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

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## Abstract

The Powder Factor utilised during blasting is known to influence the comminution properties and downstream metal recovery processes. Improper selection of Powder Factor values may generate blast products that consist of boulders and require secondary handling which comes with an extra cost. 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 ore in CUT 4 A-Zone pit. The comminution behavior, energy usage and grinding cost following blasting with different Powder Factors were estimated from their Bond ball work indices. The abrasive indices were also determined by using the JK method. Bond ball work index test results obtained 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 respectively. The energy consumed and cost incurred on size reduction of a tonne of ore for PF 0.72, PF 0.88 and PF 0.96 were 9060.3 kW and Gh¢10 326.00, 8868.9 kW and Gh¢10 107.90 and 8 741.3 kW and Gh¢9 962.50. From the 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 ball work index, Powder Factor, Ore haulage, Material used, 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 (AAIL) 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 and ensure smooth operations.

### 1.1 Geological Mineralisation 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 15 km. 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 mineralisation 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.

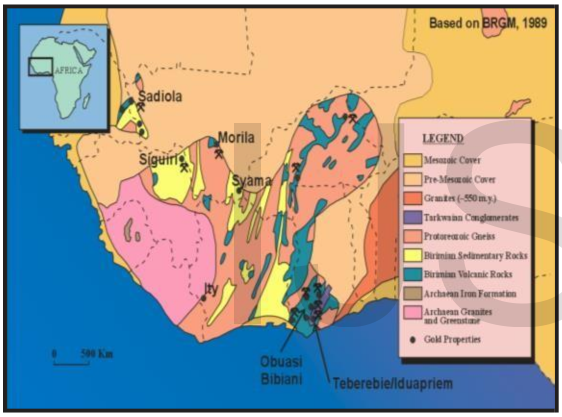


**Fig.1 Geology of West Africa**

## 2 Materials and Methods Used

Rock samples were taken from AngloGold Ashanti Iduapriem Mine. Three samples were taken after fragmentation with each powder factor. Samples at the bottom and close to where explosives were lodged, those at the middle and at the top of the holes. These were referred to as 'bottom', 'middle' and 'top' samples.

These samples were subjected to laboratory investigations including Bond ball work Index, Abrasive Index and Gravity Recoverable Gold. Cost Analysis was also carried out.

### 2.2 Bond Ball Work 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).

For this study, Representative samples of the ore was being prepared to all passing 3.35 mm. The tests were performed according to the guidelines developed by F C Bond (Nappeir-Munn,1996). The weight of material contained in 700 cc was weighed and placed in a Bond mill. After every grinding cycle, the mass of the minus 106 µm fraction was replaced with fresh feed to keep the mass of the mill feed constant. The cycle was repeated until the net mass of minus 106 µm material produced per mill revolution attained equilibrium with a circulating load of 250%. The Bond ball work index was calculated using Equation 1.

$$W_i \equiv \frac{44.5}{(P_1)^{0.23} \times (Gbp)^{0.82} \times 10\left(\frac{1}{\sqrt{P_2}} - \frac{1}{\sqrt{F_2}}\right)} \quad (1)$$

where $W_i$ is the work index, $P_1$ is the screen test size in microns, Gbp is the net grams undersize per revolution, $P_2$ is the 80% product passing size in microns and $F_2$ is the 80% feed passing size in microns.

### 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 305 mm by 305 mm laboratory mill fitted with 4 x 6 mm 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.

## 3.0 Results and Discussions

Samples were taken from AngloGold Ashanti Iduapriem Mine and each of the samples were subjected to analysis. The results of ore hauled, the lab investigations on abrasive and Bond ball work indices, and gravity recoverable gold are discussed.

### 3.1 Ore haulage

The data obtained using the Split Desktop Image Software and groundtruthing shows that the powder factors utilised affected the product particle sizes. The 80% passing sizes for powder factors 0.72, 0.88 and 0.96 were 1040 mm, 965 mm and 965 mm respectively. The 0.96 powder factor however, generated more fines.

Good fragmentation makes it easier for the shovel to excavate the loose rock into trucks and also enables the actual volume of the rock to be known which in turn increases production. Boulders create voids in the truck's bucket which causes the truck to get full up faster than its required volume. When fines are also generated, it results in increase in loading time for the trucks. From Fig. 2, it can be seen that over a 15-day period, PF 0.88 had the highest volume of ore hauled because the particles generated after blasting made muckpile diggability better and loading easier than PF 0.96 and PF 0.72. In addition, 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.

### 3.2 Abrasive Index

Figure 3 shows the results of the abrasive index investigations. PF 0.96 had the highest average abrasive index with an average value of 0.53 which implies that, it is the softest rock among the samples taken.

