

APPLICATION OF HIGH FREQUENCY SCREENS IN CLOSING GRINDING CIRCUITS

Laércio Albuquerque, Jobe Wheeler, Steven Valine And Brenno Ganahl
Derrick Corporation, USA

Godofredo Barrios
Goldex S.A., Peru

ABSTRACT

The emphasis of this paper is to look at the operation of high frequency screens in closed circuit grinding, where important results are achieved propitiating economic gains at the comminution stage and downstream processes including flotation, dewatering, and filtration operations. The classification operation in grinding circuits has been slowly evolving during the last 100 years. The history of classification equipment brings to mind rake classifiers and spiral classifiers, that even with higher efficiencies than hydrocyclones, were not able to follow the evolution of the concentrator plants. High tonnage throughput opened the doors for the standardization of hydrocyclones as the classification stage in closed grinding circuits. The comminution process is often the most energy intensive stage of mineral processing. Researchers have determined that the classification stage in the comminution process has the largest potential for improvement. The intention of this paper is to inform mineral process engineers of the benefits that high frequency screens offer over hydrocyclones. This will be done by reviewing the purpose for the evolution of classification in the comminution process, documenting past and recent studies, and explaining the modern technology that is currently available.

History

In 1925 E. W. Davis conducted comparative tests between rake classifiers, screw classifiers and screens as classifiers in closed circuit grinding⁽¹⁾. He concluded that vibrating screens obtain higher grinding mill capacities with less overgrinding compared to the rake and spiral classifiers. However due to the limitations in technology during his time, vibrating screens were determined to be uneconomical. A 1945 study by E. Reed Albert stated “lower grinding costs are possible with screen circuits”⁽²⁾. In reality, after the Second World War, hydrocyclones became the preferred equipment in closed grinding circuits. In another study performed by. Hukki, R. T & Allenius, H. in 1968 it was concluded that “the master key for great improvements in capacity and in energy consumption in closed grinding circuits is improved sharpness of classification”^(3,4). This study also concluded that to reduce overgrinding and increase separation efficiency a screening device was required, however no such machine was available for industrial applications at this time. Many studies have determined the principal characteristic of an ideal classification device is to immediately remove a particle after it is ground to the proper liberation size.

Development of Grinding and Classification Technology

It was discovered that closing a grinding circuit with a classification device was beneficial to the comminution process. The first classifiers used in closed grinding circuits were mechanical rake and spiral classifiers and both were used effectively in early grinding circuits. However, operational costs were high due to excessive wear on the moving parts and these devices also suffered from capacity limitations.

The hydrocyclone became the most popular type of classification device during the late 1940's because of its capability to handle the higher production rates of the more modern concentrators. The use of high energy pumps was required to make the hydrocyclone operation more efficient. The capacity of hydrocyclones kept increasing to meet the demands of the high throughput concentrators but the hydrocyclone efficiencies remained relatively low. Hydrocyclones designs continued to be improved but separation efficiencies are still typically in the range of 45% to 65%.

The basic principle of hydrocyclone separation remains a function of particle size and specific gravity. In other words, the hydrocyclone is not a true size separation device. Hydrocyclones send the heavier particles, which are often liberated valuable minerals, back to the mill. This effect is more pronounced in applications where there are high specific gravity differences between the valuable minerals and the undesirable minerals.

The inefficiency of the hydrocyclone separation requires the use of high circulating loads to minimize the residence time in the mill. High circulating loads increase the power requirements per ton. Even with the reduced residence time, the excessive bypass of fine particles to the hydrocyclone underflow that reports back to the mill, the passage of middling particles to the hydrocyclone overflow and downstream processes, the excessive generation of ultrafines, and poor separation efficiency has left room for improvement.

It has always been understood that screens separate particles based on true particle size and screens have long been accepted as a standard device in coarse size classification. However, for fine particle separations, screens were considered to be impractical and uneconomical due to factors such as low capacity, high screen panel consumption, and blinding

Derrick Corporation recognized the potential gains that fine screens could offer to improve closed circuit grinding. With this knowledge Derrick set out to address the concerns that mineral processing engineers had in regards to durability and effectiveness of fine screening equipment. Derrick Corporation developed high frequency screens that could be applied to produce efficient fine separations and achieve high circuit capacities. Derrick realized that fine screens needed the following important characteristics:

- Rugged construction and mechanical dependability
- Resistance to blinding
- Wear resistance surfaces
- Low power consumption
- Ease of maintenance
- Cost effectiveness
- Produce favorable metallurgical results

Through extensive research Derrick discovered that screen width was a crucial factor in determining fine wet screen capacity and efficiency⁽⁶⁾. Derrick used this information to develop the Multifeed Screen (Figures 1 and 2). The Multifeed was applied in grinding circuits achieving screen efficiencies above 90%.

