WHAT'S NEW WITH THE DIGITAL IMAGE ANALYSIS SOFTWARE SPLIT-DESKTOP®?

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ABSTRACT

Technical decisions, blasting costs, operational efficiency and productivity and equipment performance can all be related to optimum fragmentation. In the past, the lack of an easy, non-disruptive, economical measuring technique has meant that, in most cases, rock fragmentation has not been defined in quantitative terms. Now, the Split-Desktop® software provides an economical alternative to manual sampling and screening and an objective quantitative measure rather than subjective qualitative estimates. New features and enhancements have further improved the software's functionality. Several case studies are presented to show how other operations have benefited from using the Split-Desktop® software providing insight to a wide range of uses and potential applications.

1.0 INTRODUCTION

This paper presents the latest features of the Split-Desktop® software and will show how to quickly acquire quantifiable results from blast fragmentation. New features include: the integration of "fire wire" or IEEE 1394 digital video (DV) to acquire digital images from a DV compatible camcorder, improved scaling of images, the integration of automatic delineation parameters, the addition of an automatic fines identification, more colors are now available to use for the delineation settings, the availability to manually delineate particles, and a new report can be generated automatically to present both graphical and tabular data in HTML format.

Three case studies are also presented that outline where other operations have benefited from using the Split-Desktop® software, providing insight to a wide range of software uses and potential applications. The first case study presents an approach for developing accurate models to predict rock fragmentation due to blasting using digital image analysis. The second case study shows the effects of different explosives on fragmentation. The final case study shows how to use available software technology to provide a structured approach for zone specific optimization of post blast fragmentation.

2.0 SPLIT-DESKTOP® LATEST FEATURES

The Split-Desktop® software refers to the "user-assisted" off-line version of the Split programs that can be run by engineers or technicians from their personal computers. The Split-Desktop software allows for quantification of fragmented rock at various locations throughout the comminution process. To begin using the software, there must be a mechanism (software and/or hardware) for acquiring digital images then downloading digital still or video camera images onto the computer. The latest software supports Fire Wire (IEEE 1394) as a method of obtaining images from video cameras that have digital video output. For digital camera images the camera software will support saving images in JPEG or TIFF formats which Split can import. For video cameras, which do not support digital output, a frame grabber is required to digitize the video signal. Split Engineering recommends the use of digital cameras to higher resolution images and higher quality images can be obtained.

The subject of these images can be a muck pile, 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. 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.

Recent improvements and upgrades to the Split-Desktop software have lead to improved functionality, increased user-friendliness, as well as a few new features. In step one of the program (scaling), fewer mouse clicks are now needed due to a single input of the known size of scaling objects used and the memory of that scale from image to image as a set of images are scaled using the same scaling objects.

The majority of the new features have been added to step two of the software, the delineation of the particles. In the previous software version, some rules of thumb were used in determining the proper delineation parameters (the selection of these values was viewed by many users as a pseudoscience). Now, the user can allow the software to choose these values automatically. These parameters are dynamically determined based on the appearance of each individual image, which leads to more accuracy in particle delineation and, hence, more accuracy and sensitivity in the resulting size distribution.

Depending on camera resolution, scale and distance from material when taking the image, there most likely will be material in the images that is below the size discernable in terms of pixels. The size of what is classified as fines depends on the scale of the image and the particles that can be seen in it. The misidentification of patches of fines as large particles can create significant errors in the size distribution calculation and is a common error in fragmentation imaging programs. This user-assisted version allows the operator to correct misidentifications, which can be time consuming depending upon the quality and complexity of the image. In this latest version, the user has the option to have the program automatically identify regions of fines within the image. This is accomplished by the incorporation of a newly developed texture classification, which reconsiders the largest delineated particles in the image (the number of which is user selected) and classifies them as fines or particles based on the measurement of texture (La Rosa, et al 2001). The areas classified as fines are then automatically filled with a color user-defined to represent fines. Due to the algorithm intensive processing and auto identification features, it takes a few seconds longer to process an image when selecting the fines identification.

Other enhancements in step two of the software include the option to delineate particles manually and vary the editing colors according to the users preference. The software needs roughly fifty particles in the image to properly delineate automatically. In certain situations environmental conditions prevent the user from taking good images. When very few particles are present it may be prudent to manually delineate the particles in the image.

In the presentation of output, step five, the software now has the capability to automatically generate a report to display both graphical and tabular data in HTML format. Finally, through continued use of the software, ideas for new features and enhancements will continue to be integrated.

