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THE ROCK-COAL BOUNDARY CONTROL METHODS SUBSTANTIATION FOR COAL MINING COMBINES

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Abstract

The issue of diagnostics provided by modern methods is considered in this paper to control the rock-coal boundary that are based on the application of various sensors and approaches. A detailed analysis for the various methods results is presented to control the rock-coal boundary that, in particular, are based on the differences in the coal and rock cuttingresistance, the method of using the differences between the elastic properties of rock and coal and their friction coefficients, and the ultrasonic method. All of them are related to the diagnostic methods with the open boundary of the rock-coal section. There also is emphasizeda necessity of new sensors creation for controlling the coal and rock boundary for combines operated in mining conditions. It is revealed that from the introduction into operation in mine conditions point of view, the most promising is the radioisotope small-sized sensors, which allow to control the boundary of the section between coal and rock in a contactless manner. Other monitoring methods that are being considered in this paper cannot be implemented in the without-human process of coal minning, but they can play an important role to create some other interesting directions and new methods for controlling the boundary between the rock and coal that will allow the creation of automatic control systems for coal-mining combines working in difficult minning conditions.

Keywords: coal combines; control methods; rock-coal boundary; elastic properties; coefficient of friction; ultrasonic method

1. Introduction

One of the main and better ways to increase productivity and production intensity is considered the technological processes automation which leads to implement industrial robots and manipulators [3, 34, 35].

Today's requirements for automatic control of the slaughter facilities suggest a problem solution of highly intensive and productive coal mining without the continuous people presence in the mine [15, 21, 32, 36].

One of the most important control subsystems is anautomatic control of the coal mining combine over the profile of coal layer.

The need to continuously monitor the position of the cutting process and cutting elements along the seizure height involves the permanent dwelling of the machinery driver on the high risk area.

To solve this problem, the efforts of large number of scientists and research teams were directed in our country and abroad. In overall, some big amount of works were carried out in two important areas:

– the area of control tools establishment for the rock-coal border;

– the area of the automation control systems (ACS) creation for the coal extracting combine in the coal layer profile (CLP).

Note that these two directions are interconnected between them, so without the reliable hardware control tool for the rock-coal border the problem of such control can't be solved in general. On the other hand, the type, characteristics and the rock-coal sensor location and installation in most pre-defines the parameters and the construction principle of the control system [1, 5-8, 31, 33]

Creation sensors "rock-coal" devoted numerous works of authors like sex and other developers. [8-10, 13, 16, 17, 19, 20, 22, 24, 26, 27, 32, 33, 36, 39]. On abroad to solve this problem were been engaged researchers from the UK, Germany, USA [13-15, 21, 42, 43, 55, 56, 62, 63].

The main elements of ACS CLP are sensors determining the distance from a certain point of the cutting machine (preferably from a cutting element) to a natural array or distinguishing the coal from the rock.

The variety of the coal occurrence geological conditions and technological varieties with mining means and methods does not allow one to formulate technical requirements for the rock-coal sensors (RCS).

One of the main RCS-characteristics is measuring range. Practically it can meet two alternatives.The necessity requirement to control the combine along the rock-coal boundary, or to leave the coal safety pack (usually for the roofing with unstable rocks predisposed to fracture). As any control system inherent errors, then to prevent the breed nip or at least to reduce its possibility, it should in any case to count for some sectors of coal residue.

On Donbas poolwhen dealing with the safety pack for the roof, its thicknessare choosing forabout 10 to 20 sm, and inMoscow-suburban pool the thickness are choosing forabout 50 to 70 sm. and even more. If to assumeactually reached the magnitude of the RCS in LP the average-square error θ=1.0 – 1.5 sm, then the minimal measuring depth for RCS should equal θ = 4 – 5, i.e. 4 – 7.5 sm.

2. Environmental control

The universal RCS creation that is able to cover a measuring range from 0 to 20 cm (if even not to count the Moscow-suburban coal pool conditions) appears like a difficult-solved task. Therefore, the truthful will be to focus on the creation of two RCS options in agreement with depth to indicate conditions (7–8 sm) and in conditions of the remaining packs for the protective roof (15–20 sm).

