A PROTOCOL FOR CONDUCTING AND ANALYSING PLANT TRIALS: TESTING OF HIGH-CHROME GRINDING MEDIA FOR IMPROVED METALLURGY

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Abstract

It is widely accepted that the type of grinding media has an impact on the grinding chemistry and subsequent flotation behaviour of the sulphide minerals being separated. There are countless laboratory investigations demonstrating that inert grinding media produces more oxidizing pulp potentials, reduced levels of grinding media corrosion products, and superior concentrate grades and valuable metal recoveries. However, taking these results to industrial scale has proved difficult.

This paper provides details of the protocol developed and used during a high-chrome grinding media plant trial. It describes the test regime employed to measure changes in pulp chemistry as well as concentrate grades and recoveries to produce a statistically meaningful result. The work also highlighted the need for close cooperation between the metallurgists on site and the researchers conducting the trial.

To demonstrate the protocol, data gathered during a plant trail in a PGM concentrate will be presented describing the changes in pulp chemistry and metallurgical response observed.

Introduction

There is ample literature available describing the affect the grinding environment has on downstream processing. Bruckard *et al*. (2011) provide a very comprehensive review of the influence grinding environment has on copper flotation, and the author has written a number of articles describing this phenomenon and how it impacts PGM recoveries during flotation (Greet, 2008; 2010). However, advancing from a laboratory study to plant trial often proves difficult.

Generally, in the metallurgical world, plant trials commence with the identification of a particular problem within the concentrator, or the application of a ’new technology’. Once the issues have been identified, a laboratory test programme is designed and executed to determine the potential magnitude of the improvement in metallurgy.

Having developed a viable solution in the laboratory and completed an economic evaluation, the next step is to test it at a larger scale. This could be at pilot-plant scale or in the main plant, depending on the nature of the solution and the degree of risk (both technical and economic) it poses to the plant.

As good metallurgists we readily recognise the need to collect data to compare the test case against some standard condition. Furthermore, we have all, to varying degrees, been exposed to the need to use statistical analysis to prove with some level of confidence that the test case is better than the standard condition. Napier-Munn (2005), for example has provided the tools need to conduct and analyse plant trials correctly, using randomized on/off block trials, the Student t-test, and comparison of regression lines, to name but a few of the statistical strategies available. However, conducting plant trials is still fraught with danger (Greet and Kinal, 2009).

Plant trial protocol

Form of the trial

Conducting grinding media plant trials is inherently difficult. The fact that the entire charge in the mill must be replaced defines the difficulty. And, therein lies much of the resistance an operation has to conducting grinding media plant trials. The need to replace the charge in a mill is a concept many operational personnel have not contemplated. Furthermore, once the mill has been converted there is no desire to revert back to the original media type unless the trial results do not show an improvement. Therefore, the classical randomized block on/off trial is out of the question.

So, before a plant commits to a trial it is necessary to supply strong evidence that the new grinding media is going to result in a reduction in media consumption, as well as reduced reagent consumption and an improvement in the metallurgical response. Without these key performance indicators showing positive signs, converting to a different grinding media type is unlikely to go ahead.

Having demonstrated that the new media will provide positive benefits in wear, reagent consumption, and metallurgy, it is time to make some decisions. The first is how to convert the mill from one grinding media to another. This can be achieved by either dumping the charge and replacing it with a new graded charge, or by gradually replacing the old charge by topping up with the new media. Both methods have merit.

Dumping the charge realizes the benefits of the new media earlier, and is the technically preferred way of conducting a media trial. However, there are a number of aspects to this option that must be considered.

The first is where the funds come from to purchase the new charge. In most instances this money comes from the capital budget, which can present a number of obstacles in getting the right approvals.

Once the money has been approved, the next challenge is the logistics of dumping and loading the mill in a reasonable time frame (generally during a maintenance shutdown). Another consideration is what to do with the old charge. All are financial considerations that may override the technical correctness of this methodology for converting the mill.

The top-up method, on the other hand, is easier to handle from a financial perspective. That is, the cost comes from the operating budget, so the strict approvals process surrounding the application for capital can be 'avoided'. So too are the logistical issues of dumping and recharging a mill. However, this methodology is complicated by the time it takes to purge the mill and the changes that occur during this time. The purge period will depend on the size of the mill and the grinding media wear rate, with purge periods of between three and 12 months common. As plant data from before the purge is compared with information gathered once the purge is complete, the trial time is considerably longer than just the duration of the purge, and may extend to 18 months. A lot can change in this time. For example, the mineralogy of the ore, the feed grade, the throughput, the circuit configuration, the reagent regime, the operating personnel, to name but a few. These variations present considerable challenges in the analysis of the trial data.

