OPPORTUNITIES FOR THE APPLICATION OF DIFFERENT MINE SURVEYING MAPPING TECHNOLOGIES IN DETERMINING VOLUMES IN UNDERGROUND MINE WORKINGS

Milena Begnovska

University of Mining and Geology "St. Ivan Rilski", 1700 Sofia; m_begnovska@abv.bg

ABSTRACT. The main task in the underground mine surveying practice is to determine the volumes of mined out mass. The possibilities for the application of modern equipment during mine surveying mapping in underground mining are evaluated. An analysis of the results obtained for the calculated amounts of mined out mass was carried out. A comparison was made of the relevancy of different technologies for the determination of volumes in mine workings.

Keywords: mine surveying mapping, modern mine surveying equipment, volume calculation

ВЪЗМОЖНОСТИ ЗА ПРИЛОЖЕНИЕ НА РАЗЛИЧНИ ТЕХНОЛОГИИ ЗА ЗАСНЕМАНЕ ПРИ ОПРЕДЕЛЯНЕ НА ОБЕМИ В ПОДЗЕМНИ МИННИ ИЗРАБОТКИ

Милена Бегновска
Минно-геоложки университет "Св. Иван Рилски", 1700 София

РЕЗЮМЕ. Една от основните задачи, свързани с маркшайдерското обслужване при подземното разработване на находищата, е определяне на обемите добита минна маса. Оценени са възможностите за приложението на съвременна техника и технологии при извършване на маркшайдерско заснемане в подземни минни изработки. Извършени са анализ на получените резултати за изчислените количества отбита и извозена минна маса и сравнение на приложимостта на различни снимачни технологии при определяне на обеми в подземни минни изработки.

Ключови думи: маркшайдерско заснемане, съвременни маркшайдерски инструменти, изчисляване на обеми

Introduction

Successful solving of various mining and technical tasks in the exploitation of the deposits of underground resources largely depends on the quality of mine surveying mapping. Based on the mine surveying mapping, a precise and up-to-date model of mine workings is created and an opportunity is provided to determine their location, size and shape in space. An important aspect of the mine surveying activity is the carrying out of a report on mined out mass and the volume of mining works, carried out periodically for each mine workings (opening, permanent, development, sill cut or extraction working).On the basis of these quantities, implementation of the annual mine development project is taken into account and the remuneration of the staff of the mining company (Tzonkov, 2019) is calculated. According to the calculations, the stability of the roofand the protection of the objects and the surface facilitiescan be predicted.

Underground mine workings are complicated and irregular in shape, their volume is defined as a function of the areas of the "body" sections.

$$V = f(P), \qquad (1)$$

Traditionally, the calculation according to the form of workmanship is done usingthe method of the vertical or horizontal sections, in the same or variable interval.

Recently, new techniques and technologies have become more and more popular. Methods for calculating the volumes of mining workings also evolve in the direction of multivariate. Most often, each company producing geodetic tools and technologies also offers relevant software for post-processing of measurements, the corresponding calculations, and the construction and maintenance of numerical models (Pflipsen, 2006). There are still many conventional geodetic programs as well as a number of continuously improved CAD applications.

Regardless of the technique used, the determination of the volume of underground mining works consists of two processes (Ivanova, 1991; Mazhdrakov, 2007; Tzonkov, 2019):

- ✓ Mapping an object whose volume is to be determined and creating a pattern on the captured surface.
- ✓ Determining the volume by entering (according to established and accepted algorithms) elementary figures in the space limited by this surface and the sum of the volumes, which form the total sought volume.

The total error in determining the volume must be determined by considering the regularities in the accumulation of errors in each of the processes.

Experimental results

Mine surveying mapping of a chamber for the extraction of gypsum in "Koshava" deposit

The Koshava Gypsum deposit is located west - southwest of the village of Koshava, Vidin district. The seizure of the stocks is done in an underground way with a chamber-and-pillar system of exploitation. The gypsum removal is carried out by the use of drilling-blasting operations. The report on mined out mass and the determination of the volume of the mining works are currently carried out by the Mine Surveying Department of the mine.

