Powder Factor Selection for Improved Rock Fragmentation at AngloGold Ashanti Iduapriem Limited

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Abstract

Improper blasting affects loading, hauling and comminution processes. Hence, the right powder factor (PF) should be used in blasting to avoid the formation of boulders. AngloGold Ashanti Iduapriem Limited has been employing three different Powder Factors (PF 0.72, PF 0.88 and PF 0.96) in blasting. 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 pitThree different powder factors were used in blasting a continuous block and the effect on shovel loading time and volume of ore hauled were recorded to know the best powder factor that should be used in blasting at AngloGold Ashanti Iduapriem Mine CUT 4 A-Zone pit. For shovel loading time, PF 0.72, PF 0.88 and PF 0.96 had a total number of 87,109 and 99 passes of trucks respectively for the 15days studied. PF 0.72, PF 0.88 and PF 0.96 have 55939 t, 57383 t and 55827 t and the estimated cost for PF 0.72, PF 0.88 and PF 0.96 were $ 3 331 640, $ 3 417 700 and $ 3 325 010. Fragmentation analysis was also carried out. From study, it was observed that, using PF 0.88 will increase production, reduce downtimes on the crusher plant and also reduce general cost incurred by the mine. From the research conducted, 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: Fragmentation analysis, loading and hauling, shovel loading time and cost estimated.

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).

Powder Factor (PF) is the amount of explosives required to fracture a cubic metre of rock and is the measure of the economy of the blasthole (Assakkaf, 2003). It can serve a variety of purposes, such as an indicator of how hard the rock is, the cost of the explosives needed, or even as a guide to planning a shot for effective fragmentation. Ineffective fragmentation can however lead to the production of boulders which may remain on the crusher window. Additional energy may therefore be needed to cause a further secondary breakage (mechanically or blasting). This also incurs additional cost on production causing a decrease in profit and the net present value of mine projects. The degree of fragmentation influences the effectiveness and efficiency of the excavation and loading operations. Characteristics of blasted rocks such as fragment size, volume and spread are fundamental variables affecting the economics of mining operations and are in effect the basis for evaluating the quality of the blast. Recent studies have shown that blast design has major effect on downstream processes (Bozic, 1998).

Mine-to-mill studies focus on the impact of blast fragmentation on product characteristics, mine machinery availability and efficiency as well as other downstream processes such as crushing, grinding and mineral recovery. The Mine-to-mill concept involves modifications to current mining, crushing and milling practices without necessarily compromising some of the mining requirements such as productivity and good grade control (Adel *et al*., 2006; Gillot, 2005; Eloranta, 1995). When Mine-to-mill is approached and managed properly, there would be an increase in crusher availability, mill efficiency, tonnages of ore hauled per day by the trucks, and an overall increase in production.

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. The secondary handling and reducing of the boulders using the hydraulic hammer and the backhoe excavator comes at an extra cost. In addition, shovel loading time and ore volume reconciliation issues exist as loaders are not able to fill their buckets due to the boulders being handled. Sometimes, the boulders that are not well reduced, end up blocking the crusher causing frequent breakdowns of the crushing plant. Hence, this research seeks to select the right powder factor to improve upon rock fragmentation.

1.2 Mineralization of the Deposit

All gold mineralization occurs within four specific zones or reefs. The four reefs recognized are A, B, C and D Reefs. Ore grade gold mineralization occurs within five specific areas at Iduapriem, named from east to west as Block 1, Block 2, Block 3, Block 4 and Block 5. At Teberebie, two specific mineralized areas exist, namely Block 7 (Teberebie) and Block 8 (Awunaben). Ajopa North deposit (Block 6) also containing the Banket Series rocks is on a narrow and steep ridge further north-west of Iduapriem and adjoins Gold Fields Ghana Limited's Kotraverchy deposit (Nesbitt, 1984).

