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THE RESEARCH OF LIQUID FILTRATION DURING THE PROCESSING OF COAL WITH A WATER-FOAM SOLUTION BASED ON ANTIPYROGEN

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Abstract. One of the measures used in mines concerning to decrease the outburst hazard of coal seams is their hydro-loosening with water under high pressure through seam wells. Injection of water and solutions on the basis of antipyrogens into a coal seam, which is prone to spontaneous combustion, is used to decrease the occurrence of endogenous fires. It is known that the saturation of coal with liquid changes the properties and mechanical characteristics, and results to the unloading of the seam of mining tunnel. Therefore, the assessment of changes in geomechanical parameters in the near-contour zone before and after hydroprocessing of the seam is a very relevant task. Knowledge of the dynamics of the formation of the stress field around the mine tunnels will allow to improve the technology of processing the coal seam with antipyrogens. Most of the information related to observations of the process of water injection in mine conditions is given in different publications of advanced basin institutes.

The purpose of the research is the definition the parameters of liquid filtration when spreading of antipyrogen in the massif and the corresponding change in the properties of coal processed with a water-foam solution based on the antipyrogen to prevent explosions and fires of outburst hazard, a tendency to self-ignition coal seams.

The research was carried out in laboratory conditions on stand of two-dimensional filtration of liquid with an antipyrogen through a coal sample, which was made in the form of cube with hole in the middle of the sample. The developed method of measurement makes it possible to establish the relative dimensionless filtration coefficient of the antipyrogen solution to water, with consideration of suffusion and colmatation effects.

The undulating character of the change in hydraulic permeability when the concentration of the antipyrogen changed within 0÷1.5% is established for the first time. At the same time, with a further increase in concentration to 4% the permeability decreases monotonically. Also, research of changes in the air permeability of samples, that are processed with antipyrogen solution over time proves that there is no threat of an increase in danger occurrence of a sudden outburst during the hydro-loosening of the heading face with antipyrogens. It can be noted that the established the character allows to significantly reduce work expenses when established the optimal hydraulic parameters of processing seam with antipyrogens.

Keywords: antipyrogen, coal seam, liquid filtration, concentration of the solution, sudden outburst.

1. Introduction

One of the most widely used measures to reduce the outburst hazard of coal seams is their hydro-loosening with water under high pressure through seams wells [1–5]. At the same time, a large volume of working out the outburst hazard seams, which are also fire-hazardous and on which various solutions of liquid on the basis of antipyrogens are also used as prophylactic measures, is performed. Injection of water and solutions on the basis of antipyrogens into a coal seam that is prone to spontaneous combustion, is used to reduce the occurrence of endogenous fires [2, 6, 7]. It is known what the saturation of coal with liquid changes the properties and mechanical characteristics, and resuts to the unloading of the seam of mining tunnel. Therefore, the assessment of changes in geomechanical parameters in the near-contour zone before and after hydroprocessing of the seam is a very relevant task. Knowledge of the dynamics of the formation of the stress field around the mine tunnels will allow to improve the technology of processing the coal seam with antipyrogens. Most of it the information related to observations of the process of water injection in mine conditions is given in different publications of advanced basin institutes. Thus, the main task of the article is to study the parameters of filtering the liquid, saturated with antipyrogens in the massif to reduce the danger and prevent explosions and fires in a coal mine.

The research of the parameters of liquid filtration when spreading of antipyrogen in the massif and the corresponding change in the properties of coal processed with a water-foam solution based on the antipyrogen to prevent explosions and fires.

2. Methods

Methodology of conducting research on filtration of water solution with antipyrogen.

The research was carried out on the stand (Fig. 1) of two-dimensional filtration of liquid through a sample – a piece of coal seam. The sample has dimensions of 40×40×40 mm with a hole located in the middle of the sample. [4, 8].

1 – pressure pneumohydraulic tank; 2 – rod of a manual pneumatic pump; 3 – pressure hose; 4 – the fitting of the lower hydraulic main to the sample hole; 5 – the lower manometer; 6 – hydraulic camera; 7 – liquid flow meter; 8 – drain hose; 9 – fitting of the upper hydraulic main; 10 – the upper manometer; 11 – drain pneumohydraulic tank; 12 – drainage hydro main

