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THE KINEMATICS OF DEFORMATION PROCESS IN CASE OF SHALLOW UNDERGROUND MINING – CASE STUDY

KINEMATIKA PROCESU DEFORMACE PŘI MĚLKÉ PODZEMNÍ BÁŃSKÉ DOBÝVCE – STUDIE PŘÍPADU

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Abstract

In the paper there has been an example presented concerning identification of parameter responsible for modelling of transient deformation state due to underground mining. Example comes from one of the Polish coal mines located in the Upper Silesia Basin. Longwall extraction with stowing was led in the 70's of the XX century at shallow depth (approx. 40m). Performed identification of Budryk-Knothe's theory parameter „c" on the basis of surveys shows very high its values, which are not usually met for extraction led at mid- and great depths. As it is known from investigations led so far, the value of this parameter depends substantially on the depth of extraction - for shallow depths they are significantly high and decrease along with deeper location of mining fields. So, one may state obtained high values of parameter „c" conform to this condition.

Abstrakt

V práci je presentován příklad, který se týká parametru odpovědného za modelování přechodného deformačního stavu vyvolaného podzemním dolováním. Příklad patří jednomu z polských uhelných dolů z Hornoslezské pánve. Dobývka v sedmdesátých letech dvacátého století byla prováděná stěnováním v malé hloubce přibližně 40 m. Aplikovaná identifikace parametru „c" podle teorie Budryka-Knotheho na bázi geodetických pozorování ukázala jeho velmi vysoké hodnoty, které nejsou obvyklé při dobývce ve středních a velkých hloubkách. Jak je patrné z dlouhodobě vedených pozorování hodnoty tohoto parametru, závisí na hloubce dobývání – v mělkých hloubkách jsou podstatně větší a směrem do hloubky klesají. Lze říci, že registrované vysoké hodnoty parametru „c" to potvrzují.

Keywords
underground mining influences, geometric-integral theories, transient deformation state

Klíčová slova
vlivy podzemního dobývání, geometricko-integrální teorie, přechodný deformační stav

1 Introduction

In recent years, there has been a noticeable increase in interest in the field of forecasting the transient deformation state caused by underground mining (Białek, 1991; Kwiatek, 1998; Strzałkowski, 1998). This is due to changes in the conditions accompanying the present mining works in Poland. The increase in the speed of mining extraction is of particular importance, which largely affects the kinematics of the deformation process (Sroka, 1999).

A lot of methods for predicting transient deformations were created, but one of the milestones in this field in Poland is the solution proposed by S. Knothe through use of the law of limited growth of Mitscherlich (Mitscherlich, 1909; Knothe, 1953a, 1953b), known in other fields of science as well. The starting point of this model is a differential equation describing the transient subsidence rate for the point located at the surface level as a result of the underground mining:

$$\frac{dw}{dt} = c \times \left[w_k(t) - w(t) \right], \tag{1}$$

where w (t) – transient subsidence,
w_k – final subsidence,
c – the coefficient of subsidence rate (often called „time factor") [1/year],
t – time.

The above dependence states, that the rate of subsidence of the point at the surface is proportional to the difference between the "potential" asymptotic value of subsidence w_k (t) and its instantaneous value w (t).

The assumption that w_k varies along with the progressing front makes it much harder to solve the equation, which is why the simplified solution has been adopted for practical reasons, where $w_k(t)$ = const. Using this assumption, we get the solution in the form:

$$w(t) = w_k \times \left(1 - e^{-c \times t}\right) \tag{2}$$

This solution is the most widely used in practice; however, the assumption regarding the fixed value of final subsidence is valid only in relation to the elementary field. So, there must be employed so called "discretized model" in which the extraction field is divided into elementary field, where we assume that such every field is extracted in different moment in time, but the time necessary for its extraction is close to zero.

