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ANGLES OF TOTAL SHIFTS AND ANGLES OF MAXIMUM CROP DURING DEVELOPMENT OF FACES DIAGONAL TO SEAM STRIKE DIRECTIONS

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When predicting deformations and determining measures to protect underworked objects, angular parameters are used: the boundary angles, the angles of total shift, the angle of maximum crop. The values of these angular parameters are given in the normative documents, but only for sections across and along the strike of the formation. However, at present, longwall face mining is mainly being carried out along a diagonal direction to the strike of the formation. In connection with this, the determination of the values of the angular parameters for such conditions is a topical task.

The method of determination and the analytical dependences of the angles of total shifts and angles of maximum crop in sections of the longitudinal and transverse axes of coal-mining faces developed along diagonal directions to the strike of the formation are proposed. These angular parameters are used for prognosis of deformations of the earth's surface and for determining the characteristic zones of influence of mine workings on the local places.

Key words: angles of total shifts, angles of maximum crop, diagonal directions of contour of working, deformation of earth surface

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Introduction. Angular parameters are used to determine the boundaries of the zones of mine workings influence on the earth's surface and predict the deformations of the latter when working and protecting buildings, structures and natural objects [8, 12, 15]. Their normative values are determined by many years of research by many authors [2, 4, 6, 9-11, 13, 14] and are given in the «Rules for underworking ...» [1] only for the main cross-sections of the trough across and along the strike of the formation.

Currently, longwall faces are often mined along diagonal directions to the strike of the formation [5, 7]. The main sections of the trough should be considered cross sections along the longitudinal and transverse axis of a working. Therefore, the determination of the angular parameters in these sections is very important.

The analytic dependences of the boundary angles in cross sections, which are diagonal to the strike of the formation, were published by the authors of this article in [3]. Therefore, in this paper only the angles of total shifts and the angles of maximum draw are considered.

Methods for determining angles of total shifts and angles of maximum draw. Let us consider the coal seam working ($\alpha = 20^\circ$) developed by «diagonal» longwall face in the contour I-II-III-IV (Fig.1). Let's assume we will replace the seam cutting area with short faces (with a slight discontinuity in time) along the strike (Fig.1, *a*) and across the strike of the formation (Fig.1, *b*) with the stopping of the bottom lines along the contour specified above. Then, according to the «Rules of underworking ...» [10], we get a flat bottom of the trough, bounded by lines 2, 3, with boundary points E_{ai} , E_{bi} on the axes of the «diagonal» face (where i is the number of points). In this case, the distances $A_iE_{ai} \neq A_iE_{bi}$. Now the problem is reduced to finding the average weight points E_i . This principle is also the basis of the methodology proposed here.

Since the lines at the angles Ψ and Θ have a constant angle of inclination in the bedrock and incrop deposits, in order to simplify the calculations, the process will be considered as occurring only in bedrock, assuming the depth seam incrop line equal to ± 0.0 . Let us draw conditional advance of the «diagonal» face line to seam incrop point (Fig.2, *b*). Then M_1 point will be both the pit limit and flat bottom of the trough, since the depth $H = 0$.

From Fig.2, *b*, the seam inclination angle along the production line I-II and the distance A_1M_1 are:

$$\operatorname{tg} \alpha'_{I-II} = \operatorname{tg} \alpha \cdot \sin \varepsilon, \quad A_1M_1 = \frac{H_{A_1}}{\operatorname{tg} \alpha \cdot \sin \varepsilon},$$

where α , ε , H_{A_1} – seam inclination angle, acute angle between longitudinal axis of working and seam strike line, seam depth at point A_1 .

