POTENCIAL AND IMPACT OF SENSOR BASED SORTING ON THE GRINDING CIRCUIT PERFORMANCE FOR A POLYMETALLIC ORE

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HIGHLIGHTS

- Integrated assessment of preconcentration effects on grinding circuit
- Improved energy and water usage by coarse gangue rejection with SBS
- Reduction on tailings generation by preconcentration with SBS

ABSTRACT

A comprehensive study was carried out for a polymetallic ore, with the aim of generating a better understanding about how preconcentration impacts the grinding circuit of the Aripuanã Project, located in Brazil. Sensor-based sorting (SBS) test work was performed according to the step methodology and the generated samples were assayed and submitted to Drop Weight Test (DWT) and Bond Work Index (BWi). The results indicate representative differences on elemental composition, breakage behavior and P80. A 50% mass rejection was achieved at 98% recoveries for Zn and Pb and the measured BWi and Axb indicate that high grade material tends to be representatively softer than gangue. Finally, process simulation with the JKSimMet was used to quantify how SAG and Ball mill throughput and energy consumption can be affected by the addition of a preconcentration stage.

KEYWORDS: Sensor-based-sorting, Pre-concentration, Test work, Bond Work Index, Drop Weight Test, Energy efficiency.

1. INTRODUCTION

The minerals industry currently faces a challenge reality, with a crescent need to attend sustainability and social demands. In addition to that, the now available mineral reserves present decreasing grades, such as larger mineralogy complexity. This creates an extremely challenging scenario for the minerals sector, thus pressing the industry for the creation of alternative routes for ore processing and demanding the application of new methods and technologies. In this context the Sensor Based Sorting (SBS) is one of the technologies that can be applied for decarbonisation and to tackle the mining waste generation challenge (Valenta, et al., 2023).

The SBS technology can be defined as an application where single particles are detected by a sensor and then separated by a mechanical process. The technology can be applied at different positions in the beneficiation flowsheet and with multiple objectives, such as preconcentration, coarse gangue rejection, stockpile recovery and ore-type diversion.

The present paper proposes a methodology for the understanding and quantification about how the grinding circuit of a polymetallic ore is affected by the addition of a pre preconcentration with SBS technology. Grinding behaviour, waste generation, water and power consumption are approached, for the integration on between preconcentration and SABC circuit. The complete evaluation is performed for the Aripuanã project, which is located in western Brazil, at the Mato Grosso state.

Aripuanã is a world-class polymetallic project owned by Nexa Resources. Its focus is on the exploration of zinc, lead and copper, as well as gold and silver as secondary resources. The project consists in an underground mine and a beneficiation plant with a 6.3 ktpd capacity. The initial beneficiation plant comprises crushing, SABC milling and a flotation circuit (Lopes, et al., 2022).

With the aim to optimize the operational circuit, Nexa carried out a large test campaign for the evaluation about preconcentration possibilities trough SBS. The results systematically presented a great potential for coarse gangue rejection with minimum metal losses. This fact represents by itself important environmental and economic benefits.

The gangue rejection on coarser fractions directly affects material composition on downstream circuit. Based on that, it is important to understand the effect on other processes such as grinding and flotation circuit, in order to generate a proper account about the generated benefits.

2. SENSOR BASED SORTING: HOW TO ACCOUNT FOR BENEFITS

Once every ore body presents its own features and properties, every sorting application is customized and comprises a personalized solution. In addition to that, the separation and sensor adjustments are affected by different materials properties, such as particle size, mineralogy, liberation, material composition and ore grades.

To develop a SBS application, an initial test work is established to evaluate the technology applicability and define the proper sensor combination for the application. For that, a representative sample which represents the average properties of the deposit is required. Variability test work can also be performed, for the understanding about how variations on the material can affect separability. The test generates an understanding about relations between mass recovery, grades and metallurgical recovery for different materials. This can be used to generate an economical evaluation about the project, such as the definition of the optimal sensors for the separation.

The use of test study to quantify separability by SBS technology is a well-developed method established by the technology manufacturers. A large amount of test results can be found in literature. A summary about literature and papers content is presented by Peukert, et al. (2022) with an aim to propose how different sensor combination could potentially be applied to detect material heteronegeity. In relation to sensors used, the main references for mining are related to X-ray Transmission (XRT), X-ray Fluorescence (XRF), Near-Infrared (NIR), Optical detectors and Eletromagnetic.

In relation to case studies presented, there is also extend literature available. A historical evaluation of the technology applicability is presented, such as case studies for diamonds, tin, phosphate and tungsten (Robben & Wotruba , 2019) .Industrial results for copper, gold and chromite in South America are approached by Esteves, et al. (2020). The aplication of XRT for coal in South Africa and USA is also explored (von Ketelhodt & Bergmann, 2010), such as the SBS applicability for Brazilian iron ore (Lima, et al., 2019) (Esteves, et al., 2022).

Souto, et al. (2020) performed an economical evaluation about the preconcentration of silicate zinc ore by SBS. The technology was applied to convert marginal ore into high grade material to feed the beneficiation plant, thus resulting in an increase of 615 t of Zn metal per year. The economical gains were evaluated for the preconcentration application, without taking into consideration the effect on downstream process, that could potentially increase the achieved benefits. Lessard, et al., (2016) evaluated the benefits of SBS addition into the SAG pebbles circuit, thus generating an abroad economical understanding. However, the process effects of reducing the mill hold up were not took into consideration.

Duffy, et al. (2015) also showed how the integration of sorting equipment into a mining operation can be applied to maximise profitability. For that, it was quantified the effect of bulk ore sorting on material extracted from the mine and changes on cut-off. The correlation with geological information with SBS separation possibilities is also approached, in a geometallurgical perspective (Äijälä, 2018). McFarlane, et al., (2019) proposed a correlation between the geo-metallurgical block model and the SBS results from a pilot plant, in order to maximize the economic impact of the operation. The results indicate potential impacts on mine grade control, production plan and mill feed strategy. However, those aspects are not deeply evaluated and the focus is on the financial gains.

