

OPTIMIZATION OF HYDROCYCLONE CLASSIFICATION BY ON-LINE DETECTION OF COARSE MATERIAL IN THE OVERFLOW STREAM*

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Abstract

This paper presents a new instrument for real-time detection of excessively coarse material in the overflow pipes of individual hydrocyclones using a non-invasive acoustic measurement technique. The hydrocyclone is an important device used in mineral processing beneficiation circuits for classification of mineral slurries by particle size. It separates a single input stream into two output streams; an underflow of coarse particles that undergo additional grinding for further size reduction, 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 typically has three to twelve hydrocyclones. Thus no information is available to detect individual hydrocyclones that are operating poorly. The system described in this paper detects the presence of unwanted excessively coarse material 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 material level. This enables operators to identify poorly performing hydrocyclones, and enables corrective action to reduce or eliminate the coarse material discharge. Improving the classification efficiency of individual hydrocyclones will improve the overall classification efficiency of a hydrocyclone cluster. This leads to less variation in the particle size distribution and slurry density in the flotation feed, which will in turn improve overall mineral recovery. The reduction of unwanted coarse material in the flotation feed reduces the accumulation of that material in flotation cells. This can lead to equipment damage, and unplanned shutdowns due to events such as blocked dart valves.

Keywords: Hydrocyclones; Coarse material; Sound; Flotation; Classification; Classifiers; Particle size; Slurry; Beneficiation; Comminution; Overflow.

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1 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 tails thus extracting and concentrating the desired material for further processing. 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. But it 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 having sufficient understanding of the current state of the separation process to facilitate process changes.

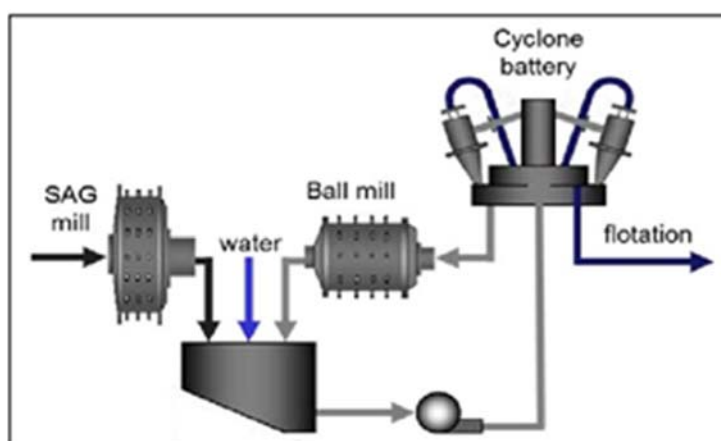


Fig. 1. Example of a common multi-stage grind circuit.

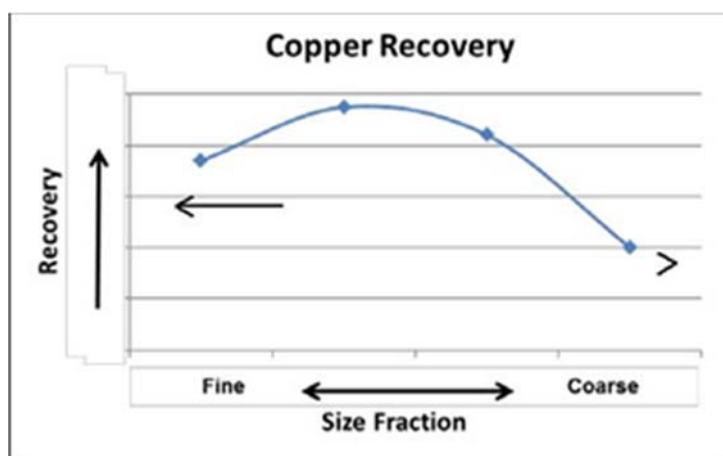


Fig. 2. Classical recovery versus particle size relationship.

2. 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.

