

GRANULOMETRIC STUDY IN COMMINUTION CIRCUITS OF SOSTENIBLE PROCESSING PLANTS, CASE STUDY TELMA MINE PORTOVELO – ECUADOR

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ABSTRACT

The purpose of this paper is to carry out a short analysis of the comminution circuit carried out in the beneficiation plant that processes the minerals from the Telma mine, exclusively with water without additional reagents. For this, an analysis of the current comminution process in the beneficiation plant is carried out, generating the FlowSheet of the system with the help of the illustration program called Adobe Illustrator CS6 in order to understand the process of the comminution circuit. Then, a review of the operational parameters of the crushers, vibrating sieves and mills, together with the evaluation of the distribution of their particles in the meshes, both in crushing and grinding, were carried out. The granulometric analyzes are carried out both in the beneficiation plant and in the Mining Laboratory of the 'Escuela Superior Politécnica del Chimborazo' ESPOCH, to superimpose data; in the first stage of mineral reduction, the reduction results were 90% of the ore; on the other hand, the analysis of granulometry distribution carried out in the discharge of the cyanidation tank, was executed in the ESPOCH mining laboratory showing that only 57.66% of the mineral has a 120 mesh particle size. Therefore, the mineral delivered by the size reduction circuit carried out in the beneficiation plant that processes the minerals from the shaft mine does not correspond to the ideal particle size, according to the required feed percentage F80 for the fines hopper. Finally, as the main recommendation, 120 mesh separators should be implemented to separate coarse particles.

Keywords: CONMINUTION, REDUCTION CIRCUIT, SIEVES, FLOWSHEET, PARTICLE SIZE.

1. INTRODUCTION

Parisaca et. Al (2015), mentions that the mining industry faces an urgent need to improve and increase the efficiency of its operations in various sectors, since the activity occupies a high place in energy costs, manufacturing costs and maintenance of its machinery. and the other activities it represents. In this context, the grinding process plays an important role, both in terms of total

operating costs and in the overall efficiency of the process, so a great effort has been made to try to optimize technically and economically this important unique operation, taking into account the general operation of industrial grinding equipment such as crushers and mills, and their respective classifiers or sievers (Magne & Titichoca, 2005).

In the different stages of grinding and concentration of the mineral, the size of the particles is one of the most relevant variables for the activity, since a greater or lesser release of mineral depends on it. The mineral activity along the crushing/sieving, grinding/sorting steps depends largely on the size of the particles to be treated at each of these process stages. Therefore, it is necessary to properly identify and quantify this variable (Casapalca, 2013).

The comminution process is where the operation's greatest energy consumption occurs and where most of the process costs are concentrated. The biggest factor that the company represents is in its comminution circuits (crushing, sieve and grinding). Therefore, its problems are analyzed in the comminution stage, specifically in the beneficiation plant that processes minerals from the Telma mine operated by the company "OROCONCENT S.A." , located in the Portovelo canton (Samaniego, 2022).

The first stage of crushing is undoubtedly the main one of the process and the most important, so sometimes the mineral arrives with the presence of moisture, which causes the material to generate sticks due to its clay agents and that causes the material to jam in its discharge from the hopper both fine and thick and when performing its meshing they cannot cross through the openings of these. Another of the problems presented by the company's profit plant presents energy fluctuations, where it causes its comminution circuits to stop and this creates problems both in losses of processed ore (processing time), as energy loss, since the start of industrial machinery creates excessive consumption in its energy (ARMAS & POMA, 2013).

In mining operations, the main technique used is the use of meshes or sieves. The distribution of the particle size in the different stages of the mineral grinding process, which tends to release valuable species of the extracted material, depends on the grain size obtained, in order to achieve a metallurgical characterization of the mineral in each individual operation, so the collection of data at each sampling point is essential to achieve an interpretation of the particle size distribution or the granulometry of the material (CISA , 202(0)).

Therefore, the present research emphasizes analyzing the comminution circuit from primary and secondary crushing as well as milling, significantly optimizing the granulometry of the treated ore, thus reducing production costs (GUPTA & YANG, 2006).

2. METHODOLOGY

For the development of this research, which comprises 3 phases: field work, laboratory of both the company and the University, cabinet; the use of the following materials is required (Table 1).

Table 1: Materials necessary for the execution of the research.