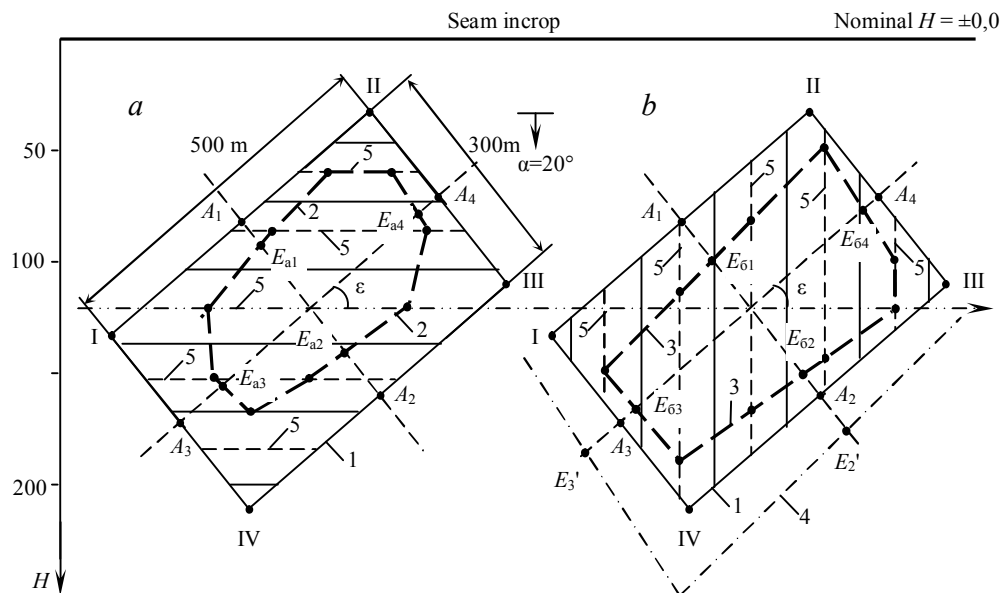


Fig. 1. Layout of «diagonal» face with seam inclination angle of $\alpha = 20^\circ$ with conditional replacement of area with short faces along the strike (a) and across the strike (b) of the formation

1, 2, 3 – pit limit points: coal seam mining with «diagonal» face; flat bottom of trough with conditional replacement of are with short faces along the strike and across the strike of the formation; 4 – when $\alpha > 90^\circ - \Psi_1$ the trough flat bottom boundary of angle Ψ_1 (with replacement of faces across the strike) is set outside the contour of «diagonal» face; 5 – longitudinal axes of short faces; ε – acute angle between longitudinal axis of «diagonal» face and seam strike line; A_1-A_2, A_3-A_4 – lateral (short) and longitudinal (long) axes of the face

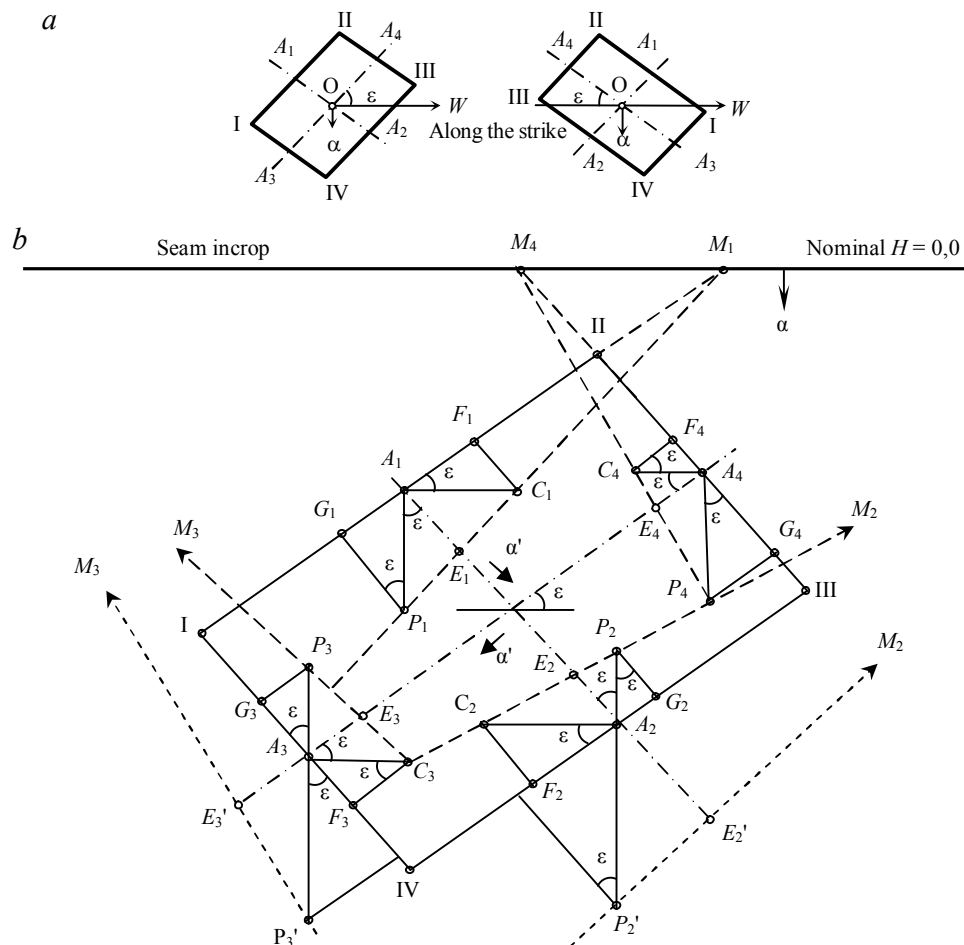


Fig. 2. Design layout for determining angles of total shifts in axial cross-sections of «diagonal» face:

a – orientation pattern of «diagonal» face along the seam strike line; b – a pattern of geometrical relations between angle and linear parameters of horizontal alignment. Also see p. 300

