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# The influence of extraction field discretization on the quality of predictions of post-mining deformations

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**Abstract.** The article discusses issues related to the assessment of the quality of forecasts of continuous deformations of mining areas performed with using modern computer software. One of the elements influencing the quality of forecast is the way of discretization of the extraction field. Such division into discrete elements is necessary, among others, due to the need of integration of the influence function over the extracted area, which usually has a shape that differs from regular geometric figures, for example a rectangle. So, in the framework of this work, the influence of the size and location of elementary fields on the error rates of selected deformation indices has been analyzed. The analysis was carried out using own software called DEFk-Win, that bases on the W.Budryk - S.Knothe prediction model.

## 1. Introduction

Rapid development of information technology has left its mark on all areas of science and practice, including of course mining industry as well. It is difficult to imagine effective performing the forecast of land surface deformation state without the use of modern computer software. This software is developed in Poland in several research centers: AGH University of Science and Technology [1, 2], GIG Central Mining Institute [3], Silesian University of Technology [4, 5, 6]. It is still the subject to development and is going to be more computationally advanced and easier in everyday use. This is of course a positive phenomenon, however for common user it may create wrong impression that one does not have to think about the mathematical assumptions necessary for making high quality predictions, because in his opinion the program "performs" all these tasks automatically for him.

One of the elements influencing the quality of forecast is the way of discretization of the extraction field. Such division into discrete elements is necessary, among others, due to the need of integration of the influence function over the extracted area, which usually has a shape that differs from regular geometric figures, for example a rectangle. Considerations addressed to this issue may be found in the works of Sroka [7], Piwowarski [8], Białek [9] and Kwinta [10]. Due to limited volume of this paper they are not described here.

Some programs do not give user a direct possibility to alter this data, while others (eg the author's own software [6, 11]) allow the user to change the way of discretization by defining the size of an elementary field. On the other hand, the quality of the calculations results is influenced not only by the size of the elementary field, but also by its orientation relative to the extraction field edges. This orientation is usually defined by the direction of progress of the exploitation front, which is not always parallel to the edge of the analyzed field over the part or the whole of the longwall advance (figure 1).

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Hence, the knowledge of the influence of size and orientation of the elementary field on the quality of predicted values of deformation indices is an important issue. This topic is devoted to this article, based on analyzes made on the basis of author's own software [6, 11].

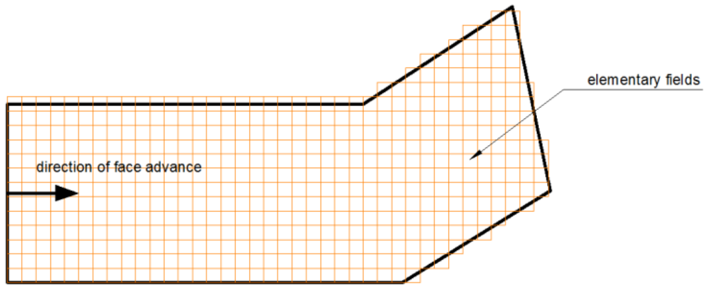



**Figure 1.** The influence of extraction field shape and the direction of advance on the discretization process.

## 2. Assumptions for performed calculations

The considerations presented in this chapter base on the latest version of own software called DEFK-Win in version 6.0, where some changes were introduced into discretization algorithms.

Program bases on the W.Budryk - S.Knothe prediction model [12, 13], which is still the most frequently used one in Polish hard coal mining industry. This model belongs to the group of so called "integral - statistic" theories, that characterize existence of "influence function". The influence function integral calculated over extracted area is a measure of subsidence for given point A(s,t) (figure 2):

$$w_A(s,t) = -\frac{a \cdot g}{r^2} \iint_P e^{-\pi \frac{(x-s)^2 + (y-t)^2}{r^2}} dP \qquad (1)$$

where:
*a* - coefficient of roof control,
*r* - radius of main influence range,
*g* - thickness of coal seam,
*x,y* - Cartesian coordinates of an elementary extraction field dP,
*s, t* - coordinates of point A in a Cartesian coordinate system,
*P* - extracted area of coal seam (extraction field),
*dP* - elementary field (discrete element).

