Integration and Optimisation of Blasting, Crushing and Grinding at the Newmont Ahafo Operation

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ABSTRACT

Metso Process Technology & Innovation (PTI) has been conducting a Mine-to-Mill or Process Integration and Optimisation (PIO) project at the Newmont Ahafo operation with the objective of increasing plant throughput. Benchmarking surveys were undertaken in January 2009 to determine process performance before implementing changes. Site specific models were then developed and used to simulate alternative operating strategies for blasting, crushing and grinding processes to increase throughput. Ahafo implemented a number of the recommendations made by PTI and then three validation blast trials on similar material were conducted in November 2009.

The post-PIO validation trial results measured over an extended period up to the end of Q1 2010 showed a total performance improvement of at least 8% in total SAG mill throughput compared to the benchmark surveys as well as previous audits on similar material.

This paper summarises the work completed to date as part of this project and the achievements made at Ahafo in increasing mill throughput.

1 BACKGROUND

The Ahafo operation is situated in the Brong-Ahafo region, mid-west Ghana between the Ashanti region and the Ivory Coast border. It is owned by Newmont Ghana Gold Limited and was opened in July 2006.

The estimated life of the Ahafo mine is 20 years. Currently, the mine has a total of 4 pits with two major open pits that feed the process plant with Apensu and Awonsu ores.

1.1 ***Ahafo Comminution Circuit***

The comminution circuit at Newmont Ghana Gold Limited Ahafo mine uses an open circuit Superior II 54 x 75 Gyratory crusher to crush the primary ore and an MMD Sizer crusher for the oxide ore. This is followed by a standard SABC circuit comprising a 34 x 16.4ft Metso 13MW SAG mill in closed circuit with Metso MP800 pebble crushers. The SAG mill Schenk double deck discharge screen aperture is 33 x 68mm for the top deck and 35 x 10mm aperture for the bottom deck. SAG milling is followed by a 24 x 39ft Metso 13MW ball mill in closed circuit with a cluster of Krebs gMax 26 inch cyclones. Two spigots, located on the cyclone feed manifold, feed a Knelson gravity gold recovery circuit. After classification, the milling product is thickened and the overflow is fed to carbon-in-leach tanks.

Figure 1 shows a schematic of the Ahafo comminution circuit.

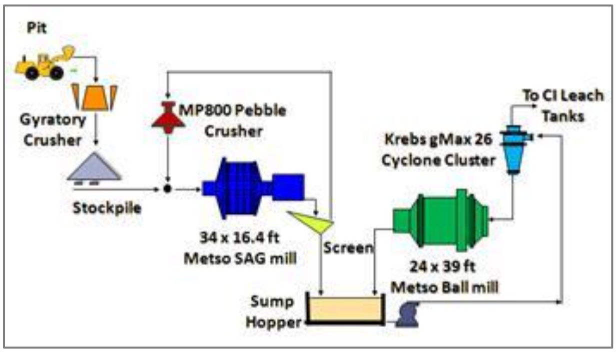

Figure 1: Ahafo Comminution Circuit Flowsheet

1.2 *Milling Circuit Challenges*

Ahafo is currently treating two main ore types (Apensu, and Awonsu) that present challenges in the ball milling and classification circuit. These ores have higher abrasion resistance and are processed with ease in the primary SAG mill but with more difficulty in the ball mill and are therefore termed *ball mill limited*. It is believed optimisation of the secondary milling circuit to achieve the target grind size whilst processing high SAG mill throughput and generating a coarser transfer size, is the next main challenge at Ahafo.

2 PIO METHODOLOGY

Metso PTI has developed integrated operating and control strategies that maximise throughput, and minimise the overall cost per tonne from the mine to the plant. This systematic review is referred to as *Process Integration & Optimisation* (PIO). PTI has applied this methodology to a number of operations worldwide to maximise the overall efficiency of the Mine-to-Mill interface.

PTI has been conducting a PIO project at the Ahafo operation with the objective of increasing plant throughput. Initially, benchmarking surveys were undertaken in January 2009. In this paper, data from these surveys is referred to as "*Before PIO".*

During this phase, PTI personnel completed the following tasks:

- Discussions with geological, mine planning, drill & blast and process/milling personnel,
- Collection of rock strength and structure data on the main ore types,
- An audit of a normal production blast,
- Measurement of the top & bottom flitch fragmentation using image analysis,
- Placement of Radio Frequency ID (RFID) SmartTags™ and antennae to track ore movements from the muck pile to the mill,
- Sampling and surveying of the primary crusher and grinding circuits, and
- Collection of historical plant data.

Site specific models were then developed and used to simulate alternative operating strategies for blasting, crushing and grinding processes to increase throughput.

Using PTI's experience in Mine-to-Mill optimisation and the results of the simulations a set of recommendations were made to site.

