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ВЫБОР ТИПА И КОНСТРУКЦИИ ОСНОВАНИЯ ЩИТОВЫХ СЕКЦИЙ МЕХАНИЗИРОВАННОЙ КРЕПИ

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Аннотация: Приведены результаты эксплуатации щитовых механизированных крепей при выемке пологих и наклонных угольных пластов. Установлено, что от выбора типа и конструкции основания щитовой секции крепи в большой степени зависит эффективность работы механизированного комплекса в условиях слабой почвы и наличия «порогов» в почве пласта. Представлены известные конструкции оснований щитовых секций механизированных крепей: сплошные жесткие и разделенные на элементы, т.е. на правую и левую лыжи, соединенные между собой шарнирным хомутом и (или) шарнирной стяжкой. Установлено, что следствием излома проушин лыж и деформации шарнирной стяжки, соединяющей по забойной части лыжи разделенного основания секции крепи является их смещение относительно друг друга, как в вертикальной, так и в продольной плоскостях при переходе секцией «порогов» в почве пласта. Предложены рекомендации по оснащению сплошных жестких и разделенных на два элемента (лыжи) оснований устройствами приподъема или поворотными лыжами, установленными на носках оснований, обеспечивающих передвижку щитовых секций механизированных крепей без запахивания почвы. Разработана матрица соответствия типов и конструктивных особенностей механизмов адаптации оснований секции крепи условиям применения и механизма передвижки секции крепи, обеспечивающего направленную передвижку комбайновой и струговой щитовой секции механизированной крепи при выемке пологих и наклонных угольных пластов.

Ключевые слова: щитовая секция крепи, механизированная крепь, основание секции крепи, конструкция и тип основания, сплошное жесткое основание, разделенное на два элемента основание, гидродомкрат передвижки, механизм передвижки.

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Selection of the type and design of the shield base of powered support units

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Abstract: The results of the operation of shield powered support units during the excavation of flat and edge coal are presented. It is established that the choice of the type and design of the base of the shield powered support unit greatly depends on the efficiency of the mechanized complex in conditions of soft floor and the presence of «thresholds» in the flat wall. The well-known designs of the bases of the shield powered support units are presented: solid rigid and divided into elements, i.e. on the right and left skids connected to each other by a tubing hanger and (or) a hinged rod. It is established that the consequence of the fracture of the skid lugworm and the deformation of the hinged rod connecting the bottom of the skid of the divided base of the powered support unit is their displacement relative to each other, both in the vertical and longitudinal planes when the unit passes the «thresholds» in the in the flat wall. Recommendations are proposed for equipping solid rigid and divided into two elements (skids) bases with lifting devices or rotary skids mounted on the toes of the bases, ensuring the movement of the shield powered support units without plowing the ground. A matrix of compliance of types and design features of mechanisms for adapting the bases of the powered support unit to the conditions of use and the mechanism for moving the powered support unit, providing directional movement of the combine and plough shield powered support unit when excavating flat and edge coal, has been developed.

Key words: powered support unit, shield support unit, base of the powered support unit, construction and type of base, solid rigid base, base divided into two elements, hydraulic jack of movement, mechanism of movement.

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Introduction

Coal face mechanized system based on shield hydrofected powered support units are the main means for obtaining high technical and economic indicators when excavating low and medium of flat and edge coal. For this purpose, sufficiently advanced complexes have been created, but the main reason for limiting their productivity in existing treatment faces are difficult mining and geological conditions, mainly insufficient strength of the rock and the presence of pronounced «thresholds» on its surface. The introduction of the bases of powered support units into soft floor and their move to the surface during movement, as well as overcoming «thresholds» in the flat wall, lead to downtime of the coal face system and a significant amount of heavy manual labor, frequent emergencies in the breakage face. The main reason for the introduction of the bases of the powered support unit into soft floor is not pressing them over the entire contact surface, but shifting the ground, as if «plowing» the bases into the ground when moving the powered support unit. In accordance with GOST 33164.1-2014 «Powered support units. Support unit. General technical conditions» soft floors include rocks with an indentation resistance of less than 2.0 MPa. Thus, in the Kuznetsk basin, mineralogy with soft floor makes up 30%, in the Pechora basin 57.2%, and in the Donetsk basin 10% [1 – 4].