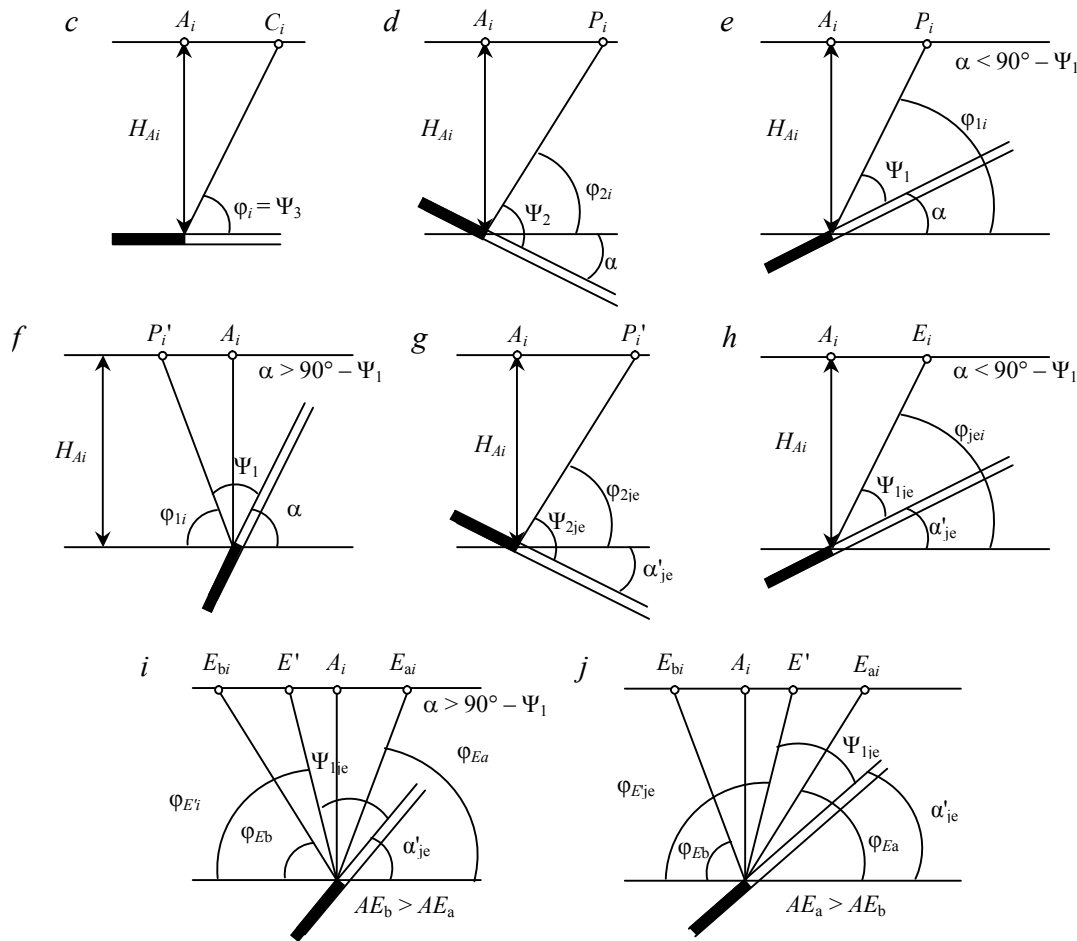


Fig. 2. Ending. Design layout for determining angles of total shifts in axial cross-sections of «diagonal» face:

c-j – the same in vertical cross-sections; A_i, C_i, P_i, P'_i – boundary points (where i – point number): contours of «diagonal» face at axial lines; flat bottom of trough, determined by angle Ψ_3 (with conditional replacement with faces along the strike); the same with angles Ψ_1, Ψ_2 (with replacement of faces across the strike) with $\alpha < 90^\circ - \Psi_1$; the same for angle Ψ_1 (when replacing faces across the strike) with $\alpha > 90^\circ - \Psi_1$; $E_i, E'_i, E_{ai}, E_{bi}$ – boundary points of flat bottom of trough at axial lines of «diagonal» face: with $\alpha < 90^\circ - \Psi_1$; with $\alpha > 90^\circ - \Psi_1$ and replacement with faces along the strike; with $\alpha > 90^\circ - \Psi_1$ and replacement with faces across the strike; $\alpha, \alpha', \varepsilon$ – angles: seam inclination; seam inclination at axial cross-sections of «diagonal» face; acute angle between longitudinal axis of the face and seam strike line; $\Psi_1, \Psi_2, \Psi_3, \Psi_{1j}, \Psi_{2j}, \Psi_{1e}, \Psi_{2e}$ – angles of total shifts at cross-sections across and along the strike and in cross-sections of «short» and «long» axes of «diagonal» face; $\varphi_1, \varphi_2, \varphi_3, \varphi_{1j}, \varphi_{2j}, \varphi_{1e}, \varphi_{2e}$ – angles of inclination of lines corresponding to angles of total shift and linear parameters of horizontal alignment

