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RECOGNITION OF STAGES OF EMERGENCE AND DEVELOPMENT OF THE ENDOGENOUS FIRE IN COAL MINES

Abstract. The nature and the main stages of emergence and development of the endogenous fires on coal mines are shown. The analysis of the main theoretical methods of researches of chemical process of self-heating and self-ignition of coal is made. It is noted that the main objective of experts of fire-prevention protection of coal mines consists in the most reliable establishment of a stage of oxidation and self-heating of coal. It is offered to accumulate and systematize results of natural data on control of structure of the mine atmosphere of problem sites for justification of signs of development of oxidizing processes in coal congestions.

Keywords: coal mine, oxidizing process, chemical reactions of oxidation of coal, stage of the endogenous fire, signs of self-ignition, carbon oxide, hydrogen, oxygen decrease.

Introduction. The problem of self-ignition of coal exists from emergence of the first coal mines. Self-ignition of coal is observed in mines and in warehouses where it is stored, on external and internal dumps of coal mines. The fires arising for various reasons including and from ignition of coal in the dug-out spaces, are found the special automatic equipment, signals from which arrive to the mountain dispatcher. On the basis of this information timely precautionary measures for an exception of their development and consequences are taken.

The endogenous fires have the specifics of development and methods of detection of the centers of self-heating and self-ignition of coal [6, 10]. The situation is aggravated with the fact that the underground endogenous fires often arise in hard-to-reach spots, such as the developed space, in the toes, in coal deposits behind insulating crossing points, in layers satellites [1, 16]. Coal layer, as a rule, in such conditions is in the deformed state, and it increases probability of self-ignition of coal. Suppression of the centers of burning in such conditions is complicated, than the highest duration of elimination of this type of underground accidents is caused. Besides, in gas mines to which the majority of coal mines of the coal-mining countries including coal basins of the Republic of Kazakhstan, the endogenous fires can cause explosions of methane-air mix that leads to catastrophic consequences belong.

The efficiency of fight against the endogenous fires arising in the developed space and in other hard-to-reach spots of coal mines, substantially depends on timeliness of detection and completeness of information on coal self-ignition process.

For this reason workers of coal mines very are interested in a question whether it is impossible by results of the analysis of air in certain places in the mine to define the beginning of self-ignition of coal, in particular, carbon monoxide availability is sign of the fire. For the answer to this question theoretical justifications of process of self-heating and self-ignition of coal are necessary.

Now are developed and a number of the theories of self-ignition based on use of kinetics of sorption of oxygen by small fraction classes of coals of different extent of metamorphism and a heat transfer in the destroyed coal [4, 5, 12] have found broad application.

The developed and known theories and methods define the beginning of ignition of coal at rather high temperature when coal has already lit up. Some researchers consider that real process of self-ignition of coal begins in mines already at 12-15 °C [5]. Therefore, the most important direction is the research of an initial stage of process. At the first stage it is necessary to begin studying of a surface of coal for the purpose of definition e è characteristics and their influence on chemical activity of coal at a temperature, usual for the mine. On the second it is necessary to study kinetics of oxidation of coal at low temperatures.

$$C_{(solid)} + O_{2(gase)} = CO_{2(gase)} + 94kkal; \quad (1)$$

at the second stage carbon dioxide interacts with carbon with formation of carbon oxide and absorption of heat

$$CO_{2(gase)} + C_{(solid)} = 2CO - 41{,}2\ kkal. \quad (2)$$

As both stages (both reactions (1)-(2)) occur at the same time, under Hess's law the total thermal effect of chemical process of oxidation of coal is determined by total reaction

$$2C_{(solid)} + O_{2(gase)} = 2CO + 52{,}8\ kkal. \quad (3)$$

Founders of the theory of self-ignition of coals on the basis of the analysis of nature of influence of separate factors have formulated three conditions necessary for process of origin and development of self-ignition [15]:

coal has to be capable to oxidation at low temperatures, so-called low-temperature oxidation;

the amount of oxygen has to be sufficient for reaction course;

the amount of the warmth which is marked out as a result of oxidation has to prevail over his branch to the environment, i.e. there has to be a positive balance of thermal energy.

