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IMPROVEMENT OF BLASTING OPERATION IN SUKARI SURFACE MINE

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ABSTRACT

Detailed blasting data had been collected from Sukari gold mine.These data were arranged and computerized to feed a simulation software.DNA i-Blast is one of the powerful software for simulating, analyzing, and prediction the blasting products.As fragmentation is the main effective parameter of blasting, so we focused on the fragmentation size distribution according to Rosin-Rammeler equation.To assure the output size, an analysis for real fragment images was carried out and it gives almost the same results. According to simulation results, two improvements in blast-hole design are suggested. First suggestion is using air-deck of 25% of the charge column, and the second is using denser explosive. One of these suggestions or both of them can be applied and gives obviously reduction in the particle sizes.

KEY WORDS: Sukari Gold Mine; SGM, Blasting, Fragmentation, DNA I-Blast, Air-Deck

تحسين عملية التفجير في منجم السكري السطحي

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الملخص العربي

لتحسين عملية التفجير داخل منجم السكري، تم جمع بيانات مفصلة حول تصميم المنجم ودمج هذه البيانات بواسطة برنامج التفجير الذكي للمحاكاة والنمذجة والذي يعد واحد من أقوى برامج النمذجة والتحليل، وكذلك ا لتنبأ بالنتائج المتوقعة. وقد تم تركيز البحث حول حجم الفتات باعتباره المنتج الأساسي لعملية التفجير، وتمت معايرة النتائج التنبؤية بواسطة تحليل صور عينات حقلية لحجم الفتات. وَبناءا على نتائج البحث والتحليل تم اقتراح تحسينان رئيسيان لتصميم عملية التفجير، أولهما، هو استخدام عمود هوائي بنسبة ٢٥% من عمود الشحن الكلي، والآخر، هو استخدام مادة تفجير تكون أكثر كثافة. تطبيق أحد تلك المقترحان أو كليهما يعطي تحسن كبير وانخفاض ملحوظ في حجم الفتات.

الكلمات الافتتاحية : منجم السكري ، سنتامين مصر ،تفجير - فتات صخري ، برنامج محاكاة ، طبقة هوائية

NOMENCLATURE			
SGM	Sukari gold mine	PF	Powder factor
ANFO	Ammonium nitrate/fuel oil	AEL	Supplier and manufacturer of Explosives
C	Compressive strength, Mpa	Ca	Measured compressive strength, Mpa
R(x)	Proportion of the material passing through the opening	x	Screen size, cm
Xc	Characteristic size, cm	n	Index of uniformity
B	Burden, m	d	Charge diameter, mm
W	Standard deviation of drilling accuracy, m	L	Charge length, m
H	Bench height, m	R	Spacing/Burden

1. INTRODUCTION

One of the most important gold mines in Egypt is Sukari gold mine (SGM) sponsored by Centamin Company. Sukari tenement area locates at the Eastern Desert of Egypt. The current pit design is considered as Super Pit; only two pits achieved such big design before. The age of the pit is planned to be 30 years started from 2009. The blast pattern produce an average of 150,000 ton/day of blasted rock. The mine consumes 37 tons of ANFO per day, with PF of 0.68 kg/m^3 to break the quartz barren rocks [1].

Blasting process represents great importance in the cost of further mining processes specially comminution process [2]. Blasting is one of the main operations in open pit mines, affecting the total revenue of the mine to a large extent [3]. It is generally necessary to break large volumes of rock, especially if the rock is medium to high strength. An indication of the importance of blasting is that more than 1 billion kg of explosives are used annually in Australia and 3 billion kg in the United States for rock breakage, more than 85% of which is used in the mining industry. Explosives are the first choice of mining engineers for primary fragmentation and will continue to be so for the foreseeable future [4].

The primary objective of rock blasting is to attain a successful fragmentation. The classification and size distribution of muckpile are the critical components of managing any blasting operation. The fragmentation affects all downstream operations including loading, hauling and crushing; so it can be used to minimize these costs [2] [5]. In order to control and optimize the process effectively, it is essential to adopt a rapid and reliable technique for assessing the degree of fragmentation. This is also important from the design point of view where various different types of explosives and blast designs can be quickly and efficiently analyzed. Reliable evaluation of fragmentation is a critical mining issue and quick and accurate measurements of size distribution are essential to manage fragmented rock. It can be used to optimize all blasting parameters to reduce overall costs [5] [6] [7].

