Powder Factor Selection for Comminution Circuit Performance Improvement at AngloGold Ashanti Iduapriem Limited

Eme P., S. Al-hassan, and R. K. Amankwah

Mining Engineering Department, University of Mines and Technology

Eme, P., Alhassan, S and. Amankwah, R. K (2018), "Powder Factor Selection for Comminution Circuit Performance at AngloGold Ashanti Iduapriem Mine", *5th UMaT Biennial International Mining and Mineral Conference*

Abstract

In this research, three different Powder Factors (PF 0.72, PF 0.88 and PF 0.96) were used in blasting to determine the best powder factor for blasting CUT 4 A-Zone pit. Sometimes, the blast product consists of boulders which require secondary handling which comes with an extra cost. This research seeks to select which powder factor gives the best fragmentation and could be used for blasting a continuous block at CUT 4 A-zone Pit. . The comminution behaviour, energy usage and grinding cost following blasting with different Powder Factors were estimated from Bond index investigation. The abrasive index test was also determined by using the JK method. Bond index test results obtained for PF 0.72, PF 0.88 and PF 0.96 were 15.7 kWh/t, 15.3 kWh/t and 15.1 kWh/t respectively. The energy consumed and cost incurred for PF 0.72, PF 0.88 and PF 0.96 were 9060.3 kW and Gh¢10 326.0, 8 868.9 kW and Gh¢10 107.9 and 8 741.3 kW and Gh¢9 962.5. From study, it was observed that, using PF 0.88 has the potential to increase production, reduce downtimes on the crusher plant and also reduce general cost incurred by the mine. It is recommended that for a better fragmentation to be obtained at CUT 4 A-Zone pit, Powder Factor of 0.88 could be used.

Keywords: Bond index, energy consumption, abrasive index and gravity recoverable gold

1 Introduction

Rock breakage is an essential part of the mining cycle and in hard rock, this is effected by drilling and blasting. Blasting involves fracturing material by the use of specific amounts of explosives so that a predetermined volume of material is broken. Good blast design and execution are essential to successful mining operations since blasting efficiency impacts significantly on the economics of a mine (Anon., 2016).

AngloGold Ashanti Iduapriem Limited has been employing three common powder factors which are 0.96, 0.88 and 0.72 in their blasting operations over the past three years. It has been observed that the mine produces boulders after blasting. The boulders need to be reduced into smaller fragments before being sent to the primary crusher. Sometimes, the boulders that are not well reduced, end up blocking the crusher causing frequent breakdowns of the crushing plant. It has been reported that downstream processes such as crushing and grinding are not efficient as attempts to mill rocks fine enough for gravity concentration leads to issues of low tonnage. Hence, this study seeks to determine the right powder factor to select in other to reduce cost.

1.1 Geological Mineralization of AAIL

The Banket Series of rocks in the mine area form prominent, ridges extending southwards from Tarkwa, westwards through Iduapriem and northwards through Teberebie to Mantraim. There are seven major ridge segments within the Iduapriem mining lease and the Banket Series rocks. These ridge segments extend over a total strike length of about 15km. The ridge segments are supported by a massive lithological unit known as the ‘Footwall Quartzite’, which is a strongly-bedded rock of blue-grey colour exhibiting a sub-parallel haematitic/black sand banding and which locally forms the basal stratigraphic unit to the Banket Reef Zone (BRZ). In Ghana, the Tarkwaian is considered to be of shallow water continental origin derived from the Birimian and associated granitoids (Moon and Mason, 1967).

The Banket Reef Zone (BRZ) comprises a sequence of individual beds of quartz pebble conglomerates, breccia conglomerates and meta-sandstones (also called quartzite and grits). All known gold mineralization within the Banket Formation is associated with the conglomerate which is found within the matrix that binds the pebbles together (Nesbitt, 1979). Gold content is a function of the size and amount of quartz pebbles present within a conglomeratic unit, hence the bigger and or more pebbles present the higher the amount of gold. In some localities, no angular unconformity can be observed at all (Woodfield, 1966). Fig 1 shows the Geology of West Africa.

