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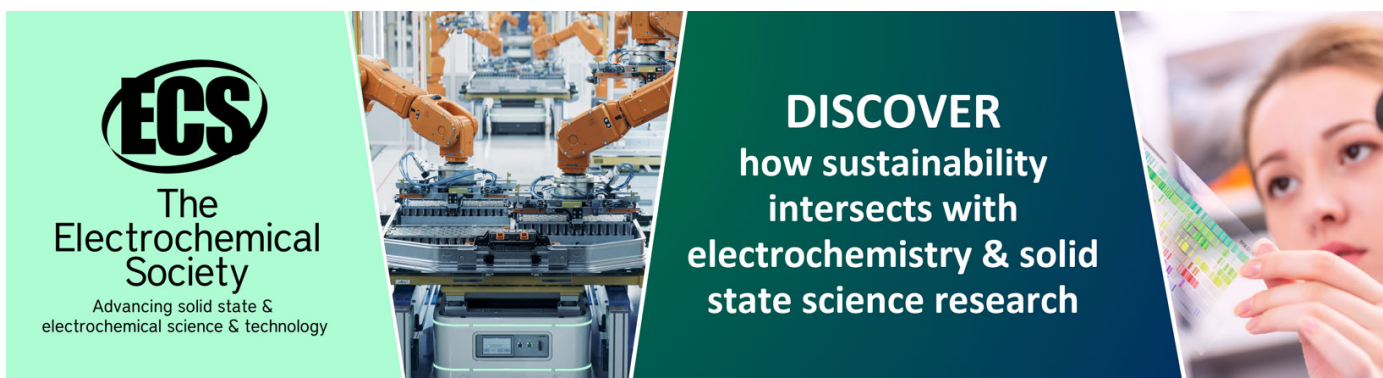
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Technical Evaluation of Associated Tin Minerals Processing at Bidang Pengolahan Mineral (BPM) Unit Metalurgi Muntok, PT Timah Tbk

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Abstract. Since 2017 PT Timah Tbk has been processing residual ore (SHP) with low tin content of $\pm 10\text{-}30\%$ wt. In order to increase tin grade and associated mineral products to be high grade ($> 70\%$ wt), an evaluation and optimization process is needed on High Tension Roll Separator processing equipment. The evaluation and optimization process was carried out on conductor products, especially index of separation efficiency of cassiterite. Sampling of the feed and the product based on the parameter settings. The feed rate is set at 250, 630 and 2100 gr/10s. The splitter opening is set at 13, 16, 20 cm of magnetic rollers. While the electric current is set at 1, 2 and 3 miliampere. Mass and grade data are then analyzed by regression and variance statistical methods and optimized by the response surface method. The evaluation results show that only the splitter opening parameters and electric current strength are significant in explaining the product results obtained with a level of hypothesis error of 5%. The results of HTRS optimization show that the best parameter conditions are in the <1.5 ampere of electric current and <14 cm of splitter openings with schulz's efficiency capable of $>90\%$ in second order of central composite design.

1. Introduction

As a company engaged in the tin mining sector, PT Timah Tbk has carried out the processing of associated minerals in tin ore. However, the production of tin concentrate and associated minerals is still below the company's production target, which is at 70% (high grade) and recovery $> 90\%$. This is aggravated along with the total mining program launched by PT Timah Tbk in 2018 to improve recovery of the ore from the remaining processing products [1]. The remaining ore produced by processing (abbreviated as SHP/Sisa Hasil Pengolahan) is the tailing resulting from washing tin ore which has been increased to $\pm 10\text{-}30\%$ Sn. However, the low level of Sn in SHP ore causes difficulty in processing to increase the level at high grade levels (70% Sn). From the conditions of production capacity problems and product quality, it is necessary to have a technical evaluation on the tin ore processing system itself. Therefore, researchers tried to optimize the processing of electrical separator with the statistical analysis. Based on the background, there were 3 formulations of the problem, how the results of the evaluation parameters of the High Tension Roll Separator (HTRS) used in the Bidang Pengolahan Mineral (BPM) PT Timah Tbk, how much influence the tool parameters had on the results obtained and the shape of the second relationship, then what was the optimization of tin ore processing with processing equipment. The purpose of this study is to understand what parameters significantly influence the dry processing of tin ore with a HTRS.



