Improved blast results from the implementation of a business intelligence system

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ABSTRACT

A business intelligence system has been developed within an explosive company to monitor the blasting process and track the layout of the blast, and other parameters such as drilling accuracy, redrilling attempts, charging of the holes and stemming by linking blast design software into decision support systems using open source Enterprise Information Integration and Business Intelligence software . Handheld computers collect real time data at the points of interaction, i.e. the blaster and the explosive mobile manufacturing units, and transmit this via mine wide wireless networks to a mine control room where it is correlated with the designs in the blast planning software. Increased productivity is achieved by providing the explosive truck with the GPS co-ordinates of each hole and the relevant explosive mass. The system is described and the benefits, which include increased productivity, improved fragmentation, prevention of fly rock, quick identification of uncharged holes and predictability of supply times, due to better consistency of drilling and charging are explained using case studies where the knowledge of the actual on-bench information has contributed to significant benefits to both the explosive company and the mines.

1. INTRODUCTION

Blasting is a very practical operation that is often seen as a simple process of filling boreholes with explosives and detonating them in sequence. A higher level overview suggests that blasting is the main productive process in a mining operation and that the quality of the output significantly affects the productivity of the mine. In turn, that quality is derived from attention to detail in a sequence of highly technical processes that are applied in diverse and difficult environments often with minimal supervision. A successful blast relies on a good design that has been optimised based on local and general experience and the accurate realisation of that design on the bench.

A business intelligence system is a set of computer programs that gathers data on the business process, maintains a record that can be used to produce historical reports, dashboards showing the current status of whether targets are being met and also allows data mining for knowledge development and process prediction (Olszak and Ziemba, 2007). Such a system has been developed within an explosive company to monitor the blasting process and track the layout of the blast, and other parameters such as drilling accuracy, redrilling attempts, charging of the holes and stemming. The blast is designed using laser surveying or 3D stereophotogrammetry so that appropriate burdens can be evaluated. The timing is allocated and investigated using simulation software. The mass per hole is determined and transmitted by wireless network to the explosive trucks. Handheld computers collect real time data at the points of interaction, i.e. the blaster and the explosive trucks, and transmit this via mine wide wireless networks to a mine control room where it is correlated with the designs in the blast planning software. Increased productivity is achieved by providing the explosive truck with the gps co-ordinates of each hole and the relevant explosive mass. Discrepancies between actual and planned parameters can be identified immediately. The information from the various regional supervisory centres is relayed to a monitoring centre at the head office to provide dashboards that represent the current status of the service delivery.

This paper briefly describes the system and some studies where the knowledge of the actual on-bench information has contributed to significant benefits to both the explosive company and the mines. The benefits shown include increased productivity, prevention of fly rock incidents, quick identification of uncharged holes and improved fragmentation due to better consistency of drilling and charging.

2. BUSINESS INTELLIGENCE TO BLASTING INTELLIGENCE

"Business intelligence (BI) refers to technologies, applications and practices for the collection, integration, analysis, and presentation of business information and sometimes to the information itself. The purpose of business intelligence - a term that dates at least to 1958 - is to support better business decision making. Thus, BI is also described as a decision support system (DSS)." (Wikipedia)

The business intelligence game has fundamentally changed since 2005, with the availability of good open source business intelligence packages, systems or solutions. Open source Business Intelligence allows small to medium-sized businesses to take advantage of the integration, dashboard and reporting functionality usually only available to large organizations due to high license fees. The core problems of business intelligence are the extraction of data, the accumulation of data in a form that allows easy analysis and the presentation of reports of key performance indicators relevant to the decision maker that needs to act on the information.

The aim of the key performance indicators is to boil the working of a business down to a few numbers that encapsulate the bulk of a business. The decision makers in any industry typically know what these numbers are, but it is always a challenge to measure them in a relevant fashion, and ensure that they are measured correctly. Blasting audits have shown their worth for controlling and optimising productions (e.g. Giltner and Koski, 2010) although our experience suggests that the data tends to be a static picture of the mining operation and remains in the files produced by the auditors. By selection of the appropriate KPIs, the business intelligence approach allows for continual logging, monitoring and reporting of the data that would arise from a static blast audit and will eventually develop the mine into a knowledge based operation (Olszak and Ziemba, 2007). Such KPIs need to be agreed between the mine, the explosive supplier and the mining contractor. The parameters can be based on service levels such as amount of product delivered or technical data such as average powder factor. Preferably, these KPIs are presented in the form of dashboards to have all the relevant information a decision maker needs available on a single page, with the ability to drill-down into the information as required. A dashboard would typically comprise several inter-connected graphs or reports that allow a problem to be understood with a few mouse-clicks.