Seams with strong floor (mines «Obukhovskaya», «Zamchalovskaya» and «Rostovskaya») were almost all accompanied by thresholds from 0.1 to 0.2 m high relative to the ground surface both in the

pitch and in the bedding course. At the same time, the «thresholds» were located almost everywhere at an acute angle to the face at 5 to 10 m. Overcoming such obstacles when moving the support units led to significant manual labor costs. The same problems occur in the foreign practice of operating mechanized system [2]. According to the results of studies [2], the bases of the support units should overcome «thresholds» on lying wall with a height of up to 0.2 m.

Currently, the bases of the shield support units are made solid rigid and divided into elements, i.e. on the right and left skids, connected only along the blockage part by a tubing hanger or along the bottom part by a hinged rod, as well as connected both along the blockage and bottom parts. In the opening of a solid rigid base or between the skids of a divided base, there is a mechanism for moving the powered support unit with both a reverse and direct-action movement jack.

As a result of operation, it was found that the choice of the type and design of the base of the shield support unit depends on the efficiency of the face mechanized system in conditions of soft floor and the presence of «thresholds» in the flat wall.

The difficulty in choosing the type and design of the base of the shield support unit lies in the lack of awareness about the possibilities and disadvantages of a particular design, the lack of clear criteria and restrictions, and the formalization of selection procedures. In these cases, heuristic techniques prevail.

The purpose of the study is to develop heuristic recommendations in the form of a matrix of the types and design features of the mechanisms of adaptation of the bases of both the combine and the plough of the shield powered support unit to the conditions of use, i.e. for excavating of flat and edge coal in difficult mining and geological conditions.

To achieve this goal, the following main tasks have been solved:

- to analysis of the existing types and designs of the bases of the shield support units are carried out;
- to analyze the results of the operation of powered support units during the excavation of flat and edge coal with soft floor and the presence of «thresholds» in the flat wall are analyzed;
- to establish restrictions on the use of possible versions of the bases of the shield support units in relation to specific operating conditions;
- to create matrix of compliance of types and design features of the mechanisms of adaptation of bases to the conditions of application has been compiled.

Research methods: analysis of information contained in literary sources, generalization of the results of the operation of shield powered support units when excavating of flat and edge coal in various geological conditions, structural synthesis.

Results

About this goal, it is advisable to use qualitative criteria for choosing the type and design of the base of shield powered support units, since the determination of quantitative criteria is a complex task and requires accurate initial data [5 – 7]. Such criteria are the conditions for ensuring the possibility of moving the support unit without «plowing» rocks characterized by soil shift during the movement of the unit and the possibility of overcoming «thresholds» in the ground with a height h up to 0.2 m. The main limitations in this case are the strength of the rock and seam inclination, which affects the transverse stability of the support unit during its movement.

As a result of the operation of the KD90 and KD90T shield powered support units when excavating flat coal seams up to 18°, it was found that the effective use of powered support units with solid rigid bases

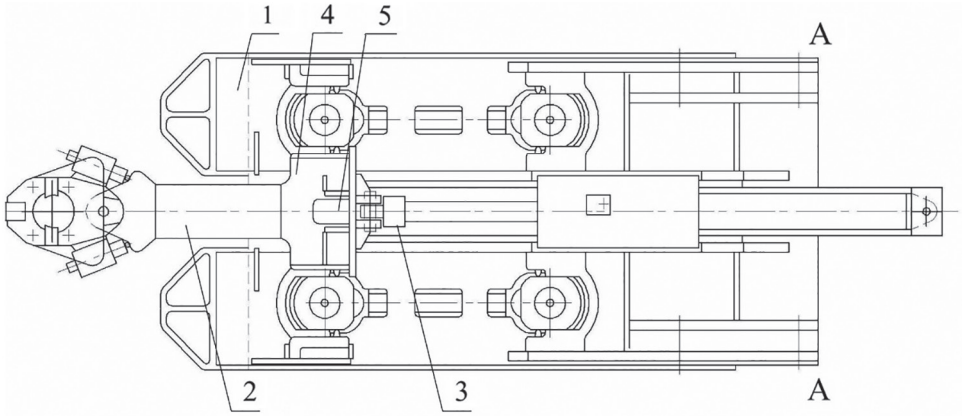

Fig. 1. Solid rigid base
Рис. 1. Сплошное жесткое основание

(Fig. 1), especially in conditions with soft floor, the device of lifting the bottom part of the bases of the support units relative to the line of rotation A-A when moving them (further: lifting the base).