In the transient Knothe's model (1), the parameter characterizing the course of the deformation process over time is the coefficient of subsidence rate „c". Knothe assumed that the value of this parameter for Upper Silesian Basin falls in the range from 0.5 to 7 [1/year]. Its value depends on many factors (Knothe, 1953b; Białek, 1991; Drzęźla 1993; Chudek 2002). Among them the most important are:

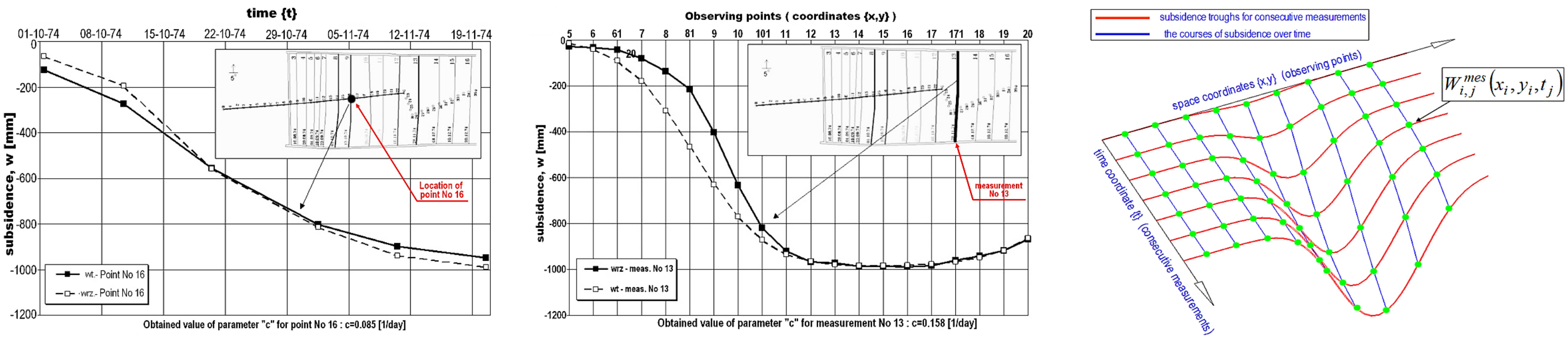
- the strength properties of the layers that built the rock mass (the stronger the rock mass, the smaller the value of the parameter „c".
- the depth of extraction (the deeper the mining is carried out, the „c" value is smaller).
- the extraction front development rate also has an important influence - the „c" value increases with increasing the speed of extraction.

In this paper, there was examined practical case of very shallow extraction. The question to be answered is: how great the value of parameter „c" may be reached with such shallow extraction. Below one can find a few paragraphs devoted to identification methods of this parameter, and then the practical example is presented, which shows the influence of the shallow extraction depth on the values of „c".

2 Calculation procedures used for identification of the parameter „c"

For prediction purposes it is necessary to determine the value of parameter „c". Several methods may be employed here. Presently used methods base on iterative algorithms and utilize specialized software (Ścigała, 2008). We distinguish here three methods (Ścigała, 2010):

a) Identification based on the course of subsidence over time of a single i-th observation point (fig.1a).
b) Identification based on the transient profile of the subsidence trough obtained in the j-th measurement cycle (fig.1b).
c) Identification based on the course of subsidence in both - time and space coordinates (fig.1c).



a) identification along time **b) identification along space** **c) identification along time and space coordinates**

Fig.1. The methods of parameter „c" identification

The determination of the parameter c according to the method a) causes that the analysis of individual observation points shows the „averaged” parameter value along the time coordinate t, whereas with method b), for each location (x, y) of the observation point, different „c” values are obtained. Based on the method b), we get the "averaged" values of the parameter „c” along the geometric coordinates of all used points, while for the time coordinate „t” we get its different values (for every measurement cycle).

A solution allowing simultaneous identification of „c” values in both - geometric coordinates and in the time, coordinate can be applied - method c) bases on both previously discussed solutions in the data space {x, y, t}.

Due to the fact that in the classic approach to the identification of parameter „c”, more than one its value is obtained - the question always arises: what value should be taken for the prediction. Usually, the average value is taken, but it cannot be unambiguously assessed whether all values should be used for the average or not - due to the determination errors that are difficult to estimate, resulting even from the location of the point in relation to the field of exploitation. The solution to this problem may be the method c), because in this case one „averaged” value of the „c” parameter is obtained (Ścigała, 2010).