Field Phase	Laboratory Phase	Cabinet phase
- Protective helmet.	- Jaw crushers	- Computer

- Reflective vest.	- Ball mill 6' x 12'	
-Gloves.	- Sieve game.	
-Balance.	- Camera	
-Shovel.	- Balance	
- Plastic bags.	- Greenhouse	
-Notebook.	- Containers	
-Pencil.	- Vibro sieve	
-Marker.	- Spatula	
-Camera	- Heat gloves	
- Hand tools.	- Plastic sleeves	

2.1. Elaboration of the current crushing and grinding circuit .

Plant visit

Consiste in carrying out the visit and analysis to the beneficiation plant and thus achieve a survey of the pertinent information, both of its equipment and its operational parameters of the same, to carry out an effective survey we proceed to know everything about the process carried out in plant and obtain relevant information that helps us understand needs and strengths in each operational section.

Circuit design

After having the relevant information of each of the equipment in charge in its comminution circuit, the achievement of the comminution process (FlowSheet) is designed in a Slider of the Abobe Illustrator CS6 program, defining each of the parts of the operational phases of the comminution system.

2.2. Evaluation of the distribution of meshes in crushing and grinding circuits. Processing plant, and ESPOCH Mines Laboratory.

2.2.1. Procedure Processing plant

Grinding

- We proceed to make the meshes that we will occupy in the crushing circuit, which will occupy meshes of 8, 4, 2 and 1 inch and have a granulometric distribution.
- The respective intake of the discharge of the thick hopper to its feeding to the primary crusher is made, which consists of collecting periodically in a period of 3 hours, which is the crushing time of the Telma material.
- Samples are collected in a valde with the help of a quarterer so that the sample is homogeneous, which samples of 25 to 30 lb. are taken.
- To analyze both its loading and unloading of the ore in the first phase of comminution, the 188 lb is taken and passed through the different types of meshes or sieves, this was done at the different sampling points of the crushing circuit.

2.2.2. Mining Laboratory Procedure - ESPOCH

Initially sand collectsamples at strategic points, where a mesh analysis was carried out with the help of the Mercy balance, later it was taken to the metallurgical chemical laboratory of the company OROCONCENT S.A. to proceed with the drying of the material, in which an industrial kitchen was used to remove all moisture and then be stored to be transferred to the Mines laboratory of the ESPOCH, in the city of Macas (Fig. 1 and 2).



Figure 1: Preparation of the sample for analysis in the laboratory.

The specific procedure carried out in the mine laboratory is as follows:

- Once the samples have been collected at the sampling points of the grinding circuit, they are transported to the city of Macas to be analyzed in the Mines laboratory of ESPOCH.
- The use of an Endecotts brand vibrate sieve is carried out, where mesh sieves were used, 4,7,10,12,18,20,30,40,80,100,120,140,200,270,325,400.
- We proceed to make a composite, of the samples to be analyzed, unloading the mill.
- After obtained and weighed with a weight less than 500 grams of each sample, we proceed to place in the sieve containers and be able to analyze their particle size distribution.
- It is performed at vibration for a time of 5 minutes with a frequency of M1 and M2, which is the strength and time of vibration, analyzing that with this characteristic an effective particle size distribution is obtained.
- Then proceed to weigh each mass retained in the sieves.
- Using a unique balance to obtain the exact masses in each measurement.
- With the data obtained, an excel table is created to find the percentages of: retention, accumulated and through, and create graphs of granulometric curves.



Figure 2: Granulometric analysis in the Minas Laboratory – ESPOCH.

3. RESULTS

3.1. Circuit comminution process diagram

In the following case (Fig. 3), the final diagram of the comminution circuit # 1 is observed, which is responsible for crushing and grinding the ore from the Telma Mine. visualizing each of the equipment and / or machinery of the process that takes plant such as: Thick hoppers, jaw crusher, sieve 1, conveyor belt, fine hopper, 6x12 mill, hydrocyclone, 5x10 whirlpool, water pump, pipes and cyanidation tank. It should be noted that the diagram only corresponds to the circuit that is responsible for reducing the size of the ore from the Telma Mine, which is located in the Rio Amarillo sector in the parish of Portovelo.