Fig. 1 shows the design of a solid rigid base *1* in the opening of which there is a mechanism for moving *2* of support unit with a flat pusher and a hydraulic jack for moving *3* of the reverse action. A device is installed in the portal *4* base *1* when lifting *5* base *1*. A solid rigid base is widely used in combine double-row of shield powered support units (KD80, KD90, 2KD90T, 3KD90T).

However, when excavating edge (18—30°) coal with combine complexes the movement of the KD90 and KD90T shield support units with the lifting of the bases contributed to the loss of the direction of movement and the transverse stability of the support unit. The reason for this was the reversal of the bases of the support unit relative to the A–A turn line.

The successful operation of the MKD90SO and MKD90SN mechanized plough complex [8] based on the two-post of the KD90S shield support unit when excavating pitching seams in difficult mining and geological conditions (the presence of «thresholds» and the tendency of the soil to shift) consisted in the fact that the solid rigid bases (Fig. 1) of the support units were not equipped with devices for lifting the bases when they were moved, which excluded the reversal of the bases relative to the A–A turn line.

In addition, the absence of resistance to the extension of the pusher of the movement mechanism, the removal of restrictions on the lifting of the toe of the pusher providing control of the conveyor and plough in the vertical plane of the formation increased the efficiency of plough installations.

The excavation of the k2 coal seam of JSC «Obukhovskaya» was carried out by coal face mechanized system of the DFO and MKR based on powered supports of DFC5 and KMR. Coal seam k2 capacity from 0.89 to 1.12 m, seam inclination — 5—10°. The rock is sand shale with a strength of more than $f = 6$ and a resistance to indentation of more than 3 MPa, accompanied by «thresholds» with a height of $h = 0.1—0.2$ m.

The bases of the support units DVK5 (Fig. 2) and KMR (Fig. 3) are divided into two elements, the so-called skids. The skids of the base of the DFC5 support unit are connected only along the blockage by a tubing hanger.

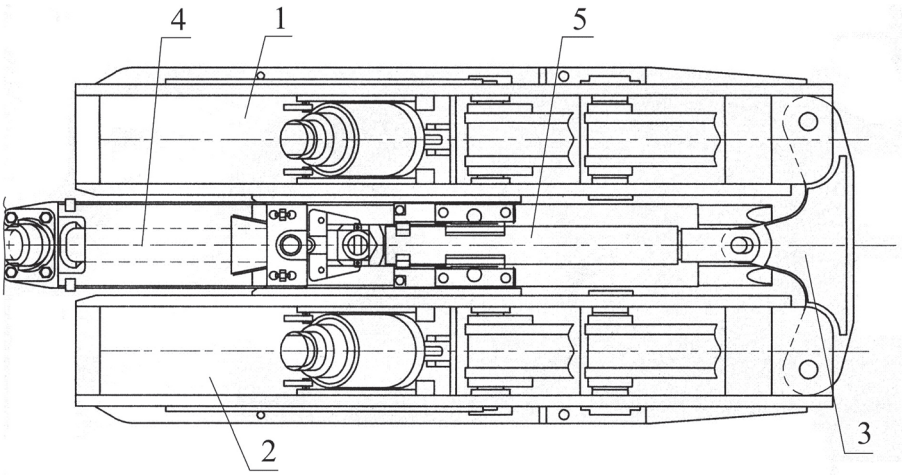

Fig. 2.The base, divided into skis, connected along the blockage by a tubing hanger
Рис. 2. Основание, разделенное на лыжи, соединенные по завальной части шарнирным хомутом

The skids of the base of the support unit of the KMP are connected only along the bottom part by a hinged rod, in which a hydropatron for lifting the base is installed. The hydropatron rests with a rod against a flat pusher of the movement mechanism, which is connected to a hinged rod through a reverse hydraulic jack.