Plant trial planning

Once the plant has agreed to advance to plant trial and the conversion method been fixed, the conditions under which the trial will run must be examined to ensure that the trial has a higher probability of producing a result. Ideally, the following items need to be considered when planning the plant trial:

- Which mill(s) is to be converted
- Access to sampling points within the grinding and flotation circuits
- The stability of the operation during the trial period
- The mine plan. Ideally, there should not be a major change in the ore blend entering the plant during the plant trial
- The introduction of any major equipment or circuit changes during the trial period that would complicate the analysis should be avoided
- Any reagent trials during the trial period that would complicate the analysis should be carefully planned.

Obviously, there will be variations during the course of the trial simply because of the time required to complete the test. However, if these variations can be foreseen their impact on the trial can be minimized. The key is to have good communication between the site metallurgist and the researcher conducting the trial.

Data collection

The data collected during the plant trial can be divided into two categories: that which is collected by the researchers to measure changes in the pulp chemistry; and routine inventory sampling completed by the operation to measure reagent consumption and metallurgical performance. In this paper only the pulp chemical and metallurgical data will be dealt with.

Pulp chemical data

In agreeing to conduct a plant trial, the researcher will ask for access to the site to complete pulp chemical surveys of the grinding and flotation circuits before and after the mills have been converted to the new grinding media. Each visit is nominally of two weeks duration. During each site visit, pulp chemical data (pH, Eh, dissolved oxygen, temperature, and oxygen demand), and EDTA extraction data are collected from the following critical process streams. For example:

- Ball mill discharge
- Ball mill cyclone underflow
- Ball mill cyclone overflow
- Rougher feed (conditioned with reagents)
- Rougher tailings.

Typically, the researcher will collect as much pulp chemical data as possible, generally 12 or more data sets. This data is used to demonstrate the changes in the pulp chemistry that occur with the change in grinding media.

Metallurgical data

By far the best source of information for measuring the metallurgical performance as the plant moved from grinding media to another is the shift mass balanced data. The shift data provided information about:

- The throughput
- The particle size distribution
- The feed grades (PGM, copper, nickel, and chromite)
- The final concentrate grades (PGM, copper, nickel, and chromite),
- The final recoveries (PGM, copper, nickel, and chromite).

This data is reviewed, and (in consultation with site personnel) cleaned by omitting shifts:

- With major downtime (i.e. less than 22 hours operating)
- Any missing data
- Removing outliers using standard residuals.

The cleansed data are then analysed using time series and 'cusum' plots to observe variations in performance with time. Quantitative statistical techniques (the Student *t*-test, comparison of regression lines, and multiple variable regression analysis) are utilized to determine the magnitude of any improvement to the metallurgical performance, and the confidence that can be given to the improvement.

An example

A plant trial was conducted on a UG2 plant using the test protocol described above. The plant monitoring programme consisted of:

- Collection of pulp chemistry data (pH, Eh, dissolved oxygen, temperature, oxygen demand, and EDTA extractable iron) through the circuit while the plant was operating with forged steel, during the purge period, and for three months after the mill was converted to high-chrome grinding media
- Collection of the shift mass balanced data for the duration of the trial so that a statistical analysis could be completed comparing the plant performance when operated with the two different media types.

Pulp chemistry changes

The Eh of the primary ball mill discharge before, during, and after the purge period is displayed in Figure 1. It is apparent that when forged steel grinding media was utilized in the primary ball mill, the pulp potential of the primary ball mill discharge was considerably more reducing than those measured once the plant had converted to high chrome. The 215 mV increase in Eh, and the corresponding increase in the dissolved oxygen content of the pulp, can be attributed to a reduction in grinding media corrosion.

