Decarbonize quarry blasting while saving money

A traceable procedure for improving surface blasts using photogrammetric 3D models from drones

Andreas Gaich, Markus Pötsch, Miriam Baumgartner

3GSM GmbH

Abstract

Photogrammetric 3D models from drone imagery are generated pre- and post-blast. The 3D models serve as input for reproducible blast designs and objective blast analyses. The two steps are tied together by tracking descriptive parameters of the design and the result. Together they form a closed loop that enables the improvement of blasting works in terms of safety, efficiency, and environmental impact.

1 Problem statement

Negative impacts of sub-optimal blasting in quarries include economic and ecologic, as well as safety aspects. Sub-optimal blast designs lead to non-uniform, unwanted fragmentation and consequently to increased efforts in loading and hauling as well as efforts in primary (and secondary) crushing. It leads to irregular bench faces and uneven floors that influence the next excavation round negatively. And there is less usable material. The ecologic aspect includes higher CO_2 emissions at the same production volume, as well as increased energy consumption for processing the muck pile.

Better blasts lead to better fragmentation which consequently impact the entire mine to mill process positively: better loading, hauling, and crushing. Related to safety and environmental impacts, better blasts provide better walls and floors and reduce impacts in the vicinity of a quarry by omitting fly-rock and reducing vibrations. And, finally, better blasts reduce production costs significantly and sustainably.

2 Method overview

The method reproduces what blasters usually perform in their daily job: they use their experience for designing a blast based on knowledge they gained from previous blasts. This applies for example by adapting the design based on local site characteristics (e.g. bench face geometry or geologic situation).

The algorithmic approach to such method requires two main components: (i) reproducible blast design, i.e. all determinant parameters of the blast site are recorded and (ii) an objective analysis of the blast result by measurement of several characteristic properties of the muck pile. From both steps representative values are determined and stored. These parameters or key performance indicators (KPIs) provide an objective, independent way to describe and compare blasts with each other.

Obviously, changes in the design lead to changes in the result. So if certain KPIs from design and KPIs from result are recorded for each blast, then blast design and blast analysis are linked together forming a control loop (see Figure 1). This control loop is executed until specified target values from production are met

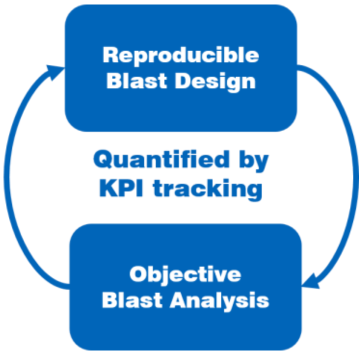

Figure 1: Principle of the blast optimization procedure: any changes in design are objectively quantified and serve as feedback for improving the design in the next round. The process is managed by tracking KPIs.

Depending on actual site conditions different KPIs from design and post-blast may be taken into account, for example:

- Burden, Spacing (and their actual deviations)
- Inter-hole distances
- Loading data (e.g. powder factor)
- Fragmentation of the muck pile (passing values x50, x80, uniformity N)
- Bank volume vs muck pile volume
- Swell factor

3 Components of the optimization loop

In the following the main elements of the blast optimization cycle are briefly addressed.

3.1 Comprehensive 3D models

Main data source is 3D models that are generated from a large set of unorganized photographs with sufficient overlap. Geometric distortions of the camera are automatically corrected while the 3D model is generated. Therefore, even low grade cameras are useful for the generation of high resolution, accurate 3D models. Positional accuracy of the 3D model either comes from ground control points or from the on-board GPS of the drone.

Typical values for the application are:

- 100 – 300 photos for a blast site
- Generation of the 3D models on site (no image upload required) in 20 – 60 minutes
- Typical positional accuracy: 1 -2 cm