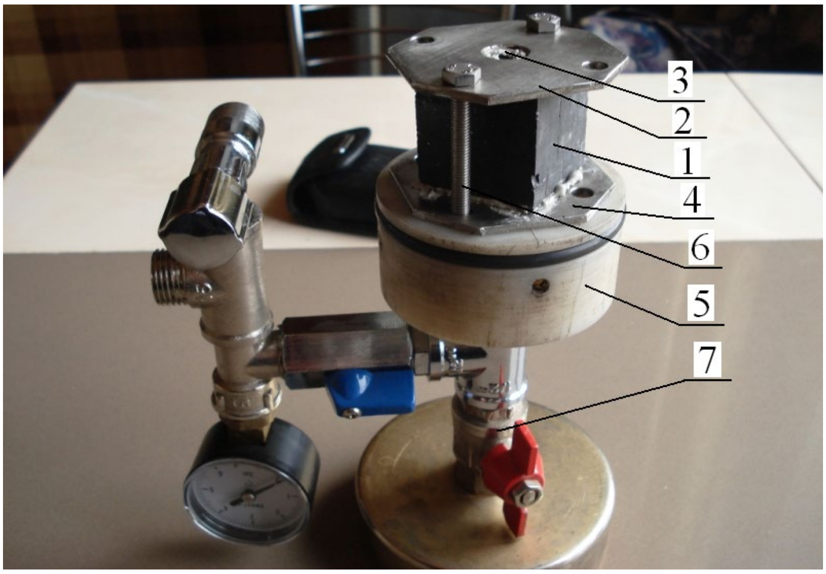
Figure 1 – Stand for filtering antipyrogens

The coal sample was compacted on the stand in two methods – by gluing to metal plates or by means of elastic gaskets (Fig. 2).

One sample dimensions are 40×40×35 mm. It was compacted by elastic gaskets, because the equality of its lower surface was not ideal. The first sample was glued to steel plates.

The research was carried out on two different samples with a minimum diameter of the central hole of 4 mm. Since the main task of the research was to evaluate the influence of concentration of antipyrogen on the filtration coefficient, the experiments were conducted in this way:

First, clean water was passed through the sample. Water was supplied from the hydraulic cameras of the stand through the outer walls of the sample to its central hole, and from there – through the lower hydro mains – to the flow meter, which was connected to the fitting.



1 – coal sample; 2 – upper plate; 3 – hole; 4 – lower plate; 5 – basis;
6 – tightening screw; 7 – drainage faucet

Figure 2 – Fastening the coal sample to the base of the stand

The working pressure in the hydraulic camera (0.1 MPa) was provided by a pneumohydraulic tank, which was connected by a hose to the fitting of the upper hydro main, pressure control was carried out by the upper manometer.

After that, as through the sample passed about – 2÷11 cm^3 of water, the water with the camera of the stand and hydro mains drained. After draining the water, it was filled with solution of antipyrogen of a certain concentration.

For the gradual change the concentration of the antipyrogen in the water, which was in the pores and cracks of the sample, it was subjected to backwashing – the solution was submitted to the central hole. For this, the lower hydro main and the central hole were filled with liquid with antipyrogen through the drainage main. After removing the air from the central hole the drainage main was closed, the stand was returned to the starting position, the flow meter was being filled with liquid and connected with a hose to the pneumohydraulic tank. The value of the back pressure was monitored by the lower manometer and was supported at the level of 0.02÷0.03 MPa.

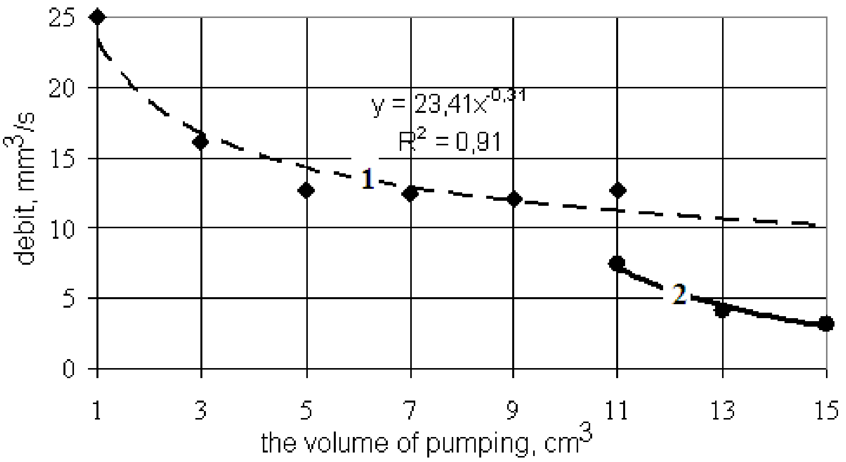
After feeding into the central hole ~ 1 cm^3 of the solution, which flowed into the camera of the stand with liquid, the backwash was stopped and, in the future, the liquid was again fed from the periphery of the sample to the central hole under a nominal pressure of 0.1 MPa. At this stage, the consumption of the solution through the sample was measured. After the end of the measurements, the cycle was repeated for another concentration of the solution.

