the roll speed increases, centrifugal force dominates the pinning force of the non-conducting particles, thereby reducing the quality of the conductor fraction. It can be further explained that the winding speed controls selective filling in the ionizing zone and discharging to the rotor.

3.2. The effect of separation roll on conductor mineral recovery

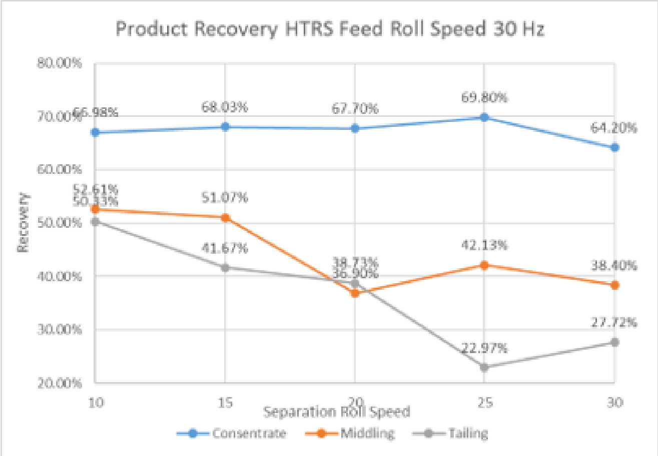
The factors caused by the feed condition itself affect the success rate of the HTRS tool. The first thing that affects the success of the HTRS tool is that the feed condition must have conductivity properties so that it can be separated using the HTRS tool. Then, the maximum size of the feed particles on the HTRS separator is 20 mesh. Furthermore, the feed flow characteristics on the roll must be good because this can increase the yield from the HTRS tool. Several things that affect the feed flow on the roll are the shape of the particles, the surface conditions, and the roll speed [21]. The speed of separation roll also has an impact on the feed flow characteristics so that if the speed of separation roll is too high, the conductor product may contain a lot of non-conducting minerals [20, 21]. The last factor is the temperature in the feed, where before the feed is put into the HTRS, it should be dried first. The supporting tool used is the Rotary Dryer which functions to dry the feed so that the temperature conditions are 80ºC-115ºC [22].

Figure 3(a) explains that the greater the separation roll speed, the higher the increase of the conductor mineral recovery tends to be. At the separation roll speed of 15 Hz, the conductor mineral recovery tends to increase to 68.03288%. The same tendency also occurs at the 20 Hz separation roll speed. At the separation roll speed of 20 Hz, there was a decrease in the recovery of conductor minerals from 68.03288% to 67.70290%, while for the 30 Hz separation roll speed there was a decrease in the recovery of conductor minerals from 69.80498% to 64.20515%. Therefore, a decrease in the recovery of conductor minerals can caused by the position of the splitter being too far from the roll, causing the non-conducting minerals to be thrown and incorporated in the conductor product. However, different conditions occurred at the separation roll speed of 25 Hz and 30 Hz where there was an increase in recovery then a decrease in recovery. This caused by an unstable feed temperature condition due to the speed of separation roll itself.

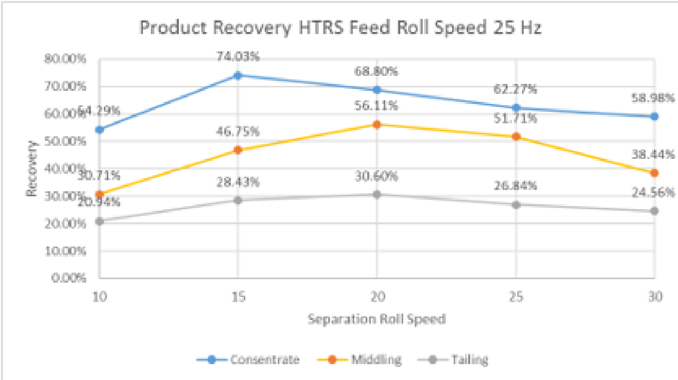
It also explained that the feed temperature is a condition where the feed is dry and feasible to separate using an HTRS tool. The feed temperature that is suitable for separation using HTRS is 80ºC -115ºC [23]. If the feed temperature exceeds the set value due to the increasing speed of separation roll, the temperature of the feed will increase, so that the conductor mineral recovery decreases. At stable feed temperature conditions, the higher the separation roll speed, the greater the recovery of conductor minerals [9]. Feed roll speed and separation roll are variables that affect cassiterite recovery [16].

