IMPROVEMENTS IN SAG MILL THROUGHPUT FROM FINER FEED SIZE AT THE NEWMONT AHAFO OPERATION

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ABSTRACT

Newmont Ghana Gold Limited's Ahafo operation have been working with Metso Process Technology & Innovation (PTI) since early 2009 to increase mill throughput from a combination of controlled blasting practices and optimised primary crusher and grinding circuit conditions. For such Mine-to-Mill projects, PTI's methodology is termed Process Integration & Optimisation (PIO).

Ahafo operate a SAG mill, ball mill and pebble crusher (SABC) circuit that processes a range of primary ore of varying hardness from different pits which is blended with soft oxide material. The PTI study focussed on ball mill limited material from the Apensu open pit.

Following a benchmarking study of all blasting, crushing and grinding practices in January 2009, PTI recommended changes in both blasting and crushing conditions in order to generate a finer feed size to the SAG mill. Additional operating changes in the grinding circuit were recommended.

A series of trials were conducted in November 2009 where three blasts were fired using a different blast design (hole diameter and explosive type) in the same area of the Apensu pit as the benchmarked material in January 2009. Top and bottom benches (or flitches) from each blast were sent exclusively to the grinding circuit and the material was tracked using PTI's SmartTag™ system.

The results from the six trials showed a significant increase in primary ore throughput at a reduced blend of oxide material. Ahafo have since standardised on these modified blasting conditions for all Apensu ore zones and have been able to sustain higher throughput compared to historical performance on similar material.

This paper summarises the phases of the PIO project, the changes made in operating practices and the outcomes of the blasting trials that validated the predicted increase in mill throughput.

KEYWORDS

SAG milling, feed optimisation, simulation, modelling

BACKGROUND

Newmont Ghana Gold Limited's Ahafo operation is located in the Brong-Ahafo Region of Ghana, approximately 290 kilometers northwest of the capital Accra. Ahafo poured its first gold on July 18, 2006 and commenced commercial production in August 2006. Ahafo are currently mining a number of open pits with the majority of ore coming from the Apensu and Awonsu working areas. A blend of both primary and oxide ore is fed to the mill to balance the head grade and recovery in the leach circuit.

Ahafo have been working with Metso Process Technology & Innovation (PTI) since early 2009 to increase mill throughput from a combination of controlled blasting practices and optimised primary crusher and grinding circuit conditions. For such Mine-to-Mill projects, PTI's methodology is termed Process Integration & Optimisation (PIO).

Ahafo Grinding Circuit

Ahafo operate a 54 x 75 in gyratory crusher for primary ore and a toothed MMD sizer for oxide ore. This is followed by an SABC circuit comprising a 34 x 16.4 ft, 13 MW semi autogenous grinding (SAG) mill in closed circuit with two, 600 kW pebble crushers. SAG milling is followed by a 24 x 39 ft, 13 MW ball mill in closed circuit with a cluster of 26 inch (660 mm) cyclones. After classification, the milling product is thickened and pumped as feed to carbon-in-leach tanks. The SABC circuit flowsheet is shown below in Figure 1.