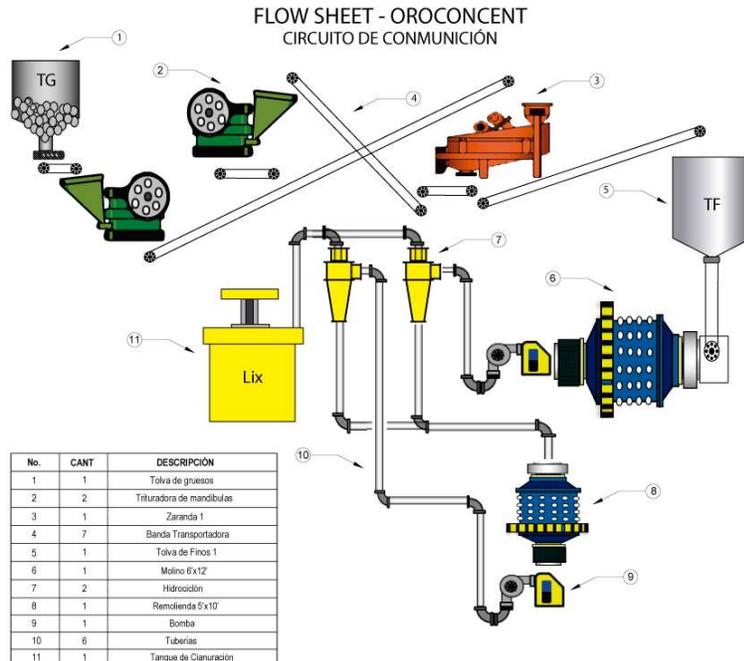


Figure 3: Flow Sheet of the comminution circuit.

3.2. Analysis of particle size distribution in crushing and grinding.

The ore reached the beneficiation plant is fragmented to a size suitable for its release of valuable particles, which comprises a primary and secondary crushing stage, consisting of a jaw crusher for both primary and secondary. This operation is the first part of the process of comminution of the mineral, which reduces the particle size of rocks exploited in the Telma mine, which arrives with an approximate size of 8 "and this when passing through the primary and secondary crushing circuit, fragments it until reaching the mesh size of -2 "an approximate size of 50 mm. This section has two series of circuits which is crushing circuit #1 and crushing circuit #2. Where the analysis was carried out only in the crushing circuit # 1, since it is only in this circuit where they process the ore from the Telma mine, own of the company.

3.2.1. Primary crusher

Primary Shredder Feed - C1

As can be seen in Table 2, the percentage of mass that was retained in each mesh size is found, analyzing that a small part of the samples taken are in a range greater than 8 "which is the optimal size so that it can be reduced, with only 5.3% of rocks greater than 8", With this it is understood that the material delivered from the mine is feasible to be processed by the primary crusher.

Table 2: Granulometric distribution of feed to primary crusher - C1

Sieve No.	Aperture (µm)	Sample weight	% Retained	% Accumulated	% Intern
8"	203200	4.535,92	5,3	5,3	94,7
4"	101600	1133,98	1,3	6,7	93,3
2"	50800	29.483,5	34,7	41,3	58,7
1"	25400	31.751,5	37,3	78,7	21,3
Intern		18.144	21,3	100,0	-
Total		85.048,55	100,00		

The following figure indicates how its granulometric distribution is, taking into account its 3 axes that are % retained, % accumulated and its % through, and thus be able to have a detailed granulometric curve according to the percentage of sample taken in the feeding of its primary jaw crusher.