In development of the endogenous fire allocate a self-heating stage, an early stage of self-ignition and a stage of burning of coal [7]. Self-heating of coal begins as soon as conditions for warmth accumulation are created. The self-heating stage generally determines duration of the incubatory period of process of self-ignition and proceeds in the range of temperatures, since the values characteristic of conditions of these mining-and-geological conditions, and up to the critical temperature of self-ignition. On reaching critical temperature the early stage of self-ignition of coal begins.

Analytical expression of this dependence in ignition zones in emergency sites for coals of the Donetsk basin is presented by a formula [7]

$$T = 456 \cdot (C_{co}/\Delta C_{O_2})^{0{,}076}, \quad (4)$$

where C_{co} – the content of carbon oxide in tests of the mine atmosphere, about. %; ΔC_{O_2} – a decrease of content of oxygen in tests of the mine atmosphere, about. %; T – temperature in the self-heating center, K°.

The temperature condition of layer caused by coal oxidation reaction by oxygen and a heat transfer in surrounding breeds and the atmosphere acts as the main condition of process of transition of self-heating to self-ignition and formations of the center of the endogenous fire.

In development of the endogenous fire, except change of temperature in the seat of fire, there are essential changes as a part of air in a coal self-ignition zone: content of oxygen decreases release of carbon oxide, hydrogen, saturated and unsaturated hydrocarbons which content considerably exceeds background values increases. These changes in structure of the mine atmosphere are also a basis for recognition of stages of development of processes of self-heating of coal.

It has practically developed so that miners took existence in the atmosphere of the site of carbon oxide in certain quantities for the main sign of origin of the endogenous fire. The theory explaining self-ignition of coals with fast oxidation of nonlimiting connections did probable that carbon monoxide is emitted only at quite high, characteristic only of the fire, temperatures [1, 4].

On the controlled site steady excess of a volume fraction of SO carbon oxide and H2 hydrogen over their background contents is accepted by other sign of intensive self-heating of coal: $CO_F \gg (6\text{-}10)\cdot 10^{-7}$ vol.%

и $H_{2f} \gg (3\text{-}5)\cdot 10^{-7}$ vol.%. Characteristic of a stage of self-heating and an early stage of self-ignition is performance of a condition

$$\frac{CO-CO_f}{H_2-H_{2f}} < 10. \quad (5)$$

However, as authors [7, 16] by results of definition of excess of carbon oxide and hydrogen over their background values consider and the ratio given above it is impossible to distinguish a self-heating stage from an early stage of self-ignition. At the same time, definition of a stage of development of the endogenous fire is of great importance as the early stage of self-ignition of coal under favorable conditions can last only several hours.

These stages can be determined by coal temperature in the center of the endogenous fire on the basis of data on a ratio of content of C_2H_4 ethylene and C_2H_2 acetylene in tests of air of the site of self-ignition of coal. Up to temperature of ignition of volatiles, growth of a share of ethylene advances growth of a share of acetylene by stages of self-heating and an early stage of self-ignition owing to what the ratio of these components naturally increases.

After achievement of temperature of ignition of the coal, depending on the mass of a coal congestion and an expense arriving to him air there can be a further growth of a ratio of ethylene and acetylene or its sharp reduction to the values characteristic of temperatures is lower than critical.

Thus, on change of volume fractions of ethylene and acetylene and their ratios it is possible to identify stages of development of the endogenous fires and to approximately determine coal temperature until his ignition.

It is a method of definition of a stage and control of development of the endogenous fires it is used in the analysis of fire-dangerous situations in mines of the Karaganda coal basin [7,16]. Use the same method for determination of temperature of the environment in the isolated emergency site, when there is no an opportunity to determine her by tool direct measurements. Need of obtaining data on temperature and dynamics of cooling of the massif and atmosphere of the fired site arises, in such situations, for justification of safety of carrying out investigation by forces of mine rescuers and solutions of a question of a possibility of opening of the fire site.