Going into the energy behaviour related to SBS applications, Ballantyne, et al. (2012) suggested an holistic methodology to evaluate energy savings related to SBS incorporation for preconcentration. Although the method is only presented for data assumptions, the results point that energy savings tend to be larger when sorting coarser fractions. Ballantyne, et al. (2018) proposed an evaluation about the energy savings, now considering a chromite and gold applications. The net energies encountered were in the order of 6-11%, as a result of the coarse gangue rejection. The values were calculated based on the mass balance and energy consumptions. In addition to that, it would also be important to understand how the grinding behaviour of the material would be affected.

Going in this direction, Starkey, et. al (2019) proposed a methodology for determining the effect of SBS on material hardness, at preliminary stages. For that, individual rocks are submitted to sensor scanning, to SAGDesign test and assays.

In addition to the new ore properties, it is also important to consider the impacts of feeding the grinding circuit with a new PSD. The inclusion of a SBS stage for preconcentration requires pre crushing the material, in order to limit the size range. It is important to take this into account and evaluate the effect on grinding circuit (Starkey, et. al, 2019).

While test results, sensor response and economic benefits of SBS applications are encountered in technical literature, the understanding of its effect on downstream process is less approached. As gangue is rejected at coarser fractions, material composition on downstream process is affected thus generating a direct impact on process behaviour and performance. Based on that, it can be noted the lack of studies with a wider and more holistic approach for the technology.

3. OBJECTIVE

The addition of a preconcentration stage directly affects the downstream process, due to the impact on material composition. Based on that, the aim of the present study is to:

- Provide an integrated methodology for the understanding of SBS effect on the grinding circuit;
- Calculate the effect of SBS on the energy, water and waste generation for the Aripuanã Project.

The study considers the results achieved in extensive SBS test campaigns, grinding test work and process simulations with JKSimMet software.

4. METHODOLOGY

The performed analysis is shown in the flowsheet in Figure 1.

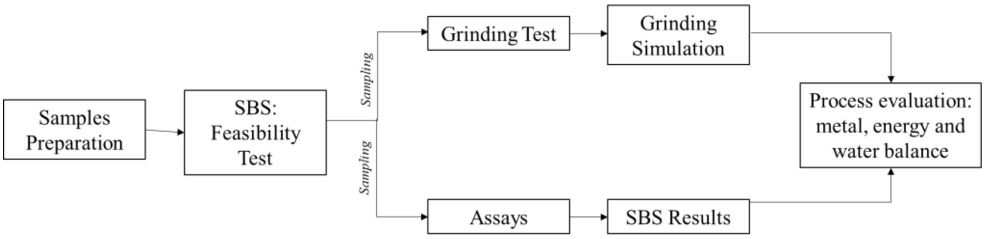

Figure 1 – Flowsheet of the analysis

Samples were collected and prepared for SBS test work, in three different size fractions: -150 +100 mm, -100 +50 mm and -50 +20 mm. A Feasibility test work was carried out, thus generating many different samples. Each sample was proper sampled and different aliquots were sent for assays and grinding test work.

The assayed samples generated elemental data that was putted together with the SBS mass balance, thus generating a quantitative metal balance of the preconcentration stage. In parallel, *Bond Work Index* (BWi) and *Drop Weight Test* (DWT) were performed, thus generating quantitative information about the grinding behavior of the samples.

After completing SBS and grinding test work, the information was putted together to generate a process evaluation and quantification of metal, energy and water balance of the circuit.

4.1. SBS: FEASIBILITY TEST

The Feasibility sorting test is performed as an initial evaluation about sorting applicability. The test requires calibration samples for sensor analysis and a bulk sample for the separation test. The test methodology is explained in details by Esteves, et al. (2022) for the evaluation of a Lithium pegmatite separation.

The calibration samples consist in small samples that should be hand-picked by a geologist and represents the different product and gangue lithologies of the deposit. Well prepared and clearly defined hand-picked calibration samples enhance the development of efficient sorting programs that can be applied for the separation of a bulk sample, according to the steps methodology. The bulk sample must be representative of Run-of-Mine (ROM), contain all the different rock-types, grades, and waste/ore ratio that can be expected in the mining activities. The test flowsheet is shown in Figure 2.

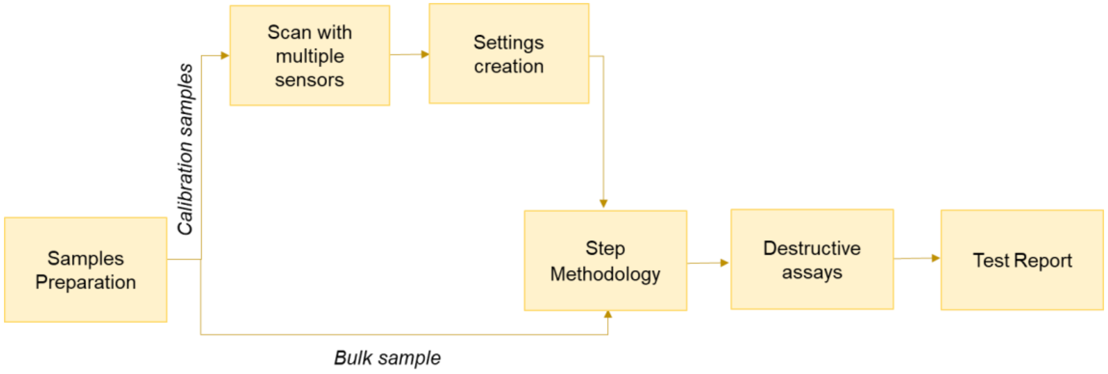

Figure 2 – SBS: Feasibility test method

For the test, calibration samples are scanned separately on the multi- sensor KSS 100 FLI XT sorter, which includes XRT, 3D Laser, Colour camera and Induction sensor.The equipement schematic is shown in Figure 3. The recorded scanned sensor responses are evaluated and used to create a customized separation setting.