The research was conducted with antipyrogen «Pirocool» in the form of a solid cylinder, which was packed in standard paper and film shells. When testing the first coal sample, the antipyrogen was dissolved in water to a concentration of 0.4%. After the end of the measurement, the solution was drained from the camera of the stand and hydro mains. A solution of antipyrogen was prepared with a concentration – of 1% and 2%. And after definition the consumption of 1% of the solution, the sample was left in the dry camera of the stand for definition the dynamics of its air permeability.

3. The results and discussion

The results of the research of two-dimensional filtration of a solution of antipyrogen in water.

Tests of sample № 1 were carried out at a constant excess pressure in the camera of the stand (on the outer surface of the sample) in the amount of 0.1 MPa. The hydro main of liquid removal with the central hole to the flow meter was located under atmospheric pressure. At first, clean tap water was pumped through sample № 1. Measurements of the pumping time of each 1 cm^3 of water were carried out without breaks. Its pumping the volume for the all period of flow measurements reached 11 cm^3. After that, the water from the stand was drained and he was filled with a solution of antipyrogen «Pirocool» with a concentration of 0.4% and the measurements were resumed. Their results are given in Figure 3.



1 – water; 2 – antipyrogen solution «Pirocool» with a concentration of 0.4%

Figure 3 – Dependence of the flow rate on the volume of liquid pumping through sample № 1 under a pressure of 0.1 MPa

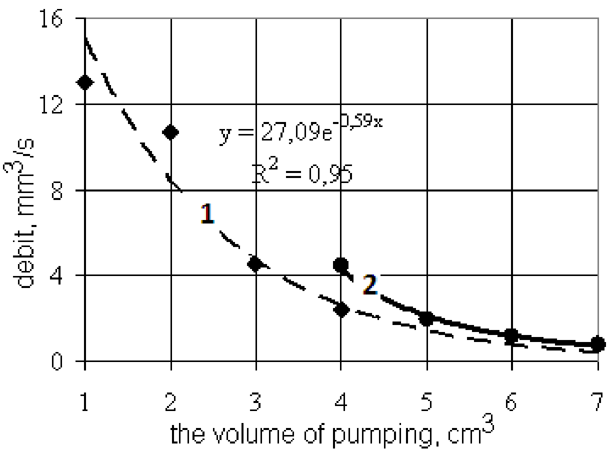
In contrast to previously conducted research [3–5, 8, 9], along the horizontal scale did not postponed the time which passed from the beginning of debit measurements, but the volume of liquid what passed through the sample. The dependence of the debit on the volume of pumping expands our knowledge about the filtration process.

So it turned out, that the falling dependence of the debit from the volume of water pumping (curve 1 Fig. 3) is described by the correlation dependence of the static form, just as before received dependences of debit and consumption from the time of pumping.

From the side of the «physics» of the filtration process, which in coal samples has significant suffusion and colmatation components, it is more appropriate to correlate the debit, or consumption with volume of pumping, because these effects are determined by it. Therefore, in the future, it makes sense to use the dependences of debit (rate) from the volume of liquid pumping through the samples under constant pressure.

In addition, it should be considered the results of before conducted at the IGTM of NAS of Ukraine of research on assessment of the physico-mechanical properties of coal with different influences, in particular, with wave influences and the injection of liquids with different surface active substances (SAS) into the coal [10, 11]. As for influence of antipyrogen on the permeability of the solution through the coal sample, then this first series of tests looked quite logical – the addition of antipyrogen to water, for sure, reduced its viscosity. This led to a decrease debit of the solution almost twice (curve 2 Fig. 3) compared to water. You can also pay attention to the change in the slope of line debit of solution (2) compared to water (1). These data fully confirm the research performed earlier by the IGTM of NAS of Ukraine [11].

The research of sample № 1 were renewed almost a day later. By this time, the antipyrogen has fully dissolved and the concentration of the solution has reached 1%. First, the sample was pumped again with water in a volume of 4 cm^3, and then with a 1% antipyrogen solution in a volume of 3 cm^3. The results of the research are given in Figure 4.



