Development of the properties of adaptability of the support sections of treatment complexes to variable mining and geological conditions

Vasilisa Teremetskaya*, *Viktor* Gabov

Saint Petersburg Mining University, 2, 21st Line, St Petersburg 199106, Russia

Abstract. In modern conditions, intensive underground coal mining is provided, as a rule by working out the dredging sections of coal seams with long cleaning faces using high-performance mechanized complexes. They consist of a dredging machine, a conveyor and a set of sections of mobile mechanized support (SMS). SMS, supporting the roof, controlling the mountain pressure (MP) and protecting the bottom-hole space, provide conditions in complex mechanized treatment faces (CMTF) for efficient and safe coal mining. However, the potential capabilities of modern complexes significantly exceed the values of efficiency indicators achieved when using them in operating conditions. One of the reasons for this situation is the insufficient adaptability of the SMS to the mining and geological conditions (MGC) changing in a wide range as the excavation sites are worked out. Therefore, at present, studies of the possibility of developing the properties of adaptivity (kinematic, power, contact, technological) of the SMS to the MGC variables are relevant. Their results will contribute to the expansion of the functional capabilities of the SMS to maintain favorable conditions in complex mechanized treatment faces for the effective operation of the mechanized treatment complex (MTC) in variable mining and geological conditions.

1 Introduction

The main volume of underground coal mining is currently provided by the CMTF of coal mines during the development of shallow coal seams of medium capacity. Every decade, the intensity of underground coal mining increases, which leads to an increase in the rated power of drives and the metal consumption of combines, conveyors, pumping stations, mechanized supports and reloaders. The desire to increase the reliability of machines and equipment leads to an increase in their strength and weight and, consequently, affects their mobility and reaction to changing conditions, the duration of operations for their movement, the time of their installation and dismantling. At the same time, the values of the indicators of the potential capabilities of the complexes significantly exceed the values of the efficiency indicators achieved when using them in operating conditions. One of the reasons for this situation is the change in a wide range of mining and geological conditions as the excavation sites are worked out [1]. Therefore, at present, studies of the possibility of developing the properties of adaptability (kinematic, power, contact, technological) of the SMS to the variables of the MGC are relevant, which will contribute to expanding the functionality of the SMS to maintain favorable conditions in the CMTF for the operation of the MTC in variable mining and geological conditions.

With an increase in the intensity of the extraction process, with the same parameters, the speed of movement of the support section increases, as well as the speed of performing basic and auxiliary operations [3]. Modern supports are designed and manufactured for the most severe conditions, and therefore they are, as a rule, overestimated in terms of their power characteristics and metal consumption. The resource of modern sections of mechanized support reaches 10-15 years [20].

Sections of mechanized support support the roof rocks, control the rock pressure and protect the working space of the treatment face. The quality of these operations depends not only on the efficiency of the support section, but also on the efficiency of the complex as a whole. SMS together provide conditions in long treatment faces for efficient and safe coal mining.

However, the potential capabilities of modern complexes significantly exceed the achieved efficiency indicators of their use in operating conditions. The degree of achievement of these efficiency indicators is very significant for coal mining enterprises [12].

One of the reasons for this situation is the change in a wide range of mining and geological conditions as the excavation site is worked out and the inability of the section to adapt to these changes. Therefore, experts point to the need to give the SMS support the properties of adaptability to these variable conditions, which will allow maintaining the nominal parameters of the operating modes and the efficiency of the MTC. To do this, it is necessary to develop the support sections by

* Corresponding author: vasilechichek_23@mail.ru

giving them the properties of adaptability to variable conditions to such an extent that the operating conditions, despite the changes, are nominal, so experts point to the need to give the support sections the properties of adaptability.

The article provides an analysis of the functions performed by the SMS and the directions of their development, discusses the main auxiliary operations, presents a section taken as a basic one, considers the main disadvantages of existing fasteners, and presents proposed technical solutions for their improvement.