2. BLASTING DATA AND METHOD

2.1 Geology of Sukari area

The Sukari orebody is a variably altered granodioritic intrusion hosted in a complex mafic and intermediate volcano-sedimentary package. The granodiorite contains variable sericite, silica, kaolinite, albite, hematite and ankerite alteration assemblages. The texture of the rock appears porphyritic in areas and equigranular in others due to the effects of the overprinting alteration; hence the orebody has been termed the Sukari Porphyry [1] [8]. The porphyry contains 99% of the known gold mineralisation which is hosted in through-going shears and veins. The host sequence contains less than 1% of the bulk gold reserves, hosted in shears and along host-porphyry contact zones. The shears and veins trend north-south and dip 45^o to 60^o to the east and are continuous throughout the Amun Zone. The porphyry outcrop is expressed as a 2500 m long ridge rising to 350 m above the local wadi level. The very steep topography causes very difficult access for drilling [1]. The mine property is divided into nine zones, six zones for open pit mine and three for underground mine. All these zones are namely in Fig. 1, but Amun zone reaches its end at 2014. Exploration is continued in Horus zone through the underground mine [1].

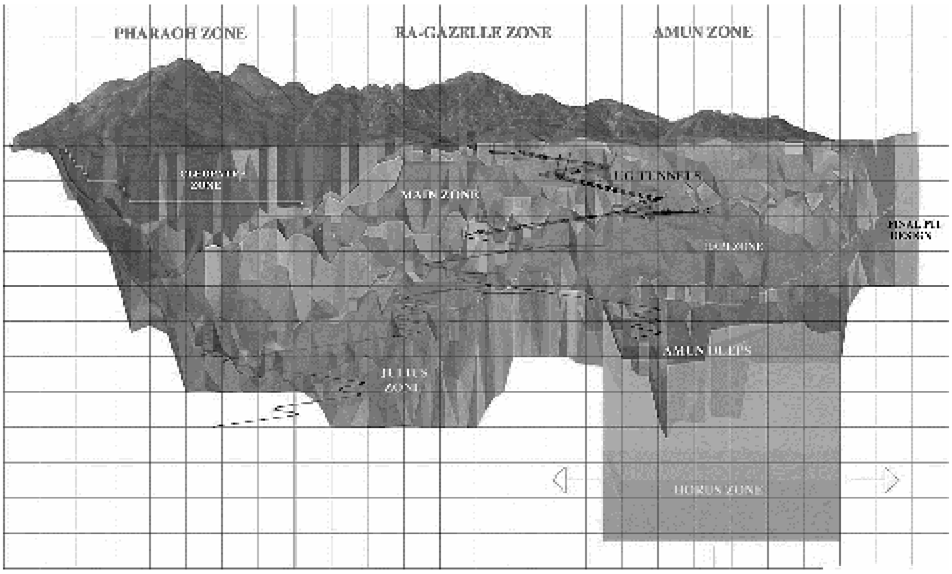

Fig. 1. Sukari gold mine zones

2.2 Blasting current state in SGM

A data of 30 shot fire of blasting operation supplied by AEL Company for the benefit of SGM had collected along the month of December 2015. These data were arrange as shown in Table 1 to feed the simulation software program.

Table 1: Blasting data of SGM in Dec. 2015

	Parameter	Value	Unit
PATTERN	Burden	4.8	m
	Spacing	5.3	m
DRILLING	Hole Depth	21.3	m
	Bench Height	20	m
	Sub-Drill	1.3	m
	Hole Diameter	165	mm
CHARGE	Column Length	16.5	m
	Stemming Length	4.8	m
	PF	0.854	g/m^3
	Type	emulsion	-

SGM had been gathered data for rock unconfined compressive strength periodically for the project feasibility stage of the operation. These data indicate that UCS of Sukari rocks varies from 2MPa for black shale to 200MPa for hard fresh porphyry). Hence the mean value which is around 100MPa can be used for software feeding. Although this study has used 100 MPa as the base case, but the actual UCS of rocks is very important in many parameters critical to estimation of drilling and blasting resources and costs. Also blasting pattern, explosive type, and penetration rate are very sensitive to rock strength.