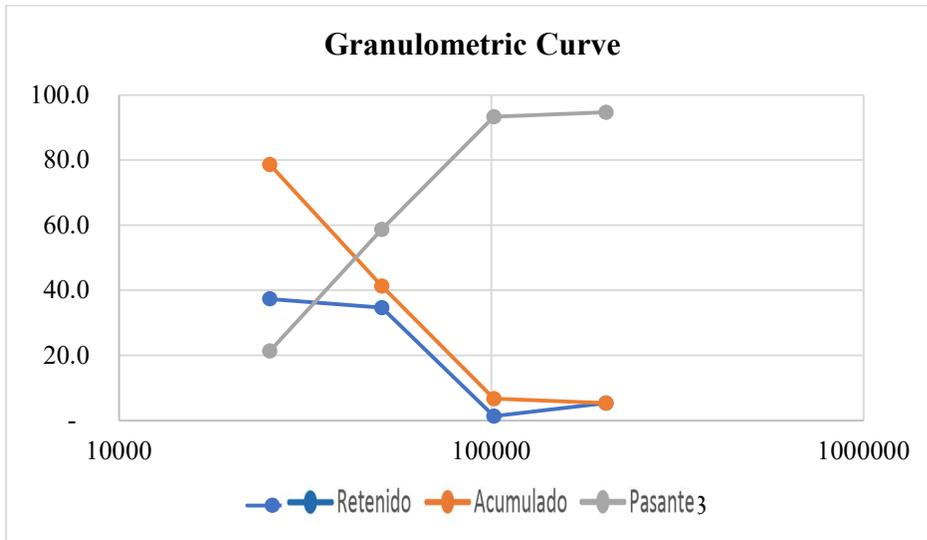


Figure 1: Feed particle size curve

Reviewing graph 1 of the particle size curve with respect to the percentage of through material, it is observed that the behavior of the graph describes an unsuitable form of the particle size distribution so it is very linear, although in its last part an idealized form is already appreciated, showing us that the particles are not well distributed. This happens, because the data taken were not made with standardized meshes with which a more complete distribution would be carried out, but they used the artisanal ones elaborated *in-situ*.

Table 3: F80 calculation

F80	
101600	93,3
82061,53	80,00
50800	58,7

As Table 3 indicates, the F80, which corresponds to 80% of feed to the primary crusher (80% of incoming material) are optimal particles to enter the primary crusher that are in a granulometric size of 82061.53 [µm].

The calculation of the particle size in which 80% of the ore passes was made from Table 2, using the Lagrange interpolation method.

Crusher discharge - C1

As can be seen in Table 4, the percentage of mass that was retained in each mesh size is observed, resulting in only 12.70% of the crushed ore being above the 2" mesh is the mineral that will be sent to the secondary jaw crusher, while 87.3% of the mineral product of the first crusher is already in an optimal granulometry.

Table 4: Granulometric distribution of primary crusher discharge - C1

Sieve No.	Aperture (µm)	Sample weight	% Retained	% Accumulated	% Intern
8"	203200	0	0	0	100
4"	101600	0	0	0	100
2"	50800	9171,85	12,70	12,70	87,30
1"	25400	58555,35	81,03	93,72	6,27
Intern		4535,92	6,28	100	0
Total		72263,12	100		

The following figure indicates how its granulometric distribution is, taking into account its 3 axes that are % retained, % accumulated and its % through, and thus be able to have a detailed granulometric curve according to the percentage of sample taken in the discharge of the primary jaw crusher.

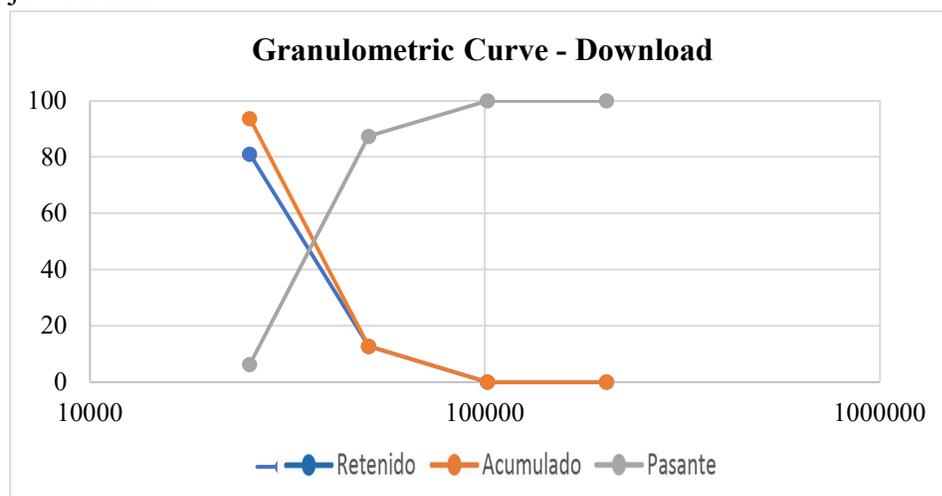


Figure 2: Discharge granulometry curve of the primary crusher.

Reviewing graph 2, of the particle size curve with respect to the percentage of passing material, it is observed that the behavior of the graph describes a more ideal behavior, indicating that the particles are more distributed, showing a more appropriate distribution of the particles. This happens, because the data taken were not made with standardized meshes with which a more complete distribution would be carried out, but they used the artisanal ones elaborated *in-situ*.

Table 5: Calculation of P80.