Over the past few years several papers have been written using the Split-Desktop software as a tool in everyday operation as well as a research tool to perform tests that previously could not be done manually. The following sections describe some case studies and information from several papers that have been published.

3.0 Using Split for Blast Fragmentation Modeling (Kemeny, et al 2001)

Recently, as part of a Department of Energy (DOE) Industries of the Future / Lawrence Berkeley Laboratory / University of Arizona contract, an approach has been developed for generating accurate models to predict the fragmentation due to blasting. Their approach uses drill-monitoring data to provide in-situ information throughout the rock mass to be blasted, which has been determined to be superior to traditional data-gathering methods such as diamond core or field sampling. Data from the Split image processing software is used to assess post-blast fragmentation and the crushability and grindability of the ore and compared to explosive energy applied per unit volume of rock.

A series of tests were conducted at the Phelps Dodge Sierrita Mine. For the tests, two blasts were analyzed, a high-energy blast (average 250 kcal/t) and a low energy blast (average 150 kcal/t). These blasts were monitored as they drilled the bench, loaded the explosive into the holes and mucked the material from the face. The figures below show an example of one blast and the variation in the F80 size of material fed to the crusher. In an effort to visualize the effect that explosive energy has on fragmentation the following graphs were generated. These plots clearly separate the high and low-energy shots into two groups, with the high energy shot showing a significant reduction in F80 on average. Within each of the shots, the data indicate trends of decreasing crushing energy with increasing explosive energy, indicating the possibility of increased micro-fracturing with increased energy.

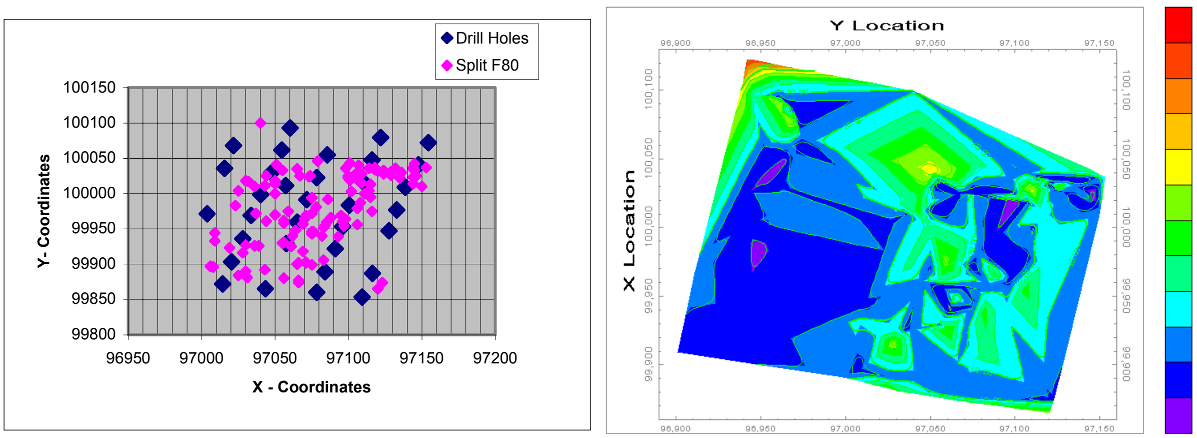

Figure 1. Shows the locations of drill holes and F80 fragmentation size as well as Contours of F80.

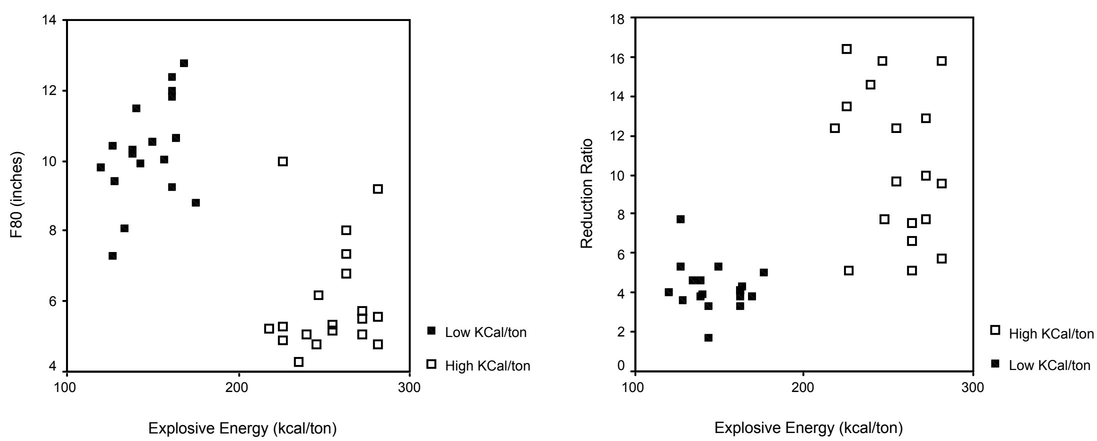

Figure 2. Explosive Energy (kcal/ton) vs. primary crusher F80 and primary crusher Reduction Ratio (the reduction ration is related to the distance between the feed and product sizes through the primary crusher).

