Enhancement of Powered Cleaning Equipment with the View of Mining and Geological Conditions

N V Babyr[1], A I Korolev[1], T V Neupokoeva[2]

[1] Saint-Petersburg Mining University, Vasilievsky Island, 21 liniya, 2, 199106, Russia
[2] Federal State Budget Educational Institution of Higher Education «Industrial University of Tyumen», 38, volodarskogo Street, Tyumen, 625000, Russia

E-mail: nik.babyr@bk.ru

Abstract: A method aimed at the enhancement of powered cleaning equipment, in particular, the section of powered support and armored face conveyor with the view of changing both mining and geological conditions is considered. The article offers the hydraulic prop operating characteristics of powered support sections with the separated functions of rock pressure protection and control, as well as non-pulse control of the resistance of hydraulic props of the support sections to the lowering of roof rocks and the structure of armored cutting conveyor with the curved flight (unit) capable of forming a support surface along the ground for directional movement of powered cleaning equipment and control the layer pressing by means of cutting. The whole unit is aimed at the adjustment of position of equipment along the ground, as well as control of the rock pressure and the ground pressing. All this enhances the operability of equipment as a whole.

1. Introduction

Russia is one of the world's leading countries in explored reserves and production volumes of the most important types of minerals. Coal is considered the main source of power and heat in the fuel and energy balance of the country. Its huge reserves in Russia allow us to assess the long-term opportunities of development of power industry based on the use of coal as a key strategic fuel that can meet the needs of mankind in fuel for hundreds of years. To some extent, the energy security, as well as economic and social stability of the country is related to the development of coal-fired power industry [1].

Coal plays an invaluable role in modern life. It is used almost in all spheres of management, not only industrial, but also private ones. Coal production is growing every year due to technological progress.

2. Materials and methods

Currently, almost 3/4 of the coal extracted from the mines is a complex powered mining face (CPMF) the main equipment of which is an excavating machine, a hydroficated support and an armored flexible conveyor. Numerous types of reliable high-performance powered cleaning equipment (PCE) with hydroficated supports have been designed to be used in various mining and geological conditions (MGC) with manual, remote, program and automated control. A significant success is observed in the

enhancement of clean-up operations in CPMF of coal mines, especially during the extraction of high-efficient coal beds (HECB).

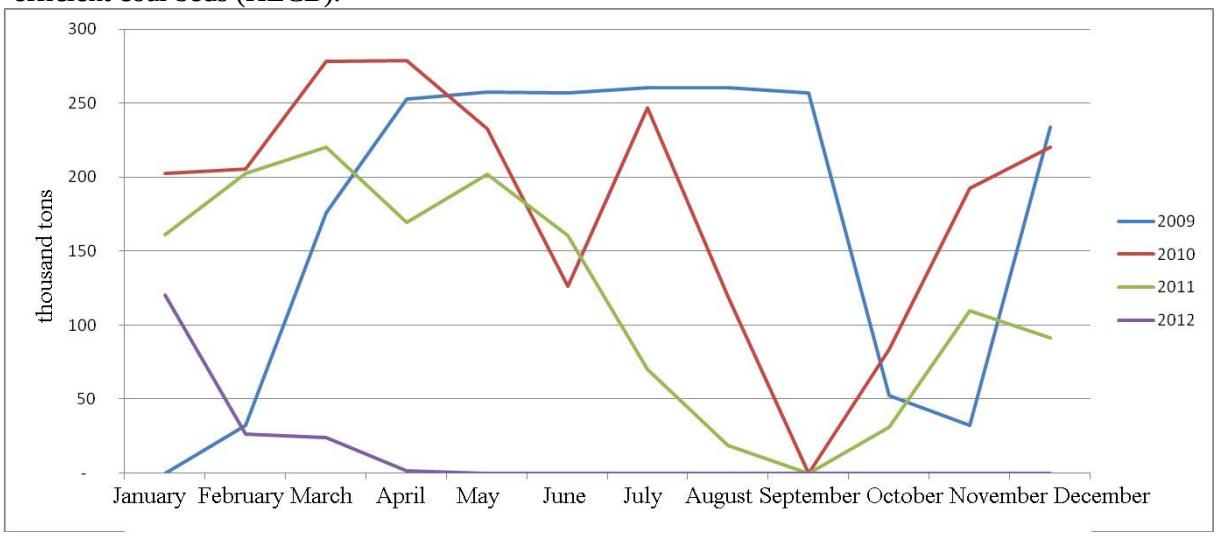

Figure 1. Mine named after A.D. Ruban, 2009-2012, lava 13.