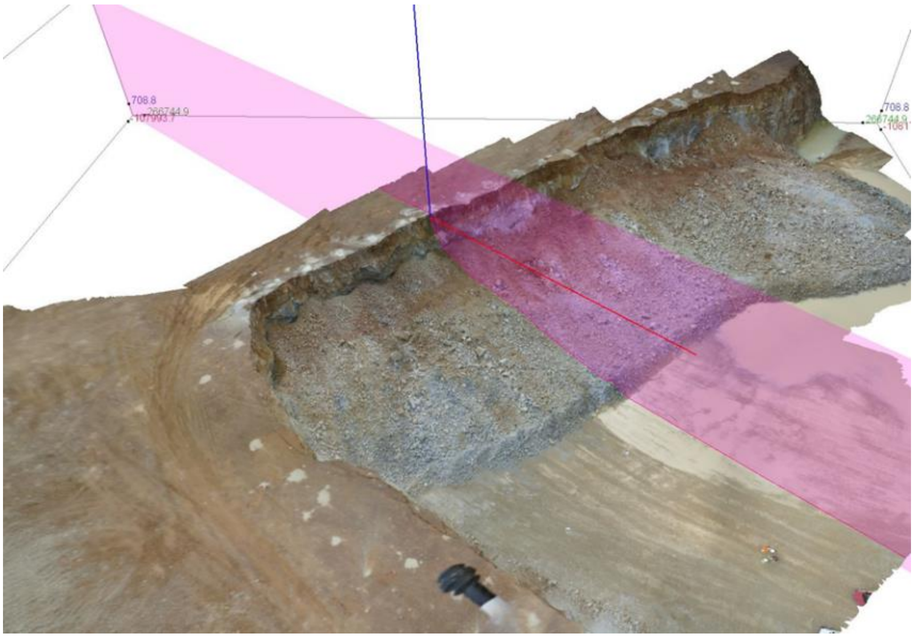

Figure 2: 3D model post-blast; the muck pile shows a length of 115 m and covers an area of 4.500 m²; the model generated from 150 photos in some minutes; images taken with an off-the-shelf drone

3.2 Reproducible blast design

In order to speak of a reproducible blast design all geometrically relevant parameters are acquired including 3D information of the area to blast and the drill pattern. Several down-the hole probes can be imported as well as MWD (measure while drilling) data or geologic features mapped with 3GSM's ShapeMetriX software.

The software component support pro-active blast designs that means it allows to adapt the boreholes to the geometric conditions of the free face. This way fly-rock and heavy burden situations are omitted and the resulting fragmentation is more favourable.

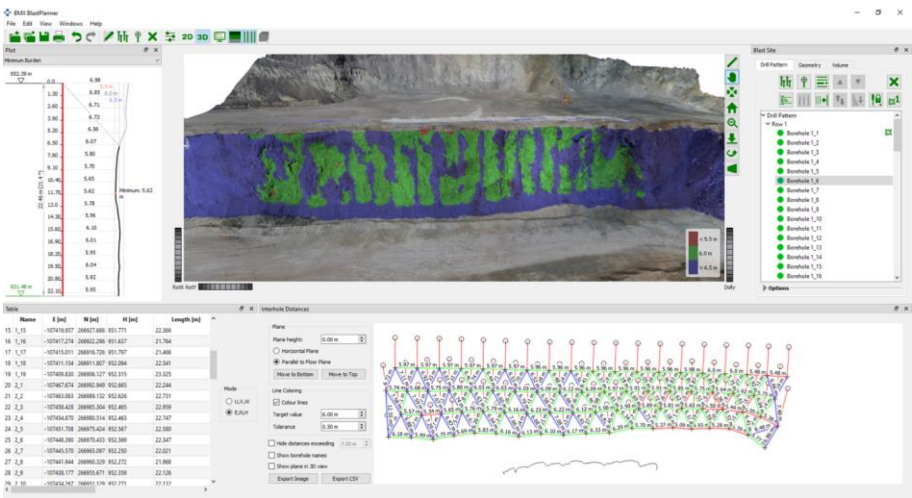

Figure 3: Pro-active blast design includes a live display of the burden distribution while changing borehole locations as well as the distances in-between the boreholes.

3.3 Automatic fragmentation analysis

An important step to assess a blasting result objectively is the determination of the fragmentation. Using photogrammetric 3D models this step becomes simpler and more accurate than previous approaches. It determines single fragments by a combined 3D-2D analysis and becomes less prone to misalignments due to shadows in the images that are not edges of particles.

The method can analyse the entire surface of a muck pile in a single run delivering multiple hundreds of thousands of individual measurements from which a robust particle distribution curve is built. Figure 4 shows a 3D model with an automatic analysis of the fragmentation and the resulting particle distribution curve. The fragments are coloured according to size which provides a straightforward qualitative impression of the size distribution and the presence of oversizes. However, the results are also available quantitatively by several passing values or the uniformity factor.

