Hydrocyclone classification optimization using real-time coarse particles detection in the overflow stream

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ABSTRACT

This work presents a new instrument for non-invasive, real-time detection of excessively coarse particles in the overflow pipes of individual hydrocyclones. It enables operators to identify poorly performing hydrocyclones in need of maintenance and remove them from service. It also enables a reduction in coarse particles arriving to flotation that causes; cell maintenance for cleanout of this material, unplanned row shutdown due to blocked dart valves, and damage to cell components such as rotors.

The hydrocyclone is an important device used in mineral processing beneficiation circuits for classification of mineral slurries by particle size. One input stream is separated into two output streams; an underflow of coarse particles that undergo additional grinding, and an overflow stream of finer particles that typically goes directly into a flotation circuit for recovery of the desired mineral. However, the hydrocyclone is a major piece of equipment in the beneficiation process that has no instrumentation for directly measuring its performance. The parameters currently measured – inlet pressure, feed flow rate, feed flow density – are common to the entire hydrocyclone cluster which has many hydrocyclones. Thus, no information is available to detect individual hydrocyclones that are operating poorly.

The system described here detects the presence of unwanted excessively coarse particles in the overflow stream of a hydrocyclone using sensors mounted to the exterior pipe surface. It provides real-time monitoring, trending, and alarming of the coarse particle level. This enables operators to identify poorly performing hydrocyclones and take corrective action to reduce or eliminate the coarse particle discharge. The system development, operating principle, and in-plant operating data will be presented.

In addition to enabling reductions in maintenance costs, the system also enables a general improvement in flotation recovery because the gradual accumulation of coarse particles in flotation cells over time decreases the cell's recovery efficiency.

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INTRODUCTION

In the mining of metals, such as copper, the ore is commonly processed in a concentrator. The concentrator typically consists of two main functions. These are the grind circuit and the flotation system. In the grind circuit the ore is crushed to an optimum particle size distribution to liberate the mineral (Fig. 1). The ground ore is passed as slurry to the flotation system to separate the mineral, or minerals, of interest from the gang material, thus extracting and concentrating the desired material for further processing.

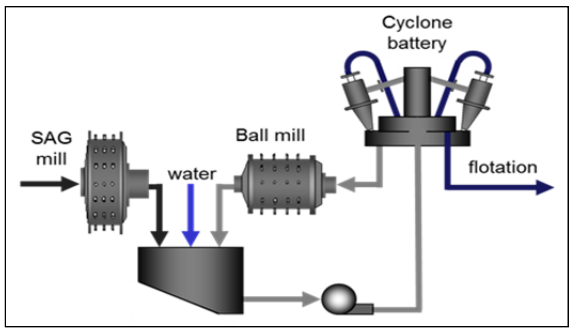

Figure 1 Example of a common multi-stage grind circuit

To efficiently liberate the minerals, the optimal size particles need to be separated from the coarse material and the coarse material is directed back to the grinding mills for further grinding. Obtaining this optimum particle size distribution is a trade-off between throughput, recovery, and grinding cost. To maximize recovery in flotation, the distribution of particle sizes will contain a minimum of excessively coarse material, which will not float. This distribution will also be free of an excessive quantity of fine material, which increases electrical power requirements disproportionately to the increase in recovery as well as reducing the collision efficiency between air bubbles and liberated mineral particles (Fig. 2). Achieving this desired particle size distribution requires a sufficient understanding of the current state of the grinding and separation processes to facilitate timely changes to the operating strategy.