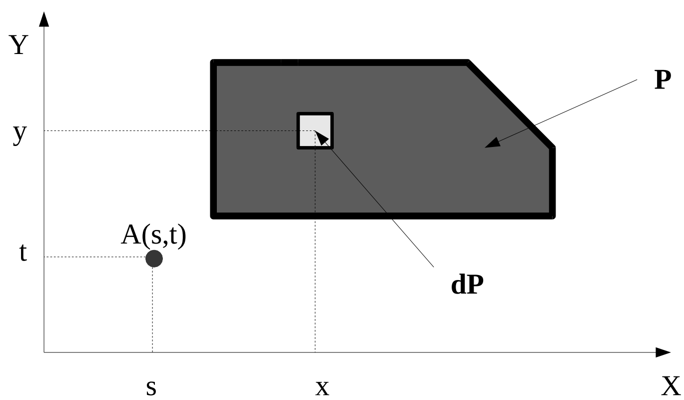
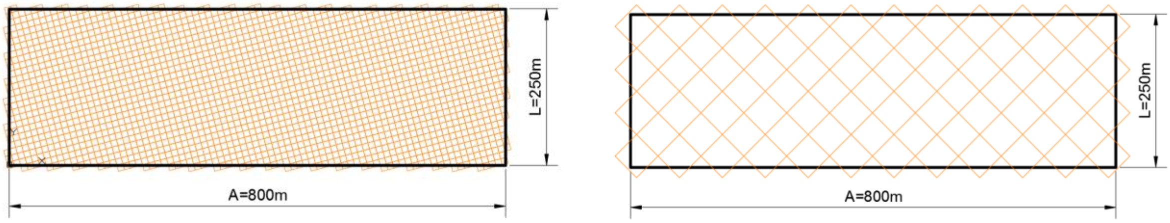



**Figure 2.** The principle of subsidence calculation in W.Budryk - S.Knothe theory.

For the purposes of assessing the influence of elementary field size and its orientation relative to the longwall edge on the quality of prediction results, a series of calculations for different combinations of some input data were performed, namely:

- 3 different widths of elementary field (discrete element): s=10m, s=25m, s=50m;
- 3 cases of different skew angle values of discrete element in relation to extraction edge : α=15º, α=30º, α=45º.

The dimensions of extraction field was assumed as: the length L=250m, total advance A=800m, thickness of extracted layer m=3.0m, depth of extraction H=500m. The sketches illustrating mentioned above elements are shown in (figure 3) and (figure 4).