Let us determine the distance A_1E_1 (between working boundary and flay bottom of trough boundary) separately with conditional replacement of face mining along the strike (a) and across the strike (b) accordingly in left and right columns:

a)

$$A_1C_1 = \frac{H_{A_1}}{\operatorname{tg}\varphi_3} \quad (\text{Fig.2, c}),$$

$$F_1C_1 = \frac{H_{A_1} \sin \varepsilon}{\operatorname{tg}\varphi_3} \quad (\text{Fig.2, b}),$$

$$A_1F_1 = \frac{H_{A_1} \cos \varepsilon}{\operatorname{tg}\varphi_3},$$

$$A_1E_{1(a)} = \frac{A_1M_1 \cdot F_1C_1}{F_1M_1},$$

$$A_1E_{1(a)} = \frac{H_{A_1} \sin \varepsilon}{\operatorname{tg}\varphi_3 - \operatorname{tg}\alpha \cdot \sin \varepsilon \cdot \cos \varepsilon};$$

b)

$$A_1P_1 = \frac{H_{A_1}}{\operatorname{tg}\varphi_2} \quad (\text{Fig.2, e}),$$

$$P_1G_1 = \frac{H_{A_1} \cos \varepsilon}{\operatorname{tg}\varphi_2} \quad (\text{Fig.2, b}),$$

$$A_1G_1 = \frac{H_{A_1} \sin \varepsilon}{\operatorname{tg}\varphi_2},$$

$$A_1E_{1(b)} = \frac{H_{A_1} \sin \varepsilon}{\operatorname{tg}\varphi_2 + \operatorname{tg}\alpha \cdot \sin^2 \varepsilon},$$

$$A_1E_{1(b)} = \frac{A_1M_1 \cdot P_1G_1}{G_1M_1},$$

where φ_2, φ_3 – inclination angles of total shift lines at cross-sections across and along the strike at point A_1 (Fig.2 *b, e*).

We obtain two values A_1E_1 – the distance from the working face boundary to the boundary of the flat bottom of the trough in the section of the transverse axis A_1-A_2 of the «diagonal» face I-II-III-IV. At $\varepsilon = 0^\circ$, the line (boundary) I-II is oriented along the strike of the formation and only the angle φ_2 affects the distance A_1E_1 , i.e. the expression A_1E_1 (*b*). Similarly, at $\varepsilon = 90^\circ$, only A_1E_1 (*a*) affects A_1E_1 . For $\varepsilon = \varepsilon = 45^\circ$ there must be an equivalent effect of the equalities with the indices (*a*) and (*b*). To fulfill these conditions, we take weighting coefficients $P_{(a)} = \sin \varepsilon$, $P_{(b)} = \cos \varepsilon$. Then the average weighting coefficient value of distance A_1E_1 is:

$$A_1E_1 = H_{A_1} \left[\frac{\sin^2 \varepsilon}{(\operatorname{tg} \varphi_3 - \operatorname{tg} \alpha \cdot \sin \varepsilon \cdot \cos \varepsilon)(\sin \varepsilon + \cos \varepsilon)} + \frac{\cos^2 \varepsilon}{(\operatorname{tg} \varphi_2 + \operatorname{tg} \alpha \cdot \sin^2 \varepsilon)(\sin \varepsilon + \cos \varepsilon)} \right].$$

From Fig.2, *c, d, e, g*:

$$\varphi_3 = \Psi_3, \quad \varphi_2 = \Psi_2 - \alpha, \quad \varphi_2 = \operatorname{arctg} \frac{H_{A_1}}{A_1E_1}.$$

Then

$$A_1E_1 = H_{A_1} \left[\frac{\sin^2 \varepsilon}{(\operatorname{tg} \Psi_3 - \operatorname{tg} \alpha \cdot \sin \varepsilon \cdot \cos \varepsilon)(\sin \varepsilon + \cos \varepsilon)} + \frac{\cos^2 \varepsilon}{(\operatorname{tg}(\Psi_2 - \alpha) + \operatorname{tg} \alpha \cdot \sin^2 \varepsilon)(\sin \varepsilon + \cos \varepsilon)} \right]; \quad (1)$$

$$\varphi_{2j} = \operatorname{arctg} \left\{ 1 : \left[\frac{\sin^2 \varepsilon}{(\operatorname{tg} \Psi_3 - \operatorname{tg} \alpha \cdot \sin \varepsilon \cdot \cos \varepsilon)(\sin \varepsilon + \cos \varepsilon)} + \frac{\cos^2 \varepsilon}{(\operatorname{tg}(\Psi_2 - \alpha) + \operatorname{tg} \alpha \cdot \sin^2 \varepsilon)(\sin \varepsilon + \cos \varepsilon)} \right] \right\}. \quad (2)$$

The formula is cumbersome, but simple in calculations. Nevertheless, to simplify it (and subsequent formulas) we introduce the notation: $A = \operatorname{tg} \alpha \cdot \sin \varepsilon \cdot \cos \varepsilon$, $B = \operatorname{tg} \alpha \cdot \sin^2 \varepsilon$, $C = \operatorname{tg} \alpha \cdot \cos^2 \varepsilon$, $D = \sin \varepsilon + \cos \varepsilon$.