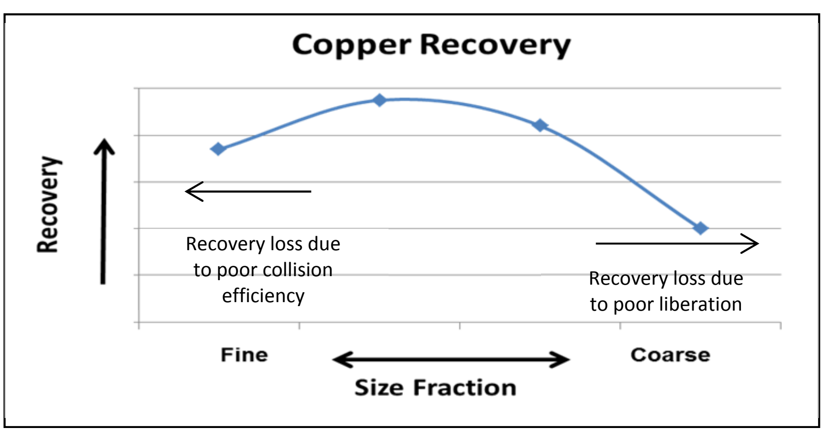

Figure 2 Classical recovery versus particle size relationship

MOTIVATION

Many operators place a premium emphasis on asset management. However, the need to extract maximum value from the grind plant means that maintenance intervals will be stretched as long as possible. Additionally, maximizing the return on equipment investment requires operating the plant at the highest throughput possible without compromising safety, excessive equipment wear, or reduced recovery. This presents a wide variety of operating conditions as one asset approaches the need for maintenance while others are new or recently refurbished. The performance of hydrocyclones is negatively impacted and they will report coarse material to the overflow when not operating as designed. Coarse material reporting to the overflow is passed directly to the flotation system. Coarse material in the flotation feed reduces the economic performance of the concentrator through lower valuable mineral recovery and, in extreme cases, through blocking of the flow path in the flotation cells.

The traditional instrumentation in each ball mill/hydrocyclone cluster system is installed on the common system components. Typically these measurements include hydrocyclone feed flow, feed density, manifold pressure, sump level, etc. Determining the exact source of the oversize can be a complicated and time consuming process for a busy operations crew. The time spent in troubleshooting the cause of oversize can result in considerable disruption to the flotation circuit before the offending hydrocyclone is taken offline. CiDRA has developed and commercially deployed a new technology for monitoring individual hydrocyclone overflow lines for large particles and the associated coarse material discharge.

VALUE

At an example concentrator the typical target grind size for flotation feed is a P80 (point or particle size that is 80% finer in the overflow) in the +150 to +250 micron (100 to 60 mesh) range. Hydrocyclone product greater than +250 micron is considered coarse or oversize. When the P80 increases to around +400 micron (very coarse) the overflow slurry becomes dense enough to begin lifting 6-12mm (large particles) with the overflow (Fig. 3). These large particles and very coarse material can block the internals of the flotation cells, significantly impacting their performance. Some causes of very coarse material and large particle events include:

- SAG (Semi-autogenous Grinding) mill grate, screen or trommel panel failure
- Hydrocyclone roping or liner/wall failure
- Degradation or failure of SAG mill pebble removal system

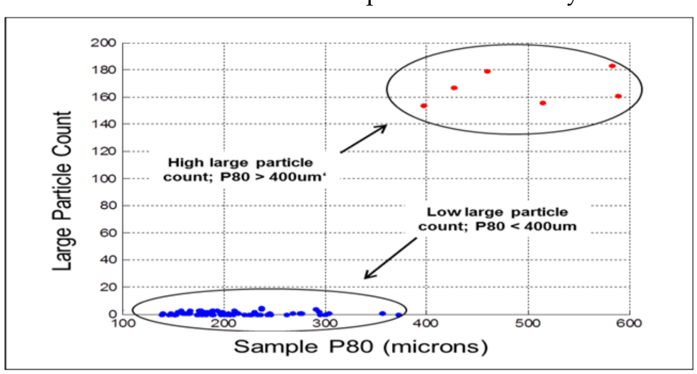

Figure 3 During field validation, 78 sieve samples were analysed and compared to concurrent large particle counts. When P80 is >400 microns, the slurry density allows large particles to be lifted, reporting to overflow

The economic impact of large coarse material events are straight forward to quantify. The following are some examples:

- Rougher row downtime (unplanned shutdown)
- Equipment damage (flotation cell internals, slurry pumps, etc.)
- Clean-up costs

In other cases the economic impacts are more complex to quantify. The following are some examples:

- Decay in flotation cell performance over time (event not large enough to lead to shut down)
- Reduced metallurgical production (recovery loss through lower residence time, disrupted flow patterns)
- Changes in the grinding circuit operating conditions
- Damage to or wear of either the vortex finder or apex of the hydrocyclone

Recovery of coarse mineral particles in the flotation circuit is significantly lower than fine particles. This is in part due to decreased mineral liberation and limitations in the ability to recover coarse particles by flotation (Fig. 4).