Mine surveying mapping of a gypsum chamber was performed (chamber 56/5 – Figs. 1 and 3) using reflectorless measurement technology. The mine surveying mapping was performed with a total station Trimble S6 (Figs. 3 and 4) by two different methods:

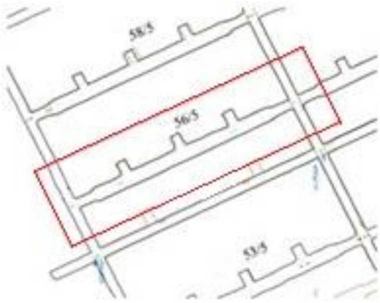

Fig. 1.

- the Surface Scanning application, built into the total station, using the "Rectangular plane" method (https://apps.trimbleaccess.com/help/en/TrimbleAccess=2017.23) to define a 3-point plane (Figure 2). Taking into account the shape and dimensions of the mine workings, four surfaces describing the floor, the ceiling and thetwo walls are selected. In each section of the mine workings three points of the specified surfaces are initially set and then, depending on the spacing between the points specified in the setup, the measurements are performed in automated mode and the results are automatically recorded in the instrument memory.Thus, the captured surfaces, overlapping a certain number of points describing the walls, the floor and the ceiling of the mine workings, provide information about the spatial position of the elements of the gallery. The scanning was performed at distances between points of 0.50 m × 0.50 m.

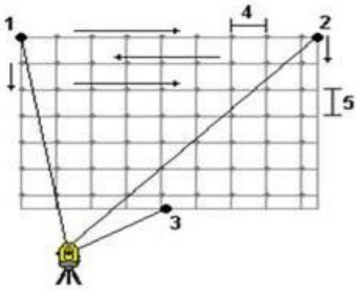

Fig. 2.

- capturing separate points in distinctive locations from the camera's outline, which is the most commonly used method when performing a mine surveying mapping.

Fig. 3.

By the "Rectangular plane" method, a total of 7541 points (for about 8 hours) were captured, while by capturing separate points in distinctive locations from the camera's outline - 666 points (for about less than 2 hours).

The volumes of mined out mass are calculated and the results are presented in Table 1.

Table 1.

Capture method	Number of points	Calculated volume, m^3
“Rectangular plane”	7541	5336.78
Capture of characteristic points	666	4532.59
Difference		804.19

Inferences

When analysing the measurement data, the following conclusions can be drawn:

1. When measured by the "Rectangular plane" method, the capture is much more detailed. In turn, the method of capturing only single points in characteristic areas of the camera's contour repeatedly reduces the working time.

2. When performing a mine surveying mapping of mine workings, the method by which the capture will be performed, according to the requirements of the normative base to ensure sufficient accuracy must be carefully assessed, but also the necessary time to capture should be provided for.

3. The resulting difference in calculated volumes by both methods is 804.19 m^3, which is about 15%. This proves the need for precise planning of mine surveying works. The difference is due to the increased roughness of the walls of the gypsum chamber (Figs. 4 and 5) as well as to the large deviations from the measured reference length found in previous investigations of the author at reflector less measurement of this mineral.

Fig. 4.

Fig. 5.

Capture of permanent mine working in "Chelopech" mine

As a good practice for conducting mine surveying mapping in underground mining conditions, the existing "Chelopech" mine operation procedure can be specified.Clear and precise requirements and a standard for unified work on measurement are introduced.

A mine surveying mapping of permanent mine working was performed in the "Chelopech" mine. There is a shotcrete - concrete fastening in the specifically captured area. The capture was done in two ways:

- With a Trimble S6 total station, using the "Rectangular plane" method, by defining a 3-point plane (Fig. 2), at distances between points of 0.50 m × 0.50 m. (https://apps.trimbleaccess.com/help/en/TrimbleAccess=2017.23)

- Usingthe CMS - Cavity Monitoring System (Grunin, 2003), through which the mine workings outlines were scanned. CMS has been developed to research, measure and capture the image of inaccessible or unsafe for staying underground cameras.It ensures that thousands of precisely coordinated points are captured that are used to determine the size, orientation, and volume of the chamber. The capture is done in automated mode. Laser scanning technology is one of the most advanced methods of capturing, providing spatial location data for objects in the form of three-dimensional computer models.

When measured with a Trimble S6 total station (Fig. 6), 3829 points (for about 3.5 hours) were registered using the "Rectangular plane" method, and 153282 points (for about 20 minutes) with CMS scanning (Fig. 7).