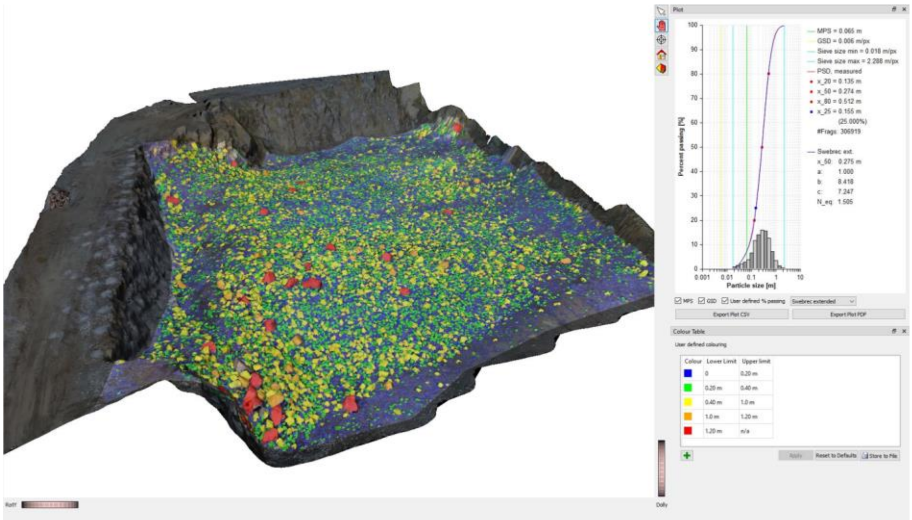

Figure 4: Automatic fragmentation analysis of the entire muck pile surface from a detailed photogrammetric 3D model; ground sample distance was 6 mm/pixel, the detection threshold for the smallest fragments was 18 mm/pixel; red blocks are larger than 1.2 m

3.4 Synthesis and KPI tracking

Figure 5 provides an overview how the components interact forming the blast optimization loop. Basis are comprehensive 3D models from drone imagery taken pre- and post-blast. The 3D model serve as input for a reproducible blast design (delivering KPIs on the drill pattern or inter-hole distances) and an objective blast analysis (assessed by KPIs from fragmentation and volume measurements). The key performance indicators (KPIs) are generated automatically by the software during the design process and when the muck pile is assessed.

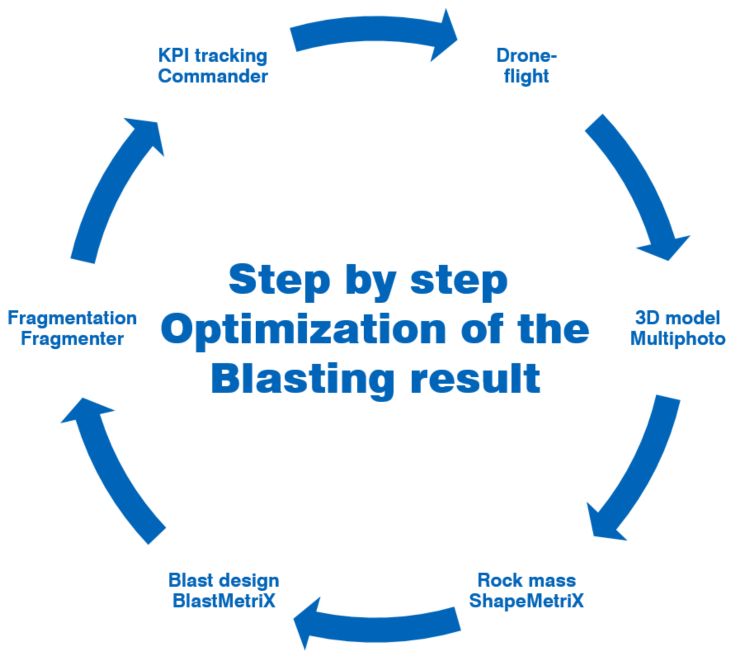

Figure 5: Components for the closed loop for stepwise blast optimization

4 Summary and practical output

Photogrammetric 3D models from drone imagery form an excellent data basis for designing blasts and assessing muck piles. Several off-the-shelf drones are applicable. From the design and the analysis several KPIs are extracted. By tracking the KPIs, blast design and blast analysis are connected which enables the adaptation of the blast design to site specific boundary conditions (rock type, fracturing, geometry).

As an example some figures from a limestone quarry are given. After the application the quarry manager noticed the following improvements:

Qualitative

- Reduced CO2 emissions
  based on reduced energy, diesel, and explosives consumption
- Faster loading (not recorded)

Quantitative

- Increased crusher throughput by 6%
- Reduced energy consumption at crusher by 9%
- Reduction of secondary breakage by 100%
- Reduced fly-rock by 100%
- Cost savings after 5 months: EUR 180.000

About:
3GSM's products improve the environmental balance of quarry works and increase safety in rock

engineering by high-end computer vision software for rock mass characterization and blast optimization.