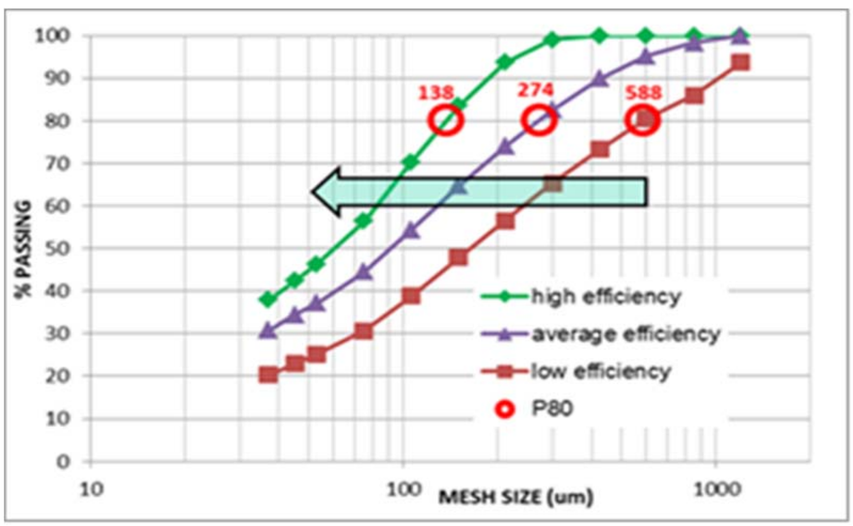

Figure 4 The family of curves in this Shumann plot demonstrates how the variations in P_{80} can affect the recovery efficiency; the goal is to move in the direction of the large arrow

The value lies in detecting a large particle event (6-12mm and larger) in the hydrocyclone overflow and then optimizing hydrocyclone performance in order to eliminate +150 micron particles from reporting to flotation. The new technology aims to:

- Provide early detection of increasing coarse material trends
- Identify hydrocyclone failures
- Identify which particular hydrocyclone(s) is/are producing the excessive coarse material or oversize

SYSTEM DEVELOPMENT

One approach to confront the previously described grind challenges is to monitor grind system performance for large particles (+6 to 12mm) at the individual hydrocyclone level, rather than the cluster level. This approach has the advantage of allowing a hydrocyclone cluster to remain in operation while a performance issue is isolated to one or more individual hydrocyclones. However, this requires a new class of instrumentation, one that monitors the performance of each hydrocyclone in real-time.

One of CiDRA's core competencies is the measurement of acoustic information through the wall of a pipe: (Gysling, Loose & van der Spek, 2005) and (O'Keefe, Viega & Fernald, 2007). This technology is not only well suited for monitoring individual hydrocyclones but also for doing so in a non-intrusive manner. In CiDRA's embodiment, *CYCLONEtrac*^{SM}, the acoustic sensor is attached to the external surface of the pipe, allowing the acoustic sensors to be installed and maintained without process interruption and without wear concerns.

Throughout the development of the *CYCLONEtrac* system, real-time acoustic data for both normal and abnormal operating conditions were recorded, including many very coarse material and large particle events. The recorded time series data was utilized to develop and optimize a proprietary algorithm that detects and displays the changes in large particle and very coarse material trends for individual hydrocyclones and the consolidated trend of each cluster of hydrocyclones. Evaluation of the trends allowed thresholds and alarms to be set, thus balancing sensitivity against false alarms. Proper setting of thresholds has allowed the operators to effectively control the separation process via manual intervention. While the system displays the trend of various sizes of coarse material, the minimum material size for repeatable detection of individual particles is approximately 6 to 12 mm (Fig. 3).

In addition to coarse material the system provides a backup solution for unreliable feed isolation valve position indicators (limit switch failures). It does so by using the same acoustic signals to differentiate between a hydrocyclone that is off (feed isolation valve shut) or one that is on (feed isolation valve open).