a) α=15º, s=10m b) α=45º, s=50m

**Figure 3.** Exemplary divisions of extraction field into discrete elements.

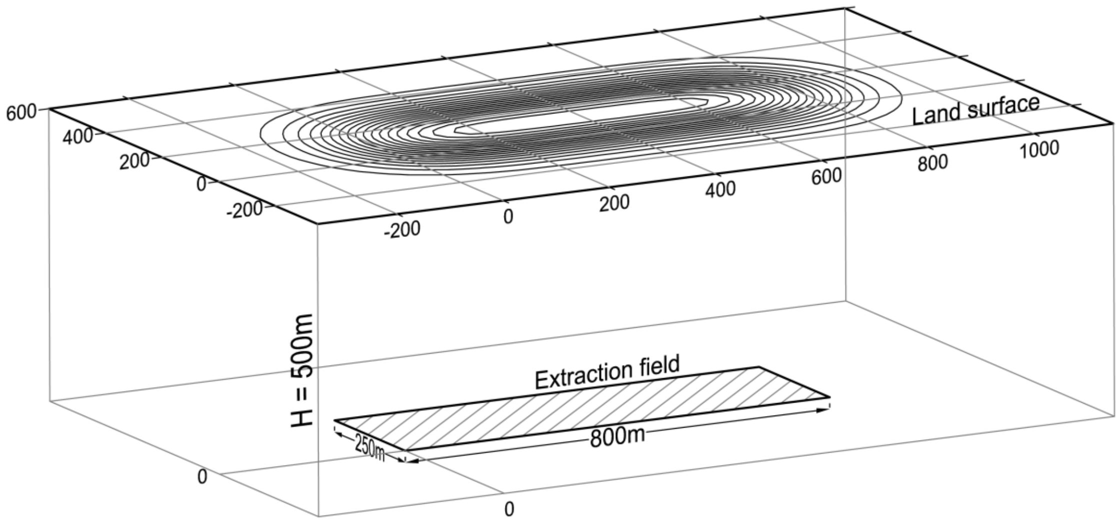



**Figure 4.** The location of considered extraction field in relation to calculating grid defined at the land surface level.

The following values of W.Budryk - S.Knothe model parameters were used:

- coefficient of roof control: *a*=0.8;
- parameter describing the influence range: tg*β*=2.0;
- proportionality coefficient of Avershin's relationship: *B*=0.32r;
- extraction boundary *d*=0m.

Calculations were conducted for a rectangular grid of calculation points covering the surface in the vicinity of the extraction field with density 25m x 25m. The size of the grid has been selected so that it

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covers the entire area subjected to mining influences. For every combination of elementary field width and skew angle, the asymptotic values of the following deformation indices were calculated: subsidence w [mm], maximum tilt $T_{max}$ [mm/m] and maximum horizontal strain $\varepsilon_{max}$ [mm/m]. The maximum values of the mentioned above deformation indices should be interpreted according to formulas (2) and (3):

$$T_{max} = \sqrt{T_x^2 + T_y^2} \tag{2}$$

$$\varepsilon_{max} = max\left( \left| \varepsilon_1 \right|, \left| \varepsilon_2 \right| \right) \tag{3}$$

where :
$T_x$, $T_y$ - tilt in directions of X, Y axes of Cartesian coordinate system,
$\varepsilon_1$, $\varepsilon_2$ - horizontal strain along principal directions.

For the purpose of assessing the quality discretization process, the "exact" values of the abovementioned deformation indices, for the exploitation field treated entirely as a rectangle, were calculated. With this approach, discretization is avoided, assuming of course that the analyzed field has the shape of a rectangle.

Based on the performed calculations, the assessment of the error of the forecast for various combinations of the above-mentioned assumptions concerning discretization of the extraction field was made. As a measure of accuracy for the given i-th point of the calculation grid, the value of the percentage error $e_i$ was determined according to the dependence :

$$e_i = \frac{v_i^{ex} - v_i^{discr}}{v_{\max}} \cdot 100\% \tag{4}$$

where :
$v_i^{ex}$ - the exact value of given deformation index calculated for the whole rectangle field without discretization,
$v_i^{discr}$ - the value of given deformation index calculated on the basis of discretized shape of extraction field,
$v_{max}$ - maximum possible value of given deformation index.

## 3. The results of performed calculations

The results of calculations are presented in the form of maps of the percentage error distribution calculated for each deformation index according to the formula (4). Due to limited volume of this work, only the error maps for 2 widths of discrete element: s=10m (the smallest) and s=50m (the biggest) are presented. These maps are shown in (figure 5), (figure 6), (figure 7). The scale of shades of gray symbolizes the error magnitude and it has been unified in all maps for given deformation index (eg. 5a-5c for subsidence error). Scale bars right to the map show the min - max part the error for given case. On every map the information is given about skew angle α and discrete element width s.

Apart from the maps, the maximum percentage error values are presented in (table 1 - table 3) for subsidence, tilt and horizontal strain accordingly.

