A simple solution to a real problem experienced during the application of a unique mining method

by Jochem Erasmus, Optron

Abstract

In the high-tech environment we live in, it is sometimes difficult to believe that the solution to a problem could be so evident. This is what happened when the productivity of a multi-million rand mining machine was severely hampered by an orientation issue. The aim of the mining machine is to mine parallel tunnels, up to 530 m deep, horizontally into the high wall. Although the mining head makes use of an inertial navigation system to control azimuth while mining, the machine needs to be aligned with the intended tunnel direction before mining can start. This task was given to the surveyor on duty and seems like a simple enough assignment. However, aligning a 25 m by 7 m steel structure to cm accuracy proved to be more difficult than anticipated. Not only did the surveyor need to be on standby 24 hours per day to align the structure whenever a new tunnel needed to be initiated, but doing the survey at night with no assistants proved to be quite a challenge. Errors were easily made during complicated calculations which resulted in costly delays while recalculating directions and offsets. The solution was to use two real-time kinematic GNSS receivers, with antennae installed on either side of the 25 m steel structure, to “stake out” the two outer ends of the structure onto a predetermined line. The position and direction of this line was determined in the mining design software and transferred electronically to the GNSS receivers, eliminating errors. A simple solution to a real problem.

Keywords

productivity, launch vehicle, tunnel direction, GNSS receivers, stake out, DXF

Introduction

A mine located close to Witbank in Mpumalanga, South Africa, recently implemented a unique mining method, called the Addcar Highwall Mining System. This method could potentially bring enormous productivity gains. Not only was this a continuous mining machine, capable of mining 24/7, with reduced manpower requirements, but it also allowed underground mining without the normal open pit process or sinking of expensive shafts with accompanying infrastructure. Although this mining method does not replace other mining methods in all cases, there are definitely specific conditions to which this method is perfectly suited. The advantages of this mining method are clear, but one of the drawbacks was that it proved to be quite a challenge to position the mining machine correctly before starting to mine a tunnel.

The principle of positioning a huge steel structure accurately is not really a difficult survey exercise when conditions are good and every minute wasted does not result in additional production losses. A quicker, more reliable way needed to be found to position the mining structure. The best possible solution would be to find a way for the operator of the machine to do the positioning himself, without the need of a surveyor to be present.

A unique mining method

The Addcar High Wall Mining System consists of a continuous mining machine shown in Fig. 4, called the continuous miner, which mines tunnels horizontally into the high wall. Although the tunnels do not have to be perfectly horizontal, there are certain vertical limits to which the miner can operate. The continuous miner is launched into the side of the high wall by a launch vehicle (see Fig. 1). This launch vehicle needs to be positioned in such a way that the orientation of the miner is correct. Tunnels need to be parallel to ensure they do not run into each other or get too close which will
reduce the width and strength of supporting pillars left behind after mining. Fig. 3 shows how the tunnels have been mined into the high wall. The mining head uses an inertial navigation system, or INS, to guide it on a specific direction while mining. Even though an INS is used to control the mining process, the launch vehicle also needs to be aligned with the intended mining direction within certain limits. If the launch vehicle was not aligned properly, the mining head would be expected to make large directional corrections in the first few metres of mining and this was simply not possible.

The launch vehicle uses mechanical “legs”, shown in Fig. 1, which lift the whole mining machine and then move it down the high wall, perpendicular to the tunnel direction, in order to position it for mining of the next tunnel. There are two “legs” which can be controlled independently and which enable the operator to move the front or the rear of the vehicle by as little as 1 cm at a time to allow alignment to the intended mining direction.

Fig. 1: Addcar launch vehicle.

Fig. 2: Car with conveyor belt.
The continuous miner consists of a rotating mining head which breaks up the ore in the seam, in this case coal, and then produces the mined substance onto a conveyor back to the launch vehicle to be stockpiled and supplied to the market. As the continuous miner moves forward into the seam, another 13 m section or car, shown in Fig. 2, is added behind it to extend the conveyor belt, but also to allow the miner to be pushed deeper into the seam. Tunnels of up to 530 m can be mined in this way and this is why it is called the Addcar system. A control cabin is fitted to the back of the mining machine from where the operator controls the whole mining process. From here he or she has a clear view of important sections of the mining machine and all relevant information is displayed on screens as well as video feed of critical processes. The direction in which the continuous miner is moving is also displayed and one of the most important tasks of the operator is to make sure the direction is maintained. This information is supplied by the inertial navigation sensors fitted to the continuous mining head.