2 Purpose, objectives and method of research

The mechanized support is designed to provide conditions for the continuity and safety of the mining process. The main tasks of the SMS are the qualitative performance of the main and auxiliary functions (Fig. 1). Previously, there were a large number of different types of supports, but most of them did not justify themselves, and the main, shield supports remained. Moreover, in the world practice, there is a wide variety of classification schemes of mechanized supports used in cleaning faces [2]. Among the specialists, the basic concepts and structures of the support sections have been established. There are different types of fasteners, their capabilities and applications. In CMTF with intensive development of reserves according to the method of interaction directly with the roof, supports of the supporting and supporting-protective type are used, less often protective-supporting, and protective, currently practically not used. During intensive work, as a rule, aggregate sections of the support are used, that is, kinematically connected to the conveyor and to each other along the length of the lava. Shield supports, double-post, single-row are mainly used. The arrangement scheme is mainly used linear with sequential and group movement.

3 Methods. The structure of the performed operations

Considering the structure and process of functioning of sections of mechanized support, it is necessary to distinguish the main cyclically repeating stable operations (Figure 1). These are maintaining the roof and controlling mountain pressure, protecting the bottom-hole space from the penetration of collapsed roof rocks, and auxiliary operations related to the positioning of the support section in the face and aimed at improving the main operations. That is, they ensure: removing the SMS strut, moving the conveyor and SMS, re-strut, adjusting the position of the SMS during their movement. They are necessary for changing cycles [19]. The effectiveness of the complex as a whole depends on the SMS as they create conditions for the operation of all other equipment and ensure safety, so the work of the complex will be effective [6].

It is advisable to divide the auxiliary operations performed by the mechanized support section into operations that improve the conditions for performing the main functions; into operations performed regularly (cyclically); into irregular operations performed "according to the situation" (Fig. 1).

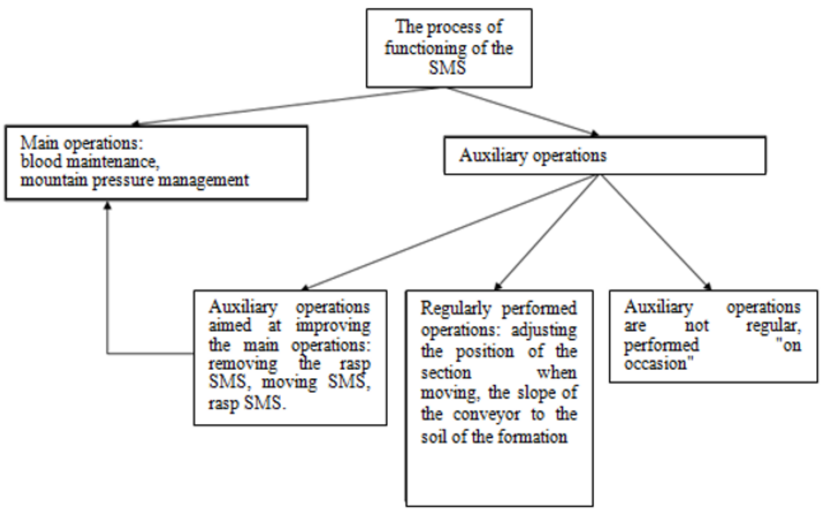

Fig. 1. Structure of SMS operations performed per cycle (compiled by the author)

4 Characteristics of the stages of SMS development

Therefore, a great development of the SMS was carried out, but the shield supports found the greatest use. The main elements are the overlap, base, protective shield, hydraulic support, and auxiliary elements: balancers, a moving jack (Fig. 2) [10].

