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INFLUENCE OF TEMPERATURE ON ACCURACY OF HEIGHT CONNECTION MEASUREMENT

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Abstract. The purpose of depth measurement is to bring the altitude from the surface to the connected horizon (level) by means of a vertical mine. Points, for which the height is determined in this way, are part of the fundamental mining vertical control, and their height should therefore be determined as accurately as possible. There are several ways of this measurement and the temperature has influence on accuracy of each of them. The paper is dedicated to evaluation of influence of temperature, applying results of height connection measurement carried out at Karviná mine. Two measurements were performed in ČSA 2 shaft and the other in shaft Mír 5 of Darkov mine in Ostrava-Karviná Coal District, CZE. Height connection measurement by a vertical mining work was done in two ways: using the depth tape and using the electro-optical distance meter.

Keywords: height connection measurement, influence of temperature, depth tape section, electronic distance meter, correction from temperature, determination of temperature, changes of temperature in vertical mining work.

Introduction

The temperature has important influence on accuracy of depth measurement even if whichever method is used. The determination of medium temperature in vertical mining work is very difficult. It is not easy to formulate dependence between temperature and depth by mathematic relation and empirical approximate relation has not made yet. Temperature of air in the vertical mining work changes and these changes are irregular. It is caused by circuitry of partial flowes in downcast shaft or by exit of partial flowes in up cast shaft. Temperature of air that enters into shaft is depended on season and weather on surface and the weather can be changed during the measurement. The temperature can also be affected by water drops on the thermometer.

1. Correction from the temperature in the depth tape section

The correction of an error due to the temperature of the section of the depth tape is based on the relations used for the correction due to the temperature of distance measured by the tape (see Kubečka 1992):

$$\Delta l_t = \alpha \ell \left(t - t_0 \right), \quad (1)$$

where: α – coefficient of thermal expansion of the material, t – the temperature during the field measurement, t_0 – temperature during the comparison of the tape, ℓ – section of the depth range

The accuracy of finding of the correction is done by relation:

$$m_{\Delta\ell} = \sqrt{(\alpha \cdot \ell m_{\Delta t})^2 + (\alpha \cdot \Delta t \cdot m_\ell)^2 + (\ell \cdot \Delta t \cdot m_\alpha)^2};$$
$$\Delta t = t - t_0. \quad (2)$$

where: α – coefficient of thermal expansion of the material, t – the temperature during the field measurement, t_0 – temperature during the comparison of the tape, ℓ – section of the depth range, m – mean error, Δt – temperature difference.

The most important part in influencing the accuracy of the determination of this correction is played by the temperature. Temperature measurements in the shaft are difficult for many reasons. The air flow in the shaft is very irregular and the temperature may also change due to weather changes on the surface. With increasing depth, the rock temperature changes as well as the air. In the shaft we have to use several thermometers for determining the temperature. The first one is located on the surface, the second one 5 meters below the bank of the shaft. Then the thermometers are placed in the shaft as possible at regular intervals and the last one measures the temperature on the connected height. The overall correction due to the temperature is calculated as the sum of the partial corrections $\Delta \ell_{ti}$ calculated for each section separately, wherein the temperature is considered as a mean value of the two measured temperatures t_i and t_{i+1} (see Kubečka 1992).

$$\Delta \ell_{t_i} = \ell_i \alpha \left(\frac{t_i + t_{i+1}}{2} - t_0 \right). \quad (3)$$

2. Measurements using a steel tape at Karviná mine

Measurements were performed in ČSA 2 shaft and in shaft 5 of Darkov mine (see Černota 2014). In both of these measurements, verified electronic Leica levelling apparatus 03 DNA were used, both on the surface and underground. 3-meter code Invar levelling rods were also used at points on the surface and underground. Steel depth tape had millimeter division and the length of 1200 meters and the reading on the tape was by means of the crosslines of the levelling instrument telescope. The technical parameters of the depth tape used for the calculation can be found in Table 1 (see Mučková 2014).

For the calculation of the correction from the temperature in the depth tape section, the temperature was measured at several points of the vertical mining work. The values of the temperature and the depth at which the temperature was measured are given in Table 2 and Figures 1 and 2 (see Mučková 2014).

