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Improving the efficiency of methane extraction from coal seams

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ABSTRACT
This article presents possible reasons for the low productivity of wells for coal methane extraction and ways to resolve them using hydrochloric acid treatment of wells. A common reason for the low productivity of wells is a decrease in the permeability of the bottom-hole formation zone. Starch, calcium carbonate, and drilling rocks, which are part of the drilling mud, change the filtration properties of the layer during the formation of a filtration crust and lead to a decrease in the initial permeability. Hydrochloric acid treatment, during which clay rocks are dissolved, is an effective method of increasing the productivity of wells. It is used to increase pick-up and prevent contamination of the bottom-hole zone of the carbonate formation. The parameters affecting the effectiveness of hydrochloric acid treatments were considered. The results of the experience of the interaction of hydrochloric acid with a clay crust are presented and analyzed using approaches to the mechanics of multiphase media. Dependences of the rate of dissolution of clay rock on the concentration of acid solution are obtained. It is established that the treatment of the productive intermediate layer of the well with hydrochloric acid in a certain concentration, its use increases the technological and economic efficiency of wells. As a result of experimental work, it was found that hydrochloric acid with an HCL concentration above 18% has a negative effect on the internal equipment of the well when processing clay shells.

Keywords: safety, coal mines, colmatation, wells, clay crust, hydrochloric acid.

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Introduction

The issue of creating safe ways of mining in coal mines has always been an important task in the mining industry. Creating a way to intensify the gas supply of coal seams on the basis of a complex set of works may be the answer to the question of how to reduce the number of human casualties and increase the efficiency of drilling and cleaning operations. Therefore, the intensification of gas emissions from coal seams is an urgent scientific and practical task [[1], [2]]. Despite the existence of scientific developments, the results of previous studies still do not solve the problem of increasing the gas release of coal seams under the influence of external forces.

Since 2015, JSC "KazTransGas" has conducted geological exploration for gas production from coal seams in the Karaganda region. For this purpose, the planned work on drilling three core and four experimental-industrial wells were carried out.

The efficiency of well construction is directly related to their productivity, and the latter is to maintain the maximum permeability of reservoirs and the duration of high-performance wells.

In recent years, the urgency of the problem of maintaining the potential productivity of wells has increased significantly, including due to the involvement in the development of complex deposits and fields with low permeability, with high requirements for the quality of their opening [[2], [3]].

The main negative factor in the completion of wells, which significantly impairs the performance of methane coal wells, is the contact of the drilling fluid with the productive formation during drilling [3]. In this case, the proximal part of the formation is clogged with the solid phase of the drilling mud, the conductive area is covered with the filtrate of the drilling mud; physicochemical interaction of the filtrate with both formations of fluids and rocks. The adverse effects of the drilling mud filter entering the formation may vary:

- causes swelling of clay particles in the reservoir layer, resulting in a sharp decrease in the permeability of the lower well area;
- water-oil emulsions are formed, which in some cases significantly reduce the permeability of the lower well area;
- Capillary forces in the porous medium and its partial displacement from the porous channels can only be accompanied by a significant change in pressure, which makes it difficult for methane to move to the bottom of the well, especially with low conductivity reservoirs;
- As a result of the interaction of the drilling mud filter with highly mineralized water, insoluble residues may form in the reservoir pores [4].

The penetration of polymers, starch, and calcium carbonate, which is part of the drilling mud into the productive layer of the drilled rock, changes the filtration properties of the formation during the formation of the filtration crust and leads to a decrease in the initial permeability [5]. To restore it, it can be treated with chemical compounds such as acids and oxidizers.

Experimental part

Hydrochloric acid in different concentrations is used in the productive intervals of the wellbore, to solve this problem. Acid treatment of wells is designed to clean the edges of clay deposits to increase the permeability of coal seams. Under the influence of hydrochloric acid, cavities, cracks, and drainage channels are formed in rocks and coal seams, as a result of which the permeability of the productive layer increases, and, consequently, the productivity of methane-coal wells increases.

Tests for the removal of clay with hydrochloric acid were conducted in the laboratory of drilling mud at Nazarbayev University. The easiest way to remove the filter shell with acid-soluble components is to install acid baths. Limestone, siderite, celestine, etc. react with the acid, effectively destroying the structure of the clay crust, and facilitating its removal from the surface of the collector [6].

Tests were carried out on the drilling mud used during the drilling of wells in the Sherubainura area. Drilling mud is prepared in accordance with the design documentation and consists of the following components such as Bentonite, Carboxymethylcellulose (CMC), Na_2CO_3, polisol, technical salt, POLIPAC UL, POLIPAC R, foam step, Dyovis, DESCO / Burplast. The acid solutions to be tested were prepared from 5 acid compositions with a concentration of 12, 14, 16, 18, and 20%, respectively, as shown in Figure 1.

