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Professional paper

APRIORI EVALUATION OF THE CROSSCUT ACCURACY IN A HORIZONTAL PLANE BETWEEN GVH-1 AND VU-1 OF THE RMU "SOKO" MINE SHAFT

APRIORI OCENA TAČNOSTI PROBOJA U HORIZONTALNOJ RAVNI IZMEĐU GVH-1 I VU-1 JAME RMU „SOKO“

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Abstract: The development of the crosscut from the aspect of mine surveying is a specific task, since there is no possibility for an independent control of its construction duringthe development. This is primarily related to the long crosscuts where the deviations of the designed direction of crosscut would have significant consequences on safety and technological activities in the mine shaft. In order to avoid errors, it is necessary to perform the preceding analysis of the crosscut accuracy, where the overall standard deviation of the crosscut is calculated. This value must be smaller than the given allowed deviation. The paper presents an a priori evaluation of the accuracy of the crosscut to be developed in the brown coal mine "Soko" for the purpose of ventilating the opening rooms of the eastern part of the deposit.

Key words: mine surveying, crosscut, apriori accuracy evaluation

Apstrakt: Izrada proboja sa aspekta rudarskih merenja je težak i odgovoran posao. Ovo se pre svega odnosi na izradu dužih proboja, s obzirom da u toku njegove izrade ne postoji mogućnost nezavisne kontrole njegove realizacije. Zato je u ovakvim slučajevima neophodna prethodna analiza tačnosti proboja, gde se na osnovu svih potrebnih elemenata, računa ukupno standardno odstupanje proboja koje mora da bude manje od zadatog dozvoljenog odstupanja. U radu je prikazana a priori ocena tačnosti proboja koji treba da se realizuje u rudniku mrkog uglja „Soko“ za potrebe ventilacije prostorija otvaranja istočnog dela ležišta.

Ključne reči: rudarska merenja, proboj, apriori ocena tačnosti

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1. INTRODUCTION

Crosscut is the term for connecting two or more mine shaft rooms. It is performed following the opening or developing of the mine, mine shaft, mining district or horizon where the crosscut direction is defined in a geometrical sense in the horizontal and vertical plane (Patarić, 1990).

From the geometrical point of view, the challenge and the complexity of the crosscut varies. Minor crosscuts that are simpler to develop do not call for an increased accuracy of the measurements. However, there are circumstances where the design calls for such conditions for crosscut development accuracy that cannot be achieved.

For this reason, it is necessary to perform the preceding analysis of the accuracy before the marking starts.

By performing the preceding analysis of the accuracy, instrument types, measurement methods and the marking accuracy are defined so that the crosscut error is smaller than the provided allowed deviation. This analysis consists of:

- Standard deviation of the geometrical base on the terrain surface;
- Standard deviation of the geometrical connection of the mine shaft with the terrain surface, and
- Standard deviation of the measurements, i.e. point marking in the mine shaft's traverse.

In case the calculated standard deviation of the crosscut is bigger than the provided allowed deviation, an analysis is performed again by using the more thorough criteria for mine shaft marking until the actually feasible limit of instrument accuracy and measurement method. Afterwards, one must adjust the crosscut development technology or adopt higher values of the allowed deviation.

2. "SOKO" COAL MINE

The "Soko" deposit and the coal mine are situated in the vicinity of Čitluk village at the Soko Banja municipality in the Eastern Serbia. The mine is set approximately 15 km east of Soko Banja, and at the same time connected with the highway Belgrade-Niš through the town of Aleksinac to the west. With the aim of reconstructing the underground production system of the "Soko" mine and utilizing the existing resource potential, during the last several years, the vast quantity of pre-investment and investment documentation as well as necessary mine development projects were developed. The mine is having the strategic importance, being a part of the electric energy transfer system of the country. The largest share of the mined coal is being transported to the thermal power plant "Morava" in the town of Svilajnac.

Coal mining at the "Soko" is completed in the central and the north wing of the Central field. Mining is now being performed in the west wing of the Central field. The concept of investment operations, developed to ensure sustained mining and mine development, is based on the opening and development of existing capacities in the north wing of the West field and the development of new capacities in the south wing of the East field for which the mining is planned during the next 8 years, according to the Main Mine development Project (Figure 1) (Faculty of Mining and Geology, 2001).