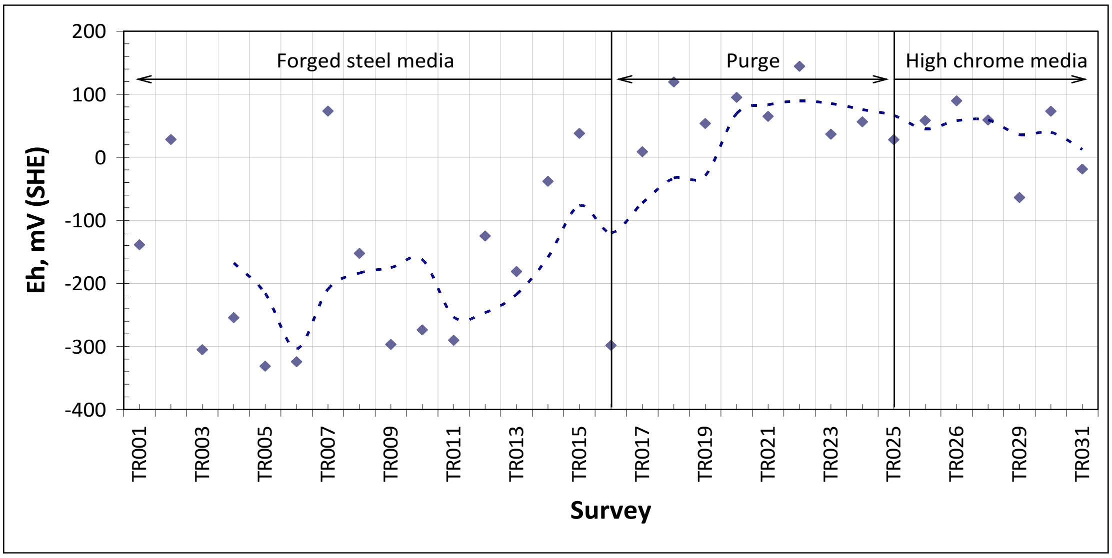

Figure 1-The Eh trend with time for the primary ball mill discharge, moving from 100 per cent forged steel, through the purge period to 100 per cent high chrome grinding media. (TR refers to the pulp chemical survey number)

The assertion that the change from forged steel to high-chrome grinding media resulted in a reduction in the corrosion rate of the grinding media is supported by the EDTA extractable iron data. Figure 2 clearly shows that the percentage of EDTA extractable iron in the rougher feed decreased from 0.02 per cent for the forged steel case to 0.004 per cent when grinding with high-chrome grinding media in the primary ball mill.

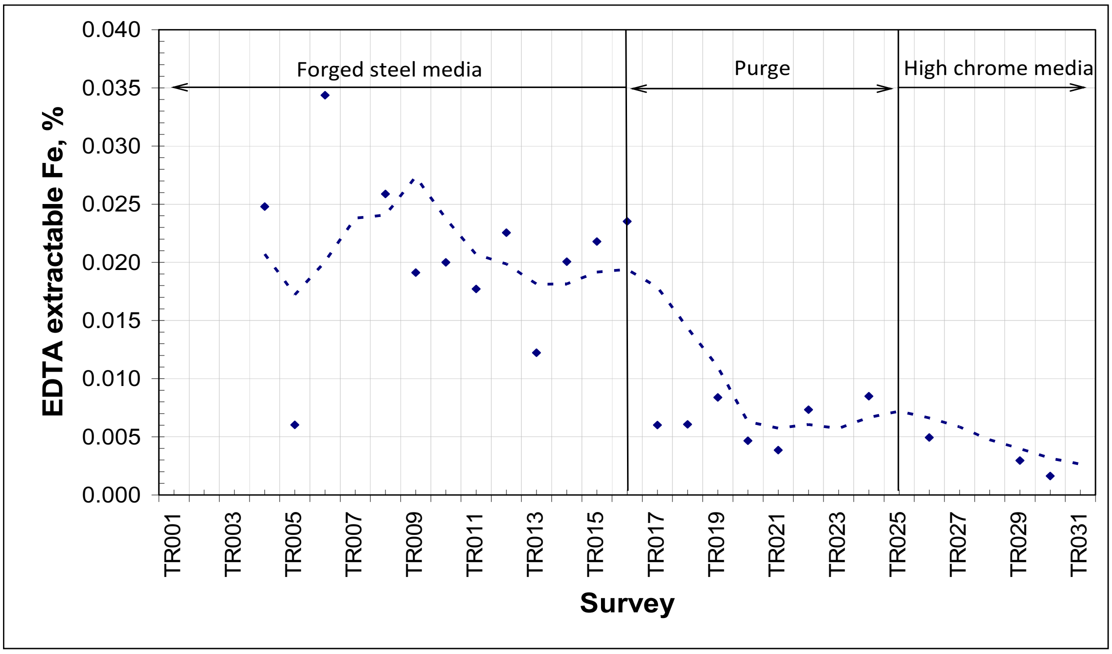

Figure 2- The EDTA extractable iron trend with time for the primary rougher feed, moving from 100 per cent forged steel, through the purge period to 100 per cent high chrome grinding media. (TR refers to the pulp chemical survey number)

These changes in the pulp chemistry indicate that changing from forged steel to a more corrosion-resistant alloy minimized the surface contamination of the sulphide minerals in the system and should produce superior metallurgical performance.

Metallurgical performance

The plant shift data was provided by the operation and cleansed according to the agreed rules.

The statistical analysis indicated that converting from forged steel to highchrome grinding media resulted in an increase in PGM recovery of 1.99 ±0.50 per cent, with 99 per cent confidence (Figure 3).