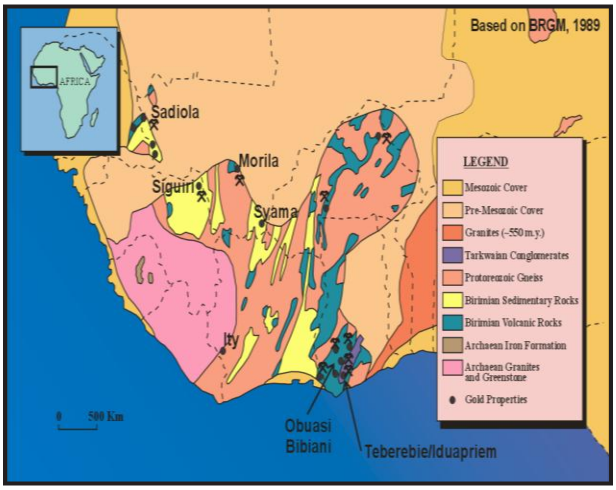

Figure 1 Geology of West Africa

2 Materials and Methods Used

Rock samples were taken from AngloGold Ashanti Iduapriem Mine. These samples were subjected to lab work such as; Bond Index, Abrasive Index, Gravity Recoverable Gold and Cost Analysis was carried out. Bond work index is a basic measure of rock hardness and it helps to determine the standard work index which is defined as the specific power required (Kwh/t) to reduce material from notional infinite size to P_{80} size of 100 µm. The gravity concentration was carried out to determine the amount of gold that is gravity recoverable. Micro crack generation helps to reduce the strength that would be needed in releasing the gold at a coarse size and hence aid gravity.

2.2 Bond Index

According to Bond’s Third Theory of Comminution, the energy input is proportional to the crack tip length created during particle breakage and equivalent to the work represented by the product. A general theory of comminution should consist of two parts, one that deals with the energy required to break mineral particles and another that examines how this energy is distributed to the particles generated after breakage (Stamboliasdis, 2006). Others have successfully developed other theories and have presented compelling narratives to the applicability and accuracy of these theories and their ability to provide better analysis. The Bond equation determines the energy required to produce a required particle size reduction (Michaud, 2015). Equation 3.7 below states the Bond’s Equation.

$$W = 10 \times W_I \left(\frac{1}{\sqrt{P}} - \frac{1}{\sqrt{F}} \right) \times t$$

The particle size reduction function is fairly straight forward and easily measured from samples taken from the feed material to the comminution vessel and from the product material. The samples are processed for a standard particle size distribution analysis and an 80% passing size noted. The 80% passing size is reported in micron units. The relationship of particle size on the power consumption is non-linear due to the inverse of the square root, with the finer sizes having a more significant impact on power consumption. The desired degree of particle size reduction is ultimately determined by the liberation characteristics of the mineral and the separation techniques applied (Evertsson, 1995). The various crushing and grinding equipment employed is determined by the effectiveness of the equipment on the particle size at the various stages of reduction. The work index is a different kind of function than particle size and is dependent on the hardness and/or toughness on the material.

2.3 Abrasive Index

Abrasive index is a laboratory test to measure the breakage parameters of a rock sample. Low energy (abrasion) breakage is characterised by using a tumbling test of selected single size fractions. The standard abrasion test tumbles 3 kg of -55 +38 mm particles for 10 minutes at 70% critical speed in a 305mm by 305mm laboratory mill fitted with 4 x 6mm lifter bars. The breakage products of all the rocks or particles for each size/energy combination are collected and sized. The size distribution produced is normalised with respect to original particle size (Anon., 2013).

2.4 Gravity Recoverable Gold

The gravity concentration was carried out to determine the amount of gold that is gravity recoverable. Micro crack generation helps to reduce the strength that would be needed in releasing the gold at a coarse size and hence aid gravity. The more micro crack generation in a rock sample, the more gold can be recovered through gravity. The 5 kg sample taken from each of the ground sample was made to pass through a Knelson concentrator.

The concentrate retained in the bowl of the Knelson was washed out with a reasonable amount of water. The concentrate was dried in an oven and the weight was measured to know the amount of concentrate gotten from gravity for each of the samples. 200 g of -1.18 mm size of head grade was removed from each of the samples before passing the material through a Knelson concentrator. The concentrate together with the head grade was sent to Intertek for further experiment to be carried out to determine the actual amount of gold in each of the samples.

3.0 Results and Discussion

Samples were taken from AngloGold Ashanti Iduapriem Mine and each of the samples were subjected to the lab for analysis. The results and discussions of the lab results gotten from abrasive index, bond index and gravity recoverable gold that was carried out would be discussed below

.

3.1 Abrasive Index

This results were gotten after carrying out abrasive index on the rock material taken from AngloGold Ashanti Iduapriem Mine.

