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Fragmentation Analysis of Blasted Rock using WipFrag Image Analysis Software

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Abstract

Blasting is an essential and the very first activity of hard rock mining. It is considered the cheapest source of energy for loosening/extracting hard rock. Improper planning and design can make basting a costly operation. Furthermore, as downstream processes are affected by properties of muckpile a blast should be designed properly to yield the desired muckpile and fragmentation. Among fragmentation and muckpile, fragmentation is the most important, and is the main parameter used to evaluate the efficiency of a blast. This paper analyzes the use of WipFrag software to evaluate the fragment size distribution of blasting with current blasting parameters of Cherat Cement quarry.

Keywords: *Blasting, Fragmentation Analysis, WipFrag Software*

1. Introduction

In hard rock mining, blasting is the cheapest excavation technique. It should be designed such as to yield an optimum fragment size distribution for downstream processes (loading, hauling and crushing), as these processes are affected by fragment size of blasted rock (Bhatawdekar *et al.*, 2019). A wise planning of drilling will consider overall mining costs, rather than blasting because blasting operation plays a pivotal role in the overall economics of opencast mines (Bhatawdekar *et al.*, 2021). Blasting operations are directly influenced by geomechanical properties and geological features of the rock (Bhatawdekar *et al.*, 2021).

Blast design to get required fragment size, will consider controllable parameters (bench height, hole diameter, spacing, burden, hole length, bottom charge, specific charge) and change these keeping in view uncontrollable parameters (rock strength, discontinuity spacing and orientation, rock density) to ensure that the desired blast output is achieved, as size of blasted rock is of utmost importance for the subsequent operations (Bhatawdekar *et al.*, 2021; Olofsson, 1990).

The most effective blast is one which gives maximum production with minimum costs (Tiile, 2016). At present, explosives contribute around 20% of direct production costs, while combining the costs of drilling and blasting, this can reach up to 30% of direct production costs. If the blast is not properly designed it will yield many boulders which increase the cost of drilling and blasting that can go up to 50% of production cost as a consequence of secondary blasting and use of heavy machinery to get a good

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muck-pile. According to Olofson, ideally fragmented rock is one which requires no further treatment after the blast (Olofsson, 1990). Through optimization of various parameters, blasting can help in reduction of total costs occurring on production.

2. Mining Site Details

The study area is located at Village Lakrai, in district Nowshera of Khyber Pakhtunkhwa (KPK) Province, Pakistan, Latitude: 33.890021, Longitude: 71.907527. Figure 1 shows Google image of Cherat Cement Quarry.

Cherat cement quarry consists of Shekhai and Utch Khattak formation. The Shekhai formation is mainly composed of limestone and marble which is interbedded with minor amount of quartzite and shale. The limestone occurs in variations from grey, brownish to pink in color. This part of the Peshawar basin consists of Attock-Cherat and Gandghar ranges. In the Gandghar ranges, at some locations, white brecciated marble occurs associated with igneous dykes. This formation has been assigned under the late Precambrian age (Kazmi and Jan, 1997).

The Utch Khattak formation in the Attock-Cherat ranges consists of limestone, argillite and shale having 200 to 250m thickness of the deposit while lower part of the formation is composed of 10 to 70m thick limestone deposit which is grey, thin bedded, fine to medium grained and in some places contains stromatolites as well. The limestone is overlain by dark greenish grey thinly laminated argillites interbedded with grey to brown thinly bedded shale. The Utch Khattak formation is overlying Shekhai formation and underlying Shahkot formation (Kazmi and Jan, 1997).

Figure 1. Google earth image of Cherat cement quarry.

3. Methodology

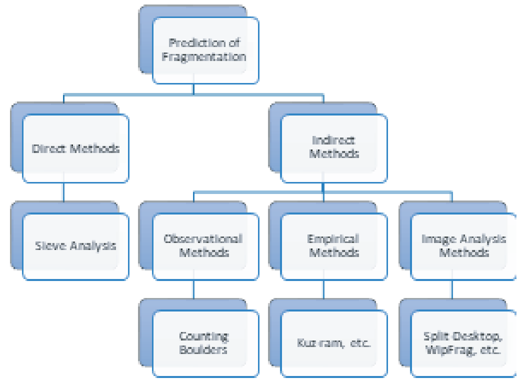

Figure 2. Different methods for fragmentation analysis.

Several techniques are used for measuring blast fragmentation like sieve analysis, empirical models predications, image analysis to machine learning models such as artificial neural networks (Armaghani, 2019) and support vector machine (Shi *et al.*, 2012) have been proposed for prediction of rock fragmentation Bhatawdekar *et al.*, 2021).

Methods for fragmentation analysis of blasted rocks are broadly classified into two groups, direct method and indirect methods.

Sieve analysis is most accurate of all the direct methods used for fragmentation analysis. However, because of large extents of rock piles, using sieve analysis is a tedious job and therefore cannot be used to measure the distribution of blasted rock fragments. This method is not possible at sites as it causes interruption in production cycles, and can only be used at laboratory scale.

Indirect methods include observational methods, empirical methods and image analysis. Observational methods are rapid and involves no cost but doesn't yield correct size distribution analysis and is used by blasting engineers for rough post blast analysis.