To determine the distances to covert coal-rock contact, that aims to control the automatic cutter machine, can only base on indirect measurement methods, i.e. on the several differences in the physical, chemical, or mechanical properties of coal and rocks. It is definitely known, however, that coal and rocks are complex multi-volatile substances with inconstant characteristics for different geological conditions. One thing is that always distinguishes coal from the rocks, it is the amount of carbon in them. Thus, the ideal sensor would distinguish them specifically on this feature. But in our time, however, there are no technical tools in the mining conditions, due to enable in the coal removal conditions with extremely limited dimensions of the equipment, are to perform the environment automatic analysis of an array for the carbon amount in it.

To create a device that distinguishes coal from the rocks on the content of mineral impurities (ashes), it is also the task achieving with difficulty, due to given the variability of the chemical composition of the ashes and mainly through the unfavourable measurement conditions that are created during the installation of the device on the coal mining combine. But it should be noted, however, that progress in the development of radiation ash-measurers, gives a reason to believe that in the near future will probably appear a question of adapting such tools to solve the discussed above problem. Currently we have to dwell on more undirected and less permanent signs of the coal and rock differences.

This variability of different traits in different geological conditions preclude the possibility of a universal sensor creating suitable for all coal basins. So, if some method will provide a reliable detection of coal and rock (even in a condition with necessity to reset it for different mine-layers) relatively at least to 15-20% of the total number of coal cutting places, then it may be considered like industrially applicable tool. In general, for all possible measure variants of the distance to the hidden rock-coal border should be requirement due to permissible value of mean-square error. If, as it was suggested, in the first approximation consider that the mean square error of ACS CLP in most cases hasn't exceed 1,0 – 1,5 cm, then of course it need to require that the RCS error was less than the specified size and part of it expectedly does not exceed the RCS-error of all other components. Then

$$\overline{\theta_{RCS}} \le \sqrt{2\theta_z} = 0.7 \div 1.0 sm$$

All known methods of coal and rocks recognition can be divided into two groups. The first group includes those that can measure the distance to the coal-rock contact, and the second group includes those that can only distinguish coal from rocks.

In first casethe signal at the sensor output is proportional to a range of coal layer thickness on top of the rock mass, and in the second case the output characteristic of the sensor will have a relay character.

The term of "measurement range" for the relay type sensors, or as they are differently called the open coal-rock borders sensors, is meaningless. The combine with the open borders sensor will inescapably work with rock nipas to give a necessary signal for the corresponding rock, it must have direct contact with it. The nip value will depend on RCS-error.

On the rocks, the strength of which is not greater than the coal strength, this method can be acceptable, especially if the nip will not take place all over the front width, but only in limited areas where especially for this purpose are set some proactive cutters. This method to reduce the volume of the rock up cutting is used, but only with the screw combines and for the rocks in which their strength is similar to the coal strength.

The main indicator for therock-coal open border sensor may serve the reliability of the output information that can be measured ratio of the correct replies number to the total tracked replies (works up) in certain characteristics of geological and operational conditions that are affected on the sensor performance of this type.

The total length of the lava segments on which RCS showed false information ratio to the lava entire length will determine the acceptable probability of the false replies positives.

When we evaluate the allowable RCS mean-square error, that measures the distance to the hidden rock-coal border with the size of 0.7 – 1 cm (14 – 20% when measuring the range of 5 cm), then we assume that takes 66% of the lava length. It can take the coal pack thickness, that may vary to ± 0.7 – 1.0 cm (with an ideal regulator), i.e., for example, to be within 1 – 3 cm. Just in economic terms, this error can be considered quite acceptable. The work with an open borders sensor is running by different way. Here the false running in 50% of the cases (with symmetrical errors distribution to both signs) leads to the rock nip.Therefore, the requirements for the permissible error that are defined by the probability of false runs in this case, should be much tougher. The exact value depends on the embodiment RCS run and elements banded to the combine, because for some types of open border sensors it can reduce undesirable consequences of issuing false signals by the way of leading cutters installation on the RCS fasten line with using two sensors at the same time and with the unfeeling zone creation etc. If no special events of this kind was applied, the probability of false runs should obviously limit the size $R_{c.l.}$ = 4.5%, that is equivalent to a rock nip acceptance on total length of 4.5 m at a 200-meter lava.