2. Literature Review

According to Wills [2], mineral processing is an activity that aims to separate valuable minerals economically based on existing technology for the needs of an industry in its utilization. Processing of minerals is a process of separating valuable minerals from valuable minerals that are carried out mechanically to produce concentrates and tailings. The separation process is very dependent on the physical and chemical properties of the minerals contained in the ore. Therefore, to separate the ore from the minerals of the followers, knowledge of the characteristics of each mineral is needed [3], [4]. Mineral information or data needed in the processing process include the type and composition of minerals in ore, the content of each mineral in the excavated material, grain size and distribution, the degree of liberation of minerals and their physical properties such as specific gravity, electrical magnetism and conductivity, adsorption and adsorption power and chemical properties of mineral [5], [6].

2.1. High Tension Roll Separator

High Tension Separator in a sense is a separation mechanism based on the nature of electrical conductivity possessed by various types of minerals [4] or a mechanism that utilizes electric field forces along with other forces to create differences in movement from mineral grains [2]. High Tension Separator itself is a manifestation of a series of tool parts that work based on certain parameters such as rotating rotors, electrodes that provide electric charges and splitters which function as separators of products that are produced both conductor, midling and non-conductor products [7].

2.2. Statistical Regression and Response Surface Methodology

According to Montgomery and Sugiyono [8],[9], regression analysis is a method or technique used to see how far the change in the value of the dependent variable, if the value of the independent variable is changed or increased lower. The resulting regression equation is then used to predict the pattern of a dependent variable. Response surface methodology is a method that combines mathematical techniques with statistical techniques used to model and analyze a response that is influenced by several variables in order to optimize the response [8],[10]. The basic idea of this method is to use experimental design with the help of statistics to find the optimal value of a process response. In the surface response method it is necessary to determine the optimum point for first-order second-order experimental changes. 2k factorial design (Two Level factorial Design) is a design that is suitable for estimating the first order model, meaning that each variable has two levels

3. Methodology

The research method is to adjust the variation of the HTRS parameters. The parameters for feed rates are 250, 630 and 2100 gr / 10s. For parameters the conductor splitter openings are set at 13, 16 and 19 cm from the rollers. Whereas for strong electric current it is set at 1, 2 and 3 milliamperes. Then the product sampling represents the tool parameter settings. Next is the calculation of the levels with the grain counting analysis method and recovery value and processing efficiency. The results of these calculations are then analyzed using statistical techniques. The significant tool parameters are then used to optimize the processing using the surface response method.

4. Result

4.1. Feed Grade

More than half of the composition of the feed is dominated by cassiterite minerals, which is 62.9% wt. While the composition of other conductor minerals such as monazite is only 1.31% wt. The total ratio of conductor minerals (cassiterite & monazite) to non-conductor minerals (ilmenite, pyrit, zircon, tourmaline and quartz) in feeds is 64.31%. The possibility of mineral separation based on electrical properties is quite large. The composition and weight grade of the feed is given in the table:

Table 1. Mineral composition in the feed

Mineral	Cst ^a	Ilm ^b	Mnz ^c	Py ^d	Zrn ^e	Tur ^f	Qtz ^g
%wt	62.90	3.32	1.31	5.10	24.70	0.0055	2.63

^a cassiterite, ^b Ilmenite, ^c Monazite, ^d Pyrite, ^e Zircon, ^f Tourmaline, ^g Quartz

4.2. Composition of Conductor Products

The graphical results of cassiterite mineral products showed no significant increase or decrease in mineral response. The response of cassiterite minerals is only in a fairly narrow range of 71 - 85% wt. This can occur if all parameters tested only have a small effect on the response. The processing efficiency used is Schulz Efficiency.

