THE REMARKS ON USING SELECTED MODELS DESCRIBING POST MINING DEFORMATIONS IN CASE OF HIGH EXTRACTION SPEED

POSTŘEHY Z POUŽITÍ VYBRANÝCH MODELŮ POPISUJÍCÍCH DEFORMACE PO UKONČENÍ TĚŽBY PŘI VYSOKÉ TĚŽEBNÍ RYCHLOSTI

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Abstract

The analyses of calculation results of post-mining deformations of ground surface modelled for the „Twenty mile" coal mine conditions (USA) have been presented in this paper. Thickness of the coal seam is 2.6 m – 2.9 m and depth of extraction is 300 m – 400 m. The lengths of walls were 305 m and life of face is 4 km. The average speed of extraction in this coal mine is about 40 m per day. The analyses were made by using Knothe's theory and author's model. The calculations were carried out with using specialized computer program. The calculated values of subsidence speed are difficult to verification, because up to now we haven't got the result of geodetic measurements from these cases.

Abstrakt

Analýzy výsledků výpočtu deformace povrchu po ukončení těžby, které byly modelovány pro situaci na dole "Twenty mile" (USA), jsou prezentovány v tomto příspěvku. Mocnost uhelné sloje je 2,6 m – 2,9 m, přičemž hloubka těžby byla 300 m – 400 m. Šířka porubu byla 305 m a směrná délka 4 km. Průměrná rychlost postupu těžby uhlí v tomto dole je asi 40 m denně. Analýzy byly provedeny pomocí autorova modelu s využitím Knotheho teorie. Výpočty byly provedeny pomocí specializovaných počítačových programů. Vypočtené hodnoty poklesů rychlosti je těžké ověřit, protože dosud nejsou k dispozici výsledky geodetických měření.

Keywords

mining subsidence, numerical model of surface deformation, high speed of face advances.

1 Introduction

The development in construction of mining machines makes that speed of face advances still increase. The speed in conditions of Polish coal mines is a few meters per day (Chudek 2010, Kowalski 2007). The similar values we can note in German's coal mines (Sroka 1999). Increase of speed of face advances influences on changes of variability indices of deformation over time, is a reason of big values of subsidence's speed. The weekly breaks of extraction are the reasons of mining damages in buildings (Kowalski 2007, Sroka 1999). Because of that, description of surface's deformation over time is a present and important problem. Maybe in future the speed of face advance in Poland will be similar to American coal mines. The extraction in American coal mine „Twenty mile" in Colorado State is 45 000 Mg from 1 wall per day, how can we read in paper (Smolnik 2009). There is extracted coal seam called Wadge. Thickness of the coal seam is 2.6 m – 2.9 m and depth of extraction is 300 m – 400 m. The lengths of walls were 305 m and life of face is 4 km. The speed of face's advance is average 40 m per day. The simulation of extraction using Knothe's model has been presented in the next part of this paper. The analyses have been provided with using an assumption of immediate influences and with using model with time variable.

It bases on differential equation, which expresses the speed of subsidence for point located over underground extraction workings:

$$\frac{dw}{dt} = c \times \{ w_k - w(t) \} \tag{1}$$

where:

w_k – final (asymptotic) subsidence,

w (t) – transient subsidence,

c – coefficient of subsidence speed (time coefficient) with constant value.

The evident is that taking into account coal face advance, the final value of subsidence changes over time. This fact complicates significantly the solution of equation (1). Because of that, for practical purposes it is comfortably to assume, that extracted field has a small area. It is possible then to assume, that time of its extraction is close to zero. This assumption significantly simplifies the solution of equation (1):

$$w_t = w_k \times \left(1 - e^{-ct}\right) \tag{2}$$

For real cases of underground mining, the extracted field can be divided into elementary stripes, for which transient subsidence is being calculated following the equation (2). The real value of subsidence is calculated by summing up "elementary subsidences" for given time horizon. It is so called "discrete model", worked out by S.Knothe (Knothe 1953).

The detailed investigations provided by A. Sroka (Sroka 1974) show that value of parameter c can be expressed by following equation:

$$c = 1.2 \times \frac{v_f}{r} \tag{3}$$

where:

v_f – speed of face advance, m per year.

r – radius of range influences [m].

