

Код МРНТИ 52.35.29

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PROSPECTS FOR THE APPLICATION OF FOREIGN EXPERIENCE IN THE CONDITIONS OF DOMESTIC COAL DEPOSITS

Abstract. The article discusses the prospects for the application of foreign experience in coalbed methane production at domestic coal deposits. The factors influencing the efficiency of methane production, including geological conditions, production technologies and economic feasibility, are analyzed. Data on the world resources of coalbed methane, the experience of production in various countries, such as the USA, China, Australia and Russia, as well as mining and geological characteristics are presented. Particular attention is paid to methods for assessing methane reserves and technologies for its production aimed at improving the safety and economic efficiency of production. The need to adapt modern technologies for methane production is emphasized.

Key words: coalbed methane, unconventional gas sources, coal seam degassing, geomechanics, resource-saving technologies, mining and geological conditions, economic efficiency.

Көмірдің отандық кен орындары жағдайында шетелдік тәжірибе қолдану перспективалары

Аннотация. Мақалада отандық көмір кен орындарында көмірлі метан өндіруде шетелдік тәжірибені қолдану перспективалары талқыланады. Метан өндірудің тиімділігіне әсер ететін факторлар, оның ішінде геологиялық жағдайлар, өндірістік технологиялар және экономикалық орындылық талданады. Көмір қабаттарының метанының әлемдік ресурстары, АҚШ, Қытай, Австралия және Ресей сияқты әртүрлі елдердегі өндіріс тәжірибесі, сондай-ақ кен орындарының тау-кен геологиялық сипаттамасы туралы мәліметтер келтірілген. Метан қорын бағалау әдістеріне және өндірістің қауіпсіздігі мен экономикалық тиімділігін арттыруға бағытталған оны өндіру технологияларына ерекше назар аударылады. Метан өндірудің заманауи технологияларын бейімдеу қажеттілігіне баса назар аударылады.

Түйінді сөздер: көмірлі метан, газдың бейвенциалды көздері, көмір қабатын газсыздандыру, геомеханика, ресурс үнемдейтін технологиялар, тау-кен-геологиялық жағдайлар, экономикалық тиімділік.

Перспективы применения зарубежного опыта в условиях отечественных угольных месторождений

Аннотация. В статье рассматриваются перспективы применения зарубежного опыта добычи метана угольных пластов на отечественных угольных месторождениях. Проанализированы факторы, влияющие на эффективность добычи метана, в том числе геологические условия, технологии добычи и экономическая целесообразность. Приведены данные о мировых ресурсах метана угольных пластов, опыте добычи в различных странах, таких как США, Китай, Австралия и Россия, а также горно-геологическая характеристика месторождений. Особое внимание уделено методам оценки запасов метана и технологиям его добычи, направленным на повышение безопасности и экономической эффективности добычи. Подчеркивается необходимость адаптации современных технологий добычи метана.

Ключевые слова: метан угольных пластов, нетрадиционные источники газа, дегазация угольных пластов, геомеханика, ресурсосберегающие технологии, горно-геологические условия, экономическая эффективность.

Introduction

The growing importance of coalbed methane (CBM) as an alternative energy source is driven by global decarbonization efforts and stricter environmental regulations aimed at reducing greenhouse gas emissions [1]. As noted by Pengfei Ji and co-authors, the integration of CBMs into energy systems allows not only to diversify the fuel base, but also to reduce the carbon footprint of the coal industry, which is especially important in the context of «zero emissions» goals [2]. In Kazakhstan, especially in the Karaganda basin, the problem of coal mine methane emissions remains critical, posing risks to occupational safety and the environment.

According to M.A. Pazyuchenko, uncontrolled methane emissions in coal mines increase the greenhouse effect, since the global warming potential of methane is 25 times higher than that of CO_2 [3].

The joint production of coal and methane, as demonstrated by world experience, can transform these challenges into economic advantages. For example, in the United States, the introduction of degassing systems made it possible to utilize up to 90% of methane, reducing ventilation costs and increasing the profitability of production [4]. For Kazakhstan, which has significant CBM resources (projected reserves in the Karaganda basin are 1.2 trillion m^3 [5]), this opens up prospects for integration into global value chains, especially given the growing demand for clean energy. The world's CBM reserves are estimated at 256 trillion m^3 , which is almost 20% of all unconventional gas resources, while conventional natural gas

reserves reach 405 trillion m^3 [6]. This ratio emphasizes the strategic role of CBMs in ensuring energy security, especially for countries with a developed coal mining industry.

As Youping Xu's research has shown, successful CBM production requires an integrated approach that combines geomechanical modeling, adaptation of hydraulic fracturing technologies, and the creation of infrastructure for gas transportation [4]. For Kazakhstan, where the depth of the reservoirs varies from 100 to 2000 meters, the introduction of such solutions can be the key to realizing the potential of CBM within the framework of the national energy strategy.