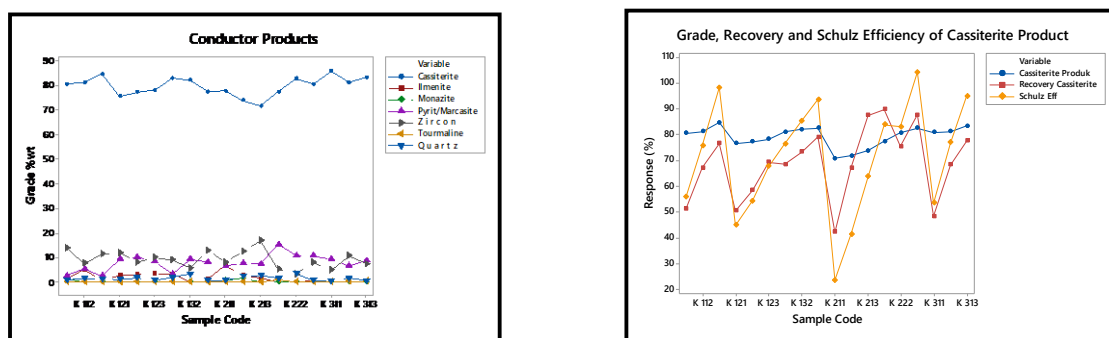


Figure 1 (a) Mineral content in HTRS conductor products; (b) Grade, recovery and processing efficiency of cassiterite minerals in conductor products

The graph shows the value of separation efficiency with a fairly large range of 40%. The lowest limit of efficiency that can be achieved is $\pm 40\%$. While the highest limit of efficiency that can be achieved is $\pm 90\%$. The tendency of the efficiency value to increase along with the increase in the value of the strong electric current given. Need analysis of variance and regression to prove the influence of tool parameters in explaining the processing efficiency obtained.

4.3. Regression Analysis of Conductor Products

Multivariable regression analysis aims to determine whether all parameters tested have a significant influence in understanding the processing efficiency response. The parameters of the HTRS are tested: feed rate, splitter openings and electric current. All parameters were tested using analysis of variance with a significance of 95%, which means that the tolerance level of error in rejecting the null hypothesis is 5%. Independent parameters variance analysis results from all three parameters, only splitter openings and electric current strength are significant.

Table 2. Analysis of variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	4239,9	1413,3	4,96	0,015
Feed Rate	1	456,7	456,7	1,6	0,226
Splitter Opening	1	1380,2	1380,2	4,84	0,045
Electrical Current	1	2837,9	2837,9	9,96	0,007
Error	14	3989,3	285		
Total	17	8229,2			

The probability value of the feed rate is greater than the error tolerance of 5% (0.05) which is equal to 0.226 so that this parameter is not significant. The splitter openings and electric current strength is 0.045 and 0.007. The regression model formed also does not meet the assumptions of model incompatibility. This is most likely because there are still feed rate parameters that have little influence on the model. So that the feed rate must be eliminated from the regression equation and optimization processes.

4.4. Parameters Correlation

The results of the correlation analysis showed that the three HTRS parameters simultaneously were able to explain the response of processing efficiency by 51.52%. This number is quite low because there are still 49% of the influence outside the control. Feeding rate has the lowest influence that is equal to 5.5%. Splitter openings have a large influence of 11.5%, while the greatest influence is the electric current strength parameter that is equal to 34.5%.