2.3 Software feeding

DNA i-Blast feeding involved three stages; namely rock mass to define formation characteristics, explosives to define the type and properties of explosive material, and loading to define the hole charging shape [9]. Then the pattern design was inserting to the program using x,y,z coordinates. After that, the holes is charged by one of predefined charge and connected by timing wires to achieve delay requirements according to the original field design. Fig. 2 shows an example of final pattern on the program in 2D and 3D view.

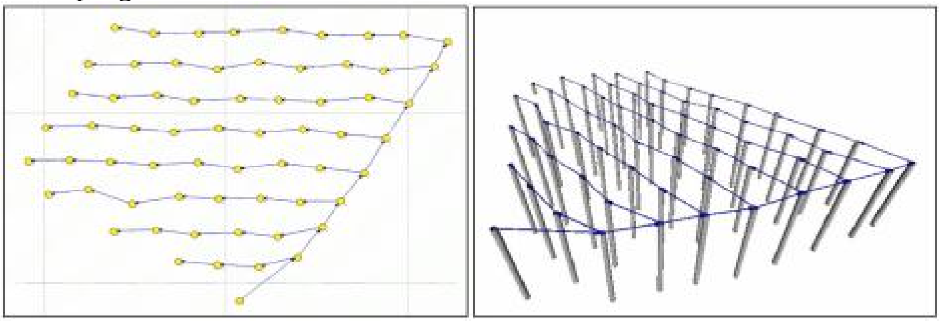

Fig. 2. Complete charged pattern in 2D and 3D view

The analysis process was achieved in the program by merging all data via statistical methods to obtain many probability trees. It is automatically choose the best analytical method according to provided data to produce the highest accuracy. Simulation and analysis processes to obtain the fragmentation size distribution from one-hole impact is achived by using Rosin-Rammiler [5] [10] Eq. 2 by the program.

$$R(x) = 1 - e^{-\left(\frac{x}{xc}\right)^{n}} \qquad \textbf{\textit{Eq. 2}}$$

Where n is varies from 0.8 - 2.0 and can be calculated from:

$$n = \left\{2.2 - 14 \times \frac{B}{d}\right\} \times \left(1 - \frac{W}{B}\right) \times \frac{L}{H} \times \left\{1 + \frac{(R-1)}{2}\right\}^{0.5} \qquad \textbf{\textit{Eq.3}}$$

2.4 Calibrate the simulation based on field experiments:

To assure the output fragmentations size from the previous simulation, field analyzes for real fragments should be achieved to check if it gives the same results. There are two main classes for size distribution measurement several methods. First is direct methods by sieving or screening analysis. It is accurate method but for production blasting, it is costly, time-consuming and inconvenient. Hence, another indirect methods that involve observational, empirical or digital methods had been developed. Using one of indirect methods by fragment image analysis technique provides rapid and accurate blast fragmentation distribution assessment possible [11] [12] [13]. I-Blast have an option based on 2D image processing for performing size distribution analysis of the blasted rock blocks. Fig. 3 shows the stages of this processing.

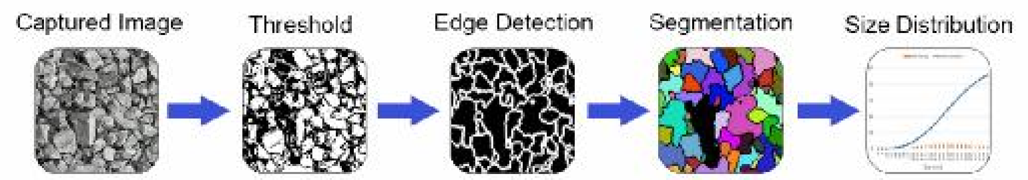

Fig. 3. Flow chart of fragment image analysis process

3. RESULTS AND DISCUSSION

3.1 Blast hole simulation

Fragmentation size distribution which shown in Fig. 4 is shown that the maximum size of fragmentation can reaches to 471 mm with 1.6% of whole fragmentation volume. The minimum size with significant portion is equal to 114 mm. The majority of size is concentrated between (260 mm – 292 mm).