Where disparate systems need to use each other's information as soon as it becomes available, this is called Enterprise Information Integration (EII). Although not strictly part of BI, good EII open source software is widely available. The biggest challenge in producing the relevant reports needed to make decisions is obtaining the data from the various sources. In most businesses, the data typically comes from Excel spreadsheets, but may come from databases or other applications. Most mining operations, especially the smaller ones, are still paper based and therefore the implementation requires adding information gathering systems along with the processing systems. Data for analysis is typically stored in a separate database so that using the analysis tools on the data does not interfere with the functioning of the source systems. In order to do a detailed analysis, the data needs to be transformed into a format that allows easy and flexible analysis. The tools that allow the data to be fetched from disparate sources, such as excel spread sheets, other systems' reports, other databases or web services, are called ETL tools. These tools can also be used for data integration where the information can be transferred in batches. For the explosive supplier this implies integration of financial and strategic reporting tools such as a SAP system with the technical information to provide the inputs for a complete mine to mill reporting system.

Data for analysis is typically stored in a separate database from the system in which it is generated. The data is stored in a way that allows for easy and flexible analysis. Often this is done in an "analysis cube" that can be effectively queried using a specialized language. More data than is strictly necessary is stored, allowing a type of "snapshot" or historical analysis of the source data. This data would then be the underlying data for statistical trends analyses. In the blasting context this analysis cube contains information such as the accumulated explosive charge per truck with the GPS position of the charge that can then be analysed to determine truck efficiencies and produce reports on how much explosive is provided to each mine and where it was placed. Once integrated into the entire mining cycle, dashboards can be used to improve operational excellence of the blasting as well as the explosive supply chain, accounting for input and output process relations in terms of safety, environment, productivity and behaviour (e.g. Lurf et al. 2007).

3. BLAST-*i*™ BLASTING INTELLIGENCE SYSTEM

The main components of the Blast-*i*™ system are shown in Figure 1 and described in detail in the subsequent sections. The roles of the people interacting with the system are named for their typical interaction with the system and may differ between different implementations and mine operations.

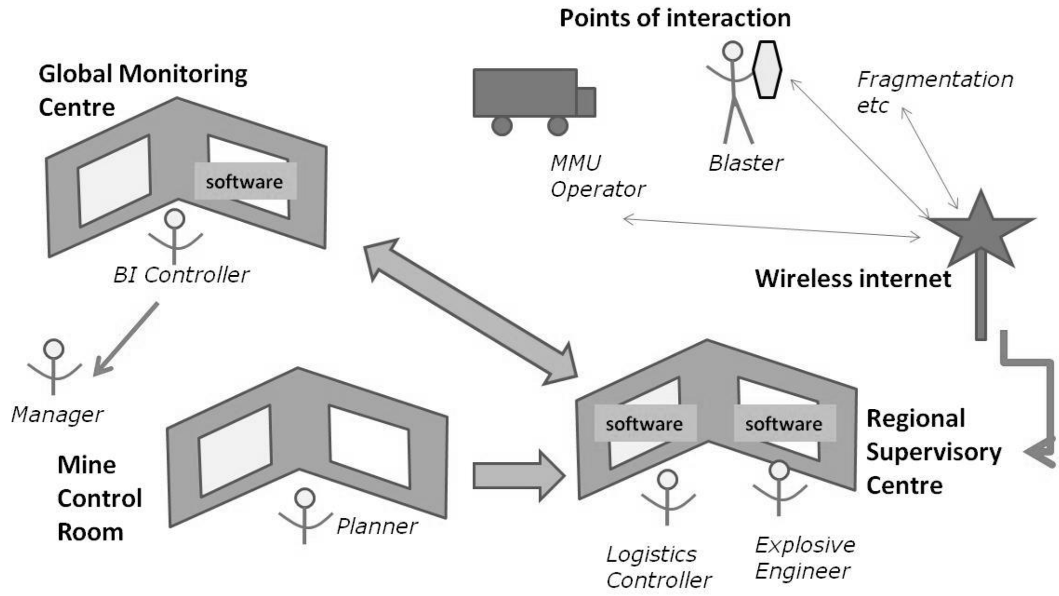


Figure 1. Schematic of Blast-*i*™ blasting intelligence system

3.1 Points of interaction

The entry points to the blasting intelligence system are the people who perform the daily activities of charging the blast. These can be divided into two sub categories, namely the blasters and the Mobile Manufacturer Unit (MMU) operators.

The blaster is in charge of ensuring that the pattern is filled to plan. This involves checking the lengths of the blast holes, ensuring that the correct charge is placed into each hole, that all the holes are filled and that the stemming lengths are correct and the stemming is placed properly. The blaster also places the initiation system and determines the timing. In practice these tasks may be undertaken by more than one person on a bench. The system has been designed so that the blaster loads and checks the holes according to the digital plan received on a GPS enabled PDA called the Personal Blast Assistant (PBA). Details of the charging can be recorded on the PBA, such as missed holes, stemming lengths, over-filled or under-filled holes, initiation systems, timing and any additional information that could affect the blast. The system recognises that the explosive engineer needs to make decisions and that these need to be recorded to schedule the relevant actions. The form on the PBA allows the blaster to record their observation and enter an action. For example, if the hole is too short, the blaster can record the length and request a re-drill. The blaster can return at any stage to identify the holes that require further action and to ascertain whether the actions have been completed satisfactorily.