In Block 1, the deposit comprises a single composite zone of C and D Reefs. At the eastern end of Block 2, the single composite C and D Reef zone gives way to multiple zones (A, B, C and D) which extend further west into Block 3 where there are up to four specific zones of ore grade mineralization. The A, B, C and D Reefs also occur at Blocks 4, 5, 7 and 8. Though the four zones are recognizable at Ajopa, only the B and C Reefs are economic. The depth of weathering of the BRZ is variable and extends to 15 meters below the surface in Block 1. It is generally shallower in Blocks 2, 3, 4, 5, 7 and 8 where the BRZ outcrops at topographically higher elevations (Nesbitt, 1984). Fig 1 Quartz Pebble Conglomerate in the Tarkwaian System.

Fig 1 Quartz Pebble Conglomerate in the Tarkwaian System

2 Materials and Methods Used

The data for this research work was collected from AngloGold Ashanti Iduapriem Mine. They were gotten after studying the shovel loading time and volume of ore hauled by the trucks. Fragmentation analysis and estimated cost was further calculated to determine the Powder Factor that gave the best productivity.

2.2 Fragmentation Analysis

Fragmentation is considered good when the blasted material is fine enough and loose enough to ensure efficient digging and loading. To improve on the fragmentation, analyses were conducted on the blasted areas using Split Desktop Image Processing Software Images of the muck pile were taken with a camera of high resolution for the analyses. The results were from Split Desktop for the images taken on the rock blasted with different powder factors.

Three images were obtained at A-ZONE CUT 4 pit and the individual results were used to predict the fragmentation for each of the powder factors (PF) used in blasting. The images were manually delineated after the scales have been set. Voids between fragments and areas of rock fragments whose edges were not clear enough to be delineated were masked as fine. The scaling objects were masked so that they would not be considered as part of the rock fragments. Fine factor was set to 50 mm before delineation was done on the rock fragments. After the scaling object has been delineated, the colour changes to green which then tells that the delineations were right and the software was ready to run. The software was run and the result was converted to an excel sheet. Fig 2, Fig 3 and Fig 4 were the images from AngloGold Ashanti Iduapriem Mine and analysed using the Split Desktop.

