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THE VARIABILITY OF INFLUENCE RANGE INSIDE THE ROCK MASS AND ITS IMPACT ON THE FORECASTED DEFORMATION STATE

VARIABILITA ROZSAHU VLIVU SEDÁNÍ HORNINOVÉHO MASIVU A JEHO DOPAD NA PŘEDPOVĚĎ DEFORMACE

Dagmara Perżyło [1]

Abstract

The article presents the results of analyses concerning various ways of describing the influence range variability inside the rock mass and its connection with distribution of predicted values of deformation indices. Furthermore, there has been described the analysis of the results of exemplary forecasts for the rock mass using the W. Budryk-S. Knothe theory. In the first part, the article contains a brief outline of the chosen important solutions concerning the description of the radius of the influence range in the rock mass. Then detailed analysis of formula describing variability of r(z) proposed by S. Knothe has been performed. The n parameter plays important role in prediction, deciding on the changes of parameter r(z) value along with the distance between the roof of extracted seam and given calculation level z. The analysis of the subsidence, horizontal and vertical strain for selected values of the exponent n = 1, n = 0.7 and n = 1.3 was conducted. Next, calculations of deviations of these deformation indices were carried out, between the values calculated at the value n = 1 (linear relationship) and given value different from 1. Finally, obtained distributions of deviation of deformation indices have been presented in the form of maps and diagrams. The obtained distributions have been analysed and the appropriate conclusions were finally drawn.

Abstrakt

V rámci predikce dopadů hlubinné těžby je významné správně určit rozsah hlavních vlivů. Nesprávný popis rozsahu hlavních vlivů může mít za následek chyby v provedených analýzách. Článek představuje analýzu výsledků vzorových předpovědí pro horninový masív pomocí teoretických vzorců W. Budryka – S. Knothe. K popisu bylo použito několika modelů, které ilustrují variabilitu rozsahu hlavních vlivů. Hlouběji byl analyzován vztah S. Knothe, na kterém je popsáno, jak důležitou roli hraje parametr n určující povahu variability r(z). Byla provedena analýza poklesů, svislých a vodorovných deformací, pro případy n=1, n=0,7 a rovněž n=1,3. Významné změny lze zaznamenat ve větších hloubkách u všech ukazatelů deformací, ale u horizontálních deformací Emax je shoda s lineární závislostí (n=1) největší. Výsledné distribuce odchylek ukazatelů deformací jsou prezentovány ve formě map a grafů. Získaná rozdělení byla znovu analyzována a byly učiněny příslušné závěry.

Keywords

underground mining influences, deformation, influence range

Klíčová slova

dopady podzemní těžby, deformace, rozsah vlivu

1. Introduction

Forecasting the influence of underground mining inside rock mass is one of the essential elements of the analysis of the impact of mining activities on both the environment and underground spaces (mainly mine workings) which are necessary for the proper functioning of the mine.

Therefore, properly made forecast of exploitation impacts for underground facilities should be characterized by high quality. Unfortunately, the forecasts for the rock mass formation require additional understanding of the variability of the theory parameters from the roof of extracted deposit to the ground surface level. In particular, this applies to the parameter responsible for the description of influence range. Incorrectly determined distribution of influence range in the rock mass can result, for instance, that the forecast results will lead to erroneous conclusions related to the assessment of whether the mine workings (horizontal or vertical) will be affected by the planned extraction or not.

In addition, a precise forecast is relevant regarding the values of deformation indices inseparably connected with the variability of influence range in the rock mass.

Taking above remarks into account, article presents an analysis of the results of exemplary predictions for the rock mass, made according to W. Burdyk — S. Knothe theory, assuming different ways of describing the variability of the radius of the main influence range in the rock mass. The detailed results of the calculations are presented in point 3, while in point 2 an outline characteristic can be found of selected models, describing the variability of the influence range inside the rock mass.