To the coal-rock sensors can be also brought a number of requirements (to magnitude of the output signal, to spark-security parameters of electronic circuits, to reliability, to work capacity in a particular range of the supply voltage and environmental conditions fluctuations, etc.), but similar requirements can be taken to any electrical and electronic equipment that is designed for use in coal mining machine. In this cases it is useful to be guided by existing regulations for the devices design of this kind.

This paper is not intended for the purpose of selecting the most promising method to create a RCS. The last tenth years of experience in this area showed that none of the proposed methods can be considered as universal, and even the best of them have rather several conditional sites.This is emphasized by higher volatility of the characteristics differences for coal and rock.

In earlier studies like [6, 8, 9, 24, 26, 28-30, 38, 39, 50]have already shown the advantages of the selected radioisotope method for the coal and rock identification, so here we confine ourselves to only a brief overview of the proposed methods, tools and their main features.

We just consider the widest control methods of the division rock-coal border.

3. Review of the control methods used for coal-rock sensors

3.1. Method based on the cutting resistance of the coal and rocks

In agreement with data excepted in a work [59] these differences have bear the constant character within one and the same mine layer.

There are several proposals for practical implementation of this method. At the suggestion taken in the workthe equality of the cutting efforts from the two mills when looking at the array sections of different hardness is implemented of the mechanical device named "differential".

Proposed some more compact version [60] for the mechanical transformation of the cutting efforts based on the use of pneumaticsensor, which is embedded in a working cutter. Cutting effort is reincarnated directly into an electrical signal by using tensor devices for example. In this case, thesensor) element can also be placed directly on the working element in one of the cutters, i.e. on the critical cutting line or, in other terms, embodied in the main implementationpoint.

The last circumstance gives this method some significant advantages among all others, as in any other cases the sensor can't be embedded directly in the bits. The experiments mentioned above on the Karbayd combine [45, 46] with stroboscopic sensors are an example of the one embodiment practical implementation for this method.

Works to create the RCS based on this principle are provided in Russia and abroad, such as USA, Great Britain etc. There are means available to eliminate some of the shortcomings inherent in this sensor. Thus, by company "Joy" [48] is proposed a device that automatically regulates the effort factor depending on the rock hardness. That allows to distinguish the coal not only from thehard rocks, but from relatively weak one, for example such as shale.

So, in England, there is patented some device [31], which consists of two sensors that are included in the differential circuit. One of them under normal conditions moves alone the rock, and another one moves alone the coal.

The disagreement signal appears at the output of the device in the case where both sensors are in a homogeneous environment. The proposed device allows to receive a dead (non-feeling) zone and thereby to eliminate the shortcomings of the two-position adjustment scheme, inevitable in the presence of only one sensor.

3.2. Method based on different elastic properties and friction coefficienti of coal and rock

This method is used in the sensor, which is designed by "Donhyprouпlemash" company [10, 49]. With the generator and piezo-elements in a metal rod, which are combined with an array,there are excited mechanical vibrations. Their frequency is chosen so that it is supported only at an outstanding friction effort that corresponds to the movement alone the coal. During the rod contact with the rock the friction power increases and occurs the fluctuations failure of the sensor fixed electronic circuit.The influence of various factors on the sensor capability is not still clarified for today, but the experiments results conducted in mine conditions can be regarded as quite encouraging.

A second position that is based on the principle of the elastic properties differences for coal and rock is backgrounded on the use of energy vibrations excited in the array by vibrations that are appeared in the mine of the working machines [86]. As applied to the drilling assembly this idea is proposed to realize by the next way. At the entrance roadway along the axis of output in the rock are fixed two seismometers: one in the ground, and the second in the layer roof.

The receivers are switched on the spacing scheme and configured in such a case, so that when the motion projectile is moving along the coal, the output signal on the device exit is equal zero. The cutting element touching onto the soil or rock roof leads to a registered vibrational energy increase and in the device output leads to a signal imbalance.

