UNDER THE SURFACE

Carl Brackpool, Hexagon Mining, details recent room-and-pillar equipment developments that are helping coal and hard rock mines increase efficiency and safety.

As target ore bodies close to the surface are being discovered and exploited, those untapped and uncharted reserves lie deeper and deeper. Underground mining methods are trying to meet the demand. These methods are encountering complexities that may be easy to overcome above ground, but require domain expertise and often non-scalable customised solutions below.

As data from a growing number of instruments, humans and mobile assets need to be outside the mine for analysis, the network infrastructure and software required to collect and process these packets become bottlenecks for true underground mining optimisation and safety.

Hexagon Mining's capabilities in underground design and optimisation are extremely mature, going back 20 years. In response to the market and customer requests, the company's core products for geo-modelling, CAD and schedule optimisation are advancing in tandem with its surface, pit tools and legacy underground applications and packaged offerings. Hexagon underground products are used in both coal mining and hard rock where drill/blast/muck cycles are the key to profitable output from the mine.

Optimisation of any mine design and plans must account for a middle era where fully autonomous mobile equipment occupies the same physical space with human operators until that future state where all underground operations are 100% robotic fleet. The company is still a long way off all operations using remote-operated shears, shuttle cars, trollies and haulage beltlines.

During the transition from century-old methods, practices and standards, to a sophisticated paradigm of self-directed, self-learning, self-guided mechanical assets, the constraints for building software and hardware systems become greater and more complex. They impact pillar polygonal dimensions and roadway calculations to accommodate longer or tighter turning radii, depending on the machine size and designs for ventilation and possibility of economically viable bi-directional passage (or at least pass-ways, pass-bays or overtaking on declines).

The next generation of Hexagon Mining's underground products are fully integrated systems based upon proven domain expertise and development verticals into specific facets of an operation throughout the life of mine:

- Design and multi-dimension planning software with visualisation (MineSight 3D).
- Engineering toolkits for stope design from block models and polygons.
- Scheduling and workflow optimisation, including fleet management (SmartMine UG).
- Safety systems for collision avoidance, fatigue monitoring and vehicle intervention.
- Personal protection systems to provide safe interoperability between miners and mobile machinery, as well as tracking and localisation in GPS-denied environments.
- Tablet-based task management and real-time dispatch, using multi-hop mesh networking to the face (MiPlan).

Combining all current Hexagon Mining products in a bundled, seamless system, or individually as modules, underground mining operations can operate safely and efficiently while targeting the highest NPV.

Hexagon's vision of a smart mine promotes the increase in sensor density for connected devices, measured in magnitudes