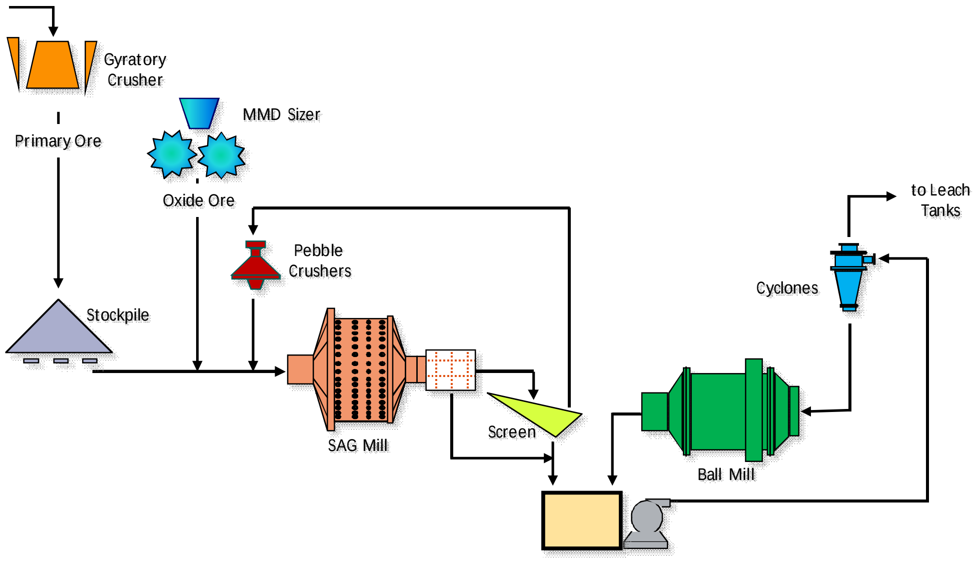

Figure 1: Ahafo Grinding Circuit Flowsheet

Mill Throughput Optimisation Project

Following initial site observations, the project objectives were established to increase mill throughput while maintaining or achieving a finer grind size. This was to be achieved through a combination of blasting, crushing and grinding operating changes. An initial benchmarking study would identify where the opportunities were greatest and what effect the combined changes would have on mill performance.

Initially, the focus was to reduce the SAG mill feed size while processing the lower tonnage Subika ore and improve the grinding circuit product size while processing the ball mill limiting Apensu ore. Subika ore was not the main ore processed during benchmarking, leaving Apensu as the principal focus for optimisation.

The benchmarking study of all comminution practices was conducted by PTI in January 2009, with calibrated models of blast fragmentation, crushing and grinding circuits being used to generate a list of prioritised recommendations. These were implemented by Ahafo including a change in blast pattern design (hole diameter and explosive type) to create additional fines and more consistent fragmentation between the top and bottom parts of the blasted bench.

Ahafo blast two benches at once and then mine separately the top and bottom flitches, with the top flitch having a significantly coarser fragmentation compared to the bottom flitch.

Ahafo implemented the modified blasting conditions over a number of months to monitor the effects of dilution, vibration and excavator digging rate. A series of validation trials were then conducted in November 2009 with the new pattern design in the same area of the Apensu pit as the benchmarked material trialed in January 2009. Top and bottom flitches from each blast were sent exclusively to the grinding circuit and tracked using PTI's SmartTag™ system.

PROCESS INTEGRATION & OPTIMISATION METHODOLOGY

The methodology involves a number of steps: benchmarking, rock characterization, measurements, modeling/simulation and where required, material tracking. A PIO project is normally comprised of a number of site visits spaced over a few months. The first site visit is to establish current operating practice, initiate rock characterization and collect measurements of blast fragmentation and mill performance. This is followed by modeling and simulation studies to determine how to best exploit the hidden inefficiencies. These recommendations are then followed by further site visits to implement the changes, monitor the results and ensure the improvements are maintained over time.

Ore Characterisation

Table 1 below compares ore hardness testwork results for the current and future Ahafo pits. During the PIO study, the Subika and Apensu pits were predominantly mill feed material. The JKMRC Drop Weight A*b values in Table 1 compared to Bond Work Index (BWi) values show that Subika ores are typically SAG mill limited while Apensu ores are ball mill limited in the Ahafo SABC circuit.

Table 1: Ahafo Ore Properties

Ore Source	Drop Weight A*b	Bond Ball Work Index, kWh/t[#]	Circuit Limitation
Subika	22 to 28	15 to 17	SAG mill
Apensu	33 to 38	15 to 22	ball mill
Amoma	26 to 57	11 to 21	variable
Awonsu	36	18	ball mill
Oxide	76[$]	10	

[#] *BWi at closing screen size of 106µm* [$] *A*b value derived from BWi by SMCC Pty Ltd.*

Ahafo also blend in oxide ore to balance the head grade and leach circuit recovery which also has an impact on mill tonnage.

Benchmarking Study

The first step of a PIO project is to benchmark the current practices by auditing the operation and control of the blasting, crushing, grinding and flotation processes.

The quality of blast pattern implementation is assessed and the resulting ROM fragmentation measured using image analysis. The crushing, grinding and separation circuits are surveyed and process control strategies reviewed. All of these measurements allow mathematical models to be developed for the complete process chain. These models are later used to simulate the impact of operational changes in the mine or concentrator on the entire process.