Table 1 Abrasive Index of each PF Used

Sample	Pf 0.72	Pf 0.88	Pf 0.96
Bottom	0.53	0.54	0.61
Middle	0.47	0.48	0.54
Top	0.32	0.42	0.45

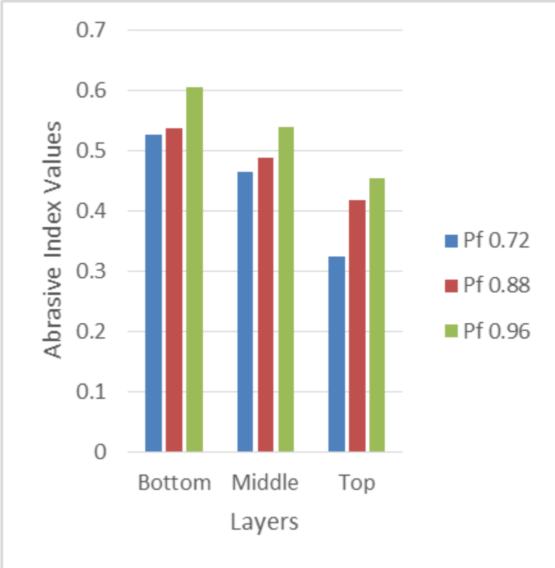

Figure 2 Abrasive Index Values against Layers

PF 0.96 has the highest abrasive index with an abrasive average value of 0.53 which implies that, it is the softest rock among the other two rock samples taken. PF 0.88 has a comparative lower average abrasive index of 0.48 which makes the rock to be relatively hard. PF 0.72 has the lowest average abrasive index of 0.44 which makes the rock harder than the other two rock samples taken. Hence, for a better fragmentation to be obtained, the block blasted with PF 0.72 should have been blasted with a higher powder factor because, from the lab work conducted, it clearly showed that the rock was hard.

3.2 Bond Index

The table below shows the Bond index value against layers that were gotten from the laboratory test conducted.

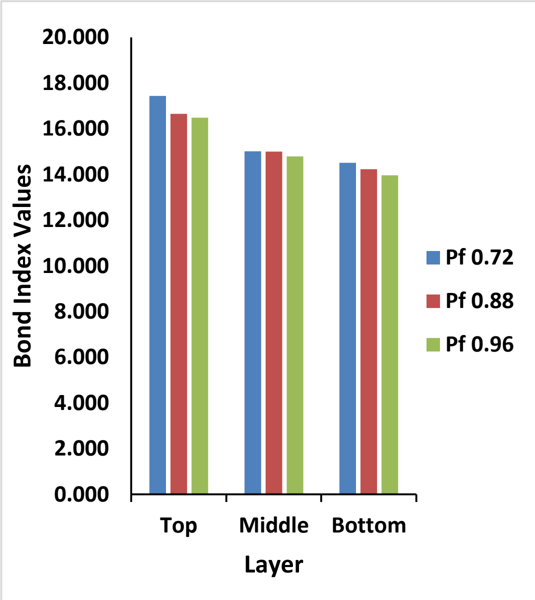

Figure 3 Bond Index Values against Layers at Different PFs

Table 2 The PF values and Bond Index Values

Sample		Bond Index
Powder Factor 0.72	Top	16.0
	Middle	13.6
	Bottom	13.1
Powder Factor 0.88	Top	15.3
	Middle	13.6
	Bottom	12.8
Powder Factor 0.96	Top	15.1
	Middle	13.4
	Bottom	12.6

From the graph, it can be seen that PF 0.72 has the highest Bond index value which implies that the energy required for crushing the rock would be very high as compared to using PF 0.88 and PF 0.96. The average bond index for PF 0.72, PF 0.88 and PF 0.96 were 14.2 kWh/t, 13.9 kWh/t and 13.7 kWh/t. From the data collected, it was seen that crusher availability was much better, the plant could run for a longer time without unnecessary breakdowns and no blockages when PF 0.88 was used. Some few calculations was done to determine the energy consumed and the cost involved for each of the powder factors used. AAIL has two Circuits but circuit one P_{80} and F_{80} values would be used for the energy consumptions and cost involved calculations.

From the calculations deduced, using PF 0.72, the energy consumed and cost involved per hour would be 9 060.3 kW and Gh¢10 326.0, using PF 0.88, the energy consumed and cost involved would be 8 868.9 kW and Gh¢10 107.9 and using PF 0.96, the energy consumed and cost involved would be 8 741.3 kW and Gh¢9 962.5.

