Innovative Technology Provides for Real-Time, On-Line Direct Measurement of Particle Size in Individual Cyclones

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ABSTRACT

In mineral processing plants, cyclones typically perform the classification duty prior to the downstream recovery process. Particle size distribution of the cyclone overflow is an important parameter and can be viewed as the product of the comminution process. Too coarse of a product will likely have poorly liberated valuable minerals and make recovery difficult. Too fine of a product may represent a missed opportunity to increase plant throughput and/or also result in low recovery due to poor kinetics. “Near-line” particle size measurement instrumentation has been in place for several decades, its availability and low measurement frequency have typically been inadequate for reliable use in automatic control. CiDRA Minerals Processing has developed a novel and robust technology that provides a highly reliable and low maintenance system for “on-line” measurement of the particle size in the overflow of individual cyclones. The system is based around a wetted sensor design with no moving parts and provides a real-time trend of the desired target grind size parameter. The system does not require sampling and associated sample transfer piping that is prone to plugging, thus avoiding high maintenance requirements. Plant data and benefits realized from the latest installations of the CYCLONEtrac PST will be presented.

KEYWORDS

Acoustic, CYCLONEtrac, Hydrocyclone, Impact-based, On-line, Overflow, Particle size, PST, Real-time

INTRODUCTION

Impact-based real-time hydrocyclone particle size measurement

Principle of operation

Acoustic impact-based particle size tracking is a unique method for measuring and controlling the particle size in cyclone overflow streams. The implementation of this technology is centered upon a sensor probe that is inserted into the overflow slurry stream via a two-inch (50 mm) hole in the overflow pipe (Figure 1). Particles within the slurry stream impact the surface of the probe generating travelling stress waves within the probe. A sensor converts these travelling stress waves into an electrical signal and proprietary signal processing techniques convert these signals into a particle size measurement that is output every four seconds. The sensor is constantly in contact with many particles in the slurry stream, thus obtaining information from orders of magnitude more particles than traditional sample-based technologies. The sensor has no impact on cyclone performance because it is located downstream of the hydrocyclone and the presence of an air core ensures there is no change in the back pressure seen by the hydrocyclone.

Figure 1. CYCLONEtrac PST particle sizing sensor mounted on hydrocyclone overflow pipe.

CYCLONEtrac PST System Overview

The PST particle size tracking system includes a measurement probe with its associated electronics on each cyclone overflow pipe, a junction box that consolidates the processed signals from the individual sensors and sends them to a computer that is typically located in the control room. Final processing takes place in that computer and the resulting particle size information is transferred to the plant system via an integrated OPC server. The software provides up to 5 discrete outputs, each with reference to a specific mesh size of interest. This system is outlined in (Figure 2 Cirulis, 2015).

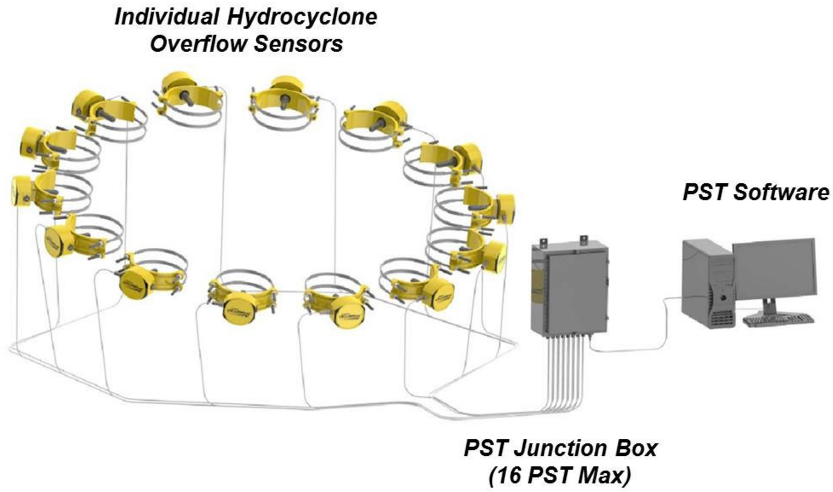

Figure 2. CYCLONEtrac PST plant scale installation diagram.