The operator of the MMU controls the amount and type of explosive placed into each hole via the PLC on board the truck. The system can supply the operator with a plan of the blast showing the mass of explosive. If the MMU charges directly into the hole the MMU is equipped with an onboard GPS. Where the MMU is at some distance from the hole, the hose operator carries a backpack with a powerful GPS to locate the position within 1 metre accuracy (see Figure 2) and snap to the position provided by the survey department or the drill monitoring system. The system records the GPS position and mass of all explosives pumped into each hole and the operator can visualise the state of the bench on an onboard screen. Any new MMU entering the bench receives the updated plan and can start charging immediately without having to infer where charging has been done previously. It is important not to remove the operator's ability to control the MMU and the system only records and provides advice on the mass for each hole. In many mines the holes are filled to the estimated stemming length as a short cut for the proper design of the blast. In this case the system can record the mass pumped. If the mass is calculated beforehand then the exact mass can be immediately charged into the hole. This improves efficiencies and controls the mass of explosive in any one section of the blast, preventing overfilling and the associated hazards such as flyrock.

Figure 2. MMU and hose operator with GPS backpack

3.2 Remote wireless internet access

The system is best applied where there is remote wireless access on the mine. Mines these days often have their own WIFI mesh networks or are situated in regions that have cell phone coverage with the ability to transfer data. The development of the system has tracked the improvements in mine-wide wireless infrastructure and linking in with the continual improvements in these emerging technologies has been the most challenging part of the system development. The system has had to be designed to be robust against loss of data and loss of wireless signal. This has been done by storing the data at the points of interaction and transmitting them only when the signal is assured. In the worst case scenario this needs to be achieved by returning to a base station with a known signal quality at regular intervals. This can be done in the ordinary schedule of the mining operation as for example returning to their vehicles or when the MMU returns to refill.

3.3 Regional Supervisory Centres

The data from the blasts is analysed at the Regional Supervisory Centres, which are local control rooms managed by an explosive engineer who supervises a number of blasters. On large mines this will be a specially designed control room on site. For smaller mines and quarries the operations can be grouped at a single convenient hub near to the operations. In some cases, the data is analysed at head office and control is achieved by telephone interaction.

The explosive engineer interacts with the patented Active Loading System which is a database-driven operating system facilitates a two-way real-time communication platform between the teams at the points of interaction (i.e. the blasters and the Mobile Manufacturing Units) and the regional supervisory centre. The benefit of this system is that the explosives engineer receives up-to-date information on what's happening on the bench, allowing immediate corrective intervention and communication with the blaster before initiating the blast. This two-way interactive communication between the bench and office empowers the blasting team to deliver the most cost efficient blast that is as close to the plan as possible.

At this stage, the data can be integrated with other information for example, the final fragmentation obtained from online systems for fragmentation analysis (e.g. Palangio et al, 2005, Chow et al, 2010) and linked into simulation tools (Everett 2010) that permit the simulation of the effect of the blast output on the rest of the mine to mill process (e.g. Workman and Eloranto, 2003).

The logistics controller interacts with the same data in a different role. They can monitor information such as the truck locations, the amount of product remaining in each truck, the charging efficiencies and can optimise the delivery of explosives to the mine to maximise productivity. They can keep track of breakdowns, turnaround times and other data that assists with planning of the supply operation.

3.4 Shared interface with mine control rooms

The Regional supervisory centre shares an interface with the mine to obtain electronic blast plans and to deliver reports. The electronic blast plans contain the position of each of the blast holes. The position can be as reported by advanced drill logging systems, or by direct surveying, or can be as planned in typical mine planning or surveying software. Good relationships are required between the IT departments of the mine and the supplier in order to implement secure systems to transfer the data.

3.5 Monitoring room at Head Office

Often in order to understand a particular problem, it is necessary to look at the information in a variety of ways and summarize in different ways. Once the data has been stored in an analysis cube in the right way, it can be presented as a pivot table and analyzed according to many different criteria, shown both as a graph, as a report or with the relevant details contained in a particular pivot cell. It was soon realised that views of the data from the Regional Supervisory Centres can be collated into knowledge for the whole company by creating dashboards that provide pictures of the history of the interactions and, even more importantly, provide some predictive capacity.

Figure 3 Monitoring room

This forms the BI "consumption" stage (Olszak and Ziemba, 2007), which derives mainly from the interaction with the end users. Olszak and Ziemba (2007) also noted that this stage "shows its major role in popularising and promoting practices that are related to data analyses and BI systems". The compilation of this information into knowledge is where the company performance can be significantly improved and interactions with customers facilitated. The reporting is, however, highly dependent on the requirements of specific users and the system must be flexible enough to allow for a variety of report formats.