P80	
50800	87,3
48509,31	80
25400	6,3

As shown in Table 5, the P80 that corresponds to 80% discharge from the primary crusher (80% of through material) are optimal particles in which they are stored in their hopper of fines and that only 12.70% of the mineral that is classified by means of its vibratory sieve returns to a secondary jaw crusher. (The calculation of the particle size in which 80% of the ore passes, was made from the table 4 using the Lagrange interpolation method).

Reduction ratio for primary crusher C1

F₈₀ = Particle size 80% feed ore.

P 80 = Particle size 80% product ore (outgoing).

$$Rr = \frac{\text{Feed Size}}{\text{Product Size}} = \frac{F80}{P80}$$

$$R_{80} = \frac{82061,53}{48509,31}$$

$$R_{80} = 1.69$$

Where it is obtained that the reduction ratio is 1.69, reducing the ore almost half of its initial size.

3.2.2. Secondary crusher

Feeding Jaw Crusher 2 - C1

De according to the previous data it was found that only 12.7% of the circulating load is sent to its secondary crusher, verifying in its following table that this is fulfilled (Table 6).

Table 6: Jaw Crusher Feeding 2 - C1

Sieve No.	Aperture (µm)	Sample weight	% Retained	% Accumulated	% Intern
8"	203200	0	0	0	100
4"	101600	0	0	0	100
2"	50800	45058	97	97	3
1"	25400	1502	3	100	0
Intern		125	0	100	0
Total		46.685,00	100		

The following graph (graph 3) indicates how the granulometric distribution is, taking into account its 3 axes that are % retained, % accumulated and its % through, and thus be able to have a detailed granulometric curve according to the percentage of sample taken in the feeding of the secondary jaw crusher.

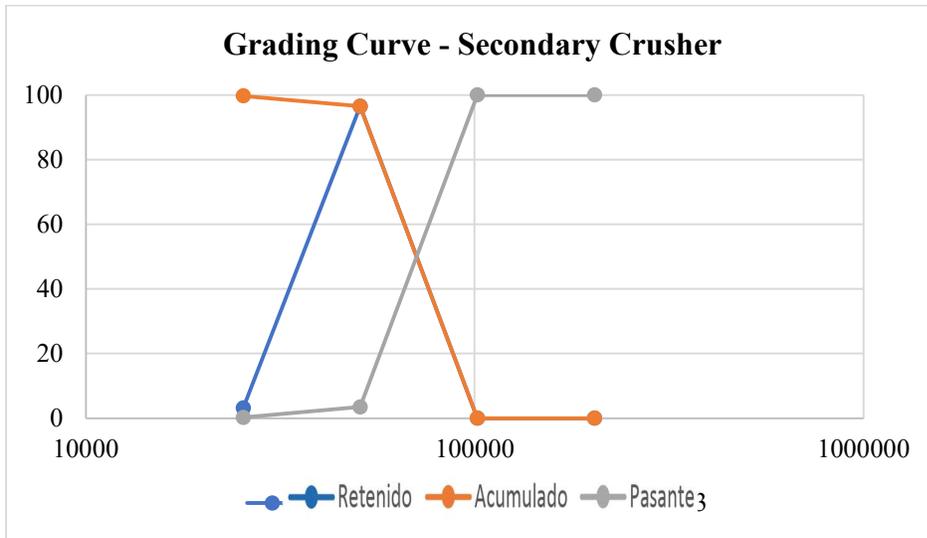


Figure 3: Granulometric curve of secondary crusher feed.

Reviewing graph 3 of the particle size curve with respect to the percentage of through material, it is observed that the behavior of the graph describes an unsuitable behavior, obtaining an initial behavior with a very low distribution, and then a linear behavior is obtained in its later phases. This happens, because the data taken were not made with standardized meshes with which a more complete distribution would be carried out, but they used the artisanal ones elaborated *in-situ*.

Table 7: Calculation of the F80.

F80	
101600	100
60273,1324	80
50800	3

As Table 7 indicates, the F80 corresponding to 80% feed to the secondary crusher (80% incoming material) corresponds to a particle size of 60273.13 [µm]. Indicating that the ore that is fed to the secondary crusher is in a size greater than 2". (The calculation of the particle size in which 80% of the ore passes, was made from the table 6, using the Lagrange interpolation method).

Jaw Crusher Discharge 2 - C1

As can be seen in Table 8, the percentage of mass that was retained in each mesh size is analyzed, the mineral retained even in a mesh equal to or greater than 2", is 4.8% a small fraction that will return to its secondary crusher, until it can be found in a mesh less than 2".

