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ОПРЕДЕЛЕНИЕ ПАРАМЕТРОВ ПОВОРОТНЫХ ЛЫЖ ДЛЯ ОСНОВАНИЙ СЕКЦИЙ МЕХАНИЗИРОВАННОЙ КРЕПИ

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Аннотация: Приведены результаты исследований по взаимодействию оснований секций механизированных крепей с породами почвы. Установлено, что при очень слабой почве и при вдавливании оснований в почву пласта и «запахивании» почвы основаниями секций крепи при их передвижке необходимо, чтобы давление у носка основания было минимальным. Эффективное применение механизированных крепей со сплошными жесткими основаниями в условиях со слабыми почвами возможно лишь в сочетании с устройствами приподъема оснований секций крепи при их передвижке. Снижение давления на почву под передней кромкой разделенного на элементы (лыжи) основания может быть достигнуто в том случае, если носки основания будут иметь устройства поворота их передней кромки. Это может быть достигнуто за счет установки поворотных лыж. Разработана конструкция поворотной лыжи основания, которая обеспечивает передвижку секций крепи без «запахивания» их в почву. Определены силовые и конструктивные параметры поворотных лыж, обеспечивающих выезд вдавленной в почву секции крепи и технические требования к конструкции поворотной лыжи, повышающих эффективность применения механизированной крепи в условиях слабых почв. Установлены угол подъема носка поворотной лыжи для перемещения секции крепи без «запахивания» основания в почву пласта и угол поворота лыжи, обеспечивающий выезд вдавленных в почву секций крепи. Установлены критерии применения механизированных крепей по сопротивляемости почвы вдавливанию и напряжению в сдвигаемом слое почвы.

Ключевые слова: механизированная крепь, основание секции крепи, вдавливание в почву пласта, «запахивание» почвы, механизм приподъема основания, поворотная лыжа, усилие передвижки, подъемная сила, угол подъема.

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Determining parameters of rotary skids for bases of powered support units

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Abstract: The article presents the studies into the interaction between the bases of powered support units and seam floor rocks. It is found that when the floor rocks are very soft and when the bases indent or plough into the seam floor during advance of the powered support units, it is necessary that the pressure at the toe of the base is minimal. The effective use of powered supports with solid rigid bases in the conditions of soft floors is possible only in combination with devices for lifting the bases of the powered support units when they are advanced. Reduction of the pressure exerted on the floor by the base divided into elements (skids) can be achieved if the base toe has devices for turning their leading edge. This can be achieved by installing rotary skids. The design of a rotary base skid is proposed, which ensures advance of the powered support unit without ploughing into the seam floor. The power and design parameters of the rotary skids, which allow removal of the powered support unit pressed into the floor, and the technical requirements for the design of the rotary skid, which increase efficiency of the powered support in the conditions of weak floor, are determined. The lift angle of the rotary skid toe to enable advance of the powered support unit without ploughing of the base into the seam floor and the rotation angle of the skid, which ensures removal of the powered support units pressed into the floor, are found. The criteria for the use of powered supports are determined with regard to the indentation resistance of the floor rocks and to the stress in the floor later under shearing.

Key words: powered support, powered support unit base, pressing into seam floor, ploughing of floor, base lifting mechanism, rotary skid, advance force, lifting force, lifting angle.

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Introduction

Longwall mining systems with powered roof supports are the basic means toward enhanced technical and economic performance in underground coal mining.

One of the main causes of limited productivity of the longwall mining systems in operating coalfaces is the expanded scope of their use in difficult mining and geological conditions. The dominant factors that sharply complicate operation of longwall machinery and, first of all, powered supports are the unstable roof, soft floor and faulting [1–15].

It is found that longwall mining of coal seams with weak floor can be effective provided that the machine bases are not pressed into the seam floor and the roof support units are advanced without ploughing into the floor. The use of devices for lifting the machine bases on weak floors is preferable when the bases are solid and rigid bases, and is only governed by the mining technology — shearing or plow winning.

In case of shearing, the solid rigid bases of the powered support units should be equipped with devices for lifting them, and it is advisable to fit the bases divided into elements (skids) with rotary skids mounted on the toes of the base skids.

Studies and experiments on models with sandy soil have found that the degree of the floor ploughing by moving support units is influenced by the shape of the toe of the base or the rotary skids installed on the toes of the base.