1 – water; 2 – antipyrogen solution «Pirocool» with a concentration of 1%

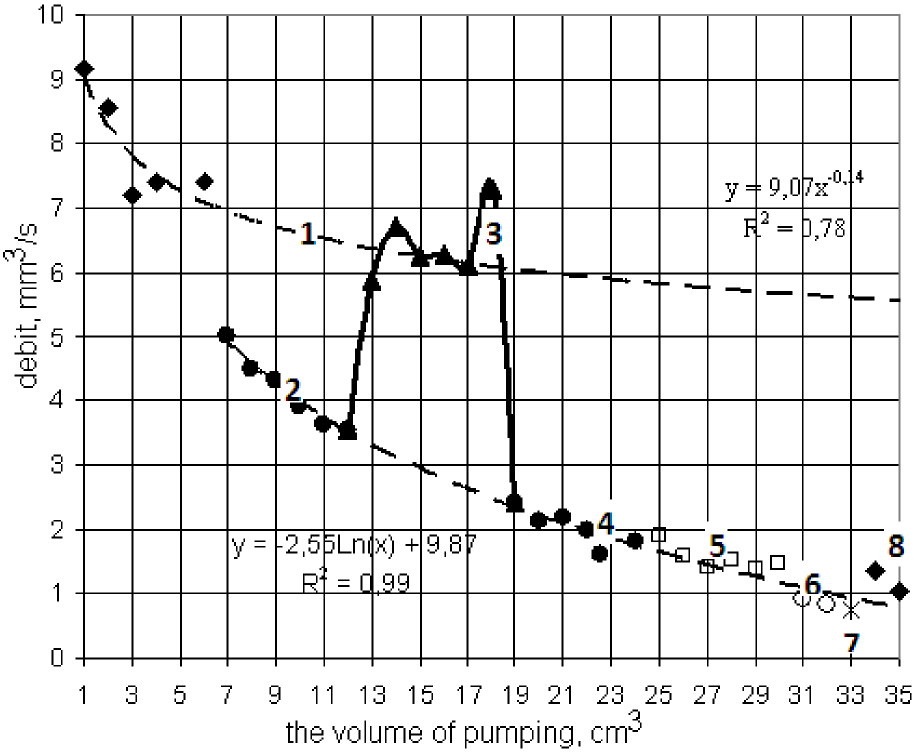
Figure 4 – Dependence of the flow rate on the volume of liquid pumping through sample № 1 under a pressure of 0.1 MPa

If at the concentration of the solution is 0.4%, the permeability of the sample is decreases almost twice, then when the concentration is increased, the permeability increases again and also almost twice. That is, a liquid with a concentration of 1% in terms of hydraulic properties corresponds to pure water, while the solution of a lower concentration (0.4%) is worse than water. On this hydraulic experiments with sample

№ 1 were stopped, and for a more detailed study the phenomenon the was observed, experiments were conducted with coal sample № 2.

After research the sample № 1, we note that repeated pumping of water, after its saturation carried out, changed (not significantly) the character of the dependence of the debit from the volume of pumping from static to exponential (Fig. 3, 4).

Tests of sample № 2 took place during several days under the same conditions of liquid movement with the same pressure parameters as sample № 1. Their results are given in Figure 5.



1 – water; 2 – antipyrogen solution «Pirocool» with a concentration of 0.4%;
3 – concentration 1.2%; 4 – concentration 2%; 5 – concentration 3%; 6 – repeating the measurement with a concentration of 3% on the next working day; 7 – concentration 3.75%;
8 – clean water on the next working day

Figure 5 – Dependence of the flow rate on the volume of liquid pumping through sample № 2 under a pressure of 0.1 MPa

The difference consisted in the fact that the concentration of the solution varied in a much wider range (0.4÷3.75%) than when testing the sample № 1.

This given it possible to monitor the influence of the antipyrogen concentration on the magnitude of debit through the sample.

The debit has a pronounced extreme character. The zone of maximum debit corresponds to the concentration of antipyrogen «Pirocool» within the limits of 1÷1.2% (the range is indicated with consideration the tests of sample № 1). At this concentration of debit of the solution even slightly exceeds the debit of pure water. Although outside the limits this zone, as with smaller ones and as well as with larger ones antipyrogen concentrations, the debit of the solution is significantly decreases compared to the debit of pure water.

This is the behavior of debit can be explained by the corresponding extreme dependence of the viscosity of the solution from its concentration. This assumption has a somewhat hypothetical character at the moment, because at the moment it is not possible to determine the dependence of viscosity on the concentration of the solution.