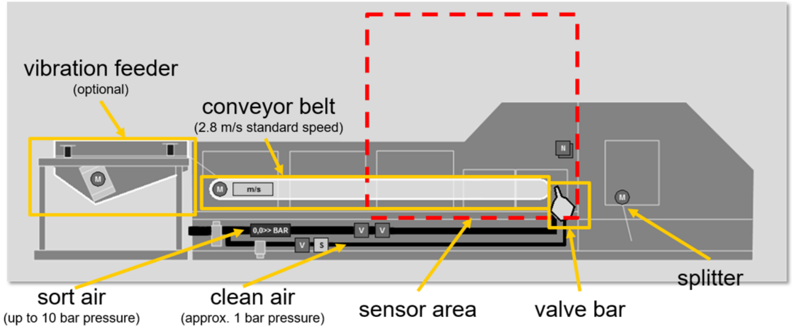

Figure 3 – Multi-sensor equipment used for test: KSS 100 FLI XT

The setting and various sensitivity steps are then simulated in a software, for the creation of a separation strategy. The idea of the step methodology is to gather more information about the material behaviour by sorting the bulk sample. For that, the developed setting is applied to the sample at different sensitiveness and different sensor combination can also be applied.

It is important to emphasize that although test work is conducted in several steps, in the industrial context a single step separation is performed. In this context, the cumulative results are expected for the selected step.

All sorted sample fractions are then sent to a lab for assaying. The assay results are used to calculate the step by step and cumulative grade/recovery evaluation.

In the present case, additional sample aliquotes were generated for the realization of a grinding test work campaign.

4.2. GRINDING TEST WORK AND SIMULATIONS

Samples were collected from one of the SBS test campaign, with the aim to generate a better understanding about how preconcentration could potentially affect material grindability. The samples were collected from the following test flowsheet shown in Figure 4, at two different size fractions (-100 +50 mm and -50 +20 mm):

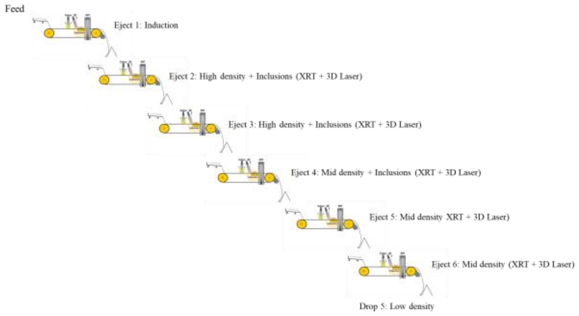

Figure 4 – SBS test flowsheet to generate samples for grinding test work

The samples were submitted to BWi and DWT test and the achieved results were used for the simulation of the SABC circuit. The simulation was performd with the JKSimMet software for three different scenarios. Case A is stated as the base case, without the inclusion of a preconcentration stage. Case B and C considers the inclusion of a preconcentration stage, for two different fractions of the PSD. In Cases B and C, the material which does not feed the SBS is mixed with the preconcentrated product and will feed the beneficiation plant. A summary about the different scenarios is detailed next, such as the simulation flowsheets.

- A: ROM feed the beneficiation plant, without preconcentration;
- B: Preconcentration of all material >20 mm;
- C: Preconcentration of -150 +20 mm.

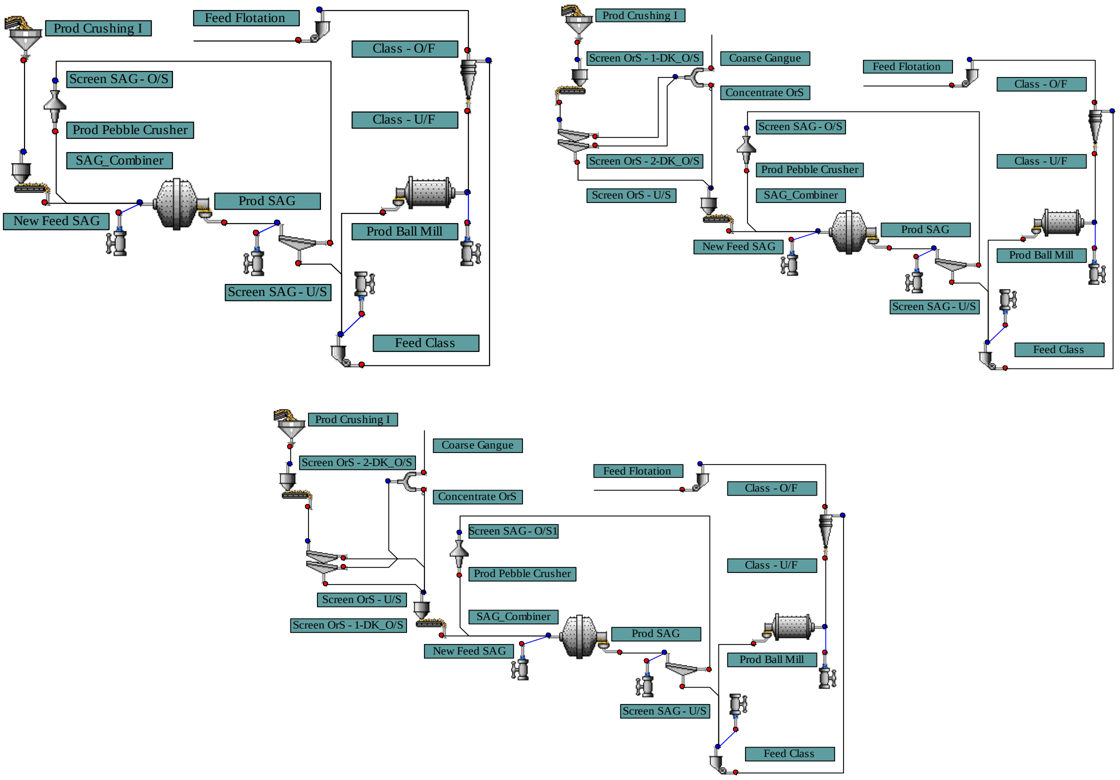

Figure 5 - Top and Left: Flowsheet: Case A,
Top and Right: Flowsheet: Case B,
Bottom: Flowsheet: Case C.