The research objective is to determine the power and design parameters of the rotary skid to ensure effective use of powered support unit on soft floors.

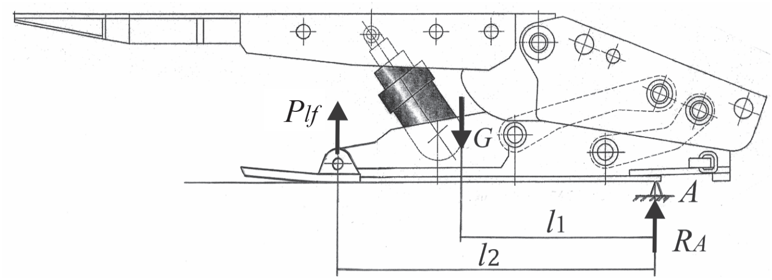

Fig. 1. Scheme for determining lifting force of support unit
Рис. 1. Схема для определения подъемной силы секции крепи

The research methods are the analysis and generalization of information contained in literary sources, as well as the field evidence of operation of powered supports on soft floors; the mathematical modeling of the powered support–seam floor system by methods of theoretical mechanics.

Results

The main cause of penetration of powered support units to floor is the lack of the lifting force to be enough to remove sunken bases from the floor and to ensure the further advance of the support units without ploughing.

Consider a single-row shield-type support unit with the base composed of two parts — the left and right skids (Fig. 1).

$$P_{lf} = \frac{G \cdot l_1}{l_2} \cdot n \text{, kN,}$$

where P_{lf} is the lifting force of the support unit, kN; G is the gravity of the support unit, kN; l_1, l_2 are the coordinates of the gravity G and lifting force P_{lf} relative to the edge of the goaf side of the base, m; $n = 1.5$ — lifting force factor with regard to the increase in the weight of the support unit due to the detached top rock on the roof support unit.

The lifting force P_{lf} for a particular support unit is constant and depends on its design parameters.

The advance force of the powered support unit:

$$P_{adv} = P_{jack} \cdot \cos\beta - G \cdot f_{fr} \text{, kN,}$$

where β is the angle of the advance force of the support unit, degrees; f_{fr} is the base–floor friction factor.

The direct-action advancing jack force:

$$P_{jack} = \frac{\pi\left(D^2 - d^2\right)}{4} \cdot P \cdot 10^3 \text{, kN,}$$

where D is the piston diameter, m; d is the rod diameter, m; P is the working fluid pressure in the delivery line, MPa.

Then the advance force of the powered support unit:

$$P_{adv} = \frac{\pi\left(D^2 - d^2\right)}{4} \cdot P \cdot \cos\beta \cdot 10^3 - G \cdot f_{fr} \text{, kN.}$$

The back-action jack force:

$$P_{jack} = \frac{\pi D^2}{4} \cdot P \cdot 10^3 \text{, kN.}$$

Then the advance force of the powered support unit:

$$P_{adv} = \frac{\pi D^2}{4} \cdot P \cdot \cos\beta \cdot 10^3 - G \cdot f_{fr} \text{, kN.}$$

Angle and stresses of floor layer under shearing

Fig. 2 shows a scheme for calculating the shear resistance of the seam floor [3].

The relation of the lifting force and the support unit advance force in the floor layer in shearing is given by:

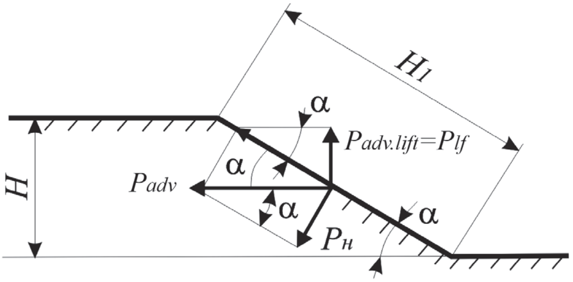

Fig. 2. Calculation pattern for floor shear resistance
Рис. 2. Схема для расчета сопротивляемости почвы сдвигу

$$P_{adv.lift} = P_{adv} \cdot \cos\alpha \cdot \sin\alpha \text{, kN,}$$

where α is the angle of sheared site of the seam floor, deg;

$$\alpha_{1,2} = \arccos\alpha_{1,2}\,, \quad \cos\alpha_{1,2} = \sqrt{0{,}5 \pm \sqrt{0{,}25 - \frac{P^2_{adv.lift}}{P^2_{adv}}}}\,.$$

When determining the sheared floor layer angle $\alpha_{1,2}$, the lifting force $P_{\text{adv.lift}}$ due to the support unit advance should be equated to the lifting force P_{lf} of the support unit, i.e., $P_{\text{adv.lift}}$. = P_{lf}.