2. Selected solutions known from the literature

In Poland, the solution suggested by S. Knothe is still used for rock mass deformations forecast, which describes the changes inside the rock mass of parameter responsible for the description influence dispersion - the radius of main influence range r:

$$r(z) = r_p \left(\frac{z}{H} \right)^n$$

where:

r_p – the radius of the main influence range,

z – the height of calculation horizon above the roof of the exploited seam,

H – the depth of extracted seam,

n – parameter describing the character of r(z) variability,

The value of the „n" exponent is assumed to be of key importance for the results of forecasts performed using the formula. Subsequent model tests conducted by D. Krzysztoń (Krzysztoń, 1963) showed that the value of parameter n is slightly less than 1. In practice, it is usually assumed that n=1 - meaning linear variation of the radius of the main influence range.

The above idea was expanded by B. Drzęźla (Drzęźla, 1978), who proposed a modification that resulted in the introduction of the so-called radius of main influence range in the roof of the exploited seam and a different value of the exponent. The dependence given by this author is represented by formula.

$$rs(z) = r\left(\frac{z + zo}{H + zo}\right)^n$$

where:

r - the radius of the impact range for the surface,

z – the height of computing horizon above the roof of the exploited seam,

zo – parameter, which should be calculated using:

$$zo = H\frac{d^{1/n}}{1 - d^{1/n}}$$

where:

$d = 1 - e^{-0,0548\ tg\beta^{-1,96489}}$

n = 0,665

A solution basing on slightly different assumptions was proposed by M. Chudek (Chudek, Stefański, 1987). This model assumes a significant impact of the layered structure of the rock mass on the deformation process. The influence range was linked to the selected physical and mechanical properties of the rock layers between the roof of the exploited seam and the given „z” horizon:

$$rz = \sqrt{\frac{z \cdot Rrs}{\gamma śr}}$$

where:

Rrs – the average weighted value of tensile strength between the roof of the exploited seam and considered horizon

γśr – the average weighted value of rocks density between the roof of the exploited seam and considered horizon

J. Zych proposed an empirical formula allowing to determine the value of tgβ parameter for any „z” horizon, depending on the physical and mechanical properties of the rock mass (Kratzsch, 1983).

$$tg\beta_z = (z+1)^{f_t(1-f_g)} - f_g$$

where:

z – the height of computing horizon above the roof of the exploited seam,

f_g – loosen ratio of the rock mass

f_t – variation ratio of the main influence range

J. Zych and P. Strzałkowski (Zych, Drzęźla, Strzałkowski, 1993) also made a proposal for an empirical dependence allowing to determine the radius of main influence range in the rock mass:

$$r(z) = 1.217 \cdot z^{0.741} \cdot f_s^{3.762} + 20^{\left(1-\frac{z}{H}\right)} - 1$$

W. Piwowarski (Piwowarski, Dżegniuk, Niedojadło, 1995) proposed a dependence for determining the value of tgβ parameter at the horizon z above the roof of the exploited seam:

$$tg\beta_z = 10^{-3} \cdot \left(122 + 96 \cdot \exp\left(-0.0007 \cdot z^2\right)\right) \cdot M \cdot \sqrt{z}$$

In A. Kowalski's paper (Kowalski, 1985) one can found the results of analyses and proposals for the description of variability of the parameter r(z) in the rock mass formation, among others using the dependence with the value n <1.

H. Kratzsch's work (Kratzsch, 1983) contains a general characteristic of various forecasting methods of the displacement of rock mass subjected to underground mining exploitation.

3. The performed analysis

As mentioned in the introduction, the appropriate adoption of the parameter n value in the formula is crucial for the forecast results, as it determines the variability of the main influence range on particular computing horizons between the roof of the exploited seam and the ground surface.