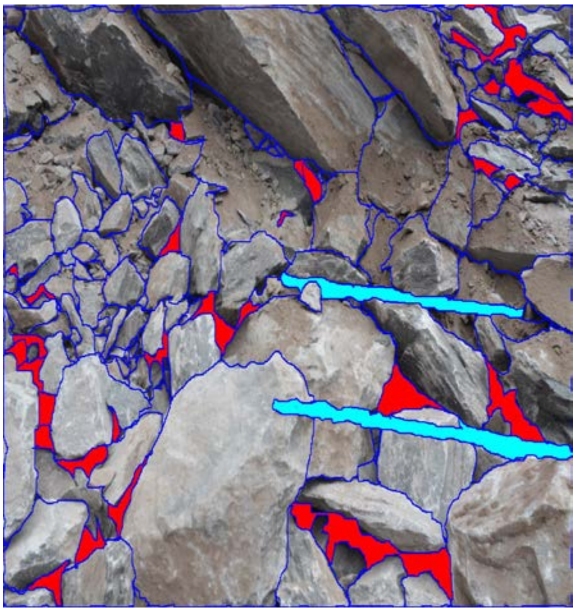

Fig 2 Image of Rock blasted us PF 0.96

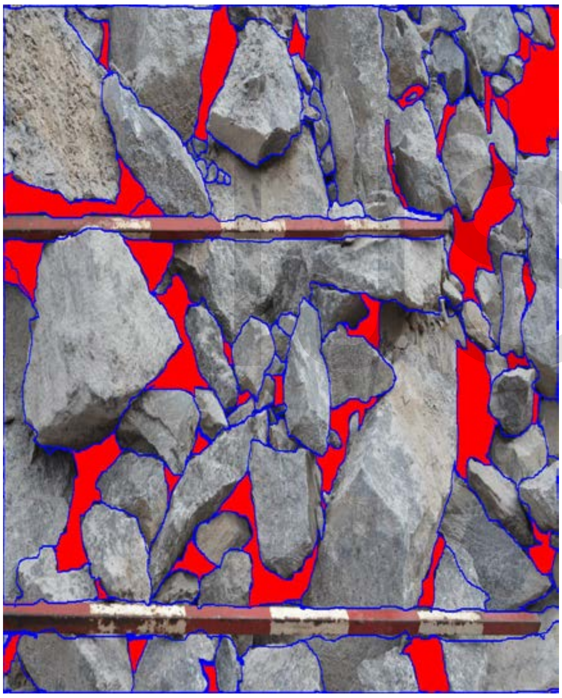

Fig 3 Image of Rock Blasted using PF 0.88

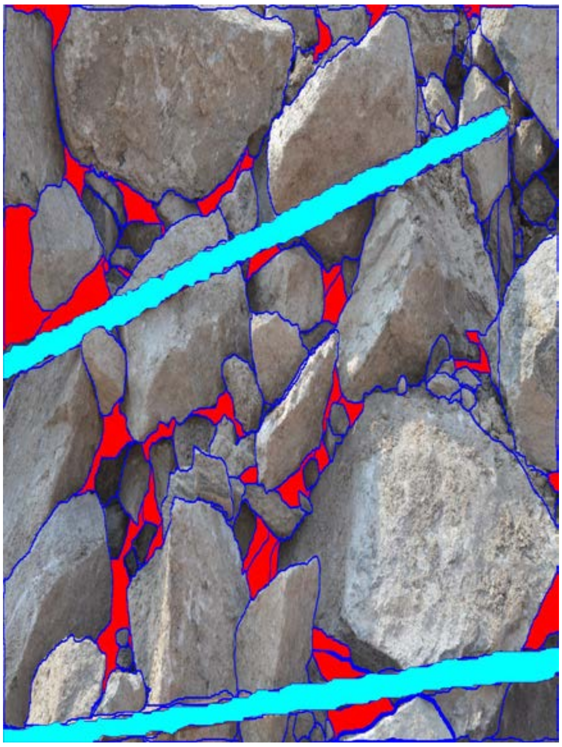

Fig 4 Image of Rock blasted using PF 0.72

2.3 Shovel Loading Time and Volume of Ore Hauled

Loading efficiency has a critical role in increasing production and reducing cost of mining operations. Effective loading is used to indicate ease of excavation and is also related to loading equipment performance which is characterized by the quality of blast. Quality blast also influences the right volume of ore hauled to be known. In addition, muck-pile characteristics and blast quality, operator practice, machine type and conditions have been found to have a significant effect on diggability (Khorzoughi and Hall, 2015). In this research, the machine type was the same and in good condition and three well trained operators, but the powder factor for blasting each block was different. Data was collected on the three continuous block blasted with different PF's, used to determine the performance of the equipment in terms of shovel loading time for 15 days. The time it took the digger to fill a truck was timed and recorded and the number of bucket that filled each truck was also recorded. This was done for the three powder factors used in blasting the continuous block. The volume of the ore hauled were taken from dispatched and analyzed respectively.

3 Results and Discussion

This study presents the results of fragmentation analysis, shovel loading time, volume of ore hauled, Bond index test, abrasive index test and gravity recoverable of gold that was carried out in this research.

3.1 Shovel Loading Time

Table 1 shows the data from shovel loading time after a careful study of 15 days. An average of each of the loading time value was obtained from the data gotten.

