Optimizing Secondary Grinding Circuits with real-time Particle Size Tracking on Individual Cyclones

Dylan Cirulis, Robert Maron*, Christian O'Keefe and Juan Medina
CiDRA Minerals Processing, USA

ABSTRACT

The prolonged duration of depressed metal prices has caused mine operators to change their focus away from adding new assets to increase capacity, to optimizing existing assets to increase throughput, recovery and efficiency. This change in focus resulting from a business crisis has been studied in other cyclic industries, and is understood to present an opportunity for significant changes, one of those being asset optimization.

To identify the asset optimization process with the best economic return, one should search for key performance metrics that are not being adequately addressed by existing technologies. One of the most important metrics is particle size measurement of the output of grinding circuits that feed rougher flotation. For years traditional online particle size analyzers have been implemented in these applications; however, in many plants their availability has been unacceptably low to permit their reliable use in real-time process control. Additionally, maintenance requirements have been high due to lack of robustness and complexity of sampling systems. Importantly, since they only measure the consolidated output of an entire battery, they do not permit the use of control strategies that can identify and address individual cyclones that are performing poorly.

This search for the best asset optimization project has recently led several concentrator plants to select and implement a novel particle size tracking technology on individual cyclones due to the deficiencies of existing technologies and the excellent financial metrics, such as a payback period of less than one year.

This paper presents the CYCLONEtrac Particle Size Tracking (PST) technology that has been installed in nine large concentrator plants. Plant data will be presented showing the benefits of improved process control enabled by using strategies based on individual cyclone measurements, and consolidated measurements of the entire cyclone battery.

INTRODUCTION

Minerals processing plants typically use grinding mills in closed circuit with hydrocyclones to produce a product with a specific particle size distribution for optimum downstream process recovery. Existing instrumentation that provides particle size measurement is considered standard in most modern concentrator plants. However, instrumentation availability is often very low, mainly owing to high maintenance requirements of the analyser and associated sampling system.

CiDRA Minerals Processing Inc. 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, such as a percentage retained on screen (e.g. % +100mesh). The system does not require sampling and associated sample transfer piping that is prone to plugging, thus avoiding high maintenance requirements.

PRINCIPLE OF OPERATION

Acoustic impact based particle size tracking is a unique method for measuring and tracking particle sizes in cyclone overflow lines. The implementation of this technology is centered upon a probe that is inserted into the slurry stream via a two inch (50 mm) hole in the overflow pipe as seen in Figure 1. Particles within the slurry stream impact the surface of the probe generating traveling stress waves within the probe. A sensor converts these traveling stress waves into an electrical signal and proprietary signal processing techniques translate these signals into a particle size measurement that is output every four seconds. The sensor effectively samples a few percent or more of the slurry stream, which is orders of magnitude more than is sampled by other traditional technologies that utilize online samplers and that do not sample individual hydrocyclones. Also, because of the location of the sensor downstream of the hydrocyclone and the presence of an air core at that point, the sensor produces no change in the back pressure seen by the hydrocyclone.

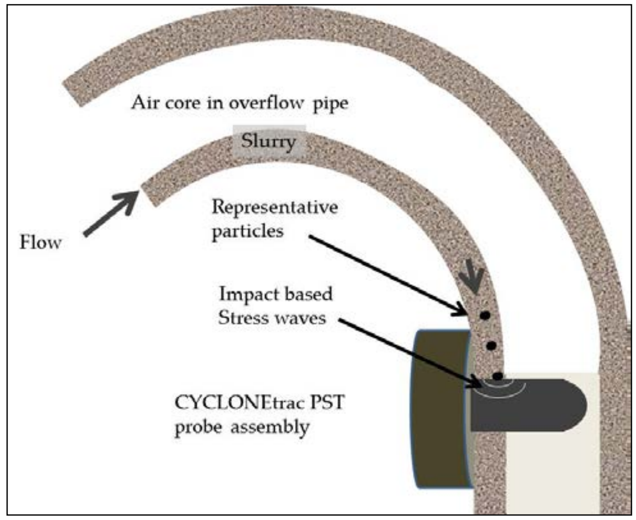

Figure 1 CYCLONEtrac PST - Installed on overflow pipe (left); illustration of principle of operation (right)