Fig. 2 shows the design of the base divided into the right *1* and left *2* skids, connected along the blockage by a tubing hanger *3*. Between the skids of the divided base there is a mechanism for moving support units *4* with a direct-acting hydraulic jack *5*. The bases divided into skids are used both in single-row (DF, DFCB, 1KT125, KS) and double-row (2KTK, KS220) of the shield powered support units.

Fig. 3 shows the design of the base, divided into the right *1* and left *2* skids, connected along the bottom part by a hinged rod *3*, in which the device for lifting the base *4* is placed when moving the support unit. Between the skids of the base there is

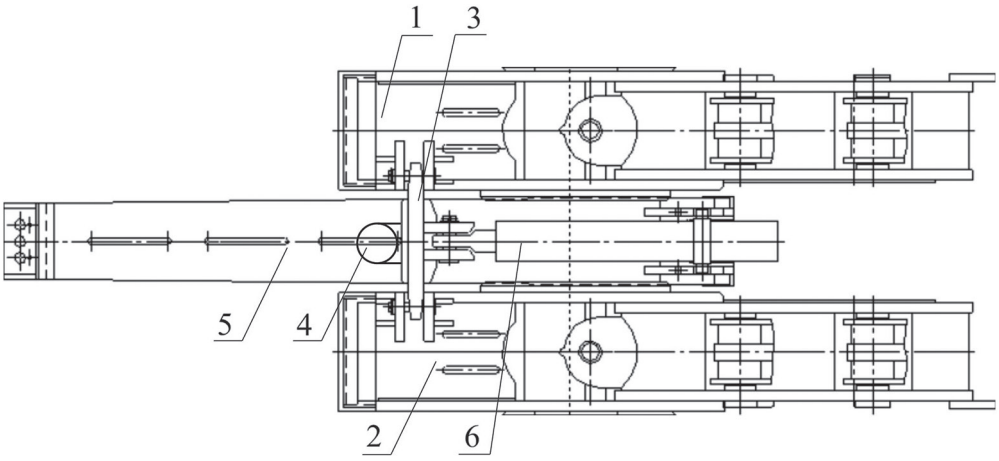

Fig. 3. The base divided into skids connected along the bottom by a hinged rod
Рис. 3. Основание, разделенное на лыжи, соединенные по забойной части шарнирной стяжкой

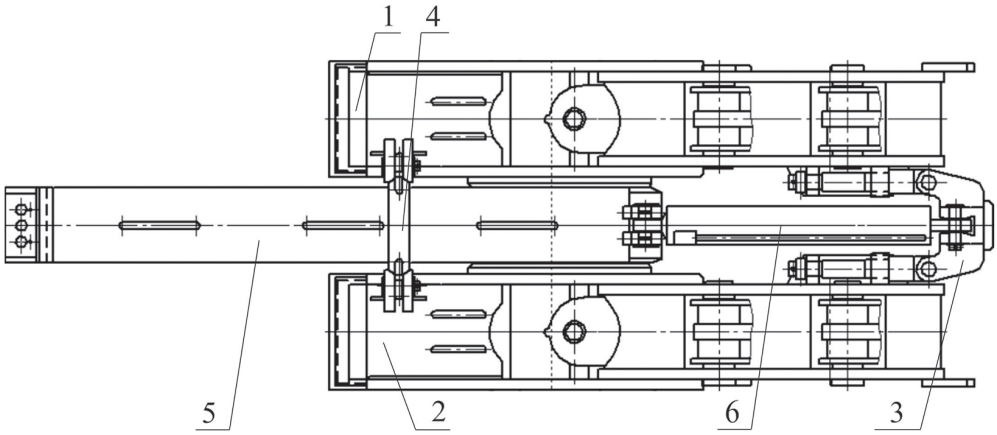

Fig. 4. The base, divided into skids, connected along the blockage by a hinged clamp and along the bottom part by a hinged rod

Рис. 4. Основание, разделенное на лыжи, соединенные по завальной части шарнирным хомутом и по забойной части шарнирной стяжкой

a mechanism for moving *5* of the support units with a hydraulic jack for moving *6* of the reverse action. The presented base was used in single row (KMP, KMR) of the shield powered support units.