Then

$$\varphi_{2j} = \operatorname{arctg} \left\{ 1 : \left[\frac{\sin^2 \varepsilon}{(\operatorname{tg} \Psi_3 - A)D} + \frac{\cos^2 \varepsilon}{(\operatorname{tg}(\Psi_2 - \alpha) + B)D} \right] \right\}. \quad (3)$$

From Fig.2, *g*

$$\Psi_{2j} = \varphi_{2j} + \alpha'_{A_1-A_2};$$

$$\Psi_{2j} = \varphi_{2j} + \operatorname{arctg}(\operatorname{tg} \alpha \cdot \cos \varepsilon), \quad (4)$$

where Ψ_{2j}, φ_{2j} – angle of total shift and angle of inclination of total shift lines from the up dip in cross-section of longitudinal axis of working (in point A_1 at Fig.2, *b*).

Similarly, analytical dependencies are obtained for determining the angles of total shifts: Ψ_{2e} (with $\alpha < 70^\circ$), Ψ_{1j} (with $\alpha < 90^\circ - \Psi_1$), Ψ_{1e} (with $\alpha < 90^\circ - \Psi_1$) respectively from the up dip of the longitudinal axis, from the down dip in the section of the transverse axis and from the down dip in the section of the longitudinal axis of the «diagonal» face. The corresponding formulas are given in Table 1, where the accepted notations are also indicated.

In addition, we will look at the angles of total shifts from the down dip side of the formation in the axial sections of the «diagonal» face with $\alpha > 90^\circ - \Psi_1$. In this case when replacing the coal mining area developed with faces across the strike the boundary of flat bottom of trough is located above the coal pillar, outside the mining contour (Fig.2, f). The details will be given on the examples of angle Ψ_{1j} at point A_2 (Fig.2, b). Here the distance A_2E_2 , when replacing the coal mining area developed by faces along the strike we calculate (applying the same method) using the formula:

$$A_2E_{2(a)} = \frac{H_{A_2} \sin \varepsilon}{\operatorname{tg} \varphi_3 + \operatorname{tg} \alpha \cdot \sin \varepsilon \cdot \cos \varepsilon}. \quad (5)$$

When replacing the coal mining area developed with faces across the strike the point E_b is located outside the contour of «diagonal» face and distance $A_2E_{2(b)}$ is determined using the formula (Fig.2, j):

$$A_2E_{2(b)} = \frac{H_{A_2} \cos \varepsilon}{\operatorname{tg} \varphi_1 + \operatorname{tg} \alpha \cdot \sin^2 \varepsilon}. \quad (6)$$

According to the justification stated above, we take weighting coefficients: $P_{A_2E_{2(a)}} = \sin \varepsilon$, $P_{A_2E_{2(b)}} = \cos \varepsilon$.

Then average weighting coefficient value is

$$A_2E_2 = H_{A_2} \left[\frac{\sin^2 \varepsilon}{(\operatorname{tg} \varphi_3 + \operatorname{tg} \alpha \cdot \sin \varepsilon \cdot \cos \varepsilon)(\sin \varepsilon + \cos \varepsilon)} - \frac{\cos^2 \varepsilon}{(\operatorname{tg} \varphi_1 + \operatorname{tg} \alpha \cdot \sin^2 \varepsilon)(\sin \varepsilon + \cos \varepsilon)} \right].$$

Let us substitute the values $\varphi_3 = \Psi_3$ (Fig.2, c), $\varphi_1 = 180^\circ - (\Psi_1 + \alpha)$ (рис.2, f) и $\varphi_{1j} = \frac{H_{A_2}}{A_2E_2}$.

Then

$$A_2E_2 = H_{A_2} \left[\frac{\sin^2 \varepsilon}{(\operatorname{tg} \Psi_3 + \operatorname{tg} \alpha \cdot \sin \varepsilon \cdot \cos \varepsilon)(\sin \varepsilon + \cos \varepsilon)} - \frac{\cos^2 \varepsilon}{(\operatorname{tg} \alpha \cdot \sin^2 \varepsilon - \operatorname{tg}(\Psi_1 + \alpha))(\sin \varepsilon + \cos \varepsilon)} \right]; \quad (7)$$

$$\varphi_{1j} = \operatorname{arctg} \left\{ 1 : \left[\frac{\sin^2 \varepsilon}{(\operatorname{tg} \Psi_3 + \operatorname{tg} \alpha \cdot \sin \varepsilon \cdot \cos \varepsilon)(\sin \varepsilon + \cos \varepsilon)} - \frac{\cos^2 \varepsilon}{(\operatorname{tg} \alpha \cdot \sin^2 \varepsilon - \operatorname{tg}(\Psi_1 + \alpha))(\sin \varepsilon + \cos \varepsilon)} \right] \right\} \quad (8)$$

or with the above given notations

$$\varphi_{1j} = \operatorname{arctg} \left\{ 1 : \left[\frac{\sin^2 \varepsilon}{(\operatorname{tg} \Psi_3 + A)D} - \frac{\cos^2 \varepsilon}{(B - \operatorname{tg}(\Psi_1 + \alpha))D} \right] \right\}. \quad (9)$$