A particular issue at Ahafo is the practice of blasting double benches (or flitches) which are mined separately. With the lower explosive loading in the top half of the blast holes, the top flitch generally has a much coarser fragmentation than the bottom flitch (see Figure 2 for example photos).

Top flitch Bottom flitch

Figure 2: Example Blast Fragmentation from Top vs. Bottom Flitch (Double Benching)

To quantify the effect of changes in blasting conditions, the PIO study trialed the top and bottom flitch material separately into the grinding circuit.

Ore Tracking

In any Process Integration and Optimisation project, it is crucial that the material being fed to the plant during the survey is the same material that has been characterized 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 Radio Frequency ID (RFID) transponders. Figure 3 shows the hardened tag and temporary antenna installation under a conveyor belt. The tags require no internal power source and therefore can remain in stockpiles and ROM pads for extended periods before being detected by the system hardware. The current design allows tags to be detected from a distance of up to one metre that is ideal for conveyor belt applications.

Figure 3: SmartTag™ RFID Ore Tracking Tag & Antenna Installation

Following detonation of the audited blast, the top flitch material was mined and placed in a segregated stockpile on the ROM pad ahead of the primary crusher. The bottom flitch material was later directly dumped into the primary crusher. SmartTags™ were placed on the muckpile surface prior to mining as well as added to the ROM stockpiles. A total of 200 tags were placed in each flitch with two antennae installations to detect the tags, one on the primary crusher product belt and one after the stockpile on the SAG mill feed belt.

The use of SmartTags™ provided clear evidence that the audited material was entering the grinding circuit and the frequency of tag detections was used to indicate whether any other ore polygons were inadvertently being sent to the primary crusher. Placing antenna both ahead and after the coarse stockpile allowed live retention time to be estimated.

Modeling/Simulation Exercise

The benchmarking trial on Apensu top and bottom flitch material provided detailed data on blast fragmentation, primary crusher and grinding circuit performance that was used to developed models of the entire system. Image analysis of photos taken from the muckpile and trucks dumping at the primary crusher were used to calibrate a blast fragmentation model. Samples of the primary crusher product material were used to confirm the amount of fines being generate in the blast. Complete grinding circuit surveys conducted while processing the top and bottom flitches were used to calibrate a *JKSimMet* model.

A simulation study was then completed to identify opportunities for higher mill throughput. A range of recommendations were made including changes in blasting (hole diameter and explosive type), primary crusher operation and grinding circuit operating conditions. Simulation results on similar Apensu material (combined with PTI experience) suggested that changes in blasting alone could increase mill tonnage by 4% while grinding circuit changes alone could increase tonnage by 6%. The combination of blasting **and** grinding circuit changes should improve throughput by **even more** than the sum of the two changes.

Ahafo received these recommendations in May 2009 and implemented the new blasting conditions immediately for all ore zones in the Apensu pit. By late 2009, Ahafo were ready to conduct the validation trials.

BLAST VALIDATION TRIALS

The objective of the blast validation trials is to confirm (as accurately as possible) the expected benefit of finer feed predicted in the simulation study. If possible, the same or similar material should be trialed so that the effect of only recognised changes are shown in the results. It is important to complete such validation studies as, in the future, changing feed or circuit conditions may mask the benefits of finer fragmentation. If higher drill & blast costs (e.g. powder factor) are an outcome of a Mine-to-Mill or PIO exercise, documented evidence needs to be available to justify the additional operating cost.

Trial Program

Ahafo set up three blast patterns using the new conditions in the same area of the Apensu pit as was trialed in the benchmarking study earlier in 2009. These blast patterns were mined separately in top and bottom flitches, resulting in six mill trials that were carefully monitored by PTI along with samples collected for sizing and hardness testwork.

Figure 4: Detonation of One of Three Validation Trial Blasts

Due to limited material in each blast pattern, mill trials were conducted for eight hours before material was depleted.

Trial Results

The results of the validation trials showed a significant increase in mill throughput as a result of the finer fragmentation. Additional photographs of the muckpile and trucks dumping at the primary crusher confirmed an increase in fines content as well as greater similarity between the top and bottom flitch fragmentation. Primary crusher performance improved with higher throughput at the same power draw compared to the January 2009 benchmarking study.