The operation of the DFC5 powered support unit the effectiveness of its work on the «thresholds» in the soil when excavating flat seams, due to the absence of a hinged bottom rods and a lifting device for the base, which are not compatible with the kinematics of the skids of the divided base.

During the operation of the mechanized support, the KMR had to dismantle the hydraulic lifting devices of the base, since they complicated the work of the powered support unit. The presence of significant kinks of the coal seam and «thresholds» in the soil caused a violation of the kinematics of the interaction of the hydraulic lift of the left and right skids with the pusher of the movement mechanism of the support unit.

At the same time, the low reliability of the connection of the hinged rod with the eyelets of the skid base was revealed when the support unit of the «thresholds» in the lying wall, consisting in the fracture of the eyelets of the rods.

During the operation of the M137 shield powered support unit in the conditions of the Rostov mine of JSC «Gukovugol», a massive fracture of the eyelets of the hinge rod connecting the base skids along the bottom part occurred (Fig. 4). The reason for the fracture of the eyelets of the hinge rods of the support units of the KMR and M137 was the peculiarity of the kinematics of the bases divided into skids during the passage of the «thresholds» units in the soil of the formation.

Fig. 4 shows the design of the base of the support unit M137, divided into right *1* and left *2* skids, connected by a hinged clamp *3* along the blockage part, and by a hinged rod *4* along the bottom part. Between the skids of the base there is a mechanism for moving the support unit *5* with a direct-acting hydraulic jack *6*.

Fig. 5 shows the structural and kinematic scheme of a single-row shield support unit with the base divided into skids in relation to the transition of «thresholds» in the lying wall. The scheme presented in Fig. 5 is also typical for a two-row shield support unit with the base divided into skids.

It follows from the diagram that the consequence of the fracture of the skid

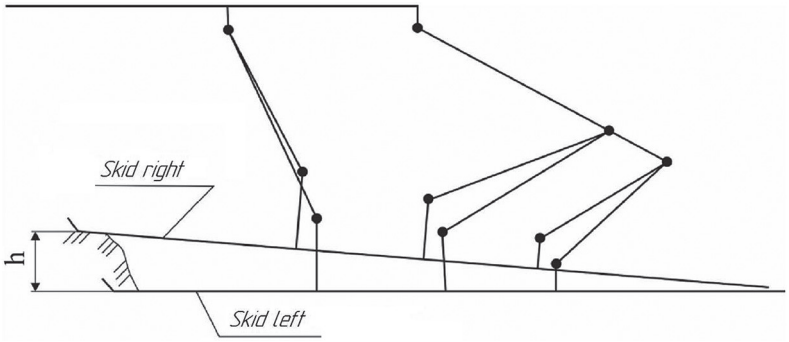

Fig. 5. Structural and kinematic scheme of a single-row shield support unit in relation to the transition of «thresholds» in the lying wall

Рис. 5. Кинематическая схема однорядной щитовой секции крепи применительно к переходу «порогов» в почве пласта

joints (eyelets of the hinge rod) of the base of the support unit is their displacement relative to each other not only in the vertical, but also in the longitudinal planes.

The analysis of the accumulated experience in the operation of complexes and the results of research during the excavation of low and medium of flat and edge coal allowed us to obtain the following conclusions:

- when excavating flat coal seams (up to 18°) [9], including in difficult mining and geological conditions, it is possible to use single-row and double-row powered support units with bases divided into two elements (skids). In this case, the skids should be connected by a yoke only along the blockage part. Between the skids there is a movement mechanism with a direct-acting hydraulic jack;
- when excavating edge coal (from 18 to 30°), the use of single-row and double-row powered support units, with bases divided into two elements (skids), is possible only with an additional connection of skids along the bottom with a flexible connection or other rod that ensures the displacement of skids relative to each other not only in the vertical, but also in the longitudinal planes (Fig. 6).