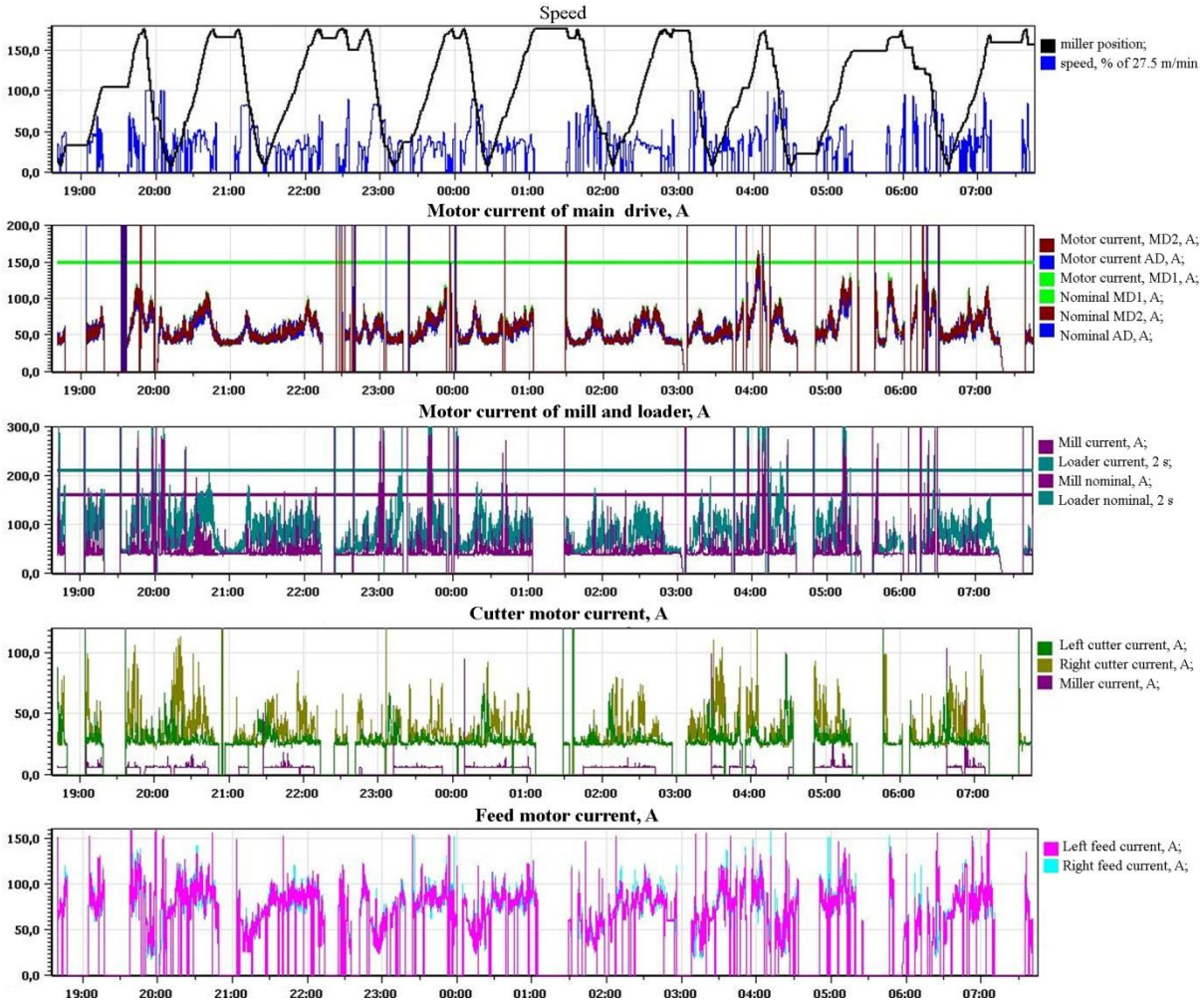

Figure 2. Speed change of miner in the lava and load change on CPMF machines drives

The analysis of the operation of PCE of the mine named after A.D. Ruban (Fig. 1,2) makes it possible to draw the following conclusions [2]:

- complex mining and geological conditions during the extraction of coal beds in mines (high gas content and water cut, seam liable rock-bumps and gas dynamic phenomena, presence of geological disturbances and unstable roofing, stratification and fracturing of the roof rocks, breakouts, changes in reservoir thickness and in its structure) have been the main constraining factors of stable work of mining faces for a fairly long period of time;
- frequent decreases in the feed rate of a miner and a lot of relatively short breaks in the operation of a miner are typical for all CPMF, while the determining factors have been little studied and the significance of their influence on the process has not been evaluated;
- high potential of equipment for clearing operations and technological provision of CPMF production process are not used at their full capacity;

This situation is explained by insufficient adjustability of modern highly powered cleaning complexes to the mining and geological conditions (MGC). An essential role in the overall adjustment of PCE to operating conditions belongs to a powered support and an armored conveyor (Fig. 3) as they are regarded as the main equipment providing all necessary conditions for the operation of both main and auxiliary equipment of the complex [3].

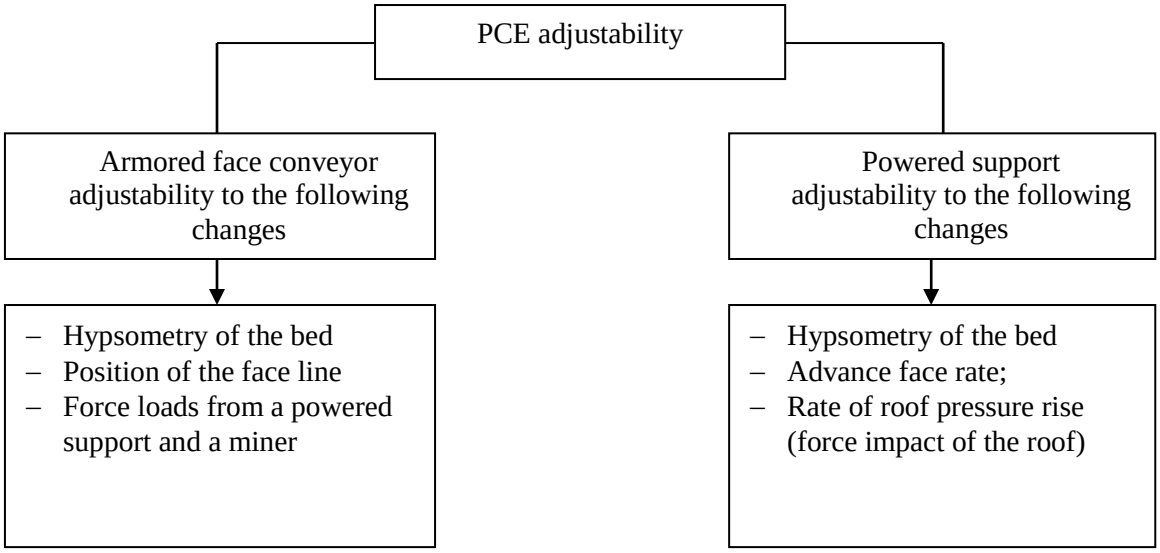

Figure 3. Structural diagram of adjustability of cleaning powered complexes

Today, the powered supports are manufactured with specific regard to mining, geological and technological operating conditions. However, even in this case the rock pressure and the strength properties of the rocks of the immediate roof are changing in a wide range, which significantly affects the performance of mining equipment and complexes. One of the reasons for this situation is an unchanging, rigid in the structure, form and parameter values operating characteristic of the hydraulic props of the support section manifested in the form of so-called “static” and dynamic “treading” of rocks of the immediate roof. The consequences of these processes are manifested in the accelerated crack formation of the rocks of the immediate roof, its sprinkling from the roof into the face space, non-symmetric loads on the supports and in the loss of contact of the overlaps with the roof [4].

The main power support element of any section of powered support is a hydraulic rack that cyclically performs the functions of force interaction through the overlap and the base of the support section with the roof rocks and the ground in accordance with its specified operating character shown in the dotted line in Fig. 5. The quality of the roofing maintenance, rock pressure and protection of the

face space from the breakouts of rock depends on the quality of each section of powered support of all operations of the cycle and their total indirect influence on the process of rock pressure control.

The process of regulation of rock pressure is carried out in accordance with the so-called equal resistance characteristic, which is marked on the diagram (Fig. 2.1) by points 3, 4, 6, and 8 showing the successive operation of the safety valve, which leads to intensification of the cracking processes in the rocks of the immediate roof.