5. RESULTS AND DISCUSSION

5.1. SENSOR SORTING TEST

In total, 20 tons of material were tested in several configurations at different test campaigns. Different areas of the mine were tested at various size fractions. For that, test was performed at multiple steps, single step approach, with the ejection of gangue or high-grade material. In summary, all possible configurations were evaluated thus generating consistent results. The test feed grades ranged according to the following:

- Pb: 0,26% to 1,83%;
- Zn: 0,95% to 3,81%.

Based on the test campaigns it was decided to apply a sensor combination technique, to maximize metal recovery for the target elements. The following sensors were used:

- Induction: to recover Pirrhotyte associated with Chalcopyrite;
- XRT+Laser: to recover sulphides inclusions and high-density material.

Figure 6 - Left: inclusions recovered with XRT + 3d Laser. Right: material with strong induction signal.

The sensor combination was applied at different test campaign, thus generating quantitative test data results. The relation between mass and metal recovery for graphics Pb and Zn is shown in Figure 7.

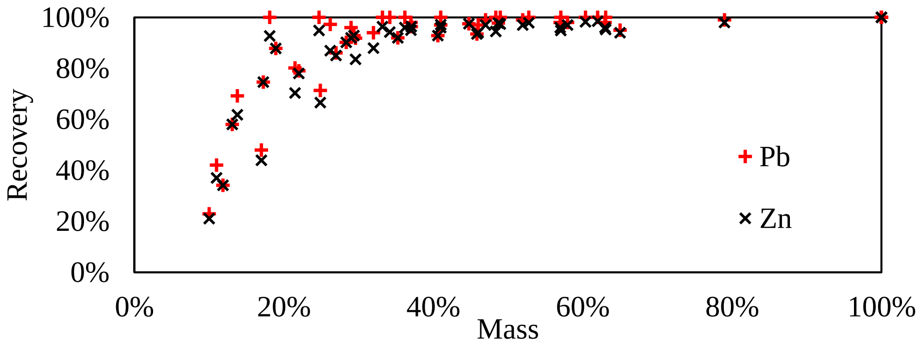

Figure 7 - SBS test results: mass x metal recovery

It shows a distinguishing result for all target elements, with the possibility to reject large amount of waste while maintaining elevated metal recoveries. Moreover, it stands out the sustaining results achieved at coarser fractions. For that, the sensor combination provided additional flexibility to operate at large sizes, up to 150 mm. By applying the traditional dual energy XRT approach would result in a full absorption pattern that could not allow for differentiation at such coarser sizes.

In addition to that, it is important to emphasize the heterogeneity aspects of the material, which is maintained at coarser sizes. The material heterogeneity is the main aspect that allows for the separation results and for the differentiation of the particles. In other words, liberation does not appear to limit the preconcentration of this material up to 150 mm, which consists in the main distinguishing aspect of the application.

5.2. GRINDING TEST WORK

The samples from SBS test were submitted to assays, BWi and DWT. The achieved results are shown next.

	Eject 01	Eject 02	Eject 03	Eject 04	Eject 05	Eject 06	Drop 06
-100+50mm	9,78	9,96	10,1	10,56	11,96	12,31	14,27
-50+20mm	8,9	10,29	11,19	11,45	11,57	11,76	13,7

	Eject 01	Eject 02	Eject 03	Eject 04	Eject 05	Eject 06	Drop 06
-100+50mm	39,83	43,14	44,69	36,53	23,63	26,28	23,6
-50+20mm	32,91	35,34	20,45	23,45	26,47	24,62	22,02

Figure 8 - BWi and DWT of preconcentrated samples.

It is possible to note a significant difference on the Axb and BWi parameters for the different samples. The BWi ranges from 8,9 kWh/t up to 14,27 kWh/t. Considering fixed size fractions, this means that Eject 1 (high grade material), presents a BWi that represents approximately 65% to 69% of the Drop (low grade) BWi.

Based on assay results, shown in Table 1, the material can be divided into four groups:

- Eject 1 and 2: High-grade;
- Eject 3 and 4: Mid-grade;
- Drop 6, Eject 5 and 6: Low-grade.

- Table 1 – Assay results of the preconcentrated samples.

Size fraction	Sample	Al2O3	CaO	Cu	Fe	MgO	Pb	S	SiO2	Zn
-50 +20mm	Eject 1	5,64	3,93	1,16	20,1	10,8	1,82	11,75	28,9	4,64
	Eject 2	5,99	5,38	0,43	13,8	13,1	2,12	7,05	27,3	9,05
	Eject 3	14,25	2,45	0,22	17,25	12,35	0,1	1,11	33,7	0,66
	Eject 4	10,35	4,49	0,12	11,4	13,4	0,11	0,78	40,7	0,56
	Eject 5	11,05	2,31	0,06	10,3	13,95	0,06	0,65	47,2	0,35
	Eject 6	10,1	3,96	0,05	8,72	15	0,05	0,49	45,6	0,25
	Drop 6	9,55	3,94	0,05	4,66	8,5	0,05	0,25	60,2	0,19
-100 + 50 mm	Eject 1	4,44	5,72	1,14	21,7	10,35	1,99	13,35	25,6	5,03
	Eject 2	3,51	3,27	0,47	14,6	10,7	5,2	14,95	25,8	15,35
	Eject 3	8,35	4,41	0,36	14,35	15,05	1,04	5,13	32,1	4,07
	Eject 4	10,65	3,7	0,24	13,35	16	0,32	2,57	36,5	1,23
	Eject 5	10,5	3,27	0,1	10,45	14,65	0,1	1,01	45,7	0,39
	Eject 6	10	2,5	0,08	9,28	14,75	0,05	0,74	48,7	0,22
	Drop 6	9,93	1,68	0,04	6,05	9,78	0,03	0,42	61,1	0,12

For the high-grade materials the Si content is up to 28,9%, being the BWi smaller than 10,3 kWh/t and Axb in between 32,91 to 43,14. The BWi behavior is similar in between the two size fractions, while Axb tends to present higher values at coarser size.

