WORKING THIN DIPPING OR STEEPLY DIPPING SEAMS
IN OPEN-CUT MINES OF THE CENTRAL KUZBASS

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The Central Kuzbass Coalfield has inclined and steeply inclined seams in synclinal and anticlinal folds. The
seam thicknesses, angles of dip, and the direction of strike are not persistent. There are many faults.

Little experience with open-cut mining of coal in such conditions has been gained in the Soviet Union or in
other countries. The Central Kuzbass open-cut mines therefore present many problems which are restricting output.

The extraction of inclined and steeply inclined seams of thickness 1.0-5.0 m is one of these problems. Much
of the coal in these seams is suitable for coking. Preliminary calculations show that these seams constitute 15-20%
of the total coal reserves in the Central Kuzbass open-cut mines and 20-25% of the reserves of coking coal. In some
cases, attempts are made to extract thin seams in open-cut mines normally working thick seams; the coal losses may
be as high as 70%. Owing to lack of equipment and poor extraction techniques, thin seams are usually worked to-
gether with the overburden and the material removed to the rock dumps.

Thin seams may have dips conformable or unconformable (reverse dip) with the working side and benches. In
the first case, thin seams may be worked on the hanging side, in the second case on the foot or hanging side.

If work is carried out on the hanging side, selective extraction of coal is possible depending on the physical
and mechanical properties of the coal and rock, the seam thickness, strike and angle of dip, the presence of faults,
the bench height, and the type of excavators used [1,2].

With seam dip > 80°, selective extraction is difficult because the permissible angle of slope of the rock bench
(80°) necessitates combined extraction of the seam and the adjoining rock (Fig. 1). The arrangement of the unit for
drilling inclined boreholes dictates that the width of the "pull" (advance) Z cannot be less than that of the safety
strip. Z can be found from the equation

\[ Z = h \left( \cot \alpha - \cot \beta \right) + \frac{M_n}{\sin \frac{\beta}{2}}, \text{ m.} \] (1)

where \( h \) is the bench height, \( m \); \( \alpha \) is the angle of slope of the bench, deg; \( \beta \) is the seam dip, deg; and \( M_n \) is the
normal thickness of the seam, m.

Impoverishment of the coal, due to the presence of roof and floor rocks, may be determined volumetrically
from the ratio of the area of the two triangles \( ABF + CDE \) (see Fig. 1) to that of the trapezium \( ABDE \)

\[ \rho = \left( 1 + \frac{M_n}{h \sin \frac{\beta}{2} \left( \cot \alpha - \cot \beta \right)} \right)^{-1} 100. \] (2)

If \( Z \), determined from (1), is less than the safety width, the "pull" must be taken as equal to the latter, and
impoverishment of the coal determined from the formula

\[ \rho = \left( 1 - \frac{M_n}{S \sin \frac{\beta}{2}} \right) 100, \] (3)

where \( S \) is the safety width, m.
The permissible impoverishment of the coal may be found from the equation

\[ \rho_{\text{lim}} = \left( \frac{\gamma_r^{\text{daf}} A_r^{\text{daf}} - \gamma_c^{\text{lim}} A_c^{\text{lim}}}{\gamma_c^{\text{daf}} A_c^{\text{lim}} + 1} \right)^{-1} \]  

(4)

where \( \gamma_r \) and \( \gamma_c \) are the densities of the rock and coal, respectively, \( \text{t/m}^3 \); \( A_r^{\text{daf}} \) and \( A_c^{\text{lim}} \) are the ash contents of the rock and coal, respectively, \%; \( A_c^{\text{lim}} \) is the limiting ash content of the initial rock, %.

Preliminary calculations show that it is economically advantageous to process material with initial ash content less than 40% in preparation plants, and with ash content up to 75% in hydrocyclone plants [3].

From data in [4], the coal losses in extraction of seams by schemes in Fig. 2a,b,c may be determined from the equations

a. \( P = \left[ \frac{\frac{m_c}{h} + \frac{M_h}{h} \left( R_{\text{G}}^D - R_{\text{G}}^S - H_0 \cot \beta \right)}{4M_h^h} \right] 100 + \rho_0 \), % \( (5) \)

b. \( P = \left[ \frac{m_c}{h} + \frac{m_r}{M_h} + \frac{m_f}{M_h} + \frac{H_0 \left( R_{\text{G}}^D - R_{\text{G}}^S - H_0 \cot \beta \right)}{4M_h^h} \right] 100 + \rho_0 \), % \( (6) \)

c. \( P = \left[ \frac{m_c}{h} + \frac{m_r}{M_h} + \frac{m_f}{M_h} \right] 100 + \rho_0 \), P \( (7) \)

where \( m_c \) is the thickness of the layer of coal stripped on the upper stage during cleaning-up operations, m; \( m_r \) is the thickness of the coal layer left on the roof side, m; \( m_f \) is the thickness of the coal layer left on the floor side, m; \( M_h \) is the horizontal thickness of the seam, m; \( H_0 \) is the height of the excavator pivot, m; \( R_{\text{G}}^D \) is the radius of the excavator "grab" at the pivot level of the arm, m; \( R_{\text{G}}^S \) is the radius of the excavator "grab" at the standing level, m; \( \rho_0 \) is the coal loss, %.

From measurements and practical experience in extraction, we can take \( m_c = 0.15 \text{ m}, m_r = m_f = 0.20 \text{ m}, \) and \( \rho_0 = 1\% \).

From (6) we find that, if the seam thickness < 1.0 m, the losses will be > 50%.

Thin seams with reverse dip can be worked on the foot or hanging side [1].

If the work is carried out on the foot side, only overall extraction is possible; we will consider two schemes (Fig. 3, a and b). In both, \( Z \) is the width of the bench strip from which the debris will be processed to extract the coal

a. \( Z = h \left( \cot \alpha + \cot \beta \right) + \frac{M_h}{\sin \beta} \), \( \text{m} \) \( \( (8) \)

b. \( Z = h \left( \cot \alpha + \cot \beta \right) - \frac{M_h}{\sin \beta} \). \( \text{m} \) \( \( (9) \)

In the case of steep seams, \( Z \) may be equal to the width of the "pull" but not less than the safety width.

In both schemes, coal impoverishment (volumetric) may be determined as the ratio of the area of the rock to the total area limited by the value of \( Z \):

a. \( \varphi = \left( \frac{1 + \frac{M_h}{h \sin \beta \left( \cot \alpha + \cot \beta \right)}}{\tan \gamma} \right)^{-1} 100 \), \( \% \) \( \( (10) \)

b. \( \varphi = \left( \frac{1 + \frac{M_h \sin \gamma}{h \sin \left( \alpha + \beta \right)} \right) 100 \), \( \% \) \( \( (11) \)

Coal losses in extraction by the scheme in Fig. 3b can be found from the equation

\[ P = \frac{M_h \sin \gamma}{h \sin \left( \alpha + \beta \right)} 100, \% \]  

Fig. 1. Extraction of a thin seam on the hanging side at angles of dip 80°-90°.