As can be seen from Table 2, the temperature measurement was carried out on the ground and 5 meters below the bank of the shaft and on the connected level. Thermometers were also hung at the places of the shaft where it was possible, but not with regular spacing. The Table 1, 2 and Figures 1, 2 also show a rising tendency of temperature with increasing depth of the measurement.

Table 1. Technical parameters of the depth tape

Thermal expansion	α = 0.0000102
Normal temperature	t_0 = 20 °C
Tape cross-section	f = 0.026 cm^2
Elasticity modulus	E = 2 100 000 kg/cm^2
Weight of 1 m of the tape	g = 0.01976 kg/m
Weight of the tape during the comparison	5 kg
Weight of the tape during measuring	5 kg

Table 2. The temperature and the depth of the temperature measurement

The temperature values measured in ČSA 2 shaft		The temperature values measured in Mír 5 shaft	
depth, m	temperature, °C	depth, m	temperature, °C
0	17	0	15
3	16.8	3	16
5	16.8	10	16
300	18.4	360	17.7
500	19.5	510	19.3
550	19.9	530	19.5
690	20.8	745	21.8
880	21.7		
930	21.0		

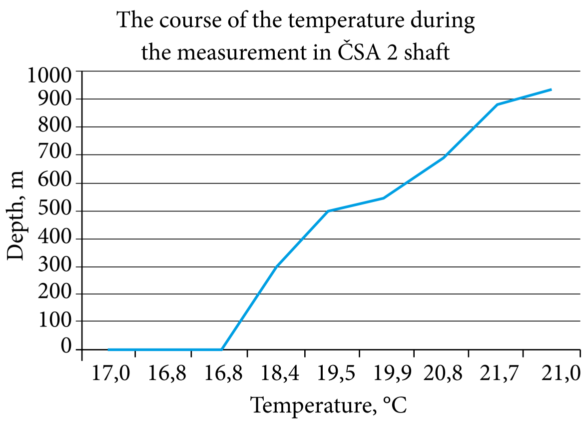

Fig. 1. The temperature in ČSA 2 shaft

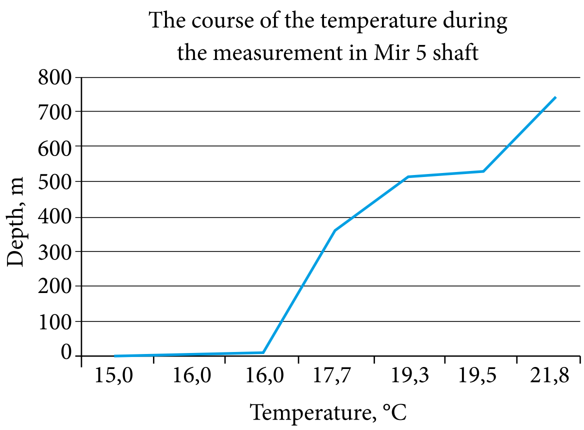

Fig. 2. The temperature during the measurement in Mír 5 shaft

The basic assumption for the calculation of the correction from the temperature of the depth tape section is the assumption that the temperature change in the vertical workings is uniform. The Figures 1, 2 show that the temperature rises with depth, but it is not a completely uniform change.

The depth tape section was divided by suspended thermometers into smaller sections, and for each subsection, correction from the temperature was calculated by the Equation (3). Complete overall temperature was then given by the sum of partial corrections by the relation.

$$\Delta\ell_t = \left[\Delta\ell_{ti}\right]. \quad (4)$$

The most probable value of the depth tape section was corrected for the systematic error, whose calculated values are shown in Table 3; the table also shows the corrected depth tape section, used to calculate the height of the newly determined point in the underground (see Mučková 2014).

Table 3. Calculated corrections of systematic errors in the depth tape section – ČSA 2 shaft and Mír 5 shaft

The depth tape section corrections	ČSA 2 shaft	Mír 5 shaft
Correction from the temperature	−0.0061 m	−0.0126 m
Correction from the stretching	+0.1586 m	+ 0.1032 m
Correction from the comparison	+0.0518 m	+ 0.0326 m
Overall correction	+0.2043 m	+ 0.1232 m
The corrected section of the depth tape	929.915_5 m	$747{,}121_6$ m

In the Table 3 we can see that value of the correction from the temperature is not insignificant. Measurements carried out at Karviná mine were realized in summer and so the difference between temperature on the surface and in underground is not great. In other season of year it would be greater and the correction from the temperature, too.