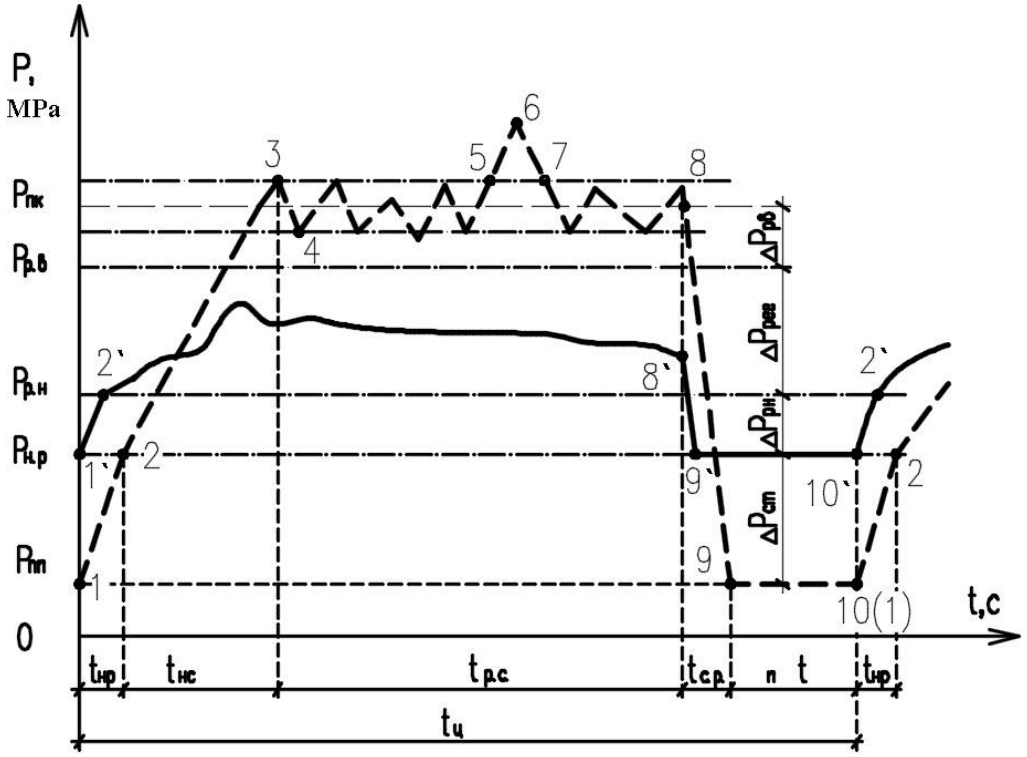

Figure 4. Idealized operating characteristics of hydraulic props of support section

According to the data accumulated during the years of operation of the equipment and complexes, in this case, the props of powered support are loaded unevenly and the operation of the safety valves demonstrates, in fact, the emergency situations. Violations of the integrity of the roof rocks (roof breaks, breakouts and peelings), in one case, are the consequences of an excessive resistance of the support, exceeding the rock strength of the immediate roof, and, in another case, these are the consequences of the successive trips of safety valve, which are accompanied by dynamic impacts on the rocks of the immediate roof.

To reduce the effect of dynamic and static "treading" of the roof, it is proposed to put the operating characteristic structure of the hydraulic props of the support sections to the form shown in Fig. 4 of the curve 1`, 2-10`. The peculiarities of the characteristic would be as follows:

- separation of the overload protection function of the section from the technological function of regulation of the rock pressure;
- control of the rock pressure is carried out by the continuous regulation of the volume of the displaced working fluid from the piston cavity of the hydraulic prop through the hydraulic converter to the pressure line of the hydraulic system of the complex, and not as a consequence of the safety valve trip;
- shifting of the support section can be done by means by contact rupture with the roof, with the help of skid or in a non-unloading mode, depending on the condition of the roof and the support section type.

The proposed operating characteristic of the hydraulic props of the powered support sections with the separation of the protection functions and the rock pressure control, pulse-free regulation of the resistance of hydraulic props to the lowering of the roof rocks results in the following features in relation to the roof management process:

- reduction of "static treading" of the rocks of the immediate roof;
- increase in the adjustability of the support sections to the slowly changing rock pressure;
- exclusion of the dynamic impacts of powered support on the direct roof in the mode of rock pressure control.