Table 2 summarizes the six validation trials compared to the benchmarking results for top and bottom flitch material separately. The expected increase in mill throughput predicted in the simulation study from the blasting and mill operating changes was clearly outdone by the validation trials.

Overall, a significantly higher feedrate was observed on both flitch material types, with a lower blend of oxide. Tonnages on both top and bottom were 1,100 to 1,200 tph indicating the change in blast design likely had a greater effect on top flitch fragmentation (as expected).

The finer material reduced the SAG mill specific energy to around 8.5 kWh/t from the benchmarking results of 10.3 to 10.8 kWh/t.

Table 2: Summary of Blasting Trial Results on SAG Mill Performance

Survey	Flitch	Feed Properties DWi, kWh/m^3	Feed Properties BWi, kWh/t	Feedrate, tph	% Oxide	SAG kWh/t	Grind P80, microns
Benchmark	**Top**	**7.9**	**15.2**	**971**	**23.8**	**10.3**	**156**
Trial 1	Top	8.3	20.8	1,167	21.9	8.4	177
Trial 2	Top	7.4	22.0	1,187	21.7	8.5	161
Trial 3	Top	7.3	18.7	1,132	13.8	8.2	148
Benchmark	**Bottom**	**10.1**	**16.0**	**1,051**	**22.0**	**10.8**	**125**
Trial 4	Bottom	7.5	18.1	1,117	12.3	8.7	214
Trial 5	Bottom	7.3	21.8	1,180	17.9	8.1	221
Trial 6	Bottom	8.5	18.0	1,149	11.9	9.0	221

The lower % oxide in the trials compared to benchmark feed was evident in the coarser final grind 80% passing (P80) sizes – particularly for the bottom flitch trials. In addition, samples of the trial feed showed a higher BWi value than was reported in the benchmark study. Further recommendations on ball mill circuit operating changes are being reviewed by Ahafo (including the option of recycling cyclone underflow back to the SAG mill). Grind size improvement is an ongoing project being investigated by Ahafo personnel since early 2010.

Blasting vs. SAG Mill Specific Energy

One of the aspects of a PIO exercise is to recognize that blasting is the first stage of comminution. The operational gains to be made are from shifting the overall comminution energy from the less efficient, higher cost stage (grinding) to the more efficient, lower cost stage (blasting). In addition, there are benefits in dealing with better fragmented/comminuted material early on in the process (e.g. excavator dig rates, truck load factors, primary crusher productivity, etc.).

The two figures below illustrate the shift in energy measured during the Ahafo mill feed optimisation project. The first figure relates to the increase in blasting energy and the second, the SAG mill response to the finer feed with a reduction in specific energy.

Figure 5: Blasting Powder Factor vs. Rock Strength

Figure 5 shows Ahafo blasting powder factors (kilogram per tonne of rock) compared to other operations against rock strength or Unconfined Compressive Strength (UCS). Included in the operations is another Newmont site that has routinely applied differential powder factors for their range of rock properties for a number of years. The blue diamond icons cover a range of operations and different rock strengths and reveal that operations are adjusting their blasting energy for harder rock strengths even without a PIO exercise being undertaken.

The Newmont site (orange circles) participated in a PIO project and identified blasting domains that demanded different blasting conditions or energy levels to achieve a consistent mill feed size distribution.

The Ahafo blasting energy level prior to the PIO exercise is shown in Figure 5 compared to the blast validation trials (post PIO). Measurement of the rock strength for the validation blasts showed that the UCS was slightly higher than the benchmarked material.

In response, the reduction in SAG mill specific energy for the blasting trials is shown in Figure 6 against the measured Drop Weight Index (DWi) in kWh/m^3. The circled area for the six blasting trials showed an average SAG mill specific energy of 8.5 kWh/t for similar DWi values. This is compared to the average benchmark result of 10.4 kWh/t.