The information from the instrumented hydrocyclones is used by the *CYCLONEtrac* system to determine not only the operational state of each individual hydrocyclone but also each cluster of hydrocyclones. In addition to a real-time display, data is fed to the concentrator's Distributed Control System and transmitted to the CiDRA data centre for the generation of daily and weekly performance and utilization reports. The displayed data, archived data, and the summary reports facilitate smart maintenance scheduling and aid in troubleshooting. This has the effect of reducing the downtime associated with periodic maintenance, repairs and unscheduled rougher cell cleaning.

COMMERCIAL DEPLOYMENT AND OPERATIONS

The *CYCLONEtrac* system has been commercially deployed on all 88 primary hydrocyclones at Kennecott Utah Copper's Copperton concentrator (KUCC) in Utah, USA since 2010: (Cirulis & Russell, 2011).

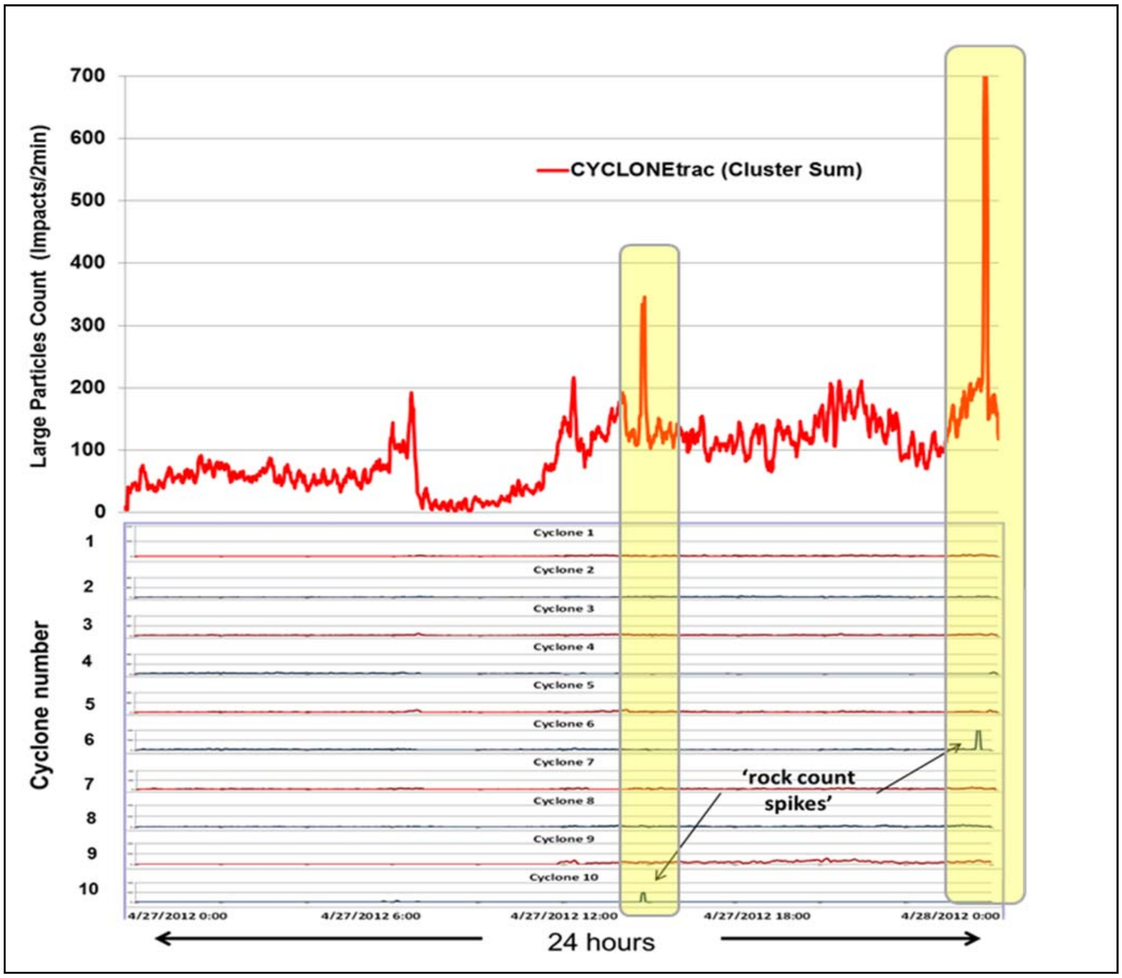

Figure 5 Single hydrocyclone causes the combined overflow of the cluster to display a spike in the coarse material trend