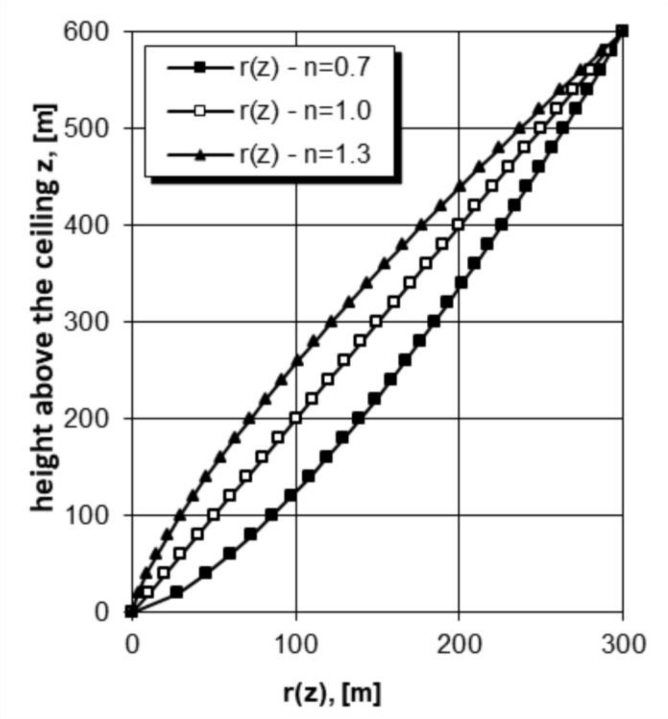

Fig. 1 Variability models of r (z) used in the calculations

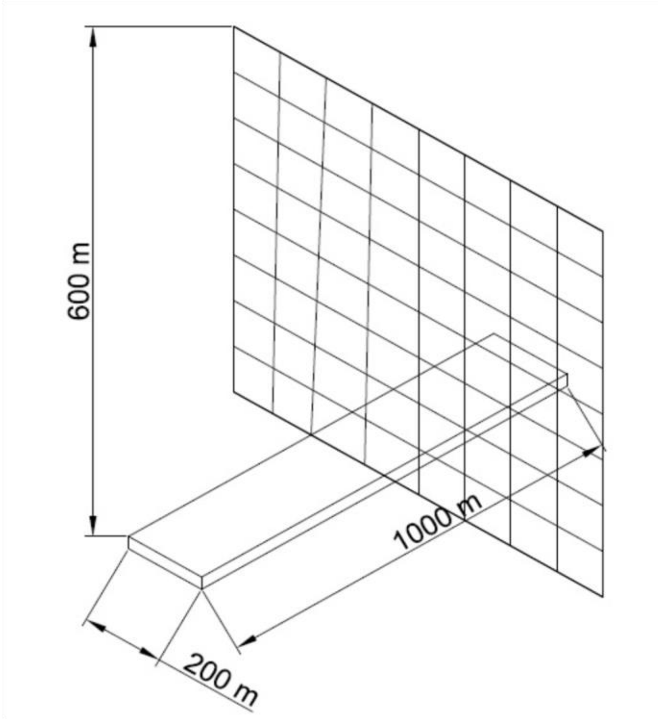

Fig. 2 The sketch of extraction used in forecast with calculation grid location

Therefore, in order to assess the deformation distribution inside the rock mass, depending on the model describing the variability of the main influence range defined by the parameter r(z), a multivariant calculations were carried out, taking in to account the following assumptions:

- parameters of W. Budryk - S. Knothe theory: tgβ=2.0, a=0.8, B=0.32r,
- variability of the parameter r(z) according to the formula, with using of three different values n: 0.7, 1.0 and 1.3. The r(z) distribution for these values (see Fig.1).

- longwall extraction with a length of 200m, advance of 2000m and a depth of 600m below terrain level - the ground surface was assumed at H = 0m elevation above sea level, and excavated deposits at H = -600m elevation above sea level (see Fig. 2).
- calculations were performed in a vertical grid located in the middle of the longwall runway, perpendicular to the longwall roadways. The bottom edge of the grid was 50m above the roof of exploited seam (see Fig. 2).
- for each point of the calculation grid, the following values were calculated: subsidence [mm], maximum horizontal strain Emax [mm/m] and vertical strain Ez [mm/m].

