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Research Article

WALL CONTROL AND BLAST PATTERN ANALYSIS USING BLAST VISION® TECHNOLOGY

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ABSTRACT

Wall control and blasting are two major activities that significantly impact the productivity and safety of open-pit mining operations. Although many monitoring equipment are used for improving slope stability, there is still a need for understanding slope behaviour during a blast. This paper describes a new technology called Blast Vision®, developed by Ground Probe, for monitoring the interaction between blasting and slope stability with a temporal resolution in the range of milliseconds. This technology represents an innovative departure from standard blast vibration sensors by measuring ground luminance changes on the ground surface through drone-based computer vision. Blast Vision application for slope stability, misfires and fly rocks is investigated in this publication.

KEYWORDS

Blasting; Slope Failure; Blast Vision; Ground Probe; Misfires; Fly rock, Wall Control.

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INTRODUCTION

Blasting is one of the primary operations in the mining industry due to its significant impacts on safety and production. Approximately 20% to 30% of the explosive's energy is effectively used in fragmenting the rock. The remaining 70% to 80% is dissipated through ground vibration, noise, fly rock, back break, and air blasts which can trigger slope instabilities leading to potential injury, loss of life, property, and production [1,2]. Designing a blast pattern should be primarily based on the displacement and fragmentation requirements [3], providing sufficient energy to travel through the rock mass and structures. Therefore, keeping the balance between a desired rock fragmentation target while maintaining slope stability and reducing blast hazards poses an interesting challenge for open-pit mines to troubleshoot daily [4]. Given these conditions, a blast-slope optimization process is necessary to maximize production and to protect the personnel, equipment, and infrastructure surrounding the blasting area. Evaluation of the impact of long-term blasting activity on slope stability can demonstrate an understanding of the post-blast slope response.

Many techniques and sensors are used to investigate, monitor, manage, and control slope displacement, ground movement, groundwater level, etc. However, they have several limitations and disadvantages. A report has been carried out by [5], providing examples of the disadvantages of monitoring equipment. First, prism and laser scanning systems cannot be used as early warning systems. Second, there are limitations when using TDR and digital photogrammetry with respect to accuracy under unfavorable weather conditions such as snow and rain. In the words of [6], "Although most mining companies have in-house systems in place for slope monitoring, experience indicates that mining operations continue to be surprised by the occurrence of negative geotechnical events." Third, only vibration sensors and visual inspection methods are available to monitor the immediate impact of blasting on slopes. Although slope stability radars are less limited and provide failure warnings in advance, they are inefficient for reading millisecond slope changes caused by blast vibrations. Additionally, vibration sensors have the physical limit of being point-based measurements, and they can only measure the blast energy. A new technology is needed to monitor slope stability and blasting more efficiently.

Ground Probe is developing a technology that can monitor the blast and its interaction with slopes and the surrounding areas of interest with a high special and temporal resolution of milliseconds from optical frames. Visual data recorded by a drone-mounted camera is processed and transformed into temporal luminance changes over an area of interest. These changes not only highlight minor moving of the ground, dilation along with structures or through different geotechnical domains, but they can also detect more significant reflectivity changes at pixel level from rockfall, raveling, fly rock, and slope failures.

Blast Vision Applications

Wall Control

According to [7], many design parameters of blasts pattern impact blast-induced vibration energy, such as explosives weight per delay, the distance between the blast site and monitoring location, burden, spacing, etc. The blast vibration produces the horizontal loads that increase the sliding force and results in a lower slope stability coefficient [8]. It can also increase the magnitude of sliding movement along major faults [9].

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Additionally, while blasting can cause small slope displacement when repeated over time, slope movements will gradually become more significant and ultimately cause slope failure [2]. Slope failures could become substantial, causing the loss of one or several crest and catch benches, and/or raveling.

Specifically, blast pattern analysis must anticipate slope instability and possible movement during an explosion. Blast Vision technology creates different magnification views of the target location to display small slope displacements and rockfalls during a blast as a crucial initial step to evaluate the blast performance in the context of slope stability. A procedure based on this technology could be used to monitor and improve blast efficiency which could help prevent slope instability and protect the walls. These points should be used in a feedback loop to better manage and control subsequent blasting operations.