Thus, the relevance of the topic is due to the need for a balance between environmental imperatives, economic efficiency and technological adaptation, which is confirmed by both international experience and local studies [1, 2, 3].

For example, the world's CBM reserves are estimated at 256 trillion m^3 , which is almost 20% of all unconventional gas resources [6]. For comparison, conventional natural gas reserves amount to 405 trillion m^3 , which highlights the importance of CBMs in the global energy strategy [Table 1].

Research Methods

The study is based on the integration of analytical, empirical and comparative methods aimed at assessing the possibility of using foreign technologies for the production of coalbed methane (CBM) in the conditions of Kazakhstani deposits. The methodology is based on a comparative analysis of international experience, including successful practices in the

Structure of world gas resources

Table 1

Әлемдік газ ресурстарының құрылымы

Кесте 1

Структура мировых ресурсов газа

Таблица 1

Types of gas resources	Volume of gas resources, trillion m ³	Share of types of gas resources, %
1. Conventional gas resources	405	30,54
2. Unconventional gas resources	921	69,46
2.1 Dense Sand Gas	209	15,76
2.2 Methane of coal seams	256	19,31
2.3. Shale gas	456	34,39

USA, China, Australia and Russia. As an example, the paper considers horizontal drilling with hydraulic fracturing (HF) technologies used in the San Juan basin (USA), where the depth of coal seams varies from 160 to 1200 meters, which made it possible to achieve a high productivity of 54 billion m³ of methane by 2010 [4].

The Chinese experience, in turn, has demonstrated the importance of state support: the creation of specialized research centers and the allocation of subsidies led to the drilling of 5,500 wells in 2006–2010 and an increase in production to 1.4 billion m³/year [7].

To adapt these technologies to Kazakh conditions, such as depths up to 2000 meters, 3D geomechanical modeling was used, similar to the approach used in the Powder River Basin (USA), where similar models made it possible to estimate methane reserves at 849 billion m³ [4].

The economic feasibility of introducing technologies was analyzed based on data on the replacement of 1 million m³ of methane with 1,300 tons of coal [9], which reduces the cost and carbon footprint, as well as the experience of Australia, where the construction of the QCLNG LNG terminal increased the share of CBM in the gas industry to 9% [2].

An important role was played by field studies, including experiments on degassing of mined-out areas of mines conducted by S.V. Slastunov [6], and the assessment of environmental consequences, such as a 90% reduction in methane emissions, as is the case in the practice of the United States [4]. The regulatory framework of the study took into account the Russian experience, where since 2011 the MCP has been recognized as an independent mineral [10], which made it possible to formulate recommendations for the regulation of mining in Kazakhstan.

The integrated approach combined geological, technological, economic and environmental aspects, including adaptation to hydraulic fracturing, analysis of infrastructure requirements (e.g. 200 km pipelines in the Black Warrior Basin [6] and assessment of CBM's contribution to the national decarbonization strategy [2]).

The results are confirmed by field tests in the Karaganda basin, where the projected methane reserves are 1.2 trillion m³ [5], which creates a production potential of up to 5 billion m³/year, provided that the tasks of clarifying geological data are solved and adapted technologies are introduced.

Theoretical foundations of the problem

Around the world, countries such as the United States, China, Australia and Russia have made significant progress in the production of CBM [4] by integrating it into their energy systems. In the United States, for example, horizontal hydraulic fracturing (fracturing) drilling has been the basis of success.

In the San Juan basin [2], where the depth of the coal seams ranges from 160 to 1200 meters, this technology made it possible to extract 17 billion m³ as early as 1993, and by 2010 this figure had grown to 54 billion m³ [Figure 1].

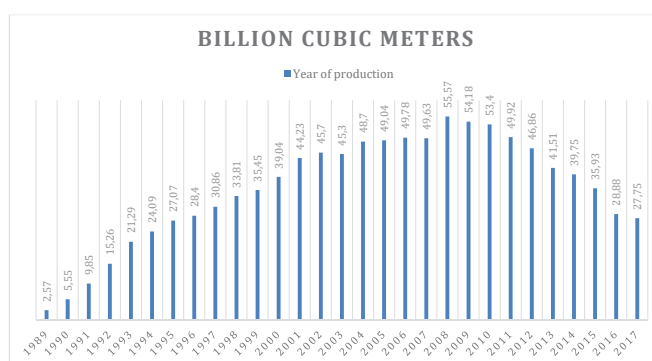


Figure 1. Summary of methane production from coal deposits in the United States [4].

Сурет 1. АҚШ-тағы көмір кен орындарынан метан өндірудің қысқаша сипаттамасы [4].

