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Measurement of Size Distribution of Blasted Rock Using Digital Image Processing

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Abstract. The purpose of this study is to measure the size distribution of blasted rock using the digital image processing software "Split-Desktop system" in order to evaluate the efficiency of blasting operation. Site of study is a limestone quarry producing limestone for cement manufacturing. Fragmentation is the ultimate measure of efficiency of any production blasting operations. The degree of fragmentation plays an important role in order to control and minimize the loading, hauling, and crushing costs.

The size distribution analysis of the rock fragmentation by sieving is a direct and accurate method but it is very time consuming and costly. Fragmentation analysis by digital image processing is a low cost and quick method. Split system is one of the digital image processing software developed to compute the size distribution of fragmented rock from digital images. In this study, size distributions were analyzed by using Split Desktop ® system. In the analysis, the mean fragment size obtained is 149.76 mm and top-size 1057.44 mm. 25% of the fragments are below 30 mm. A thorough appraisal of blasting operation is suggested to enhance the efficiency of all the post-blast operations such as Loading, Hauling, crushing and Grinding and also reduces the cost of secondary breakage.

Keywords: Fragmentation, Rock blasting, Digital image processing, Split-Desktop

1. Introduction

The key objective of production blasting is to achieve optimum rock fragmentation. The degree of rock fragmentation plays an important role in order to control and minimize the overall production cost including loading, hauling, and crushing costs. Optimum rock fragmentation improves the energy efficiency of comminution (Crushing & Grinding) processes and thousands of kilowatt-hours energy per year can also be saved.

Blasting is the first step of the size reduction in mining and it is followed by crushing and grinding unit operations. The efficiency of these unit operations is directly related to the size distribution of muckpile. Therefore, reliable evaluation of fragmentation is a critical mining problem[1].

Production of finer fragments in blasting operation reduces the work-load of primary crushers; therefore increasing the crusher efficiency and reducing the crushing cost. Also crushing rate per hour will increase.

2. Size Distribution Analysis Using Digital Image Processing

Measurement of fragment size of blasted rock is considerably important in order to evaluate the efficiency of the production blasting operation. There are several methods of size distribution measurement and fall under two broad categories; direct method and indirect methods. The sieve analysis is the direct and accurate method of measuring size distribution. Although it is the most accurate technique among others, it is not practical for such a large scale due to being both expensive and time consuming. For this reason, indirect methods which are observational, empirical and digital methods have been developed[1]. Observational methods include the visual observations of muckpiles immediately following the blasting. It is widely used by blasting engineers to arrive at an approximation.

In some empirical models such as Larsson's equation, SveDeFo formula, KUZ-RAM model, etc, blasting parameters are considered to determine the size distribution of blasted rock[2].

Recent fragmentation assessment techniques using digital image processing program allow rapid and accurate blast fragmentation size distribution assessments. Digital image software was developed through the 1990s and at present it is a worldwide accepted tool in the mining and mineral processing industries. Its main advantage is that it can be used on a continuous basis without affecting the production cycle, which makes it the only practical tool for evaluating fragmentation of the run of mine.

However, some errors are also associated with the digital image analysis. It is extremely hard to obtain accurate estimates of rock fragmentation after blasting. Following are the main reasons for error in using image analysis programs[3].

a. Image analysis can only process what can be seen with the eye. Image analysis programs cannot take into account the internal rock, so the sampling strategies should be carefully considered.

b. Analyzed particle size can be over-divided or combined; which means larger particles can be divided into smaller particles and smaller particles can be grouped into larger particles. This is a common problem in all image-processing programs. Therefore, manual editing is required.

c. Very fine particles can be underestimated, especially from a muckpile after blasting. There is no good answer to avoid these problems.

There are several softwares namely SPLIT, WipFrag, GoldSize, FragScan, TUCIPS, CIAS, PowerSieve, IPACS, KTH, WIEP, *etc.* that are commercially available to quantify the size distribution. The accuracy of these systems varies between 2 % to 20 %[4]. In this investigation, the SPLIT-DESKTOP system was used for size distribution computation.

2.1 SPLIT System for Size Distribution Analysis

Split system is an image-processing program designed to calculate the size distribution of rock fragments through analyzing digital grayscale images. Digital grayscale images can be acquired manually through use of a digital camera, individual frame capture from video or through scanned (digitized) photographs.

The Split software is the result of over nine years of research and development at The University of Arizona. Split-Desktop combines the elements of Split, a software program copyrighted by the Arizona Board of Regents and exclusively licensed for further development and marketing to Split Engineering, LLC, with elements and research input from Julius Kruttschnitt Mineral Research Centre of Brisbane, Queensland, Australia. The original Split software programs were written using source code modifications to NIH Image, a public domain image-processing program developed by Wayne Rasband at the United States National Institutes of Health[5].

