GPS in Blasting Applications[1]

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Abstract: The onset of recent technologies means significant changes in all aspects of mining. Successful implementation of the newest technologies can allow a full mine-to-mill concept. However, activities once deemed a necessary cost of mining, must now be seen as a part of the greater automated system. Explosive activities are one such element of the successful modern mining plan. Automation of the blasting system currently involves managing and manipulating seemingly disconnected components. Drilling, surveying, geology, and engineering all play a significant role in the aspects of blasting; yet rarely do they communicate in a manner that yields results beneficial to the automated mine. In each of these disciplines, a key component of reliable decisions is the location of the blast. This paper attempts to show a system by which all disciplines can use the advent of GPS technology to coordinate and improve on the use of explosives as a part of the total automated mine.

Additional Key Words: Explosives, Carlson Software

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GPS Aided Blasting

Blasting activities are a necessary and expensive component of most mining applications that deal with rock formations. Whether as matter of product or waste, the use of explosives is often one of the most costly components of extracting minerals from the earth. Costs of materials, equipment, labor, and damage claims can seem proportionally higher for this component of mining than for any other.

For many years, this cost may have been seen as nothing more than a necessary evil in the business of mining. But when one looks at the larger picture, it can be reduced to the proper manipulation of knowledge to extract a product. Before the mine begins, all planning and decisions are made from a sparse sampling of data. The blasting division on the other hand, has real observations on the open face of the rock. It is the first place where real-time data can be gathered firsthand. Unfortunately, without true and accurate positions, the data is of limited use.

The advent of global positioning systems (GPS) use makes all decisions made for mining faster, more reliable, and generally better informed. When used in conjunction with the real-time information gathered by the blasting crew, on the working face of a surface mine, the information can benefit in more ways that conventionally considered.

GPS Equipment Selection

The initial decisions to implement GPS in blasting applications must weigh the needs and desires against the cost and benefits. Because GPS exists at many levels of accuracy and cost, the first decision must be made on the level of accuracy desired. As a primer, the basic GPS systems available are reviewed.

GPS receivers come in three basic levels, with some optional features at each level that provide some enhancements. The first type is the off-the-shelf receiver. Many of these receivers are self-contained units of power, receiver and display. Others are simple receivers that attach to handheld or laptop computers. These types of GPS use simple triangulation between multiple satellites to calculate a position. The advantage of these types of receivers is the low cost (generally less than $500), and ease of use. They require little if any GPS knowledge, and are compatible with many off-the-shelf software packages. The major disadvantage is the accuracy. Since the distance to the satellites is in the neighborhood of 20 miles, any slight error is atmospheric conditions, or angle can cause significant error. These receivers have therefore generally ten to fifteen meters of error (+/- 10-15 meters.) Many of the receivers also can access Wide Area Augmentation System (WAAS) satellites reducing the error about fifty percent.

However, a common rule-of-thumb for GPS coordinates should be considered at this point. The average error described by any GPS receiver is in the horizontal plane. The elevation error is roughly three times the horizontal error. So, an error of five meters horizontally is about fifteen meters in elevation.

The second type of receiver is a GIS grade unit with a correction attachment. The attachment can be one of two types. The first reads a private service correction satellite for a fee. The second uses the U.S. Coast Guard beacon for corrections. This type requires the unit be about 20 miles from a navigable waterway. In either case, this type of unit has an error of about one meter horizontally. The cost for this type of system can approach $5000 plus any annual subscription fee.

The third type of receiver is a Real Time Kinematics (RTK) system. It consists of a base station receiver and one or more mobile receivers (rovers). The base station is on a known fixed position. By communicating directly with the satellites and calculating the exact error, the base can broadcast corrections to the rovers by a radio link. These systems have a horizontal accuracy of about one centimeter. This system has a cost ranging from $30,000 to $50,000 for one base station and one rover. Additional rovers add about one-half that amount for each unit.

The selection of a system is governed by the application for which it will be used. Overburden blasts in coal mines may have a much less stringent set of data requirements than say an ore mine. On the other hand, once the complete realm of data that may be gathered from a blasting GPS system is seen, even those relatively simple shots may be found to yield important information. Therefore, the implementation of GPS in blasting applications is completely dependent on a series of user desires. Questions asked may include:

- Is the location data to be used for documentation purposes?
- Is the location data to be used for vibration control?
- Are uncontrolled structures to be protected at a relatively large distance?
- Is the location data to be used for staking of the holes?
- Is the location data to be used for automated drill guidance control?
- Is the location data to be used for locating a particular hole?
- Are the holes tightly spaced?
- Are the hole locations pre-determined by design, or made on a case-by-case basis?
- Does blasting data flow office to field, and back (opposed to field to office only)?
- Will down-hole data be used to update a computer geologic model?

Generally, if the only the first three questions are answered yes, the first two types of GPS systems are probably accurate enough. Horizontal distance errors of even fifteen meters have little affect in documenting general location, or in determining loadings to protect uncontrolled structures. If any of the other questions are answered yes, the RTK GPS systems are the best method of managing the blasting data.

Data Flow

Three components exist where blasting information must be present: the managing office, the drill, and the loading crew. Communication between these components is key to a successful drill and blast program. For this example, we consider the office as the central hub of the program. It may actually consist of any combination of management from surveyors, engineers,

and blasters. But in the conclusion of any event, it is the location where permanent information is recorded.