Author (Kowalski 2007) has calculated value of parameter c on the basis of geodetic measurements provided over high speed extraction. The received value (c=24 1/year) was higher than maximal one presented by S. Knothe (c=7 1/year)

That modification of equation (1) (Strzałkowski 1998) relied on the assumption that c = c (t), leads for discrete model (w_k (t_k; x) = const.) to the following dependence:

$$w(t;x) = w_k(t_k;x) + E \times e^{-\int c(t)dt} \tag{3}$$

where :

w (t; x) – transient subsidence

w_k (t_k; x) – final subsidence,

t_k – time, after which subsidence reaches its final value,

x – coordinate, $x \in R^2$

E – integration constant. Its value was assumed to be E = -w_k for simplification purposes.

Obtained values of parameter $c_c = \int c(t)dt$ have been approximated by using the following function:

$$c_c = \int c\ dt = a \times tgh\left(\frac{t}{b} + c\right) \tag{4}$$

2 Calculation and analyses of it results

In this paper the calculations were made with assumptions as follow:

- Length of wall - 305 m,
- Thickness of coal seam – 2.6 m,
- Depth of extraction – 400 m,
- Speed of face advance – 40 m/day.

The analyses with using: Knothe's theory, with an assumption of immediate influences, with using Knothe's model with time variable, for c=72 1/year (according eq. (3)) and author's model (for a1=10 b=50[day] d=0.2), have been presented in the paper. The calculations have been provided for extraction led with weekend breaks and without breaks.

The basic information about mining extraction accepted to calculation has been presented in tables 1 and 2. The scheme of location selected to calculation point in relation to field of extraction has been presented in fig.1.

Tab 1 The basic dates of mining extraction provided with weekend extraction breaks conditions.

Coal seam	Parcel	Beginning	Ending	g[m]	a[deg]	H[m]
300	1	02-06-2008	06-06-2008	2.6	0	400
300	2	09-06-2008	13-06-2008	2.6	0	400
300	3	16-06-2008	20-06-2008	2.6	0	400
300	4	23-06-2008	27-06-2008	2.6	0	400

Tab 2 The basic dates of mining extraction provided without weekend extraction breaks conditions.
g – thickness of coal seam,
a – subsidence factor,
H – depth of extraction

Coal seam	Parcel	Beginning	Ending	g[m]	a[deg]	H[m]
300	1	02-06-2008	21-06-2008	2.6	0	400

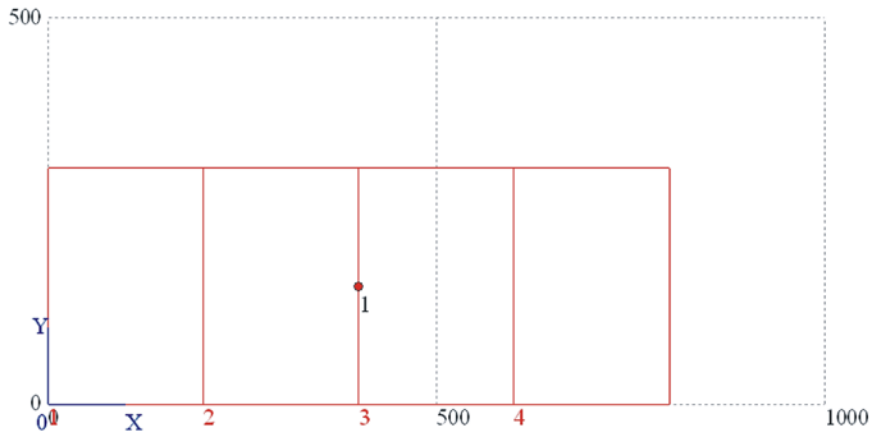

Fig. 1 Location of calculation point in relation to field of extraction

The diagrams of subsidence over time as a result of calculation for selected point have been presented in figure 2. The maximum values of other deformation indices have been presented in tables 3.

On the basis of presented results of calculations we can draw as follows:

The weekend breaks in mining extraction can be observed in the results of geodetic measurements, as it is shown in papers (Kowalski 2007, Ścigała 2003). This effect of breaks in extraction we can receive using S. Knothe's theory with an assumption of immediate influences and author's model (see eq. 3). Knothe's model with time variable does not give this possibility. Inclination and deformation calculated with using this model are less than calculated with using other model analyzed in this paper. The speed of mining subsidence obtained with using Knothe's model is 200 mm per day, and author's model is about 350 mm per day. We can wonder: which values are more probable? On the basis of a diagrams presented in paper (Peng 2009) we can see that if speed of face advance is 30 m per day, speed of subsidence is about 260 mm per day.

