Features of development process displacement of earth's surface when dredging coal in Eastern Donbas

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Abstract. The results of studies of the process of the earth's surface displacement due to the influence of the adjacent longwalls are presented. It is established that the actual distributions of soil subsidence in the fall and revolt of the reservoir with the same boundary settlement processes differ both from each other and by the distribution of subsidence, recommended by the rules of structures protection. The application of the new boundary criteria – the relative subsidence of 0.03 – allows one to go from two distributions to one distribution, which is also different from the sedimentation distribution of protection rules. The use of a new geometrical element – a virtual point of the mould – allows one to transform the actual distribution of subsidence in the model distribution of rules of constructions protection. When transforming the curves of subsidence, the boundary points vary and, consequently, the boundary corners do.

1. Introduction

Excavation of minerals from the earth is complicated by underworking surface objects. When underworking these objects and when planning the construction in mining areas, it is necessary to know the values arising during the mining of deformations of the ground surface. The magnitudes of displacements and deformations are calculated according to two methods, adopted in Russia. These are the method of standard curves and the probabilistic method [1-10]. The standard curve method is used when there are calendar plans for mining development, and the probability one – in their absence. The magnitudes of displacements and deformations, calculated according to the method of typical curves, are called expected, and according to the probabilistic method – probable.

The subject of the research is the angular parameters of the displacement and distribution of earth surface subsidence in the trough by using the method of standard curves. The applied method of standard curves are characterized by a certain level of error, which is currently insufficiently studied. The calculation error is taken into account through the introduction of expected and probable values of the reserve factors (overloading). The expected and the probable values are multiplied by these coefficients, and further, when selecting the measures for protection of undermined objects, thus obtained calculated values are accepted.

The higher the calculation error, the greater the safety factor, therefore, is the greater the calculated value, which is closely related to the expenditures on measures for protection of surface objects. Reduction in error calculation leads to the decrease of the safety factor and the reduction of material resources when addressing the issues of underworking and protection of surface facilities. The issues, associated with improving the accuracy of determining the angular parameters of the displacement and
distributions of subsidences in the trough, both from a single lava and from the adjacent longwalls, currently remain unsolved.

2. Materials and methods
The curve of land subsidences is the basis, used to calculate the curves of the slope, curvature, horizontal displacement and relative horizontal deformations. Much attention has been paid to calculation of soil subsidence by Russian and foreign scientists. They have developed methods, which are applied in the calculation of deformation of mining objects. They are considered to be empirical methods, methods based on distribution functions and theoretical models. Our study of the curves of land subsidence is based on field data observations in the coal fields of the Eastern Donbass. Processing the results of measurements of soil subsidence is workable with the use of new methods for the determination of the boundaries of the trough displacement. Figure 1 shows a vertical section across the strike of reservoir \( l_d \) by adjacent longwalls No. 109 and No. 111 of «Almaznaya» well (Gukovsky coal district of Rostov region).

![Figure 1. The formation of the trough of displacement in time](image)

By the subsidence of 15 mm, based on the last observation (28.04.08), let us define boundary
corners, which are: \( \beta_0 = 84.9^0 \) and \( \gamma_0 = 77.1^0 \). The measured angle of maximum subsidence is \( \theta = 90.8^0 \). According to the rules of protection, \( \theta = 90^0 - 0.8\alpha = 83.6^0 \), the difference of the angles \( \theta \) is equal to \( +7.2^0 \). The above-mentioned deviation between the calculated and measured angles of maximum subsidence is explained by the influence of adjacent longwall No. 109 on the earth’s surface. Let us install the form of unit curves of subsidence in semi-troughs by the fall and revolt of the reservoir, taking the point with the subsidence of 9 mm as the boundary. Isolated curves in semi-troughs of displacement can be represented in the form of the Gauss function:

\[
S(z) = e^{-az^2}
\]

As a result of processing, one will receive expressions of isolated curve:

In the semi-trough by the fall \( S(z) = e^{-2.48z^2} \) ; \( (1) \)

in the semi-trough by the uprising \( S(z) = e^{-3.39z^2} \) \( (2) \)

Figure 1 shows a typical curve of the rules of protection, a single curve of subsidences in semi-trough by the fall and a single curve of subsidences in semi-trough by the uprising, which do not correspond to each other.