Several empirical methods have been developed to predict fragmentation distribution. A widely used empirical method for estimation of fragmentation of blasted rock is kuz-ram model which was developed by Cunningham (Cunningham, 1983) by integrating Kuznetsov (1973) and Rosin & Rammler (Rosin *et al.*, 2021) distribution functions. Empirical models are pre-blast predictions based on rock, explosive properties and blast design parameters, and does not measure actual fragments (Nefis and Talhi, 2016). Predictive methods offer pre-blast modification to select optimum parameters.

Image analysis determines size distribution from captured photographs, it is rapid, low cost method and yields sufficient accuracy (Shehu *et al.*, 2020; Siddiqui *et al.*, 2019; de Souza *et al.*, 2018; Lawal, 2021). Common software packages available are, Split-Desktop, WipFrag, and Gold-Size (Babaeian et al., 2019). All these software analyze digital images with reference to a predefined scale object. Image analysis is a post-blast measurement of actual muck-pile while empirical methods provide an idealistic prediction (Shehu *et al.*, 2020). Image analysis doesn't offer pre-blast modification, by measuring muck-pile. Image analysis doesn't cause interruption in production cycle, however, it may consume finances for acquiring software and analyzing each image, as muck-pile must be constantly photographed during loading operation to cover whole muck-pile.

3.1 WipFrag System

WipFrag is an image analysis system for measuring size of materials such as blasted or crushed rock (Tom, 1985; Tom *et al.*, 1995). WipFrag accepts images from a variety of sources such as roving camcorders, fixed cameras, photographs, or digital file.

It uses algorithms to identify individual blocks, and create an outline "net", using state of the art edge detection technique. If desired, manual intervention (editing of the image net) can be used to improve its fidelity (Maerz, 1996).

3.2 Imaging Muck-pile

Due to non-homogeneous nature of muck-pile, and weather conditions muck-pile imaging is tricky step and requires great care. To overcome these problems, muck-pile must be imaged from constant angle and distance at consistent lighting. Multiple high-quality images must be taken during loading to cover whole muck-pile as surface of the muck-pile is never representative of whole muck-pile. A random picture from field is shown in Figure 3.

4. Results and Discussion

At least ten photos were taken of each muck-pile during loading to cover the whole muck-pile and get realistic fragment size distribution. A football of length 9" was used as a scale object (see Figure 3).

Eight blasts were analyzed with WipFrag software. Table 1 shows drilling and blasting parameters.

Table 1. Current blasting parameters at Cherat cement quarry

Parameter	Value	Unit
Hole Diameter	89	mm
Burden	3	m
Spacing	3	m
Stemming	2.5	m
Bench Height	6-16	m
Charge Length	3-12	m
Specific Charge	0.6	Kg/m^3
Initiation System	Detonating Cord	
Drilling Pattern	Square	

Following is the step by step procedure for image analysis with WipFrag

- Import Images to WipFrag
- Define Scale
- Set Edge Detection Parameters
- Manual Editing (If required)
- Get Output (Size Distribution)

Figure 4 shows image with edges detected, Figure 5 shows output of blast no. 01. Three parameters X50 which show mean particle size, D80 and D90 which represents the size, at which 80% and 90% of the material will pass respectively, are calculated for all eight blasts as shown in Table 2.

Table 2. Analysis results

Blast No.	Results	
1	X_{50}	94.48
	D_{80}	406.61
	D_{90}	672.00
2	X_{50}	81.29
	D_{80}	331.69
	D_{90}	625.04
3	X_{50}	113.6
	D_{80}	309.42
	D_{90}	573.21
4	X_{50}	259.9
	D_{80}	667.9
	D_{90}	867

5	X_{50}	211.5
	D_{80}	401.9
	D_{90}	515.3
6	X_{50}	64.61
	D_{80}	316.76
	D_{90}	603.24
7	X_{50}	54.09
	D_{80}	297.67
	D_{90}	408.69
8	X_{50}	47.62
	D_{80}	212.57
	D_{90}	292.26

Figure 3. A random photo of muck-pile football as scale.

Figure 4. Generated net.

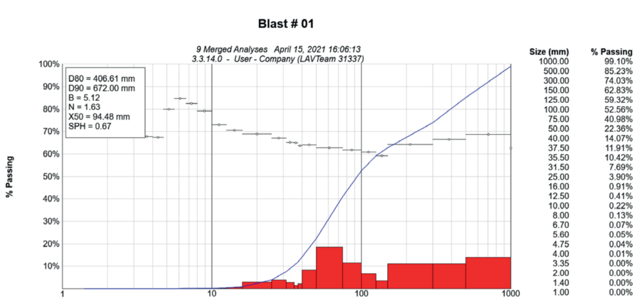

Figure 5. Output of Blast # 01.

5. Conclusion

The WipFrag software which is based on image analysis technique is very useful for evaluating the quality of blasted rock fragments in mining operations and can be used with ease, without interrupting production cycle. Image analysis is one of the best choices for measuring post blast muck-piles condition. However, care must be taken during imaging muck-pile as issues of light variability, camera positioning, and sampling biases may affect the results. Furthermore, image analysis can be used as process control tool. For process control, cameras can be installed on conveyor belts or crusher hopper to constantly monitor size of material and to control the size of material fed to processes such as crushing and grinding.

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