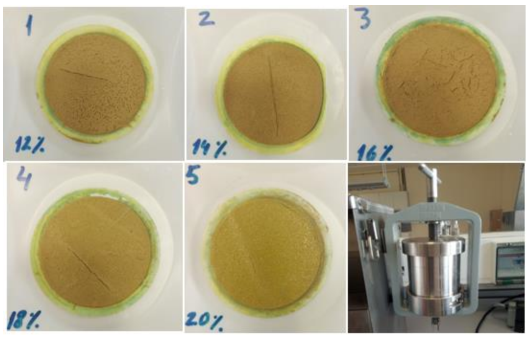

Figure 1. Results of clay samples

Residues of clay suspension were washed with water from the surface of the filtration crust before acid treatment.

Filtration of the acid solution through the clay crust was carried out by the vacuum method (6.9 bar) at a pressure difference.

The first stage is the "latent" phase of the reaction, in which the rate of filtration of the acid through the crust (the volume of the filtrate detected in real-time) is directly proportional.

The second stage is the phase of active interaction of the acid with the filtration crust, which is characterized by a deviation from the vertical dependence of stage 1.

As the acid concentration increases, the duration of the "latent" phase of the reaction decreases. Thus, in the case of this experiment, the latent reaction time for 20% hydrochloric acid is about 5 minutes. For 12% acid, this period was 31 minutes [7]. According to the 5 tests performed, the diagram of the dependence of the filtration time on the concentration of the acid solution is given (Figure 2) [8].

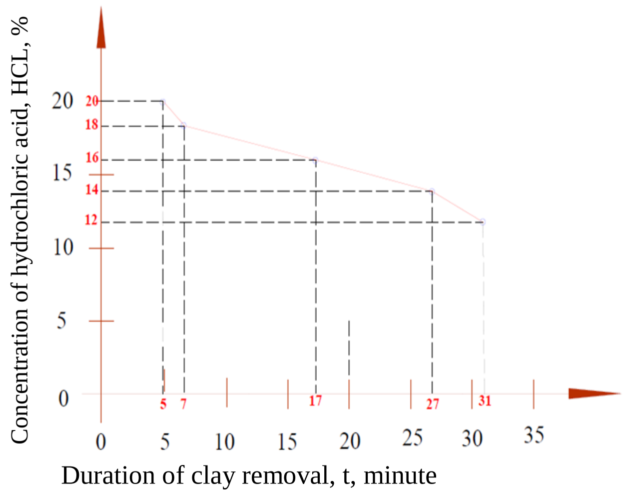

Figure 2. Diagrams of the dependence of the filtration time on the concentration of the acid solution

y - concentration of hydrochloric acid, HCL, %; x time of clay crust removal, t, min - a total of 25 samples were conducted.

The dependence of the start time of the methane production process on the percentage of hydrochloric acid treatment is in the form of cubic regression (Figure 3).

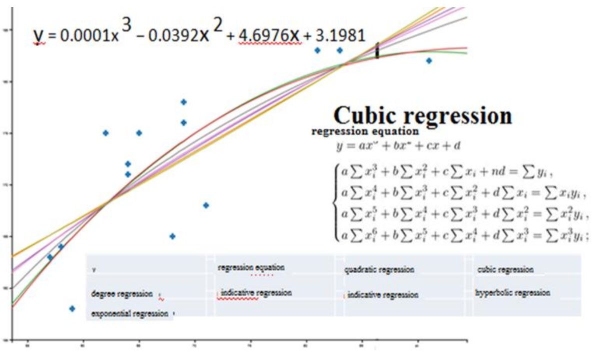

Figure 3. Approximation of a function of a single variable

Thus, an increase in the volumetric concentration of acid increases the permeability of the folds in the filter press, which is a direct indicator of the effectiveness of the destruction of the clay crust [9].

It can be seen that the optimal acid concentration in the processing of clay and effective acid degradation is 18% HCL. Acid concentrations are operatively justified, as low concentrations increase the processing time (more than 17 minutes), while high concentrations have a strong corrosive effect on the equipment inside the well used in drilling and production, especially with a small difference in crust time (2.5 minutes) [10].

One of the main principles of choosing the concentration of acid components in the acid solution is to ensure the maximum amount of soluble clay crust with a minimum amount of acid. Numerous studies and applications show that the optimum concentration of hydrochloric acid is 18% in the main technologies transferred from different regions of the country to the Sherubainura fields [11]. This is convenient because industrial hydrochloric acid contains 37% by weight of the main substance, which allows you to easily prepare the commercially diluted acid solution in half with ordinary water and without any calculations [12].