Table 1 Shovel Loading Time with Different Powder Factors

Powder factors	Shovel Loading Time	Values
Powder factor 0.72	Total Loading Time (mins)	33.9
	Total Number of Passes	87
Powder factor 0.88	Total Loading Time (mins)	30
	Total Number of Passes	109
Powder factor 0.96	Total Loading Time (mins)	34.7
	Total Number of Passes	99

PF 0.88 had the best loading time which means that, it has a better and more consistent uniform fragmentation which made it easier for the shovel to easily scoop the rock material into the truck than when PF 0.96 and PF 0.72 were used. Powder factor of 0.72 has the least loading time and it took a longer time for the shovel to load into the truck due to the boulders that resulted after blasting. There 5% reduction in shovel loading time when PF 0.88 was used than using PF 0.96 and 11% reduction in shovel loading time when PF 0.88 was used than using PF 0.72. As a result of the better fragmentation and the micro-cracks which helped to reduce the stress on the crusher, there was about 2% decrease in primary crusher downtimes using PF 0.88 than using PF 0.96. There was about 8% decrease in primary crusher downtimes using PF 0.88 than using PF 0.72, as a result of the better fragmentation and the micro-cracks which helped to reduce the stress on the crusher plant. With respect to the volume of ore hauled by trucks, Table 2 and Fig 5 show the total volume of ore hauled for 15 days.

Table 2 Sample PF's and Total Volume of Ore Hauled

Sample PF's		Total Volume of Ore Hauled (t)
Powder Factor 0.72	Top	55689
	Middle	55997
	Bottom	56132
Powder Factor 0.88	Top	57921
	Middle	57445
	Bottom	56782
Powder Factor 0.96	Top	56798
	Middle	55895
	Bottom	54789

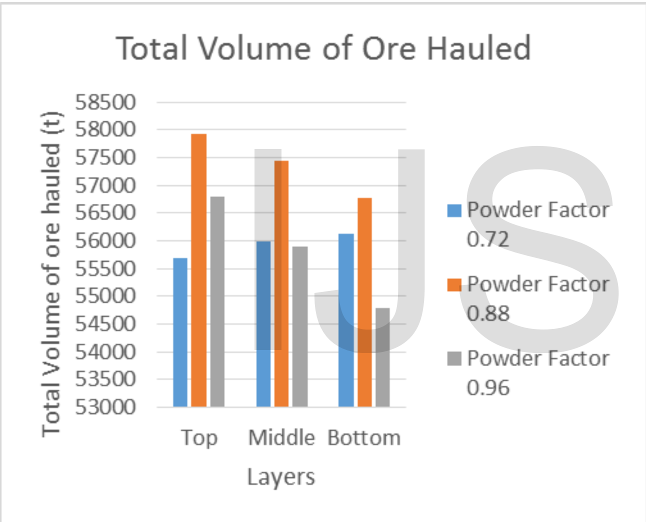

Fig 5 Total Volume of Ore Hauled against Layers for various Powder Factors

The better the fragmentation, the easier it becomes for the shovel to excavate the loose rock into the truck. Good fragmentation also enables the actual volume of the rock to be known which in turns increase production. Boulders create void in the truck's bucket which causes the truck to get full up faster than its required volume and when fines are also generated, it result in increase in loading time for the trucks. From Fig 5 and Table 2, it can be seen that PF 0.88 has the highest volume of ore hauled because, it gave a better rock fragmentation after blasting, easier and faster to excavate into the trucks than using PF 0.96 and PF 0.72. From the calculations, PF 0.72, PF .88 and PF 0.96 estimated cost were $ 3 331 640, $ 3 417 700 and $ 3 325 010. It was observed that, PF 0.88 resulted in 0.78% increase in productivity than using PF 0.72 and PF 0.88 resulted in 0.73% increase in productivity than using PF 0.96. For a higher productivity to be achieved, PF O.88 could be used.

3.2 Fragmentation Analysis

The results and discussion for the fragmentation measurements were obtained through analysis on the images taken, using Split Desktop Image Software. The results in Fig 6 to Fig 11 were gotten from the analysis on the images of the rock samples taken.