The stresses in the floor layer under shearing: $\sigma_{shear} = \dfrac{P_{adv} \cdot \sin^2\alpha}{H \cdot L \cdot n}$, MPa,

where L is the width of the sheared floor layer, equated to the width of the skid, cm; H is the thickness (height) of the sheared floor layer, cm; $n = 2$ is the number of the rotary skids.

The studies [3] have found that the thickness of the first sheared layer is at least 5–6 cm.

The criterion of permissible stresses of floor rocks in shearing: $\sigma_{shear} \leqslant [\sigma_{shear}]$, where $[\sigma_{shear}]$ is the permissible stress in the floor soil layer under shearing, which is governed by the properties of the floor rocks.

For specific mining and geological conditions, the permissible stresses in the sheared floor layer are determined using special technical devices, for example, as described in [3].

From the studies, the shear resistance of floor rocks is 9–12 times less than the floor indentation resistance, i.e.: $\sigma_{ind} = (9 \div 12)\ \sigma_{shear}$

Fig. 3 shows the loading pattern of a single-row shield-type powered support unit [1].

The calculations should be performed at $H_{\max}$ of a support unit.

The equation for determining the force R_3 on the rotary skids:

$$R_3 \cdot l_{10} - 2P_1 \cdot l_9 \cdot \cos\gamma_1 + 2P_1 \cdot h_5 \cdot \sin\gamma_1 - 2T_1 \cdot l_8 \cdot \cos\gamma_3 - 2T_1 \cdot h_6 \cdot \sin\gamma_3 = 0$$

$$R_3 = \frac{2P_1 \cdot \left(l_9 \cdot \cos\gamma_1 - h_5 \cdot \sin\gamma_1\right) - 2T_1 \cdot \left(l_8 \cdot \cos\gamma_3 + h_6 \cdot \sin\gamma_3\right)}{l_{10}} \text{, kN,}$$

where $2P_1$ is the resistance of two props of the powered support unit, kN; $2T_1$ is the force in two front levers of the caving shield, kN; l_8, l_9, l_{10}, h_5, h_6 and h_7 are the coordinates of application of the forces $2P_1$, $2T_1$ and $2T_2$, m.

The force in two front levers, $2T_1$, is determined from the system of equations:

$$\Sigma X = -2P_1 \cdot \sin\gamma_1 + 2T_1 \cdot \sin\gamma_3 + 2T_2 \cdot \sin\gamma_4 + F_T = 0\,;$$

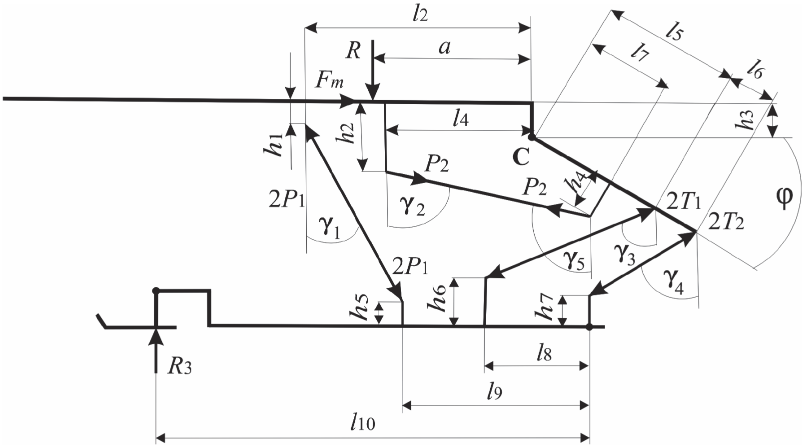

Fig. 3. Loading pattern of single-row shield-type powered support unit
Рис. 3. Схема нагружения секции однорядной щитовой механизированной крепи

$$\Sigma Y = 2P_1 \cdot \cos\gamma_1 + 2T_1 \cdot \cos\gamma_3 + 2T_2 \cdot \cos\gamma_4 - R = 0\ ;$$