On-line impact-based PST or alternative "near-line" cyclone overflow particle size measurement methods, whether laser diffraction, ultrasonic or caliper, all require empirical calibration by correlating their signals against reference particles or actual slurry samples analysed with standard laboratory procedures (Wills, 2016). The impact-based CYCLONEtrac PST also requires calibration to compensate for influences from cyclone type and sensor installation location. To ensure a good composite calibration that can be applied across all the cyclones in a cluster, calibration samples must be taken from the overflow of each cyclone in a cluster. Unlike "near-line" methods, with PST, once such calibration takes place, it does not have to be performed again when the probe is replaced due to wear, if the same model of replacement probe is used. In addition, samples must be taken beyond the expected operating range of the cyclones to ensure accurate measurements when the cyclone is operating outside its normal operating range. Calibration ranges must cover above and below the usual operational conditions including but not limited to roping events, startups, shutdowns, and grind outs. This avoids the measurement uncertainty that occurs when calibration models are used to extrapolate measurements beyond their calibrated range. The particle size distribution of the samples is determined in a metallurgical laboratory using a standard procedure for wet and dry sieving. Where it is not possible to use a laboratory, and only a single size output is required (e.g. X% +150micron), CiDRA has a custom wet sieving procedure for rapid processing of samples.

Experience shows that the resulting calibrated signals exhibit a standard deviation that is less than 4.5 percentage points from the corresponding true values. An undetermined but significant portion of this standard deviation can be attributed to the sample collection procedure. Cyclone overflows typically have limited access for sampling, so a full cross-stream sample is normally difficult. Instead plunge cuts or partial cross-stream cuts are performed. An example of the results from the commissioning at a copper concentrator is shown in (Figure 3 O'Keefe, 2016)

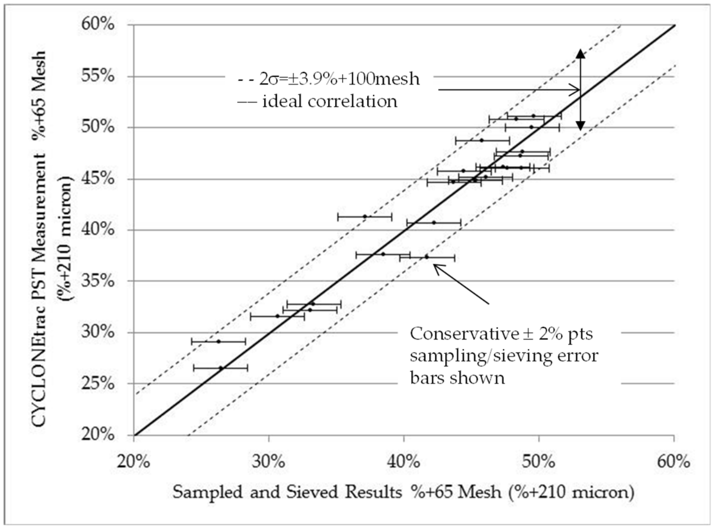

Figure 3. Example of PST results from single cyclone compared to sampled and sieved measurements.

Improving Net Metal Production

On a high level, an operating site can be characterized by the net production of the value metal (NMP), which is determined by the simple expression:

$$NMP = h\ T\ R$$

Where h represents the head grade of valuable metal being recovered, T is the plant throughput and R is the metal recovery (Maron et. al. 2017). Inherent in this methodology is the usual observation that throughput (T), recovery (R) and NMP are strongly correlated to ground product size, in such a way that there would exist in every application an optimal grind size that maximizes NMP. (Figure 4, Maron, 2017) shows an example of optimal NMP as a function of particle size using data from a large copper concentrator.