3 Conclusions

Present mining extraction led in US characterizes high speed of face advance. In conditions of coal mine „Twenty mile" in Colorado the average speed is 40 m per day. We can wonder: is this speed of face advance possible in conditions of Polish coal mine in next years? It is a difficult question, because extraction in Poland is led under urbanized areas. The high speed of face advance causes high speed of subsidence and other deformation indices, which cause damages in buildings. The calculated values of subsidence speed are difficult to verification, because up to now we haven't got the result of geodetic measurements from these cases. On the other hand, the damages to buildings arise as well as the speed of subsidence is equal 100 mm per day or 300 mm per day.

Tab 3 The maximum values of deformation indices

- ***dw/dt – speed of subsidence,***
- ***d^2w/dt^2 – acceleration of subsidence,***
- ***T_{max} – maximum inclination,***
- ***ε_{max} – maximum horizontal deformation.***

Indices of deformation	**S. Knothe's model immediate influences**		**S. Knothe's model with time variable c = 72 [1/year]**		**Author's model a_1=10 b=50[day] d=0.2**	
	Extraction without breaks	**Extraction with breaks**	**Extraction without breaks**	**Extraction with breaks**	**Extraction without breaks**	**Extraction with breaks**
dw/dt [mm/d]	297	397	228	191	349	342
d^2w/dt^2 [mm/d^2]	69	380	55	55	105	328
T_{max} [mm/m]	9.90	9.90	5.74	7.14	8.99	9.28
ε_{max} [mm/m]	+4.82 -5.08	+4.82 -5.08	+2.23 -5.08	+2.34 -5.08	+4.33 -5.08	+4.35 -5.08

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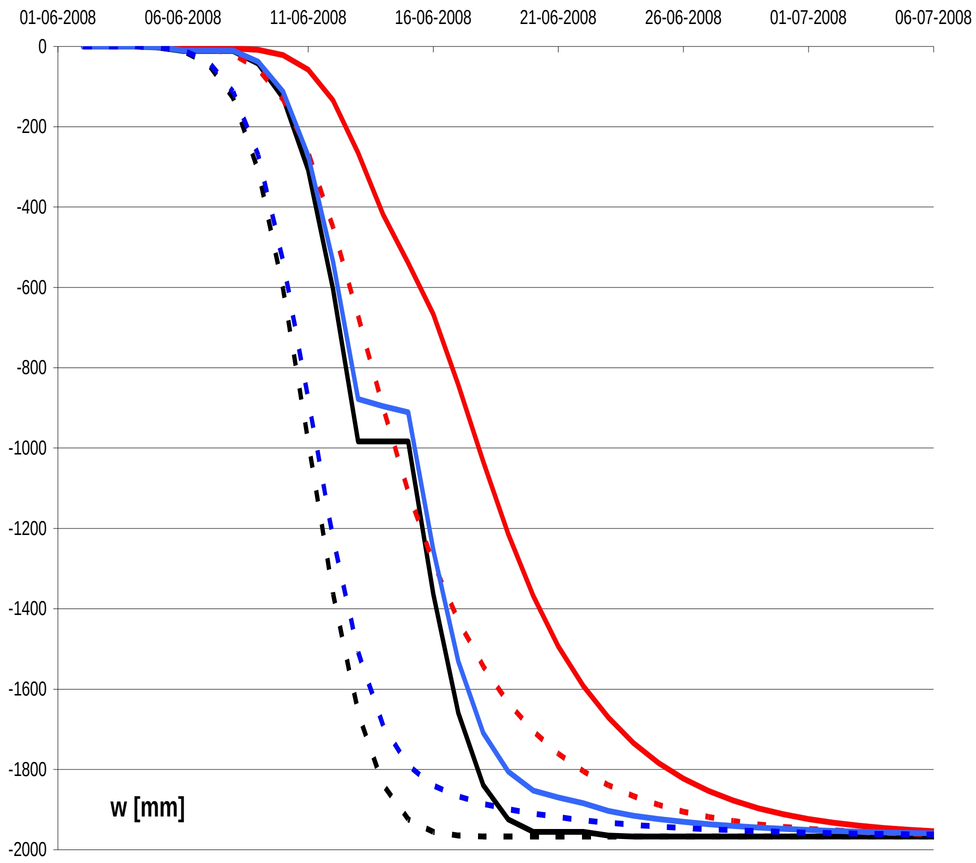

Fig. 2 The courses of subsidence ov

- ***calculated with using Knothe's th of immediate influences.***
  - ***Black solid line – subsi extraction led with wee dashed line– without b***
- ***calculated with using Knothe's m for c=72 1/year.***
  - ***Red solid line– subside extraction led with wee dashed line– without b***
- ***calculated with using author's m for a1=10 b=50[day] d=0.2.***
  - ***Blue solid line– subsid extraction led with we dashed line– without b***

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