3 Analysed case

In the analysed case, which comes from Upper Silesia Basin in Poland, extraction with stowing was led with two longwalls located at the average depth of 40m. The height of extracted deposit was equal to 2.5 m. Due to surface protection requirements, the extraction was carried out with stowing, and the average speed was slow, at the rate about 2 m/day. At the surface level the surveys were led on the line consisted of 28 observing points. The average distance between points was 10 m; measuring actions were performed with 1-nth period. Extraction started with eastern longwall No.1 of dimensions 90 m x 210 m toward north in April, 1973. Extraction field No.2 of dimensions 80 m x 240 m started on the September, 1st in the same direction. All mining works were finished in December 1973.

Tab.1 The obtained values of parameter „c” on the basis of transient profiles of subsidence troughs

Survey date	Obtained „c” values [1/year]
21-05-1973	69.4
05-06-1973	158.8
05-07-1973	193.5
Average „c” value	140.5

Fig.2 shows the location of the measuring line with the longwalls being analysed, while in fig.3 measured profiles of subsidence troughs are presented. As it can be seen from fig.3, maximum subsidence measured in the beginning of July did not exceed 250 mm.

Firstly, parameters responsible for asymptotic deformation state were identified with using own software DEFK-Param (Ścigała, 2008). For identification purposes, southern wing of asymptotic subsidence trough had been chosen, between observing points 12 and 30.

The following values of Budryk-Knothe theory parameters were obtained:

- coefficient of roof control: a = 0.089;
- parameter describing the influence range: tgβ =1.426;
- extraction boundary: d = 0 m; the comparison between measured of modelled profile of subsidence trough is presented in fig.4.