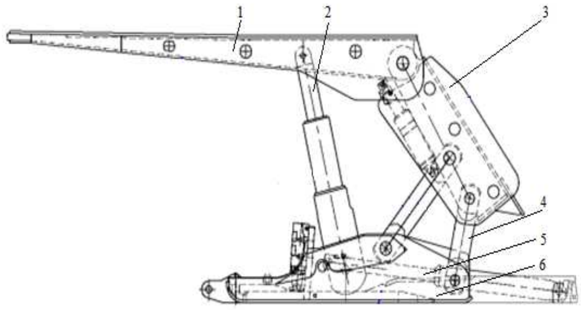

Fig. 2. Typical section: 1-overlap, 2-hydraulic supports, 3-protective shield, 4-balancers, 5-moving jack, 6-base [10]

According to the number of structural elements and their kinematic connections, they can be represented as follows:

A· SP·[0+FT]·S·4l

(A – all elements are aggregated, that is, they have a kinematic connection throughout the face, SP - supporting and protective, single-row with elongated overlaps, double-column with a forward tilt, shield, 4 – link with a catamaran-type base).

When lifting and moving, there is a jamming and a turn of the rack. Thanks to the hydropatrons and retractable shields, the racks occupy a perpendicular position relative to the roof soil, and when filling up on the side, the rack can be corrected [4], [5]..

The load acting on the mountain support is the result of the influence of the mountain massif, the stability of which is disturbed due to the process of mining. The various loads supported by the effects arising in this situation and the effects caused by it depend on a number of factors. Before choosing a mechanized support, it is necessary to correctly analyze and determine all the mining and geological conditions in the area. The results of this test should be applied when selecting various components of the section, in particular the control system and the rack security system [8].

Due to the fact that mining and geological conditions change in a wide range, it is necessary to change its parameters in order to preserve the nominal capabilities of the mechanized support section. Since it is no longer possible to change the structure, you can change the values of parameters (power, width, etc.) [8]. You can also change the positions of elements or sections. The degree of development of this adaptability is the initial elements of adaptation [18].

The main factors affecting the efficiency of using high-tech mechanized treatment complexes in mining and geological conditions are:

- development of seams in areas close to zones of increased rock pressure;
- dislocation zones of geological disturbances;
- change in the thickness of the reservoir in the zones of geological erosion;
- zones of changes in the state of the roof and fracturing;
- changes in the structure of the layer: splitting, lenticular inclusions of rocks;
- changes in the structure and nature of the rock of the immediate roof;
- high content of methane;
- hazards of impact on mountains;
- formation of domes (vaults) and so on.

5 Discussion. Adaptation

Adaptation [20] is the adaptation of technical devices or systems to changing external and internal conditions, which contributes to increasing the efficiency of their use.

Significant differences in the efficiency of operation of the same type of mechanized treatment complex under different mining and geological conditions in coal mines are usually explained by the complexity of these conditions or the lack of technical measures taken to excavate the complex and coal seams [2]. Changes in mining and geological conditions especially significantly affect the reliability of the mechanized complex of equipment, the quality of the technological process that regulates the rock pressure, as a result of which the stability of the overall technical process of processing the face decreases. Such a situation can also be considered as insufficient adaptability to the changing mining and geological conditions of the complex (mainly mechanized support elements).

Traditionally, there are 3 types of adaptability [7], [15], [19], [16]:

1. Dynamic adaptivity is aimed at reducing the maximum dynamic loads, reducing the deformation rate, thereby reducing the pressure and reducing the support. And it is achieved by using safety valves, dampers, elastic elements, automatic control devices of the principle of inertial action. Dynamic adaptability is the most important and it determines reliability in operation, maximum loads, and, therefore, deserves special attention.

2. The adaptability of the contact is estimated by the range of pressure changes that occur in contact between the ceiling and the base and the lateral interaction with the roof and the soil. This is facilitated by supporting elements, such as various types of visors and soft gaskets. This adaptability is currently solved in a very narrow range. There are only expressed ideas, but there are no real constructions of contact-adapted sections.

3. Kinematic adaptivity consists in the mutual mobility of the kinematic links of the support sections, providing optimal force interactions with the roof and side rocks.