On-line cyclone overflow sizing methods, whether laser diffraction, ultrasonic, caliber or impact based, require calibration by correlating their signals to reference particles or to samples that are correspondingly analyzed with laboratory screens (Outotec, 2009). The impact based CYCLONEtrac PST also requires calibration to compensate for influences from cyclone type, ore 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. Once such calibration takes place, it does not have to be performed again even if the probe is replaced. 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 including but not limited to roping events, startups, shutdowns, and grindouts. This avoids the measurement uncertainty that occurs when calibration models are used to extrapolate measurements beyond their calibrated range.

CYCLONEtrac PST Technology Comparison

CYCLONEtrac PST differs from the traditional particle size measurement approach in a number of ways. Table 1 outlines some of the key differences between the available technologies used for particle size measurement in comminution circuits. CYCLONEtrac PST was developed to bring a particle size measurement solution to comminution circuits. A demonstrated combination of high on-line availability and fast update rate enable closed loop control of the circuit product.

Table 1 Particle size measurement technology comparison

Feature	CYCLONEtrac PST	Traditional Consolidated Cyclone Overflow Measurement Systems Using Calipers, Ultrasonics, or Laser Diffraction	Laboratory Sieving
Update rate	4 seconds	3-9 minutes	Typically 2 hours with 12-24 hours latency
Enables sustainable closed loop control	Yes	No, (typically limited by system availability and data latency)	No
Full stream analysis	Yes	No	No
Sampler Free	Yes	No	Yes
Availability	>98%	Typically low with exceptions	High
Number of particle sizes reported[a]	The one key particle size needed for control. (2 or more possible in future)	Multiple[b]	Multiple[b]
Calibration Frequency	One time	Continuous	N/A
Performance monitoring of individual hydrocyclones	Yes	No	Possible but not typical

a. The majority of control systems today utilize only one particle size as an input

b. Multiple sizes typically include one size reported to the control system, the rest for general reporting and process monitoring

CONTROL STRATEGIES AND THEIR BENEFITS

Two basic control strategies are possible with PST. First, the individual particle size measurements enable a battery-level control strategy whereby individual measurements are combined into a single measurement such as a median. The median signal can then be used to adjust other parameters such as feed density, battery pressure, feed tonnage, etc. to adjust particle size and achieve an informed tradeoff between particle size and throughput. Second, the individual particle size measurements also enable a cyclone-level control that can be used to identify cyclones that are performing poorly, and then corrective action can be taken by restarting the cyclone or closing the cyclone and opening a replacement cyclone. Both strategies and their respective benefits are explained in the following two sections.

Benefits of Controlling Particle Size, Battery-Level Control

The particle size of the product stream from the grinding circuit is a critical key performance indicator (KPI) because it is directly linked to the mineral recovery, grinding efficiency and overall plant throughput. There exists a trade-off between the circuit input (i.e. fresh feed or throughput) and the circuit product (i.e. cyclone overflow particle size). With the development of CYCLONEtrac PST comes the commercial availability of a robust on-line particle size measurement allowing for the development and optimization of particle size control schemes that can take advantage of this trade-off within the circuit constraints.

A large concentrator recently developed a new multivariable control scheme using CYCLONEtrac PST. Grinding efficiency is maintained by holding the particle size and ball mill power within a desired range through manipulation of the cyclone feed percent solids. Figure 2 shows an example of the variables under control and their set points/targets.