It is likely that they encountered a manifestation of the physic-chemical interaction of the antipyrogen solution with coal samples. In favor of this assumption a change in character of the dependence of debit from the pumping volume from static for pure water to logarithmic for the antipyrogen solution. These trends are given for the upper and lower lines of Figure 5.

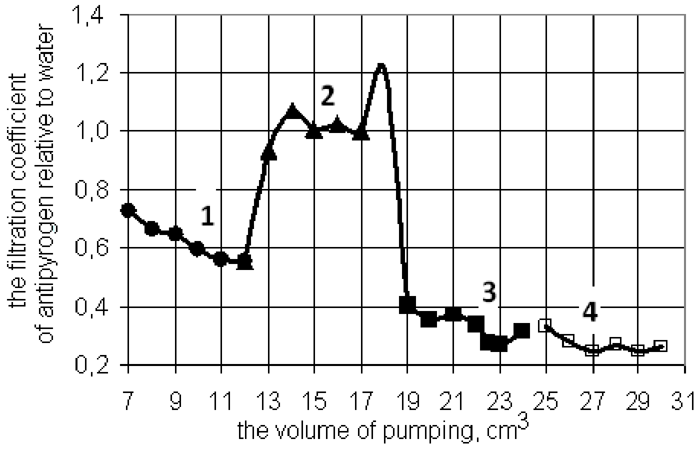
It is very interesting that one logarithmic trend almost perfectly describes the behavior of the debit at different concentrations of the solution, with the exception of 1.2% concentrations of extreme debit.

The interruptions in the experiment process do not much effect on location of the experimental points relative to the logarithmic trend line. This is evidenced by the comparison of the debits of groups of points 5 and 6 under the concentration of 3%. After this, the concentration of the solution was increased to 3.75% and point 7 was obtained.

After this measurement, the solution was drained from the camera and hydro mains of the stand, then the measurement of two points 8 for pure water was conducted. They are located slightly higher than point 7 and the logarithmic trend line, but quite near to it. The difference between the absolute debits of pure water (the first of points 8) and 3.75% solution (point 7) is not very large 0.6 mm^3/s. But against the background of the low the value of the debit of 3.75% of the antipyrogen solution (0.75 mm^3/s), the relative increase of debit of pure water (to 1.35 mm^3/s) – reaches 1.8. At the same time, the influence of suffusion and colmatation effects at the beginning of pure water injection is minimal. Analogous comparison of the debits of 0.4% antipyrogen solution (3.2 mm^3/s) and pure water (13 mm^3/s) during the tests of sample № 1 (Fig. 2, 3) showed an excess of the debit of pure water at 4.1 times. And comparison of the debits of pure water through sample № 1 before injecting the solution (12.7 mm^3/s) and after injecting the solution (13 mm^3/s) showed their practical coincidence, despite the fact that some time had passed between these measurements and was pumped 4 cm^3 of solution. These facts testify to the complex character of the filtration of antipyrogen solutions, which is hardly reduced only to a change in their viscosity.

Despite on the imperfection of our ideas about the mechanisms of filtration of the antipyrogen solution in the coal massif, the developed method of measurement makes it quite easy to establish the relative dimensionless filtration coefficient of the antipyrogen solution to water, with consideration suffusion and colmatation effects.

The relative filtration coefficient is determined by separation the experimental value of the expenses of the antipyrogen solution on a conditional value of the expenses water, which is calculated by its elongated correlation static line of experimental expenses for the corresponding points of the horizontal axis of the pumping volumes. The curve received in this way is shown in Fig. 6.



1 – 0.4%; 2 – 1.2%; 3–2%; 4–3%

Figure 6 – Dependence of the filtration coefficient relative to water of water solution of antipyrogen «Pirocool» with different concentrations

The analysis of this graph shows that the debits through the sample at concentrations of 2÷3% change very little within the limits of pumping 5 cm^3 of the solution (groups of points 3 and 4). Some more the run-up has in these limits a group of point 2 – mainly through to the last point. Points of group 1 have the greatest slope to the horizontal axis. Here, the deviation of the maximum or minimum debit value from the medium reaches ~ 20%. Within such the limits of error, it is possible to use one medium value of the debit for a certain concentration, without paying attention on the change depending on the volume of solution pumping. Data processed in this way from fig. 6 supplemented with the obvious value of the filtration coefficient relative to water, which is equal to one at zero antipyrogen concentration, allowed to get an approximate dependence of the filtration coefficient relative to water from the concentration of the antipyrogen of «Pirocool» within of 0÷3.75%. The approximate dependence is given in Figure 7.