If according to the calculations it will be $\varphi_{1j2} > 0^\circ$ (i.e. $A_iE_{ai} > A_iE_{bi}$), then the boundary point E' of flat bottom of trough of «diagonal» face is located inside the contour I-II-III-IV (Fig.2, j) and angle of total shifts equals:

$$\Psi_{1j} = \varphi_{1j} - \alpha'_{A_1-A_2};$$

$$\Psi_{1j} = \varphi_{1j} - \operatorname{arctg}(\operatorname{tg} \alpha \cdot \cos \varepsilon). \quad (10)$$

With $\varphi_{1j2} < 0^\circ$ (Fig.2, j)

$$\Psi_{1j} = 180^\circ - |\varphi_{1j2}| - \alpha'_{A_1-A_2};$$

$$\Psi_{1j} = 180^\circ - |\varphi_{1j2}| - \arctg(\tg\alpha \cdot \cos\varepsilon). \quad (11)$$

Similarly, the analytic dependence is determined for the angle Ψ_1 (at point A_3 in Fig. 2, b) of total shifts on the down dip in the section of the longitudinal axis of the «diagonal» working. The formulas are given in Table. 1.

The method of determining the angles of maximum seam crop will be considered using the example of a section along the transverse axis A_1-A_2 of a «diagonal» working (Fig.3).

From triangle A_1MA_2 (Fig.3)

$$A_1M = \frac{A_1A_2 \sin \Psi_{1j}}{\sin(\Psi_{1j} + \Psi_{2j})}; \quad A_2M = \frac{A_1A_2 \sin \Psi_{2j}}{\sin(\Psi_{1j} + \Psi_{2j})}.$$

The OM line drawn from the middle of working at the angle of the maximum crop is the median of the triangle and its length is determined by the formula

$$OM = \frac{1}{2} \sqrt{2(A_1M^2 + A_2M^2) - A_1A_2^2};$$

$$OM = \frac{A_1A_2}{2 \sin(\Psi_{1j} + \Psi_{2j})} \sqrt{2(\sin^2 \Psi_{1j} + \sin^2 \Psi_{2j}) - \sin^2(\Psi_{1j} + \Psi_{2j})}.$$

From triangle OMA_2

$$\sin \gamma = \frac{A_2M \sin \Psi_{1j}}{OM};$$

$$\gamma_j = \arcsin \left[\frac{2 \sin \Psi_{1j} \sin \Psi_{2j}}{\sqrt{2(\sin^2 \Psi_{1j} + \sin^2 \Psi_{2j}) - \sin^2(\Psi_{1j} + \Psi_{2j})}} \right]. \quad (12)$$

The angle of maximum crop θ_j at the cross-section of transverse axis of «diagonal» working is:

$$\theta_j = \gamma_j - \arctg \alpha'_{A_1-A_2}$$

$$\theta_j = \arcsin \left[\frac{2 \sin \Psi_{1j} \sin \Psi_{2j}}{\sqrt{2(\sin^2 \Psi_{1j} + \sin^2 \Psi_{2j}) - \sin^2(\Psi_{1j} + \Psi_{2j})}} \right] - \arctg(\tg\alpha \cdot \cos\varepsilon). \quad (13)$$

The same is for cross-section of longitudinal axis of «diagonal» working

$$\gamma_f = \arcsin \left[\frac{2 \cdot \sin \Psi_{1f} \sin \Psi_{2f}}{\sqrt{2(\sin^2 \Psi_{1f} + \sin^2 \Psi_{2f}) - \sin^2(\Psi_{1f} + \Psi_{2f})}} \right]; \quad (14)$$

$$\theta_f = \arcsin \left[\frac{2 \sin \Psi_{1f} \sin \Psi_{2f}}{\sqrt{2(\sin^2 \Psi_{1f} + \sin^2 \Psi_{2f}) - \sin^2(\Psi_{1f} + \Psi_{2f})}} \right] - \arctg(\tg\alpha \cdot \cos\varepsilon). \quad (15)$$