Considering the ways to increase adaptivity, it is necessary to consider separately both contact, kinematic, and dynamic, because each specific method can solve

some task, and then, considering a joint action, we can talk about a complex manifestation of adaptivity.
To give the support sections adaptive properties, it is necessary to improve their structure, kinematics, the design of the section itself and its blocks and its individual kinematic elements [17]. When changing the geometric parameters of the bottom-hole space, the parameters of the elements of the support section (bases, floors, balancers, jacks, etc.) change accordingly. By giving adaptive properties to sections of mechanized support, the following tasks are solved [19]: contact distribution, changing the direction of resistance of the support section with a change in the angle of incidence, etc.

6 Results and Discussion

Previously, there was a support section presented by Korovkin: the section is not adaptive. The size does not change; as the force increases, deformation occurs. The next option: a hydraulic rack was added. Next, the enclosing part was included. The section has become two-row .

There is an increase in the contact area. The movement of the support is carried out with a support without the formation of gaps between the roof and the soil: a section of hydrofected support with a telescopic overlap (Fig. 3) [12].

The support section, which has a telescopic overlap, a guide and support beam, consists of a visor-1, a downhole overlap-2, a portal of a downhole overlap-3, a portal of an overlap-4, a blockage overlap-5, an enclosing shield-6, a base-7, a hydraulic support-8, a hydraulic jack of the base-9, a portal of the base-10, a guide beam-11, a downhole conveyor – 12. It provides a balance of force and torque when moving the bottom hole overlap, and the part as a whole has an increased support, a straight roof face strip for high-quality maintenance, to prevent the development of cracks, while moving the bottom hole overlap and racks, without removing the racks from the clogged overlap and adjacent sections. This reduces the “trampling” of the roof, while achieving the following technical advantages: the possibility of increasing the cross-section of the bottom hole space. Therefore, reducing the performance limitation of the natural gas combine, reduction of the time of movement of the overlapping part of the bottom of the well compared to the total time of movement of the support part. This depends on the mining, geological and technical conditions of the mechanized complex, a larger number of mobile schemes of the group of support parts can be performed in complex mechanized treatment faces.

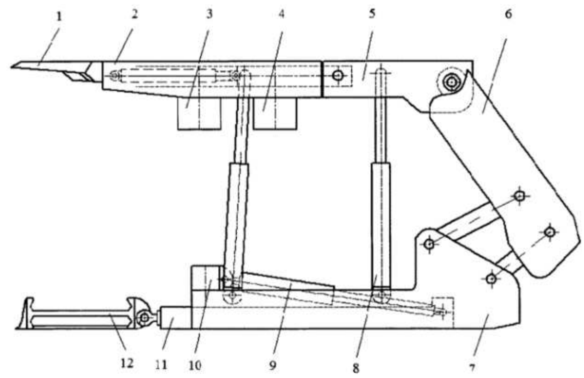

Fig. 3. Section of hydrofected support with a telescopic overlap. [12]

The section of the mechanized support with a guide and support beams (Fig.4) [15] consists of a visor-1, a portal on the overlap-2, a hydraulic jack on the overlap-3, a top-4, a block fence of the section-5, a hydraulic support-6, hydraulic jacks for moving along the base-7, the base of the section-8, a portal on the base-9, a guide beam-10, a downhole scraper conveyor-11.

The mechanized support part of the cleaning mechanized complex is made of a support element. The support element is a guide beam along the base and a support beam along the floor, providing a walking movement of the part, the support element at the same time. The movement of the part can be carried out with active or passive support of the roof overlap, destruction in contact with the roof, depending on the strength characteristics of the soil, rock and soil.

