CASE STUDY

DYNO42 & SIGNASHOT: PROPRIETARY SIGNATURE HOLE ANALYSIS SOFTWARE AND TECHNICAL EXPERTISE CONTROL COAL MINE CAST SHOT VIBRATION

PROJECT SUMMARY

DYNO42 & SIGNASHOT PROVIDE SIGNATURE HOLE ANALYSIS (SHA) TOOLS TO DETERMINE OPTIMAL CAST BLAST TIMING FOR VIBRATION

A cast blasting coal mine located in Indiana had begun to deck cast blasts and was considering a switch to a smaller diameter hole as the mine progressed closer to two separate two-inch-per-second (IPS) limit pipeline risers. The objective of the project was to not only stay under the two-inch-per-second vibration, but to do this while continuing cast blasting maintaining a single powder column, current hole diameter, efficient shot lengths, and the mine's desired timing ranges.

The DynoConsult team utilized the Dyno Nobel suite of signature hole analysis (SHA) tools, Dyno42 and SignaShot, in conjunction to identify a timing scheme that was optimal for vibration but also fell within the mine's desired timing ranges for hole-to-hole and row-to-row timing. The project utilized six signature holes per every other mining cut. Dyno42 would use these waveforms to analyze all desired timing sequences and shot length scenarios for the cast blast. These results could then be filtered down based on peak particle velocity (PPV), frequency (Hertz, Hz), and other attributes such as minimum delay (milliseconds, ms). Once one or multiple timings had been proposed then this timing scenario(s) could be simulated by SignaShot to provide a statistical analysis of the PPV resulting in high confidence in the upper and lower bounds of the PPV. This process would result in a selection of a timing scheme for that area of the cut.

SignaShot could then be used on a shot-by-shot basis to determine a predicted average PPV, as well as upper and lower bounds of PPV for the specific shot scenario. This was particularly useful due to the layout of the pit to the two pipeline risers that were each monitored by permanent seismographs with fixed geophone locations. SignaShot's inputs and calibration process account for the increasing or decreasing distance and orientation of the geophone to each respective pipeline location with regards to the cast blast.

The project was successful as the vibration limits were not exceeded and the mine was able to maintain the status quo with regards to its cast blasting programing. The postponement of transitioning to smaller diameter holes saved operational costs and efficiency. Additionally, the "business as usual" cast performance and costs resulted in an agreement with the pipeline owner, who had been holding out in anticipation of the mine feeling financial pressure, to move the pipeline removing the vibration constraints on the pit.

The results of each blast were also reviewed for adherence to SignaShot prediction and compared to a scaled distance calculated PPV to quantify the efficacy of the software.

Cast Blasting at Coal Mine in Indiana

BACKGROUND

COAL MINE VIBRATION LIMITS NEARED AS MINE PROGRESSES TOWARDS PIPELINE RISERS

The coal mine located in Indiana is a multi-seam dragline operation utilizing cast blasting that allows explosive energy to move a percentage of the overburden to its final location. The 10-5/8" cast holes are drilled at an incline and range from 85' to 95' in depth.

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The pit runs parallel to a pipeline and progressing towards the structure. When buried, the pipeline has a state regulated 5-inch-per-second (IPS) limit but risers, of which there were two in proximity to the pit, are limited to 2 IPS. One riser was located mid-pit with the other riser located at the end of the pit. These risers were monitored by permanent seismographs with fixed geophone orientation.

The monitors were able to remotely report the vibration results. The life of mine plan anticipated negotiation with owners of the pipeline to allow waiver of vibration limits and later relocation of the pipeline. However, at the time of the project, inception negotiations had ceased. Due to this, the mine anticipated higher operation costs and lower efficiency as hole size would be reduced, which would result in more holes and shot length being decreased. This would result in more blast delays and lower cast performance, and other blasting parameters would potentially need to be adjusted to ensure the 2 IPS limit was not exceeded. The two guiding determinations to the mine for when to deck and change hole size were their site-specific scaled distance equation and trends in the vibration results. An example of this is the mine had observed higher than expected peak particle velocities (PPV) when blasting in the middle of the pit and therefore had started to deck for this section of the pit.

Pipeline Riser and Permanent Seismograph

PROJECT GOALS AND RESULTS

DYNO42 DELIVERS SUCCESSFUL TIMING & SIGNASHOT PROVIDES CONFIDENCE NEEDED

The objective of the project was not only to stay under the two-inch-per-second vibration, but to do this while continuing cast blasting, maintaining a single powder column, current hole diameter, efficient shot lengths, and the mine's desired timing ranges.