There are two formats of Split system, one is fully automated and operates continuously on images taken from a conveyor belt. The other is the Split-Desktop® software refers to the "user-assisted" off-line version of the Split programs that can be operate on saved images.

The subject of these images can be a muckpile, haul truck, leach pile, draw point, waste dump, stockpile, conveyor belt, or any other location where clear images of rock fragments can be obtained. Once the images are taken and saved to a computer, the Split-Desktop software has five progressive steps for analyzing each image[6].

The first step in the program allows the scale to be determined for each image taken in the field. The second step performs the automatic delineation of the fragments in each of the images that are processed. The third step allows editing of the delineated fragments to ensure accurate results. The fourth step involves the calculation of the size distribution based on the delineated fragments. Finally, the fifth step concerns the graphing and various outputs to display the size distribution results.

3. Measurement of Size Distribution of Blasted Rock at Limestone Quarry

Site of investigation is a limestone quarry producing limestone for cement manufacturing. The mining method at the quarry uses the traditional open pit practice of drilling and blasting a planned rock bench, loading of material with wheel loaders, and hauling to the primary crusher by heavy duty rear-dump trucks.

3.1 Description of Site

The limestone quarry belongs to Dewan cement (formerly Pak-land cement) located near Karachi, Pakistan. The limestone deposit is of Miocene age and belongs to Gaj formation. The geology is simple and essentially uniform. In the upper 1-2 m, there is an overburden of weathered clay shale of sandy nature and low cohesion. The limestone formation below this has a thickness of 6-25 m; the bedding planes are horizontal or sub-horizontal and crossed by some nearly vertical joints as shown in Fig. 1. The upper part of limestone deposit is highly fractured causing hole-collaring problems during drilling. The quarry is mined in one bench. Limestone rock is medium-hard and has compressive strength of 87 MPa and density is 2.66 tons/m^3.

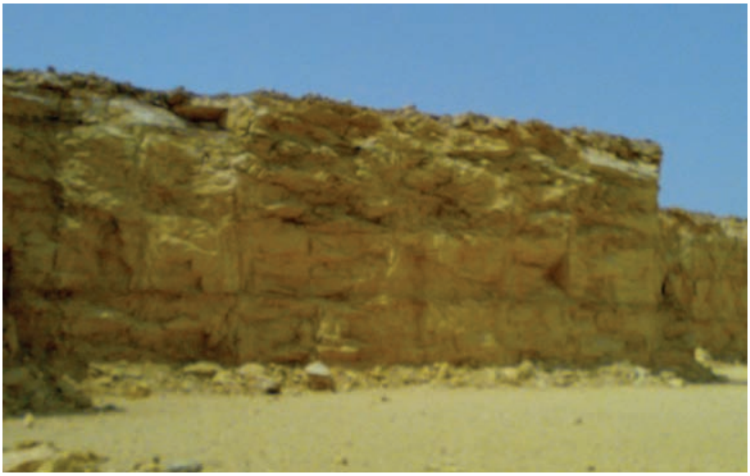

Fig. 1. Bench view of quarry, the upper fractured zone and horizontal bedding planes are clearly visible.

Drilling is done with heavy duty down-the-hole hammer drill to a preset blasting pattern. The blasting parameters are designed to suit the rock conditions and gradation requirements. The holes are charged with primed cartridge at the bottom with Shock-tube for detonation. ANFO is filled as column charge. Two types of high explosives are used; Gelatinous dynamite and Emulite. Each hole contains 15 kg of high explosive and 60 kg of ANFO. Other blasting parameters are given in Table 1.

Table 1. Blasting parameters.

Parameters	Description
Hole diameter	104 mm
Bench Height	12 meters
Sub-drilling	0.5 meter
Burden	3 meter
Spacing	4 meter
Stemming	3 meter
Blasting Pattern	Rectangular
Initiation System	Nonel or Shock-tube
Powder Factor	0.5 kg / m^3

3.2 Image Acqusition

Image acquisition of blasted rock for size distribution analysis is the most critical phase of the analysis. Important issues in image sampling are: The location of the image, the image angle from the surface of the muckpile, and the scale of the image. In order to obtain good images, which are both capable of being analyzed and representative of the entire rock assemblage, sampling strategies must be carefully considered.

The location of image taking is important, and there are two sampling methods, random and systematic. Both methods have been used for this investigation. Another consideration is the angle of the surface being photographed. Ideally, the surface should be perpendicular to the camera lens.

Fig. 2. Typical image taken in the field for calculation of size distribution.