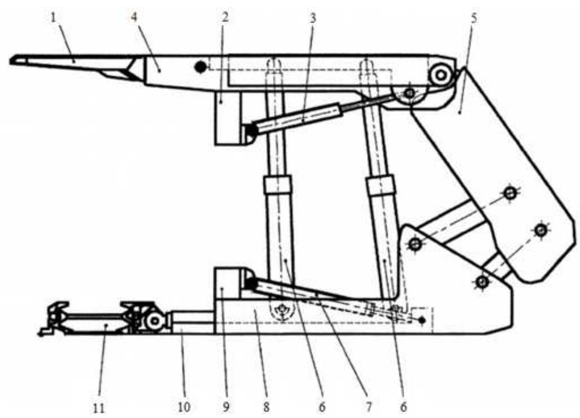

Fig. 4. General view of the section of mechanized support with a guide beam. [15]

The section of the mechanized support with a telescopic base and overlap (Fig. 5) [7] consists of a visor – 1, a bottom - hole overlap - 2, a bottom - hole portal - 3, bottom - hole hydraulic pillars - 4, bottom - hole portal - 5, a console hinge - 6, a landing overlap – 7, landing hydraulic pillars - 8, an enclosing shield - 9, a landing base - 10, a bottom-hole base – 11, a base portal-12, a bottom-hole portal of the base – 13, a guide beam – 14, a bottom-hole conveyor – 15, the hinge of the downhole hydraulic jack – 17.

A section with a telescopic base and an overlapping mechanized support, containing an overlapping and catamaran-type base made in the form of a snowboard.

The sides are connected by a portal in which there is a rod, one end of which is connected to a conveyor. The other is in the form of a hydraulic jack, a hydraulic bracket is placed between the base plate and the base, and the lifting mechanism of the snowboard base mounted on the rod in a vertical position. A hydraulic cartridge and a sliding bearing – bearing portal – pass into the roof. The support part is connected to the base in a telescopic form, and when the landing and bottom-hole steps overlap, the possibility of moving each other does not exceed one movable step of the support part, and the base of the landing stage is connected to the base by two liquid steps.

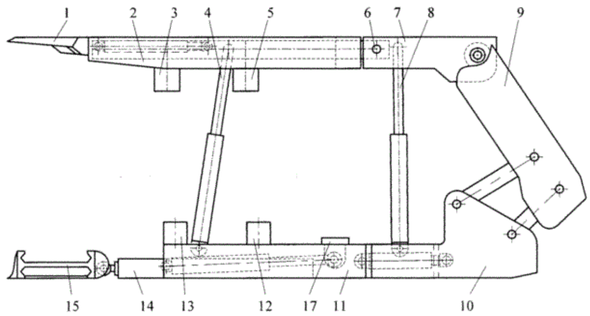

Fig. 5. A section of mechanized support with a telescopic base and overlap. [7]

There are sections with sliding sides on the overlap, and you can make the sides and on the base, and then the section can be controlled. Adaptability consists in mobility, adjustment of position, adjustment during each operation. By introducing the considered kinematic links, we make it possible to control the sections of the support when moving, when controlling, when the roof resists.

Tests of the mechanized support are carried out for its individual components and parts. They include mechanical and hydraulic systems, as well as control systems. The tests are carried out in real conditions, including on test benches, and in the form of model tests. There are also various ways to load test components and parts.

Taking into account modern knowledge, practical experience and requirements for mechanized support, we can say that hydraulic support is the most important factor affecting the level of system efficiency. Proper control systems and overload protection devices make it possible to fully utilize the full potential of the entire support, including various parts, and adapt to the geological conditions in which mining is also carried out. From an economic point of view, the role of security systems is also very important. It should be emphasized that the mechanized support is the most expensive machine in the mechanized complex, so it must be protected from possible damage and breakdowns.

The disadvantages of the known design are: the inability to move the support section in the event of an increase in the support; the unbalanced position of the support section in the vertical plane; an increase in the possibility of interference between the soil and the roof when moving to the face. When removing the load and subsequent strut, the movement of the section is accompanied by immediate static trampling of the rock.

7 Conclusion

A key component of an effective system currently used for the development of underground coal deposits is a mechanized support. Its reliable and efficient operation in the field of mining ensures the safe and efficient operation of the mining process. Changes in the mining and geological conditions in the mountains have led to the appearance of many requirements that the support sections must meet. These requirements increase with the deterioration of environmental conditions, which is obvious with an increase in the depth of mining operations. Therefore, research and testing are being conducted to adapt the support to these unpredictable production conditions.

