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Numerical modeling of the task of support tension near cleaning

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ABSTRACT
The problem of stresses and displacements of an oblique-layered massif near a mine working, which is located entirely in one of the rock layers, is considered when the mine is tested by the effects of cleaning works in a coal seam. This effect is taken into account by specifying a system of normal and shear forces at the boundary of the lower layered half-plane with a hole. The problem is solved by imposing the complex Kolosov – Muehehelishvili potentials and Fourier integral transforms. Based on the method of Fourier integral transforms in the theory of elasticity, a system of integral with respect to normal and tangential contact forces is obtained for the case of two different layered half-surfaces. In this work, systems of integral equations are obtained in solving the problem of the reference pressure on an obliquely buried coal seam near the mine working. In this paper, the method of integral Fourier transforms in the theory of elasticity, obtained a system of integral with respect to normal and tangential contact forces for the case of two different layered half-surfaces.

Keywords: massif, drift, reference array, complex potential, slaughter, model, coal seam, integration nodes, half- plane, Simpson's formula.

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Introduction

A new analytical description of the reference pressure on the coal seam, taking into account the variable ductility (stiffness) of the seam, which decreases (grows) with distance from the bottom, allows us to conduct research in the framework of elasticity theory without resorting to representations of the theory of plasticity.

The mechanism of the influence of the reference pressure during the overwork of the coal seam with pillars by the drop on the field drift differs significantly from the mechanism during the development of the seam along the strike; the development and distribution of stresses in the formation soil around the field drift are of a staged nature, changing in the dynamics of the treatment works.

Comprehensive studies of the stress state of field workings in the dynamics of the manifestation of reference pressure during the development of strata by pillars by fall were carried out by B. B. Atymtaev, the theoretical calculation of which was based on the finite element method [[1], [2]].

These studies indicate that so far many questions have not been fully clarified: the mechanism of interaction between treatment and preparatory workings during mining by pillars in the fall.

In the work, systems of integral equations are obtained when solving the problem of support pressure on an oblique buried coal seam near the mine. It is assumed that the inclined-layered mountain massif the rectangular mining length $2a$ was carried out at the full capacity of the coal seam h_p (Figure 1). The top and bottom of the formation are modeled by complex half-planes I-2 and 3-4, representing heterogeneous rocks of different thicknesses of the immediate.

Experimental part

Due to the geometric symmetry of the medium relative to the axis, the problem can be divided into symmetric and antisymmetric parts (compression and shift at infinity). For a symmetric task $y > a$, the system of integral equations is as follows:

$$\frac{1}{c^2}\left[K^\infty + K_1(y)\right]f^B(y) + \frac{a_{11}^\infty}{\pi}\int_a^\infty f^B(t)\ln\left|y^2 - t^2\right|dt + \int_a^\infty f^B(t)L_{11}(t,y)dt -$$
$$- a_{12}^\infty\int_y^\infty g^B(t)dt + \int_a^\infty g^B(t)L_{12}(t,y)dt = L_{13}(y) -$$
$$- \frac{p^0 a}{\pi}a_{11}^\infty\left[\frac{y}{a}\ln\frac{y-a}{y+a} - \ln\left(y^2 - a^2\right) + 2\right] - \frac{1}{c_2}K_1(y)p^0, \quad (1)$$
$$\frac{1}{c^2}\left[S^\infty + S_1(y)\right]g^B(y) + \frac{a_{21}^\infty}{\pi}\int_y^\infty f^B(t)dt + \int_a^\infty f^B(t)L_{12}(y,t)dt +$$
$$+ \frac{a_{22}^\infty}{\pi}\int_a^\infty g^B(t)\ln\left|\frac{y-t}{y+t}\right|dt + \int_a^\infty g^B(t)L_{22}(t,y)dt = L_{23}(y)$$

Here $f^B(y)$ $g^B(y)$, additional normal and tangential contact stresses acting on the edges of layered half-planes. Their behavior and size in the vicinity of the mine is determined by the properties of the coal seam, its compliance [[3], [4], [5]].

a_{ij}^∞, K^∞ - constant depending on the elastic characteristics of the layers and the formation, K^∞ can go to zero. $L_{ij}(t,y), L_{ij}(y)$ - smooth continuous functions, decreasing with increasing variable. $K_1(y), S_1(y)$ - monotonically decreasing continuous functions characterizing the deformability of the Winkler coal seam during compression and shear, respectively. p^0, τ^0 - constants characterizing the basic stress state of the rocks.