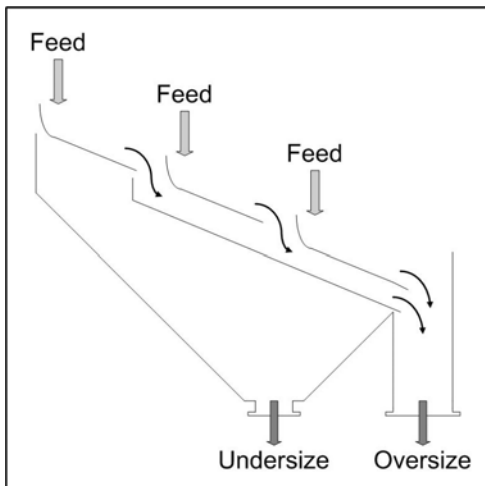


Figure1: Multifeed Flow Distribution



Figure 2: Multifeed Screens

The Multifeed in addition to Derrick's blinding resistant Sandwich Screen® panel was an excellent and successful start to introducing fine screens into grinding applications. The Multifeed has been used in a variety of mining operations. With the ever increasing demands of mineral dressing operations, the main problem related to the screens continued to be the ability to obtain high capacities. Derrick's strive for continuous improvement drove the research and development that would produce the most advanced fine screening equipment to date.

Derrick Stack Sizer™

Increasing machine capacity became a main focus for Derrick Corporation. The new machine to be developed had to be based on the understanding that the screen deck width is the main importance for separation performance. In 2001 Derrick Corporation released a new high frequency screen called the Stack Sizer (see Figures 3 and 4). The Stack Sizer is the highest capacity and most efficient fine sizing wet screen produced to date. The increased capacity widened the practicality of fine screen applications in mineral processing plants. The main difference of the Stack Sizer design, when compared to the early Multifeed screens, is the five short screens in parallel, stacked one above the other. This Stack Sizer has 2 to 5 times more capacity than the Multifeed screens.

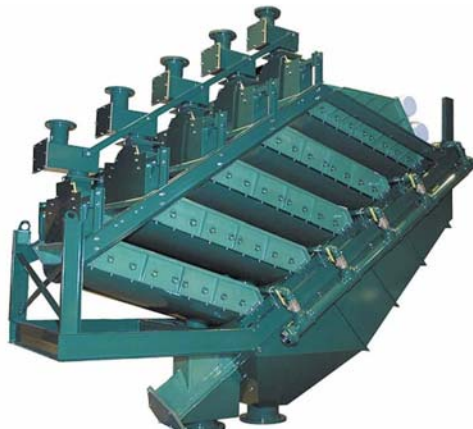


Figure 3: Stack Sizer

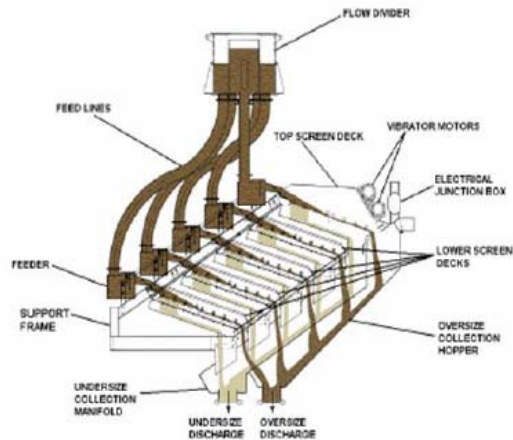


Figure 4: Stack Sizer Flow Distribution

High Open Area Urethane Screen Surfaces

Perhaps even more revolutionary than the Stack Sizer, was the development of a tensionable high open area urethane screen surface. Derrick provides long life, high capacity urethane screen surfaces with typical effective open area ranging from 35 to 45 percent. These design of these urethane screen surfaces virtually eliminate blinding and many customers have reported screen panel life in excess of one year. The urethane screen surfaces are currently being made with apertures as fine as 75 microns.