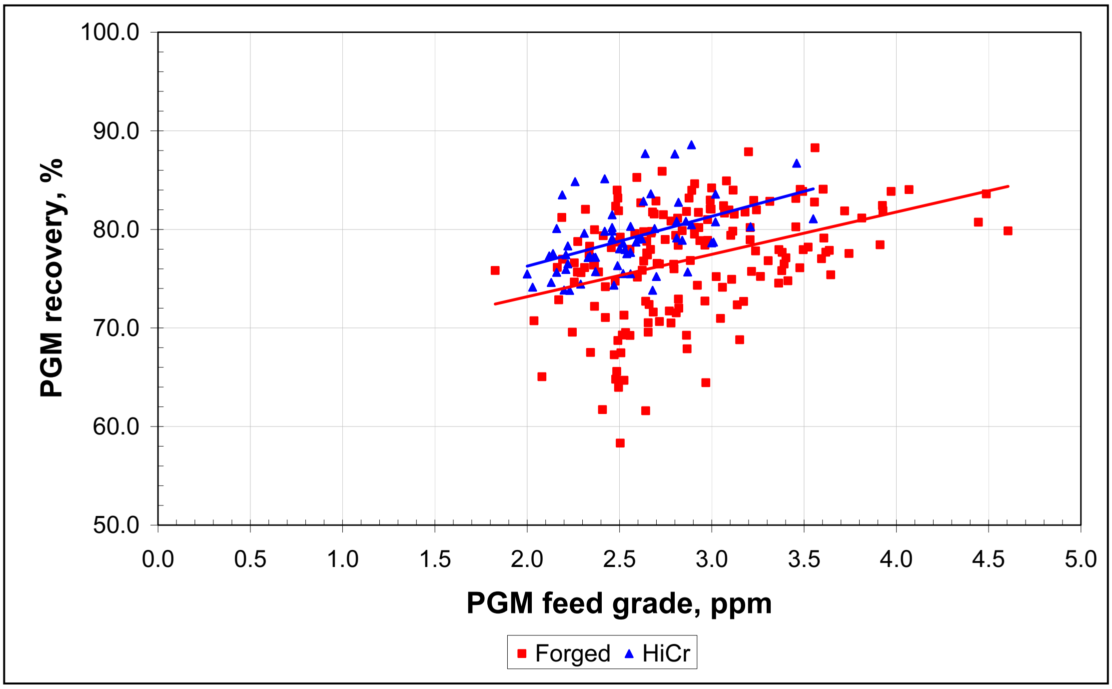

Figure 3-Overall PGM recovery and PGM feed grade comparing primary grinding with forged steel and high-chrome grinding media in the primary ball mill

A similar analysis was completed for the PGM concentrate grade. The data suggested that there was no statistical difference in PGM concentrate grade between the two grinding media types. However, the chromite grade in the final PGM concentrate was reduced significantly when grinding with high-chrome grinding media. The data indicated that the chromite grade has decreased by 0.96 ±0.06 per cent, with greater than 99 per cent confidence. The reduction in chromite grade may be attributed to a change in the froth structure; however, further research is warranted to validate this assertion.

Further examples

This approach has been adopted in a number of trials around the world for different commodities. For example:

- Laboratory work at Perilya Broken Hill led to a plant trial using high-chrome grinding media that resulted in a 2 per cent increase in zinc recovery (Greet *et al.*, 2009)
- Laboratory and pilot-plant tests work at Xstrata Copper's Ernest Henry Mine resulted in a plant trial that showed a 2 per cent increase in copper recovery (Greet *et al.*, 2011)

- Laboratory studies at Newcrest's Ridgeway concentrator advanced to plant trial that resulted in a 1 per cent increase in copper recovery and a 2.1 per cent increase in gold recovery (Greet *et al.*, 2012).

These plant trials, and many others, have been successful because of the strong collaboration and good communication between the metallurgical team on site and the researchers in following a robust, agreed strategy for conducting the test programme.

The results achieved provide the site with the magnitude of the metallurgical improvement and the degree of confidence the researcher has in the outcome.

Conclusions

In summary, grinding media trials are by their very nature not trivial and do take considerable time to complete. So, to achieve success the following advice is offered:

- Communication is king. It is of paramount importance to involve all key human resources to ensure that all foreseeable problems in going to trial can be discussed and planned for. This means involving everyone: operations, maintenance (both electrical and mechanical), metallurgists, management, and supply
- Establish an agreed protocol that covers the time frame for the trial, the data collection, and the analysis methodology
- Collect the right data (pulp chemical, metallurgical, and operational) and enough of it before and after the conversion so that you will have confidence in the statistical analysis comparing one media type against another
- Be patient!

The application of the above methodology did lead to positive results for the plant in question. Further, this methodology is being applied to other commodities around the world.

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