With the *CYCLONEtrac* system now fully deployed and integrated into concentrator operations, there are specific scenarios that are illuminated by providing actionable information to the operator. This information provides the operator with the ability to determine if there is an issue with the performance of an entire cluster or with only one or a few individual hydrocyclones. An HMI (human-machine interface) in the control room displays trends on the aggregated performance of each hydrocyclone cluster.

The operator discriminates between the two types of events, individual hydrocyclone operating abnormally or a broader system related problem, by consulting the event level trends for the individual hydrocyclones of the poorly operating cluster. If a single hydrocyclone is indicated as the cause (Fig. 5) then the offending hydrocyclone may be isolated and an alternate placed in operation. In other cases, multiple hydrocyclones are responsible for the increase in large particle count. The operator is alerted to this condition by the trend graph and settable alarms for one or more hydrocyclone clusters. In this case the operator must take action to correct plant operating parameters, such as feed density, to the indicated hydrocyclone cluster(s) (Fig. 6).

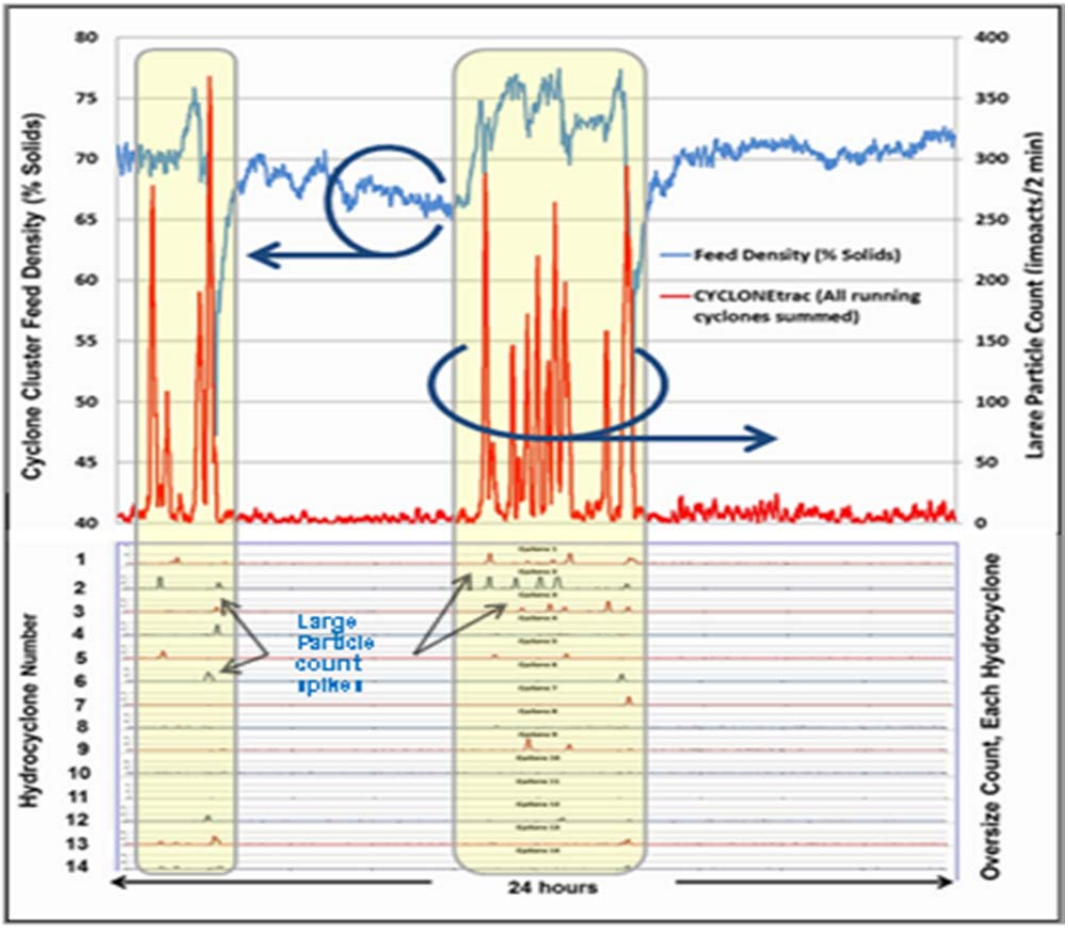

Figure 6 Multiple hydrocyclones cause the combined overflow of the cluster to display spikes in the coarse material trend which is coincident with increases in feed density to the cluster