From the results, PF 0.96 consumed the least energy. PF 0.96 has 1.8% energy consumption less than using PF 0.72 and PF 0.96 also has 0.72% energy consumption less than using PF 0.88. Since the energy consumption between PF 0.96 and PF 0.88 is less than 1%, the energy consumption and cost incurred for PF 0.88 is said to be reasonably good. Also, PF 0.96 has the lowest bond index due to the soft nature of the rock which made it easier for crushing and grinding the rock materials into fines.

3.3 Gravity Concentration

Gravity Concentration was conducted to determine the amount of gold recovered for each of the PF's used. Table 3 shows the gold recoveries for each of the PF's used.

Table 3 Gold Recoveries using the three different Powder Factors

Sample Powder Factor	PF 0.96	PF 0.88	PF 0.72
Feed grade, g/t	0.94	1.16	0.8
Feed weight, g/t	5000	5000	5000
Conc. Weight, g	79.1	78.3	72.1
Conc. grade, g	26.8	27.9	5.8
Mass Pull %	1.6	1.6	1.4

From the Gravity Concentration carried out, PF 0.88 which is Table 3 recovered the highest amount of gold with 42.8% of gold recovered through gravity. Also, the macro-crack on the rocks contains pebble quartzite which indicates that the rock contains an amount of gold

Table 4 Summary of Results obtained

Summary	PF 0.72	PF 0.88	PF 0.96
Abrasive Index	0.44	0.48	0.53
Bond Index	14.2 kWh/t	13.9 kWh/t	13.7 kWh/t

Cost	Gh¢10 326.0	Gh¢10 107.9	Gh¢9 962.5
Gravity Concentration	33.7%	42.8%	11.1%

In general, considering the values on Table 4, PF 0.88 will reduce the general cost incurred by the mine, reduce downtimes on the crusher plant and increase production. For the next continuous block to be mined at A-ZONE CUT 4, powder factor of 0.88 could be used because it would bring great benefit to AngloGold Ashanti Iduapriem mine.

4 Conclusions

This research was carried out at AngloGold Ashanti Iduapriem Mine. The change in rock strength parameters induced by changes in powder factor during blasting and its effect on comminution circuit performance was considered. With respect to energy consumption cost and during grinding, using PF 0.72, PF 0.88 and PF 0.96, the energies consumed and costs involved would be 9060.3 kW and Gh¢10 326.0, 8 868.9 kW and Gh¢10 107.9 and 8 741.3 kW and Gh¢9 962.5. Since the energy consumption between PF 0.96 and PF 0.88 is less than 1%, the energy consumption and cost incurred for PF 0.88 is said to be reasonably good With regards to abrasive index, PF 0.96, PF 0.88 and PF 0.72 were 0.53, 0.48 and 0.44. This showed that the rock that was blasted with PF 0.72 was the hardest rock and should have been blasted with higher PF or the blasting parameters changed for a good fragmentation to be achieved.

There was 2% decrease in primary crusher downtimes when PF 0.88 was used compared to using PF 0.96 and 8% decrease in primary crusher downtimes compared with PF 0.72. The crusher was more available and utilized better with less breakdowns for PF 0.88 and gravity recoverable gold was highest for PF 0.88 with 42.8%. Using PF 0.88 will also reduce general cost incurred by the mine and increase production. It recommended that, for continuous block at A-ZONE CUT 4 pit, powder factor of 0.88 could be used for optimum fragmentation to be achieved and this will as well prevent secondary handling. Also, Blasted and insitu rock materials should be regularly sent to the lab for analysis, to easily determine when to vary the powder factor for good fragmentation to be maintained.

Acknowledgements

The greatest thanks, praise and adoration belongs to the Almighty God who kept me going, His uncountable love, blessings, kindness and grace throughout my study. I earnestly acknowledge and appreciate the contributions of Prof. Richard K. Amankwah and Prof. Sulemana Alhassan for their knowledge, constructive analysis and comments have helped me develop generally as an individual, to an extent that this research became a success. Their remarks shall forever be at the front of my thoughts. All lecturers of the Mining Engineering Department and allied departments have also imparted positively in the pursuit of my academic agenda. With great appreciation, I say "Thank You" to the Mine Manager of AAIL called Mr. Stephen K. Asante Yeboah, Mr. Michael, Mr. Mathias and the mining department team of AngloGold Ashanti Iduapriem Limited who in one way or the other gave me the maximum support throughout my research. Lastly to all my lovely family and friends who helped me in diverse ways in making this thesis a reality. I say "God richly bless you".

References

Anon. (2006), "Internal Report-AngloGold Ashanti, Iduapriem", www.anglogold.com. *Unpublished Report*, AngloGold Ashanti Iduapriem Ltd., Tarkwa, Accessed: December 30, 2016.