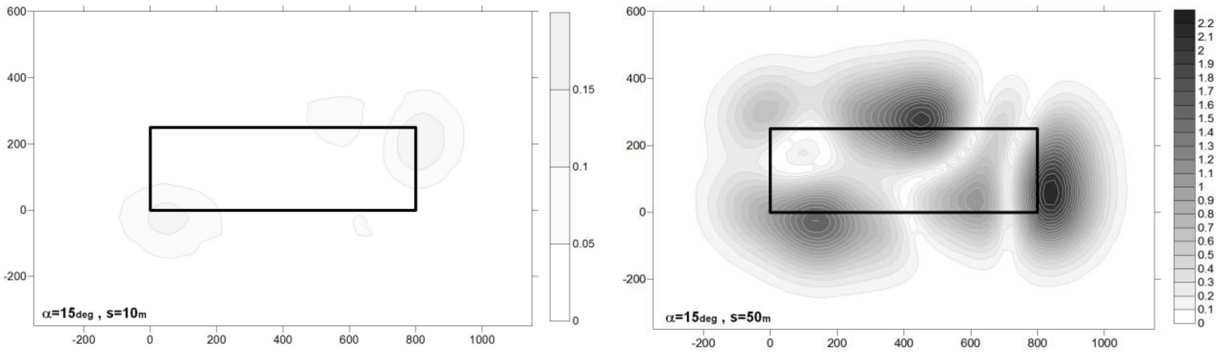


**Figure 5a.** The distribution of percentage error $e^w$ of subsidence prediction for discrete elements with skew angle α=15 degrees.

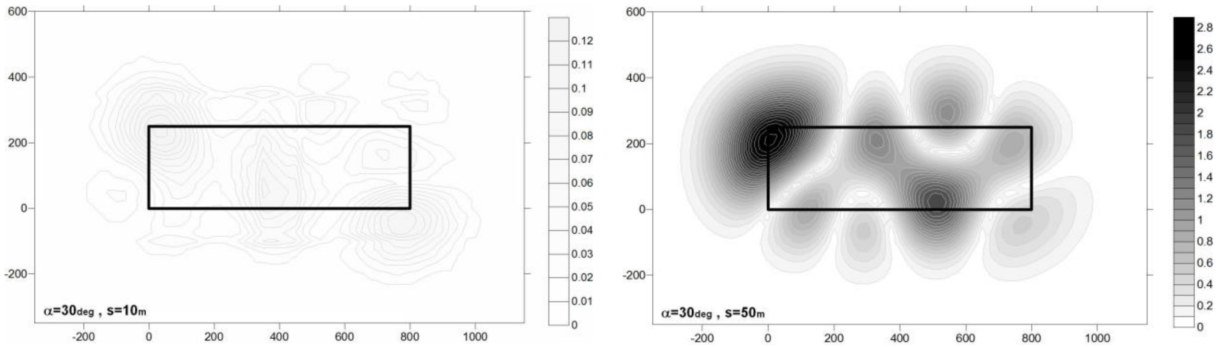


**Figure 5b.** The distribution of percentage error $e^w$ of subsidence prediction for discrete elements with skew angle α=30 degrees.

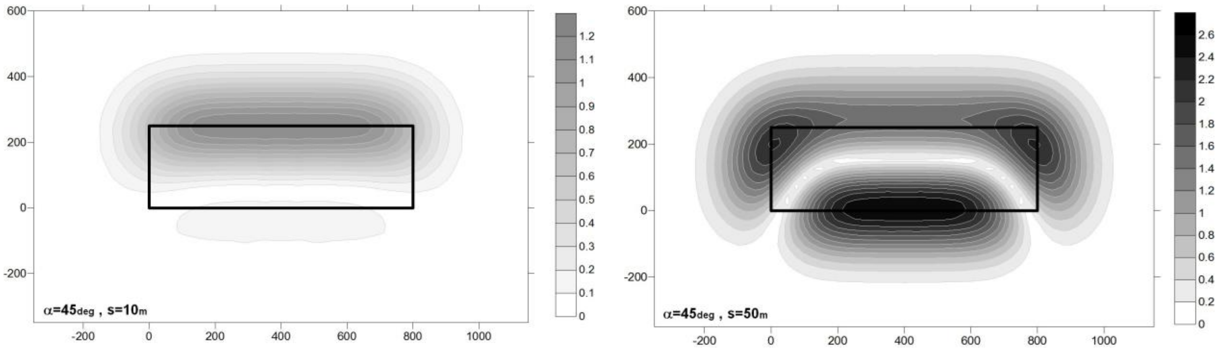


**Figure 5c.** The distribution of percentage error $e^w$ of subsidence prediction for discrete elements with skew angle α=45 degree.