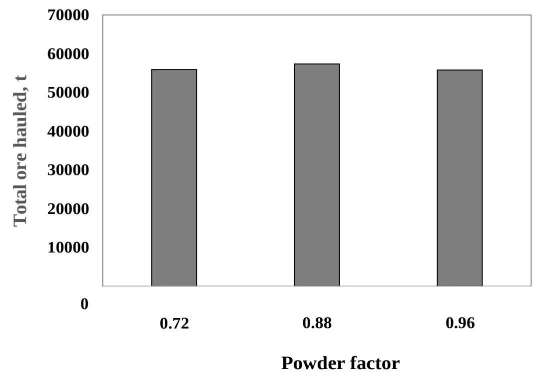


**Fig. 2 Tonnage of ore hauled over 15 days for the various powder factors**

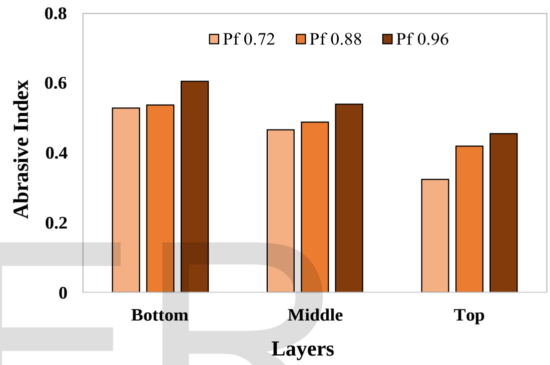


**Fig. 3 Abrasive Index Values against Layers**

PF 0.88 had a comparatively lower average abrasive index of 0.48. PF 0.72 has the lowest average abrasive index of 0.44. However, all of them can be classified as having high resistance to abrasion (Napier-Munn *et al*., 1996).

### 3.3 Bond Ball Work Index

Figure 4 shows the Bond ball work index value against layers that were obtained after blasting. From the graph, it can be seen that PF 0.72 had the highest Bond ball work index value which implies that the energy required for crushing the rock would be higher compared to using PF 0.88 and PF 0.96. The average bond ball work 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.

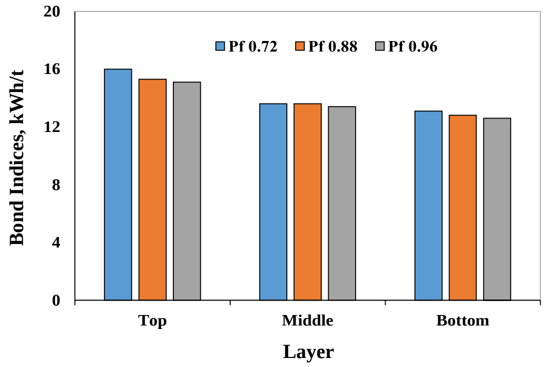


**Fig 4 Bond ball work Index Values against Layers at Different PFs**

From the data collected on the mine, 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 were 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¢10 326.00, using PF 0.88, the energy consumed and cost involved would be 8 868.9 kW and Gh¢10 107.90 and using PF 0.96, the energy consumed and cost involved would be 8 741.3 kW and Gh¢9 962.50. 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 ball work index due to the soft nature of the rock which made it easier for crushing and grinding the rock materials into fines.

## 3.4 Gravity Concentration

Gravity Concentration was conducted to determine the amount of gold recovered for each of the PF's used. Table 1 shows the gold recoveries for each of the PF's used. The results of gravity concentration were influenced by the grade of the samples taken and not much can be deduced from it relative to the Powder Factors as the grades were different.

**Table 1 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 |
| Recovery, % | 33.7 | 42.8 | 11.1 |

However, from the gravity concentration carried out, PF 0.88 recovered the highest amount of gold with 42.8% of gold recovered through gravity.

A summary of the results is presented in Table 2. In general, considering the values, PF 0.88 will reduce the general cost incurred by the mine, reduce downtimes on the crusher plant and increase production.

**Table 2 Summary of Results obtained**

| **Summary** | **PF 0.72** | **PF 0.88** | **PF 0.96** |
|---|---|---|---|
| Tonnes hauled, t | 55939 | 57383 | 55827 |
| Abrasive Index | 0.44 | 0.48 | 0.53 |
| Bond Index, kWh/t | 14.2 | 13.9 | 13.7 |
| Cost, GH¢ | 10326.0 | 10107.9 | 9962.50 |
| Gravity Conc, % | 33.7 | 42.8 | 11.1 |

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 per tonne of ore milled, 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 utilised better with less breakdowns for PF 0.88. 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.

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