For the mid-grade material, the Si content reaches up to 40,7%. The BWi reaches up to 11,45 kWh/t and Axb shows a wide range in between 20,45 and 44,69. For that, it is seen a large difference in the Axb behavior in between the different size fractions, although the Si content of the samples does not vary at the same level.

For the low-grade material the BWi and Axb presents similar behavior in between both size fractions. In general, it can be observed a significant increase on BWi, values and a decrease on Axb, being the Si content up to 61,1%.

To better understand the relation between Si% content and the BWi and Axb parameters, the information was putted together in Figure 9.

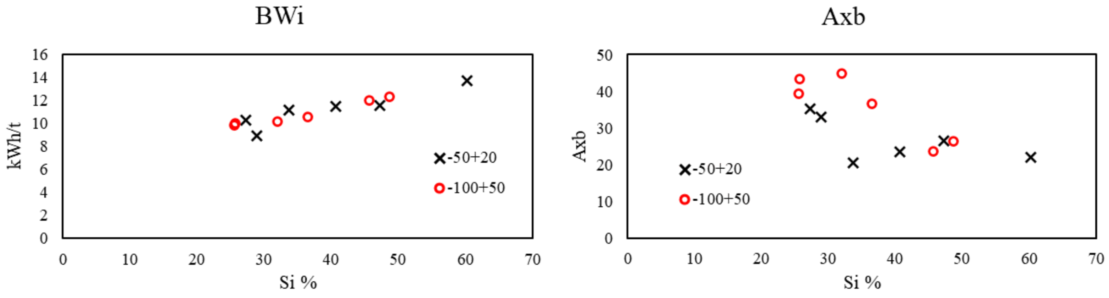

Figure 9 - Correlation between Si% grades and grinding parameters for the preconcentrated samples.

It is possible to observe similar patterns in between the different size fractions, for the BWi. In contrast, the two size fractions present difference behavior for Axb, specially for intermediate values of Si%. This could be investigated for a better understanding about the reasons behind this effect.

In summary, the overall results indicate the amount of energy to grind low grade material is significantly greater than for high grade and mid-grade material. In addition to that, the grinding media and wear parts consumption could potentially be smaller due to the softer characteristics of the material.

Finally, the BWi and DWT were calculated considering the Drop 6 as waste material and the combined Ejects as the product. The BWi represents approximately 80% to 85% of the initial value of the feed. A higher reduction is observed for the -50 +20 mm size. Differently, the Axb impact is higher on the -100 +50 mm size range, when an increase of 1,3 times is observed.

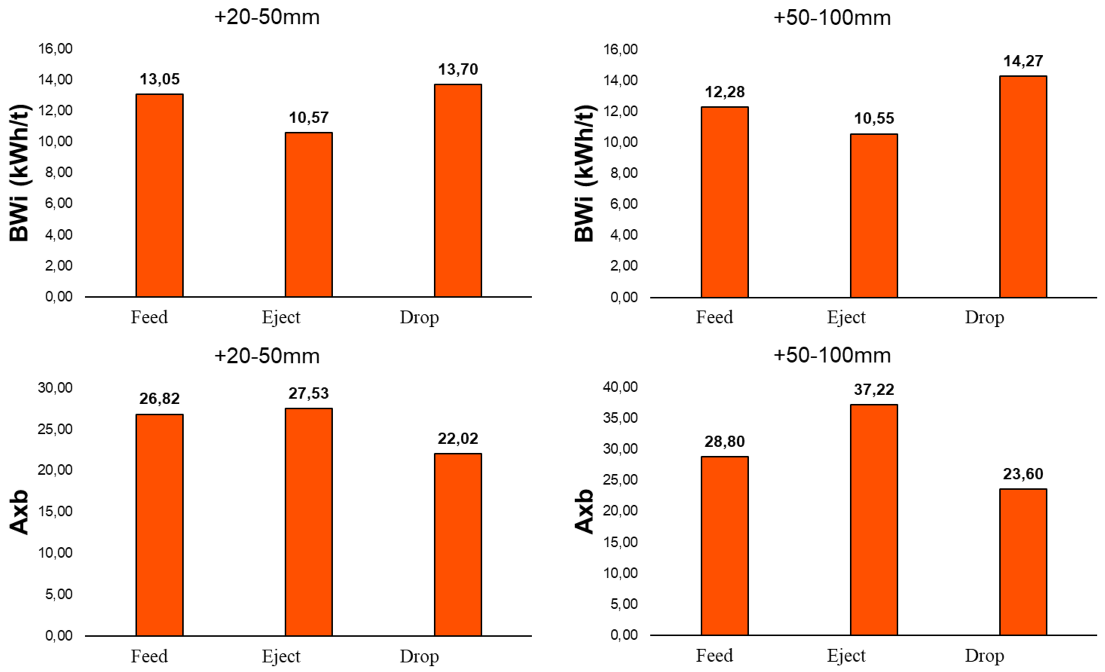

Figure 10 - BWi and DWT for feed, product and waste stream of the preconcentration stage

To summarize, it is conclusive that preconcentration causes a direct impact on the grinding behaviour of the material. The grinding parameters achieved can now be used to evaluate the effect on the SABC circuit.

5.3. PROCESS SIMULATIONS

Based on the SBS test results, it was decided to realize a process evaluation for a 50% mass split. The overall capacity and power consumption were analyzed for the SBS application, taking the test information and material PSD into account. Table 2 summarizes the achieved results.