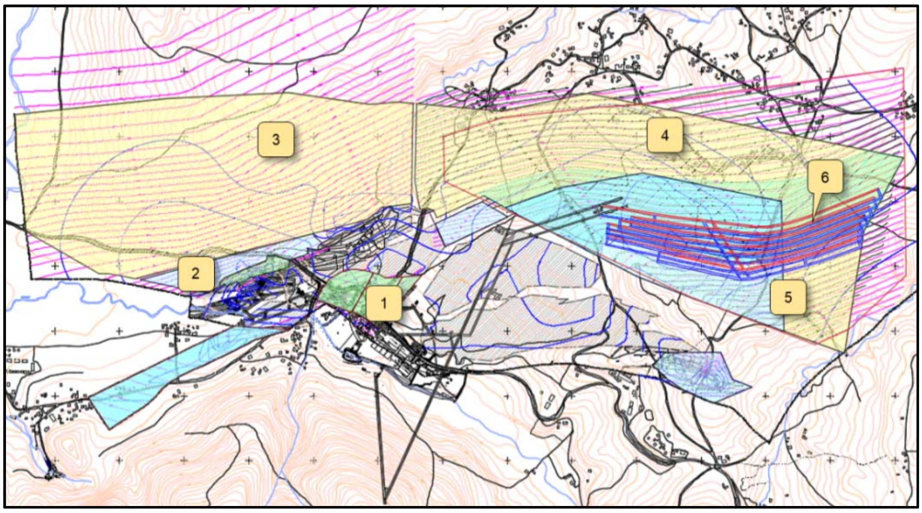

Figure 1 - "Soko" coal mine mining field plan
Central field (1); West wing of the Central field (2); West field (3); East field (4);
South wing of the East field (5); Designed mining workings (6)

3. DEVELOPING THE CROSSCUT BETWEEN THE GVH-1 I VU-1

By a Project task, it has been foreseen to construct the crosscut between the rooms GVH-1 and VU-1 (Technical documentation of the "Soko" mine). For the purpose of crosscut construction, i.e. the development of the underground room GVN-2, cca 400 m long, and for the purpose of ventilation of the eastern deposit area opening rooms, it is necessary to mark the crosscut direction in a horizontal and vertical plane successively. In order for crosscut to be constructed with the minimum deviation error, it is necessary to perform the a priori evaluation of crosscut accuracy. Based on the accuracy evaluation, both type and the class of an instrument to be used for marking is determined, as well as the measurement method.

The construction of the crosscut starts from the point A1, located in the room GVH-1. It was designed that the crosscut is constructed in the point 4H, located in the room VU-1. The length of the crosscut is 395.09 m, while its horizontal plane projection amounts to 378.12 m. By crosscut analysis, a total of 15 traverse points were planned to be marked, by an average distance of 25 m.

Standard deviations of positions of points A1 and 4H are not known, which is hindering the a priori evaluation of the crosscut accuracy. In addition, the position of the existing points in mine shaft traverses were not controlled since they were set. In order to determine possible deviation of the existing traverse points, and to ensure the quality in constructing the crosscut, the analysis starts with the points on the terrain surface, i.e. the point I near the entry point of GTN-1. This means that Mine Surveying team of the Mine will have to perform measurements on existing traverses prior to this, with the accuracy defined by an analysis, and then afterwards start marking the designed traverse points, i.e. the crosscut. The length of the traverse in this case is 1 537 m. Figure 2 shows the designed crosscut on the mine shaft plan.