According to experiments conducted in the laboratory of Nazarbayev University, the melting reaction of the clay crust is intensive at complex concentrations of 12-18%, and when its concentration is less than 12%, the crust does not dissolve in time or does not react at all [13].

The low permeability of coal seams causes low gas release. Therefore, in order to increase the permeability of coal seams during hydraulic fracturing, samples of K3 and K10 coal seams were studied for the effect of 18% hydrochloric acid on the desorption of methane in the laboratory "Methane Energy" in the Mining and Metallurgical Complex of Karaganda Technical University (Figure 4).

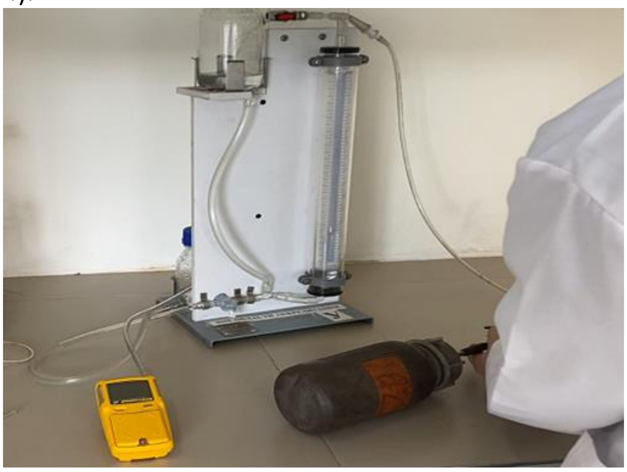

Figure 4. Geokrak desorption unit

The degassed gas from the sampling bottles was degassed.

- The volume of gas released is 140 ml under normal conditions;
- The detector recorded more than 80 levels of methane %;
- 50 g of charcoal was removed and poured 50 ml of water at room temperature;
- After waiting for 10 minutes, the gas medium was surrounded and no traces of methane were found;
- Due to the small volume of coal, the coal was refilled into test vacuum bottles and it was decided to pour 200 ml of 18% hydrochloric acid;
- After waiting for 5 minutes, they turned the valve of the desorption unit and began to correct the gas leak. The volume of gas released at 11 minutes under normal conditions was> 250 ml [14].

The exact concentration of methane in the exhaust gas mixture was determined on an Agilent 7890V gas chromatograph.

According to the chromatograms, the concentration of methane after exposure to 18% of coal was 62%, and the remaining fraction was the concentration of carbon dioxide formed as a result of the decomposition of carbonates in the structure of coal (Figure 5) [[15], [16]].

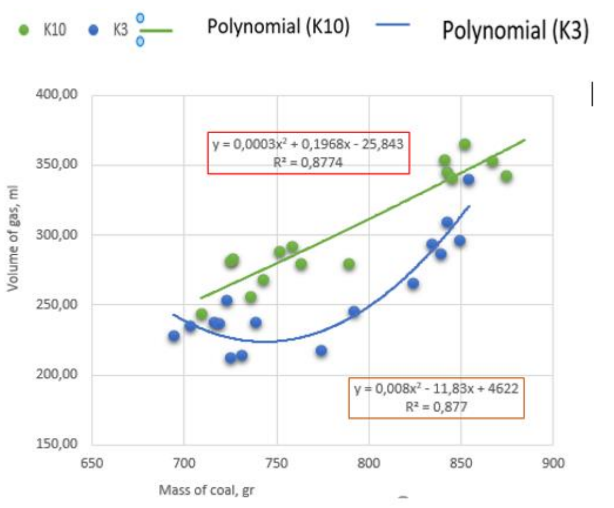

Figure 5. Prediction of methane release by coal mass

Research results and discussion

Thus, the 18% solution increases gas consumption by an average of 17-19% due to the increase in permeability and, consequently, the diffusion of methane in the coal seams [[17], [18]].

Research has been conducted to achieve maximum results in solving the problem of gas emissions from coal seams.

The difference in the proposed work is the intensification of gas release from coal seams on the basis of a fundamental study of the viscosity, strength, and density of the coal mass to identify structural bonds and increase the permeability of coal and methane [[19], [20]].

The result of the fundamental research work was the intensification of gas separation of coal seams by conducting a set of studies, including testing of coal seam samples for viscosity, and permeability of coal seams to identify structural bonds and increase the permeability of coal and methane.

The novelty of the research work:

- increase in gas emissions from coal seams due to the optimal location of methane coal wells in the establishment of regularity;
- intensification of gas release from coal seams under the influence of external forces.

Conclusions

The results of the work will ensure the safety of underground mining in coal mines and reduce the greenhouse effect of methane emissions from coal seams into the atmosphere.