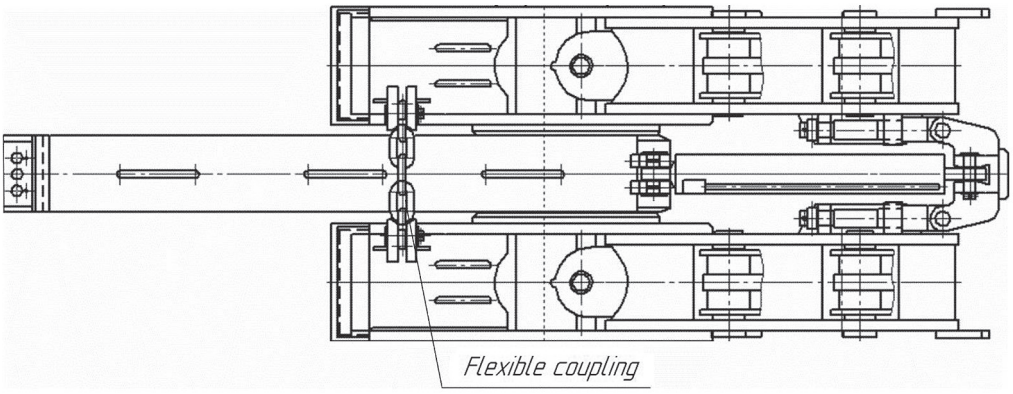

Fig. 6. The base divided into skids, connected along the bottom by a flexible connection and along the blockage by a hinged clamp

Рис. 6. Основание, разделенное на лыжи, соединенные по забойной части гибкой связью и по завальной части шарнирным хомутом

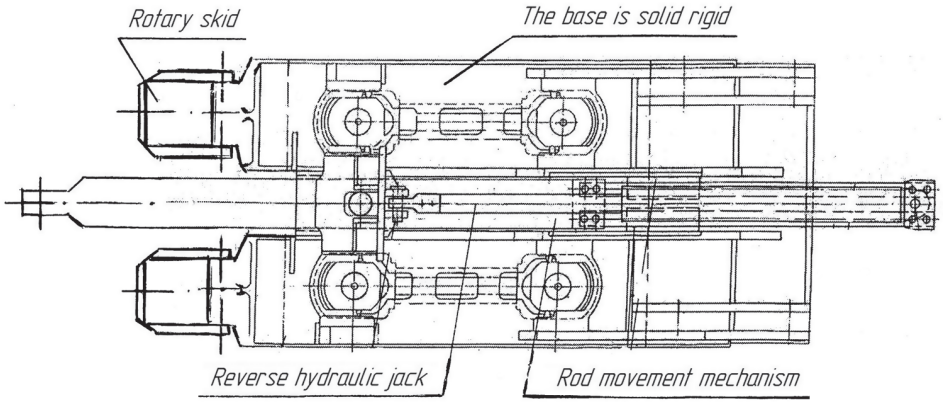

Fig. 7. Perspective adaptive solid rigid base
Рис. 7. Перспективное адаптивное сплошное жесткое основание

The connection along the blockage of the base skids ensures the transverse stability of the support unit when moving it when working out only flat seams. This is confirmed by the characteristic of the support unit of the DFC (Don-Fall 5) [8].

Ensuring the transverse stability of the support unit when working out pitching seam is possible only with an additional connection of the skids along the bottom part with a flexible connection.

At the same time, when excavating both flat and edge coal, the bases should be equipped with rotary skids that ensure the movement of the support unit without «plowing» the ground [10, 11].

At the same time, when excavating flat coal, a solid rigid base can be equipped with both a lifting device for the base and rotary skids that ensure the movement of the support units without «plowing» the ground, and when excavating edge coal, only rotary skids.

Figures 7 and 8 show promising adaptive solid rigid and skid-divided bases, with mounted rotary skids on the toes of a solid flat base and on skids of a split base.