Mining complexities that may be easy to address above ground, are less straightforward underground, and require domain expertise and often non-scalable customised solutions.
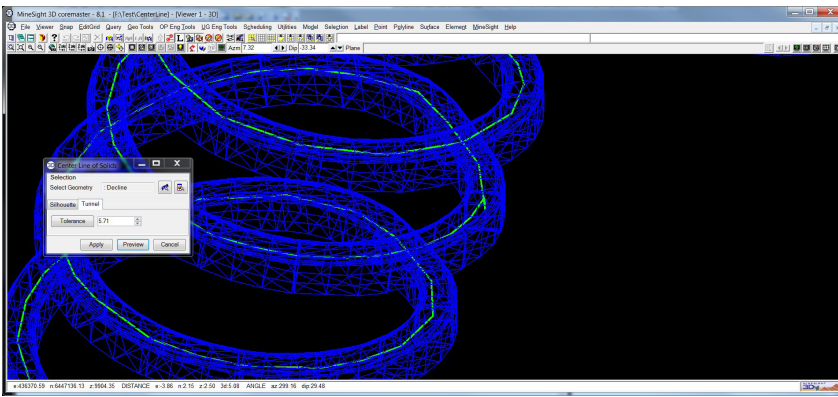
Hexagon Mining's UG software tools begin by generating a centre line for a 2D polygon or a 3D solid, either by generating a 2D silhouette of the solid, calculating the centre line and projecting back to the solid, or by treating the solid as a point cloud and condensing this cloud into a polyline.
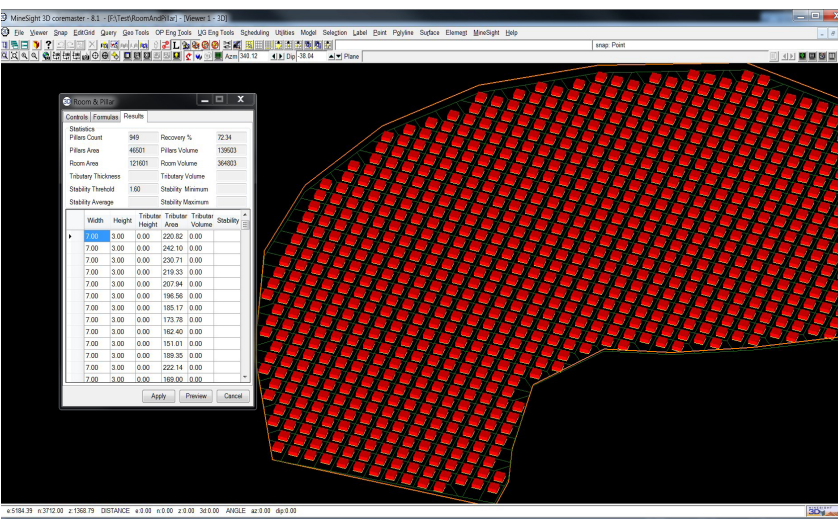
Plotting and engineering calculations for design runs take minutes. Threshold and excessive resulting load stability results in different shading for reviewing the initial inputs. The objective is to strive for the smallest pillars while maintaining the fidelity of the supports.

of 10x to 100x, and beyond. Whilst the aim is not to promote 'buzzword compliance', Hexagon Mining is enhancing its underground products to work within the Hexagon corporate platforms of these Internet of Things (IoT), as well as machine health, predictive analytics in machine learning, and AI. These applied transformative sciences and use cases are the foundation for underground room-and-pillar customer offerings with tangible value.

A pillar of support

Room-and-pillar mining has been used as a mining method for centuries. It is predominantly used in coal operations, but several Hexagon customers in Brazil and South Africa also use it in gold mining, where geostatic models were built inside MineSight suites and stopes and pillars were engineered in SmartMine UG. As the global coal and potash markets stabilise and rebound from downtrends, Hexagon Mining is improving all legacy underground tools to be ready for the market when the demand for coal production increases.

MineSight 3D (MS3D) will launch next-generation room-and-pillar solutions in a series of releases, beginning in 2018, amplifying the focus on existing and future coal customers. New features for existing products include application of rock mechanics data analytics for use in roof and pillar load bearing supports calculation. Ventilation design to optimise systems and enable ventilation on demand platform development with convergence tools is a key focus, with the understanding that Hexagon's systems work seamlessly when networked to other vendor inputs and their data.

Getting down the lift, so to speak, Hexagon Mining tools begin with generating a centre line for a 2D polygon or a 3D solid, either by generating a 2D silhouette of the solid, calculating the centre line and projecting back to the solid, or by treating the solid as a point cloud and condensing this cloud into a polyline.