Fig. 6.

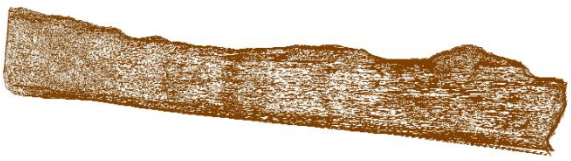

Fig. 7.

From the two surveys done in this way, the volumes of seized rock mass are calculated and presented in Table 2, Fig. 9 and Fig.10.

Table 2.

Capture method	Number of points	Calculated volume, m^3
„Rectangular plane" - Trimble S6	3829	1037.62
Scanning - CMS	153282	1023.40
Difference		14.22

In Fig. 8 a combined image of the captured mine workings elements is presented by both methods (Trimble S6 total station and CMS).

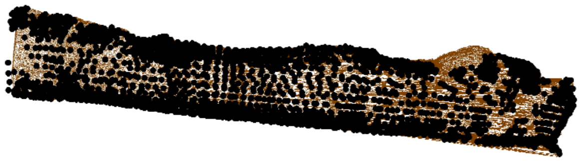

Fig. 8.

Inferences

A comparison is made between two different technologies.

1. The difference in the calculated volumes by the two methods is 14.22 m^3, which is about 1.5%. This gives us a reason to conclude that the two technologies are equally applicable in the described conditions.

2. After analysing the results, the following should be noted: each measuring technology has its own positive and negative aspects: different detail, different time for measurements, different number of specialists required to carry out the measurement.

3. When capturing underground mining, account must be taken of the specific conditions in the mines, the purpose of the mine surveying mapping, the tasks to be solved by the results, and the proper assessment of the application of one or the othermethod of capture.

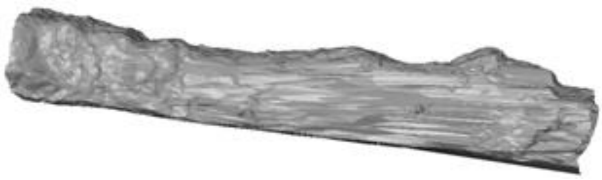

Fig. 9.

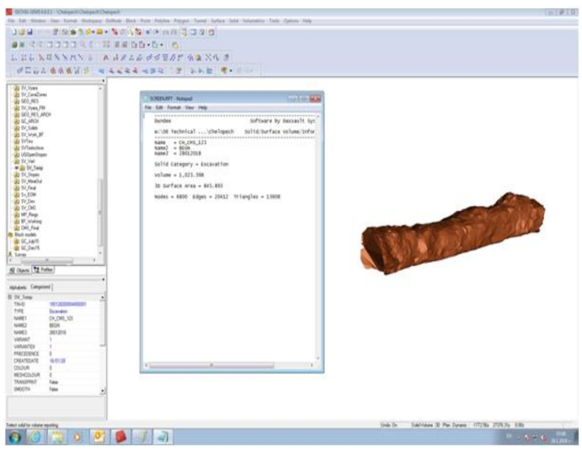

Fig. 10.

Conclusion

In a previous study of the author, such a mine surveying mapping was made in "Krushevdol" underground mine (Begnovska et al., 2014). A horizontal drift - gallery 1 level 450, was originally measured by a total station SOKKIA SET 5 (total station capabilities allow the measurement of lengths only to a reflective prism) and a Laser Distance Measurer - BOSCH. The same gallery was also captured with a total station Trimble S6. With the capture made in this way, the difference between the determined volumes of mined out mass between both methods is about 75 m^3, which is about 18%.

The presented methods do not exhaust all possibilities for capturingmine workings. This can also be done in a photogrammetric way (Gospodinova, 2018; Gospodinova et al., 2018). Studies for the creation of a digital photogrammetric model in an underground mine workings and its comparison with mine surveying mapping with a total stationhave been presented. The volumes by the two methods were calculated and a comparison was made between the two technologies, and it was concluded that the methodology was applicable for the capture of underground mining and the calculation of volumes.

As far as themine surveying mapping and the calculation of volumes of mined out spaces are concerned, it is difficult to give a concrete answer to the question of what is the best method. Various factors such as: shape (configuration) and size of the space captured, equipment available, required precision, and economic indicators should be taken into account. The use of measurement and computing technology, combining modern hardware solutions and corresponding software, are the key prerequisites for obtaining accurate and fast results, which is valid for every type of mine surveying activity.