Factors that Affect Wet Screening⁽⁷⁾

Feed Rate. The capacity of a screening machine is defined as the optimal feed rate to meet the desired product specifications. Feed rate, usually expressed as dry mass flow (t/h), is one of the more critical factors affecting screen performance. The capacity of the screen will determine the number of screening machines required. Exceeding capacity (or over feeding a screen) will result in the misdirection of undersize particles and fluid to the oversize stream as well as a reduction in screen surface life. Depending upon other factors, the optimal feed rate can be exceeded to some extent without a significant decrease in efficiency. The capacity of wet fine screen is best determined by full-scale testing to optimize all factors affecting screen performance.

Feed Density. As explained above, undersize particles are transported through the screen openings by the fluid and therefore, the volume fraction of fluid will affect screen efficiency. Screening efficiency will increase with decreasing feed density. From a practical standpoint, a screen feed density of roughly 20% solids by volume has been found to be a reasonable compromise, independent of dry solids specific gravity. To maximize undersize efficiency (the correct placement of undersize), the screen feed slurry could be even low, perhaps as low as 10 to 15% solids by volume. It has also been shown that it is usually more beneficial to add water to the screen feed slurry than to add the same amount of water directly to the screen surfaces with spray nozzles.

Feed Size Distribution. The size distribution of the material fed to a screen is one of the more important factors affecting both capacity and performance of a wet screening machine. The oversize particles must conveyed off the screen and capacity usually decreases as the amount of oversize increases. Another important factor is the amount of near-size material in the screen feed. Near-size material is defined as the particles that are 2 mesh-size equivalents larger and smaller than the screen opening. Near-size, oversize material inhibits the ability of the undersize material to get through the screen openings and, in some cases, can cause some plugging problems. Selection of screen media is quite important when dealing with significant amounts of near-size material.

Screen Opening and Open Area. The larger the opening, the greater the machine capacity. Conversely, as the desired separation size decreases, so does machine capacity. For example, say that full-scale tests determine that machine capacity is 100 t/h with a 2350 micron (60 mesh) screen opening. Machine capacity could drop to 20 to 40 percent with a 150 micron (100 mesh) openings. At a given size, the open area of a particular screen surface also affects capacity. To increase screen panel life, it may be desirable to use a more robust screen cloth with lower open area. However, doing so will result in a lower machine capacity.

Characteristics of Closed Circuit Grinding With Screens^(2, 5)

The most substantial changes that occur when substituting hydrocyclones to screens in closing circuit grinding are:

- Increased productivity
- Reduced circulating load
- Lower power consumption per ton
- Reduced overgrinding of valuable minerals
- Increased recovery of valuable minerals
- Reduced reagent consumption in flotation
- Reduction in overall operating costs

The mill charge may need to be adjusted to balance for the decrease of circulating load and increase of new feed tonnage.

Areas that should be taken in consideration by the mineral process engineer are the downstream unit operations and beneficiation methods of mineral separation used in the plant. A careful characterization, by a device such as a QEMSCAN, of the classification circuit can give the optimum mineral liberation size prior to any changes. After substituting the hydrocyclones with screens the operator should keep in mind that the grinding circuit product will have a lower specific area. The lower specific area reduces the reagent consumption in the downstream flotation

processes. Another major benefit that screen size classification offers is control over the top size of the particles that leave the grinding circuit. For example, copper flotation circuits often have poor recovery of particles coarser than 70 mesh. A screen can be used to reduce the amount of particles coarser than 70 mesh that leave the grinding circuit. Plant operators should look at all unit operations to take full advantage of the improvements that screens offer in the grinding circuit.

Case Study – Cia Minera Condestable S.A.⁽⁹⁾

CIA Minera Condestable is an underground copper mine located south of Lima and has been in production since 1963. Condestable produces copper concentrates that contain Au with a process capacity of 4100 t/d. A recent expansion project applied Derrick Stack Sizer high frequency screens as the classifier to close the grinding circuit, completely replacing the hydrocyclones. The results obtained are presented on Table 1.