This is the first phase in defining tunnels and silhouettes that will be the basis for laying out pillars from polygon studies of influence. For long-term planning, this inaugural step attaches
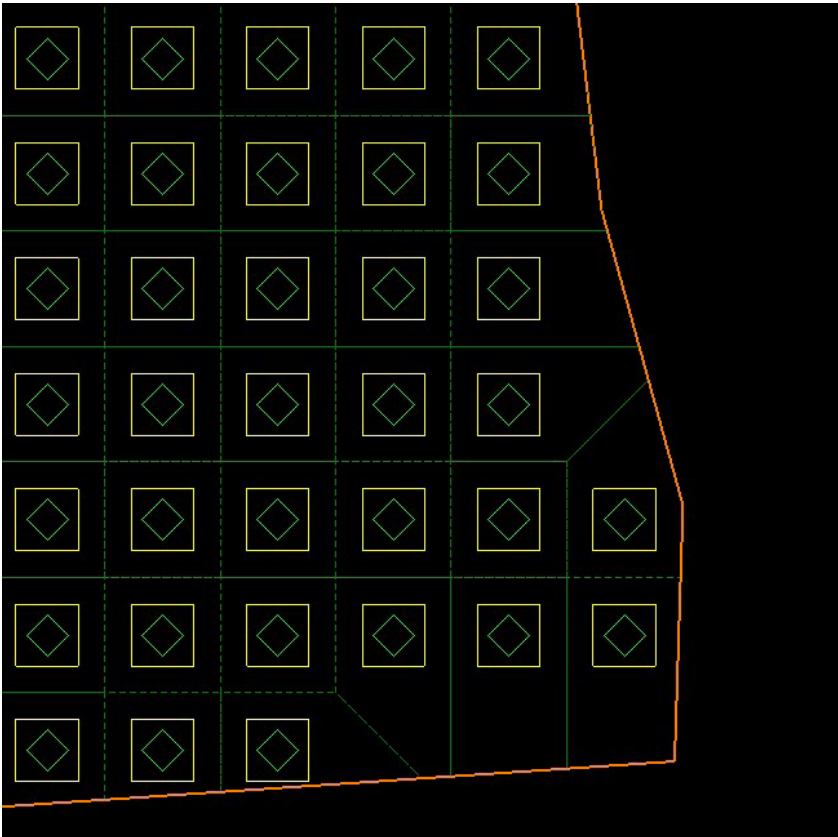
An initial layout is created before the next phases of stress analysis. Square pillar shape has typically been the practice. However, Hexagon is developing additional palette options to accommodate new algorithms with contours that allow for support with proper footing, and roof control while still providing for complex machine movement without runout bays for multi-turn 90° turns.
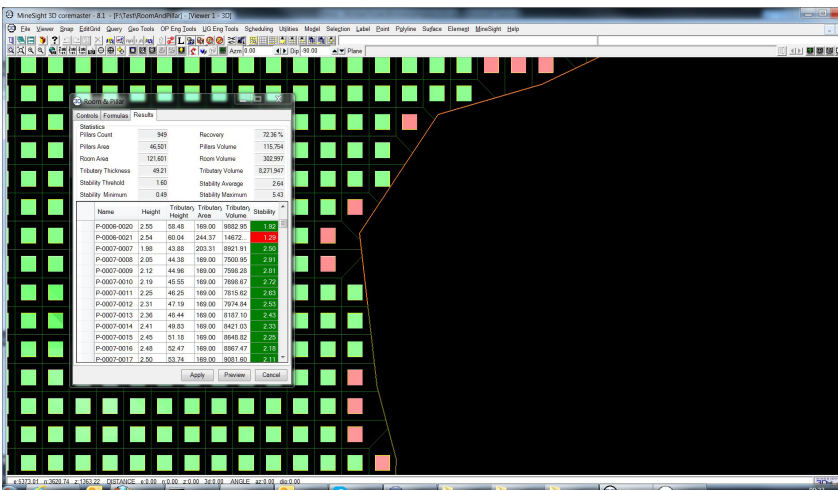
The table for pillars can be manipulated to sort ascending or descending in order to display values for focus on new calculations and planning runs.

drift, declines and ramps up development for entries and returns used in future calculations for beltlines, ventilation and panel or face developments. Then polygon, surface or solid, using either the CAD or the object browser, result in 2D images with pillar centroids and nearby ore boundaries as constraints.