**Table 1.** The juxtaposition of maximum percentage errors $e^w$ of subsidence prediction for all analyzed cases of discretization.

| Width of discrete element, s [m] | Skew angle, α | | |
|---|---|---|---|
| | 15º | 30º | 45º |
| 10 | 0.14 % | 0.11 % | 1.20 % |
| 25 | 0.45 % | 0.45 % | 1.95 % |
| 50 | 2.19 % | 2.74 % | 2.59 % |

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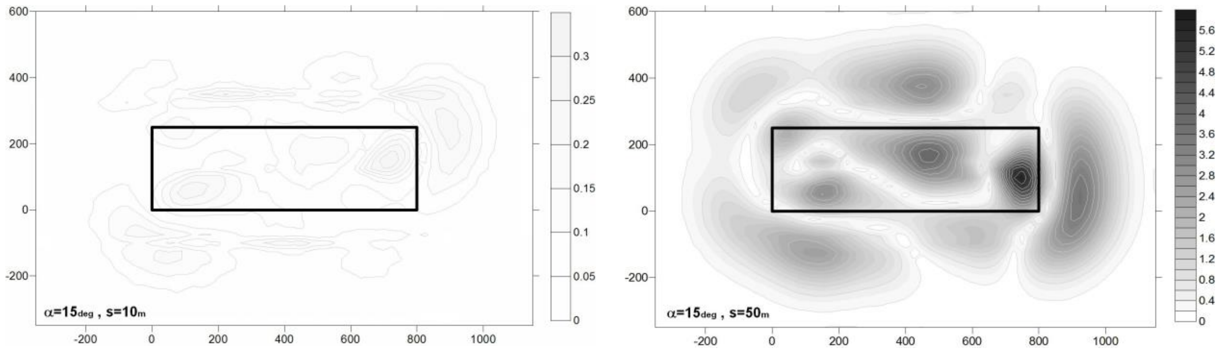


**Figure 6a.** The distribution of percentage error $e^T$ of maximum tilt prediction for discrete elements with skew angle α=15 degrees.

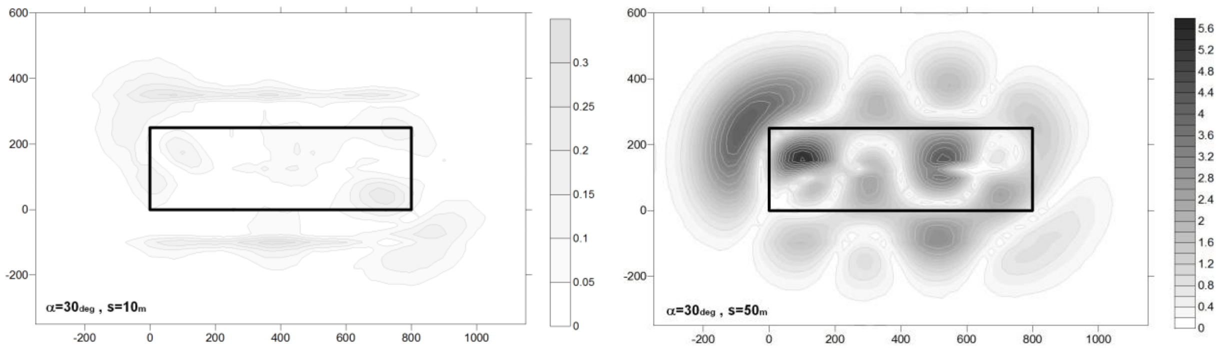


**Figure 6b.** The distribution of percentage error $e^T$ of maximum tilt prediction for discrete elements with skew angle α=30 degrees.