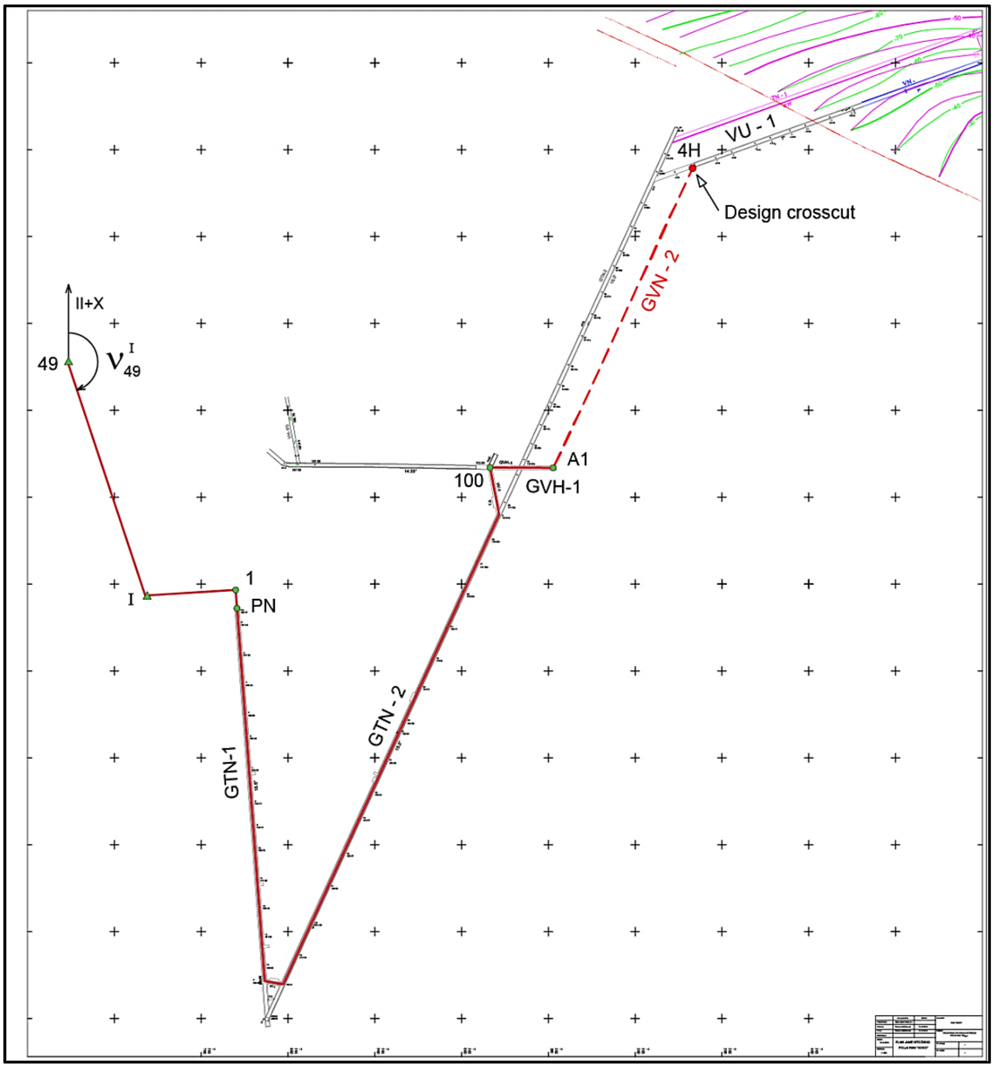

Figure 2 - Designed crosscut shown on the mine shaft plan (Scale = 1:1000)

4. APRIORI EVALUATION OF THE CROSSCUT ACCURACY

The designed width of the underground mining room that is developed by a crosscut is 2.00 m, while the allowed crosscut error is 0.50 m. The standard deviation of the crosscut point mark for the probability of 95% is calculated by using an equation:

$$\sigma = \frac{0.50}{2} = 0.25\text{m} \qquad ....(1)$$

The crosscut error is influenced by the errors of the values provided and measurement errors. The errors of the values provided are:

- Positional error of the starting point of the traverse, and
- The error of the starting bearing.

Measurement errors are:

- Measurement errors of angles, and
- Errors of traverse side lengths measurements.

The starting point for the a priori accuracy of crosscut development evaluation is the trigonometric point I near the mine shaft entrance with the following coordinates and standard deviations:

$$y_I = 7581702.40 \pm 0.02\text{m}; \quad x_I = 4832582.34 \pm 0.02\text{m}$$

The starting bearing is taken between the trigonometric points 49 and I. The value of the bearing and its standard deviation is:

$$\nu_{49}^{I} = 228^\circ 20' 32'' \pm 5''$$

For the needs of a priori accuracy evaluation, standard deviations of angle measurements in the traverse of $\sigma_\beta = 20''$ were adopted, as well as the relative standard deviations of the traverse side length measurements of $\sigma_{drel} = 1{:}5000$.