Table 1: CIA Minera Condestable – Expansion Results with Stack Sizers

	Actual	After Expansion	Gains/Losses
Daily Production TMSD	4100	5500	+34%
Annual Production KT	1.497	2.008	+34%
Feed Cu% Grade	1.329	1.245	-6%
Cu Recovery	90%	90%	
Concentrate Production TMS	68845	86516	+26%

A 34 percent increase in total production, to the amount of an additional 1400 t/d, was due to an increase in the grinding circuit classification efficiency. While the plant was operating with hydrocyclones it was processing 171 TMS/h. After changing to the high frequency screens it increased production to 229 TMS/h. Prior to the installation of Derrick's laboratory in Buffalo, New York, USA and the test results are presented below in Table 2.

Table 2. Screen Test Results with Derrick Stack Sizer Screen
Compañía Minera Condestable S.A. - Mill Discharge 1 & 2 - 14 March 2006, Buffalo, NY, USA

Test No.	Feed ¹		Oversize		Undersize				Efficiency ² at 70 mesh			
	Slurry (m ³ /h)	Dry Solids (MTPH)	Solids (%)	Weight (%)	Solids (%)	Weight (%)	Solids (%)	Plus 70 Mesh	Minus 200 Mesh	Oversize (%)	Undersize (%)	Overall (%)
Tests with 0.23 mm (70 mesh) polyurethane panels												
1	187	126	46.8	52.3	81.7	47.7	31.8	9.8	52.2	91.2	88.3	89.8
2	204	137	46.8	52.7	82.1	47.3	31.6	8.2	55.1	92.7	89.4	91.1
15	170	130	51.2	53.4	84.7	46.6	0.0	10.3	56.5	90.6	88.4	89.6
16	187	143	51.2	54.5	84.3	45.5	0.0	8.5	59.5	92.5	87.5	90.1
Tests with 0.30 mm (50 mesh) polyurethane panels												
3	204	137	46.8	50.5	82.5	49.5	32.4	11.3	54.2	98.7	84.8	90.5
4	227	152	46.8	50.3	81.8	49.7	32.6	11.5	53.7	98.5	85.1	90.6
13	170	130	51.2	55.6	83.9	44.4	0.0	10.5	56.2	95.3	81.9	88.3
14	193	148	51.2	50.5	83.5	49.5	0.0	13.1	52.8	92.6	86.0	89.1
Tests with 0.35 mm (45 mesh) polyurethane panels												
5	227	149	46.0	46.3	81.9	53.7	33.4	17.1	50.6	97.5	85.1	89.6
6	250	163	46.0	45.0	81.5	55.0	33.9	18.8	47.7	96.9	85.2	89.4
11	182	141	51.6	51.2	83.4	48.8	0.0	13.0	55.0	96.9	83.6	89.1
12	199	154	51.6	52.7	82.4	47.3	0.0	13.1	55.1	96.8	81.4	87.7
Tests with 0.43 mm (40 mesh) polyurethane panels												
7	256	167	46.0	39.4	82.5	60.6	35.7	25.5	45.3	96.5	89.8	91.9
8	284	186	46.0	39.3	82.2	60.7	35.8	25.3	45.8	96.3	91.1	92.8
9	216	167	51.6	40.0	84.8	60.0	40.9	25.6	44.6	96.2	89.2	91.5
10	250	193	51.6	43.4	83.5	56.6	39.9	23.5	47.0	97.5	86.4	90.0

The Derrick Stack Sizer screens continue to operate without any major problems. The operation parameters defined by the Derrick laboratory tests have been kept and are given the expected results. The control of the percentage of solids in the screen feed has been determined as the most important parameter to produce the best screen performance. Table 3 shows the technical comparisons between the two classification systems, prior to and after the expansion.

Table 3: Technical Comparisons Hydrocyclone - Screen

Operational Parameters	Hydrocyclone	Stack Sizer
Circulating Load	204%	96%
Classification Efficiency	62%-64%	85%
Tonnage Processed TMS/Hr	59	68
Size Distribution Control	Variable	Uniform