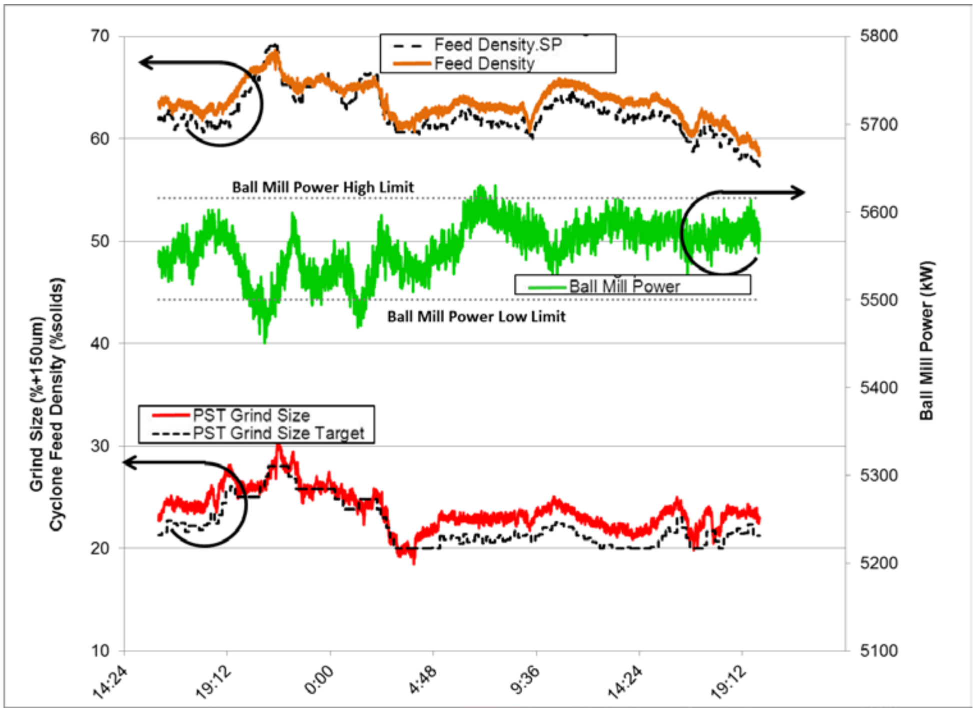

Figure 2 Example of CYCLONEtrac PST based control

A paper by Cirulis et al, 2015, describes the case study and control in more details. Using a CYCLONEtrac PST based control scheme the operation was able to demonstrate:

- up to a four and half percent reduction in particle size at the same throughput
- up to 10 percent increase in throughput at the same particle size

Benefits of Measuring Individual Cyclones, Cyclone-Level Control

Up to now, there has been no instrumentation on individual cyclones, making it very difficult to identify cyclones that are performing poorly and to quantify this effect on the grind-classification process. A single poorly performing cyclone can have a significant impact on the entire grinding and classification circuit and cause severe disruption to downstream processes. The major impacts include but are not limited to:

- Extended downtime due to cell, slurry line or tank blockages
- Lost efficiency due to poor coarse particle recovery

The root causes of these events are varied but are commonly a cyclone blockage (rubber liner, object) or exceeding the cyclone capacity, which is defined by pressure, flow and the cyclone dimensions. An example of a cyclone (Cyclone 7) entering an out of class state following a 10 percent increase in the SAG mill feed is shown in Figure 3 below. Due to the short-circuiting of the cyclone feed, the load on the remaining cyclones is reduced, as inferred by the lower particle size product each cyclone produces. Once cyclone 7 is closed the cyclone feed flow and pressure recover and after a surge in cyclone pressure another two cyclones start to perform poorly for ten minutes after which they are closed.