The solid rigid base (Fig. 7) is equipped with a rod mechanism for moving with a reverse-action hydraulic jack and is designed for double-row powered support units when excavating inclined coal seams

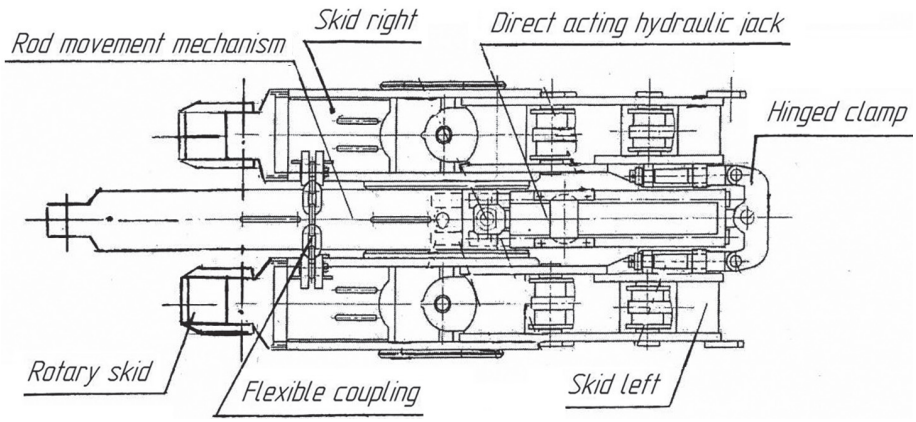

Fig. 8. Perspective adaptive base divided into skids
Рис. 8. Перспективное адаптивное основание разделенное на лыжи

Matrix of conformity of types and design features of mechanisms of adaptation of bases of powered supports to conditions of application

Матрица соответствия типов и конструктивных особенностей механизмов адаптации оснований механизированных крепей условиям применения

Type of base	Type of movement mechanism	Hydraulic jack of move-ment	Type of adaptation mechanism	Flat seams to 18 degrees		Edge seams from 18 to 30 degrees		Drawing of the base
				Strong floor with «thresholds» to 0,2 m and without	Soft floor with shift when moving	Strong floor with «thresholds» to 0,2 m and without	Soft floor with shift when moving	
Coal cutting								
Solid rigid	Flat pusher	Reverse action	Device for lifting the base	–	●	–	–	1
Coal cutting and plow winning								
Solid rigid	Rod	Reverse action	Absence	○	–	●	–	1 without a base lifting device
Solid rigid	Rod	Reverse action	Rotary skis	–	○	–	●	7
Solid rigid	Rod	Direct action	Rotary skis	–	●	–	–	2 with the rotary skids
Skids connected by a blockage	Rod	Direct action	Absence	●	–	–	–	2
Skids connected by a blockage	Rod	Direct action	Absence	–	○	–	●	8
Skids connected on the blockage and bottom-hole parts	Rod	Direct action	Absence	○	–	●	–	6
● – move option; ○ – the option of moving is possible; – – the option of moving is not possible								

with soft floor and can be used when excavating flat coal with soft floor.

The base is divided into skiвs (Fig. 8), connected along the blockage by a hinged clamp, and along the bottom — by a flexible connection. Between the skiвs there is a rod mechanism for moving with a direct-acting hydraulic jack.

The base is designed for powered support units when excavating edge coal with soft floor and can be used when excavating flat coal with soft floor.

The perspective of the presented bases lies in the movement of the support units without «plowing» the soil and their directional movement due to rotary skids and the rod mechanism of movement. The flexible connection provides the kinematics features of the skid-divided base when crossing the «thresholds» in the soil of the formation and allows the excavation of pitching seams.

A solid rigid base and divided into skids without rotary skids can be used in support units for excavating both flat and edge coal with strong soils, as well as with the presence of «thresholds».

Table shows a matrix of compliance of types and design features of mechanisms for adapting the bases of powered supports to the conditions of use.

Definitions in the matrix:

Soft floor — rocks with an indentation strength of less than 2 MPa;

Strong floor — soil rocks with an indentation strength of more than 2 MPa;

Rotary skids are skids mounted on the toes of the base (skids), which ensure the movement of the support units without «plowing» them into the flat wall [10].

Fixing the position of the unit — setting the preset position of the support unit at the end of the movement relative to the downhole conveyor.

Rod movement mechanism — provides directional movement of the support unit [12—18].

Direct action jack — the movement of the support unit is carried out by the force of the rod cavity when it is folded.

The jack of the reverse action — the movement of the support unit is carried out by the force of the piston cavity when it is extended.

The connection of the skids along the blockage is only by a hinge clamp.

The connection of the skids along the bottom of the flexible connection or other rod, which ensures the displacement of the skids relative to each other not only in the vertical, but also in the longitudinal planes.