So what did not work as expected?

The task of aligning the launch vehicle with the intended mining direction was left to the surveyor on duty. He had to calculate parallel lines, based on the width of the mining head as well as the suggested horizontal spacing between tunnels. However, since the launch vehicle is a huge steel structure with no specific centre point which could be used for alignment, other reference points had to be identified and an offset to the centre line had to be calculated to ensure that the centre of the launch vehicle is in the intended position before mining of a new tunnel could commence. It would have been great if the centre of the front and rear of the launch vehicle were visible from the same instrument setup but this was not the case. The surveyor used to have reference points along the high wall where he could setup his total station, orientate to a back sight and then turn off the angle used to align the launch vehicle. This never worked extremely well and there was always a little bit of guessing involved. As with any open pit mining operation, these control points were constantly being removed by other mining activities, roads being graded etc. This used to cause delays while the surveyor had to bring in new control points from the remaining or primary control.
Another difficulty was for the Addcar operator to communicate with the surveyor from inside the control cabin in order to know how much the launch vehicle had to move at the back and the front end for the centre to be on line. Every minute wasted in positioning the vehicle resulted in production losses and it was crucial to do this as quickly and accurately as possible the first time. For this reason a surveyor had to be on standby 24/7, since changing from one tunnel to the next could happen at any time during the day or night. When it happened at night, the surveyor had to make his back sight and alignment observations in the dark. Illuminated prisms could have solved the problem partially, but observing the reference marks on the launch vehicle in the dark, still proved to be quite difficult.

However, the main reason for finding a quick and easy solution to this alignment problem, was to eliminate delays which resulted in costly production losses. Any successful business needs to optimise its performance and this highly productive mining method was about to lose its edge over alternative mining methods because of a basic positioning problem.

**The simple solution to this real problem**

Since the issue were essentially one of positioning, it was evident that the solution would be survey related. Real-time kinematic (RTK) GNSS survey methods are being used daily for positioning in most open pit mines today and is not considered new technology anymore. This method allow surveyors to fix positions within a few centimetres of accuracy within seconds and it was the obvious choice to assist in this case. For an RTK survey to be successful, a base station as well as a rover is required to ensure the mentioned accuracies. This could potentially make the suggested solution uneconomical since two expensive GNSS receivers would be required. On this site, however, the mine was already using a RTK base station for normal survey tasks and therefore the existing infrastructure could be utilised eliminating additional cost implications.

Two GNSS antennas were fitted on top of the launch vehicle, as far apart from each other and as close to the centre line of the vehicle as possible. Care was taken to measure the width of the roof in order to make sure that the positioning antennas were installed on the centre of the launch vehicle structure. The aim was to make the distance between the two antennas as large as possible to reduce the possibility of extrapolation taking place. With the two positions being used for alignment, on the outside of the vehicle a longer baseline was available for more effective alignment. This is a basic survey principle. GNSS receivers which make use of external antennas were employed since it did not made sense to fit the GNSS receiver, which contains delicate electronics, to the outside of the vehicle where it would be exposed to the environment on a daily basis. The GNSS receivers were therefore installed inside the control cabin with coaxial cables connecting them to the antennae on the roof.

Since at least one side of the launch vehicle would be operating very close to the high wall blocking the view to a significant percentage of the sky, receivers capable of tracking the GLONASS constellation as well as the GPS constellation were specified. Utilising both satellite systems increases the number of satellites available, reducing the chance of inaccurate position fixes which could again cause downtime when it could be least afforded. As can be seen in Fig. 5, two tablet controllers were also fitted inside the control cabin, out of the way of the operator but close enough so he or she could easily view them while positioning the launch vehicle. These tablet controllers are connected to the GNSS receivers and display the real-time position of each GNSS antenna on the roof to the required cm accuracy.