Blast Vision® technology detects small movement changes of slope such as rockfalls while most of the radars are blind to detect such small-scale movements. This high accuracy of change detection helps and improves stability of slopes. This technology will also detect minor and significant slope raveling (Figure 1) Although slope raveling may not be considered a slope failure, it could create significant complications that lead to safety issues. For example, when the raveling happens in top walls, some materials may reach the level of an active bench, are caught by lower catch benches, and fill them. This process may result in the loss of functionality of these catch benches with respect to future rockfalls and raveling. In other words, the lower catch benches can no longer prevent rockfall entering the active working area after being filled with previous raveling material. This situation could create a significant safety problem if the boulders hit mineworkers and equipment.

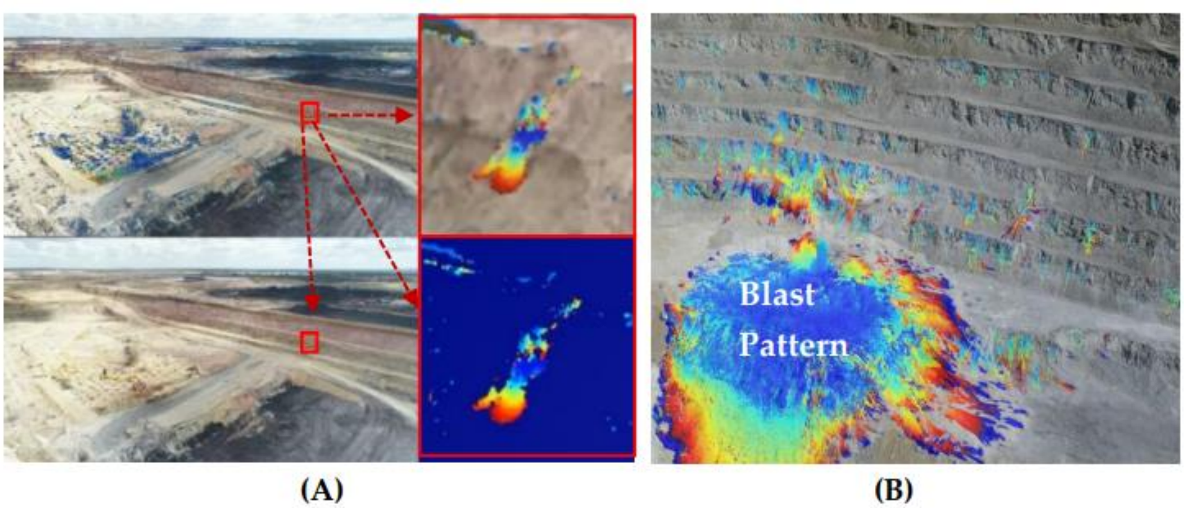

Figure 1. Visualization of ground fall: (A) Blasting area including zoomed views of wall raveling and (B) Slope movement response to a blast provided by Blast Vision® technology.

Figure 1. (A) shows the area of blast and slope changes in four different views. The bottom left is the raw picture of the blast, and the top left shows the slope change detection in time provided by Blast Vision®. These locations can be zoomed for a better visibility that can be seen in both top and bottom right views.

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They show minor slope raveling as results of blast impact on slopes. Figure1. (B) illustrates the blasting location and movement as well as wall movement detections during the blast. As it can be seen the major slope movement and raveling happened on the lower left benches.

Blast Vision technology minimize the noise of drone movement created by poor weather condition by using different visual thresholds. By using lower treshhold, minor slope changes can be detected, while increasing treshholds detect more extensive movements. In addition, Blast Vision® reveals change over time by assigning color to every video frame. Hot colors are indicative of more recent changes, while colder colors depict to a previous movement [Figure 1. (B)]. Hence, detecting pixel-level changes on a specific video frame by assigning colors to it helps visualize the blast's impact on the wall.

Flying Particles

According to [10], fly rock is considered as a rock thrown beyond the blasting zone. It can result in a significant accident in surface mining operations. According to hazard reports and accident data from MSHA (Mine Safety and Health Administration) and other government organizations, blasting incidents were 11 times more frequent than other mining accidents [10]. Fly rocks can damage slopes, infrastructure, and pieces of equipment and cause fatal and non-fatal injuries. Based on [11], of the 356 blast-related injuries reported during 1978-1993, 28.3% were caused by fly rock debris. Therefore, fly rock should be managed and controlled to prevent accidents.