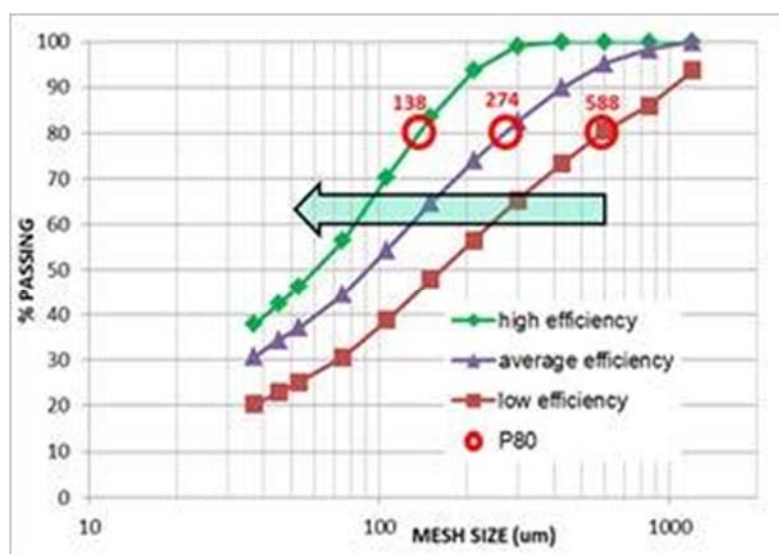


Fig. 3. A family of curves in this Shumann plot shows how the variations in P₈₀ can affect recovery efficiency. Goal is to move in the direction of the large arrow.

3. 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 or larger particles (large particles) with the overflow (Fig. 2). These large particles and very coarse material can

block the internals of the flotation cells, significantly impacting their performance. Some causes of excessively coarse material events include:

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

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.);
- Cleanup 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 unscheduled shutdown);
- Reduced metallurgical production (recovery loss through lower residence time, disrupted flow patterns);
- Changes in the grinding circuit operating conditions;
- Damage or wear in the vortex finder or apex of the hydrocyclone.

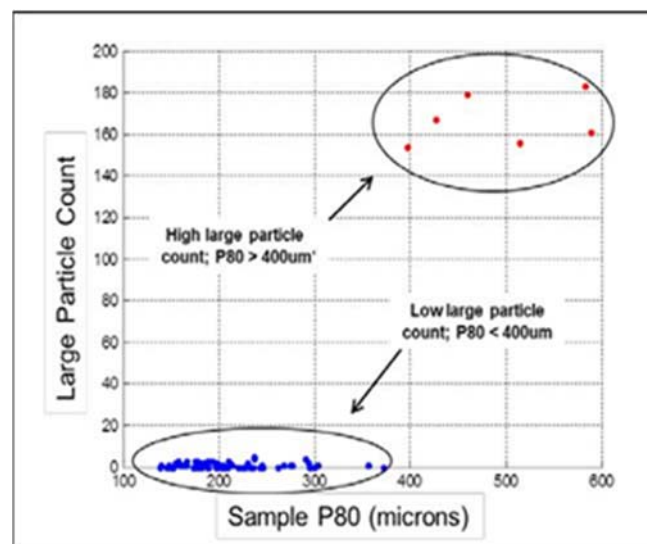


Fig. 4. During field validation, 78 sieve samples were analysed and compared to large particle counts. When P80 increases to >400 microns, the density of the slurry allows large particles to be lifted and report to flotation.

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. 3).

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.

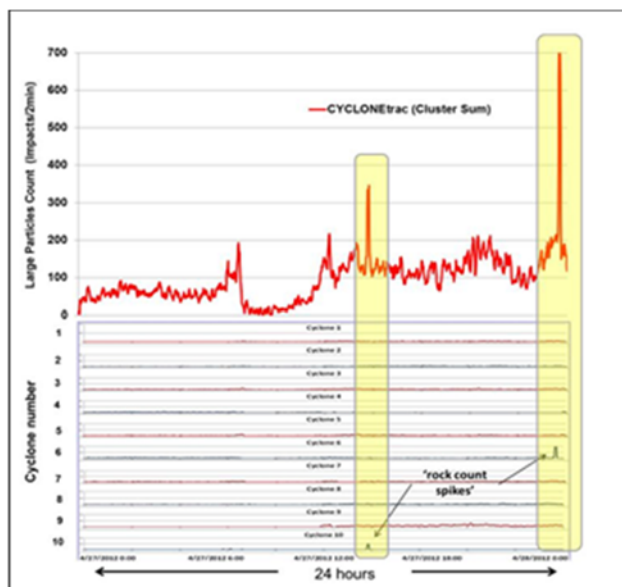


Fig. 5. Single hydrocyclone causes the combined overflow of the cluster to display a spike in the coarse material trend.