In order to do this in the blasting intelligence system, certain data is compiled and transmitted securely back to a main database at the head office and can be viewed on multiple screens (See Figure 3) by the global blasting intelligence controller. By correct selection of the business analysis toolkit, in this case using Pentaho, the appropriate reports can be constructed relatively quickly and easily via the World Wide Web to mangers within the explosive company or at customer sites. Modern software developments have provided off –the-shelf applications that have enabled this reporting to be presented as dashboards and distributed by email, sms or as interactive websites.

3.6 Knowledge based software

Software for the Blasting Intelligence System has been developed from the points of view of the two main users – the explosive engineer and the logistics controller.

Firstly, the explosive engineers need to be able to obtain a blast plan, determine a suitable design, apply timing and simulate the blast and specify the mass of explosive in each hole. Whilst the blasts are being charged the information must be available to enable the explosive engineer to determine if the charging is happening to plan and to be able to let mine management know when the bench will be ready to blast. The system is designed to be able to apply the outputs of any blasting software, though a specific set of software has been developed to have separate, but consistent, interfaces to enable users to specialise in the application of the software that is most relevant to their job requirements. The interaction of the three software components and their unified internal data base with the blast process is shown schematically in

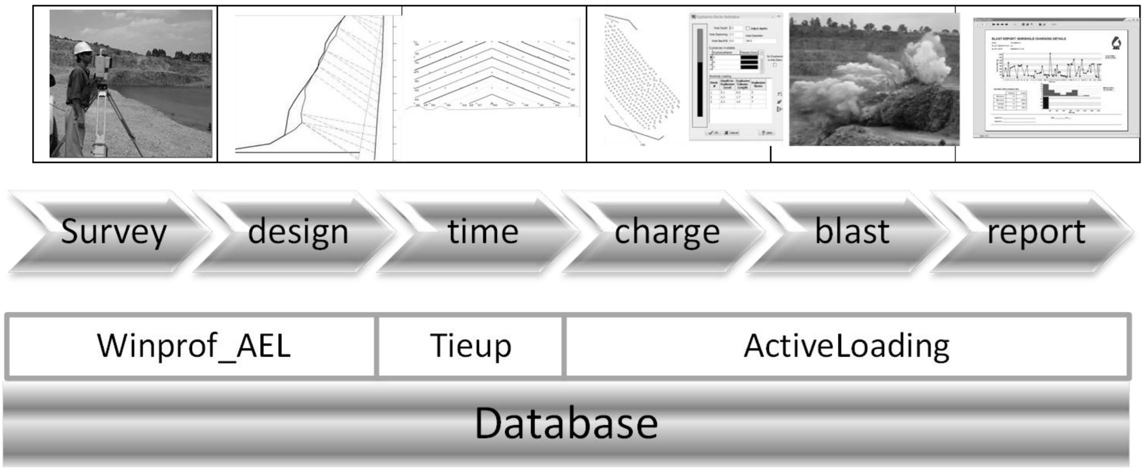


Figure **4**.

The Winprof_AEL software imports the layout of blasts from three dimensional bench profiles obtained using laser profiling or stereophotography. The code enables the explosive engineer to visualise the hole positions to ensure consistent burdens and hence prevent excess toes or unwanted flyrock. The planned design can be compared with the actual drilled pattern. The explosive engineer then applies the AEL Tie-Up software to open the same blast from the common database and times the blasts. Alternatively, the software can import layouts exported from the mine databases and supplied via the shared interface with the mine control room. The timing can be directly exported to the electronic detonation systems. The Active Loading System is the final component of the software trio and is a total blast management system that produces the electronic charging plans for each blast, collects explosive charging data automatically from suitably equipped Mobile Manufacturing Units in the field and manages the data being entered into electronic clipboards on Personal Blasting Assistant devices on the bench.