A digital camera was used to get the images of the blasted muck, which were used in SPLIT. Images were taken randomly in the field and a basket ball of 24 cm in diameter (9.4488 inch) was used to provide scale in the images. Single scaling object was used in this investigation. Total 15 images were taken for analysis.

3.3 Fragment Delineation

After the image acquisition the next step was to produce the binary images from the acquired digital images that show the outlines of the particles visible in the image. In this step Split-Desktop performs the automatic delineation of the particles. As it can be observed from the Fig. 3b, the binary image actually allows three color levels: white for particles, black for boundaries and fines, and gray for areas that do not count in the size distribution such as the scaling object.

Fig. 3a. Grey-scale image

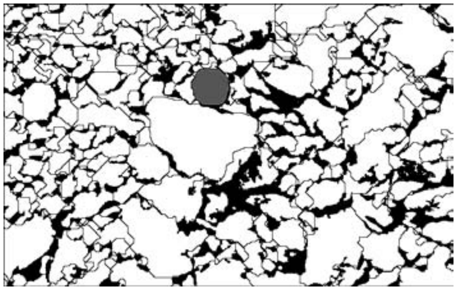

Fig. 3b. Delineated binary image.

The three most important delineation parameters are Noise size, Watershed ratio and Gradient ratio[6].

Noise Size: The noise size parameter is used to determine the size, in pixels, of the smallest pixel grouping that is used in the split algorithm. Noise size value may range from 3 to 90 and default value is 7. If the image contains larger rock fragments and boulders, noise value may set to as higher as 80 to 90 and if it contains finer fragments, the value may reduce to 3.

The Noise size value for this investigation was found empirically by using various values and finally 22 was found best-fit for the images.

Watershed ratio: The watershed size ratio controls the number of divisions made during the watershed algorithm which is used to make additional divisions based on the shape of the particles. The default value is 1.5, which usually gives satisfactory result for most images. Increasing this number makes fewer divisions and decreasing it makes more. This value can be changed typically between 0.33 and 3. In this investigation, watershed ratio was set at 1.85.

Gradient ratio: The gradient is a numerical measure of grayscale change from light to dark. The typical average

Gradient Ratio is 0.14. A higher value will create fewer dividing lines and a lower value will create more. The gradient ratio for this analysis was set at 0.18.

3.4 Binary Image Editing

Editing of the binary images is often required to enhance the delineation of the individual fragment because the built-in delineation algorithm of Split-Desktop not so precisely outline each and every fragment so some manual editing must be done.

In this step the particle edges should be clearly outlined in a continuous line, patches of fine material should be noted by filling in, and the objects (such as sky, loading equipment and the floor in front of the pile and scaling object) within the image that are not to be sized should be removed.

3.5 Computation of Size Distribution Curves

Once the binary images have been completely edited, computation of size distribution can be carried out. In this step, the distribution of fines in each image can be calculated using two approaches Rosin-Rammler or Schumann distribution. In the present study, a combination of these two approaches was used to best-fit the fines distribution.

The final step and the most critical influence on the size calculation is the Fines Estimation. Split-Desktop can measure particles automatically, but in every image there is a point below the resolution of the image where particles can no longer be “seen" and delineated. At this point, Split-Desktop will estimate the remaining finer material. The "fines" cutoff chiefly depends on the resolution in pixels/unit of the image. Since the black pixels in the image represent both fines and outlines of particles, a percent of these pixels is included in the fines calculation. This percentage of black to be counted as fines can vary for each muckpile and can be adjusted by the user[6].

For the images that contain too much fines, the High option can be selected and also other options such as None, Low and Medium can be selected accordingly depending upon the fines percentage in each image.

4. Discussion of Results

The seven most representative images of blasted muckpile were analyzed and mean values were obtained. The obtained size distribution curve is shown in Fig. 4.