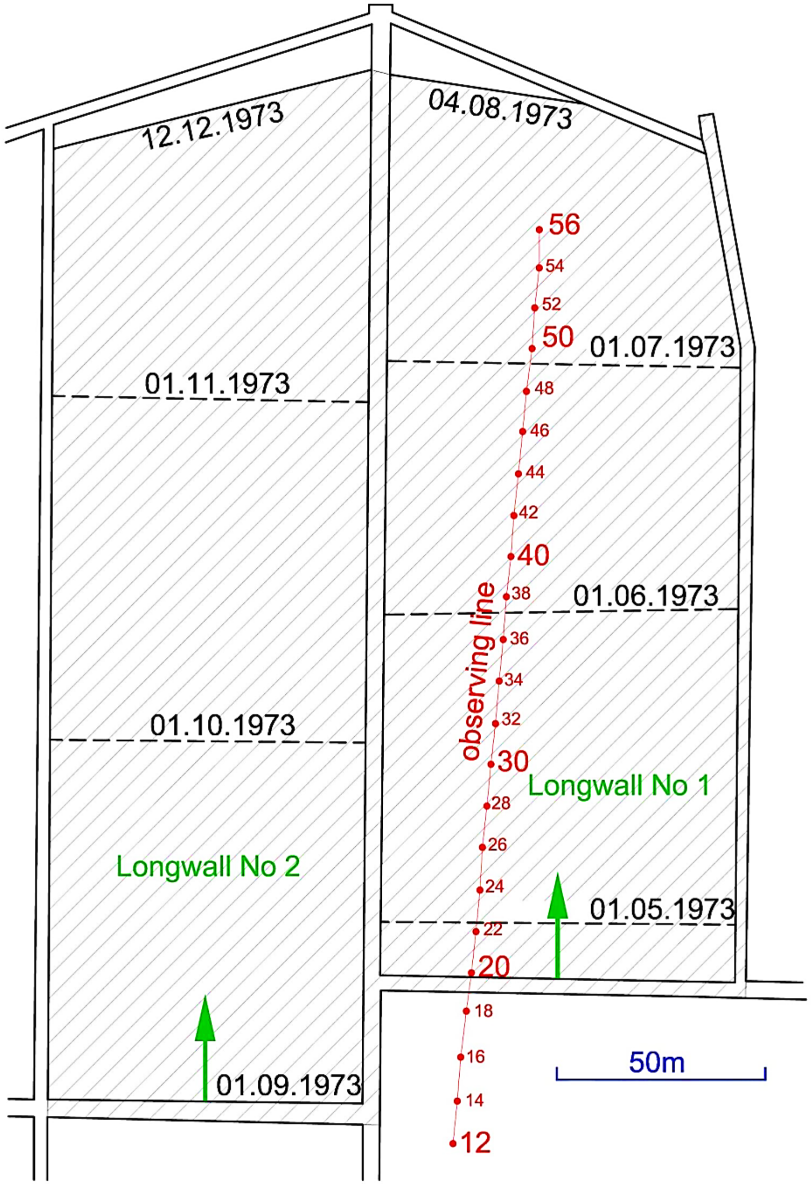


Fig.2. Location of the measuring line against analysed extraction

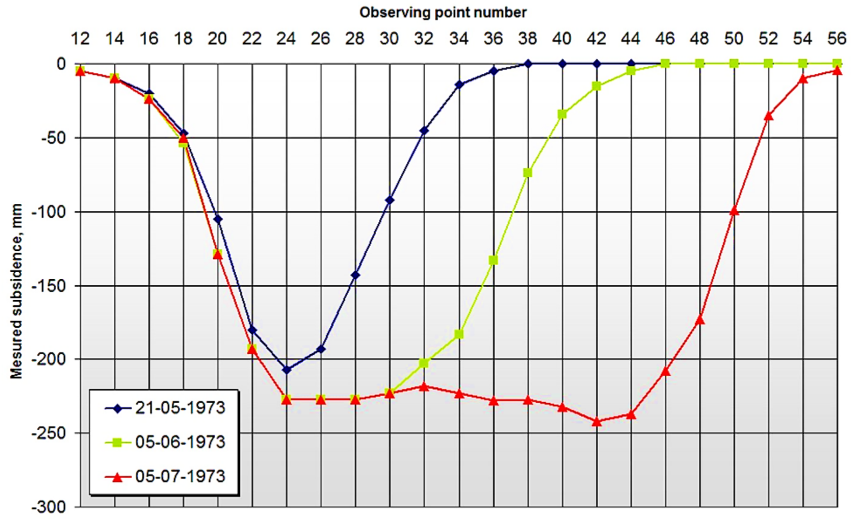


Fig.3 Subsidence trough profile measured above the extraction area

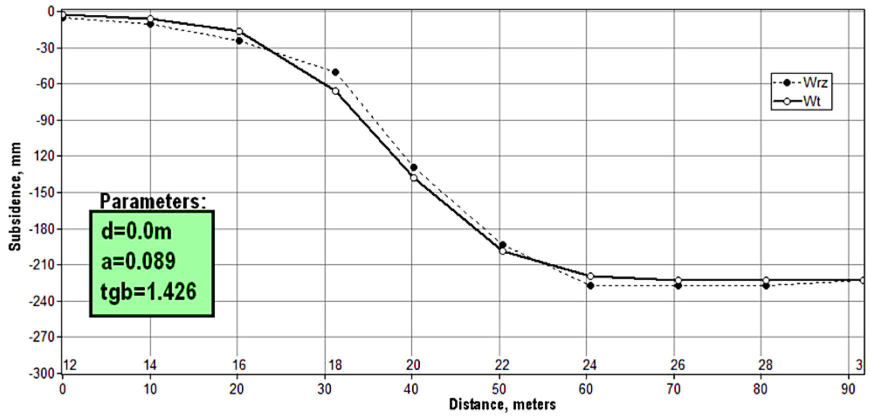


Fig.4 The comparison between measured of modelled profile of subsidence through

Having parameters that describe asymptotic deformation state, the identification of parameter „c" was performed, with using software BK-ctxy software (Ścigała, 2010). In this case identification was led with using method b) described above, which bases on the approximation of transient profile of subsidence trough (in space coordinates). Identification was performed for 3 profiles, so 3 different values of parameter „c" have been obtained. They are presented in tab.1. The comparison between measured of modelled profiles of transient subsidence troughs is presented in fig.5.