![Fig. 5: Tablet controllers.](image-url)
Tunnel directions were determined in the mine planning software and transferred to the controllers in the control cabin electronically in DXF format. This eliminated any human error when calculating offsets or when pointing the total station in the intended mining direction. Staking points or lines, using RTK GNSS methods, is something which is common in an open pit operation and this is why this solution is so simple and relevant. Because two antennas were used, one RTK position on each side of the launch vehicle was available. These two positions were then staked out to the defined line by the operator, as can be seen in Fig. 6 and since the antennae coincided with the centre of the launch vehicle, the vehicle ended up being aligned with the intended mining direction within a few centimetres. Because the system was so easy to learn and use, the operators became accustomed to the process very quickly and the involvement of the surveyor was reduced to generating the DXF file and overseeing that it is loaded correctly onto the controllers.

**Fig. 6: Staking to the line.**

The solution proved to be very effective. Alignment could now be done within minutes by the Addcar operator and expensive delays when changing over between tunnels were eliminated. Since the operator could now position the launch vehicle without assistance from a surveyor, no surveyor was required to be on standby 24/7 anymore. No control points were required which could get in the way of the rest of the mining process. The communication problem which existed between the surveyor and the Addcar operator was also a thing of the past. All of this meant a significant increase in production and a reduction in running cost due to fewer people being required. The advantages made huge economic sense to mine management and they are extremely satisfied with the result. A simple solution to a real problem during the application of a unique mining method.

**Challenges which had to be dealt with**

**Fixing the antennas to the roof**

As with any new project some challenges were presented which had to be dealt with. Mounting the antenna to the roof of the launch vehicle proved to be quite difficult, firstly because of a safety issue since the roof is more than 8 m above ground level. Special equipment had to be used to work safely at that height. The second problem was that the structure is made of 4 mm steel. Drilling a 16 mm hole in the steel roof to fix the antenna using a standard threaded bolt at 8 m above ground level, was not an option as it was a safety risk. It was therefore decided to make use of magnetic mounts. The flat steel roof proved to be a very suitable surface for a magnetic mount and one had to use extreme force to move the mount once in place. It is highly unlikely that the antenna position would change, relative to the rest of the structure, even though it was not fixed with a drilled hole.

**Feeding the cables to the control cabin**

Since the distance between the GNSS receiver and the GNSS antenna was close to 30 m, a special type of RG213 coaxial cable had to be used. This cable is 9 mm in diameter and very difficult to feed around tight corners. However, a
bigger challenge was to get from outside of the control cabin to the inside where the receivers were mounted. The cabin is manufactured from 10 mm steel and it would be almost impossible to drill a hole in the outside of the cabin, big enough to feed two antenna cables as well as two radio antenna cables through. Luckily the designers of the Addcar system made two service entries of which one was suitable for us to use. It was still tricky feeding a 9 mm cable where it needed to go but we managed to do it to an acceptable level of neatness. The two radio antennas were fitted on an existing mast which is also used for other communication media.

Creating and exporting the DXF file in the correct format

Most mining design software is intended for use in the northern hemisphere and it is a common problem to convert drawings from a northern hemisphere to a southern hemisphere system. South Africa is one of a few countries in the world which uses South as the azimuth origin and a coordinate system which increases in a southerly and westerly direction. Luckily Modelmaker came to the rescue and once the DXF file was created in the mining design software, it could be imported into Modelmaker and then exported again, using special settings, to customise it for use in a southern hemisphere application. The intended tunnel positions were therefore displayed on the screens of the tablets with a number identifying each unique tunnel.

Conclusion

This may not have been one of the most scientifically researched projects reported on at this conference. However, it is a unique, practical use of existing technology known to the survey industry. The same principle is used extensively in the construction market where the blade of a dozer or the mast of a drill rig is controlled and orientated by GNSS methods. In the agricultural environment the same technology is used to ensure that farming machinery move on the same straight parallel lines, season after season. This is referred to as controlled traffic. For all of these applications there are specialised products available, designed with the specific application in mind. In this specific case the standard product available off the shelf proved to be more than sufficient for the job in hand. No modification had to be made, only special installation methods had to be improvised.

Real-time GNSS survey has been around for more than 20 years. The technology is well proven and significant improvements were made to this survey method over the years. Very few people actually realise how amazing this technology really is. These days GNSS survey is considered to be a utility and we can hardly do without it anymore. To fix accurate positions on the surface of the earth using satellites which are 20 000 km away is truly a wonderful achievement.

References


Contact Jochem Erasmus, Optron, Tel 012 683-4500, jerasmus@optron.com