Equations of type (1), containing a variable coefficient in front of an unknown function, are assigned to Fredholm integral equations of the 3rd kind. For the reduced system, in which integration is carried out on a semi-infinite interval, moreover, with a variable lower limit, there are no studies in the literature.

Relatively $f^B(y)$ $g^B(y)$, we know that they are continuous, at large they decrease as y^{-2}, and in the vicinity the production is limited. An exception is a special case (the reservoir is absent or it is not compressible) - then the stresses tend to infinity at $y \to a$.

The authors' attempt to approximate $f^B(y)$ $g^B(y)$ by Laguerre polynomials with subsequent reduction (1) and the infinite system of linear algebraic equations (BSLAU) did not lead to success. Received BSLAU was poorly conditioned. This, obviously, is explained by the fact that $L_n(y)e^{-y}$ they are not very suitable for approximating the desired functions.

System (1), therefore, was solved numerically by the Krylov-Bogolyubov method, by piecewise approximation of the desired functions by quadratic trinomials. Unknown, accepted $f^B(t_k)$ $g^B(t_k)$.

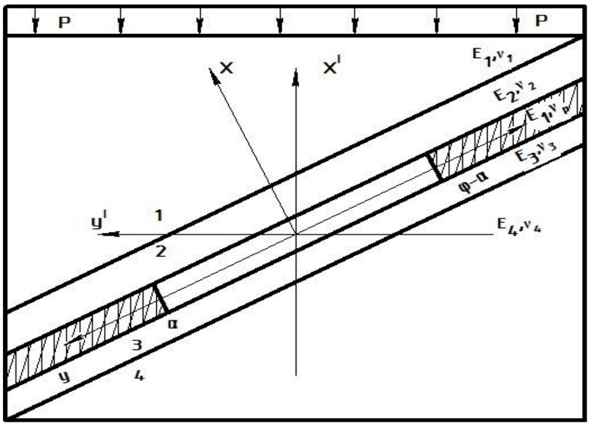


Figure 1. The name of the figure model of the array with sewage treatment

Integration nodes were assigned as follows. The value of the extreme, largest node t_{2M+1} is chosen so that it can be put with the accepted accuracy $f^B(t_{2M+1}) = 0,$. The interval $\left[t_1, t_{2M+1}\right]\left(t_1 = a\right)$ is divided into pairs equal and increasing in arithmetic progression segments. [[5], [15]] Wherein

$$t_{2k+1} = a + u_1 K + d\,\frac{(K-1)K}{2},$$
$$t_{2k} = a + u_1\left(K - \frac{1}{2}\right) + \frac{d}{2}\left(K-1\right)^2, K = 1, M,$$

where u_1 is the first member of the arithmetic progression, and $d = 2\left(\frac{t_{2M+1} - a - u_1 M}{(M-1)M}\right)$ its denominator.

A variable step is necessary for anyone to ensure uniform accuracy during integration. At the beginning of integration t_k, it's close to a, the desired functions $f^B(t_k)$ $g^B(t_k)$ change quickly and a smaller step is needed here than at a distance, where they flatten out and decrease asymptotically [[6], [7], [8]].