Moreover, although the direction of improving the adaptive properties of sections is not developing too quickly, it can already be concluded that adaptive sections of mechanized support can provide more stable modes of operation of treatment complexes in variable mining and geological conditions, as the excavation site is worked out.

The adaptability of the support section helps to reduce the cycle time of operations, increase the productivity of complexes.

The article is of a debatable nature.

References

1. D. Szurgacz, J. Brodny, Energies 2020, **13**, 405 (2020)
2. N.V. Titov, Yu. V. Turuk, S. D. Vasiliev, Mining information and analytical bulletin (scientific and technical journal), **4**, 215-219 (2010)
3. M. Tutak, J. Brodny, J. Proceedings of the 17th International Multidisciplinary Scientific GeoConference SGEM 2017, Vienna, Austria, 27–29 November; pp. 635–642, (2017) doi:10.5593/sgem2017H/43/S29.080.
4. D. Szurgacz, J. Brodny. In Proceedings of the 18th International Multidisciplinary Scientific GeoConference SGEM, Albena, Bulgaria, 2-8 July; pp. 343–350, (2018)
5. M. Axin, Ph.D. Thesis, *Mobile Working Hydraulic System Dynamics,* Dissertations No. **1697** (2015)
6. A.V. Stebnev, V.V. Buevich, Notes of the Mining Institute, Founders: St. Petersburg Mining University, ISSN: 2411-3336, eISSN: 2541-9404, UDC: 622.23.05. (2017)
7. V. V. Gabov, D. A. Zadkov, N. V. Babyr, A.V. Stebnev, V. V. Buevich, Mining equipment and electromechanics. **3**, 28-34 (2016)
8. B. A. Frolov, V.I. Klishin, V.S. Verin, *Methods of improving the adaptability of powered roof supports* (Novosibirsk: Nauka, 1983)
9. S. I. Panin, V.M. Tarasov, Manual ICJ.**2Ш-04** RE (2010)

10. V.G. Yatskikh, L.A. Spector, A.G. Kucheryavy, *Mining machines and complexes* (Nedra, 1984)
11. G.V. Maleev, V.G. Gulyaev, N.G. Boyko *Design and construction of mining machines and complexes: Textbook for universities* (Moscow: Nedra, 1988)
12. V.I. Klishin, Yu. V. Matviyets, FTPRPI, **2**, 23-29 (1993)
13. Tu. A. Korovkin, *Mechanized supports of treatment faces* (Nedra, 1990).
14. V.I. Klishin, *Adaptation of mechanized supports to dynamic loading conditions* (Novosibirsk: Nauka, 2002)
15. V. V. Gabov, V. A. Morozov, A.V. Stebnev Patent of the Russian Federation, No. 176896 *Section of mechanized support with telescopic base and overlap* (01 February 2018)
16. V. V. Gabov, A. V. Stebnev, S. G Mukhortnikov., D. A. Zadkov, N. V. Babyr; Patent of the Russian Federation No. 175187 *Section of mechanized support with telescopic overlap* (27 November 2017).
17. G. Buyalich, M. Byakov, K. Buyalich, E. Shtenin, E3S Web Conf., **105**, **03025** (2019)
18. J. Gil, *Flow analysis in pressure limiting systems of the hydraulic rack workspace in a mechanized wall housing,* Ph.D. Thesis, AGH University of Science and Technology (2014)
19. V. V. Gabov Patent of the Russian Federation - No. 169381 Section of mechanized support with guide and support beams (16 March 2017).
20. W. Jinhua, Y. Bin, K. Hongpu, W. Guofa, M. Debing, L. Yuntao, J. Pengfei, Int. J. Coal. Sci. Technol., **2**, 97–161 (2015)
21. J. Gil, M. Kołodziej, D. Szurgacz, K. Stoiński, Min. Inform. Autom. Electr. Eng., **56**, 33– 38 (2019)