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Average Graph of Land Surface Curvatures Induced Mining Operation Determined by Use of Fourth Order Polynomial

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Abstract. In the article the obtainment method of average graph of curvatures, observed on terrain surface as a result of underground mining exploitation of hard coal seam, has been presented. Approximation of curvatures measured graph by use of fourth order polynomial divided into a few parts and the least squares method has been done. Average graph of measured subsidence as a first one has been determined. Then average graph of observed curvatures as a second derivative of subsidence approximated values has been obtained. Statistics indicate that proposed method of obtainment of average graph of observed curvatures can be alternative for smoothed splines and gives much better results than they. Fourth order of polynomial is enough for determination of average graph of observed curvatures on condition division it into parts.

INTRODUCTION

Approximation of mining land deformations indicators values, caused by underground exploitation of hard coal deposits and observed by geodesic surveys, is very important due to evaluation of prognostic models used for forecasting of mining exploitation impacts.

There are known applications of smoothed, cubic splines to determination of average graphs of measured indicators of deformations [1 – 7]. The basic problems with their use are:

- finding of proper value of smoothing parameter of approximating function [8];
- too much generalization of empirical data graph (especially in case of curvatures);
- too small extreme, average values compared with extreme, measured values of deformations indicators;
- too large values of variability coefficient of random dispersion in comparison with its values occurred in literature [9].

Higher orders polynomials can be alternative for smoothed spline functions and solution of these problems. That's why in the article an example of approximation of average graph of curvatures observed values has been presented. There a polynomial of fourth order has been used. In order to obtain better fit of average graph to empirical data, it into several parts has been divided.

RESEARCH MATERIAL

Research material comes from the Upper Silesian Coal Basin located in the southern part of Poland. Some hard coal mine conducted an operation of the 338/2 seam by use of the longwall system with a cave-in of roof rocks. Declination of hard coal seam has the value of 7°. Exploitation of the 001 longwall was carried out on depth of 580 m and in height of 2.0 m. Dimensions of a longwall were following: length 250 m and run 750 m.

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Impacts coming from exploitation of the 001 longwall were observed on 53 points of the measuring line No. 1. It perpendicularly to a longwall run has been stabilized. Average distance between subsequent measuring points was amounted 40 m. Total length of observational line exceeded 2 km. Location of geodesic points on background of mining excavation at the Fig. 1 has been shown.

Before beginning and after end of exploitation the situational and altitude surveys on measuring line have been carried out. Measurements of points heights were done by use of a precise leveler with an accuracy of 0.1 mm. It was used a geometric levelling from the middle. Lengths of line segments by use of a distance-meter device with an accuracy of 1 mm have been measured.

Values of mining terrain curvatures on base of the geodesic measurements results have been determined. Taking into account the heights differences after and before exploitation of three neighboring points (subsidence *S* of the *i-1*, *i* and *i+1* points), and lengths of two neighboring sections after exploitation end (lengths *L* of the *i-1*,*i* and *i*,*i+1* segments), it can be calculated the *C* curvature observed between three neighboring points *i-1*, *i*, *i+1* from the following formula:

$$C_{i-1,i,i+1} = \frac{2S_{i-1} - 4S_i + 2S_{i+1}}{L_{i-1,i} + L_{i,i+1}}, \quad (1)$$

where: *C* – curvature [$10^{-3}\cdot 1/m$]; *L* – section length [m]; *S* – subsidence [mm]; *i* – point number.

Observed graph of curvatures along measuring line at the Fig. 2 has been presented (red dots).