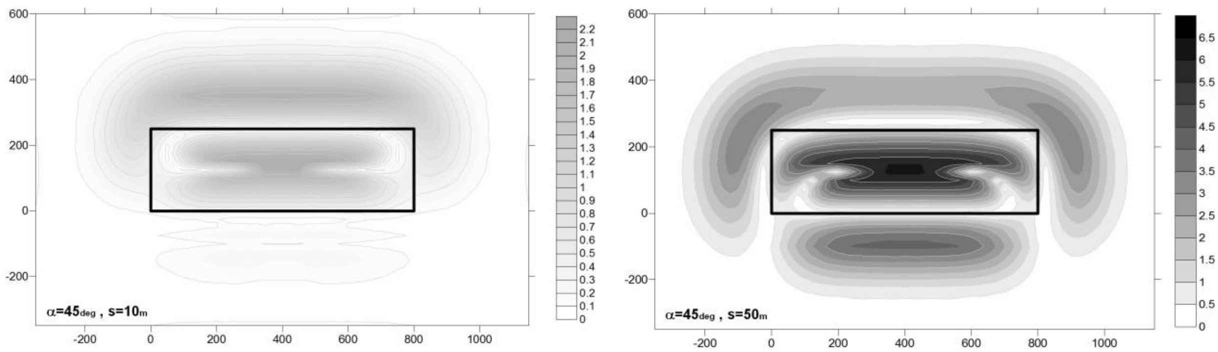


**Figure 6c.** The distribution of percentage error $e^T$ of maximum tilt prediction for discrete elements with skew angle α=45 degree.

**Table 2.** The juxtaposition of maximum percentage errors $e^T$ of tilt prediction for all analyzed cases of discretization.

| Width of discrete element, s [m] | Skew angle, α | | |
|---|---|---|---|
| | 15° | 30° | 45° |
| 10 | 0.29 % | 0.28 % | 2.08 % |
| 25 | 1.02 % | 1.10 % | 4.07 % |
| 50 | 5.77 % | 5.46 % | 6.15 % |

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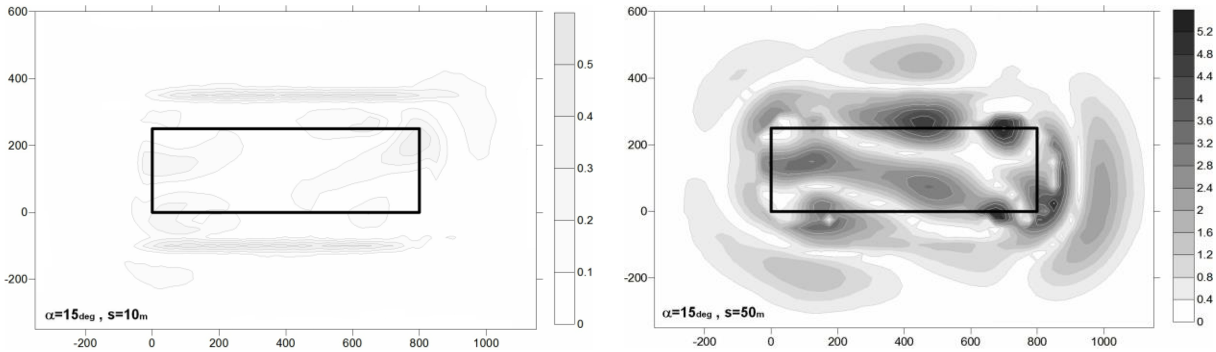


**Figure 7a.** The distribution of percentage error $e^{\varepsilon}$ of maximum horizontal strain prediction for discrete elements with skew angle α=15 degrees.