Industrial regions of Kazakhstan, which do not receive enough gas, can be fully self-sufficient through the production of their own methane from coal seams. First of all, we are talking about Karaganda, Akmola, and Pavlodar regions [[21], [22]].

Conflict of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest regarding others.

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Көмір қабаттарынан метан алудың тиімділігін арттыру

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ТҮЙІНДЕМЕ

Бұл мақалада көмір қабаттарыннан газ бөлінуін арттыру арқылы көмір шахталарында тау-кен жұмыстарын қауіпсіз жүргізуді қамтамасыз ету мәселелері қаралды. Көмір қабаттарынан газ бөлінуін қарқындату мақсатында бір қатар зерттеулер жүргізілді. Ұңғымалардың төмен өнімділігінің ықтимал себептері және ұңғымаларды тұз қышқылымен өңдеуді қолдану арқылы оларды шешу жолдары келтірілген. Ұңғымалардың төмен өнімділігінің жиі кездесетін себебі – төменгі ұңғыма аймағының өткізгіштігінің төмендеуі. Крахмал, кальций карбонаты, бұрғылау ерітіндісінің құрамына кіретін бұрғылау жыныстары сүзу қыртыстарын түзгенде қабаттың сүзу қасиеттерін өзгертеді және бастапқы өткізгіштіктің төмендеуіне әкеледі. Сазды жыныстарды еритін тұз-қышқылмен өңдеу ұңғымалардың өнімділігін арттырудың тиімді әдісі болып табылады. Тұз қышқылымен өңдеудің тиімділігіне әсер ететін параметрлер қарастырылды. Көп фазалы ортаның механикасы тәсілдерін қолдана отырып талданған тұз қышқылының саз қабығымен өзара әрекеттесу тәжірибесінің нәтижелері келтірілген. Сазды жыныстың еру жылдамдығының қышқыл ерітіндісінің концентрациясына тәуелділігі анықталды. Ұңғыманың өнімді аралық қабатын белгілі бір концентрацияда тұз қышқылымен өңдеу ұңғымалардың технологиялық тиімділігін арттыратыны анықталды. Эксперименттік жұмыстардың нәтижесінде 18% жоғары концентрациясы бар HCL тұз қышқылы сазды қабықтарды өңдеу кезінде ұңғыманың ішіндегі жабдықтарға теріс әсер ететіні анықталды. Зертханалық жағдайда жүргізілген эксперименттердің нәтижесінде қышқылдың өңдеудегі ең оңтайлы концентрациясы және саз қабығының тиімді қышқылдық ыдырауы 18% HCL екендігі анықталды. Эксперимент нәтижелері бойынша 18% ерітінді өткізгіштіктің артуына байланысты газ бөлуді орта есеппен 17%-ға және 19%-ға арттырады.

Түйін сөздер: қауіпсіздік, көмір шахталар, кольматация, ұңғымалар, саз қабығы, тұз қышқылы.

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Повышение эффективности извлечения метана из угольных пластов

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АННОТАЦИЯ

В данной статье рассмотрены вопросы обеспечения безопасного ведения горных работ на угольных шахтах путем повышения газоотдачи угольных пластов. С целью интенсификации газовыделения угольных пластов проведен ряд исследований. Приведены возможные причины низкой производительности скважин и пути их решения с использованием обработки скважин соляной кислотой. Наиболее частой причиной низкой продуктивности скважин является снижение проходимости нижней зоны скважины. Крахмал, карбонат кальция, буровые породы, входящие в состав бурового раствора, изменяют

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фильтрационные свойства пласта при образовании фильтрационной корки и приводят к снижению начальной проницаемости. Обработка глинистых пород растворимой соляной кислотой является эффективным методом повышения продуктивности скважин. Рассмотрены параметры, влияющие на эффективность переработки соляной кислоты. Приведены результаты опыта взаимодействия соляной кислоты с глинистой оболочкой, анализируемого с помощью методов механики многофазных сред. Получена зависимость скорости растворения глинистой породы от концентрации раствора кислоты. Установлено, что обработка продуктивного промежуточного слоя скважины соляной кислотой в определенной концентрации, ее использование повышает технологическую эффективность скважин. В результате экспериментальных работ установлено, что соляная кислота HCL с высокой концентрацией 18% оказывает негативное влияние на внутреннее оборудование скважины при обработке глинистых оболочек. В результате экспериментов, проведенных в лабораторных условиях, было установлено, что наиболее оптимальная концентрация кислоты в обработке и эффективное кислотное разложение глинистой пленки составляет 18% HCL.По результатам эксперимента 18% раствор увеличивает газовыделение в среднем на 17% и 19% за счет увеличения проницаемости.

Ключевые слова: безопасность, угольные шахты, кольматация, скважины, глинистая корка, соляная кислота.

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