DynoConsult expertise along with the use of both Dyno42 and SignaShot allowed the project to meet this goal with provided timings that allowed the mine to keep its cast blast design as-is. SignaShot performed so well in its predicted PPV the mine ceased decking in mid-pit after the simulations of the selected Dyno42 timing showed vibrations would not exceed the 2 IPS limit.

The postponement of detrimental changes to the cast program contributed to the pipeline owners resuming negotiations and reaching an agreement on the future of the pipeline

During the project Dyno42 was used to generate a range of timings for each additional signature hole, and these results were analyzed through SignaShot. The mine would provide final approval upon reviewing the recommended timing(s). With this timing selected, then SignaShot could run a shot-by-shot simulation based on shot location and other needed inputs. The simulated PPV average and minimum/maximum were compared to the actual PPV to measure the efficacy of the software. Additionally, the SignaShot accuracy results were compared to the result of the site accepted scale distance prediction to show differences in the results of the two approaches.

For the 27 SignaShot simulations run for shots there was no exceedance of the max predicted value and average difference of actual vibration versus simulated of .00974 IPS. The deviation for the values was .165 IPS. For the same 27 events the site calibrated scale distance prediction averaged a -.388 IPS showing the equation trending towards being overly conservative and potentially leading to premature adaption of changes to the cast blast design. Additionally, the scale distance prediction had been previously drastically exceeded contributing to the decision to deck some shots in the middle of the pit and was then exceeded again by a decked shot prior to the full introduction of SignaShot to the site.

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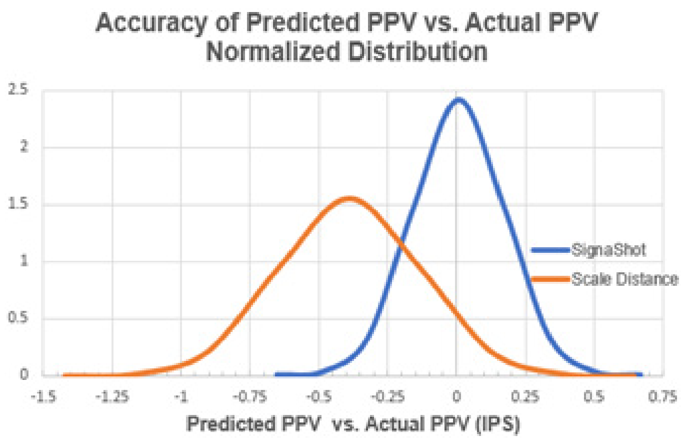
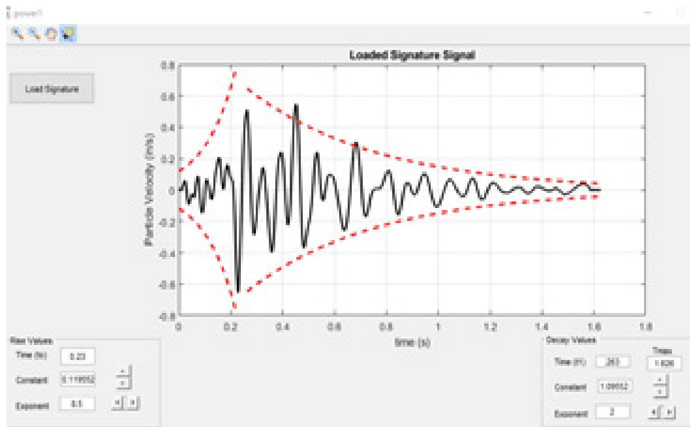


SignaShot Predictions Outperformed Scale Distance with a Mean Difference of ~0 IPS and Lower Deviation



Processing Signature Hole Signal for SignaShot

TECHNOLOGY APPLIED

DYNO42 & SIGNASHOT SIGNATURE HOLES ANALYSIS (SHA) SOFTWARE

Dyno42 & SignaShot are proprietary software offerings available through Dyno Nobel that facilitate signature hole analysis (SHA) to predict and control blast vibrations. SHA is a technique in which one blasthole in the project area is detonated and the vibration results captured as points of concern. The goal is to capture a waveform free from all influences other than the geology in which it travels. Various timing sequences can then be modeled based upon this wave to find a timing scenario that targets a higher frequency, a lower amplitude, or both while best maintaining blast performance.

During the project Dyno42 was used to generate a range of timings for signature holes and these results were analyzed through SignaShot.