$$\Sigma m_{(C)left} = 2P_1 \cdot l_2 \cdot \cos\gamma_1 - 2P_1 \cdot \left(h_3 - h_1\right) \cdot \sin\gamma_1 -$$

$$-P_2 \cdot l_4 \cdot \cos\gamma_2 - P_2 \cdot \left(h_2 - h_3\right) \cdot \sin\gamma_2 + F_T \cdot h_3 - R \cdot \alpha = 0$$

$$\Sigma m_{(C)right} = 2T_1 \cdot l_5 \cdot \cos\left(\varphi - \gamma_3\right) + 2T_2 \cdot \left(l_5 + l_6\right) \cdot \cos\left(\varphi - \gamma_4\right) -$$

$$-P_2 \cdot h_4 \cdot \sin\left(\gamma_5 - \varphi\right) - P_2 \cdot l_7 \cdot \cos\left(\gamma_5 - \varphi\right) = 0.$$

The friction force: $F_m = f_{\text{fr}} \cdot R$, kN,

$$2T_1 = \frac{2P_1 \cdot \cos\gamma_1 \cdot f_{fr} - 2P_1 \cdot \sin\gamma_1 + \dfrac{P_2 \cdot h_4 \cdot \sin\left(\gamma_5 - \varphi\right) + P_2 \cdot l_7 \cdot \cos\left(\gamma_5 - \varphi\right)}{\left(l_5 + l_6\right) \cdot \cos\left(\varphi - \gamma_4\right)} \cdot \left(\sin\gamma_4 + \cos\gamma \cdot f_{fr}\right)}{\dfrac{l_5 \cdot \cos\left(\varphi - \gamma_3\right)}{\left(l_5 + l_6\right) \cdot \cos\left(\varphi - \gamma_4\right)}\left(\sin\gamma_3 + \cos\gamma_3 \cdot f_{fr}\right)},$$

kN,

where P_2 is the resistance of the angular hydraulic jack, kN; R is the resultant resistance of the powered support, kN; a is the coordinate of the resultant resistance of the powered support unit, m; f_{fr} = (0.15–0.4) s the steel–roof rock friction factor dependent on the moisture content of rocks; l_2 is the distance from the prop supports to the hing. C connecting the canopy to the rear caving shield, m; l_4 and h_2, l_7 and h_4 are the coordinates of the resistance P_2 of the angular guide jack, m; l_5 is the distance from the hinge of the front lever to the hinge connecting the rear caving shield with the canopy, m; l_6 is the distance between the hinges of the front and rear levers, m; h_1 is the coordinate of the hinge connecting the prop axes o the caving shield relative to the canopy surface, m; h_3 is the coordinate of the hinge connecting the canopy to the rear caving shield relative to the canopy surface, m; φ is the angle of tilt of the rear caving shield, deg; γ_1, γ_2, γ_3, γ_4 and γ_5 are the tilt angles of the props, angular hydraulic jack, front and rear levers, respectively, deg.

The average pressure of one base skid on the seam floor: $P_{skid} = \dfrac{R_3}{2 \cdot L \cdot b}$, MPa,

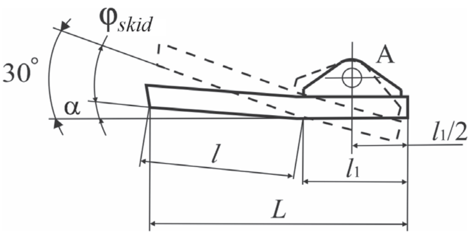

Fig. 4. Rotary skid
Рис. 4. Лыжа поворотная

where b is the width of one skid, cm; L is the skid length, cm.

The validity criterion for the powered roof support is:

$$\sigma_{ind} \triangleright P_{skid} \text{ or } (9 \div 12)\sigma_{shear} \triangleright P_{skid}.$$

When $\sigma_{ind} \triangleleft P_{skid}$, the powered support units are pressed into seam floor.

Design parameters of the rotary skid

Fig. 4 shows the proposed design of the rotary skid.

The toe of the rotary skid should be raised at an angle α equal to the angle the sheared layer of the floor, which ensures advance of the support unit without ploughing of its base into the seam floor.

The model experiments with sandy soils [2] show that the certain advantages (minimal ploughing of the floor rocks) belong to the base toes with the bottom cant at an angle of 30°.