4.0 Using Split-Desktop to Assess Differences in Explosive Products (Esen, et al 2000)

As part of a study between the Middle East Technical University in Ankara Turkey and a local limestone quarry operation the effect of explosive type on the resultant fragmentation was investigated. Two blast tests in which ANFO and BARANFO 50 were used as the main blasting agent were conducted. Both blasts were carried out at the same bench of the quarry, having the same structural geology and same surface blast design parameters. The only varying parameter was the blasting agent. Both tests were monitored by continuous velocity of detonation recorder. Digital images were acquired from the muck pile after each blast test to quantify fragmentation. Images were analysed by using Split-Desktop software and size distributions of muck piles obtained from both blasts were determined.

Table 1. Physical properties of limestone and surface blast design parameters.

Uniaxial Compressive Strength, MPa	99.0
Indirect Tensile Strength, MPa	8.0
Density, g/cm^3	2.707
p-wave velocity, m/s	6204
s-wave velocity, m/s	3156
Laboratory Dynamic Elastic Modulus, GPa	71.475
Laboratory Dynamic Poisson's Ratio	0.325

Hole diameter	89 mm
Bench height	7.5 m
Hole length	9.2 m
Burden	2.60 m
Spacing	3.60 m
Stemming length	2.5 m
Ignition system	Electrical
Blast hole pattern	Staggered
Delay between rows	30 ms

Table 2. Technical properties of ANFO and BARANFO 50.

	ANFO	BARANFO 50
Appearance	Prill	Prill+Crushed
Loading density, g/cm^3	0.820	0.928
Average VOD, m/s	3316	3838
Detonation pressure at given hole diameter and rock properties, GPa	2.617	4.551
Effective shock energy, MJ/kg	0.161	0.355
Effective heave energy, MJ/kg	0.529	1.144
Total useful shock energy, MJ/kg	0.374	0.839
Total useful heave energy, MJ/kg	3.717	5.559
Total useful energy, MJ/kg	4.091	6.398

In the first test 34 kg of ANFO was charged into each blast hole. On the other hand, 39 kg of BARANFO 50 was loaded into each blast hole in the second test due to its higher loading density.

Table 3. Comparison of both blasts in terms of resulting fragmentation.

	Explosive	P20, mm	P50, mm	P80, mm	Top size, mm
Case 1	ANFO	90.81	230.78	480.37	911.95
Case 2	BARANFO 50	36.07	119.57	233.87	468.96
Size Reduction Ratio		2.52	1.93	2.05	1.94

As a result of this research, it was shown that significantly finer fragmentation was obtained by utilizing BARANFO 50 as the main blasting agent at a constant blast hole pattern. As an alternative, it is possible to expand the blast hole pattern if the fine fragmentation is not desired, potentially saving on drilling and blasting costs to achieve the same result. Moreover, since fragmentation affects all post-blast mining operations (loading, hauling, crushing, grinding, etc.), a comparison of explosives should not be performed based solely on the purchase price, but on the overall affect on the operation. For a quantitative comparison, explosive performance should be assessed by fragmentation analysis software.

5.0 Methodology for Blast Fragmentation Optimization (Higgins, et al 1999)

The basic steps in explosive engineering are to design, implement and observe the results of a blast. This case study presented recently developed software technology that has enhanced the process of explosive engineering at every step to provide a structured approach for the optimization of blast fragmentation. Using a set of integrated software tools, this study established a first pass approach to characterize the rock mass to identify zone specific blasting parameters. A modified Kuz-Ram equation (Cunningham, 1983, 1987) was used to predict the size range for the actual blasts, and then to compare that with the standard design parameters and the actual fragmentation image analysis results. The modified Kuz-Ram equation includes a calculation for the rock factor based on the blast index developed by Lilly (1986).