There is no need to install on the combine any special equipment. This makes a certain advantage of the proposed device, but any information about its practical test is missing yet.

3.3. Ultrasound method

Based on the degree difference of the ultrasonic waveband attenuation (frequency ~400 Hz) in the coal and rock. This method was proposed in works [18, 19], which held a series of experimental studies with ultrasonic sensors in the mine lining sheets conditions. To convert electrical oscillations into mechanical and vice versa, there were used magnetic strict elements. Mechanical vibrations were excited in the steel hub (emitter) which was pressed to the test environment. The tests in the mine lining sheets conditions showed that the signals difference on coal and rock were unstable, but in general was very significant and with average as 1:10.

In agreement with data in [43], the signal ratio in a greater amount depends on the state of the investigational array, i.e. from the environment fracturing and the sensor pressing force to the environment. Based on the conducted research the authors came to the conclusion that "while working on cleaning and coal catting machines may only use the method of the partial machinery introduction into nature." The research works on ultrasonic sensors continues towards to find a means to avoid these shortcomings.

Other control methods based on open rock-coal borders does not represent great practical interest. In principle it's possible, for example, to distinguish coal from rock by photometric method, but the surface state of the rock-coal array in mine conditions is not conducing to receive a stable information. This is confirmed by the data given in the review article [50].

The same fact prevents the practical application of the method based on the difference in the coal and rock reflectivity in respect to the ultrashort wave and ultrasonic vibrations, though the idea of automatic control for coal mining machines with using such sensors were reflected in the patent literature.

The proposed method [42]. Differences of coal and rock, which is based on differences in their resistance indentation stamp tested so far limited laboratory studies, but discrete action and dependence of measurement results on a number of minor facts do not allow to show great optimism in relation to its prospects.

4. Theoretical background to use a scattered gamma radiation

Sensors developed in A.A. Scochinsky IGD are based on the effect of scattered gamma-radiation. The intensity of scattered gamma-radiation depends on the atomic number and the scattering density [44, 46,47]. In a two-layer environment it also depends on the thickness of the upper layer that the sensitive sensor element contacts with its surface, and the interlayer of which can be used to solve the set problems. It should be noted that the advantages of this method in comparison with all other existing ones are that this method uses the greatest number of features characterizing both: coal and enclosing rocks by their density and chemical composition.

Let's consider some aspects of γ-radiation, which are presented on the model (Fig. 1).

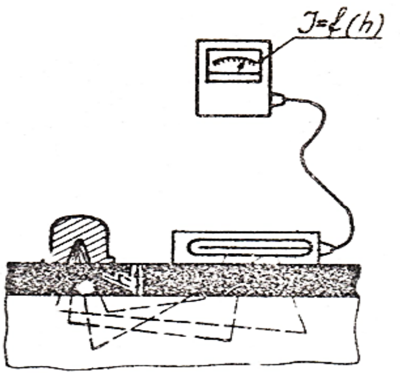

Fig. 1. The principle scheme of radionics isotope sensor determining the interface between rock and coal (flat contact)

If the γ-irradiation source and receiver (detector) are set on the medium surface of two-layers environment, with the upper layer having a thickness h, and the lower one is half-infinite (fig.1), then the irradiation intensity scattered by this environment and registered by the receiver in the general case will be determined by the following function:

$$I_p = f\left(w_0, z_1, z_2, \rho_1, \rho_2, R, h, A, \varepsilon_g, S_g\right) \quad (1)$$

where w_0 is energy of primary irradiation; z_1, z_1 are effective atomic numbers of the upper and lower environment; ρ_1, ρ_2 are effective densities of the upper and lower environment; R is a distance between the radiation source and the center of the receiver (base); A is a radiation source activity; ε_g is efficiency of the radiation detector; S_g is active surface of the radiation detector.