Therefore, the maximum angle of rotation of the skid should not be more than:

$$\varphi_{skid} = 30° - \alpha, \text{ deg},$$

where α is the angle the floor layer under shearing.

The skid rotation angle φ_{skid} provides removal of the support unit base pressed into floor and is adaptable to change in the shear resistance of the seam floor rocks.

The length l of the rotary skid part raised by the angle α (Fig. 2):

$$l = H_1 + 30 = \frac{H}{\sin\alpha} + 30, \text{ mm},$$

where H_1 is the length of the generatrix of the sheared layer, mm; l_1 is the length of the support part of the skid, mm (design parameter).

Based on the design of the base of the support unit, the support part of the skid should have a length that provides the least pressure of the rotary skid on the seam floor. In this case, l_1 is to be less than l.

The length of the rotary skid:

$$L = \left(\frac{H}{\sin\alpha} + 30\right) \cdot \cos\alpha + l_1, \text{ mm},$$

The skid width b depends on the width of the base skid or the toe of the base, and must be less than their values.

Conclusions

1. The domestic and foreign studies into the interaction of the bases of powered support units with seam floor rocks in production faces are reviewed.
2. The design of the rotary base skid has been developed, which ensures advance of the powered support unit without ploughing into seam floor.
3. The criteria for the use of powered supports are determined with respect to the floor resistance to indentation and to the stress in the shear layer.
4. The power and design parameters of rotary skids are determined.

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ОТДЕЛЬНЫЕ СТАТЬИ ГОРНОГО ИНФОРМАЦИОННО-АНАЛИТИЧЕСКОГО БЮЛЛЕТЕНЯ (СПЕЦИАЛЬНЫЙ ВЫПУСК)

К ВОПРОСУ ОЦЕНКИ ТЕХНИЧЕСКОГО СОСТОЯНИЯ И КАЧЕСТВА ОБСЛУЖИВАНИЯ ТРАНСМИССИИ ГОРНОЙ МАШИНЫ ПО ПАРАМЕТРАМ АКУСТИЧЕСКОГО СИГНАЛА С УЧЕТОМ СМАЗКИ ЕЕ ЭЛЕМЕНТОВ

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Проведены экспериментальные исследования со смазочными маслами и консистентными смазками. Показано подобие проявления фрикционных процессов для ряда смазочных материалов по данным измерений акустического сигнала ультразвукового диапазона (АСУД) в условиях детерминировано изменяемых нагрузок и скоростей. Это дает возможность осуществлять работы по техническому обслуживанию и ремонту горной техники на оценочных данных АСУД при функционировании трансмиссий горных машин, для выявления дефектов их ресурсоопределяющих сопряжений. Выбор типа лубрикатора подшипниковых узлов имеет определяющее значение. Подтверждена возможность оценки технического состояния сопрягаемых узлов и деталей приводов горных машин, в частности подшипников без разборки редуктора.

Ключевые слова: трансмиссия, привод, техническое обслуживание, подшипниковый узел, износ, датчик, смазка, износостойкость, акустический сигнал ультразвукового диапазона, ресурсоопределяющий узел, искусственная рабочая среда, техническое обслуживание и ремонт.

TO THE QUESTION OF ASSESSING TECHNICAL CONDITION AND QUALITY OF SERVICE OF MINING MACHINE TRANSMISSION BY PARAMETERS OF ACOUSTIC SIGNAL, TAKING INTO ACCOUNT LUBRICATION OF ITS ELEMENTS

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Experimental studies with lubricating oils and greases are conducted. It is shown that such diagnostics allows to carry out confident control of technical condition of transmissions at transition to maintenance on technical condition. Application of such an approach makes it possible to carry out and plan the routine maintenance of mining equipment and its repair, on the basis of the estimated data of the acoustic signal of the ultrasonic range during the functioning of the transmissions of mining machines, to identify defects in their resource-determining couplings. The choice of the type of lubricator of bearing units, has a determining value. The possibility of assessing the technical condition of the mating assemblies and parts of mining machinery drives, in particular bearings without disassembling the reducer is confirmed.

Key words: transmission, drive, maintenance, bearing unit, wear, sensor, lubrication, wear resistance, ultrasonic acoustic signal, resource-determining unit, artificial working environment, maintenance and repair.