Given these initial parameters, several blast designs were implemented and the outcomes were observed. However, the implementation of the design (drilling and loading) often does not coincide with the original design due to unanticipated field conditions. By using records of the actual drilling and loading, the analysis tools were able to contrast the differences between design and actual in terms of energy distribution, rate of maximum instantaneous charge and instantaneous burden relief, among others. Then, digital images of the broken rock were used to quantify blast fragmentation with image processing software, to produce size distribution data. This data was back correlated to the Kuz-Ram equation to modify the variables in the equation to generate zone specific coefficients, effectively closing the loop to derive optimal blast design parameters for each rock mass zone.

calculated	
X_{50}	9.9 in
n	0.82

x	$\%_{passing}$
1.0	10.13%
2.0	17.15%
3.0	23.05%
4.0	28.20%
6.0	36.96%
8.0	44.21%
10.0	50.35%
12.0	55.63%
16.0	64.22%
20.0	70.86%
30.0	82.04%
40.0	88.60%

Rock Factor	0.06
Uniformity Exponent	1.00

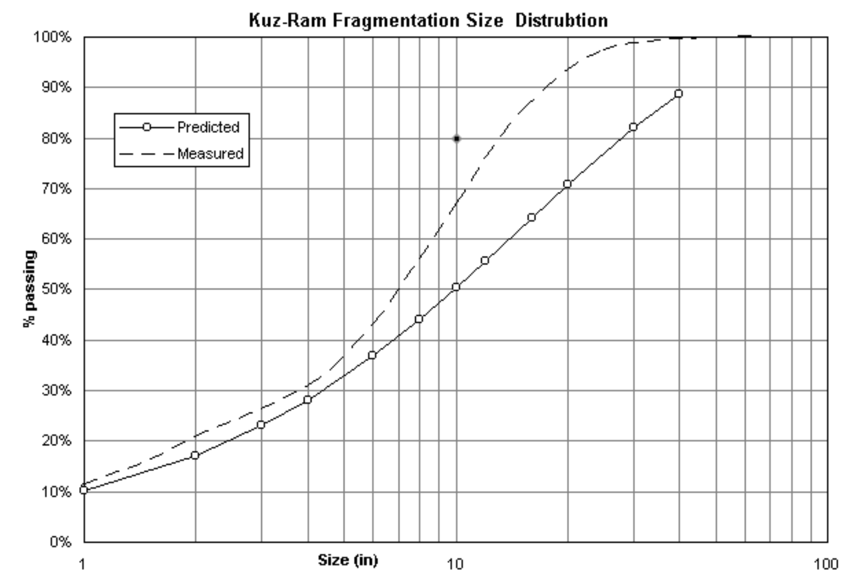

Figure 3 Kuz-Ram calculation for Standard Blast Parameters

Figure 3 shows the predicted size distribution versus the measured results from Split-Desktop. Once the measured results were observed they modified the uniformity coefficient and rock factors to produce a close fit with the measured data, as shown in Figure 4. The goal was to produce zone specific parameters that yield a correlation of the site-specific Kuz-Ram size distribution with measured results of the post-blast fragmentation. Once the zone specific rock mass parameters and new coefficients for fragmentation prediction were identified, it was then possible to make justifiable decisions for altering blast parameters to achieve a P_{80} of a desired size, in this case 10 inches. Several of the blast parameters can be altered and their affect on fragmentation as well as drill and blast costs can be calculated. Some proposed alternatives were:

1. Reduce burden and spacing from 24 by 24 to 20 by 20 feet. This would increase the number of holes in a blast (and thus the amount of drilling and explosives) by about 40%. The predicted size distribution from this modification is shown in Figure 5.
2. Increase hole diameter from 10 $^5/_8$ inches to 12 ¼, and maintain deck lengths, which would increase the amount of explosive by one third. This would depend on available drill power and time to drill the larger diameter.
3. Use a higher energy explosive. An increase of about 30% is required, but the split between shock and gas energy would need to be investigated first in comparison to the current explosives.
4. Increase the length of the explosive decks by about 15%. However, this would reduce the amount of stemming, which would require a change of stemming material in order to properly confine the energy of

the explosive. At present, there is very little or no stemming ejection, so it is unlikely that such a large reduction could be justified.