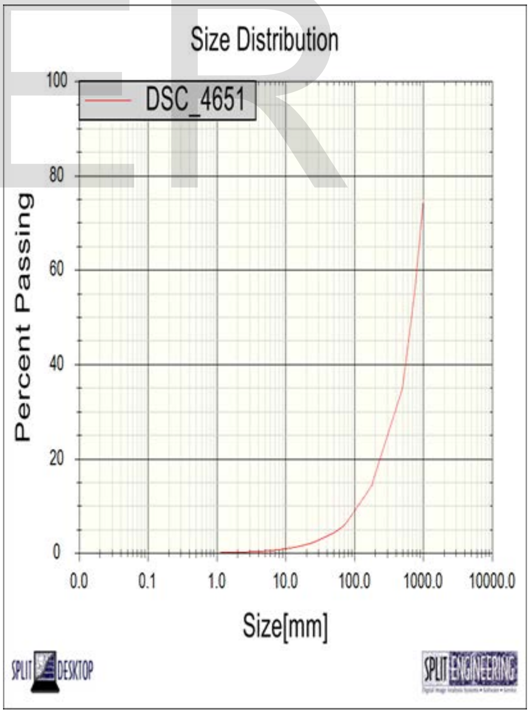

Fig 6 Percentage Passing of ROM Ore against Size Distribution using PF 0.96

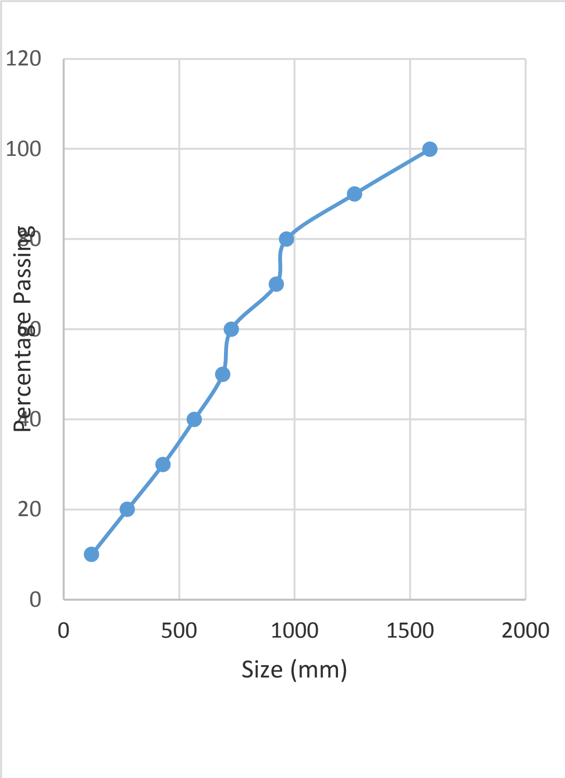

Fig 7 Percentage Passing of ROM Ore against Size Distribution using PF 0.96

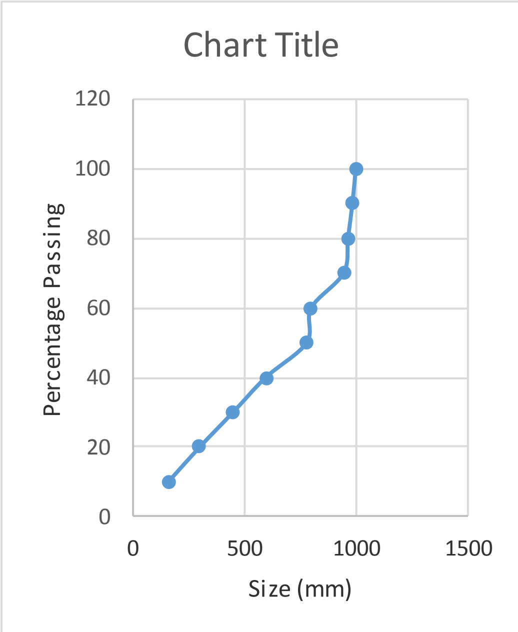

Fig 9 Percentage Passing of ROM Ore against Size Distribution using PF 0.88

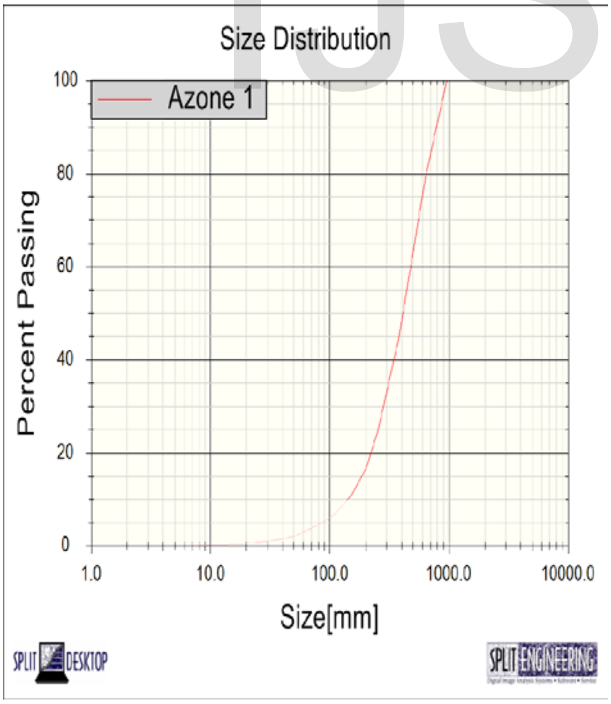

Fig 8 Percentage Passing of ROM Ore against Size Distribution using PF 0.88

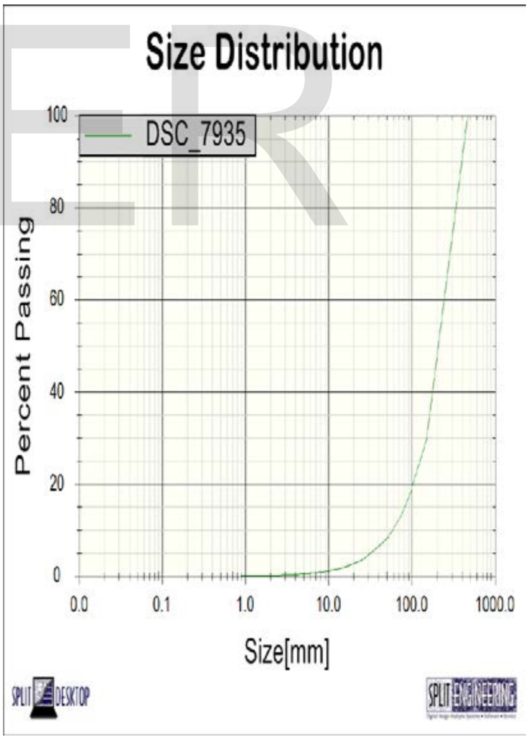

Fig 10 Percentage Passing of ROM Ore against Size Distribution using PF 0.72

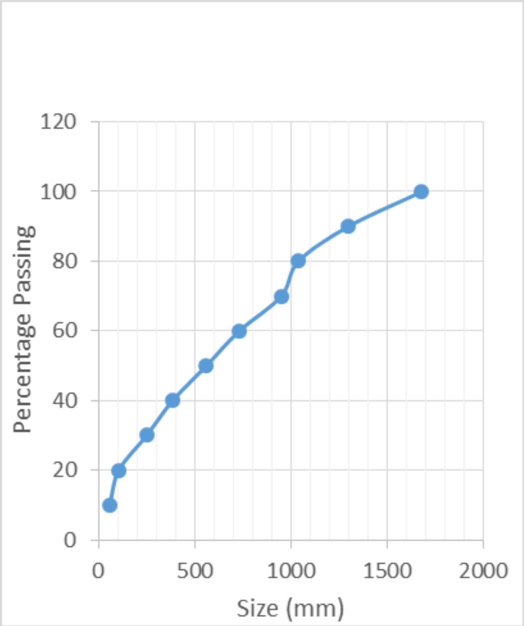

Fig 11 Percentage Passing of ROM Ore against Size Distribution using PF 0.72

The material that can pass through the primary crushers is 38″ or about 965.2 mm. From Fig 6 and Fig 7, 80% of the feed material can freely pass through the crusher gape. From Fig 6 and Fig 7, 20% of the feed material will pass through the crusher gape at a size of 276.10 mm, 50% at a size of 688.80 mm and 80% at a size of 965.13 mm. From Fig 8 and Fig 9, 20% of the feed material will pass through the crusher gape at a size of 300.85 mm, 50% at a size of 780.12 mm and 80 % at a size of 965.16 mm. From Fig 10 and Fig 11, 20% of the feed material will pass through the crusher gape at a size of 105.63 mm, 50% at a size of 560.87 mm and 80% at a size of 1040.34 mm. These has proven that powder factor has a great effect on rock fragmentation based on the fragmentation analysis carried on.