Table 8: Discharge particle size distribution.

Sieve No.	Aperture (µm)	Sample weight	% Retained	% Accumulated	% Intern
8"	203200	0,0	0,0	0,0	100,0
4"	101600	0,0	0,0	0,0	100,0
2"	50800	2548,0	4,8	4,8	95,2

1"	25400	48051,0	90,4	95,2	4,8
Intern		2548,0	4,8	100,0	0,0
Total		53147,0	100,0		

The following graph 4, indicates how its particle size distribution is, taking into account its 3 axes that are % retained, % accumulated and its % through, and thus be able to have a detailed granulometric curve according to the percentage of sample taken in the discharge of the secondary jaw crusher.

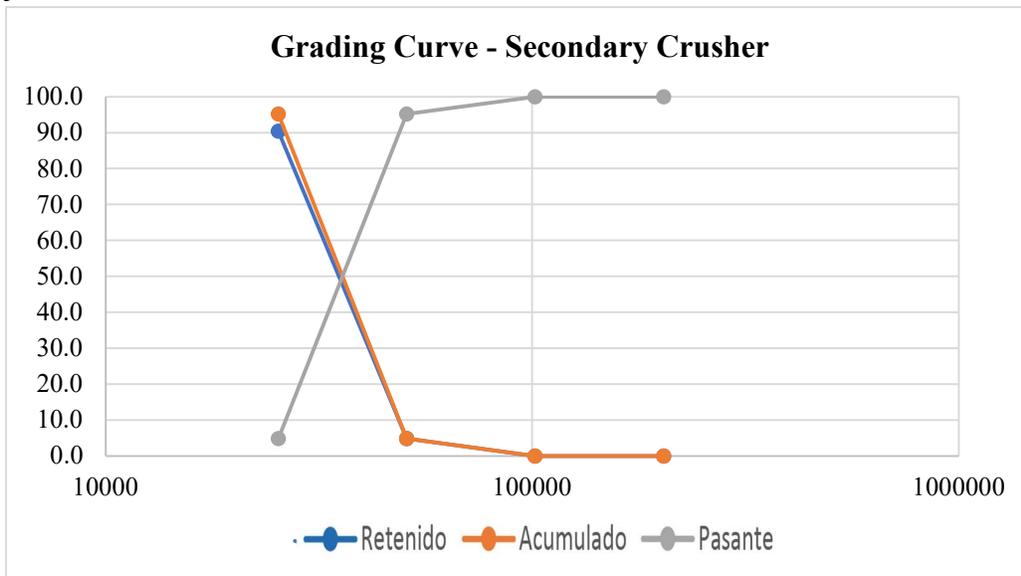


Figure 4: Discharge granulometric curve of the secondary crusher

Reviewing graph 4, of the particle size curve with respect to the percentage of through material, it is observed that the behavior of the figure is more ideal, indicating that the particles are more distributed. This happens, because the data taken were not made with standardized meshes with which a more complete distribution would be carried out, but they used the artisanal ones elaborated *in-situ*.

Table 9: Calculation of the P80

P80	
50800	95,2
21128,1	80
25400	4,8

As Table 9 indicates, the P80 corresponding to 80% feed to the secondary crusher (80% outgoing material) corresponds to a particle size of 21128.1 [µm], which indicates that only 4.8% of the ore is not reduced to an optimal size to be deposited in its fine hopper which the reduction ratio indicates that it almost halves the size of the ore. (The calculation of the particle size in which 80% of the ore passes, was made from the table 8 using the Lagrange interpolation method).

Reduction ratio for the Secondary crusher - CI

F₈₀ = Particle size 80% feed ore.

P 80 = Particle size 80% product ore (outgoing).

$$Rr = \frac{\text{Feed Size}}{\text{Product Size}} = \frac{F80}{P80}$$

$$R_{80} = \frac{40273,1}{21128,1}$$

$$R_{80} = 1.9$$

Where it is obtained that the reduction ratio is 1.9, that is, the mineral is reduced to practically half of feed size.

3.2.3. Granulometric sorter

When performing the following analyzes in its crushing stage, we found that, in the system of its particle classification by means of a vibratory sieve, it fulfills an important function when separating the particles, as observed in its table 9, the mineral must be greater than or equal to 2 "which it does by fulfilling the parameters that the mineral must enter its secondary jaw crusher with a larger size or equal to a 2" mesh.