Table 2 - Scenarios B and C for the preconcentration plant with SBS

Scenario	Size fraction for SBS	% of feed material for SBS	SBS: mass recovery	% of ROM for the beneficiation plant	SBS capacity	Sorting power (per unit)
A	-	0%	0%	100%	-	-
B	+20mm	76,20%	50%	62%	115 t/h	315 kW
C	-150+20mm	60,41%	50%	70%	98 t/h	330 kW

The table refers to the operational conditions for a single machine installation. The calculated power considers the sorting machine and air compressor system. This does not include the energy for the peripheral equipment used for materials handling.

The SBS product is mixed with the by-passed material and then feed the beneficiation plant. For Case B this by-pass material means the amount of material in the -20 mm size fraction. This does not mean that 20 mm is the minimum size for the application. It was a minimum size established by the amount of data generated from the test work and will be consistently used for the evaluation. In Case C the by-pass material includes -20 mm and +150 mm size fraction. Another possibility would be to close the crushing circuit to limit the top size at 150 mm, thus maximizing the amount of sortable material. However, it was decided to maintain the actual PSD in order to simplify the analysis.

The amount of sortable material has a direct impact on processing capacities, power consumption and also metal balance. In relation to the metal balance, (Lopes, et al., 2022) proposed an understanding about the preconcentration effect on the metal balance for the Aripuanã project, in a daily basis. For that, the ROM was fixed at 6300 tpd and the sorting test results were used for an evaluation about the overall effect on metal balance. In addition to the SBS test results, a flotation model based on feed grade was used to estimate the metal recovery at this stage, which various according to plant feed grade. For the model, the waste grade is fixed independently on flotation feed grade, resulting in metal recovery increments when flotation feed increases. A similar approach is presented in Figure 11, for the metal balance in a t/h basis.

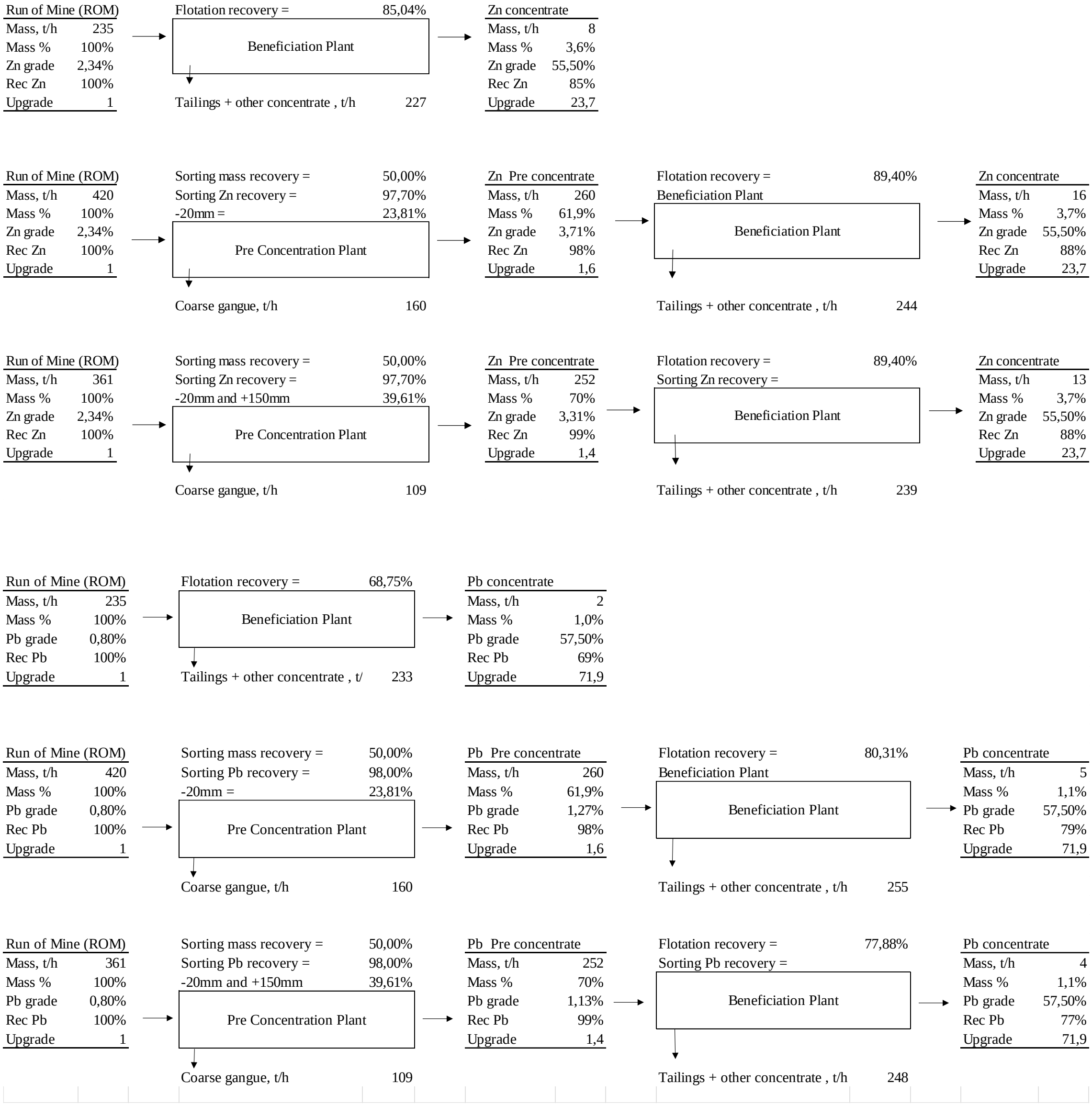

Figure 11 - Metal balance for Zn and Pb at the three different scenarios: A, B and C

It is possible to note that the addition of a preconcentration stage results in an increment on metal production, considering the same ROM material. Although a small metal lost occurs on the sorting stage, this is compensated by an increment on flotation metal recovery due to the increase on its feed grade. This has a direct impact on the financial aspects of the project.