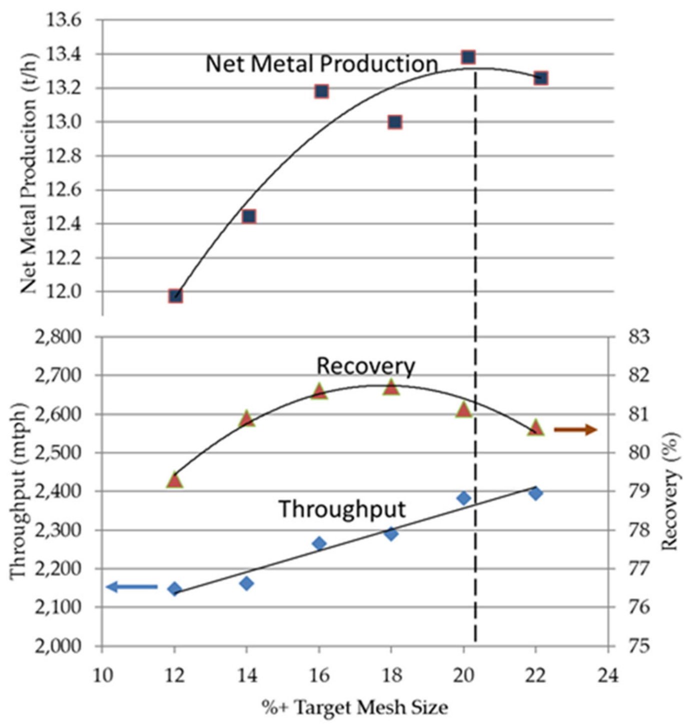

Figure 4. Optimal Net Metal Production as a function of grind size

With particle size under control with CYCLONEtrac PST, it is possible to lower or increase the particle size target to achieve the optimum grind size which would maximize the NMP and the performance of the process. A methodology for assessing potential improvements in NMP using CYCLONEtrac PST has been applied using data from several large copper concentrators in South America (Maron, 2018).

Plant Data

Gold Operation – South America

In mid-December 2016, a CYCLONEtrac PST system was installed and fully commissioned at a gold plant in South America. CYCLONEtrac PST probe sensors were installed on the cyclones associated with the ball mill in the primary grinding stage (Figure 5).

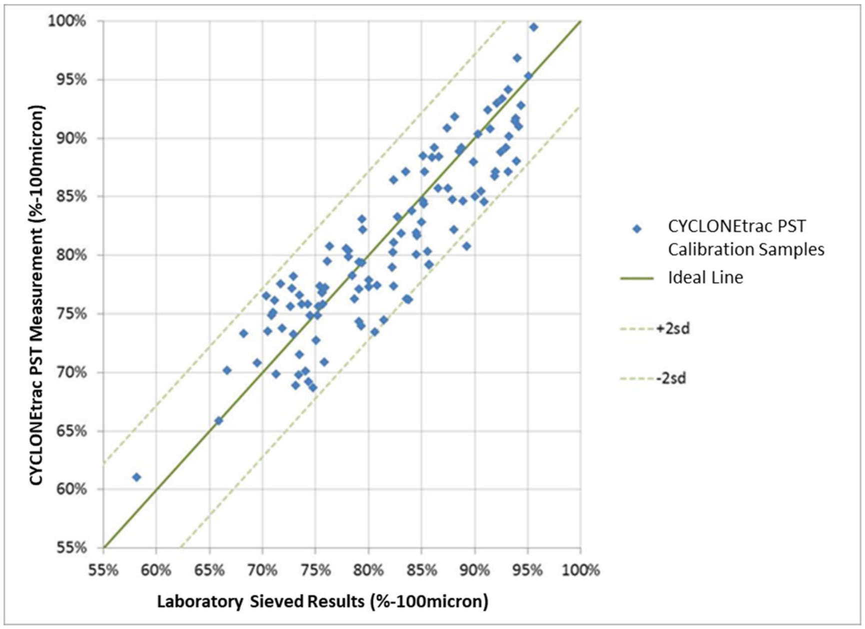

Figure 5. CYCLONEtrac PST 100micron measurements compared to the sieved samples for a gold plant

The CYCLONEtrac PST system was calibrated using the data from the wet sieve analysis, with a resulting 2-sigma of ±7.20%. The system showed a strong correlation with process variables and tracks process upsets in real time, such as a change in cyclone feed density (Figure 6), which allows operators to quickly react to events on a cyclone-by-cyclone basis.