The dialogue and user interfaces provide a workflow to develop the layout. As the room-and-pillar design plan evolves, the engine is built to take advantage of the industry's Salomon and Munro formula for deriving pillar strength, loading and surfaces for maximum stability and yield reserve utilisation. This is key when using Hexagon Mining's room-and-pillar features inside MS3D for determination of pillar stability and calculating the strength of the pillars and the weight of the tributary being supported.

The results from running test cases with a significant number of user and condition-defined variables is an initial layout before the next phases of stress analysis.

When determining the pillar size, it is important to remember that traditionally a square pillar shape is the practice. However, new algorithms are being developed with contours to allow for support with proper footing and roof control while still providing for complex machine movement without runout bays for multi-turn 90° turns. Hexagon understands this and is developing additional palette options in accordance with world standards and academic research for hybrid formulas.

By editing the existing formulas native to the product, mine engineers can run and re-run designs, including 2D and 3D previews, with a variety of definitions, based on customer and site-specific geology/rock mass properties.

In each example of design runs, threshold and excessive resulting load stability results in different shading for reviewing the initial inputs. The objective is to strive for the smallest pillars while maintaining the fidelity of the supports.

What once took days of plotting and engineering calculations, now takes minutes with these room-and-pillar modules inside MS3D and with greater confidence in the data and outputs. By concentrating on specific sections and clusters of pillars, a flexible design is achieved, which is unique to the strata layers above.

Refining to suspect-specific pillars eliminates mass file runs with middle-curve calculations to reset baselines. The table for pillars can be manipulated to sort ascending or descending to display values for focus on new calculations and planning runs.

Once satisfied for building economically viable pillar size and spacing, and support stability (roof up to

the topography), the visualisation tools in MS3D can be output as fly-through in 3D, wireframes, rendered models, and reserves or coal deposits as layers or solids. The usual file formats are supported and provide the flexibility for combining data and subsets from other tools in building the master data table or database of record. If the plan includes retreat mining, the last phases of mine life can be run as medium-term plans (MTP) with constant adjusting of calculations, based on data from support data collection and stresses.

Once the plan is finalised, the scheduling for entry development is imported into Hexagon Mining's SmartMine UG. Once ingested, the overall scheduling of mining phases is run for short-term planning and then reconciled as the mine advances. Task-specific functions are distributed to the operator via in-cab displays or handheld tablets and devices, in regions where hardware has been certified for safe use, including intrinsically safe operations at the phase or beyond the last cross-cuts.

SmartMine UG is designed to take advantage of communications that are approved and supplied for the underground coal industry. As the voice and data communications requirements in underground mining increases exponentially, Hexagon has developed anchors network repeaters that can be used to improve meshing, or alternatively as store-and-forward methods for non-critical mining information streams. Room-and-pillar mining has proven a tough environment for line-of-site radio and wireless communications, more so than longwall operations. Hexagon Mining is working with the best-in-class networking vendors to develop integrated systems and implementations that can support faster data for analysis. In ventilation planning and modification, this is critical. For safety, miner tracking and post-incident plans are used; this weave of planning, engineering, scheduling and asset tracking (autonomous or otherwise) further improves confidence in a mine operation that is profitable and compliant.

Focussed on the future

Hexagon Mining continues to develop products in underground coal mining that are easy to deploy, support and purchase. Room-and-pillar is at the forefront of this suite of tools. It also marks a shift from tightly interwoven features – that may not be used in specific mines – towards packages of modules that can be enabled or disabled, depending on the pricing and deployment plans for each specific customer. The company understands that planning and scheduling is a part of the larger life-of-mine solution from exploration, to coal prep plants and ultimately the shipping port. For many mines, room-and-pillar methods are the best way to extract from flat, but non-contiguous, coal seams. Driven by customer inputs and requirements, the product management teams within Hexagon Mining are leveraging existing sites using their tools and by responding to where customers believe they should be in applying digital mining technologies. *WC*