4. 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 [1,2]. This technology is not only well suited for monitoring individual hydrocyclones but can do so in a non-intrusive manner. In CiDRA's embodiment, CYCLONEtracSM, 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. 4).

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

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DCS, and transmitted to the CiDRA data center 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 helps to reduce the downtime associated with periodic maintenance and repairs.

5. COMMERCIAL DEPLOYMENT AND OPERATIONS

The CYCLONEtrac system has been commercially deployed at Kennecott Utah Copper's Copperton concentrator in Utah, USA since 2010 [3].

With the CYCLONEtrac system now fully deployed and integrated into concentrator operations, there are specific scenarios that are illuminated by information provided 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 an individual hydrocyclone. An HMI (human-machine interface) in the controlroom displays trends on the aggregated performance of each hydrocyclone cluster.

The operator discriminates between the two types of events by consulting the event level trends for the individual hydrocyclones in that cluster. If a single hydrocyclone is indicated as the cause (Fig. 5) then the offending hydrocyclone may be isolated and an alternate is placed in operation. In other cases, multiple hydrocyclones are responsible for the rapidly increasing large particle event trend of a hydrocyclone cluster. In this case the operator must adjust the feed density to the hydrocyclone cluster (Fig. 6).

The response to a hydrocyclone in an alarm state is for an operator to sample the individual overflow stream for oversize and then sample the remaining hydrocyclones in the cluster. If the sample confirms there is oversize, the hydrocyclone is isolated. The operating strategy and control response plans for such events have been adopted and well received by operating crews who regularly use the system.

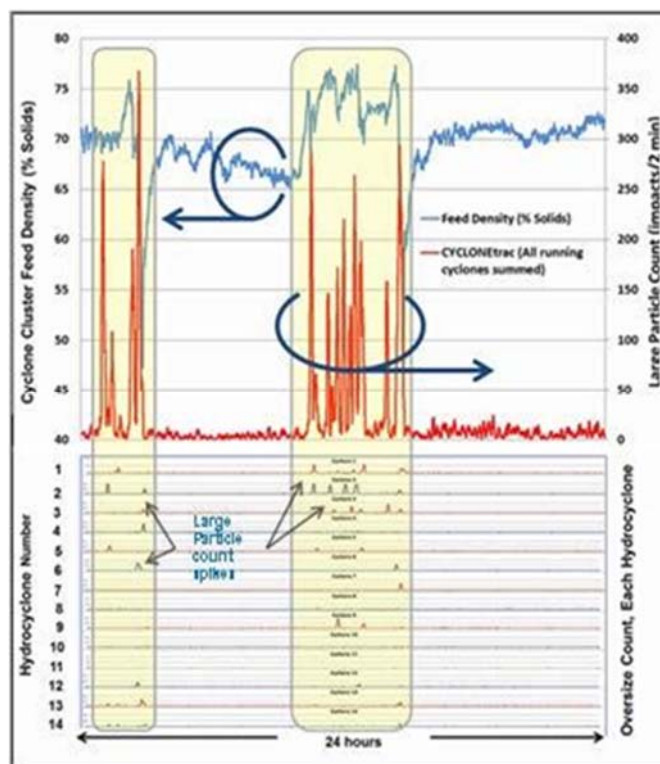


Fig. 6. Multiple hydrocyclones cause the combined overflow of the cluster to display spikes in the coarse material trend which is coincident with increases in feed density to the cluster.

6. 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. In parallel with the CYCLONEtrac development root cause analyses on some oversize events 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 CYCLONEtrac is evident in the quick response to large particle events by taking action to eliminate the overload condition which would in turn reduce the downstream impacts on flotation.

The continued focus on the root cause of oversize events and immediate response to early indicators (in the SAG mills) has dramatically reduced large events impacting flotation. Nevertheless, the Copperton Concentrator now has a system that will detect oversize and large particle events, is non-intrusive to the process and requires limited maintenance.

7. 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 mounded on the outside of the overflow pipes. Therefore the system is very reliable and requires little maintenance.

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 as well as being fed-back to improve future performance.

Performance data is now available for each individual hydrocyclone rather than the cluster as a whole unit. The full potential of this data is still being explored, and there exists opportunities for utilization of data, from the operating mode output, to be incorporated into routine hydrocyclone maintenance 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.

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