The results of the calculations were used to build a deviations matrix of the above-mentioned deformation indices, between the values obtained with using linear r(z) variability model - n = 1.0 and nonlinear models n = 0.7, 1.3. The deviation for the i-th point of the was calculated according to the dependence, for example, for the exponent n = 0.7:

$$\delta_i = \frac{d_i^{(n=1.0)} - d_i^{(n=0.7)}}{d_{\max}^{n=1.0}} \cdot 100\%$$

where:

$d_i(n=...)$ - value of a given deformation index for the exponent value n = 0.7 or 1.3

$d_i(n=1.0)$ - value of a given deformation index for the exponent value n = 1.0

$d_{max}(n=1.0)$ - the maximum value of a given deformation index for the exponent value n = 1.0 determined from all calculation grid points

Based on the results of calculations of deviations determined by formula, maps of their distribution were worked out along the analyzed rock mass cross-section. Due to limited volume of this paper, selected distributions of deviations for horizontal strain have been presented deviations for n = 0.7 (see Fig. 1) and deviations n =1.3 (see Fig. 4) and vertical strain - deviations for n = 0.7 (see Fig. 5) and deviations for n = 1.3 (see Fig. 6).

Additionally, for each of the analysed deformation index, the charts showing the distribution of its deviations along some horizontal levels located over the roof of the exploited seam were prepared (see Fig. 7 - 9). The following horizons were taken: H = -500 m above sea level, -400 m above sea level, -300 m above sea level, -200 m above sea level -100 m above sea level, -50 m above sea level.

Analysing the deviations distribution for every deformation indices presented in the paper, the following remarks can be made:

In case of subsidence, deviations distribution presented for n = 1.0 (see Fig. 7) shows an excess of subsidences in relation to the calculated one for n = 0.7 in the area outside the extracted field, while the reverse situation is noticeable directly over the extraction. The maximum differences reach about +/- 12% for the horizon close the roof of the exploited seam (-500 m above sea level) and about +/- 1%