The response to one or more hydrocyclones in alarm state is for an operator to isolate the offending hydrocyclone (which may be easily automated) and sample the overflow stream of the remaining hydrocyclones in the cluster for large particles. The result of these samples will confirm the breadth of the problem and provide direction for finding the root cause of the poor classification performance. The operating strategy and control response plans for such events have been adopted and well received by operating crews who regularly use the system.

VALUE REALIZATION

The measurement system was developed to support detection of large particle events; however, the main focus for the concentrator was to identify and resolve system and operating issues to eliminate the source of oversize. *CYCLONEtrac* development, by CiDRA, and root cause analyses, by the operator, on some oversize events has identified the SAG mill discharge as a problem.

At times the properties of the ore can create an increase in the ball mill recirculating load and in some cases lead to a hydrocyclone overload condition. The value of the new system is evident in the quick response to large particle events by taking action to eliminate the overload condition which in turn reduces the downstream impacts on flotation.

The new system has facilitated an enhanced focus on the root cause of oversize events and immediate response to the actionable information the system provides has dramatically reduced the impact of large particle events on flotation. Now the Copperton Concentrator now has a system that will detect oversize material and large particle events, is non-intrusive to the process, requires very limited maintenance and is being integrated with KUCC's DCS (Distributed Control System).

CONCLUSIONS

The *CYCLONEtrac* technology offers the ability for the operator to detect performance issues with individual hydrocyclones in a cluster. The real-time information enables the operator to take timely corrective action thus minimizing the downstream effects to flotation. Additionally the system provides the individual hydrocyclone isolation state. These features are provided from sensors mounted on the outside of the overflow pipes. Therefore, the system is very reliable and requires little maintenance. Due to the design of the sensor head, which is proprietary, the signal is very robust and is not influenced by vibration, electromagnetic interference, or other ambient industrial processes. The system parameters and thresholds are tuned empirically as there is no direct standard to reference for calibration.

The *CYCLONEtrac* system has now been formally integrated into Copperton operations. The system has become a standard tool for the operations personnel in the daily operations of the concentrator. The archived data is frequently used by the Technical Services group to study previous events and develop lessons learned. These lessons provide feed-back to improve future performance.

Performance data is now available for each individual hydrocyclone in addition to data for the cluster as a whole unit. The full potential of this data is still being explored, and opportunities exist for utilization of data from the operating mode output to be incorporated into routine hydrocyclone maintenance, control algorithm development, runtime tracking and replacement frequency. Currently the information is being used by the operators in a manual control mode but it is well suited for incorporation in an automated control loop. An OPC (Object linking and imbedding for Process Control) interface has now been integrated into the system to allow direct access to the output signals which will be provided to the DCS.

REFERENCES

Cirulis, D. and Russell, J. (2011) 'Cyclone Monitoring System Improves Operations at KUC's Copperton Concentrator', *Engineering & Mining Journal*, Volume 212, number 12, pp. 44–49, (viewed 10 May, 2013, URL- http://emj.epubxp.com/issue/50645).

Gysling, D.L., Loose, D.H. and van der Spek, A.M. (2005) 'Clamp-On Sonar-Based Volumetric Flow Rate and Gas Volume Fraction Measurement for Industrial Applications', *Flomeko*, 6-9 June, 2005, (viewed 8 May, 2013).

O'Keefe, C., Viega, J. and Fernald, M. (2007) 'Application of Passive Sonar Technology to Minerals Processing and Oil Sands Applications', *Proceedings of the 39th Annual Meeting of the Canadian Mineral Processors* (2007), pp. 429–457, (viewed 8 May, 2013).