It is allowed to use rotary skids mounted on the toes of the bases of the combine and plough of shield powered support unit when excavating flat and edge coal with soft floor, since they ensure the operation of the mechanized complex without cyclical stripping of the formation soil from the block mass in the space between the bottom of the base and the conveyor.

The use of a device for lifting a solid rigid base of a combine shield powered support unit when excavating edge coal with both soft floor and strong floor is not recommended due to the increased risk of loss of transverse stability of units when moving them.

The use of a device for lifting the solid rigid base of the plough of shield powered support unit when excavating both flat and edge coal is strictly prohibited due to a violation of the stability of the feed force of the plough plant conveyor to the face and controllability of the conveyor and plough in the vertical plane of the formation.

The use of a reverse-acting hydraulic jack in a solid rigid base makes it possible to increase by 1.46—1.60 times the force of moving the support unit in comparison with a direct-acting hydraulic jack.

In almost all versions of the bases, it is recommended to use a rod movement mechanism, except for a solid rigid base with a base lifting device, for which a mo-

vement mechanism with a flat pusher is required.

The above analysis results have been synthesized by us into a matrix of conformity of types and design features of mechanisms for adapting the bases of powered supports to the conditions of use (Fig. 9), which makes it easier to choose the necessary option.

Conclusion

1. The results of the operation of shield powered supports during the excavation of flat and edge coal with soft floor and the presence of «thresholds» in the flat wall, which allowed to establish restrictions on the use of specific variations of the execution of the bases.

2. Recommendations are proposed for equipping solid rigid and skid-separated bases with lifting devices or rotary skids mounted on the toes of the bases (skids) that ensure the movement of the support units without » plowing» the ground.

3. Recommendations have been developed in the form of a matrix of conformity of types and design features of mechanisms for adapting the bases of powered supports to the conditions of use, which made it easier to choose the necessary option.

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РУКОПИСИ, ДЕПОНИРОВАННЫЕ В ИЗДАТЕЛЬСТВЕ «ГОРНАЯ КНИГА»

МОДЕЛИРОВАНИЕ ГИДРОДИНАМИЧЕСКОГО ВОЗДЕЙСТВИЯ НА УГОЛЬНЫЕ ПЛАСТЫ

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Коликов К.С., Фан Туан Ань, НИТУ «МИСиС»;
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Освоение нетрадиционных углеводородов – метана угольных пластов, является одним из условий обеспечения комплексного освоения углегазовых месторождений. Базовой технологией данного направления является гидродинамическое воздействие на угольные пласты, в результате которого за счет раскрытия трещин создаются условия для извлечения метана. При этом важное значение имеют напряжения, действующие в массиве и определяющие характер распространения трещин. Перед проведением гидравлического воздействия проводят комплексный анализ Reservoir Characterization для построения геомеханической модели. Для отслеживания развития трещины применяется микросейсмический мониторинг. Стал применяться подземный гидроразрыв для интенсификации газовыделения в пластовые скважины предварительной дегазации. Для оптимизации параметров гидродинамического воздействия было проведено моделирование с использованием ПО Fracpro.

Ключевые слова: гидравлический разрыв пласта, метан угольных пластов, геофизические исследования скважин, давление, моделирование, дегазация.

MODELING OF HYDRODYNAMIC EFFECTS ON COAL SEAMS

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The development of unconventional hydrocarbons – methane from coal seams, is one of the conditions for ensuring the integrated development of coal and gas deposits. The basic technology of this direction is the hydrodynamic effect on coal seams, as a result of which, due to the opening of cracks, conditions are created for the extraction of methane. Before carrying out hydraulic impact, it is advisable to conduct a comprehensive analysis of Reservoir Characterization to build a geomechanical model. Microseismic monitoring is used to track the crack development. In recent years, underground hydraulic fracturing has been widely used to intensify gas release into reservoir wells of preliminary degassing. To optimize the parameters of the hydrodynamic impact, modeling was carried out using Fracpro software.

Key words: hydraulic fracturing (hydraulic fracturing), coalbed methane (CBM), Geophysical well surveys (GIS), pressure, modeling, degassing.