A priori evaluation of the accuracy of the designed crosscut was performed according to the principle of piling errors of the offshot traverse points coordinates.

Point coordinates in the offshot traverse are calculated by using the following equations:

$$y_i = y_{i-1} + d_i \cdot \sin \nu_i; \quad x_i = x_{i-1} + d_i \cdot \cos \nu_i \tag{2}$$

where:

y_{i-1}, x_{i-1} - coordinates of the previous traverse point;

d_i - length of the traverse side between the points *i*-1 and the point *i*;

ν_i - bearing of the side between these two points.

Standard deviations of the traverse points are calculated by using the equations (Ganić et al. 1994):

$$\begin{aligned} \sigma_{y_i} &= \sqrt{\left(\frac{\partial y_i}{\partial y_{i-1}}\right)^2 \cdot \sigma_{y_{i-1}}{}^2 + \left(\frac{\partial y_i}{\partial d_i}\right)^2 \cdot \sigma_{d_i}{}^2 + \left(\frac{\partial y_i}{\partial \nu_i}\right)^2 \cdot \sigma_{\nu_i}{}^2} \\ \sigma_{x_i} &= \sqrt{\left(\frac{\partial x_i}{\partial x_{i-1}}\right)^2 \cdot \sigma_{x_{i-1}}{}^2 + \left(\frac{\partial x_i}{\partial d_i}\right)^2 \cdot \sigma_{d_i}{}^2 + \left(\frac{\partial x_i}{\partial \nu_i}\right)^2 \cdot \sigma_{\nu_i}{}^2} \end{aligned} \tag{3}$$

where:

$\frac{\partial y_i}{\partial y_{i-1}}, \frac{\partial y_i}{\partial d_i}, \frac{\partial y_i}{\partial \nu_i}, \frac{\partial x_i}{\partial x_{i-1}}, \frac{\partial x_i}{\partial d_i}, \frac{\partial x_i}{\partial \nu_i}$ - partial derivatives of functions y_i and x_i by variables;

$\sigma_{y_{i-1}}, \sigma_{x_{i-1}}, \sigma_{d_i}, \sigma_{\nu_i}$ - standard deviations of the variables,

where:

$$\sigma_{\nu_i} = \sqrt{\sigma_{\nu_{i-1}}{}^2 + \beta_i^2} \tag{4}$$

Table 1 shows the calculated values of standard deviations of traverse point coordinates, i.e. the last point 4H.

Table 1 - Standard deviations of the mine shaft traverse deviations

Point	$\sigma_{\nu i}$ ["]	σ_{di} [m]	$\partial y_i/\partial y_{i-1}$	$\partial y_i/\partial \nu_i$ [m]	$\partial y_i/\partial d_i$	$\partial x_i/\partial x_{i-1}$	$\partial x_i/\partial \nu_i$ [m]	$\partial x_i/\partial d_i$	σ_{yi} [m]	σ_{xi} [m]
Δ49										
	5.0									
ΔI									0.0200	0.0200
	20.6	0.0076	+1	+8.1808	+0.9768	+1	-37.3137	+0.2142		
⊙1									0.0214	0.0204
	28.7	0.0037	+1	-18.3628	+0.0787	+1	-1.4502	-0.9969		
⊙PN									0.0215	0.0207
	35.0	0.0036	+1	-17.9214	+0.0735	+1	-1.3201	-0.9973		
⊙1'									0.0217	0.0210
	40.3	0.0070	+1	-34.8539	+0.0741	+1	-2.5903	-0.9972		
⊙2									0.0228	0.0222
	45.0	0.0068	+1	-33.8794	+0.0730	+1	-2.4798	-0.9973		
⊙3									0.0240	0.0232
	49.3	0.0070	+1	-35.1246	+0.0735	+1	-2.5902	-0.9973		
⊙4									0.0254	0.0242
	53.2	0.0054	+1	-27.1650	+0.0741	+1	-2.0195	-0.9972		
⊙5									0.0263	0.0248
	56.8	0.0080	+1	-40.1072	+0.0748	+1	-3.0096	-0.9972		
⊙7									0.0286	0.0261
					⋮					
⊙X3									0.0940	0.0654
	135.7	0.0042	+1	+19.2332	+0.4015	+1	-8.4311	+0.9159		
⊙A10									0.0949	0.0657
	137.2	0.0045	+1	+20.4072	+0.4150	+1	-9.3086	+0.9098		
⊙A11									0.0959	0.0661
	138.7	0.0059	+1	+26.7613	+0.4221	+1	-12.4604	+0.9066		
⊙A12									0.0976	0.0669
	140.1	0.0056	+1	+25.4710	+0.4195	+1	-11.7724	+0.9077		
⊙A13									0.0991	0.0676
	141.5	0.0063	+1	+28.2574	+0.4378	+1	-13.7610	+0.8991		
⊙A14									0.1010	0.0684
	142.9	0.0057	+1	+25.6990	+0.4362	+1	-12.4592	+0.8998		
⊙A15									0.1026	0.0692
	144.3	0.0064	+1	+28.7083	+0.4360	+1	-13.9084	+0.9000		
⊙4H									0.1046	0.0701