Kecojevic et al. [12] explains the factors that can cause fly rock during a blast which include discontinuity in the geology and rock structure, improper blast hole layout and loading, insufficient burden, very high explosive concentration, and inadequate stemming. Although advances in fly rock prediction have been made to date, a holistic solution is still needed. The prediction of fly rock is based mainly on the fly rock's velocity and launch angle but the shape and size of the fly rock and air drag are important factors as well [13]. To better manage the fly rock during the blast and validating prediction tools, an accurate monitoring technology is needed.

As far as it comes to post-blast analysis of fly rock, Blast Vision® technology can detect fly rock during the explosion and it also provides the fly pattern for each rock, the velocity of the rock, and the time when fly rock is launched using video frame numbers. Also, this technology allows the landing locations for each fly rock to be determined.

In addition to fly rock detection, Blast Vision® technology provides detailed information about each single fly rock which can be used for validating fly rock prediction models. Rock characteristics such as shape, size, velocity, type, etc., are factors that play a significant role in fly rock predictions. for example, the blast hole diameter directly impacts the size of the fly rock. The larger blast hole diameters create larger dimensions fly rocks [14, 15]. Although every rock's trajectory is different, individual trajectories are identified. Having accurate timing based on video frames of the fly rock provided by Blast Vision® technology can help validate fly rock prediction models. Figure 2. (A) illustrates the flying particle visualization during a blast using Blast Vision® technology. Figure 2. (B) shows the distance between start point of a fly rock and the final landing location of fly rock that is measured by Blast Vision® technology.

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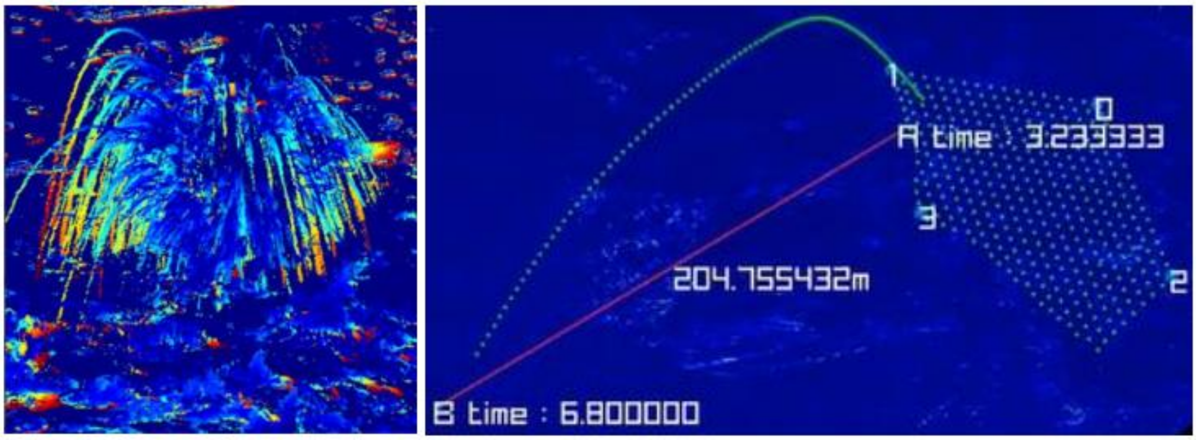

(A) (B)

Figure 2. Flying Particles Visualization

Misfires

Misfires happen when the blast holes loaded with explosives partially or entirely fail to detonate. Misfires cause safety problems and can also increase the cost of mining [16]. According to the U.S. Mine Safety and Health Administration (MSHA), from 1978 to 1985, misfires caused 63 injuries and six fatalities [16]. According to [17], deep-hole blasting is efficient, low cost and common in the mining industry and landfill projects, but misfires accident is a major disadvantage of their use. Therefore, detecting and managing misfires is vital, although it is still a difficult challenge.