Therefore, when looking at the results, the ore that is processed with its secondary jaw crusher only corresponds to 2" mesh material. Thus fulfilling with affectivity the classification only of matter that meets that particle size.

3.2.4. Mill 6'x12'

Power Mill 6'x12' (MB-C1)

Table 10: Mill feed 6'x12'

Sieve No.	Aperture (µm)	Sample weight	% Retained	% Accumulated	% Intern
8"	203200	0	0	0	100
4"	101600	0	0	0	100
2"	50800	0	0	0	100
1"	25400	12000	42,86	42,86	57,14
Intern		16000	57,14	100	0
Total		28000	100		

Table 11: Calculation of the F80

F80	
50800	100
38947,46	80
25400	57,14

As Table 11 indicates, the F80 that corresponds to 80% feed to the 6'x12' mill (80% of incoming material) are optimal particles to enter its grinding which are in a granulometric size of 38947.46

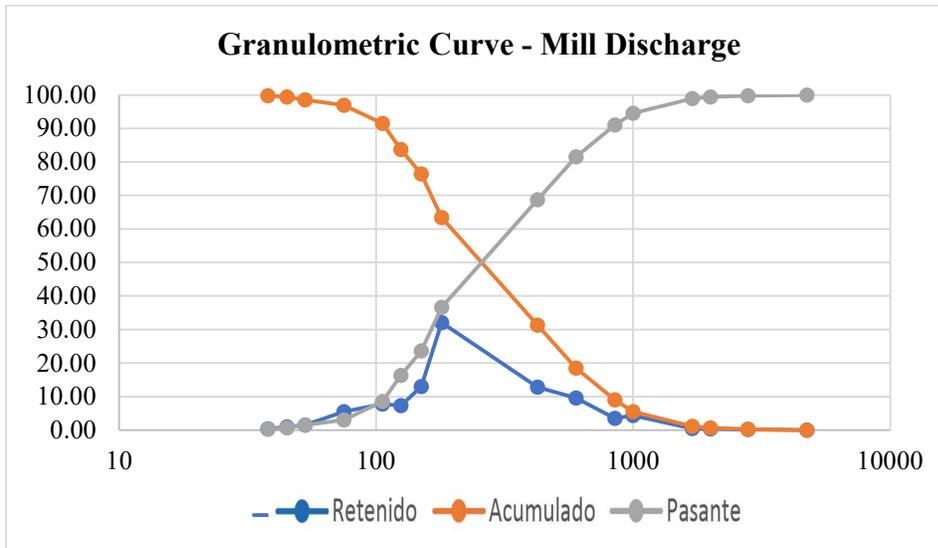
[μm]. Which corresponds that 100% of the mineral complies with this effective granulometry. (The calculation of the particle size in which 80% of the ore passes, was made from the table 10 using the Lagrange interpolation method).

Discharge of the Mill 6'x12'

Table 12: Particle size distribution, 6'x12' mill discharge

Sieve No.	Aperture (μm)	Retained Weight	% Retained	% Accumulated	% Intern
4	4750	0,2	0,03	0,03	99,97
7	2800	1,3	0,22	0,25	99,75
10	2000	2,34	0,39	0,64	99,36
12	1700	3,05	0,51	1,14	98,86
18	1000	26,21	4,35	5,49	94,51
20	850	20,91	3,47	8,96	91,04
30	600	57,5	9,54	18,50	81,50
40	425	77,2	12,81	31,31	68,69
80	180	193,45	32,09	63,40	36,60
100	150	78,25	12,98	76,38	23,62
120	125	44,05	7,31	83,69	16,31
140	106	46,92	7,78	91,48	8,52
200	75	32,91	5,46	96,94	3,06
270	53	9,3	1,54	98,48	1,52
325	45	5,48	0,91	99,39	0,61
400	38	2,24	0,37	99,76	0,24
Intern		1,45	0,24	100,00	0,00
Total		602,76	100		

Graph 5 corresponds to the granulometry curve of the distribution of the mineral analyzing its percentage retained, accumulated and through, describing a curve of the percentage of mineral through well defined indicating that the distribution of its particles was made correctly. While, in table 12, it is observed that the feasible ore that is below a mesh No. 100 is 36.60% which is the size of the ore that will be deposited in the leaching tank.