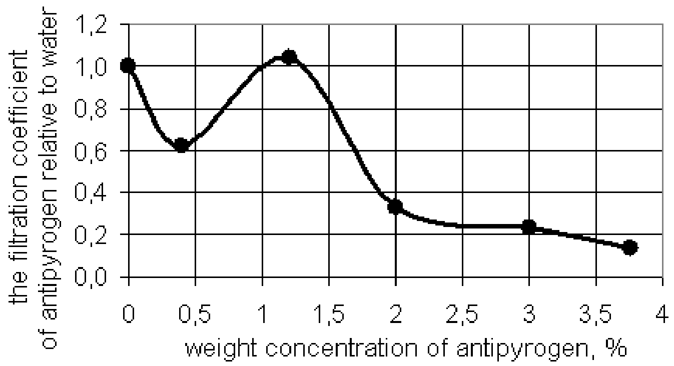


Figure 7 – Dependence of the filtration coefficient of water solution relative to water on the concentration of the antipyrogen «Pirocool»

The revealed not trivial wavy character of the dependence of the relative filtration coefficient from the concentration of the antipyrogen has in addition to scientific novelty and a certain practical significance. They confirm the results of previously performed practical research, obtained by other authors when the injection of liquid into the layer and when the evaluation of fire prevention measures, that are performed in the mines [12–14].

It should be noted that established by the authors the character allows to significantly reduce work expenses when establishing the optimal hydraulic parameters of processing seam with antipyrogens by means of research injections in mine conditions.

Laboratory research of the safety of processing coal with antipyrogens from the side of possible provocation a sudden emission.

The actuality of these researches is conditioned those to the considerations, that a certain amount of coal seams is characterized as a tendency to spontaneous combustion, so and the outburst hazard. When developing them, it is desirable to perform corresponding prophylactic measures. In order to prevent sudden emissions during conducting preparatory seams elaboration, it is recommended to use hydro loosening of the heading face – injection through anticipatory wells of water under high pressure. And to prevent spontaneous combustion the same injection under pressure of water solutions of antipyrogens is recommended.

It makes sense to combine these measures and conduct hydro loosening of the heading face with a solution of antipyrogen. The established scheme for the location of wells for hydro loosening provides the processing of coal near the sides of the tunnel to a depth of 1÷2 m.

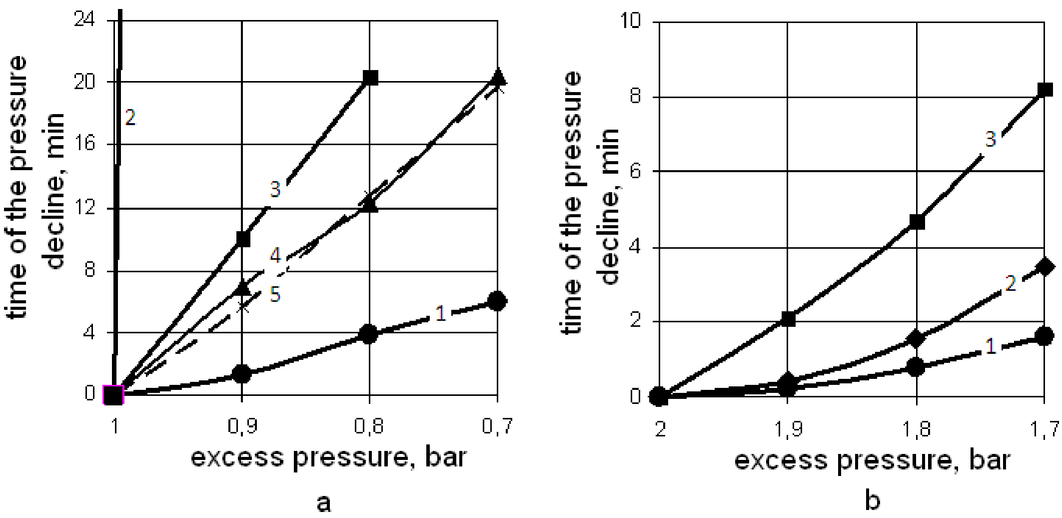
In connection with this, there is a question regarding the effectiveness of saturation of the near-contour zone of the seam with antipyrogen through wells in the heading face, taking into account the further change in the stress-deformed state of the sides of the tunnel. That is, does not such a situation occur when the pores and cracks that were filled with liquid during the processing of the face will expand after its advancement forward, as a result of which again the air migration channels into the depth of the massif will be released?