Except the aforesaid, it should be noted the following in addition. The known methods of assessment of process of self-heating of coal are based on the analysis of products of reaction of oxygen with coal whereas according to the theory coal - an oxygen complex, at an initial stage oxygen is physically occluded by the surface of coal with insignificant allocation of warmth [16]. Then with increase of temperature splitting of unstable oxygen complexes with formation of the final products of oxidation of coal – carbon oxides and water at which allocation of warmth increases by 1,5–2 times [6, 9] begins.

Thus, a conclusion is formulated that control of concentration of oxygen – the most sensitive indicator of early emergence of the center of self-heating of coal as gives the chance to track all process of low-temperature oxidation. Influence of content of oxygen sharply increases in the mine air with temperature increase: the she is higher, the at its smaller concentration oxidation process can proceed. Dependence of self-heating on the content of oxygen in the mine environment – one of the main factors influencing fire danger of mining operations upon their transition to the deep horizons [4, 8, 11].

The authors of work [16] studying tendency to self-ignition of coals of various brands at temperatures of 40 and 80 °C have executed calculations of amount of the carbon oxide which is emitted at low-temperature oxidation of coal. Generalizing these data for various sizes of humidity V^r and temperature of heating, the following settlement dependences of the relation of volume content of carbon oxide and a decrease of oxygen are received:

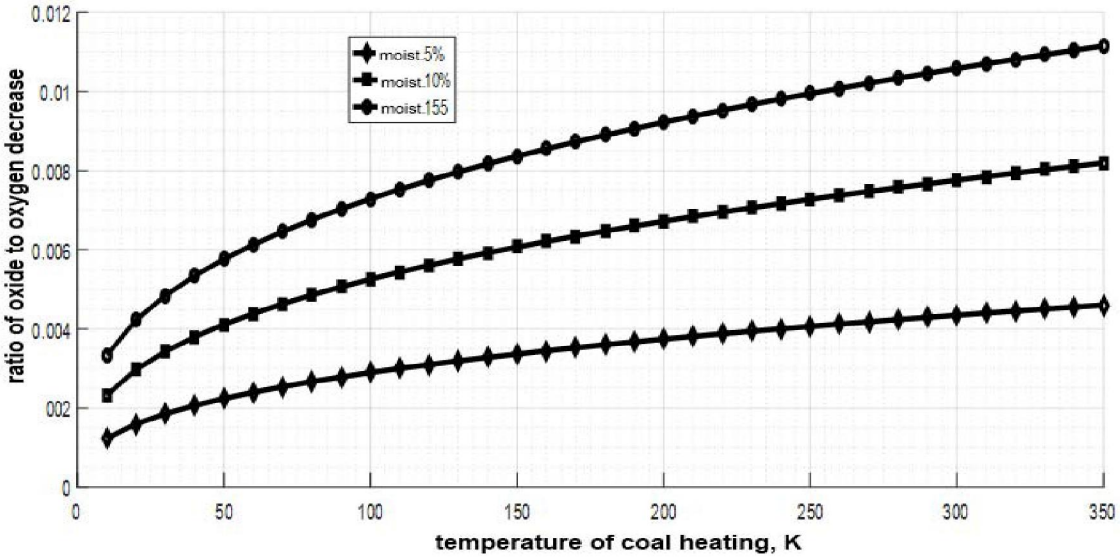
$$C_{co}/\Delta C_{o2} = (0{,}0001 \cdot V^{\varepsilon} + 3 \cdot 10^{-5}) \cdot t^{-0{,}003 \cdot V^{\varepsilon}} + 0\acute{o}384 \quad (6)$$

for temperature 380° K

$$C_{co}/\Delta C_{o2} = 0\acute{o}007 \cdot t^{0{,}18+0{,}004 \cdot V^{\varepsilon}} \quad (7)$$

In the figure 1 schedules of dependence of attitude $C_{co}/\Delta C_{o2}$ on a formula (5) are shown at humidity of V^r= 5, 10 and 15% for the range of temperature of self-heating of coal within 350° K.