Figure 3(b) shows a decrease in the feed roll speed to 25 Hz and an increase in the separation roll speed at 15 Hz, an increase in recovery occurs and exceeds the limit for Sn content which is determined as a requirement for smelting. The decrease in separation roll speed causes a change in the incoming feed flow. The occurrence of different behavior with greater or lesser separation roll speed is caused by poor feed flow characteristics due to changes in separation roll velocity [23]. As a result of the splitter distance that is too close to the roll, the conductor product does not enter the hold tank [24]. As a result, the distance between the splitter and the roll is greater, allowing the conductor and non-conductor products to enter the out of place storage due to the feed flow characteristic conditions, the distance between the splitter and the roll is too far so that the possibility of non-conducting minerals entering the conducting minerals is greater [16].

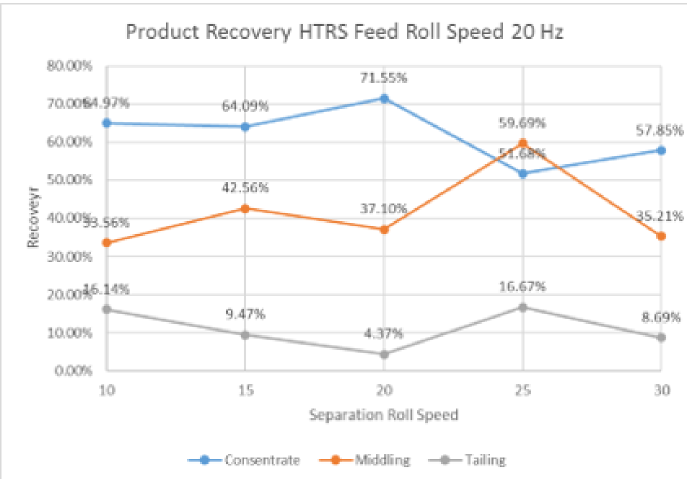
Lastly, Fig. 3(c) indicates by decreasing the feed roll speed by 20 Hz and varying the separation roll speed, the recovery value exceeds 70% at the separation roll speed of 20 Hz. It explained that in the arrangement of a large number of non-conductor particles ending up in the conductor channel, thereby overwhelming the mass flow scale, again making the calculation of the results less accurate. Conversely, there is a decrease in the recovery of the conductor minerals. At a low feed roll speed setting, insufficient centrifugal force, as a result the conductor particles cannot overcome the pinning force triggered by the corona wire. These conducting particles end up in the non-conducting conduit, causing poor separation.



(a) Graph of the effect of separation roll speed on velocity (30 Hz feed roll)



(b) Graph of the effect of separation roll speed on velocity (25 Hz feed roll)



(c) Graph of the effect of separation roll speed on velocity (20 Hz feed roll)

Fig. 3. Graph of the effect of separation roll speed on (a) Velocity 30 Hz feed roll, (b) Velocity 25 Hz feed roll and (c) Velocity 20 Hz feed roll.

3.3. Optimization design

The results of the optimization design of the effect of feed roll speed and separation roll on cassiterite recovery are shown in Table 2. The variable feed roll speed of 25 Hz and separation roll speed of 15 Hz, which produced the highest cassiterite recovery, namely 74.02652%, were retried with 5 trials. The results obtained by recovery values are varied but the recovery value > 70%. From 5 experiments, 2 times resulted in the highest recovery value from the results of the first stage experiment. The feed rolls speed and the separation roll speed at the intermediate stage turned out to make the feed flow loaded with ions from the electrodes able to jump over the farthest splitter so that it enters the conductor.

Table 2. Test results of feed roll speed optimization of 25 Hz and separation roll speed 15 Hz.

Test No.	Product (%)		
	Concentrate	**Middling**	**Tailing**
01	72,75061	35,32386	8,07290
02	75,75136	13,38132	8,07290
03	74,72749	6,03302	8,07290
04	77,42896	2,71722	8,07290
05	74,65660	15,60236	8,07290
Average	75,06300	14,61156	8,0729

4. Conclusions

From the early stage of experiment done to see the effect of feed roll speed and separation roll speed on concentrate product obtained by High Tension Roll Separator (HTRS), continued by the optimization experiment, there are several points to be concluded. Firstly, the feed roll speed that was varied with the separation roll speed resulted in a concentrate level of ≥ 70% at a feed roll speed of 20 Hz and a separation roll of 15 Hz. Then, on the separation roll speed increased at 20 Hz, the resulting concentrate decreased. The optimal value of the combination at a feed roll speed of 20 Hz and separation roll of 15 Hz which is retested to produce concentrate levels according to the requirements concentrate levels of smelting.

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