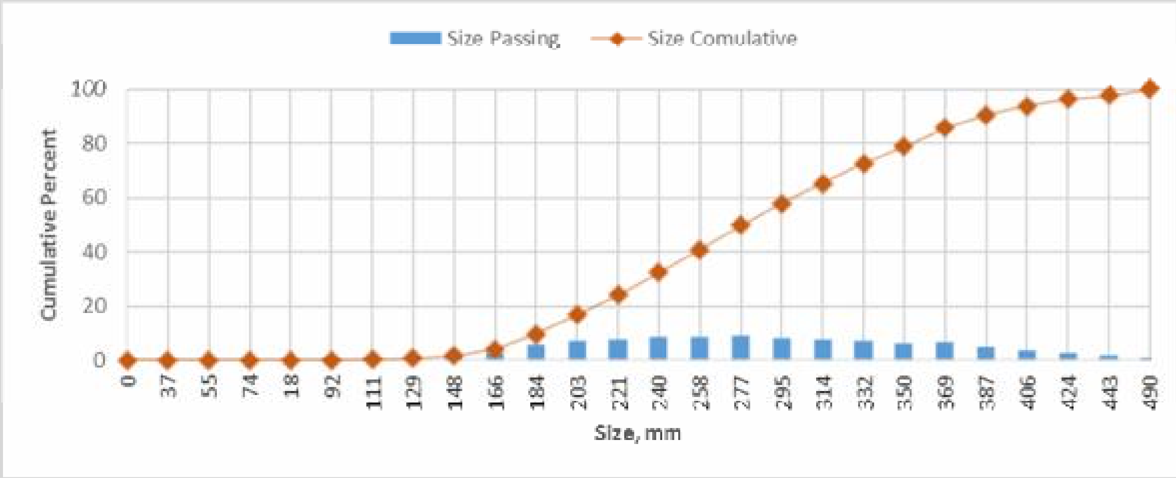

Fig. 4. Fragmentation size distribution

Size Cumulative curve shows that 50% of whole fragmentation volume is obtained at size 255 mm. The mean fragmentation size is approximately 236 mm Table 2 shows detailed results for statistical analysis of this data.

Table 2: Statistical description of size distribution

Maximum	490 mm	Percentile 25	171 mm
Mean	266 mm	Percentile 50	268 mm
Standard Deviation	127 mm	Percentile 90	422 mm

3.2 Image analysis process

Fig. 5 shows the Cumulative size distribution of fragmentations detected by image processing technique in comparing to the cumulative size distribution in Fig. 4, which obtained from blasting simulation. It is very clear that the two curves is almost the same with little reduction of about 5 cm in image analysis curve. This difference is due to the accuracy of image processing is limited to somewhat large fragments which is easily detected digitally. In addition, the maximum size in blasting simulation is about 47 cm while for image simulation is 48.6 cm. Hence, the simulation may be acceptable.