On function graphs it is visible that relation $C_{co}/\Delta C_{o2}$on quite distinguishable value in the range of temperatures up to 70-80 °C accepts that is close to the critical temperature of self-ignition of coals of the Karaganda basin. Therefore, the considered sign can be used in practice of recognition of stages of self-heating and self-ignition of coals for prevention of emergence of the endogenous fires with specification of empirical coefficients for various brands of coal. It is quite solvable task on condition of appropriate data processing, the mines received according to the relevant services at the organization of planned control of problem sites in processes of conducting mining operations.



Schedules of dependences of the relation of content of carbon oxide to an oxygen decrease in the mine atmosphere from temperature of self-heating of coal at humidity of coal of 5% (the lower line), 10% and 15%

The results of the state-of-the-art review of methods of a research of oxidizing processes considered in article, stages of origin and development of the endogenous fires in coal mines show that the problem of development of informative signs of recognition and prevention of self-ignition of coal is relevant and now.

Conclusions:

1. The problem of timely recognition of stages of self-heating and self-ignition of coal on coal mines is still relevant for prevention of emergence of the endogenous fires in view of complexity of oxidizing processes in various conditions.

2. It is quite possible that for each layer and brand of coal it is necessary to develop, prove and accept individual sign for assessment of a condition of fire danger.

3. To systematize and to methodically process results of natural measurements and observations on the analyzed and investigated problem sites of mines for the purpose of creation of basin databases for the subsequent operational decisions in emergencies.

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КӨМІР ШАХТАЛАРЫНДАҒЫ ЭНДОГЕНДІ ӨРТТІҢ ДАМУ МЕН ПАЙДА БОЛУ КЕЗЕҢІ

Аннотация. Көмір шахталарындағы эндогенді өрттердің дамуы мен пайда болуының негізгі табиғи кезеңдері көрсетілді. Көмірдің өздігінен жануы мен өздігінен қызу химиялық үрдісін зерттеудің негізгі теориялық әдісінің сараптамасы жасалды. Көмір шахталарында өртке қарсы әрекет ететін мамандардың негізгі мақсаттарының бірі көмірдің өздігінен қызуын және қышқылдану кезеңін нақты анықтау болып табылады. Көмір үйінділерінде қышқылдану үрдістерінің даму қасиеттерін негіздеу үшін қиын аймақтарда ауа шахтасының құрамын бақылау бойынша табиғи алынған мәліметтер нәтижелерін жүйелеу және жинау ұсынылды.

Түйін сөздер: көмір шахтасы, қышқылдану үрдісі, көмір қышқылдануының химиялық реакциясы, эндогенді өрт кезеңдері, өздігінен жану қасиеттері, көміртегі оксиді, сутегі, оттегі шығыны.

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РАСПОЗНАВАНИЕ СТАДИЙ ВОЗНИКНОВЕНИЯ И РАЗВИТИЯ ЭНДОГЕННОГО ПОЖАРА В УГОЛЬНЫХ ШАХТАХ

Аннотация. Показаны природа и основные стадии возникновения и развития эндогенных пожаров на угольных шахтах. Выполнен анализ основных теоретических методов исследований химического процесса самонагревания и самовозгорания угля. Отмечено, что основная задача специалистов противопожарной защиты угольных шахт заключается в наиболее достоверном установлении стадии окисления и самонагревания угля. Предложено накапливать и систематизировать результаты натурных данных по контролю состава шахтной атмосферы проблемных участков для обоснования признаков развития окислительных процессов в угольных скоплениях.

Ключевые слова: угольная шахта, окислительный процесс, химические реакции окисления угля, стадии эндогенного пожара, признаки самовозгорания, оксид углерода, водород, убыль кислорода.

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