Overall standard deviation of the position of the last point of the traverse, i.e. the crosscut amounts to:

$$\sigma_{y,x} = \sqrt{\sigma_{y_i}{}^2 + \sigma_{x_i}{}^2} = \sqrt{0.1046^2 + 0.0701^2} = \pm 0.1259\text{m} \qquad (5)$$

Regarding their geometrical shape, in developing the underground mine rooms and a priori assessing the accuracy of the last traverse point coordinates, i.e. the crosscut, the significance of the transversal error of the crosscut is dominant. It is therefore necessary to decompose the overall standard deviation of the position of the last point to the transversal and longitudinal component (Stoiljković et al. 2013). The angle δ is:

$$\delta = \arctan\frac{\sigma_y}{\sigma_x} = 56^\circ 10' 16'' \quad (6)$$

Standard deviation of the transversal component of the crosscut is:

$$\sigma_t = \sigma_{y,x} \cdot \sin\left(\delta - \nu_{A15}^{4H}\right) = 0.0636\text{m} \quad (7)$$

while the standard deviation of the longitudinal component is:

$$\sigma_l = \sigma_{y,x} \cdot \cos\left(\delta - \nu_{A15}^{4H}\right) = 0.1087\text{m} \quad (8)$$

where the bearing of the last side is $\nu_{A15}^{4H} = 25^\circ 50' 56''$, calculated in the traverse.

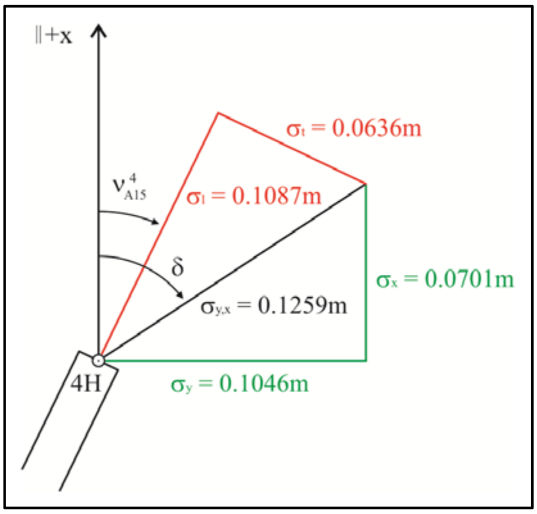

Figure 3 - Components of standard deviation of the crosscut point.

5. CONCLUSION

Before constructing the tunnel and underground mining rooms but after the a priori accuracy evaluation has been made, the calculated standard deviation is compared with the standard deviation of the crosscut point markings for the probability of 95%.

The A priori accuracy evaluation has shown that the transversal component of the crosscut error will be lower than the maximum allowed value, if the marking of horizontal angles is performed with the standard deviation of $\sigma_\beta = 20''$, and the marking of traverse sides length with the relative standard deviation of $\sigma_{drel} = 1{:}5\,000$.

This means that the marking of crosscut can be performed by using the classical optical theodolite with common accuracy and the tape which the "Soko" mine has.

In cases when the a priori accuracyevaluation gives standard deviation higher than the maximum allowed crosscut error, it is necessary to increase accuracy of angles and lengths markings, demanding the use of instruments with increased or high accuracy.

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