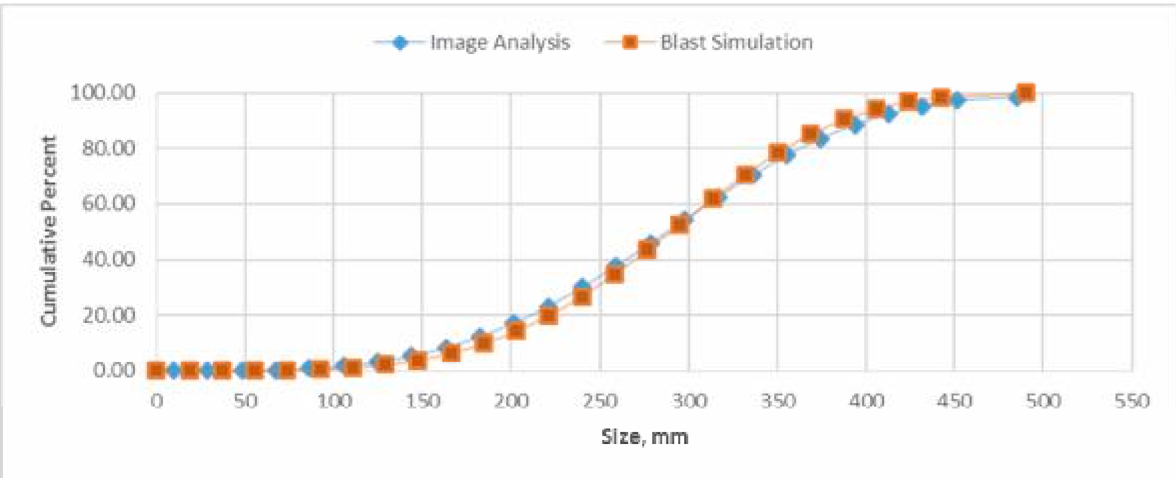

Fig. 5. Fragmentations cumulative size distribution obtained from image analysis comparing to distribution obtained form blasting simulation

4. IMPROVEMENT SUGGESTIONS

In blasting field, conducting field experiments is very difficult because of the high cost and strict security procedures. After calibrating the simulation results and ensuring their proximity to the field results the great importances of the simulation model is appeared. Where it can be confirmed with a degree of confidence the expected results of the blasting. Consequently, there are two suggestions to improve blasting results as follows:

4.1 Using Air-deck

Experience within the UK has confirmed that air-deck volumes of 25-30% can be employed in all rock types. Fig. 6 shows notable reduction in maximum fragmentation size from 471 mm to 432 mm.

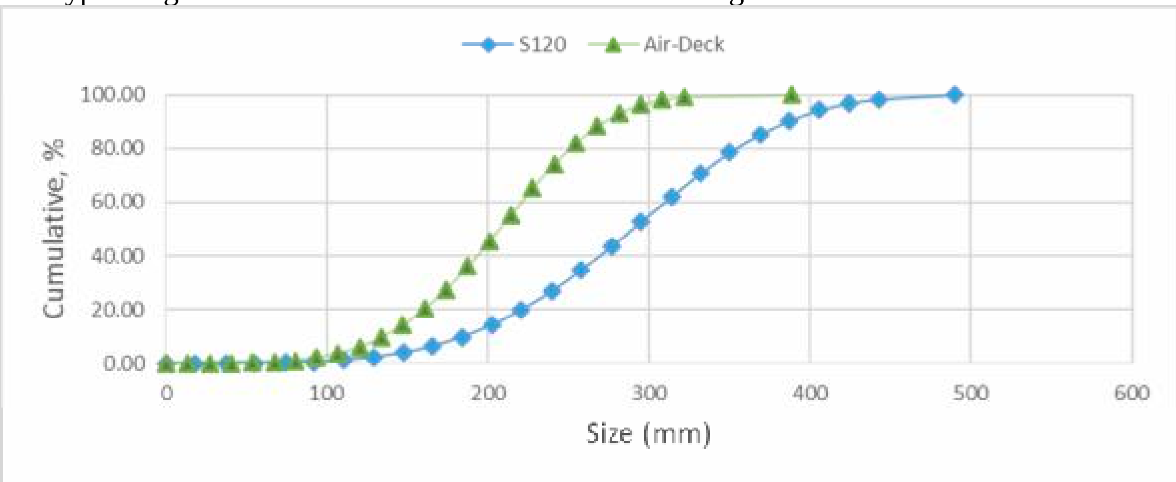

Fig. 6. Blasting current state in comparing to using air deck

With this method, 25% of whole fragmentation volume is obtained at size 124 mm. The mean fragmentation size is approximately 195 mm. Table 3 shows in detail the comparison between results in two cases as statistical description.