Graph 5: Granulometry curve of the 6x12 mill discharge.

As Table 13 indicates, we visualize the P80, which corresponds to 80% of the product of the mill 6'x12' (80% of outgoing material) are particles that are sent to the classifier (hydrocyclone) which is in a granulometric size of 579.51 [µm]. (The calculation of the particle size in which 80% of the ore passes, was made from the table 12 using the Lagrange interpolation method).

Table 13: Calculation of P80.

P80	
600	81,5
579,51	80
425	68,69

Reduction ratio for the Mill 6'x12'

F₈₀ = Particle size 80% feed ore.

P 80 = Particle size 80% product ore (outgoing).

$$Rr = \frac{\text{Feed Size}}{\text{Product Size}} = \frac{F80}{P80}$$

$$R_{80} = \frac{38947,46}{579,51}$$

$$R_{80} = 67.20$$

Where it is obtained that the reduction ratio is 67.20 indicating that its reduction is 67 times its size, this significant relationship occurs thanks to the fact that the types of mills are SAG which works with a large feed size, which helps the mineral itself also contribute to the reduction.

4. CONCLUSION AND RECOMMENDATIONS

The comminution circuit carried out in the beneficiation plant located in the El Tablón sector of the Portovelo canton in the province of El Oro was evaluated, a notable difference was identified

between the circuit used in the plant with respect to that used with the sieves in the Mining Laboratory of the ESPOCH Morona Santiago Headquarters. On the one hand, the analysis carried out in the plant shows that 77% of the ore that reaches the leaching hopper is in a -200 mesh (75 microns), while the test carried out in the Mines laboratory of ESPOCH indicates that only 57.66% is within the optimal range. Understanding that the 200 mesh target must be above 80%, it is concluded that the ore delivered by the size reduction circuit is not delivering the ideal particle size according to the required feed percentage F80 (for the fine hopper).

Each of the main measurements and/or quantifications carried out in the plant must be reviewed/calibrated, for an optimal constant operation of the beneficiation plants. In them the most outstanding for our study, the granulometric analysis of each of the equipment that make up the comminution circuit. For this, it is essential to start with the realization of an analysis of the current comminution process in the processing plant. Generating a flow diagram through the Adobe Illustration CS6 program, which delivers a FlowSheet of the current system designed in the comminution circuit, which did not allow to identify the oversized equipment or that with little effectiveness contribute to the process of reducing the size of the particles.

The distribution of the meshes in the comminution process is evaluated, showing several novelties in each of the parts of the process. Primary crusher, being the first stage of the comminution process it is confirmed that the primary crushing shows the most satisfactory results, because it delivers 87.3% of the mineral product in a suitable granulometry to be directly deposited in the hopper of fines. Classifier, it is concluded that it satisfactorily meets the required parameters. Secondary crusher, it is identified that it works only with the percentage of 12.7% of the mineral that the primary crushing could not reduce to the ideal size, and although it has a similar reduction ratio as the primary crushing, it would currently be oversized in view of the fact that the total feed mass of the secondary crusher is very low. Grinding, this reduction phase is the most important, since it reduces the ore to a feasible size to be deposited in the cyanidation tank, delivering a mineral size of 579.51 microns that represents a sieve number less than No. 30. Considering that this particle size is required to reduce it much more with the help of the swirl and thus achieve 80% of the mineral in its optimal size.

It is recommended, in each of the ore processing plants, to supplement safe points that help the collection of data, where sampling is allowed for both the crushing circuit and the grinding and thus facilitate a more detailed analysis of its granulometry. In the same way, in each comminution circuit, realize a more effective monitoring of control both for its crushers and mills, where it was observed that the mineral by having moisture creates jams in the discharges of the hoppers of thick and hopper of fines, so the possibility of implementing drying equipment of the mineral to avoid the aforementioned problems arises. If this is not possible, manage the constant cleaning in the discharges of the equipment in order to maintain operational homogeneity.

Finally, it is suggested to analyze the feasibility of implementing a secondary crusher of smaller caliber than the primary crusher (lower energy consumption), due to the oversizing that this equipment usually presents in the plants, given that for this specific case it only processes 12.70% of tonnage per day. In the same way, to carry out an investigation focused on the simulation of an

ideal comminution circuit for the entire plant, which proposes optimized dimensioning for each of the sections of the process, in which they superimpose each of the variables analyzed in this evaluation.

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