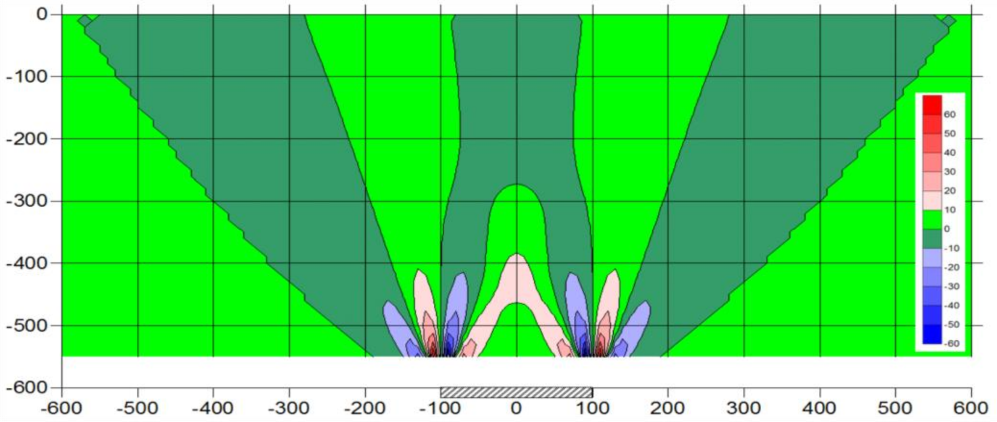

Fig. 3 The map of deviations distribution for horizontal strain Emax, for n=0.7

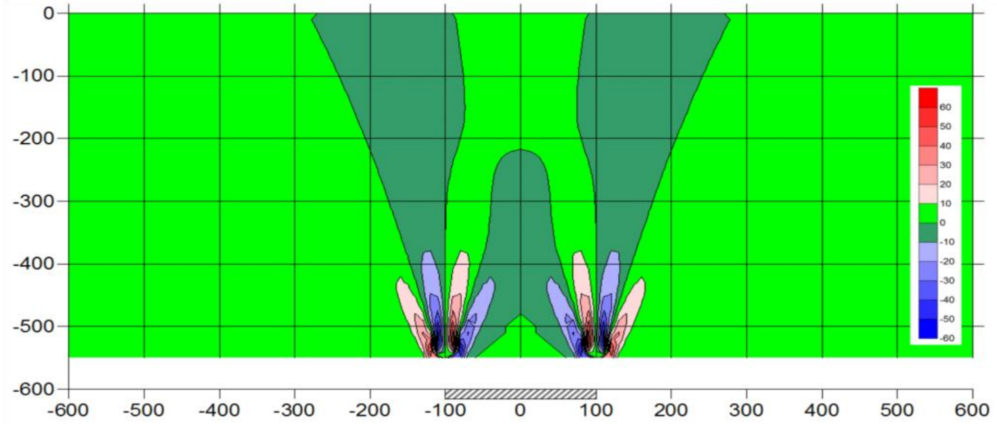

Fig. 4 The map of deviations distribution for horizontal strain Emax, for n=1.3

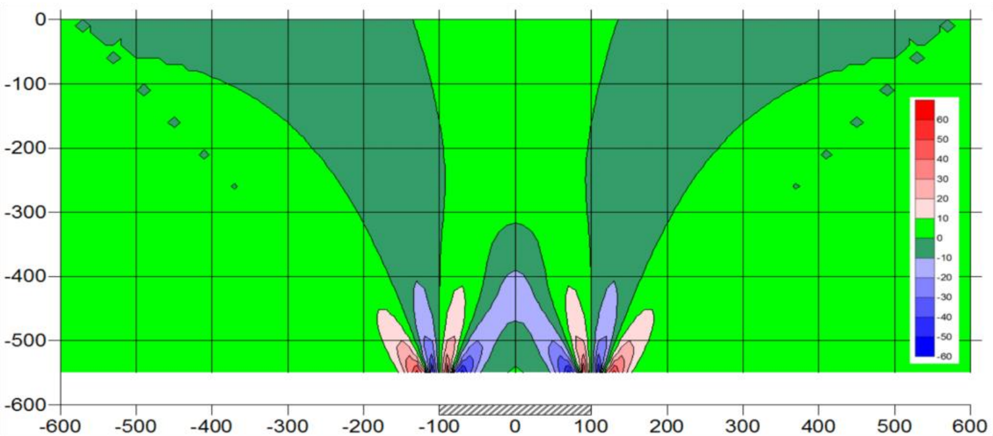

Fig. 5 The map of deviations distribution for vertical strain Ez, for n=0.7

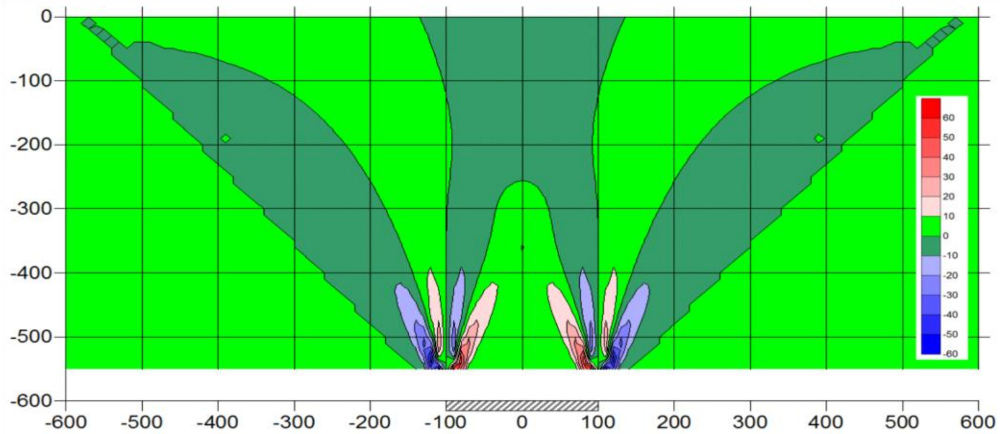

Fig. 6 The map of deviations distribution for vertical strain Ez, for n=1.3

for the land surface. In case of n = 1.3, the maximum deviations are similar, while the signs are opposite in relation to the previous case, with greater gradient of deviations.