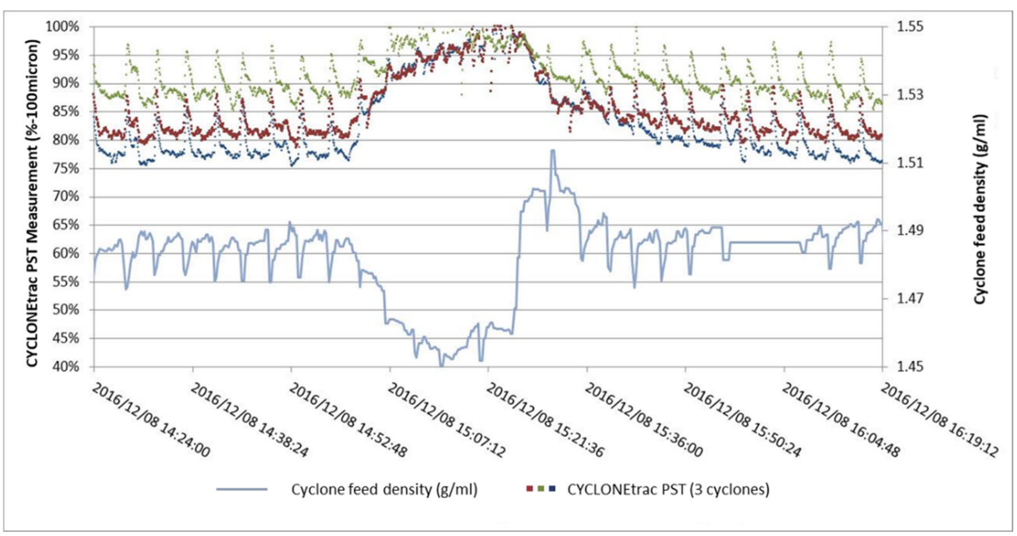

Figure 6 CYCLONEtrac PST system tracking process upsets in real time

The CYCLONEtrac PST system was installed in conjunction with other instruments and integrated into a specialist system for enhanced mineral recovery. Therefore, it is difficult to isolate the impact of the CYCLONEtrac PST system alone. However, the table below shows a throughput increase of more than 8.6% on Ball Mill 01 and at the same time, a reduction in grind size variability (decrease in standard deviation). The resulting ball mill product size is higher; however, this operation studied the impacts of higher grind size and CYCLONEtrac PST was the enabling factor to allow this to happen in practice due to real-time control (Table 1).

Table 1. Grind circuit control improvements

SCENARIO	DESCRIPTION	BALL MILL 01 (M01)	RETAINED 200# M01	
		t/h	Average	Std. Dev.
0	Plant before improvements	105	37	3.2
1	Ball mill water addition control	108	37	3.5
2	Density control	110	36	3.0
3	Density control using the PST	110	36	1.8
4	**PST integrated to a specialist system**	**114**	**82**	**1.5**

Source: data collected after 4-6 months from PST installation.

Copper Operation - USA

CiDRA Minerals Processing offers CYCLONEtrac PST single cyclone surveys as a way of allowing operations personnel to observe the PST data in their plant for a limited time. The survey involves the temporary installation of a PST sensor, cyclone overflow calibration sampling and data collection using CiDRA's standalone equipment. Typically, the survey can be completed within one week.

(Figure 7) shows a 24-hour period of data collected during a single cyclone survey at a copper concentrator in the USA. In this case the PST instrumented cyclone (bottom trace) was alternating between two operational states depending on the level of ball mill loading, as shown by the ball mill power trace. The PST data shows the cyclone overflow grind size changed abruptly from approximately 30% +212micron to approximately 50% +212micron as the ball mill power falls. The coarser cyclone overflow is above the target grind size for this operation and downstream flotation recovery is likely being impacted during this time periods. With feedback from CYCLONEtrac PST on all the cyclone overflow streams, the grinding circuit could be optimized to avoid negative downstream impacts.