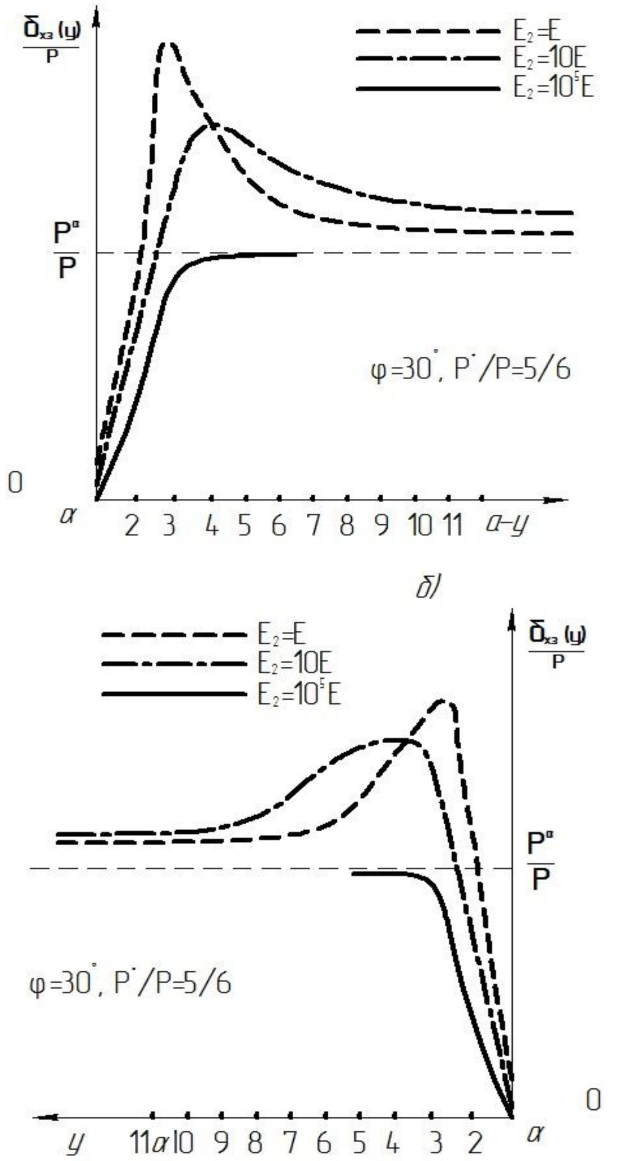


Figure 2. The name of the figure plot of reference pressure at different roof stiffness:
a) - uprising; b) - in the fall.

Replacing the integrals with sums according to the Simpson formula for unequal divisions $y_n, n = 1, M$ and writing down each of the equations for the nodes, we obtain a SLAE of order 4M with respect to unknowns, $f^B(t_k)$, $g^B(t_k)$. When calculating the coefficients of the matrix of the system, all the integrals containing the logarithmic terms were calculated analytically, taking into account the fact that, $f^B(t_k)$ $g^B(t_k)$ on the interval, they are approximated by quadratic trinomials. Since the logarithmic singularity is integrable, in the expressions obtained it is easy to pass to the limit at those nodes where $y_n = t_{2M+1}$ the singularity arises. In integrals with a variable lower limit, if the lower limit fell in the middle of the pair segment y_{2m}, then the corresponding member of the sum was also calculated analytically [[9], [10],[11]].

Compiled a double precision calculation program. The system of the hundredth order $(M = 25)$ was solved, while

$$t_{2M+1} = 11a, \ a = 1, \ u_1 = 0{,}02$$

$$K_1(y) = \alpha_0 e^{-\alpha_1(y-a)}, S_1(y) = \delta_0 e^{-\delta_1(y-a)} \qquad (2)$$

In (2), for physical reasons, it is accepted, $\alpha_0 = \delta_0 = 100$. $\alpha_1 = \delta_1 = 5$ which corresponds to the compliance of the crushed near the formation.

The system turned out to be well-conditioned. She becomes vyrazhenny only for the mentioned special case. Even for him $t_1 = 1{,}0005$, putting the received results coincided well with the exact solution. At the nodes near the gap, where large voltages coincided, the integers coincided, and with increasing accuracy the accuracy increased - tenths coincided, then hundredths coincided [[12], [13], [14]].

It is appropriate to note here that in all cases the conditions were checked during the invoice process:

$$p^0 a = \int_a^\infty f^B(t)dt \ , \ \tau^0 a = \int_a^\infty g^B(t)dt$$

Integration was carried out according to the Simpson formula to the node t_{2M+1}. The coincidence of such integral characteristics occurred to the nearest hundredth.