In case of horizontal strain presented for n = 0.7 (see Fig. 8), a large amplitude of deviations can be noticed. The largest decrease is recorded for the depth -500 m above sea level (about 25%) noticeable over the exploitation field, and the largest increase also for the same depth by about 25% outside the field. Directly over the conducted operation, in its central part, an increase in value by an average of about 10% is observable. For the case of n = 1.3, also the largest amplitudes are recorded for the depth -500 m above sea level. Above the exploitation field an increase of about 45% is visible, while in the external part - a decrease of about 45%. In the central part, directly above the extraction, there is a decrease in the value of about 20% but also stabilization, similar to that observed for linear variability of r(z).

In the case of vertical strain Ez - for n = 0.7 (see Fig. 9), a large amplitude of the deviation values is noticeable. The biggest differences were recorded for the depth of -500m above sea level. The largest increase amounts about 17% and is visible outside of the conducted exploitation and by the internal longwall edge. The decrease by approx. 19% is noticeable directly over the conducted extraction and at the outer part near the exploitation edge. For the case of n = 1.3 the deviations for Ez also characterise large amplitude and the highest increase of approximately 28% was recorded directly over the extraction and in the outer area near the longwall edge. A considerable drop in the value of approx. 28% occurs outside the conducted exploitation and in the inner area near the edge.