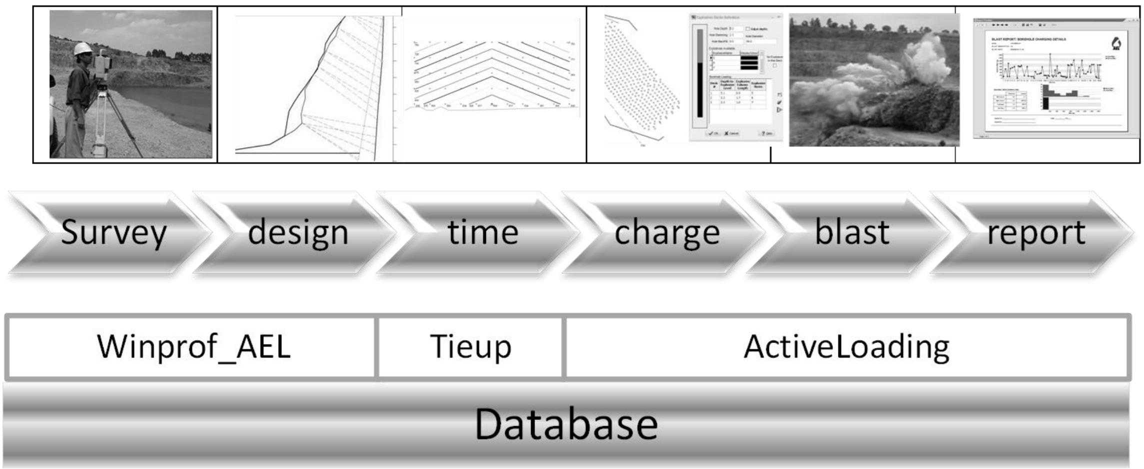


Figure 4. Software process flow

Secondly, the logistics controller at the mine must be able to know where each explosive truck is situated at any time, how much it has pumped and be able to evaluate the efficiencies of each truck. The Blast Plan Scheduler (see Figure 5) allows the logistics controller to see which plans have been submitted by the explosive engineer for charging, to allocate these to the relevant MMU and then to evaluate which have been acted upon. The logistics controller can view when the trucks are actively charging on the bench and has a symbolic display of whether the GPS system are connected, when the PLCs are turned on, and when the MMU is charging each hole. If the status is not to plan, the logistics controller can then send messages to request the relevant operators to fix the problem. The logistic controller can log any breakdowns on the MMUs and keep a history of the issues of each of the trucks.

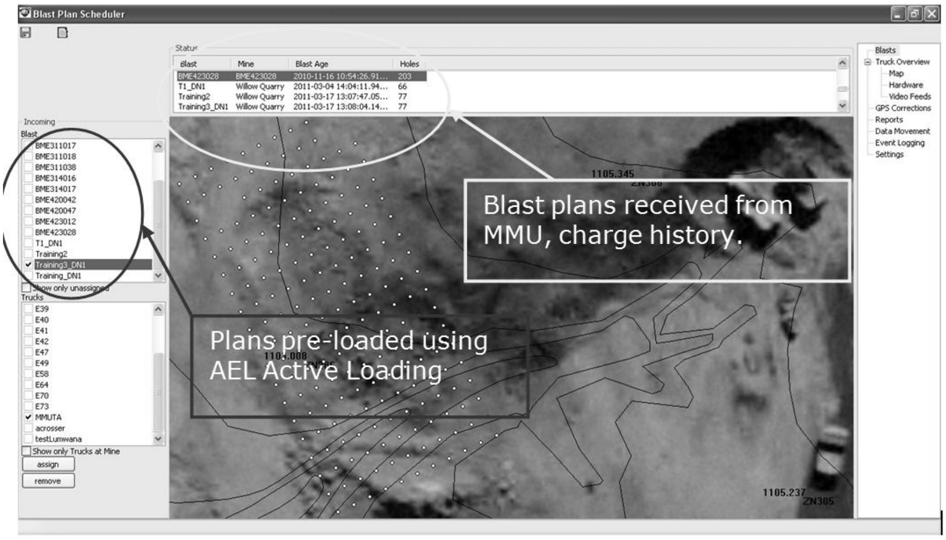


Figure 5. Blast plan scheduler

4. CASE STUDIES

A number of example case studies are presented to illustrate the benefits of the Blasting Intelligence software.

4.1 Blast pattern consistency

An issue that causes considerable conflict between an explosive company and the mines it supplies occurs if a blast has been fired and the outcome is not as expected. Occasionally, a blast will have a section of unbroken rock and then an investigation is required to determine the root cause. The mine will tend to say that the explosive was of poor quality and did not detonate, however there may have been no holes drilled at that point, if holes were drilled, they may have collapsed and have had insufficient explosive pumped into them, or they may have been drilled, but forgotten during the charging process. In this case, the quarry had charged a small blast based on a manual layout of the drill hole pattern. The plan of the pattern as produced by the GPS carried by the hose handler shown in Figure 6 indicated considerable variation between the hole positions and the desired burden and spacing. This indicated that there would be significant deviation from the planned rock fragmentation. In addition, a zone of mud and water filling a depression had completely hidden one hole. This was not charged at the time of the plot and once the explosive engineer was alerted to the lack of charge in the hole. This was particularly important because the holes in the surrounding area had been undercharged, probably as result of mud in the holes. Had this blast been fired as it was charged in Figure 6, there is no doubt that a pillar of solid rock would have been left in the centre of the muckpile. This would have impeded the muckpile heave and would have been very hard to dig out and may have required secondary blasting in difficult and unsafe conditions.