Considering the graphs plotted by split engineering, it didn't clearly show the percentage passing against size distribution. So, a manually plotted graph Fig 7, Fig 9 and Fig 11 was drawn which clearly depict the percentage passing of the material against size distribution and 80% passing against size distribution is clearly seen for each of the powder factor used. Therefore, PF 0.88 gave a better rock fragmentation with size of 965.16 mm for 80% passes as clearly indicated on the manually plotted graph.

Since 80% of the feed material passing through the crusher gape is lower than the crusher gape size when PF 0.96 and PF 0.88 were used, the fragmentation of the blast is good except for PF 0.72 which has less than 80% of the feed material passing through the crusher gape size, which implies that the fragmentation of the blast is not good. Blasting with PF 0.72 will produce many boulders; the fragmentation size obtained would be bigger than the crusher gape size, which will in turn lead to a lot of blockages, consistent breakdown and down times on the crusher plant. Therefore, for ease feeding of the crusher gape and dumping more consistent good fragmented ore into the crusher plant, PF 0.88 should be used as that will be cheaper than 0.96.

4 Conclusions and Recommendations

This research which was carried out at AngloGold Ashanti Iduapriem Mine considered a continuous block at CUT 4 A-ZONE which was blasted with three different powder factors. With respect to shovel loading time, it was observed that, Powder Factor of 0.88 has the highest loading time as a result