Through a well-coordinated effort across multiple disciplines, Ahafo implemented a number of changes in operating practices and in November 2009 three validation blast trials on similar material were conducted. In this paper, data collected from this validation phase is referred to as *"After PIO".*

2.1 *Ore Tracking*

In all PIO projects it is crucial that the material being fed to the plant during the survey is the same material that has been characterised in the mine from the audited blast. PTI have developed a material tracking system called, *SmartTag*™, that allows parcels of ore to be followed from the mine, through the crusher and intermediate stockpiles or ROM pads, and finally into the grinding mills. The SmartTags™ are built around robust RFID transponders. Figure 2 shows the hardened tag. They require no internal power source and therefore can lay in stockpiles and ROM pads for extended periods before being detected by the system hardware. The tags are detected as they pass along a conveyor belt.

Figure 2: A SmartTag™ Hardened Casing

At Ahafo the antennae were placed under the belts to avoid the possibility of being struck by coarse material.

3 MEASURED PROCESS IMPROVEMENTS

3.1 *Ore Characteristics*

PTI uses measurements of both rock strength[1] and rock structure[2] for rock characterisation. Geotechnical drill core samples and measurements of Is_{50} and RQD are used to populate the geological block model with estimates of mill throughput using the PTI methodology. This forms the basis for the throughput-forecasting model.

Metallurgical hardness test work of the primary crusher products, during benchmarking in January 2009 and during validation in November 2009, was conducted at the Newmont laboratories in Denver, USA. Samples were subjected to single particle impact breakage test, *SAG Mill Comminution* (reported as DWi), as well as grindability tests, *Bond Work Index* (BWi).

A summary of the average ore competence test results before and during the PIO project is shown in Table 1.

Table 1: Average Ore Hardness

	Benchmark Before PIO (Jan 09)	Validation After PIO (Nov 09)
Is50, Mpa	**3.63**	**4.83**
UCS, Mpa	**87**	**116**
Ore SG, t/m3	**2.73**	**2.72**
DWi, kWh/m3	**7.91**	**7.64**
BWi, kWh/t	**15.2**	**20.5**

The hardness results show that the ore processed during implementation of the PIO project was more competent. Therefore, the step-change gain in throughput achieved could not be attributed to treating soft ore during implementation of the PIO recommendations.

[1] Measured by Point Load Index (PLI), reported as Is_{50}, and/or Uniaxial Compressive Strength (UCS).
[2] Measured by Rock Quality Designation (RQD) and/or fracture frequency.

3.2 *Drill and Blast (D&B)*

A review was conducted on drill and blasting processes through discussions with mining personnel, observing D&B practices in the field and by auditing historical data. Key observations and recommendations from the review are summarised in Table 2.

Table 2: Ahafo Review of Drill & Blast Practices

Before PIO	PTI Recommendation
Short Term Planning lacked D&B schedule	**Incorporate Drill & Blast Schedule**
No Blasting Guidelines	**D&B Templates and Blast Master**
Inconsistent Bench Preparation	**Standardise Bench Preparation**
No Blast Fragmentation Model	**Develop Ahafo Blast Frag. Model**
Limited Frag. prediction	**Ability to Simulate Frag. Options**

Three alternative blast designs were simulated to improve run-of-mine (ROM) fragmentation. The design changes and the resulting impact on fragmentation are shown in Table 3. The most significant effect of the design changes is on the increased generation of fines.

Table 3: Simulated Blast Design Options

Blast Design	Actual, Before PIO	Option 1	Option 2	Option 3
Bench height, m	8	8	8	10
Burden, m	3.5	3	3.5	4
Spacing, m	4	3.5	4	4.5
Hole diam, mm	140	140	165	200
Explosive				
Powder Factor, kg/t	0.36	**0.48**	**0.53**	**0.57**
Fragmentation Estimates				
F80, mm	467	372	362	373
Fines (-14mm)	17.7	22.6	23.9	25.3

Option 2 was implemented by Ahafo as it offered the most cost-effective solution for the desired fragmentation.

The high energy blast design resulted in a much tighter fragmentation distribution compared to blasting practices before the PIO project.

3.3 ***Primary Crusher Performance***

PTI reviewed the performance of the primary crusher before and after the PIO project was conducted at Ahafo. It was recommended that Ahafo measure the actual closed-side-setting (CSS) once a week during the maintenance shutdown and maintain a CSS of between 5 and 6 inches based on the operating power draw. The mantle position also required a 2 to 4% adjustment on a weekly basis to maintain a consistent tight gap. The resulting improvement to crusher performance are summarised in Table 4.