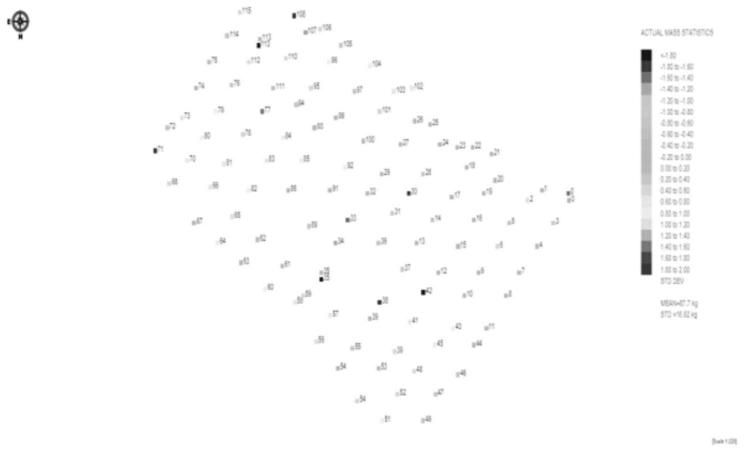


Figure 6. Explosive charge plan showing irregular pattern and missing holes

The poor layout of holes has almost doubled the burden and the effect of this can be illustrated using the Kuz-Ram Fragmentation model (Cunningham, 2005). Figure 7 shows some fragmentation data obtain from the mine and analysed using the SPLIT optical analysis programme. The rock factor A is fitted to this data for the relevant design burden of 3.0m and the design spacing of 2.5m on 15m holes 102mm in diameter. This fit is also shown in Figure 7. The fitted curve shows more fines than observed in the optical analysis and this is due to the scaling of the photographs taken, as they were intended for an oversize minimisation project. The effect of the poor hole distribution is shown by the curve denoted “Missing holes” in Figure 7. This indicates that the characteristic size increases from the initial 405mm to 622mm. The maximum size increases to nearly 3m as the uniformity drops significantly from 1.33 to 0.89. The lower uniformity co-efficient also indicates an increased fines component. Thus, the poor layout of the blast will contribute to considerably more secondary breaking, more energy used in the crusher with lower throughput and increased wastage of material as fines.

Conversely, Figure 7, can be interpreted as demonstrating how much improvement can be obtained if the blasting patterns are improved. The benefit of the blasting intelligence system is that once the blasters become aware of the system and how it can monitor the progress the quality of the blasting improves and so the system can also be used for quality assurance.

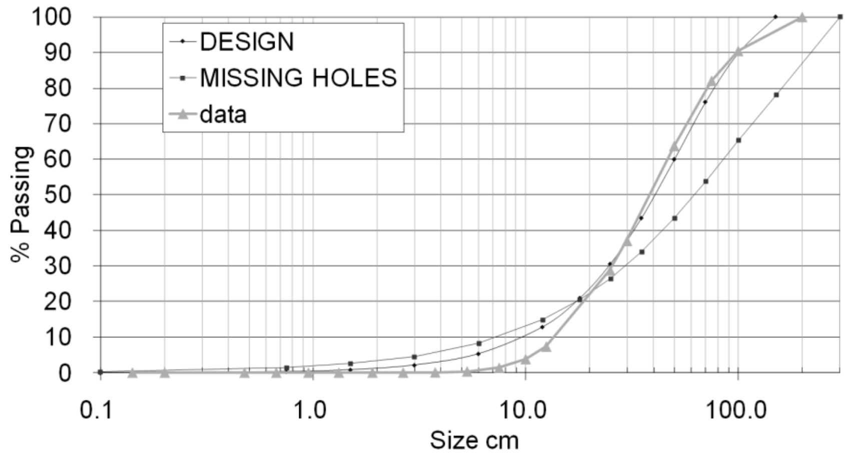


Figure 7. Effect of poor explosive distribution on fragmentation

4.2 Flyrock prevention

The second study involves blasting on the top benches of a local quarry. In these benches the degree of weathering varies considerably and so the rock mass has formed into a series of solid cones interspersed with a weak, boulder strewn conglomerate as shown in Figure 8.

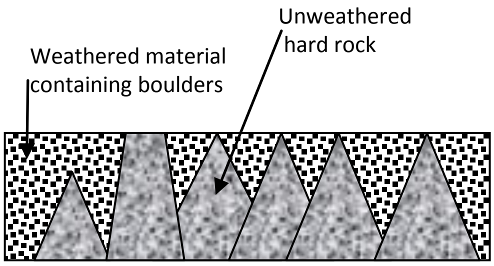
a)  b) 

Figure 8. a) Photograph of top benches being charged and b) Schematic of rock cones interspersed with boulder material

Figure 9 shows the “spot plot” of the charge masses produced by the ActiveLoading programme and indicates that a line of holes has not been charged. On closer inspection, it was found that the holes had not been drilled. Without the system, a poor blast outcome would most likely have been blamed on poor explosive product performance. However, the data provides a record of the actual reason. The missing holes occurred right where the harder rock intersected the bench surface. This is the worst possible place to miss out holes as the lack of explosive in the hard rock would have left a pillar of hard rock standing in the middle of the muck pile.