With the current practice of designing conveyors with the unchanged operating parameters for severe operating conditions it is impossible to provide their maximum efficiency in all operating conditions, which are very diverse. The efficiency of conveyors can be increased in case the operating parameters meet the actual operating conditions and the actual technical state of the power system [9].

In spite of great diversity of external factors and a wide range of loads of armored face conveyors it is very difficult to ensure their full compliance with the operating conditions. Firstly, due to the insufficient technological flexibility of the conveyors, due to the increased metal capacity the power of which varies stepwise depending on different number of drive blocks and the same strength of a traction organ; and secondly, because of different geological conditions, as well as technical condition of the conveyors. The discrepancy between the conveyor and the specific operating conditions leads to instability of position of a complex in space regarding the face line, energy consumption, resource loss with the steady motion and reliability [10].

Based on the accumulated data and the experience of cleaning works the main disadvantages of the armored conveyors are as follows:

- poor adjustability to the complex hypsometry and to the face line due to the excessive rigidity of the conveyor belt;
- failure to separate transportation of coal and rock and, consequently, failure to have selective excavation;
- low availability factor as the traction chain is closed in the vertical plane, which leads to difficulties as far as maintenance and repair concerns;
- mismatch of their kinematic and power parameters to real operating conditions

Based on the analysis of manufacturing documents and design features of scraper conveyors the directions for improving the armored face conveyor have been formulated in terms of giving it additional functions that would ensure the development of additional adjustability of cleaning powered equipment and complex (Fig. 5), as well as manufacturability and reliability which are reduced to the following needs [11]:

- ground profiling for directional movement of the complex along the ground;
- cutting of the bed to control its pressing and the rock pressure;
- separate transportation, selective excavation of mineral resources and an increase of reliability and maintainability.

Based on the results of the analysis of patents, as well as technical and design documentation the most suitable solution to increase the equipment and complex adjustability to difficult mining and geological conditions is the armored face cutting conveyor (Patent RU 2574090).

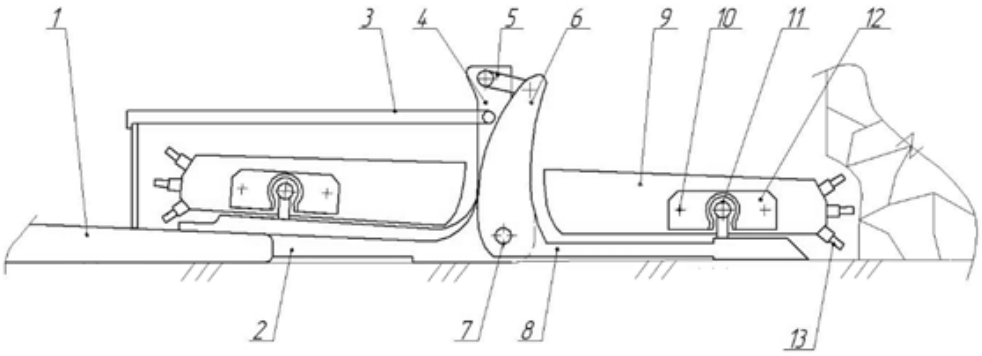

Figure 5. Armored face cutting conveyor where: 1 are the bases of the support section, 2 are the foundation pans, 3 is the support plate, 4 is the support prop, 5 is the hydraulic jack, 6 is the support arm of the face pan, 7 is the support pin, 8 is the face pan, 9 is the scraper, 10 are the pull chains, 11 is the supporting guide, 12 is the sliding carriage, 13 are the cutters [9].

The scraper 9 with the cutters 13 and the pull chains 10 transports the shattered mass, cleans, shapes the ground and cuts the bed. Adjustment of the position of a face pan 8 along the ground is carried out by a hydraulic jack 5 with the support on the support prop 4 and support arm 6. Transportation of auxiliary loads in special carriages and transportation of people can be done with the help of the support plates 3 of the foundation pans 2. The chains 10 are located on two sides symmetrically from the supporting guide 11 in the sliding carriage 12 to balance the forces acting on the scrapers. To increase the stability and evenly distribute the pressure of the support base over the entire area of the ground so that to avoid possible digging-in of the powered support base section into the ground when skidding or shifting with the support, the base of the support section1 is made elongated and, to a greater or lesser extent, may be placed under the pans of the flight of armored face conveyor.