Blast Vision® software can indicate potential misfires holes that should be carefully checked after the blasting to prevent any possible hazard. During the blasting, the entire pattern is expected to detonate and no movement on some parts of the pattern can belong to holes that did not detonate. These misfire's locations can be accurately addressed by using zoomed views of the Blast Vision® technology. Figure 3 shows an example of potential misfires for a mine blast. The top sections are raw field pictures, and the bottom areas are changes in time visualization. The zoomed views show the detected area of concern within the blast pattern; however, the area around this hole shows a different behavior, creating a misfire potential in this specific area.

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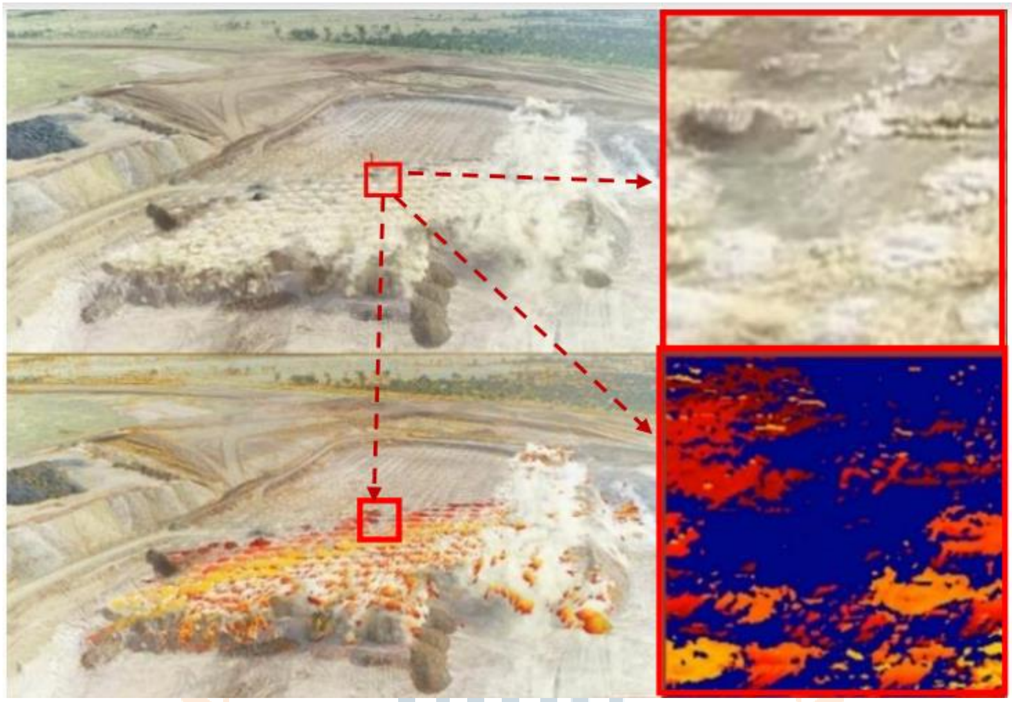

Figure 3. Change in Time Processing for blast pattern analysis

CONCLUSION

Ground Probe is developing Blast Vision® technology for blast pattern analysis, wall control, movement detection and potential misfire area detection. A drone video of the blast is required to run the application. Blast Vision® technology stabilizes and trims the video footage to minimize the noise and produce an optimal length consequently. Blast Vision® has different applications in slope stability and blasting.

The first application of Blast Vision® technology is wall control. This technology is used to better monitor slopes or any target infrastructure during a blast. It can detect rock movements and displacements, slope failures, rockfalls and loss of crest and catch benches. Based on an analysis of the data from Blast Vision®, improvements can be done to the blast modelling. The second application of this technology is detection of flying particles during blasting. This technology provides information of flying rock locations, velocity, and the time when particles are launched and tracking until the land. This accurate and detailed data play a significant role in fly rock prediction models and can be used for model validations too. The last Blast Vision® application is blast pattern analysis. This technology shows the behavior of the ground around holes and can help to detect potential misfires. As these holes can cause serious safety problems and even fatalities, it is very important to detect them after blasting. Monitoring zoomed areas of blast pattern as well as accurate blast movement detections can lead to determining misfire and prevent any possible hazards. These can be proceeded by using Blast Vision® technology. All different use cases of Blast Vision® technology can decrease the unpredictable hazards and damages created by slope movements, potential misfires, etc and result in better safety and productivity management.

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