Of further concern is the significant overcharging observed in the holes in between the harder rock regions and indicated by colouring the individual holes based on ratio of the actual to planned charge mass. This suggests that explosive was being filled into cavities or joints in the softer weathered material and raises the potential for flyrock considerably, particularly since the rock was weak and contained larger boulders. The benefit of having the Blasting intelligence system installed on the MMU is that when this plot is viewed by the explosive engineer at the quarry, remedial actions can be taken prior to blasting and hence avoid costly mistakes and environmental and safety hazards. The graphical representation of over- and under-filled holes adds significantly to the understanding of the blasters on the bench and the reporting will drive behaviour to improve the quality of the bench preparation.

Figure 9. “Spot plot” of Explosive charge plan with arrows indicating missing lines of holes

4.3 Improved production efficiency

A case study at Jwaneng Diamond Mine, approximately 160km west of the capital city of Gaborone, Botswana was reported by Joseph (2009). The base case was started in 2006 as there was a problem of drilling control that led to borehole depths that were either too deep or too short. A drill depth monitoring exercise was implemented to ensure that all holes were drilled to within 30cm of the target depth and positions just before being loaded with explosives. While this exercise, which was conducted by both Jwaneng Mine and AEL, improved the drilling results from about 70% to more than 95% accuracy, the charging cycle times per hole increased to very high levels of about 7 to 10 minutes per blasthole. At the time, the same amount of explosive was required to be charged into each hole, causing and inconsistent energy distribution into the rock mass. After implementation of the automated blast loading system, an improvement to less than 50% of cycle time per blasthole was observed compared to the original practices. The graph of the total cycle time per hole for a single blast is shown in Figure10 in comparison to the range of original cycle times.

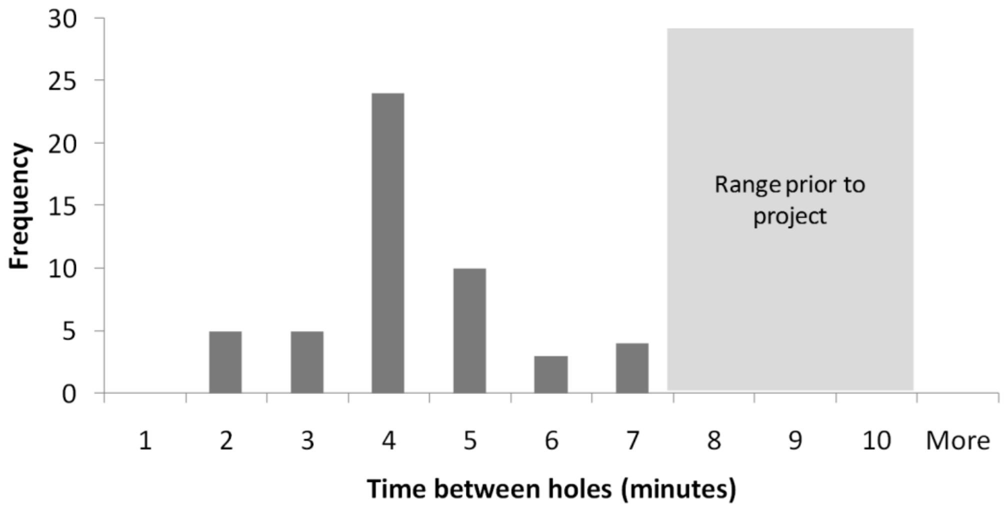


Figure10. Improved charging cycle times due to automated blast loading (after Joseph, 2009)

4.4 Production performance prediction

To date, nearly 3 million tons of explosives loading has been monitored since 2005 through the system in its various phases. This case study takes some data from a single MMU on a large open pit mine and analyses the time taken between holes in order to develop some models for predicting product performance. On a mine that is placing 800 to 1400 tons of explosive into a blast, involving 50 to 90 truck loads each blast will takes a number of weeks to prepare. The ability to know more exactly when each block is ready to fire becomes vital for short term planning on the mine. This predictability requires the development of models of the length of time that it takes each MMU to actually change the explosive that it carries to the bench. The histogram of times taken between start of charging one hole and the start of charging the next hole has been plotted in Figure 11for a set of 77 days of monitoring of a single truck at a large open pit mine. It can be seen that there are four different time period shown on the graph, which has a nonlinear x axis. The time between holes is roughly 1 to 10 minutes. Then, there is a set of data around 30 minutes that indicate short on-bench stoppages for various reasons such as inspections, waiting for drilling and minor repairs. The third data region involves travelling to and from the bench to refill the truck, which could take anything from 1 to 3 hours per round trip on this mine, depending on the distance to the silos. The final set of data involves overnight gaps, services, and gaps when other trucks charged the bench and this truck only returned to the original bench some days later.