The answer to this question is given by the research of our Institute on the dynamics of changes in the stress state of the regional part of the seam during the time [3, 9]. The classic form of the distribution curve of the maximum stresses by distance from the face tunnel, which is given in numerous publications already for about 50 years, is not formed immediately, but over time. So, through 27 hours (i=10) after the excavation cycle, the maximum stresses are reach the magnitude of everything of 1.1 γH, and the magnitude of 1.45 γH is reached only through 135 hours (5.5 days). From this follows the conclusion about that the common value of maximum stresses ~ 2γH is reached no earlier 1–2 months after the rock mass excavation cycle. And during all this time, the stresses of the entire edge part of the seam only increase.

Comparison of the air permeability of the sample was conducted in this way. The air pressure in the working camera of the stand was quickly increased by the manual compressor of the pneumohydraulic tank. After that, the pressure drop time was recorded. The pressure drop from 1 to 0.9 bar (one division of the manometer scale) for a dry sample was one minute 50 seconds (1.83 min.). Right after saturating the sample with water, it was not possible to record a noticeable decrease in air pressure in the working camera of the stand during ~ 5 minutes on the manometer scale. The same picture was observed and after pumping a 0.4% antipyrogen solution through the sample. That is, immediately after hydroprocessing with water or a solution, the sample can be considered no permeable to air at a pressure of 1 bar.

After that, the solution with a concentration of 0.4% was drained from the camera of the stand and hydro mains into a beaker for additional dissolution of the antipyrogen in order to increase the concentration to 1%. The sample was in this state to the beginning of measurements on the next working day, about 18 hours. This interval corresponded to the interval between two cycles of processing of the heading face in the repair shifts. After that, its air permeability was made measurement. The pressure drop time from 1 to 0.9 bar made up 14 minutes 11 seconds (14.18 min.). That is, about through of 18 hours, the air permeability of the processed sample was in 8 times less than of the dry. Right after the repeated saturation of the sample as water so and a solution of antipyrogen with a concentration of 1%, its air permeability again became almost zero.

In the future, the hydroprocessing of sample № 1 was stopped, and its air permeability was monitored for 5 days. The results of observations for this time are shown in Figure 8.



time of processing with a solution of antipyrogen:
1 – to processing; 2 – right after processing; 3 – a day later; 4 – after 2 days; 5 – after 5 days

Figure 8 – The results of observations of the dynamics of the pressure decline of air filtered through a coal sample after processing with a 1% solution of antipyrogen:
a) initial excess pressure of air 1 bar; b) initial excess pressure of air 2 bar

At an initial excess air pressure of 1 bar, the tempo of its decline predictably increased over time. A significant slowdown in the tempo of pressure drop began after two days of observations. This is evidenced by the almost is full coincidence of the pressure drop tempo lines 4, 5 on Fig. 8, and respectively through two and five days. But for higher value of excess air pressure of 2 bar, the predictability of the tempo of decline over time was broken. The pressure drop tempo immediately after saturation of the sample with antipyrogen (line 2 Fig. 8 b) was greater than through a day (line 3 Fig. 8 b).

The obtained data indicate about that the character of the change in air permeability of the sample depends not only from the passage of time, and also from air pressure. In the future, this effect will be researched more thoroughly.

The research is conducted in the article on the main indicator of the two-dimensional filtration process – the hydraulic permeability of antipyrogens through coal samples – revealed a non-trivial wavy character of the dependence from the concentration of antipyrogen. This is not mentioned in the results of previously performed research by other authors on liquid injection into the seam, and in the assessment of fire prevention measures performed in mines [12–14]. This, most likely, can be explained by the chemical properties of the relatively new antipyrogen «Pirocool». But and the impact of our two-dimensional filtering research methodology, which is applied for the first time, is also possible. In all previous works, only one-dimensional filtration was researched.

It should be noted that the character established by the authors allows to significantly reduce the expenses of work when established the optimal hydraulic parameters of seam processing with antipyrogens «Pirocool» by means of research injections in mine conditions.

In the experiments also showed a significant discrepancy the experimental data the theoretical for two-dimensional filtration by to a linear law, which was previously established for the movement of water from the side surfaces of the sample to its central hole [4, 8]. Now it is confirmed and for the case of the movement of water in the reverse direction – from the central hole to the side surfaces. As it was established, such a tendency to decrease over time the expenses of water into the central hole, which is most likely explained by sufosis and colmatation [4, 8], was preserved and for antipyrogen solutions. This factor, which is still not taken into account in theoretical models, makes it difficult to search the form of the law of liquid filtration in coal seams. It should also be noted that the wavy character of the change in hydraulic permeability at change the concentration of antipyrogen within the limits of 0÷1.5% has been established. At the same time, with a further increase in concentration to 4%, the permeability decreases monotonically.