It can be seen that from expression (1) with taking fixed parameters of the sensor, the variables would be only $z_1, z_2, \rho_1, \rho_2, h$. Between calculation methods we can find the application of the Monte-Carlo method [4, 57]. In all cases with taking into account the real geometry, however, the calculation of therepeatedly scattered radiationintensity is considered rather as one of the difficult tasks. Qualitative results that represent the basis of the technique features can be obtained by considering the problem in the approximation of a single dispersion. This approximation is widely used, for example, in geophysics due to determine the nature of the relationship between parameters that determine the count speed to receive a rational form of semi empirical formulas, etc. In cases like this usually are considered simplified models.

$$dI = 3,7*10^7\,\mathrm{KA}d_{C4}\varepsilon_g \frac{1}{4\pi z_1^2}\exp\left(-\mu'_y\rho_y z'_y\right)\times$$
$$\times\frac{1}{4\pi z^2}\exp\left(-\mu''_y\rho_y r''_y\right)n_0\frac{d\sigma}{d\theta}(\theta)\,dVdl, \quad (2)$$

where K is the average number of γ-quants for decay; d_{C4} is the detector diameter and with $S_g = d_{C4}\left(\ell_2 - \ell_1\right) = d_{C4}\ell_{C4}$; μ'_y is weighted relaxation coefficient for radiation at an angle to a direct γ-ray; $\mu''_y = \mu''_y(\theta)$ is the same for a scattered γ-ray; and n_0 is number of electrons in 1 cubic centimeter of matter.

$$n_0 = 6.02 \cdot 10^{23} \left(\frac{z}{\mathrm{A}} \right) p \qquad (3)$$

The value $\frac{d\sigma}{d\theta}(\theta)$ is determined by the formula of Klein-Nishin:

$$\frac{d\sigma}{d\theta} = \frac{r_0^2}{2} \left\{ \frac{1}{\left[1+\alpha_\omega(1-\cos\theta)\right]^2} \left[1+\cos^2\theta + \frac{\alpha_\omega^2(1-\cos\theta)^2}{1+\alpha_\omega(1-\cos\theta)} \right] \right\} = \frac{r_0^2}{2} p(\theta), \qquad (4)$$

where $r_0 = 2{,}818 \cdot 10^{-13}$ cm; $\alpha_\omega = \frac{\omega_0 (M_{EB})}{0{,}511}$.

$$\alpha_\omega = \frac{\omega_0 (M_{EB})}{0{,}511}.$$

Substituting formulas (3) and (4) into (2), we receive an expression for the account speed on the coal pack:

$$I_y = C \left(\frac{z}{\mathrm{A}} \right)_y \rho_y \int_{x_1}^{x_2} \int_{y_0}^{y_1} \int_{z_1}^{z_2} \int_{\ell_1}^{\ell_2} \frac{P(\theta)}{z_1^2 z^2} \exp\left[-\rho_y \left(\mu'_y r'_y + \mu''_y r''_y \right) \right] dx dy dz d\ell \qquad (5)$$

where $C = 5.60\,\mathrm{KA}\ d_{C4} \varepsilon_g = const.$

Similarly, an expression can be written for the rate of account on the rock after passing the radiation of the coal layer (see fig. 2);

$$I_n = C \left(\frac{z}{\mathrm{A}} \right)_\Pi \rho_\Pi \int_{x_1}^{x_2} \int_{y_1}^{y_2} \int_{z_1}^{z_2} \int_{\ell_1}^{\ell_2} \frac{P(\theta)}{z_1^2 z_2^2} \times$$
$$\times \exp\left[-\left(\rho_y \mu'_y r'_y + \rho_\Pi \mu'_\Pi r'_\Pi + \rho_\Pi \mu''_\Pi r''_\Pi + \rho_y \mu''_y r''_y \right) \right] dx dy dz d\ell \qquad (6)$$

$$\frac{d\sigma}{d\theta} = \frac{r_0^2}{2} \left\{ \frac{1}{\left[1+\alpha_\omega(1-\cos\theta)\right]^2} \left[1+\cos^2\theta + \frac{\alpha_\omega^2(1-\cos\theta)^2}{1+\alpha_\omega(1-\cos\theta)} \right] \right\} = \frac{r_0^2}{2} p(\theta).$$