of the better fragmentation it gave and it was also observed that, PF 0.88 has 5% reduction shovel loading time than using PF 0.96 and 11% reduction in shovel loading time over PF 0.72. With respect to volume of ore hauled, PF 0.88 gave the highest volume of 57383 t compared with 55827 t and 55939 t for PF 0.96 and PF 0.72 respectively as a result of the good fragmentation and easy excavation of the rock into the trucks. .

From the calculations, PF 0.72, PF .88 and PF 0.96 estimated cost were $ 3 331 640, $ 3 417 700 and $ 3 325 010. It was observed that, PF 0.88 resulted in 0.78% increase in productivity than using PF 0.72 and PF 0.88 resulted in 0.73% increase in productivity than using PF 0.96

Using Split Desktop Image Software, PF 0.96 and PF 0.88 had good fragmentation because, they have up to 80% material sizes of 965.13 mm and 965.16 mm passing through the crusher gape size but PF 0.88 gave a more consistent good fragmented rock material than PF 0.96. While PF 0.72 has up to only 70% size of 950.28 mm passing through the crusher gape size which means, the fragmentation was not good enough. It is recommended that, all data involving Shovel loading time, volume of ore hauled and crusher availability should be recorded and kept well in case of any future usage since there was no easily accessible data recorded on them. Further research considering the blast parameters can also be carried out in determining the rock fragmentation and the best Powder Factor to be used.

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