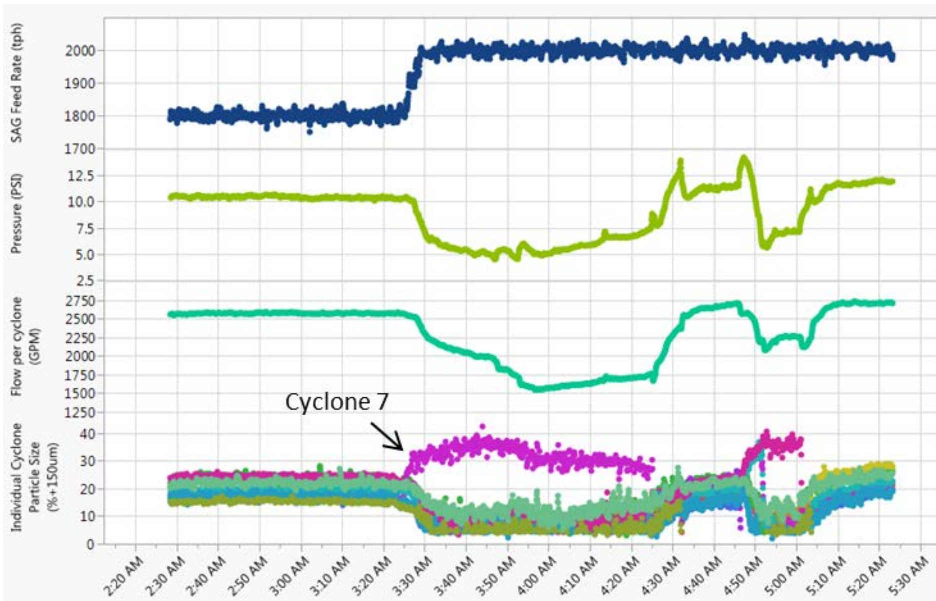

Figure 3 Example of a poorly performing cyclone

In addition to out of class events like in Figure 2, cyclones in a cluster perform differently under normal operation. This can be due to items such as uneven flow distribution and wear rate variability. CYCLONEtrac PST enables active cyclone control, whereby the optimum particle size distribution is produced by ensuring coarse cyclones are closed.

For example:

At a specified time interval, the coarsest cyclone is closed if it is more than 1 sigma above the median CYCLONEtrac PST signal. Simultaneously another cyclone is opened to keep the pressure disturbance minimized.

Data from a concentrator with a known recovery as a function of particle size was used to model the recovery per cyclone as a function of the CYCLONEtrac PST signal. The results of the active cyclone control were then simulated using the following strategy:

1. Every 30 minutes, the coarsest cyclone is closed, if it is more than 1 sigma above the median PST signal
2. When it is closed, its signal is replaced with the median (i.e. statistically the new cyclone gives the median grind)

The recovery and the copper losses to tails were then recalculated to get approximately $2 million per year in savings with active cyclone control. This does not include the benefits of out of class cyclone detection or global particle size control, which can be an order of magnitude higher in value.

CALIBRATION PROCEDURE AND RESULTS

The CYCLONEtrac PST requires calibration as do all other on-line cyclone overflow sizing methods. The PST calibration was briefly described in the Principle of Operation section of this paper. The ability to calibrate on a variety of ore types, cyclone types, and installation pipe locations determines the robustness of the technology. To evaluate this, in late 2015 it was decided to embark on a program to gain as much experience as possible with calibration of PST. The program examined data from existing commercial installations on full batteries of cyclones, as well as data taken from calibrations performed on single cyclones. Examples of calibration results for each type of installation are shown in Figures 4 and 5 below. In all, nine different installations were examined covering four ore types (copper, gold, iron, phosphate), four cyclone types, cyclone orientations ranging from horizontal to vertical, and sensor installation locations on overflow pipes that ranged from horizontal to vertical. Details of this work were previously published (O'Keefe, C., Maron, R., Cirulis, D., Medina, J., 2016). The conclusion of this work is that acoustic impact based particle sizing technology implemented in the CYCLONEtrac PST has demonstrated excellent performance when compared to the sampled and sieved data for a variety of ore types, cyclone types and orientations, overflow pipe configurations and particle sizes. Differences between the PST measurements and the sieved samples are due to both measurement noise and sampling/sieving uncertainty.