With h $\to$ 0, the account speed is determined only by γ-scattering on the rock, and the expression (6) will take a look:

$$I_{n1\alpha} = C \left(\frac{z}{\mathrm{A}} \right)_\Pi \rho_\Pi \times$$
$$\times \int_{x_1}^{x_2} \int_{y_0}^{\infty} \int_{z_1}^{z_2} \int_{\ell_1}^{\ell_2} \frac{P(\theta)}{z_1^2 z_2^2} \exp\left[-\rho_\Pi \left(\mu'_\Pi r'_\Pi + \mu''_\Pi r''_\Pi \right) \right] dx dy dz d\ell \qquad (7)$$

For h $\to \infty$, the equation (5) takes some another form:

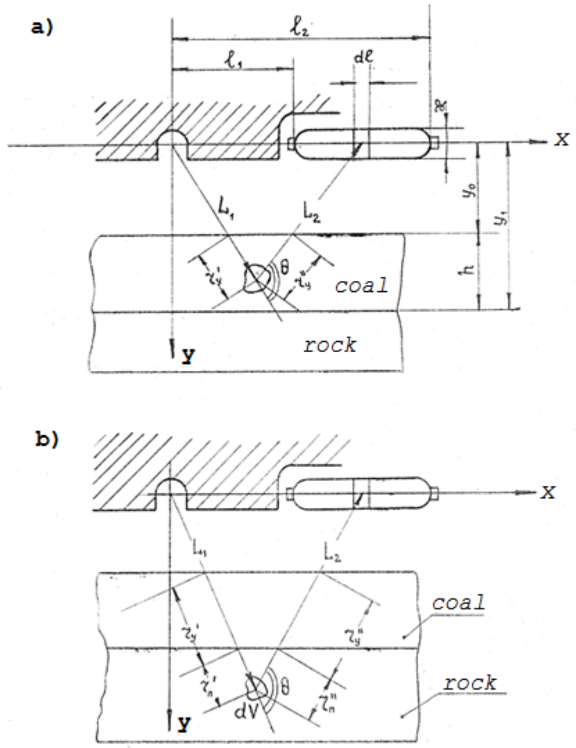

Fig. 2. The view of the γ-radiation general scattering in a two-layer environment

$$I_{y1\alpha} = C \left(\frac{z}{\mathrm{A}} \right)_y \rho_y \times$$
$$\times \int_{x_1}^{x_2} \int_{y_0}^{\infty} \int_{z_1}^{z_2} \int_{\ell_1}^{\ell_2} \frac{P(\theta)}{z_1^2 z_2^2} \exp\left[-\rho_y \left(\mu'_y r'_y + \mu''_y r''_y \right) \right] dx dy dz d\ell \qquad (8)$$

For practical purposes some particular interest takes the relative magnitude

$$\frac{I_y + I_\Pi}{I_{y,\infty}} = \frac{I_P}{I_{y,\infty}} \qquad (9)$$

where I_p is the count rate of the scattered γ-quants, received by the detector.

The dependence of this value from the coal layer thickness h is the main characteristic of the "rock-coal" sensor.

Also very important characteristic that characterizes the signals drops or differential ability is the ratio of the δ-speed count of RCS on infinitely thick rock and coal layers:

$$\delta = \frac{I_{\Pi,\infty}}{I_{y,\infty}} \qquad (10)$$

where the values $\mathrm{I}_{\Pi,\infty}$ and $\mathrm{I}_{y,\infty}$ are determined by expressions (7) and (8), respectively.

To solve the equations (5 – 8) it need to express incoming integral expressions of the values θ, z, z_2,

r'_y, r''_y, r'_n, r''_n via x, y, z. The values $\mu''_y = \mu''_y(\theta)$ and

$\mu''_\Pi = \mu''_\Pi(\theta)$ can be represented as:

$$\left.\begin{aligned} \mu''_y(\theta) &= \mu'_y + b_y(1-\cos\theta), \\ \mu''_y(\theta) &= \mu'_\Pi + b_\Pi(1-\cos\theta) \end{aligned}\right\} \qquad (11)$$

where $b = \dfrac{\mu(180^\circ) - \mu(0)}{2} = \text{const.}$

The integration boundaries x_1, x_2, z_1, z_2 are determined by the geometry of the collimators near the radiation source and detector and in general case they can be dependent as a function of y.