The obtained values of the time factor „c" differ significantly from those proposed by S. Knothe. The average value of this parameter in analyzed case is equal to 140.5 [1/year]. The results of the research show that the assumption, that the parameter „c" depends on the extraction depth holds true - at lower depths, the value of parameter „**c**" should be greater.

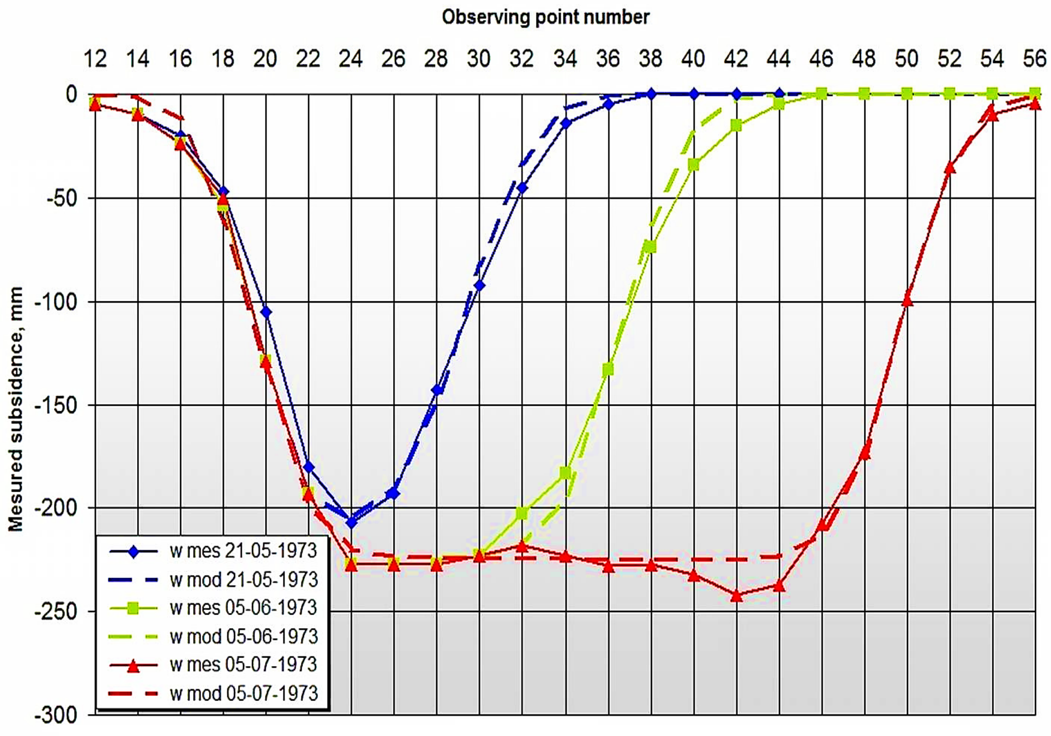


Fig.5. Comparison of measured and modeled profiles of transient subsidence through

4 Conclusions

Analysed case comes from very shallow extraction led in Upper Silesia Basin in the 70yrs of 20-th century. Due to surface protection needs, extraction was led with stowing, which allowed to minimize the deformations at the surface level - maximum subsidence did not exceed 0.25m and the identified value of coefficient of roof control „a" was less than 0.1.

On the other hand - despite of such low deformations values, the rate of deformation process was significant - obtained values of parameter „c" that describes the kinematics of deformation process in Budryk - Knothe theory is extremely high - out of upper bound of 7.0 [1/year], proposed by S. Knothe. Presented case confirms very strict relation between the depth of extraction and the rate deformation changes at the surface level. It has of course indirect influence on the value of parameter „c".

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