Other important results obtained at Condestable beneficiation plant was a 17% increase in the amount of ore processed, better operational control, more uniform particle size distribution produced by the grinding circuit, and a reduction in power consumption per ton. The increased production rate was achieved without an increase in overall energy consumption. An economic evaluation of the investment showed the purchase and installation of one Derrick high frequency

screen Stack Sizer was US\$300,000.00. With the economic gain generated by the 17% increase in production that resulted in US\$2,630,000.00 per year, the return of investment was 1.4 months. Several other mining companies in Peru have replaced hydrocyclones with Stack Sizers in their grinding circuits with similar results. As showing in Table 4, a total of 31 Stack Sizers are operating in Peruvian grinding circuits to date. This trend was started in 2004 by Sociedade Minera El Brocal. Brocal was considering the purchase of an additional ball mill to increase production rates. Following full-scale Stack Sizer screen tests at Derrick, the installation and operation of Stack Sizers at Brocal clearly demonstrated that production rates, metal recovery, and power consumption could be significantly improved with better classification.⁽⁸⁾

Table 4: Application of Stack Sizers in Peru

PERU DERRICK STACK SIZER APPLICATIONS							
YEAR	COMPANY	LOCATION	MODEL	QUANT	PANEL mm	ORE TYPE	Position
2004	SOC. MIN. EL BROCAL	COLQUIJIRCA	2SG48-60W-5STK	3	0.5	Lead/Zinc	Grinding replace cyclones
2005	CÍA. MIN. ARES	EXPLORADOR	2SG48-60W-5STK	1	0.18	Gold/Silver	Grinding replace cyclones
2005	CÍA. MIN. ARES	ARES	2SG48-60W-4STK	1	0.18	Silver/Gold	Grinding Mix with cyclones
2006	SOC. MIN. EL BROCAL	COLQUIJIRCA	2SG48-60W-5STK	1	0.5	Copper	Grinding replace cyclones
2006	CONDESTABLE	CONDESTABLE	2SG48-60W-5STK	4	0.3	Copper	Grinding replace cyclones
2006	COLQUISIRI	COLQUISIRI	2SG48-60W-4STK	1	0.43	Lead/Zinc	Grinding replace cyclones
2006	CÍA. MIN. ARES	ARCATA	2SG48-60W-5STK	1	0.18	Silver	Grinding Mix with cyclones
2006	CATALINA HUANCA	C.HUANCA	2SG48-60W-5STK	1	0.3	Lead/zinc	Grinding replace cyclones
2006	MILPO	EL PORVENIR	2SG48-60W-5STK	1	0.3	Lead/zinc	Grinding replace cyclones
2006	MINERA CORONA		2SG48-60W-2STK	1	0.23	Copper/Zinc	Discharge Rod mill
2007	MILPO	EL PORVENIR	2SG48-60W-5STK	1	0.3	Lead/Zinc	Grinding replace cyclones
2007	SOC. MIN. EL BROCAL	COLQUIJIRCA	2SG48-60W-5STK	1	0.7 y 0.23	Lead/Zinc	Grinding replace cyclones
2007	LOS QUENUALES	ISCAYCRUZ	2SG48-60W-5STK	4	0.23, 0.3	Lead/Zinc	Grinding replace cyclones
2007	MILPO	CERRO LINDO	2SG48-60W-5STK	4	0.3 y 0.35	Lead/Zinc	Grinding replace cyclones
2008	LOS QUENUALES	YAULIYACU	2SG48-60W-5STK	3	0.23, 0.3	Lead/Zinc	Grinding replace cyclones
2008	MILPO	EL PORVENIR	2SG48-60W-5STK	1	0.3	Lead/Zinc	Grinding replace cyclones
2008	CÍA. MIN. ARES	EXPLORADOR	2SG48-60W-5STK	2	0.18	Silver/Gold	Grinding replace cyclones

CONCLUSIONS

The history and advancement of grinding and classification technology during the last century has been a slow process compared to other sciences. The comminution process continues to be the most energy intensive operation in most mineral processing operations. Studies conducted by researchers through the years have demonstrated that the largest potential improvement in the comminution process could be achieved by improved classification. Today, with the increasing cost of energy and the rising value of metals and minerals, the benefits of improved classification through the use of Derrick high frequency screens is now a practical reality.

The commercial-scale replacement of hydrocyclones with Derrick high frequency screens in closed grinding circuits has demonstrated significant metallurgical and economic benefits, including

increased production rates and lower power consumption. Downstream unit operations such as flotation and dewatering also benefit due to a reduction in overgrinding and specific surface area, resulting in improved product grade and recovery and reduced dewatering costs.

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