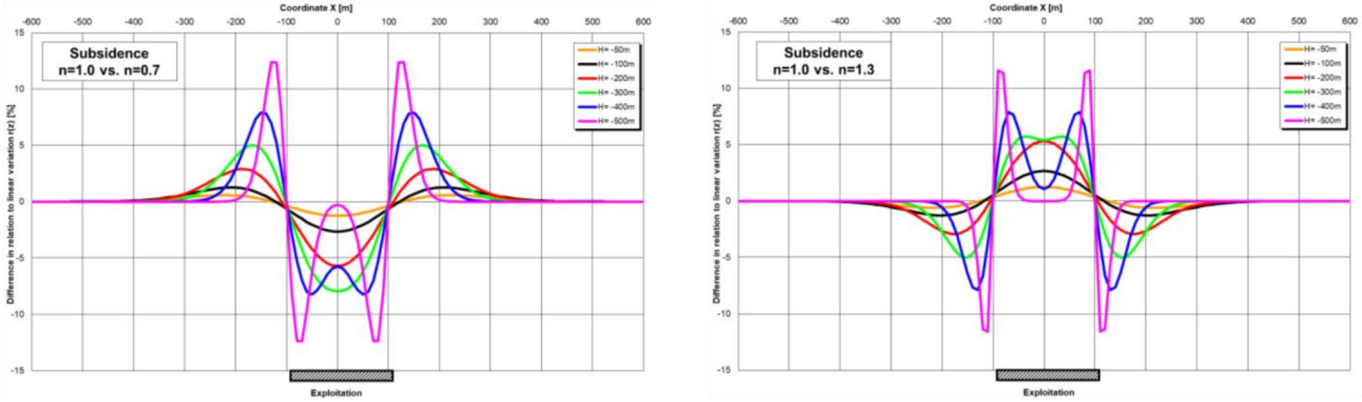

Fig. 7 The distribution of deviations δ for subsidence on selected horizons

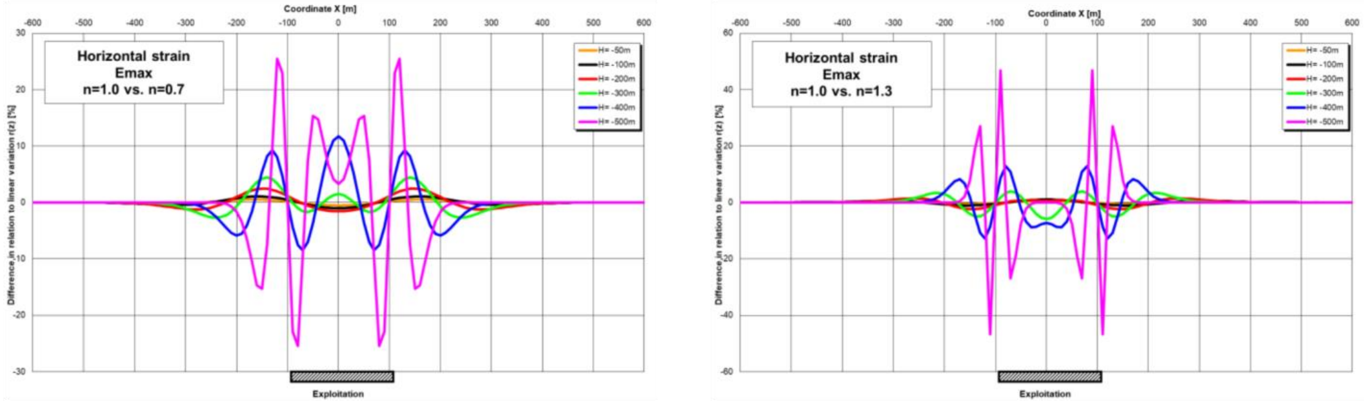

Fig. 8 The distribution of deviations δ for horizontal strain Emax on selected horizons

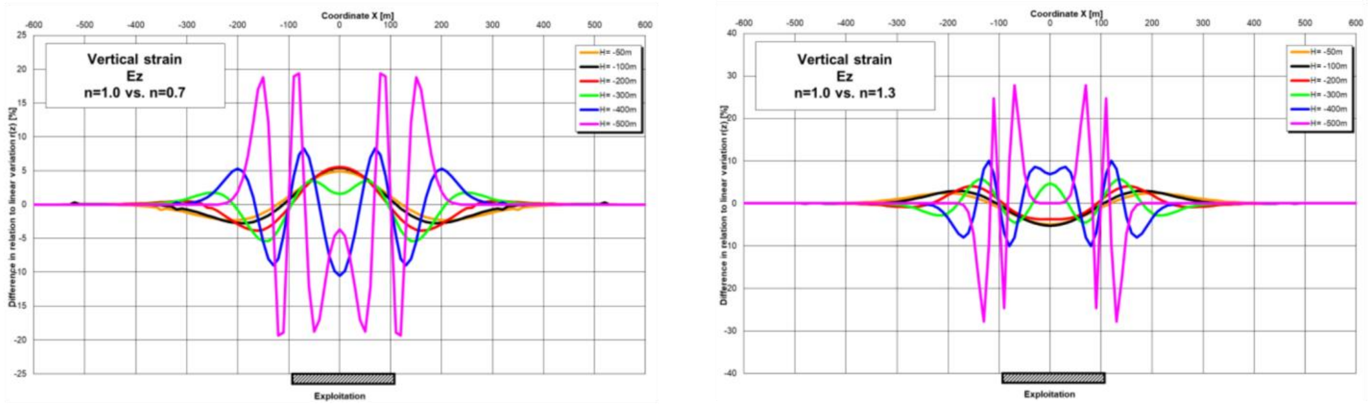

Fig. 9 The distribution of deviations δ for vertical strain Ez on selected horizons

4. Summary

In the framework of this publication, the considerations regarding the deformation forecast of the rock mass performed with using different approaches to non-linear variability of the radius of main influence range have been presented. If a non-linear variability model r(z) according to formula is used, a larger influence ranges are obtained with the value $n<1$. In such case of forecast for mine roadways located at the distance close to the influence range, predicted impact will be favorable for their protection - they will be situated within the area of expected influences of mining exploitation according to the forecast. At the same time an important element should be taken into account – using such a model will cause that fragments of mine roadways located closer to the extraction field may fall into areas of decreased values of deformation indices. In particular, large fluctuations refer to horizontal and vertical strain.

The forecast performed with the value of $n>1$ will be characterized by significantly reduced influence ranges. Therefore, this approach should be used with great care, especially if the prediction concerns objects away from the planned exploitation fields. On the other hand, there will be zones in the vicinity of exploitation edges, where forecasted values of deformation indices will be decreased compared with the linear model.

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Author:

[1] mgr inż. Dagmara Perżyło, Silesian University of Technology, Poland, 44-100 Gliwice, Akademicka 2, e-mail: dagmara.perzylo@polsl.pl