Table 3: Blasting current state in comparing to using air deck

DATUM	CHARGE	
	S120	**Air-Deck**
Maximum	490 mm	389 mm
Mean	266 mm	195 mm
Standard Deviation	127 mm	95 mm
Percentile 25	171 mm	124 mm
Percentile 50	268 mm	194 mm
Percentile 90	422 mm	307 mm

4.2 Using denser explosive

Using higher density explosive type, e.g. S135 from AEL Company can significantly improve blasting results. Fig. 7 shows notable reduction in maximum fragmentation size from 471 mm to 407 mm. It is also clear that this method surpasses the air-deck method.

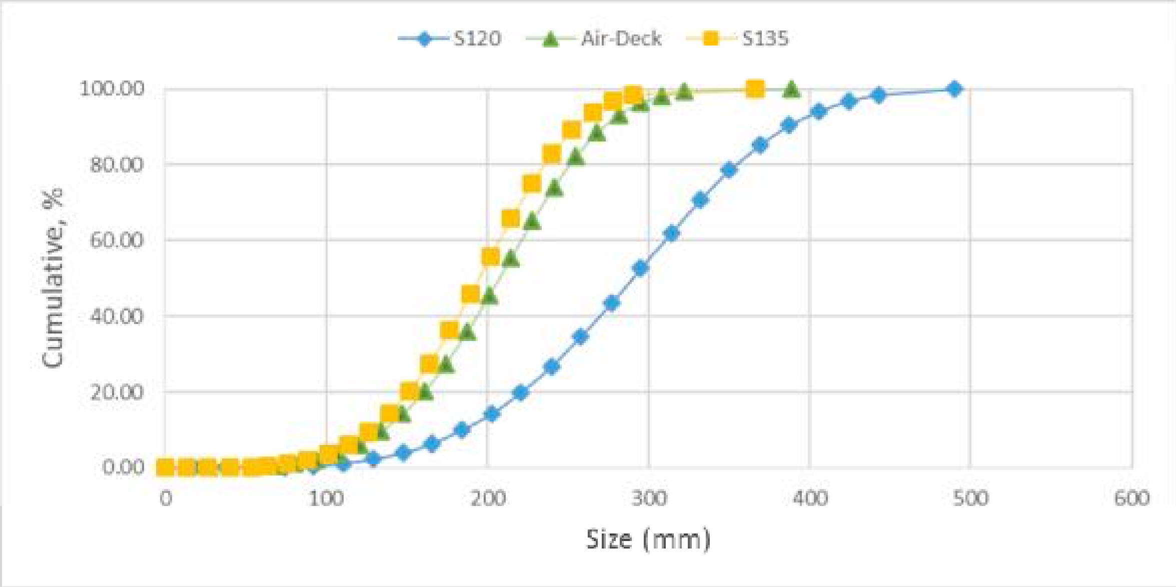

Fig. 7. Blasting current state in comparing to using air deck and denser explosive

With this method, 25% of whole fragmentation volume is obtained at size 114 mm which is about equal to the crusher set (113 mm). The mean fragmentation size is approximately 204 mm. Table 4 shows in detail the comparison between results in three cases as statistical description.

Table 4: Blasting current state in comparing to using air deck and denser explosive

DATUM	CHARGE		
	S120	**Air-Deck**	**S135**
Maximum	490 mm	432 mm	366 mm
Mean	266 mm	195 mm	178 mm
Standard Deviation	127 mm	95 mm	89 mm
Percentile 25	171 mm	124 mm	114 mm
Percentile 50	268 mm	194 mm	177 mm
Percentile 90	422 mm	307 mm	278 mm

4. CONCLUSION

1) Using air deck technique reduces the average fragmentation size from 266 mm to 195 mm with the same amount of explosive.
2) Using denser explosive (namely S135 from AEL in this study) can reduces the average fragmentation sizes from 266 mm to 178 mm with the same amount of explosive.
3) In case of S135 explosive material, 25% of whole fragmentation products got in size 114 mm which approximately equals to the crusher set.
4) It expected that the combining of two improvement suggestions (i.e. air-deck and denser explosive) can provide better results.
5) In addition to the blasthole design and explosive type, the simulation model can be used to study many other parameters influencing the blasting process, as well as suggest many improvements.

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