The results achieved on grinding test were used to perform process simulation of the SABC circuit, by using the *Variable Rates SAG Model* of JKSimMet software (Morrel & Morrison, 1996). The simulations were performed by keeping a fixed plant capacity, according to the metal balance and flowsheets presented earlier. This resulted in an increase on the ROM rate once the preconcentration plant rejects a significant amount of material at coarser fractions.

The simulation generated the material PSDs, shown in Figure 14,Figure 13 and Figure 14. Case B presents the finest material for the SAG feed and fresh feed. This is a result of the higher amount of coarse material rejected by preconcentration, once this scenario considers all material above 20 mm in the preconcentration plant.

In relation to the ball mill, Case B and C presents similar PSD for feed and product, while scenario A shows the coarser distributions, as expected. However, at this moment the scenario C presents a slightly finer distribution than scenario B, which consists in an inversion of the previous results. Based on that, it can be concluded that although Case C presents the coarser material for the grinding circuit, it generates the finer product and greater amount of material in the target marker size (150 μm).

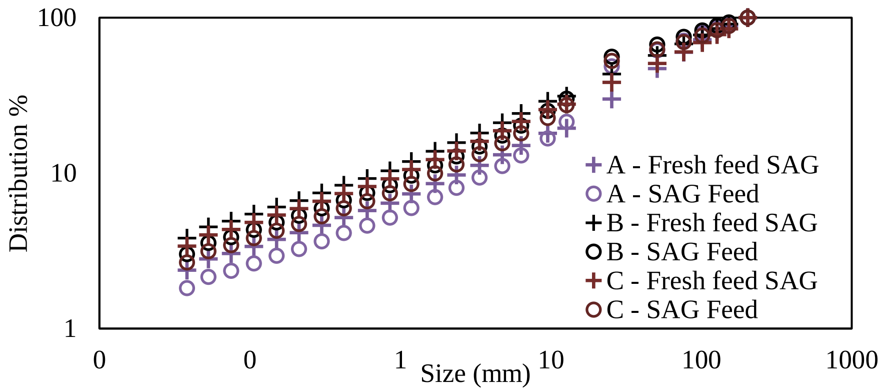

Figure 12 - PSD of SAG overall feed and fresh feed

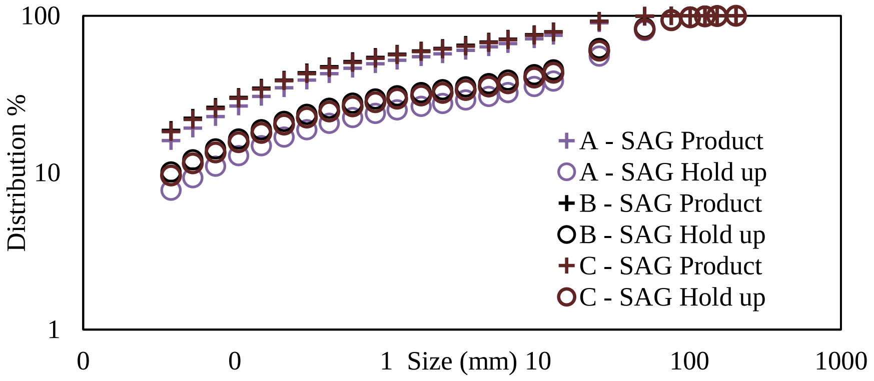

Figure 13 - PSD of SAG product and held up

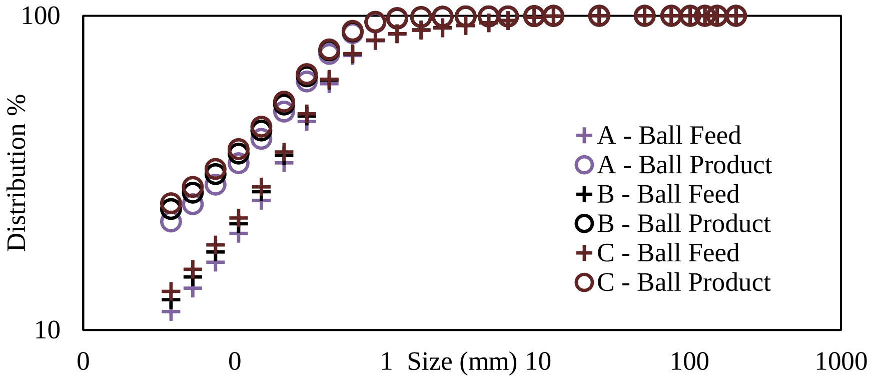

Figure 14 – PSD of ball mill feed and product

In addition to the PSDs, the process results achieved on the simulations are shown in Table 2, together with the preconcentration information calculated previously:

Table 3 - Top part: Preconcentration mass balance and power consumption.
Bottom part: Simulation results for the grinding circuit.

Plant	Parameter	Unit	A	B	C
Preconcentration Plant	Feed	t/h	235	420	361
	>150 mm	t/h	-	-	57
	<20 mm	t/h	-	100	86
	SBS product	t/h	-	160	109
	SBS reject	t/h	-	160	109
	SBS Capacity	t/h	-	115	98
	Number of SBS		-	4	4
	Total Power	kW	-	1260	1320
Grinding Circuit	New feed SAG	t/h	235	260	252
	Specific energy SAG	kWh/t	9,27	8,35	8,62
	Installed Power SAG	kW	2800	2800	2800
	Measured power SAG (motor)	kW	2292	2285	2287
	Specific energy BALL	kWh/t	10,11	9,13	9,42
	Installed Power BALL	kW	2800	2800	2800
	Measured Power BALL (motor)	kW	2500	2500	2500
	Power Pebbles crusher	kW	160	160	160
	F_{80}	µm	121893	109136	134880
	T_{80}	µm	2556	2138	2183
	P_{80}	µm	139	129	128
	Axb	-	29,4	34,4	34,0
	BWi	kWh/t	12,5	10,6	10,6
	Total water consumption	m3/h	476	504	478
	Water specific consumption	m3/h/t	2,03	1,94	1,90

As discussed previously, the gangue rejected at preconcentration presented a higher energy consumption behaviour. In this context, the AxB of SAG feed increased from 29,4 (Case A) to 34 (Case C) and 34,4 (Case B). The BWi was achieved as 12,5 kWh/t (Case A) and 10,6 kWh/t (Case B and C). The values were based on the grinding test work, considering a 50% mass split and material PSD.