3. Influence of temperature on distance measured by electronic distance meter

The method of height connection measurement utilized the interconnection of height and distance measurement. Application of this method of the depth measurement shortens the time of measurements in the shaft. The accuracy of depth measurement using the electro-optical distance meter is mainly dependent on the accuracy of the distance measurement of the distance meter used. The accuracy of distance meters is characterized by the value of root-meansquare error in the form of (see Mučková 2001):

$$m = \pm\left(a + b \cdot 10^{-6} d\right), \quad (5)$$

in which the symbol a expresses the constant component of the error and b is the coefficient of the second error component directly proportional to the measured distance d.

When light passes through the atmosphere, its velocity is changing depending on the temperature and the ambient atmospheric pressure. It is therefore necessary to correct the measured values by means atmospheric correction. The atmospheric correction system is built into the device and distance measurements are automatically corrected.

The atmospheric correction K and length L after correction are obtained as follows. The average values of the temperature and atmospheric pressure are entered into the memory of the electronic distance meter. It automatically calculates the atmospheric correction K according to the formula (see Instruction).

$$K = \left(279.6 - \frac{106.0 \cdot p}{273.2 + t}\right) \cdot 10^{-6}, \quad (6)$$

where p is the ambient atmospheric pressure [mmHg] and t is the ambient temperature [°C].

Then, after entering the correction, the distance is obtained from the formula:

$$L = \ell\left(1 + K\right), \quad (7)$$

where ℓ is the distance measured by the device at $K = 0$.

4. Measurements using electronic distance meter at Karviná mine

For the levelling part of measurement, the same surveying equipment was used as for measurement using the depth tape. To measure the distance, which replaced the depth tape sections, the device Topcon GPT-7001 was used with the accuracy of the distance measurement of 3 mm + 2 ppm specified by the manufacturer.

When measuring the electro-optical distance meter were measured atmospheric conditions (Table 4) on the surface and underground and were used to calculate the correction of the measured distance.

With respect to this measurement, it is necessary to add that it was done in the downcast shaft, where the conditions for measurement are always better than in the upcast shaft. Although the depth was about

Table 4. Measured values of temperature, pressure and humidity in ČSA 2 shaft and Mír 5 shaft

surface		ČSA 2	surface	Mír 5
	tempe-rature	23.8 °C		22.3 °C
	pressure	1091 hPa		1063 hPa
	humidity	59%		58%
11.floor			9.floor	
	tempe-rature	16.7 °C		18.6 °C
	pressure	985 hPa		981 hPa
	humidity	70%		67%

1 km, the conditions in the shaft allowed the passage of the distance meter signal to the reflective device and back. In the upcast shaft, there could be the accumulation of humidity and dust, and layers of air of different densities could also form, which could prevent the passage of the distance meter signal and the measurements would not be possible.

Conclusion

Both methods were realized in the same day but not the same time. On the basis of measured values were calculated differences in elevation between fixed points that are put down in Tables 5 and 6.

Table 5. Values of the differences in elevation between fixed points, ČSA 2 shaft, Mine Karviná

	1st method	2nd method	difference
Fixed points	/m/	/m/	/mm/
137 – G38	–926,579	–926,577	2
137 – G39	–926,333	–926,331	2

Table 6. Values of the differences in elevation between fixed points, Mír 5 shaft, Mine Darkov

	1st method	2nd method	difference
Fixed points	/m/	/m/	/mm/
219 – G43	–744,477	–744,486	–9

In Tables 5 and 6 the first method means measurement by steel depth tape and the second one measurement by electronic distance meter.

When we compare the differences in height between fixed points obtained during both depth measurements performed, we can conclude that ČSA 2 shaft, the difference in elevation is bigger than during the measurement using a steel tape, although these differences are around the value 2 mm. In contrast, in Mír 5 shaft, the difference in elevation value obtained using the electronic distance meter is by 9 mm higher. Both ways of height connection measurement met the tolerance and their accuracies correspond to each other.

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