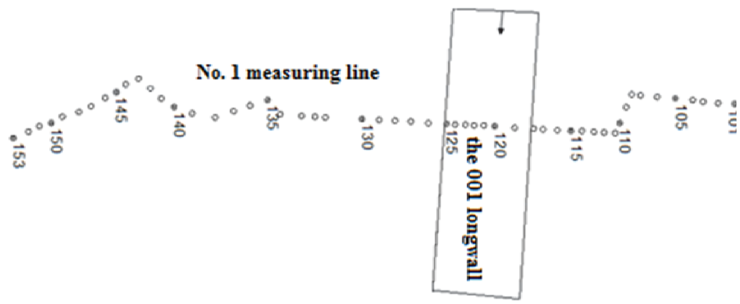


FIGURE 1. Observational points and mining excavation

CURVATURES APPROXIMATION

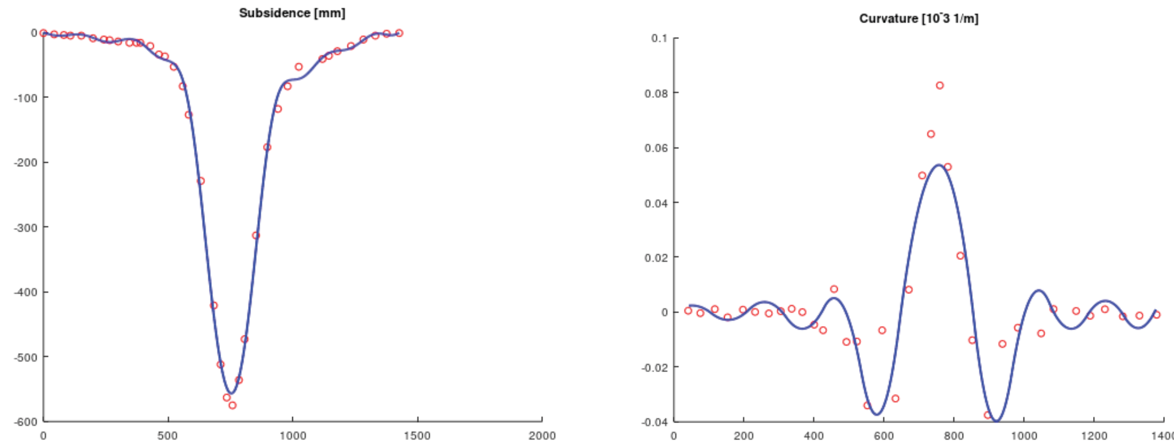
Approximation of average graph of curvatures, observed along the No. 1 measuring line and caused by exploitation of the 001 longwall, by use of the Octave computer program has been done. The least squares method and polynomial of fourth order have been used. It into 15 parts has been divided. As first average graph of measured subsidence has been determined. Then the second derivative of function representing average graph of observed subsidence has been calculated. Empirical (red circles) and analytical (blue lines) graphs of subsidence and curvatures at the Fig. 2 have been shown.

Table 1 presents statistical data concerning measured (*M*) and approximated (*A*) graphs of the *S* subsidence and the *C* curvatures. It contains their maximum values (M_{max}, A_{max}), standard deviation between measured and approximated graphs (σ_{M-A}) and values of variability coefficient of random dispersion of measured graphs of deformation indicators (*V*).

In case of subsidence, maximum average value constitutes 96.87 % of maximum measured value. Standard deviation between measured and average values of subsidence has the value of 9.54 mm, what is 1.66 % of maximum measured value. Variability coefficient of subsidence random dispersion equals only to 1.71 % (value smaller than 2.9 % appearing in the literature [10]).

Maximum approximated value of curvature constitutes 64.89 % of maximum observed value. Standard deviation between measured and average values of curvatures is equal to $0.011\cdot 10^{-3}$ 1/m, what constitutes 12.83 % of maximum observed value of curvature. Value of variability coefficient of random dispersion of curvature equals to 19.75 %, what can be recognized as a good result. It can take values up to 33.5 % according to the results included in the works [10 – 11].

Deformation indicator	M_{max}	A_{max}	σ_{M-A}	***V* [%]**
Subsidence *S* [mm]	575	557	9.54	1.71
Curvature *C* [10^{-3} 1/m]	0.0826	0.0536	0.0106	19.75



(a) (b)

FIGURE 2. Observed (red points) and averaged (blue lines) graphs of mining land subsidence (a) and curvatures (b)

SUMMARY AND CONCLUSIONS

In the article problematic of average graphs approximation of measured values of mining area deformations indicators has been undertaken. The topic is very important from the viewpoint of accuracy assessment of land surface continuous deformations forecasts made before beginning of mining exploitation.

Cubic splines are used for determination of average graphs of observed deformations indicators but they aren't very effective in case of curvatures. That's why in the paper use possibility of the lower orders polynomials has been tested.

Average graph of curvatures induced exploitation of longwall by use of the least squares method and a fourth order polynomial has been determined. Polynomial into 15 segments has been divided.

Values of variability coefficients of random dispersion of measured subsidence and curvatures indicate that polynomial of fourth order can be useful in approximation of average graphs of observed values of continuous deformations indicators, especially in case of curvatures (after graph division into the parts) and is very good alternative for the smoothed spline functions.

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