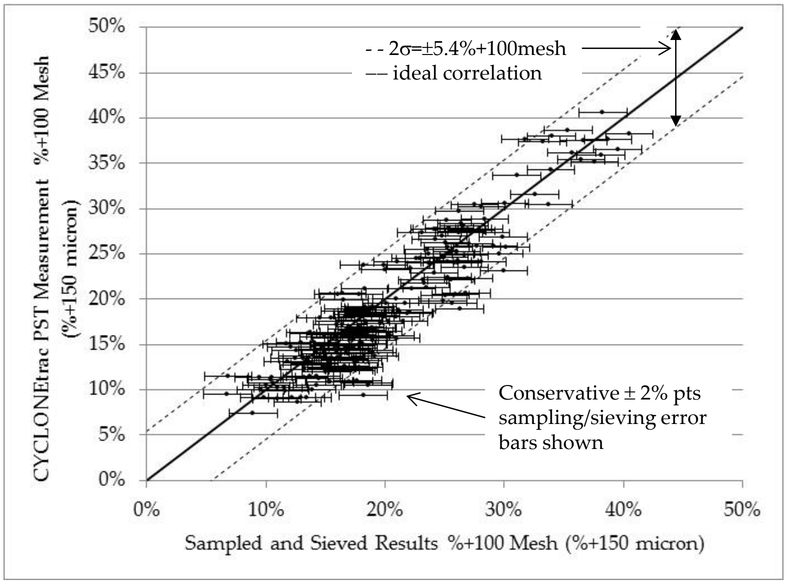

Figure 4 CYCLONEtrac PST 150 micron measurements compared to the sieved samples for a large copper concentrator

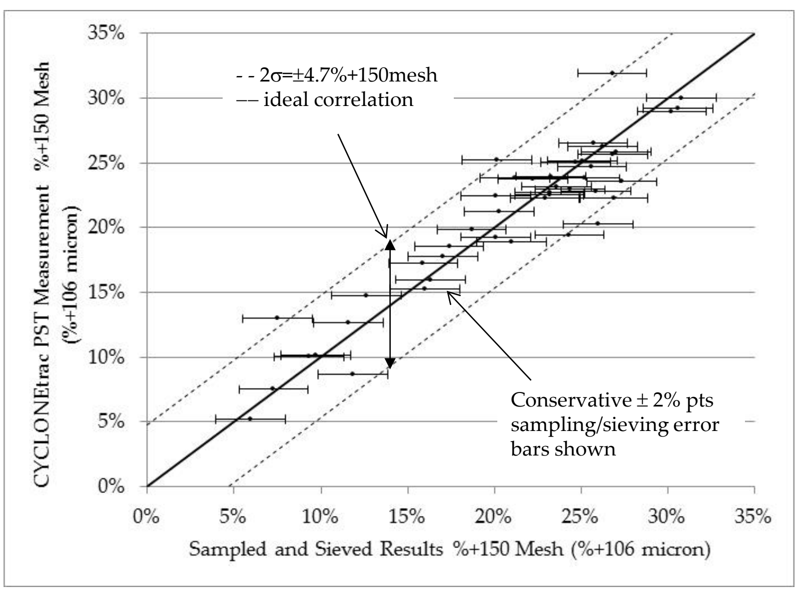

Figure 5 CYCLONEtrac PST 106 micron measurements compared to the sieved samples for a gold concentrator

CONCLUSION

CiDRA Minerals Processing has developed on-line particle size measurement technology that offers significant advantages over what is considered standard equipment in the industry. The CYCLONEtrac Particle Size Tracking (PST) system is now commercially installed at two large copper concentrators. This paper was written to provide a technology comparison and a discussion of the benefits that can be realized from installation of the PST System. The use of CYCLONEtrac PST in a global particle size control scheme has demonstrated significant economic benefit to a large copper concentrator. Furthermore, using CYCLONEtrac PST for active individual cyclone control offers additional economic benefit to an operation.

ACKNOWLEDGEMENTS

We acknowledge the cooperation of staff from multiple plants for the installation and calibration of the CYCLONEtrac PST systems.

REFERENCES

Cirulis, D., Dunford, S., Snyder, J., Bartsch, E., Rothman, P., Maron, R., Newton, D., O'Keefe, C., and Mercuri, J. (2015) 'Process optimization using real team tracking of coarse material in individual cyclone overflow streams', *Metplant 2015*, Perth, Australia, 7-8 Sep.

O'Keefe, C., Maron, R., Cirulis, D., and Medina, F. (2016) 'Survey of Real-Time Individual Cyclone Particle Size Tracking (PST) In Multiple Concentrators', *Automining 2016*, Santiago, Chile, 30 Nov – 2 Dec.