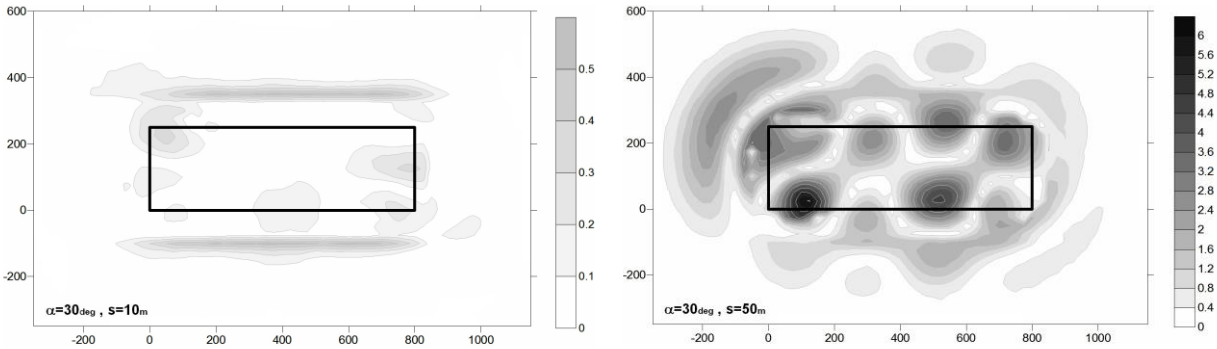


**Figure 7b.** The distribution of percentage error $e^{\varepsilon}$ of maximum horizontal strain prediction for discrete elements with skew angle α=30 degrees.

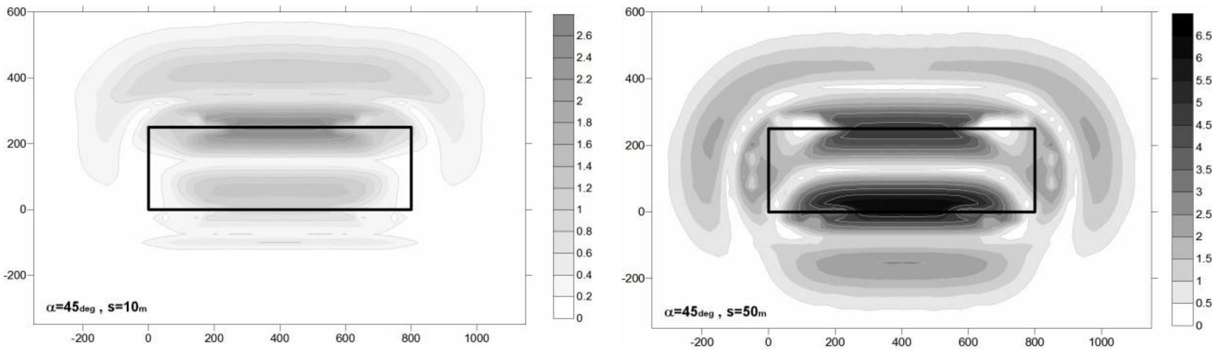


**Figure 7c.** The distribution of percentage error $e^{\varepsilon}$ of maximum horizontal strain prediction for discrete elements with skew angle α=45 degrees.

**Table 3.** The juxtaposition of maximum percentage errors $e^T$ $e^\varepsilon$ of horizontal strain for all analyzed cases of discretization.

| Width of discrete element, s [m] | Skew angle, α | | |
|---|---|---|---|
| | 15° | 30° | 45° |
| 10 | 0.49 % | 0.55 % | 2.69 % |
| 25 | 1.14 % | 1.61 % | 4.47 % |
| 50 | 5.32 % | 6.05 % | 6.43 % |

## 4. Conclusions

In the presented paper some issues have been presented concerning the impact of extraction field discretization on the quality of forecasts of underground mining influences on the land surface. Performed calculations and their results allow to draw the following conclusions:

- The values and distribution of prediction error caused by discretization of extraction field differ depending on the deformation index. The smallest errors are observed for calculated subsidence - they do not exceeded in the presented example 3% of maximum possible subsidence. Greater error values are observed for calculated tilt and even more for horizontal strain. Detailed values of maximum error values calculated according to the formula (4) are given in tables 1-3.
- On the basis of obtained error values ant their distribution it may be stated, that from the point of view of prediction quality, accepted size of discrete element should not exceed 25m, which is equal to 0.1r (radius of main influence range) for simple geometry of extraction field. It is recommended however using s=10m (approx. 0.05r) especially in cases when geometry of extraction is complicated and the depth of extraction is less than 500m (the influence of discrete element size on prediction error increases for shallow extraction)
- Space distribution of prediction error in the area influenced by given extraction is strictly related to direction in which discretization was made. So the locations of maximum error are variable - this property is strictly related to specific algorithm used in a given software. It is of course more evident, when the size of discrete element is greater.

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