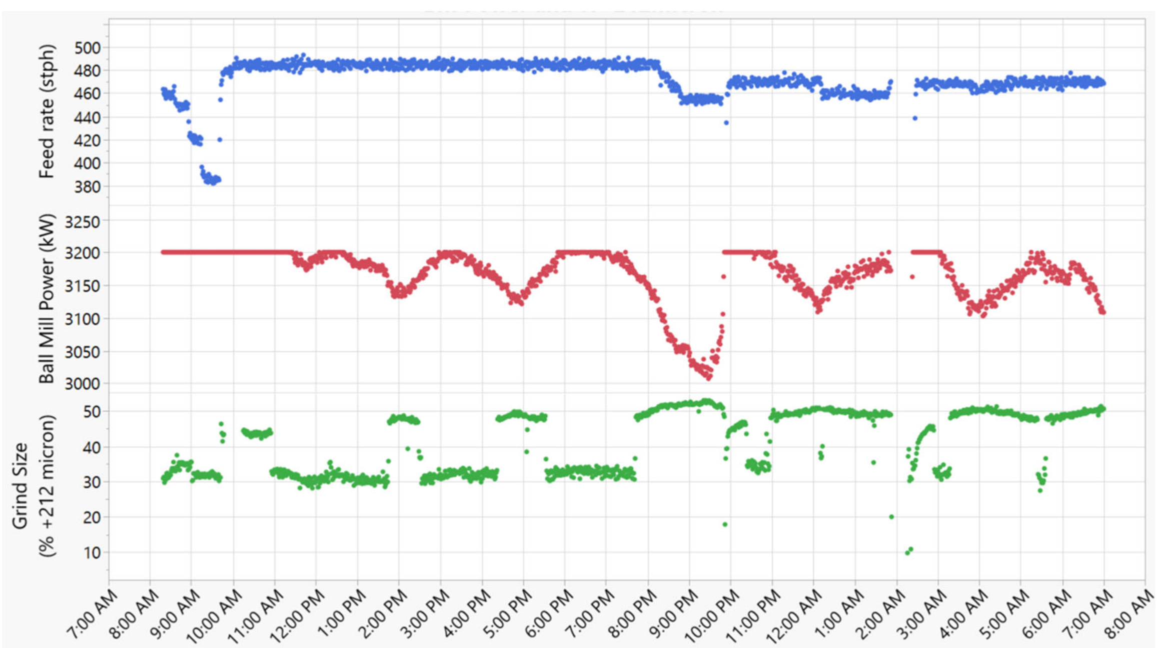

Figure 7. Example of PST results from single cyclone survey of a copper operation in the USA

Gold Operation - USA

The CYCLONEtrac PST system can now track multiple sieve sizes of interest. The first commercial installation of this feature was recently deployed at a gold operation in the USA, using 150micron, 106micron and 53micron as the sizes of interest. The benefit of tracking individual cyclone performance remains, as shown in (Figure 8a), where a cyclone enters an out of class state and remains that way for approximately 5 hours. A Weibull model of the particle size distribution based on the 3 sizes before and during the event is shown in (Figure 8b). Before the event, the P80 is on the finer side with a typical distribution for a cyclone overflow stream operating efficiently. However, during the event there is a large increase in the P80 (approximately 60micron) and a flattening of the distribution indicating poor cyclone efficiency.