But, the question arises of the safety of such a combination of hydro-loosening and antipyrogenic processing of the heading face by the factor of excessive blocking of seams gas. If such a blocking leads to a significant increase in seams pressure, it can provoke a sudden ejection during conducting heading works.

For the primary answer on this question, we conducted comparison the air permeability of coal sample № 1 after the first saturation with water, and then after saturation with an antipyrogen with a concentration of 0.4%.

Thus, repeated release of air migration channels into the depth of the sides of the heading tunnel during the first 3 days after processing with an antipyrogen of its face is unlikely. In the future, it is possible to additionally process the sides of the tunnel by spraying with an antipyrogen for a more guarantees of hindering air access in the depth of the massif.

4. Conclusions

1. Conducted research of the main indicator of the two-dimensional filtration process – the hydraulic permeability of antipyrogens through coal samples.

The significant non-compliance of the experimental data with the linear law during two-dimensional filtration, which was previously established for the movement of water from the side surfaces of the sample to its central hole, was confirmed and for the case of water movement in the reverse direction – from the central hole to the side surfaces.

2. The tendency of water expenses into the central hole to decrease during the time, which is most likely explained by suffusion and colmatation, was preserved and for solutions of antipyrogen. This factor, which is still not taken into account in theoretical models, makes it difficult to find the form of the law of liquid filtration in coal seams.

3. For the first time the wavy character of the change in hydraulic permeability was established when the concentration of the antipyrogen «Pirocool» changed within of 0÷1.5%. With a further increase in concentration to 4% the permeability decreases monotonically.

4. Research of changes in the air permeability of samples, that are processed with antipyrogen solution, over time prove that there is no threat of an increase in danger occurrence of a sudden ejection during the hydro-loosening of the heading face with antipyrogens.

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ДОСЛІДЖЕННЯ ФІЛЬТРАЦІЇ РІДИНИ ПРИ ОБРОБЦІ ВУГІЛЛЯ ВОДО-ПІННИМ РОЗЧИНОМ НА ОСНОВІ АНТИПІРОГЕНУ

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Анотація. Одним із застосовуваних на шахтах заходів щодо зниження викидонебезпечності вугільних пластів є їх гідророзпушування водою під високим тиском через пластові свердловини. Нагнітання води та розчинів на основі антипірогенів у вугільний пласт, який схильний до самозаймання, застосовується для зменшення виникнення ендогенних пожеж. Відомо, що насичення вугілля рідиною змінює властивості та механічні характеристики, і призводить до розвантаження пласта гірничих виробок. Тому оцінка зміни геомеханічних параметрів у приконтурній зоні до та після гідрообробки пласта є дуже актуальною задачею. Знання динаміки формування поля напруження навколо гірничої виробки дозволить вдосконалити технологію обробки вугільного пласта антипірогенами. Більша частина інформації відносно до спостережень за процесом нагнітання води в шахтних умовах наводиться в різних публікаціях передових басейнових інститутів.

Метою досліджень стало визначення параметрів фільтрації рідини при розповсюдженні антипірогену в масиві та відповідної зміни властивостей вугілля, обробленого водо-пінним розчином на основі антипірогену для запобігання вибухів та пожеж викидонебезпечних, схильний до самозаймання вугільних пластів.

Дослідження проводились у лабораторних умовах на стенді двовимірної фільтрації рідини з антипірогеном через вугільний зразок, який був виготовлений у формі кубика з отвором, що розташований по середині зразка. Розроблена методика вимірів дозволяє легко встановлювати відносний безрозмірний коефіцієнт фільтрації розчину антипірогену до води з урахуванням суфозійних та кольматаційних ефектів.

Вперше встановлено хвилястий характер зміни гідравлічної проникності при зміні концентрації антипірогену в межах 0÷1,5 %. При цьому з подальшим збільшенням концентрації до 4% проникність монотонно знижується. Також дослідження зміни повітряної проникності зразків, що оброблені розчином антипірогену, з плином часу доводять відсутність загрози підвищення небезпеки виникнення раптового викиду під час гідророзпушування прохідницького вибою антипірогенами. Можна зазначити, що встановлений характер дозволяє суттєво зменшити витрати праці при встановленні оптимальних гідравлічних параметрів обробки пласта антипірогенами.

Ключові слова: антипіроген, вугільний пласт, фільтрація рідини, концентрація розчину, раптові викиди.