In research works [45, 46, 48, 50], devoted to the radioisotope rock-coal sensors creation is shown that with radiation energies more than 0.5 MeV the chemical composition oscillation influence of the diffusers, that is characterizing by their effective atomic numbers z_1 and z_2 may be small. However, with the increasing of radiation energy, the dimensions of the protective shell and, accordingly, of the sensors in general, areincreasing in sizes and this can be a serious obstacle on the way to their practical use in some cases. Therefore, the further researches were been aimed to improve the technical characteristics of the rock-coal sensors RCS, and to reduce their dimensions. All this led to the creation of two sensor modifications: with sources of rigid (hard) γ-radiation RCSr and with sources of soft γ-radiation RCSs. Metrological characteristics of both types of sensors are different and can bepurposefully considered separately.

5. Conclusions

As a result of the reasoned analysis, the most promising in terms of implementation and industrial development are small radioisotope sensors that allow to control the separate border interface between coal and rock by the noncontact method. But this doesn't mean that other control methods can't be implemented in the lonely coal dredging.

Of course, it should direct some efforts on further research in areas that have been reflected in this article. It will allow to make compete in the creation of other interesting ways to create new control methods of the separate boundary between rock and coal.

On the basis of new researches will be possible to create an automatic control system for coal mining combine, working in difficult rock-geological conditions.

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Обґрунтування методів контролю границі порода-вугілля для вугільно добувних комбайнів
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У даній статті розглядається питання діагностики сучасними методами контролю границі розділу порода-вугілля, які базуються на застосуванні різноманітних датчиків та підходів. Наведено детальний аналіз результатів роботи різних методів для контрою границі порода-вугілля, а саме таких як метод, заснований на різниці опору різання вугілля та породи, метод використання різниці пружних властивостей породи і вугілля, їх коефіцієнтів тертя та ультразвуковий метод.Всі вони відносяться до методів діагностики з відкритою границею розділу порода-вугілля. Акцентується необхідність створення нових датчиків контролю розділу границі вугілля та породи для комбайнів, які працюють в гірничих умовах.

З'ясовано, що найбільш перспективними, з точки зору впровадження в дію у шахтних умовах є радіоізотопні малогабаритні датчики, які дозволяють контролювати границю розділу між вугіллям та породою безконтактним способом. Інші методи контролю, що розглядаються, не можуть бути впроваджені в процес безлюдної виїмки вугілля, однак можуть відіграти важливу роль в створенні інших цікавих напрямків та нових методів контролю границі розділу між породою та вугіллям, які дозволятимуть створювати системи автоматичного керування вугільно добувними комбайнами, що працюють в складних гірничих умовах.

Ключові слова: вугільні комбайни; методи контролю; границя розділу порода-вугілля; пружні властивості; коефіцієнт тертя; ультразвуковий метод

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В данной статье рассматривается вопрос диагностики современными методами контроля границы раздела порода-уголь, основанными на применении различных датчиков и подходов. Приведен подробный анализ результатов работы различных методов контроля границы порода-уголь, таких как метод, основанный на разнице сопротивления резки угля и породы, метод использования разницы упругих свойств породы и угля, их коэффициентов трения и ультразвуковой метод. Все они относятся к методам диагностики с открытой границей раздела порода-уголь. Акцентируется необходимость создания новых датчиков контроля раздела границы угля и породы для комбайнов, работающих в горных условиях.

Установлено, что наиболее перспективными с точки зрения внедрения в действие в шахтных условиях является радиоизотопные малогабаритные датчики, которые позволяют контролировать границу раздела между углем и породой бесконтактным способом. Другие рассматривающиеся методы контроля не могут быть внедрены в процесс безлюдной выемки угля, однако могут сыграть важную роль в создании других интересных направлений и новых методов контроля границы раздела между породой и углем, что позволит создавать системы автоматического управления угольно добывающими комбайнами, работающими в сложных горно-геологических условиях.

Ключевые слова: угольные комбайны; методи контроля; граница раздела порода-уголь; упругиесвойства; коэффициент терния; ультразвуковой метод

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