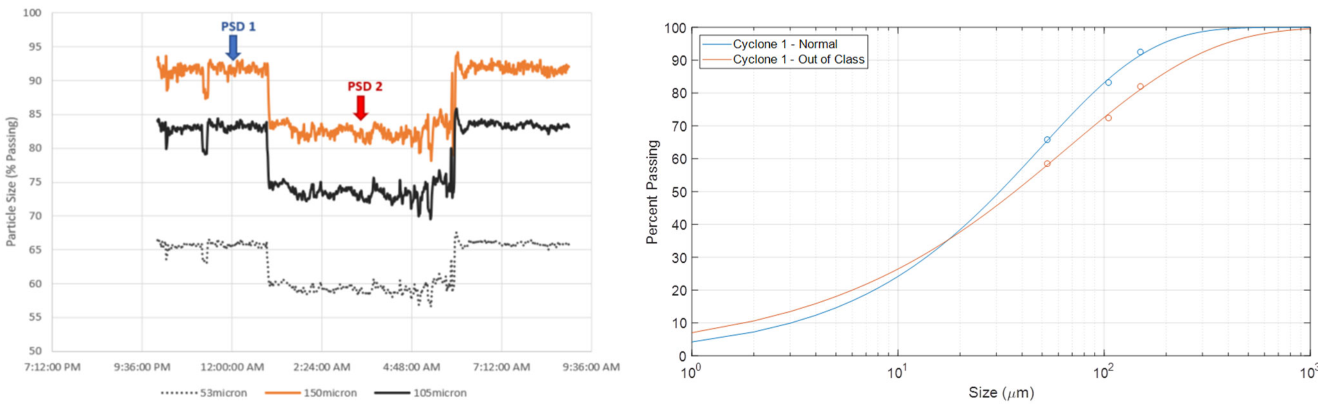

Figure 8(a,b) a. Out of class cyclone, tracking 3 particle sizes at a gold operation b. Modeled particle size distribution

Recommended cyclone operating pressure varies by manufacturer, model and application. Higher operating pressures increase the centrifugal force inside the cyclone and will lower the cut size and water split to the underflow (Lynch, 2015). Cyclone pressure can be controlled by the number of cyclones in operation. (Figure 9a) shows the resulting increase in pressure from closing a cyclone. (Figure 9b) shows the particle size distribution at low and high pressure, with an increase in pressure lowering the coarse fraction and increasing the fine fraction in the cyclone overflow. Of course, changes in cyclone operation in a closed circuit cannot be considered in isolation as there would likely be an increase in the recirculating load in this case. Nevertheless, this example highlights the importance of pressure control and with the addition of CYCLONEtrac PST on cyclones, opens the door for improved optimization.

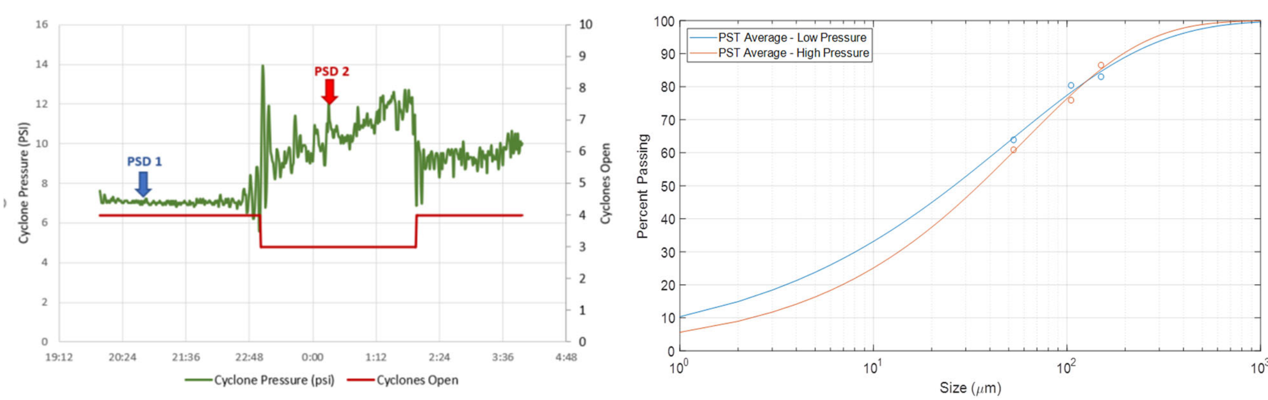

Figure 9(a,b) – a. Increase in cyclone operating pressure b. Particle size distributions at higher and lower pressure modeled from CYCLONEtrac PST outputs (arrows on Figure 9a indicate time of size distributions)

Summary and Conclusions

Reliable product size measurement in comminution circuits is key for optimizing control, especially for downstream recovery processes that can be sensitive to particle size, such as flotation. As discussed in this paper, CiDRA's PST technology provides a highly reliable and low maintenance system for true on-line measurement of the particle size to be incorporated into a grinding/classification system control strategy.

The PST system is commercially operating in premier copper and gold operations around the world and has been trialed in many more. The data presented in this publication shows the potential application of particle size measurement for individual cyclones and the insight it could provide operators into their plant performance. Realized benefits through incorporating PST into a control strategy include increased throughput, lower particle size and lower energy consumption at the same throughput and increased mineral recovery (Cirulis, 2015).

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