4.5. Optimization of Mineral Processing

Determination of the optimum conditions of the parameters so that the best processing results can be obtained both in terms of quality and quantity. The first optimization process is used Full Factorial Design. Full factorial design includes two parameters that have a considerable influence based on correlation analysis, the splitter openings and electric current. The lower limit of the splitter opening is 13 cm while the upper limit is 19 cm. For the electric current which is 1 miliamper of the lower limit and 3 miliampere of the upper limit. The design also contains a replicated center point 4 times, 16 cm of splitter openings and 2 miliampere of electric current. For the Central Composite Design added 4 axial runs.

Table 3. Full Factorial and Central Composite Design of HTRS

Run	A	B	Factorial Design		Central Composite Design	
			Splitter Opening	Electrical Current	Splitter Opening	Electrical Current
1	-	-	13	1	13	1
2	+	-	19	1	19	1
3	-	+	13	3	13	3
4	+	+	19	3	19	3
5	-1	1	-	-	11.7573	2
6	-1	1	-	-	20.2424	2
7	1	-1	-	-	16	0.585786
8	1	-1	-	-	16	3.414214
9	0	0	16	2	16	2
10	0	0	16	2	16	2
11	0	0	16	2	16	2
12	0	0	16	2	16	2

4.6. Analysis of Variance

Based on the results of analysis of variance of Full Factorial Design, all the main effects on the HTRS are significantly below 5%. Both parameters give a probability of errors under 5% (0.05) of both splitter openings with a P value of 0.017 and a strong electric current with a P value of 0.042. However, the interaction effect does not provide significant results where the P value is 0.737 or greater than the 5% significance. This is also followed by the regression model not fulfilling the assumptions of model

incompatibility. Therefore the optimization experiment requires that it be carried out in a higher order or the Central Composite Design (CCD).

The results of the variance analysis of CCD show that the model has met the assumptions of linearity. The main effect is significant in the interval of 5% confidence in both splitter openings with P values of 0.013 and electric current strength with a P value of 0.017 so that the probability leads to the rejection of the null hypothesis. The quadratic effect is only significant in the splitter openings with a P value of 0.026 or less than the 5% significance level. While the electric current strength with a P value of 0.143 or greater than 5% significance level. The interaction effect of splitter openings and electric current is not significant at all with a P value of 0.779.

Table 4. Analysis of variance of Full Factorial and Central Composite Design

Source	Full Factorial		Central Composite	
	F-Value	P-Value	F-Value	P-Value
Model	11.57	0.036	6.61	0.02
Linear	17.46	0.022	11.51	0.009
Splitter Opening	23.35	0.017	12.3	0.013
Electrical Current	11.57	0.042	10.73	0.017
Square	-		4.97	0.053
Splitter Opening * Splitter Opening	-		8.68	0.026
Electrical Current * Electrical Current	-		2.83	0.143
2-Way Interaction	0.14	0.737	0.09	0.779
Splitter Opening * Electrical Current	0.14	0.737	0.09	0.779
Lack-of-Fit	-	-	2.15	0.273

The regression model formed tends to accept null hypothesis on the assumption of model incompatibility with a P value of 0.273. Correlation analysis showed a strong relationship of all effects to the response by 84.6%. This proves that all parameters have a strong influence on the results of cassiterite minerals. As for less than 20% which is influenced by other factors beyond control. The following is the second order regression equation that was formed:

$$y = 290.9 - 23.41X_1 - 23.2X_2 + 0.651(X_1)^2 + 3.35(X_2)^2 + 0.246(X_1X_2) \quad (1)$$

y = Schulz Efficiency (%)

X₁ = Splitter Opening (cm)

X₂ = Electrical current (miliampere)

4.5.2 Response Surface Characteristic. The second-order optimization model obtained was able to predict the response of processing efficiency statistically to 90%. The response area was obtained at the splitter openings of less than 14 cm and strong electric currents below 1.5 milliamperes. In this area optimization can achieve processing efficiency of 80% to more than 90%. The second-order regression model requires the values of the two parameters to be lower in order to achieve optimum levels. But of course this can affect recovery and separation efficiency. Following picture of the second order surface contour response:

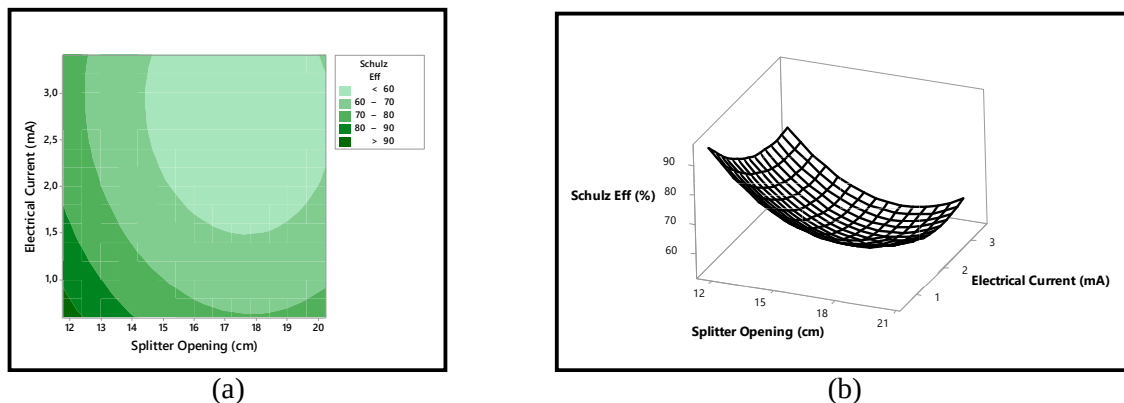


Figure 2. (a) Optimizing contour of processing; (b) 3D surface response of processing

5. Conclusion

For the HTRS parameters only the splitter openings and electrical currents are significant with a null hypothesis rejection rate of 5%. The parameter value of the splitter openings is inversely proportional to the response of the cassiterite processing efficiency produced. Whereas the parameter of electric current strength is directly proportional to the response of cassiterite processing efficiency. The three parameters tested were able to explain the response of the cassiterite processing efficiency obtained with a correlation of 51.5%. To optimize the surface response method, the best HTRS parameter conditions are found in areas less than 1.5 milliamperes for electric current strength and less than 14 cm for splitter openings. The results of the second order regression optimization formed can estimate processing efficiency up to > 90%.

References

- [1] Babel Pos 2018 *Aktivitas Total Mining PT Timah Libatkan Masyarakat*. Pangkalpinang. (<http://babelpos.co/aktivitas-total-mining-pt-timah-libatkan-masyarakat>)
- [2] Taggart A F 1954 *Handbook Of Mineral Dressing: Ores and Industrial Minerals* (USA: John Wiley & Sons, Inc)
- [3] Drzymala J 2007 *Mineral Processing: Foundations of theory and practice of mineralurgy* (Wroclaw University of Technology)
- [4] Wills B A and Tim N M 2006 *Mineral Processing Technology* (Australia: Elsevier Science & Technology Books)
- [5] Fuerstenau M C and Han K N 2003 *Principles of Mineral Processing* (Society for Mining, Metallurgy, and Exploration, Inc. USA)
- [6] Kelly E G and Spottiswood D J 1982 *Introduction to Mineral Processing* (Canada: John Wiley & Sons Inc)
- [7] Mineral Technologies 2013 *High Tension Roll Separator CHTR 1x3x1800x270 dia: Operation & Service Manual Operation & service Manual* (Indonesia: PT Spektrum Krisindo Elekrika)
- [8] Montgomery D C 2013 *Design and analysis of experiments* (USA: John Wiley & Sons, Inc)
- [9] Sugiyono 2014 *Statistik Untuk Penelitian* (Bandung: Alfabeta)
- [10] Myers R H et al 2009 *Response Surface Methodology Proses and Product Optimization Using Designed Experiments* (USA: John Wiley & Sons, Inc)

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