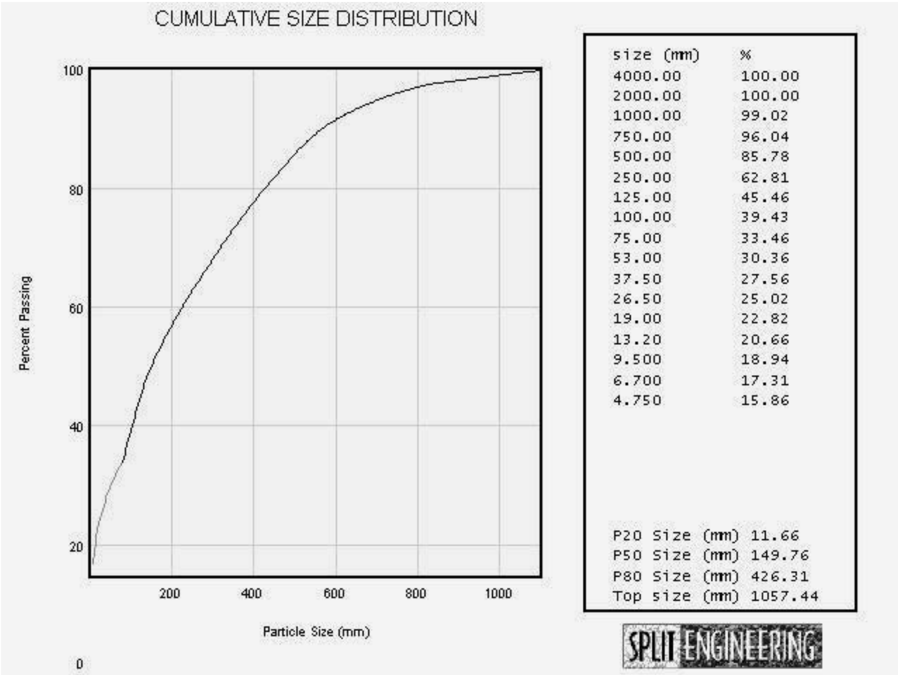

Fig. 4. Size distribution results.

The percentage values, Rosin-Rammler uniformity index and mean fragment size are given in Tables 2 and 3.

Table 2. Cumulative percent passing.

Size [mm]	% Passing
2000	100
1000	99.02
750	96.04
500	85.78
250	62.81
125	45.46

Table 2. Contd.

Size [mm]	% Passing
100	39.43
75	33.46
53	30.36
37.5	27.56
26.5	25.02
19	22.82
13.2	20.66
9.5	18.94
6.7	17.31
4.75	15.86

Table 3. Fragment size characteristics.

Size fractions	Size (mm)
P10	2.08
P20	11.66
P30	50.79
P40	102.15
P50	149.76
P60	225.02
P70	318.24
P80	426.31
P90	566.48
Top-Size	1057.44
Rosin-Rammler uniformity index	0.81
Mean fragment size	**149.76 mm**

5. Conclusion

The results obtained from the analysis of muckpile images using Split-Desktop shows that the mean fragment size is 149.76 mm and P20, P80, and Top-size are 11.66 mm, 426.31 mm and 1057.44 mm respectively. The primary crusher installed at the quarry accepts the feed size as large as 1000 mm and crush down to the 30 mm. As the results indicate that approximately 25% of the fragments are below 30 mm; hence the fragments do not require crushing and pass the primary crusher screen smoothly and effortlessly. Results also indicate that only 1% of the material is above 1000 mm therefore it requires secondary breakage.

The Rosin-Rammler uniformity index of the entire muckpile is 0.81. This index is generally used to approximate the size distribution of rock in blasted muckpiles. The value ranges between 0.5 (very non-uniform) and 2 (very uniform). So the obtained index value confirms non-uniform size distribution. Non-uniform size distribution affects the loading and hauling operations and crusher's efficiency.

As the results indicate that 25% fragments are below 30 mm, which is product size of primary crusher, this percentage can be enhanced by optimizing the overall blasting operation. The Burden and spacing are two most important factors in the blasting because these factors can be adjusted to obtain required fragmentation. Proper explosive in an appropriate quantity can also results in good fragmentation and reduce the overall cost of production.

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قياس التوزيع الحبيبي للصخور المتفجرة باستخدام عملية التصوير الرقمي

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المستخلص. إن الهدف من هذه الدراسة هو قياس التوزيع الحبيبي للصخور المتفجرة باستخدام برنامج حاسوب لعملية التصوير الرقمي "Split- Desktop System" ، وذلك بغرض تقييم أداء عملية التفجير. وتمت الدراسة بموقع محجرا للحجر الجيري المستخدم في صناعة الأسمنت. إن درجة تفتت الصخور هي المقياس الفعال لعملية التفجير حيث تلعب دورا مهما في التحكم في العمليات التعدينية بعد التفجير مثل التحميل والنقل والتكسير والطحن. ومن المعروف أن التوزيع الحبيبي لتفتت الصخور باستخدام التحليل المنخلي هي الطريقة المباشرة والدقيقة ولكنها تحتاج إلى وقت وجهد وتكلفة، ولكن التوزيع الحبيبي لتفتت الصخور باستخدام الطريقة المقترحة هو الأسرع والأقل تكلفة. وقد تم الحصول من نتائج تلك الدراسة على مقدار الحجم المتوسط للتوزيع الحبيبي لتفتت الصخور المفجرة حيث بلغت ١٤٩,٧٦ مم، وعلى أقصى حجم للحبيبات بمقدار ١٠٥٧,٤٤ مم ، كما تم تقدير نسبة التفتت للحبيبات الأقل من ٣٠ مم بمقدار ٢٥٪.