Anon. (2013), "Optimizing Dewatering Processes in Mining Operations", http://www.waterra-in. Accessed: July 28, 2017.

Anon. (2013), "SGS Mineral Services – T3 SGS 151", http://www.SGS.com/mining Accessed: December 22, 2017.

Adel, G., Kojovic, T. and Thornton, D. (2006), "Mine-to-Mill Optimization of Aggregate Production", *Unpublished Final Report on Work Carried out at Bealeton Quarry and Pittsboro Quarry*, United States, Missouri, 19 pp.

Bozic, B. and Braun K. (1991), "Tectonic Fabric and Blasting in Dolomite Rocks", *7th International Congress on Rock Mechanics*, Aachen, pp. 95-100.

Fuerstenau, M. C., Chi, G., Bradt, R. C. and Ghosh, A. (1995). "Improved Comminution Efficiency through Blasting During Mining", *Unpublished Report*, Department of Chemical and Metallurgical Engineering, University of Nevada, Reno, NV. USA, pp. 93-99.

Evertsson, C. M. (1995), "Prediction of Size Distributions from Compressing Crusher

Machines”, *Proceedings of Explo95 Conference*, Brisbane, Qld, Australia, pp. 173-180.

Forbah Jnr, J. Y. and Amankwah, R. K. (2010), “Effects of Rock Fragmentation on Comminution – a Case Study at Damang Gold Mine”, 1st UMaT International Mining and Mineral Conference, 4-7th August, Tarkwa, Ghana, pp. 198-205.

Kanchibotla, S. S. (2000), “Mine to Mill Blasting to Maximise the Profitability of Mineral Industry Operations”, Proceedings of the 26th Annual Conference on Explosives and Blasting Technique, International Society of Explosives Engineers, Vol 2, USA, pp. 349-359.

Kennedy, B. A. (1975), Surface Mining, Society for Mining, Metallurgy and Exploration (U.S.) Second Edition, New York, 575 pp.

Kesse, G. O. (1985), the Mineral and Rock Resources of Ghana, A.A. Balkema, Rotterdam, Netherlands, 610 pp.

Khorzoughi, M. B. and Hall, R. (2015), “Diggability Assessment in Open Pit: A Review”, International Journal of Mining and Mineral Engineering, pp. 10-14.

Kose, H., Aksoy, C. O., Gönen, A., Kun, M. and Malli, T. (2005), “Economic Evaluation of Optimum Bench Height in Quarries”, The Journal of the South African Institute of Mining and Metallurgy, pp. 125 - 135.

Lowrison, G. C. (1974), the Size Reduction of Solid Materials: Crushing and Grinding. Butterworth, London, pp. 49-66.

Moon, P. and Mason, D. (1967), “The Geology of ¼ º Field Sheet 129 and 131, Bompata SW and NW”, Ghana Geological Survey Bulletin, 51 pp.

Schoenert, K. (1972), “Role of Fracture Physics in Understanding Comminution Phenomena”. *Trans. AIME 252*, pp. 21-26.

Schoenert, K. (1986), “On the limitation of energy saving in milling”, World Congress Particle Technology, Part II, Comminution, Nurnberg, April 16-19, p. 1.

Stamboliasdis, E. T. (2006), “The Energy Distribution Theory of Communition Specific Surface Energy, Mill Efficiency and Distribution Mode”, Unpublished Report, Department of Mineral Resource Engineering, Technical University of Crete, Greece, pp. 140-144.

Author

Eme, Precious is a young hardworking lady who is studying MSc. Mining Engineering at UMaT and a BSc. Mechanical Engineering holder, from UMaT. She has key interest in rock strength determination, Fluid machinery, Industrial Maintenance, rock mechanics, drill and blast, crusher availability determination, plant breakdown analysis and cycle loading times of shovel determination.

Prof Richard K. Amankwah is a senior lecturer at the Minerals Engineering department. He is currently the dean of FMRT and has key interest on Mine-to-Mill, Cost reductions in the mine and rock strength determinations. He has been lecturing for more than 15years and his research has helped improved upon some mining companies and industries both in Ghana and outside Ghana.

Prof. Sulemana Alhassan is a senior lecturer at the University of Mines and Technology. He is a senior lecturer at the Mining Engineering department. He has key interest in Surface Mine Planning, Resource Estimation, and Statistical Model. He has been lecturing for more than 15yrs and his research has helped improved upon some mining company’s productivity and industries in Ghana.