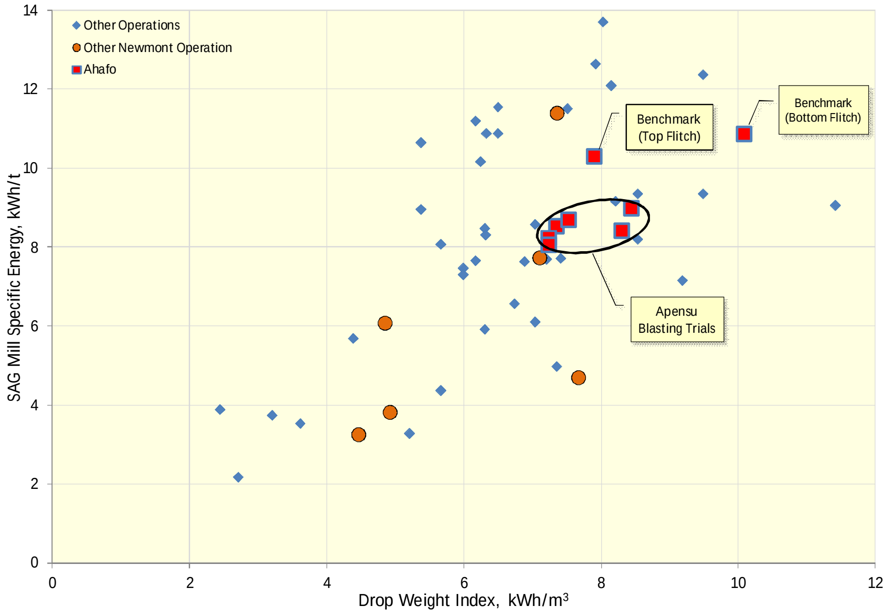

Figure 6: Change in SAG Mill Specific Energy with JKMRC Drop Weight Index

The reduction in SAG mill specific energy by 18% is a significant improvement in efficiency from the finer feed size generated by value-added blasting. Table 3 below summarizes the throughput increase at Ahafo over the past few years since the start of the PIO project.

Table 3: Throughput Improvements at Ahafo Over Time

Condition	Period	Primary tph	Oxide tph	Total tph	% -106µm
Before PIO	Oct 08 – Jan 09	722	294	1,016	–
Benchmark Average	Jan 09	780	231	1,011	75.7
Validation Trials	Nov 09	965	191	1,156	76.6
Ongoing	Jan – Mar 10	938	163	1,101	76.3
% Change		**30%**	**-45%**	**8%**	**–**

ADDITIONAL GRINDING CIRCUIT IMPROVEMENTS AT AHAFO

Following recommendations by Metso PTI, Ahafo has maintained tighter settings on both the primary and pebble crushers to maximise the fineness of the product size. Additionally, Ahafo implemented the following in June 2010:

- a Metso advanced control package on the SAG mill including AudioMill™, VisioRock™ (primary crusher product and SAG mill feed) and OCS© based expert grinding control software;
- installation of an additional cyclone to allow more flexibility and remove the restriction to control feed density when the pressure is rising;
- increased ball mill media charge resulting in higher power draw.

The above have resulted in increased plant stability and improved throughput.

CONCLUSIONS

Newmont Ghana Gold Limited's Ahafo operation have been working with Metso Process Technology & Innovation since early 2009 to increase mill throughput from a combination of controlled blasting practices and optimised primary crusher and grinding circuit conditions.

Following a benchmarking study of all blasting, crushing and grinding practices, PTI recommended changes in both blasting and crushing conditions in order to generate a finer feed size to the SAG mill. Additional operating changes in the grinding circuit were recommended.

Blast validation trials conducted in late 2009 showed a significant increase in mill throughput due to the finer feed conditions. The trial results also showed a general coarsening of the final grind size – likely from the lower blend of oxide in the feed. Grind size improvement is an ongoing project being investigated by Ahafo personnel since early 2010.

Ahafo have since standardised on this blast design for all Apensu ore zones and have been able to sustain higher throughput compared to historical performance on similar material.

The PIO exercise completed at Ahafo demonstrated the importance in considering blasting as the first stage of comminution. A small increase in well-applied blasting energy resulted in a reduction of SAG mill specific energy by 18% for similar hardness feed material.

Ahafo continues to monitor the effect of feed size on the grinding circuit using the VisioRock™ image analysis system on the SAG mill conveyor belt and by taking samples occasionally for ore hardness characterisation. Through a continuous partnership between Ahafo and Metso PTI, significant improvements in overall process performance have been achieved using the PIO methodology along with other initiatives implemented by Ahafo.

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