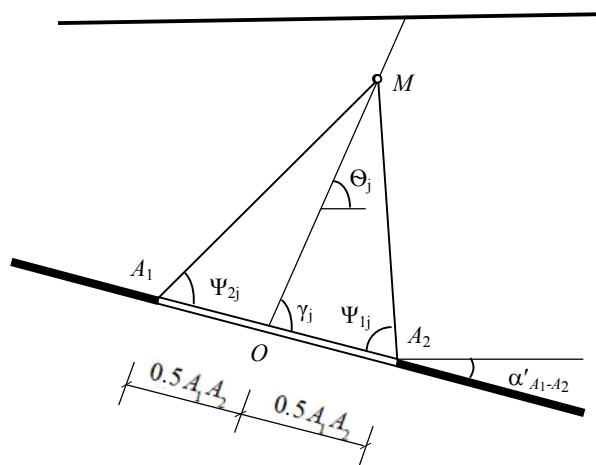


Fig.3. Cross-section of longitudinal axis A_1-A_2 of «diagonal» working

Table 1

Formulas for determining angles of line inclinations (φ) and angles of total shifts (Ψ) at cross-section of traverse (index i) and longitudinal (index f) axes of «diagonal» working

Cross-sections	Working boundaries (Fig. 2 b)	Angles of line inclinations at angles of total shifts	Angles of total shifts
Along traverse (short) axis of working (A_1-A_2 at Fig. 2)	At the upper boundary of the working (at point A_1) with $\alpha < 70^\circ$	$\varphi_{2j} = \arctg \left\{ 1 : \left[\frac{\sin^2 \varepsilon}{(\lg \Psi_3 - A)D} + \frac{\cos^2 \varepsilon}{(\lg(\Psi_2 - \alpha) + B)D} \right] \right\}$	$\Psi_{2j} = \varphi_{2j} + \arctg(\lg \alpha \cdot \cos \varepsilon)$
	At the lower boundary of the working (at point A_2) with $\alpha < 90^\circ - \Psi_1$	$\varphi_{1j} = \arctg \left\{ 1 : \left[\frac{\sin^2 \varepsilon}{(\lg \Psi_3 + A)D} + \frac{\cos^2 \varepsilon}{(\lg(\Psi_1 + \alpha) - B)D} \right] \right\}$	$\Psi_{1j} = \varphi_{1j} - \arctg(\lg \alpha \cdot \cos \varepsilon)$
	At the lower boundary of the working (at point A_2) with $\alpha > 90^\circ - \Psi_1$	$\varphi_{1j} = \arctg \left\{ 1 : \left[\frac{\sin^2 \varepsilon}{(\lg \Psi_3 + A)D} - \frac{\cos^2 \varepsilon}{(B - \lg(\Psi_1 + \alpha))D} \right] \right\}$	With $\varphi_{1j} > 0^\circ$ $\Psi_{1j} = \varphi_{1j} - \arctg(\lg \alpha \cdot \cos \varepsilon)$ With $\varphi_{1j} < 0^\circ$ $\Psi_{1j} = 180^\circ - \varphi_{1j} - \arctg(\lg \alpha \cdot \cos \varepsilon)$
Along longitudinal (long) axis of working (A_3-A_4 at Fig. 2)	At the upper boundary of the working (at point A_4) with $\alpha < 70^\circ$	$\varphi_{2f} = \arctg \left\{ 1 : \left[\frac{\cos^2 \varepsilon}{(\lg \Psi_3 - A)D} + \frac{\sin^2 \varepsilon}{(\lg(\Psi_2 - \alpha) + C)D} \right] \right\}$	$\Psi_{2f} = \varphi_{2f} + \arctg(\lg \alpha \cdot \sin \varepsilon)$
	At the lower boundary of the working (at point A_3) with $\alpha < 90^\circ - \Psi_1$	$\varphi_{1f} = \arctg \left\{ 1 : \left[\frac{\cos^2 \varepsilon}{(\lg \Psi_3 + A)D} + \frac{\sin^2 \varepsilon}{(\lg(\Psi_1 + \alpha) - C)D} \right] \right\}$	$\Psi_{1f} = \varphi_{1f} - \arctg(\lg \alpha \cdot \sin \varepsilon)$
	At the lower boundary of the working (at point A_3) with $\alpha > 90^\circ - \Psi_1$	$\varphi_{1f} = \arctg \left\{ 1 : \left[\frac{\cos^2 \varepsilon}{(\lg \Psi_3 + A)D} - \frac{\sin^2 \varepsilon}{(C - \lg(\Psi_1 + \alpha))D} \right] \right\}$	With $\varphi_{1f} > 0^\circ$ $\Psi_{1f} = \varphi_{1f} - \arctg(\lg \alpha \cdot \sin \varepsilon)$ With $\varphi_{1f} < 0^\circ$ $\Psi_{1f} = 180^\circ - \varphi_{1f} - \arctg(\lg \alpha \cdot \sin \varepsilon)$

Note. $A = \lg \alpha \cdot \sin \varepsilon \cdot \cos \varepsilon$, $B = \lg \alpha \cdot \sin^2 \varepsilon$, $C = \lg \alpha \cdot \cos^2 \varepsilon$, $D = \sin \varepsilon + \cos \varepsilon$; Ψ_1 , Ψ_2 , Ψ_3 – angles of total shifts at cross-sections across and along the seam strike [1]; α – angle of seam dip; ε – acute angle between longitudinal (long) axis of working and seam strike line.



