Mind the digital gap

Thomas Boutaugh, PEC Consulting Group – PENTA Engineering Corp., USA, discusses the advances in technology in the underground coal mining industry since the 1970s.

People forget what powered the world they live in, with cell phones, air conditioners, lights and provided electric power to myriads of industries and transportation systems. The world was a coal-based power generation. Without it, people would not be enjoying the luxuries they now enjoy. People plug into a wall outlet and like magic, they can run an appliance.

Some people make decisions with no information, meaning that there is a high likelihood they will be wrong. With information, this probability can be shifted more towards the lower end of the spectrum. So, when does the decision need to be made? Can it wait a little so that more information is available before making the decision?

Over one of the company's engineers' 50 years' experience, the biggest disappointment they have witnessed is the loss of know-how due to people leaving or companies closing their doors. Technological advances have come and gone and yet it seems like the industry is constantly reinventing the wheel. How is this regained? The coal industry is highly competitive, which means that if technology and information is kept secret a miner can keep a competitive edge. The problem with this approach is that the technology may get lost, technology which includes computer programmes. Some companies invested in a staff of computer programmers that wrote all their software. As new computer platforms came along, the software was being constantly modified to adapt the software. Much of the mining software is now lost because it has not been kept up with new operating systems. Some of the old discarded software is better than preserved software available in the market today.

In the mining industry, advances have been made that will improve safety, for example underground ventilation or ground controls that can benefit everyone. The software that was developed could save lives and, if shared, would have the capability to benefit everyone. Some companies are spending

Figure 1. A boring machine.

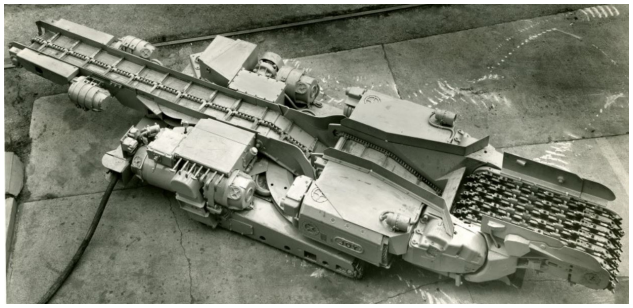

Figure 2. A ripper miner.

more money on research and development than others. Contributing to these companies financially and redistributing technology that is safety related would help the world.

Mining methods

By using computer simulations, changing mining methods have been able to help turn a company that is losing millions of dollars into one which makes millions of dollars. In the 1970s, the US was landing men on the moon and thus space frontier was on everyone's mind.

Deep underground in coal seams that were formed from compacted vegetation growing in swamps millions of years ago, underground surveyors were examining the locations of the mine faces so that the draftsman could generate maps. They drilled a 0.25 in. hole in the roof, hammered a wooden plug into the hole and then hammered in a metal spad with a hole in it, through a brass tag with a number on it. This number corresponded to a number on the map that the draftsman was generating, helping workers to locate underground mine development. They would hang a string with a plumb bob on it and shine their cap lamp behind it and the transit-man would tell them to tap the spad to the right or left to get the string at the correct alignment. The shift foreman would then use the same spad to hang a string and line up the entries underground.

'Conventional' mines

One 'conventional' mine that was surveyed by underground surveyors had coal that was 50 in. thick. Each coal face was cut at the bottom with a cutting machine, drilled, blasted and then cleaned up with coal loading machines. The coal was then hauled from the coal face to railcars using an electric shuttle car. After the area was cleaned up, a roof bolter would drill the entry roof and place anchor bolts to support the roof.

Boring mines

The second mine surveyed was using a large coal cutting machine called a boring machine.

The boring machine was very large and slow. It would cut 100 ft of coal before it could move to another location. The circular shape of the entry left by the borer had enough stability to support the roof until the roof bolter could get in and bolt the roof. However, due to the slow cutting, the boring machine dumped the coal on the ground behind the machine so that it could continue cutting. A low profile (scoop) loading machine was used to gather the coal and convey it into waiting shuttle cars.

The boring machine also presented multiple dangers and health and safety hazards. This is because the machine is blocked by the pile of coal and could not be moved to the next location until the coal behind it was cleaned up. In addition, the mine operator, loading machine operator and the shuttle-car operator were all working under unsupported roof.

In the 1970s, the Mine Health and Safety Act passed laws that required coal mines to improve safety. One of the new rules was that no man could go beyond unsupported roof. This law eliminated the use of boring machines and required that continuous mining machines be more mobile.

Ripper miner

The third mine that was surveyed was using these new, safer ripper machines (Figure 2). The depth of cut was reduced to the distance between the tip of the cutting head to the protected cab that the operator sat in. The cutting head is very narrow so, although it was a more mobile machine, it required many slices into the coal to carve out an entry.

Later, a full-face continuous miner was introduced that allowed for one cut before moving on to the next cut. As the laws changed, operators had to adjust their operations in order to stay in business. Satellite bolters were added on the sides of the continuous miner to simultaneously allow for bolting to be done and the continuous miner to cut coal. A centre bolter was used to bolt the middle of the entry after the continuous miner was moved to the next location to cut. The satellite bolters placed the roof bolter operator in a dangerous location as they stood between the mining machine and the ribs.

Technology in the mining industry

As the laws changed, companies were constantly adapting to meet new regulations. Previously, computer simulations were used to analyse different mining methods to increase operation efficiencies and consequently cut costs.