Dyno42 utilizes the signature hole data and the Dirac signal processing algorithm to provide timing analysis based on amplitude (PPV in IPS), frequency (Hz), or a best practices combination. The analyzed delay range can be automatically set based upon industry or set to a custom range. The design and quick results allow for a wide range of delays for different shot configurations and monitoring points to be analyzed. The deterministic results of this software are determined solely by the inputs and initial conditions.

For this project the signature hole waveform would be captured at both pipeline risers. Six different shot lengths would be analyzed using the respective waveform to each location. The excel output for these 12 scenarios could then be compiled and sorted to find a common timing sequence that produced higher frequencies, lower amplitude, and met the mine's desired delay ranges for cast performance.

Finding a common timing that performed well amongst all scenarios and to both pipeline riser locations was beneficial to the mine in terms of operational consistency for the blasters on the bench.

SignaShot is an additional software tool that utilizes statistical analysis in its simulation of delay sequences. The in-depth analysis utilizes synthetic waves from Fourier series, calibration to blast event, and statistical probability to drive its prediction capability. The stochastic approach for additional evaluation of the Dyno42 timing results provides statistical confidence in the upper and lower limits of the prediction values.

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For the project, SignaShot was utilized in two ways. First, if there were timing scenarios that produced similar results in Dyno42 then a SignaShot simulation of the various scenarios could provide additional insight and help on selection of the timing sequence. Secondly, SignaShot was routinely used to simulate upcoming blasts to provide a predictive PPV whether as a check or validation to a change in shot length, etc.

Over the course of the project the SignaShot predicted PPV versus the recorded PPV had an average difference of.00974 IPS. These results speak not only to the accuracy but also to the flexibility of the software. Often at points of concern there are permanent seismographs with a fixed geophone orientation which can lead to issues with SHA due to the shot location changing in distance and orientation to the monitoring equipment. This could require an inordinate amount of signature holes to achieve consistent results.

VALUE ADDED

PROJECT ALLOWS CONTINUED USE OF LARGE DIAMETER HOLES LEADING TO OPERATIONS COST SAVINGS AND MORE

The project delivered value to the mine on multiple levels. This included operational cost, operational efficiency, license to operate, and long term mine strategy.

In terms of drill and blast operational cost, by continuation of the use of the larger 10 5/8" diameter the number of drill holes did not increase. An increase in drill holes would have led to an increase in number of detonators and boosters used and a drastic increase in drill footage. The mine credited SignaShot with providing the confidence needed at the time to proceed with two additional cuts in the pit with 10 5/8" holes. A projected cost savings for the duration of the project based upon these factors was more than $100,000.

Regarding operational efficiency, being able to maintain the same hole size and not having to reduce shot length (as a function of a restriction on number of holes) versus a smaller hole size, decked holes, or shortened shot length results in greater cast and effective cast performance. The efficiency gains can be hard to quantify as a final number due to the various impacts on cast performance and lack of empirical data for a smaller diameter hole in this pit. However, it is known cast performance did not suffer a reduction in performance during the project and was not exposed to a potential reduction through changes in the cast design due to the effectiveness of the vibration control timing generated through Dyno42 and SignaShot.

Lastly, it impacted the mine's long term mine plan for this pit. The mine had anticipated negotiation for a waiver and relocation of the pipeline within the mine plan. While negotiations with the pipeline owners were ongoing the mine began to forecast increased operational costs anticipating an agreement would not be reached in time to prevent impacts to the drill and blast program. With negotiations at an impasse, DynoConsult assisted the customer in setting up a signature hole analysis project utilizing Dyno42 and SignaShot. By eliminating the area where holes were being decked and postponing changes to the cast design, the project contributed to reducing the negotiation leverage of the pipeline while also maintaining a regulatory and social license to operate by not exceeding vibration limits on the pipeline. This and other factors led to an agreement between the pipeline and mine providing a vibration waiver until the pipeline was relocated.

AUTHOR'S NOTES

Vibration data from 3/6/2020 was omitted due to geophone being reset to a different orientation by vendor prior to shot.

Operational costs saved calculated in "Value Added" are based upon an approximation of drill cost per foot and average accessory and bulk explosive costs. The assumed pattern dimensions for a smaller hole diameter were made in consultation with the mine. The cost savings were calculated for elimination of decked holes for a length of a cut at the beginning of the project, the postponement of a change in hole size for the entire length of the following cut, and the length of the next cut that had been blasted prior to the signing of a vibration waiver limit.

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