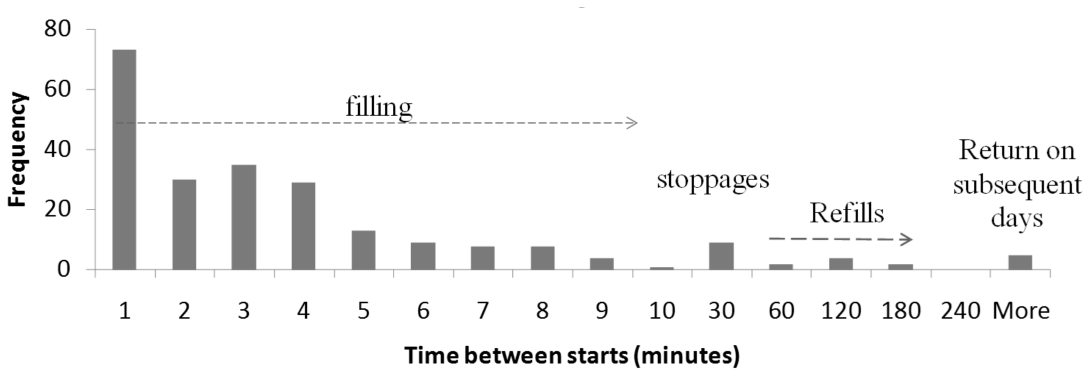


Figure 11. Frequency distribution of time between holes for a MMU over 77 days

The time between holes, with delays removed, can be analysed on a cumulative basis to determine the maximum charging rates that are determined for the specific mining conditions and on-bench work procedures. The cumulative time on the bench and associated mass of explosive pumped is shown in Figure 12. The plots indicate three different actual charging rates. The slower rates are due to charging smaller diameter holes. This requires the pump to be set on a slow rate and because the holes require smaller charges, there must be more accuracy with the stemming measurements and hence this takes longer. Pumping large holes at a fast rate is the most efficient means of delivering the product.

The prediction of the time that the bench can be ready to blast can now be analysed in more detail. At this stage, a simple equation that takes into account the charging rate R in tons per hour, the average number of stoppages T_s and the round trip duration T_r is applied. More work is being done to include a statistical analysis that applies the variation in the data to provide best and worst case estimates.

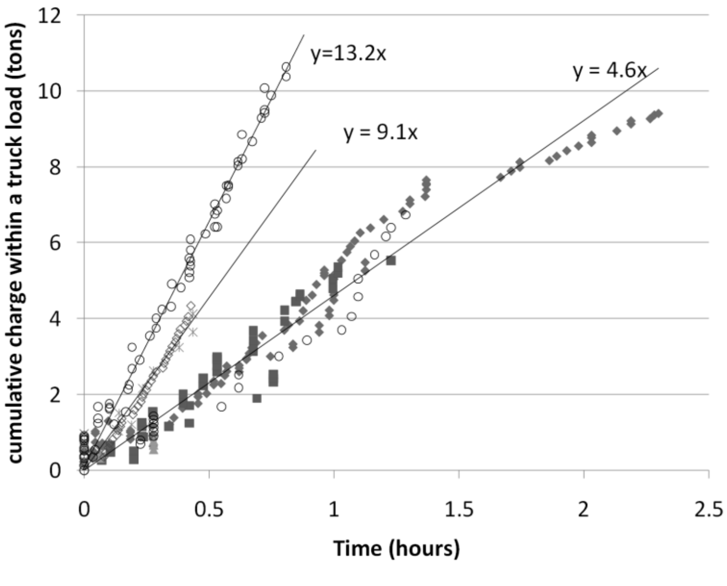


Figure 12. Plot of rate of explosive delivery for various benches logged

CONCLUSIONS

A business intelligence system has been developed within an explosive company to monitor the blasting process and track the layout of the blast, and other parameters such as drilling accuracy, redrilling attempts, charging of the holes and stemming by linking blast design software into decision support systems using open source Enterprise Information Integration and Business Intelligence software. The system is described and the benefits are explained using case studies where the knowledge of the actual on-bench information has contributed to significant benefits to both the explosive company and the mines.

The mine benefits by knowing the exact distribution of explosive charge and saves on drilling and redrilling costs. Production delays due to excavating in hard digging conditions as a result of having uncharged regions are eliminated by identify missing holes. The application of less safe working practices to blast out pillars of rock within the muck pile can be eliminated. Flyrock issues that are a safety hazard and deteriorate relationships with neighbours can be eliminated. The system builds up knowledge of problem areas and these can be blasted more effectively when similar conditions occur on lower benches. Systematic reporting and predictive capabilities improve the production scheduling and hence the overall mine productivity. The explosive company benefits by the elimination of claims and the improvement of drill and blast planning and scheduling. This improves the business productivity and the relationships with the customers.

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