Table 4: Primary Crusher Performance

Gyratory Crusher	Before PIO (Jan 09)	After PIO (Nov 09)	% Change
Crusher Tonnage, tph	**1,049**	**1,324**	**26**
Phase Current, amps	**476**	**525**	**30**
Power Draw, kW	**321**	**355**	**10**
Specific Energy, kWh/t	**0.31**	**0.27**	**-12**
Product Size (P80), mm	**116**	**116**	**0**
Product Fines (% - 12.5mm)	**16.1**	**21.4**	**33**

The main benefit realised after drill and blast changes as well as primary crusher recommendations, was an increase in the amount of fines (% - 12.5mm). Primary crusher throughput thus increased, whilst the product size was maintained at 116mm.

3.4 ***SAG Mill Performance***

To monitor the effect of feed size and hardness on the grinding circuit, two surveys were conducted during the PIO project. One survey was conducted during the top bench flitch of the test blast and the second survey when processing material from the bottom bench.

At the end of each survey the SAG mill was crash-stopped and the total charge of rock, and ball loads were measured. The survey data was then used for mass balancing and model calibration.

It was recommended that Ahafo maintain a tighter gap setting and operate the MP800 pebble crusher at 10mm and not more than 15mm (the benchmark CSS size). Additionally, it was suggested not to target maximum power but rather maintain a stable total load of equal or less than 250t by running the SAG mill variably.

After implementation of drill and blast changes as well as the crushing and SAG mill recommendations, the benefits achieved during validation (November 2009).are shown in Table 5. Notably, a 19% increase in total throughput and a 20% decrease in SAG mill energy were observed.

Table 5: SAG Mill Performance

SAG Mill Circuit	Before PIO (Jan 09)	After PIO (Nov 09)	% Change
Total Tonnage, tph	971	1155	**19**
Primary, tph	740	963	**30**
Oxide, tph	231	192	**-17**
Oxide, %	24.8	16.6	**-33**
Power, MW	10	9.8	**-2**
Specific Energy, kWh/t	10.8	8.6	**-20**

4 SIGNIFICANT IMPROVEMENTS

Implementation of the mine-to-mill (PIO) project at Ahafo has resulted in sustained measurable step-forward achievements in drill and blasting practices, and the process plant throughput.

4.1 ***Drill and Blasting***

The on-going drill and blasting improvements are;

- Finer ROM fragmentation (PF=0.53kg/t and 23.9% increase in fines – Table 3), through;
    - ❖ Increase of blast hole diameters (from 140mm to 165mm),
    - ❖ Decrease of blast hole spacing in ore in the Apensu pit (from 4 x 4m to 3.5 x 4m),
    - ❖ Change of Explosive (from 100% emulsion to 80/20 dense prill blend. VOD increased (from 5200 to 5800-5900m/s),

- Placement of extra blast holes over phase 1 crest edge.

- Elimination of hard toes in high grade ore regions.
- Elimination of major free faces in most ore blasts due to significant increase in timing speed in ore.
- Increased blast size, and elimination of dilution and boulders along shot breaks through implementation of pre-split.
- Increased accuracy and speed in fragmentation without creating vibration (Use of Unitronics electronic detonators).

4.2 ***Throughput***

As part of an on-going support contract with Metso PTI, the performance of the mine-to-mill process was monitored through the first quarter of 2010. Table 6 highlights the significant and longer-term improvements in overall performance achieved through the PIO project. The key improvements are;

- A total throughput increase of 8.4%, which was sustained in the first quarter of 2010,
- A step-up of at least 7% in the target grind size, relative to that measured during benchmarking.

Table 6: Throughput improvements at Ahafo over time

Period	Primary (tph)	Oxide (tph)	Total (tph)	Grind % -106µm
Before PIO (Oct 08 - Jan 09)	**722**	**294**	**1016**	**-**
Benchmark, before PIO (Jan 09)	**740**	**231**	**971**	**70.8**
Validation, after PIO (Nov 09)	**963**	**192**	**1155**	**76.6**
On-going (Q1 2010)	**938**	**163**	**1101**	**76.3**
% Change through 2010 Q1	**30%**	**-45%**	**8.4%**	**7.8%**

5 FURTHER REFINEMENTS

Further model and simulation analysis shows that to sustain a higher tonnage and to cope with a coarser transfer size, a ball mill mixture of 38 and 76mm media is required. The cyclone feed should be run as dilute as possible to maintain the cyclone pressure. Further optimisation of grind at high throughput needs to be established.

There is an on-going site support contract between Ahafo and PTI, which allows for the opportunity to refine and interrogate grinding challenges.

6 CONCLUSIONS

Through the use of PIO and Ahafo engagement, significant improvements in overall process performance were achieved. A total performance improvement of at least 8% was measured over a 12 month period. Ahafo has potential to benefit fully from the PIO project by exploring the effect of Apensu and Awonsu ore blends and expected variability in ore hardness (BWi). Finally, Ahafo can incorporate PIO benefits and develop standard operating practices for the SAG and ball mill circuits when processing ball mill limited ore types.

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