The first communication link is that of the office to the drill. Locations of blast holes are determined in one of two scenarios. Either mine planning predetermines the locations, or they are determined at the blast site to meet conditions. The second link is from the office to the loading crew. A design is delivered to the crew, and as-loaded information is returned.

All these communications can consist of a conventional paper trail where records are managed by hand, and transferred by physical means. This historical system is adequate, but can lead to miscommunication. The errors can be in record keeping, or as basic as improper design and layout. In a technology based setting, all the information is provided to and from the three components in a manner that insures efficient, safe, and reliable blasts.

The optimum blasting program must consider four components:

- Energy Level
- Energy Distribution
- Precise Timing
- Energy Confinement

If we look at energy distribution, and confinement only, we find three pieces of information that directly influence the results of those components:

- Geologic Structures
- Distance From Open Face
- Pattern And Spacing

These three factors all have a common thread of information. That thread is location. Location of geologic conditions, existing open faces, and hole pattern layout all involve precise locations in three-dimensional space. GPS provides the means to relate all these factors as a part of the total three-dimensional solution.

As a part of a total solution where RTK GPS is used, Carlson Software has developed a suite of three products that begin to provide the total information link on blasting activities to the units involved. These consist of: SurvCADD (Mining, Advanced Mining, and Blasting Modules), BlastCE, and DrillStar.

SurvCADD is an AutoCad based software package used for all aspects of surveying and engineering. In particular, the Mining modules provide full three-dimensional modeling of geologic data. Randomly placed exploratory drill data can be manipulated into an area wide estimate of geologic structures. In addition, basic blast pattern layout is available including positioning by top and bottom collars created by the geologic modeling.

The specialized Blasting module of SurvCADD advances that basic layout. If we review the concerns of energy level and confinement, we remember that hole depth, decking, load, detonation sequencing, and stemming all play an important role in optimum blasting. We also know that other information must be collected to prepare a proper event. Location of

uncontrolled structures, seismic information, access to past information for regression analysis, and the ability to produce reports are all required to produce the event.

The Blasting module is a tie between three-dimensional data, and maintained in a database structure. It is in essence a very specialized GIS application. The database contains all the information about explosives, blaster's names, seismographs, initiation systems, primers, and locations of uncontrolled structures. Since at any particular time, the individual event information may not be complete, it is considered in the design phase. For each event the locale, date and time of detonation, environmental conditions are entered. Then holes locations, depths, top-bottom-side clearance features, amounts of materials used, primers, connections, and timings can be entered if and as they are determined.

Once all that information is entered in the design phase, some standard reporting is accomplished. Total explosive, explosive per delay period, nearest structure, and scale-distance can be seen at the press of a button. Three-dimensional views of the blast can be made. Previews of the timings can be observed in animation.

Once the design information is complete, it must get to the blast site if it is to have any use in aiding the blasting crew. The software has two methods to get that data to the field.

DrillStar

The first field system is DrillStar, a machine guidance program written especially for blast-hole drill rigs. Through the use of physical transfer of the information by small computer storage cards, or by wireless a mine network, the event information is uploaded to a computer on the drill rig. The driller simply moves to holes in a pre-designed shot pattern.

Everything entered into the design to this point assumes that the decision-making processes are initiated in the office. However, the main screen of the drill guidance system allows the user to set parameters, and make an initial design with no information from the office. This provides the maximum flexibility for all operations.

The system guides the driller with a real-time targeting system. The driller can also mark particular geological features in the down-hole process. With a wireless link, the progression of the work is continuously updated in the office. As the drill pattern is complete, the as-drilled holes, and any associated information can then be returned to the office by physical means or wireless network for further manipulation.

The benefits of such a machine guidance system are:

- Real-time positioning information provides immediate performance feedback and real-time "as-built" surveys
- Real-time geologic modeling
- Increases productivity, eliminates staking, and satisfies regulatory requirements
- Work can continue in poor visibility

BlastCE:

The next field system is BlastCE. BlastCE is a data collection package for handheld computers. It integrates GPS location with the actual in-place loading and timings of drill holes. Like Drillstar, the data can be uploaded from office designs, or can be completed in the field as loaded with no initial design. With the office supplying only a list of materials to choose from, hole layouts, timings, and loading can all be accomplished on a handheld computer in the field. BlastCE also accommodates electronic detonator IDs on each explosive deck.

By simply entering simple data queries, the entire shot can be designed. With RTK GPS, the data can be tied to a particular location in space. Each hole can be seen in section view, or in a plan view that moves as the user moves. So when electronic detonators require replacement, or a hole is inadvertently skipped, the handheld unit can guide the blaster to a particular spot on the pattern. When the field work is complete, the user simply uploads the collected information back into the office SurvCADD Blast module.

As additional information is gathered concerning a single event, that information is also entered into the database. Seismograph readings, environmental conditions and other information is entered to keep permanent records of the event. When the information is complete, any report can be requested. Detailed reports with quantities, monthly summaries, or a hard copy shot reports are typical of the reports that can be generated. The process information from each event is immediately available for the next event.

The Future

Carlson software can provide any of the blast design information in electronic form. Using the electronic data, and integrating GPS on automated loading trucks, can streamline the process even further.

Conclusion

The explosives industry is at a milestone in time. In an age of technology where human error is minimized by automation, the industry can find solutions that reduce costs, prevent damage, and optimize production. GPS is simply a single component of the system by which these advantages are realized.