Conclusions. Thus, the authors of the article proposed a method for determining and analyzing the dependences of the angles of total shifts and the angles of maximum crop in sections of the longitudinal and transverse axes of coal-mining faces developed along diagonal directions to the strike of the formation.

Table 2

Angles of inclinations of total shifts lines φ (at cross-section) and angles of total shifts Ψ at cross-sections of axes of «diagonal» workings calculated according to formulas from Table 1 ($\Psi_1 = 55^\circ$; $\Psi_2 = 55^\circ + 0,3\alpha$; $\Psi_3 = 55^\circ$)

Seam inclination angle α , degree	Angle between longitudinal axis of working and seam strike ε , degree	Angles of total shifts lines inclination at cross-section of traverse axis of working, degree		Angles of total shifts at cross-section of traverse axis of working, degree	
		From up dip side φ_{2j}	From down dip side φ_{1j}	From up dip side Ψ_{2j}	From down dip side Ψ_{1j}
20	0	41.0	75.0	61.0	55.0
	20	50.5	76.2	69.4	57.3
	40	57.2	73.4	72.8	57.8
	60	59.4	68.2	69.7	57.9
	80	57.6	60.3	61.2	56.7
	90	55.0	55.0	55.0	55.0
40	0	27.0	-85.0	67.0	55.0
	20	39.5	-89.7	77.8	52.1
	40	52.2	82.9	84.9	50.2
	60	55.9	73.8	78.7	51.0
	80	56.1	62.1	64.4	53.8
	90	55.0	55.0	55.0	55.0
60	0	13.0	-65.0	73.0	55.0
	20	30.6	-76.1	89.0	45.5
	40	46.5	-89.0	99.5	38.0
	60	47.1	78.7	88.0	37.9
	80	53.0	64.4	69.8	47.7
	90	55.0	55.0	55.0	55.0

Note. When $\varphi < 0^\circ$ the boundary of flat bottom of the trough is located outside the working contour, i.e. above the coal pillar (point E' at Fig.2, j)

Table 3

Angles of inclinations of total shifts lines φ (at cross-section) and angles of total shifts Ψ at cross-section of longitudinal axes of «diagonal» workings calculated according to formulas from Table 1 ($\Psi_1 = 55^\circ$; $\Psi_2 = 55^\circ + 0,3\alpha$; $\Psi_3 = 55^\circ$)

Seam inclination angle α , degree	Angle between longitudinal axis of working and seam strike ε , degree	Angles of total shifts lines inclination at cross-section of longitudinal axis of working, degree		Angles of total shifts at cross-section of longitudinal axis of working, degree	
		From up dip side φ_{2f}	From down dip side φ_{1f}	From up dip side Ψ_{2f}	From down dip side Ψ_{1f}
20	0	55.0	55.0	55.0	55.0
	20	58.9	64.7	66.0	57.6
	40	58.9	71.1	72.0	57.9
	60	54.4	75.1	71.9	57.6
	80	45.9	76.4	65.6	56.7
	90	41.0	75.0	61.0	55.0
40	0	55.0	55.0	55.0	55.0
	20	56.3	68.3	72.3	52.3
	40	54.9	78.6	83.2	50.3
	60	46.9	86.9	82.9	50.8
	80	32.2	-86.8	71.8	53.7
	90	27.0	-85.0	67.0	55.0



Ending of Table 3

Seam inclination angle α , degree.	Angle between longitudinal axis of working and seam strike ε , degree.	Angles of total shifts lines inclination at cross-section of longitudinal axis of working, degree		Angles of total shifts at cross-section of longitudinal axis of working, degree	
		From up dip side φ_{2f}	From down dip side φ_{1f}	From up dip side Ψ_{2f}	From down dip side Ψ_{1f}
60	0	55.0	55.0	55.0	55.0
	20	49.9	72.1	80.5	41.5
	40	46.2	84.9	94.3	36.8
	60	42.4	-82.7	98.7	41.0
	80	18.5	-69.9	78.2	50.5
	90	13.0	-65.0	73.0	55.0

Note. When $\varphi < 0^\circ$ boundary of flat bottom of the trough is located outside the working contour, i.e. above the coal pillar (point E' at Fig.2, j).

For visual perception in Table 2, 3 show values of the angles of inclination of total shifts (φ) and the angles of total (Ψ) shifts in the axial sections of the "diagonal" faces are calculated according to the formulas of Table 1. They make it possible to trace the nature of the variation of the named angles as a function of the angle of incidence of the formation α and the angle ε between the longitudinal axis of working and the strike of the formation. This, in turn, facilitates the forecast of deformations of the earth's surface from the influence of workings.

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