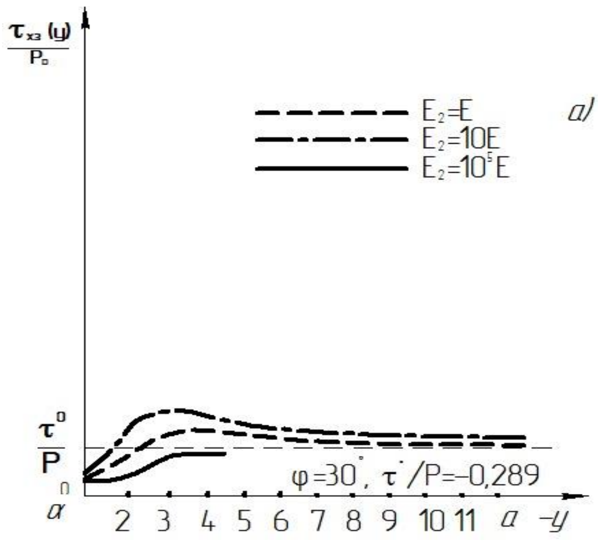
Results and discussion

The described model of the net working out, taking into account the elastic - plastic properties of the coal seam, by introducing variable bed coefficients of the Winkler base, taking into account the angle of inclination of the layers and their heterogeneity, after numerical implementation, provided such values of the reference stresses that are completely consistent with the physical concepts of reference pressure and qualitatively coincide with field observations.

Figures 2 and 3 give support for the total normal and tangential contact stresses obtained after the numerical implementation of symmetric and antisymmetric problems at an angle of inclination of the layers $\varphi = 30^0$.

$$\nu_j = \nu_p = 0{,}25. \ E_1 = E_p = E_4 = E,$$
$$E_3 = 10^5 E, \ E_2 = E, \ 10E, \ 10^5 E,$$
$$h_p = a = 1, \ h_1 = h_2 = 20a.$$

The proposed model of the mine working, taking into account the elastic-plastic properties of the formation, the angle of inclination of the layers and their heterogeneity, after numerical implementation, gave such values of the reference stresses that are in full agreement with the physical ones presented about the reference pressure [[15], [16], [17], [18], [19], [20]].



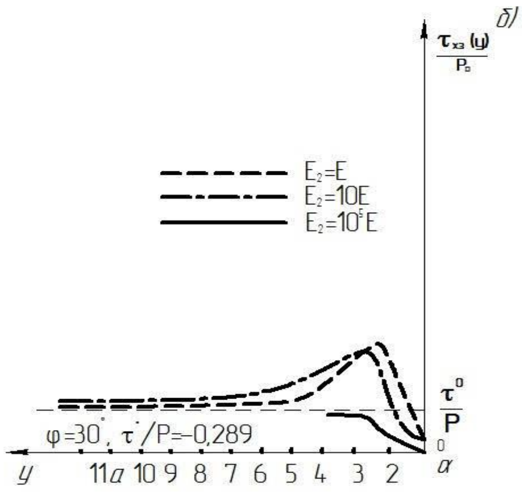


Figure 3. The name of the figure plot of the reference shear stresses of different reservoir flexibility: a) - uprising; b) - in the fall.

Conclusions

These methods are purposeful to use, it is necessary to link them with a specific system for developing coal seams and methods for preparing a minefield. Some conclusions on the choice of the location of field drifts and their maintenance from the point of view of the factor "stress state" are recommended for implementation in mines "Karagandaugol."

Thus, the developed model of drift embedded in a layered medium, in the zone of influence of the treatment space, allows one to fully study the picture of the stress-strain state of rocks around the drift up to treatment output.

Conflict of interests

On behalf of all authors, the correspondent author declares that there is no conflict of interests.