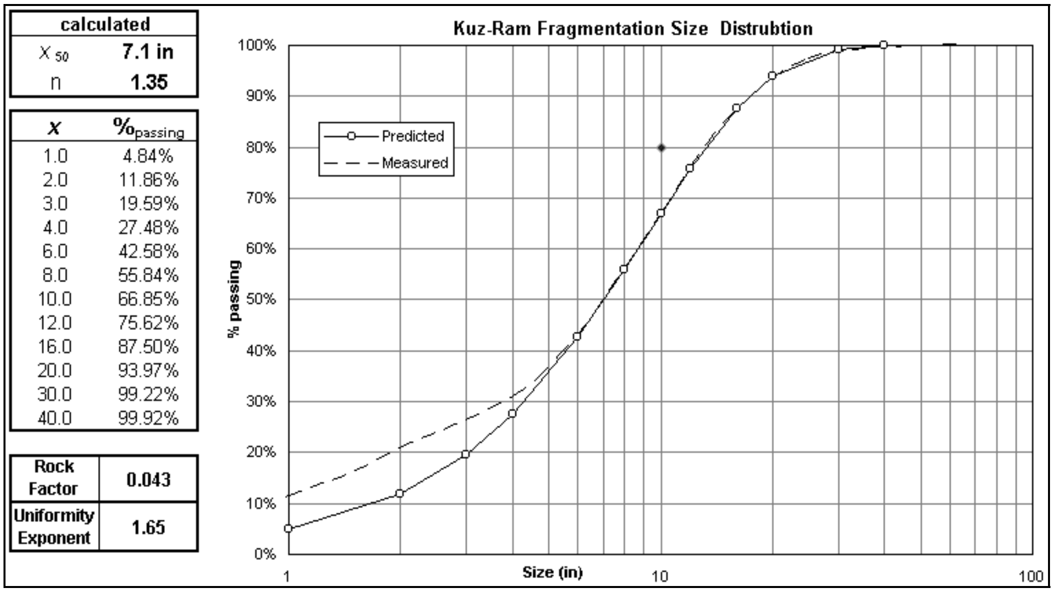

Figure 4. Standard Blast Parameters with modified Uniformity Exponent and Rock Factor Coefficient

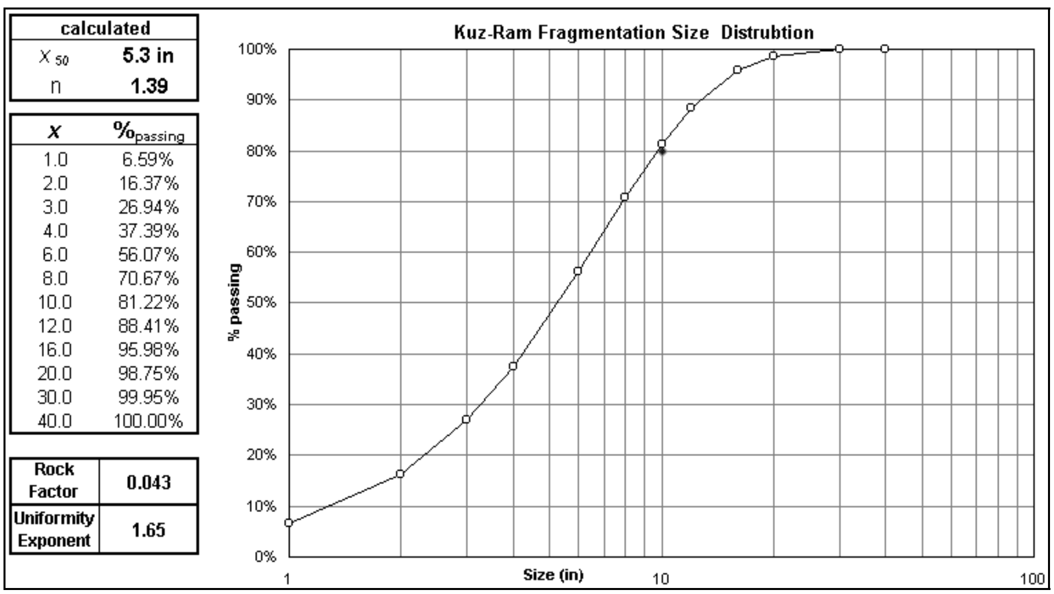

Figure 5 Predicted Fragmentation with the Burden and Spacing reduced to 20 ft x 20 ft

6.0 CONCLUSIONS

The Split-Desktop software has been shown to be useful in various practical and research applications, allowing studies to be performed that were not feasible before digital image analysis. The knowledge gained from these studies has pushed forward our understanding of explosive engineering to help close the loop in designing, implementing and quantifying each blast. The feedback from the quantification of post blast fragmentation has allowed for the development of models that help to better predict fragmentation. The new enhancements to the software will allow the users to perform a wider variety of tasks, as well as empower the users to make expert level analysis by using the automated features. These new features should result in more consistent and objective quantification of fragmentation.

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