Various methods for mine surveying mapping of underground spaces are presented in the development. They are also applicable in studying the stress-strained state of the rock massif (Tzonkov, 2014; 2019). Knowledge of the state of the array or object and the processes in it is based on a high-precision determination of the spatial position change of observed points in time provided by the proposed methods.The need to predict the deformable state of the environment and facilities requires the application of appropriate monitoring methods to identify and track the deformation processes and to implement timely measures for their regulation. Knowledge of them would lead to making adequate decisions on the development system, work order in the space and time of individual jobs, safety measures, and risk prediction in specific situations.

When analysing the results of the author's research carried out so far and published in various scientific publications and proceedings, and the relevant inferences and conclusions formulated, the following questions arise, which determine the intentions for future research:

- Classification of mine workings in relation to the deviation from the draft section and determination of the optimal option for mine surveying mapping (justification of the distances between the detailed points when the capture is taken).

- Calculation of volumes of mined out spaces with different roughness of the walls of mine workings.

- Definition of a method for mine surveying mapping in areas with higher humidity of the rocks and with increased roughness, as well as capturing of underground spaces with a reflective environment formed by minerals with different optical properties.

References

Begnovska, M., R. Petkov, D. Atanasova. 2014. Markshayderska snimka na horizontalna izrabotka v rudnik “Krushevdol“ chrezrazlichni tehnologii. – *Chetvarta natsionalna nauchno-tehnicheska konferentsia s mezhdunarodno uchastie “Tehnologiii praktiki pri podzemen dobiv i minno stroitelstvo”*, Devin, Bulgaria, 254–261 (in Bulgarian with English abstract).

Gospodinova, V. 2018. Prilozhenie na tsifrovata fotogrametria za markshaydersko kartografirane na podzemni minni izrabotki. – *Shesta natsionalna nauchno-tehnicheska konferentsia s mezhdunarodno uchastie “Tehnologiii praktiki pri podzemen dobiv i minno stroitelstvo”*, Devin, Bulgaria, 171–176 (in Bulgarian with English abstract).

Gospodinova, V., P. Georgiev, P. Ivanov. 2018. Sazdavane na chislen fotogrametrichen model v podzemen rudnik. – *Shesta natsionalna nauchno-tehnicheska konferentsia s mezhdunarodno uchastie “Tehnologiii praktiki pri podzemen dobiv i minno stroitelstvo”*, Devin, Bulgaria, Devin, Bulgaria, 155–161 (in Bulgarian with English abstract).

Grunin, A. G. 2003. Primenenie lazernoy skaniruyushtey sistemyi CMS dlya markshayderskih rabot. – *Geoprofi, 2*, 30-31 (in Russian).

Ivanova, I. 1991. Snimka na nedostapni prazni prostranstva v podzemni rudnitsi. – *Geodezia, kartografia, zemeustroystvo*, 3–4 (in Bulgarian).

Mazhdrakov, M. 2007. *Markshayderstvo. Metodika na markshayderskite raboti v otkritite rudnitsi*. Universitetsko izdatelstvo “Sv. Kliment Ohridski”, Sofia, 52–67 (in Bulgarian).

Pflipsen, B. 2006. *Volume computation – a comparison of total station versus laser scanner and different software*. Master´s Thesis in Geomatics, University of Gävle, 9–13.

Tzonkov, A. 2014. Izsledvane na geomehanichni protsesi chrez markshayderski izmervania. – *Chetvarta natsionalna nauchno-tehnicheska konferentsia s mezhdunarodno uchastie “Tehnologiii praktiki pri podzemen dobiv i minno stroitelstvo”*, Devin, Bulgaria, 147–155 (in Bulgarian with English abstract).

Tzonkov A. 2019a. *Geomehanichni izsledvania chrez markshayderski izmervania*. IK “Sv. Ivan Rilski”, Sofia (in Bulgarian).

Tzonkov, A. 2019b. *Markshayderstvo pri podzemno razrabotvane na nahodishta (kratak kurs)*. IK “Sv. Ivan Rilski”, Sofia, 108–111 (in Bulgarian).

https://apps.trimbleaccess.com/help/en/TrimbleAccess=2017.23.