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Штабельдегі көмірді өздігінен қыздырудың математикалық моделі

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ТҮЙІНДЕМЕ

Бұл мақалада шекаралық және бастапқы жағдайларда штабельдің қуыстарындағы оттегінің *C* көлемдік үлесі мен көмірдің өздігінен қызуының t температурасына қатысты жылу және газ алмасу процестері екінші ретті сызықты емес екі дифференциалдық теңдеулер жүйесімен сипатталатын көмірдің өздігінен қызуының математикалық моделі келтірілген. Дифференциалдық теңдеулерді құрастыру кезінде штабельдегі көмірдің өздігінен қызуы және өздігінен жанудың пайда болуы, оның ауамен жанасу бетіне жақын орналасқан және оттегінің әсер ету аймағы деп аталатын қатардың мөлшерімен салыстырғанда салыстырмалы түрде аз қабатта байқалатындығы ескеріледі. Бұл математикалық модельде құрастыру кезінде көмірдің орнықтылығын сипаттайтын *Ф* - жылу шығарудың меншікті қуаты параметрінің, көмірдің өзіндік қыздыру процесіне әсері ескерілді. Дифференциалдық теңдеулерді құрастыру кезінде температура мен өткізгіштік, диффузия коэффициенті, штабельдегі көмірдің меншікті жылу сыйымдылығы, сусымалы тығыздық, тотығудың жылу әсері, қатардың бос болуы, жылу шығару қуатының экспоненциалды өсуінің температуралық коэффициенті сияқты физикалық параметрлер қолданылды. Осы математикалық модельді іске асыру үшін өлшемсіз айнымалылар енгізілді, бұл тор әдісін қолдануға мүмкіндік береді. Алынған нәтижелерді талдау келесі нәтижелерді алуға мүмкіндік берді: уақыт өте келе температура профильдерінің өзгеруі; қатардағы оттегі концентрациясының профильдерінің уақыт өте келе өзгеруі; жылу шығарудың меншікті қуатының қатарындағы температура профиліне әсері, температураның жоғарылауымен жылу шығару қарқындылығының экспоненциялдық өсуін сипаттайтын параметрдің температура профиліне әсері. Лыковтың диффузия коэффициентіне пропорционалды критерийлері және Нуссельттің тиімді жылу өткізгіштігімен және көмірдің тиімді температуралық өткізгіштігімен байланысты критерийлері көмірдің өздігінен қызуының динамикасына ең көп әсер ететіні анықталды. Алынған нәтижелер қатардың өзіндік қызуы бір жағынан ауа оттегісінің қарқынды енуімен, ал екінші жағынан әлсіреген жылу қабылдағышқа байланысты деп айтуға мүмкіндік береді. Өзіндік қыздыру және өзіндік қыздырудың отқа ауысуы жылу соққысының күшеюі кезінде пайда болатын турбулентті диффузияның пайда болуымен байланысты, оның әсері штабельдің бетіне перпендикуляр бағытта күшейуі мүмкін.

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Численное моделирование задачи об опорном давлении вблизи очистной выработки

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АННОТАЦИЯ

В настоящей работе рассмотрена задача о напряжениях и смещениях наклонно-слоистого массива вблизи горной выработки, целиком расположенной в одном из породных слоев, когда выработки испытывает влияния очистных работ в угольном пласте. Это влияние учитывается путем задания системы нормальных и сдвигающих усилий на границе нижней слоистой полуплоскости с отверстием. Цель исследования: определить напряженное состояние слоистой полуплоскости, ослабленной отверстием круговой формы при заданных на границе произвольных нагрузках, оценить распределение контактного напряжения на полуполосах, разведенных вдоль продольной оси и сжатых слоистыми полуплоскостями, найти напряженно состояние анизотропной плоскости вблизи свободного отверстия произвольной формы при заданных напряжениях на бесконечности и на контуре сближенного продолговатого отверстия, задача решается методом наложения комплексных потенциалов Колосова – Мусхелишвили и интегральных преобразований Фурье. На основе метода интегральных преобразований Фурье в теории упругости, получена система интегральных относительно нормальных и касательных контактных усилий для случае двух разнародных слоистых полупоскостей. В работе получены системы интегральных уравнений при решении задачи об опорном давлении на наклонно залегающий заглубленный угольный пласт вблизи очистной выработки.

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