Electric shuttlecars were converted to battery or diesel engines to eliminate the use of electric cables as they interfered with the mining operations. However, this then meant that the mining method had to be changed to match the new equipment. Working at many different types of mines, both underground and surface, over many different coal deposits provides valuable experience and can help with the decision-making process.

Using this experience, engineers have converted a two dragline operation that was losing money and limiting the life of the mine to a single dragline, a truck and shovel operation. This

turned a losing operation into a profitable operation while extending the life of the mine another 15 years. Computer simulations allowed engineers to run many scenarios and to calculate the costs of each scenario. This is the kind of information that is needed to make the right decision. Using this method in two other operations allowed mines to go from losing US$15 million/yr to making US$15 million/yr.

During the 70s, Fortran IV was the programming language and card readers and card punch machines were the equipment being used. Some companies had a digitiser and a tape reader to digitised surface contours and existing mine maps and the drill hole information was stored in a database. Combining all this information enabled grids to be generated.

Grids is like laying a piece of mesh on a drawing and grid points can be identified where the mesh lines intercept each other. This point represented a northing, easting and an elevation and multiple Z values. This could be the top of elevation for each rock strata from the surface to the coal seam.

This could also be coal analysis; ash, sulfur, Btu, etc. Using this data, mathematical simulations could be generated to manipulate the grids values. Monstrous grid files were used with these simulations whereas with today's computers, multiple simulations could be run in a very short time. These simulations would be very useful to all mining companies if they were to be shared rather than discarded. Obviously, cost data from each operation would need to be incorporated. It is imperative that mining engineers learn some programing to enable them to communicate with programmers.

Computer models were generated to calculate the profit and loss at each grid point. Converting this information to a graphical exhibit or drawing can show the profit and loss at each grid point over the entire mine. From this information, management can put together the right plans for the life of mine. The drawing can be colour coded to make analysis by a non-engineer easier. White signifies the profitable areas, yellow represents a warning that the mine is close to break-even, orange could mean break-even and red indicates a loss.

Room and pillar mining

Room and pillar mine planning is more than just laying out a series of squares and rectangles on a map. The size of the pillars and width of the entries are mostly determined by the roof's geologic conditions, but consideration should be given to the type of mining equipment and mining sequence for the most economical and safe method of producing coal. A poorly laid out mine will quickly shut down if it is not making money.

Computer simulations were generated using real-time data from either equipment suppliers or real-time data from the mine, as well as the geologic data from the drill holes and the coal chemical analysis to generate operating costs. With multiple operating mine sections underground, one could show which section will generate the most profits at the mine and still meet the specifications of the client.

The small squares with numbers inside them represent a block of coal that is cut in one sequence. The length of the cut is determined by the equipment and varies between suppliers. The numbers represent the sequence of the continuous miner as it moves from one spot to the next. As the miner is moving

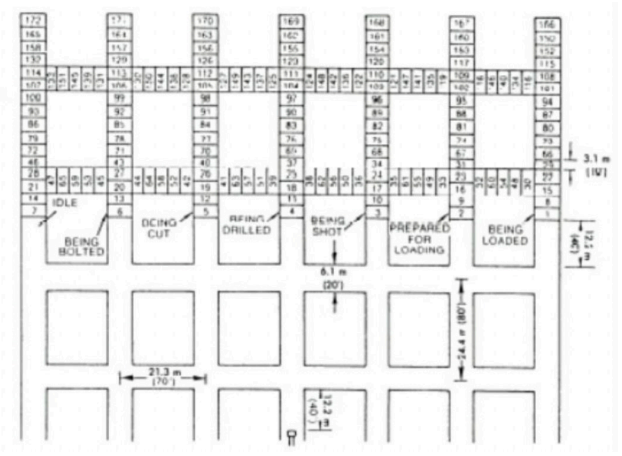

Figure 3. A typical mine sequence projection.

from block to block, the grid information is used to speed up or slow down the miner based on the seam thickness. The simulation will calculate the production for the shift and from this, one can determine the best layout for the mining conditions. This information is also useful for writing specifications for new equipment. Close collaboration between the equipment suppliers and engineers help to maximise production.

Multiple linear regression is a tool that is used to analyse many sections or operations at the same time where one can maximise profit while meeting client specifications. It is best to use the computer to help determine the best method that will maximise profit instead of spending millions of dollars and finding out the wrong equipment or the wrong mining method has been selected. With the speed of today's computers, multiple simulations can be performed at the same time, making them another great tool for helping management make decisions.

One of the most profitable mining companies attributed their success to writing its own software inhouse. They had software to do complete feasibility studies with a few parameters, which enabled them to quickly make operation decisions. They had software that could do permit applications and make modifications quickly and programmes that predicted subsidence on the surface, which allowed the engineer to find the cost implications and plan accordingly.

Conclusion

All this software was available and is probably lost now. It could have been used by the entire world to make coal mining safer and more efficient, and this is why companies should consider sharing their software. This could be donated to a university or maybe given to MSHA to be made available to others. Many programmers are retiring and new programmers are taking their place. But to be effective, it is important to get experienced engineers and programmers together.

More and more people in the work force are retiring every year and it is important not to lose all the knowledge that has been gained over the last 50 years. A man landed on the moon 50 years ago, so technology was not so bad. Miners need to share knowledge so that the industry is not reinventing the wheel. WC