3. Conclusion

The layout of a face cutting conveyor with horizontally closed chain results in the following:

- increased stability of technological process of coal mining in complex powered mining face with difficult mining and geological conditions;
- possible separate transportation of coal and rock, therefore, selective coal mining;
- increased availability ratio of face conveyor and the time of OMC's mining efficiency.
- When the proposed characteristics of the hydraulic props of powered support with separated functions of protection and control of the rock pressure are applied, it is possible to achieve the following:
- sustainability of the cleaning process by reducing both static and dynamic "treading" of the rocks of the immediate roof;
- static adjustment of the support section to randomly changing rock pressure;
- transfer of some part of energy of the rock pressure acting on the support section to the hydraulic system of the cleaning equipment or complex and its useful application.

Basing on the analysis it can be concluded that one of the most important issues of mining in complex powered mining face is to maintain stable position of PCE and purposeful movement of cleaning face especially in the areas of geological disturbances (bed fractures, thinning, discharges). To do this, it is necessary to have a clear direction of movement of cleaning face with respect to the line along the entire length of lava. On the other hand, the strength of the side rocks can significantly change, especially in the area of mining and geological disturbances which significantly affects the ground pressing and the disruption of the continuity of the immediate roof. An active control of the rock pressure in the face is possible only in case of coordinated adjustment to the changing conditions

of both powered support and face conveyor. At the same time, applying the proposed hydraulic characteristics of powered support sections the stability of the process of cleaning is increased by the reduction of the static and dynamic "treading" of rocks of the immediate roof, as well as the static adjustability of the support section to the randomly changing rock pressure is improved. In turn, the conveyor is given the frame functions of a complex along with the profiling of the ground for the directed movement of the entire complex and the cutting of the ground to maintain the rock pressure [12]. All in all the machines and equipment of cleaning powered complexes are adjusted to changing mining and geological conditions and the rhythm of miner's operation is stabilized both by the values of the feed rate and by the time of short-term stops.

References

[1] Klishin V I 2002 *Adaptation of powered supports to conditions of dynamic loading.* (Novosibirsk: Science)
[2] Buevich V V, Gabov V V, Zadkov D A, Kabanov O V 2015 Pulse-free control of the operation mode of the hydraulic props of the hydroficated support sections of cleaning powered complex. *Mining equipment and electromechanical engineering* 26 - 30
[3] Buevich V V, Gabov V V, Kabanov O V 2014 *Hydrophobic support with adjustable resistance and energy recovery.* Patent of the Russian Federation No. 2510460. MKP E21D23
[4] Cheng Jingyi, Wan Zhijun, Peng Syd S, Liu Sifei, Ji Yinlin 2015 What can the changes in the shielding of resistance tell us during the period of shearer's cutting and neighbor shields' advance? *International Journal of Mining Science and Technology*. dx.doi.org/10.1016/j.ijmst.2015.03.006.
[5] Aleksandrov V I, Vasilyeva M A and Pomeranets I B 2017 *Estimation of efficiency of hydrotransport pipelines polyurethane coating application in comparison with steel pipelines.* (Saint-Petersburg Mining University, Saint-Petersburg)
[6] Gabov V V, Zadkov D A 2017 Peculiarities of stress field formation during cutting isotropic material by mining machine cutters. IOP Conference Series: Earth and Environmental Science
[7] Ivanov S L, Shishkin P V 2017 Integral criterion of mining machines technical condition level at their operation. *IOP Conference Series: Earth and Environmental Science*
[8] Goncharov K A, Grishin A V 2017 Theoretical study of the influence of belt tension on belts. *IOP Conference Series: Earth and Environmental Science*
[9] Korneev S V, Varchenko Yu E, Avershin A A, Tugai V V 2005 *Efficiency of adaptation of armored face conveyors* (UEPA, Stakhanov, Ukraine)
[10] Korneev S V 2005 *The concept of adaptation of armored face conveyors*. (Ukrainian Engineering and Pedagogical Academy)
[11] Korolev A I, Gabov V V 2016 *Armored face conveyors of cleaning powered complex adaptive to changing mining and geological conditions*, Innovations in Transport and Mechanical Engineering: proceedings of the IV International Scientific and Practical Conference, Volume II (St. Petersburg: National Mineral and Raw University Gorny) 176 p.
[12] Korolev A I 2017 Increase in the adaptability of cleaning powered complex to the changing mining and geological conditions by means of modernization of its armored face conveyors. *Mining Information and Analytical Bulletin*