The grinding characteristics and new PSD directly affected the SAG performance, thus resulting in capacity. In this sense, the capacity increased approximately 7% for Case C and 10% for Case B. The reason for the higher capacity increment on Case B is the fact that a higher proportion of the ROM is preconcentrated in this scenario. In addition to the higher capacity, a smaller measured power was achieved for the SAG mill. The increment on capacity and slight decrease on measured power results in a better energy efficiency performance for the SAG mill. For the ball mill, the measured power is maintained, being the higher effect on the product PSD. In this sense, there is a higher fines generation considering the same mill power.

After having the process information and overall metal balance, it is possible to finally correlate the results and generate an understanding about the energy, water and waste generation, for the different scenarios. The achieved results are presented for the total balance.

Table 4 – Power, water, mass rejection and metal balance achieved.

Parameter	**Unit**	**A**	**B**	**C**
ROM	t/h	235	420	361
Zn concentrate	t/h	8	16	13
Pb concentrate	t/h	2	5	4
Total Power	kW	4952	6205	6267
Total Water	m3/h	476	504	478
Coarse material rejected	t/h	**0**	**160**	**109**
Fine material rejected	t/h	**224**	**240**	**235**

Taking into consideration the Pb and Zn concentrate production, it is possible to perform an analysis about energy and water consumption, such as waste generation per t of concentrate produced. That information can be used for cost evaluation and to generate an assessment about resources utilization.

Table 5 - Resources quantification for the generation of 1t concentrate (considering Pb and Zn production).

Parameter	**Unit**	**A**	**B**	**C**
Water usage	m3	45	25	28
Energy usage	kWh	464	308	363
Fine waste	t	21	12	14
Coarse gangue	t	0	8	6

It is possible to note a significant decrease on the amount of energy necessary to generate a t of Pb and Zn concentrate. The best scenario is obtained for Case B, which results in a 56% percent of water usage and 66% of energy consumption, in comparison do Case A. Fine waste generation is calculated as 57% of Case A, although there is an additional waste generation the form of coarse gangue. However, the coarse gangue presents a much smaller deposition cost and small environmental impact. As this material does not contain relevant amount of metal this could be easily used for paving or as aggregate. In relation to Case C the same benefits can be observed, although there is a small increase in waste generation, water usage and energy usage, in comparison to Case B. This occurs once there is a smaller fraction of the ROM material that is preconcentrated.

6. CONCLUSIONS

Given the arise use of the SBS technology, it is necessary to perform a holistic evaluation about its effects on downstream process. In this sense, a more abroad evaluation is necessary for the proper quantification of resources used. For that, not only the overall mass and metal balance should be considered, but also the understanding about process performance of preconcentrated material. As gangue is rejected prior to the beneficiation plant, there is an important shift on the elemental composition and material properties of the beneficiation plant feed. The behavior of the new feed material should be evaluated and take into account for the proper evaluation of the new metal and resources balance.

The present paper proposes an evaluation about the effect on the grinding behavior for a polymetallic ore. For that, BWi and DWT are performed for samples generated from a SBS test work. The study is part of a more abroad analysis which performed SBS test for approximately 20 t of different samples from the mine. The SBS test and grinding test work were used to perform process simulations with JKSimMet. Finally, all those results were putted together to generate a proper account on the Pb and Zn production, such as the energy, water, and waste generation required for that. The analysis is performed for three different scenarios: without preconcentration (A), preconcentration of all -20 mm material (B), preconcentration of -150 +20 mm material (C).

SBS test results indicate that preconcentration of the Aripuanã ore can be performed with a 50% mass rejection, resulting in Pb and Zn recoveries greater than 97%. The test was performed for the -150 +20 mm size range and the results systematically pointed to elevated metal recoveries at all size fractions.

The BWi and DWT test of the preconcentrated samples indicated large differences in between samples of different grades. In addition, the BWi showed a large correlation with Si% content on the samples. Considering the product and waste generated by preconcentration, it was observed that product showed a BWi value in between 80% to 85% of the feed material. The Axb of the product reached up to 1,30 times the feed Axb. The effect on BWi was more intensive at the finer size range (-50 +20 mm), while the effect on Axb was evidenced at the coarser size (-100 +50 mm).

The preconcentration also affected the PSD for the grinding circuit. Two different PSD for preconcentration were evaluated in the analysis. The combination of PSD effect and grinding behavior resulted in an increased capacity for the SAG mill from 235 t/h up to 260 t/h, which means an additional 10% capacity for the mill. This number is a direct result of the new material properties. In addition to that, there is also the effect of the preconcentration mass balance.

Up to 38% of the ROM was rejected by the preconcentration plant, which means this amount of material would be rejected at coarser sizes and does not feed the beneficiation plant. Based on that, there is an important saving on energy and water that would be necessary to process this material at the plant.

As a results of the aforementioned benefits, it was noted a decrease on water and energy usage. Based on that, the water, energy and waste generation required to produce 1 t of Pb/Zn concentrate were evaluated. Considering the best scenario for the preconcentration (Case B), the following results are achieved, in relation to the case without preconcentration:

- 56% water usage;
- 66% energy consumption;
- 57% fine waste generation.

It is important to highlight the fact that additional waste is generated at coarse fractions. This material could be potentially used for other activities such as path or the development of by-products as sand-ore or aggregate material. However, due to the recovery increment on the overall metal balance, there is a decrease on total waste generation, even with the inclusion of coarse gangue.

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