![Figure 1. Typical curve of the rules of protection](image)

**Figure 2.** Comparison of single subsidence curves with the model curve of safety rules

It is established that the determination of the boundary of the trough according to the criterion \( S(z) = 0.03 \) allows one to bring closer the actual distributions of soil subsidences. Let us select the boundary points of the displacement on curves (1) and (2) according to the criterion of relative subsidence of 0.03. The expression of the converted single curve will look like this:

\[
S(z) = e^{-3.57z^2}
\]

Let us compare the single curves with each other and with the model curve of safety rules. It can be seen that the individual curves of subsidences by the fall and revolt of the reservoir are virtually identical in Figure 3. However, they differ from the typical curve of soil subsidence of safety rules (1998).

Let us install edge angles \( \beta_0 \) and \( \gamma_0 \) using boundary criterion \( S(z) = 0.03 \). The boundary angle by the uprising of the reservoir will be \( 75.9^0 \) and by the fall — \( 82.5^0 \).

Let us calculate edge angles \( \beta_0 \) and \( \gamma_0 \) using a new geometric element – a virtual point, which allows one to transform the actual singular curves into the model curve of safety rules. The result of
the calculation of the coordinates of the virtual points will be \( z_{VT} = 0.45 \) and \( S(z_{VT}) = 0.366 \). Using these coordinates let us get a transformed single curve that looks like \( S(z)_{T} = e^{-5.96c^2} \). Let us compare the transformed curve with the curve of the safety rules (Figure 4).

![Figure 3](image3.png)

**Figure 3.** Comparison of actual single curves and curve of safety rules (1998)

![Figure 4](image4.png)

**Figure 4.** Comparison of transformed curve of subsidence by fall with model curve of safety rules of constructions

### 3. Discussion

The greatest deviations between estimated and actual boundary angles are observed from the side of dip. This is explained by the fact that the rock was first exposed to lonwall No. 111. The boundary area from the first fall is characterized by uplift, as if pinched from one end of the beam, and then by the vertical offsets. From the uprising of the layer, the earth's surface was first subjected to the influence of overlying lonwall No. 109, and then the influence of longwall No. 111. This dual influence is reflected in the nature of vertical displacement in the boundary area of the uprising of the reservoir. In this case, subsidence of the earth's surface in the direction of the goaf dominate. The actual angle of maximum subsidence \( \theta = 90.8^0 \) does not correspond to the calculated angle of
maximum deposition $\theta = 83.6^\circ$ of the safety rules.

The actual angle is greater than the estimated one by $7.2^\circ$. This discrepancy is explained by the gravity of the vector of the maximum subsidence to two longwalls (No. 111 and No. 109), at that, longwall No. 111 has a greater impact on this vector. The actual distribution of soil subsidence in the fall and revolt of the reservoir at the same boundary subsidence of 9 mm are different from each other. The use of a boundary criterion $S(z) = 0.03$ allows us to bring together these distributions. However, the convergence of the actual distribution differs from the model curve of safety rules. The use of a new geometric element of the trough – a virtual point allows bringing closer the actual distributions of subsidences with the distribution of safety rules. This changes the boundary corners.

4. Conclusion

The task of improving the accuracy of forecast parameters of the displacement of the earth's surface is solved by the use of new methods of data processing of instrumental measurements at the observation stations laid over the mine workings of coalmines. At that, a method of approximation, using the Gauss function, the new boundary criteria, the relative subsidence of 0.03, a method of determining the trough boundaries by determining it by means of the new geometric element – a virtual point – are used. In the work, the curves of the investigated land subsidence and angular parameters of the displacement are studied according to the observations at the mine (East Donbass).

The curves of subsidence were considered in semi-troughs by the fall and revolt of the reservoir, which are limited by the point of maximum subsidence and the boundary point. It should be noted that the maximum subsidence is most pronounced in the curve; therefore, it is defined much more precisely, compared to the boundary point. The boundary point is set according to the currently accepted boundary criteria that lead to a significant variation in edge angles and lengths of the displacement. There is a quite significant interval, within which with certain probability the calculated point can be. This is so-called error of the estimated location points. The paper demonstrates that the application of new methods of instrumental measurements processing allows one to extend possibilities of the method of standard curves towards the improvement of the accuracy of the calculation, and thereby to reduce the cost on measures for the protection of underworked objects.

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