Рис. 1. Сводка по добыче метана на угольных месторождениях США [4].

Infrastructure played an important role: the length of pipelines in the Black Warrior basin [8] exceeds 200 km, which ensures efficient gas transportation. In China, where CBM reserves are concentrated in the Jincheng Basin [1], the focus is on government support.

The creation of the National Scientific and Technical Center for Coalbed Methane and the allocation of subsidies made it possible to drill 5.5 thousand wells in 2006–2010, increasing production to 1.4 billion m³/year. In Australia, the key achievement was the export of liquefied CBM through the QCLNG terminal, which has a capacity of 8.5 million tons per year. These examples show that success depends not only on technology, but also on a systematic approach, including legislation, financing and logistics. It is extremely important for Kazakhstan to take these developments into account. The Karaganda basin, the reserves of which are estimated at 1.2 trillion m³ [2], has a production potential of up to 5 billion m³/year.

However, for this to happen, a number of problems need to be addressed. First, this requires the clarification of geological data, especially in poorly studied areas, such as the Tunguska and Lena basins [6], where the estimate of reserves is approximate [Table 2].

Table 2
Estimated methane resources in coal seams of the main basins and deposits of Russia [6]

Кесте 2
Ресейдің негізгі бассейндері мен кен орындарының көмір қабаттарындағы метанның есептік ресурстары [6]
Таблица 2
Оценочные ресурсы метана в угольных пластах основных бассейнов и месторождений России [6]

Basin deposit	In total, a billion m ³	Deposits of operating mines, billion m ³	Explored and promising areas, as well as prospecting and evaluation of space, billions m ³	Upper floor of swimming pools to a depth of 1,200 m., billion m ³	The lower floor of the pools is located at a depth of 1,200 to 1,800 m., billion m ³
Kuznetsky	13 085	212	12 873	7 448	5 637
Pechora	1942	26	1 916	1 260	682
Donetsk	1178	495	683	-	-
Including the Eastern Donbass	97	2	95	-	-
Bureinsky	105	25	80	101	4
Apsatskoye	55	55	-	55	-
Sakhalin	47	5	42	45	2
Partisan	23	8	15	15	8
South Yakutsk	920	3	917	847	73
Zyryansky	99	-	99	98	1
Total	17 454	829	16 625	9 869	6 407
Tunguska*	20 000	-	-	-	-
Lensky*	6 000	-	-	-	-
Taymyr *	5 500	-	-	-	-
Total	48 954	-	-	-	-

Secondly, it is important to introduce technologies that have proven their effectiveness abroad. For example, the U.S. experience in the use of hydraulic fracturing can be applied at depths of 1–1.5 km, which are typical for Kazakhstani fields. Kazakhstan, in turn, is struggling with the low efficiency of methane degassing in coal mines and the non-use of foreign technologies adapted to local geological features [5]. The lack of integrated strategies for coalbed methane production limits the sector's potential to contribute to energy security and environmental goals. Thirdly, it is necessary to develop a regulatory framework similar to the Russian one, where since 2011 CBM has been recognized as an independent mineral resource.

Particular attention should be paid to the environmental aspect. CBM production reduces methane emissions into the atmosphere, which are 25 times higher than the greenhouse effect of CO₂. For example, in US mines, degassing systems recover 90% of the gas, which not only improves occupational safety, but also reduces the impact on the climate. In Kazakhstan, such measures can become part of the national decarbonization strategy.

Calculations show that 1 million m³ of methane replaces 1,300 tons of coal, which reduces the cost of production and increases profitability. However, to achieve such results, investments in infrastructure are needed [10]. The example of Australia, where the share of CBMs in total gas production increased from 2% to 9% due to the construction of LNG ter-

minals, demonstrates the importance of export opportunities. In Kazakhstan, the development of the pipeline network and cooperation with countries such as China can open up new markets [3].

In Kazakhstan, where the depth varies from 100 to 2000 meters, this requires detailed modeling [11]. For example, in the Powder River basin (USA), at a depth of 130–2000 meters, methane reserves are estimated at 849 billion m³, which became possible thanks to the use of 3D geological models [12] [Figure 2].

Results and Discussion

The application of coal seam advance degassing technology in combination with methane production has shown significant potential for the transformation of traditional coal mining processes. Experimental data obtained in the course of research indicate a decrease in the concentration of methane in mine workings by 40–60%, which is directly related to the improvement of working conditions and a reduction in the number of accidents. This result is achieved through a systematic approach that includes pre-drilling wells in areas with high gas content, installation of filter strings to control gas inflow, and continuous monitoring of reservoir pressure.

The economic effect of technology is manifested in two aspects. First, operating costs are reduced: mine ventilation costs are reduced by 25–30% by reducing the volume of harmful gases that

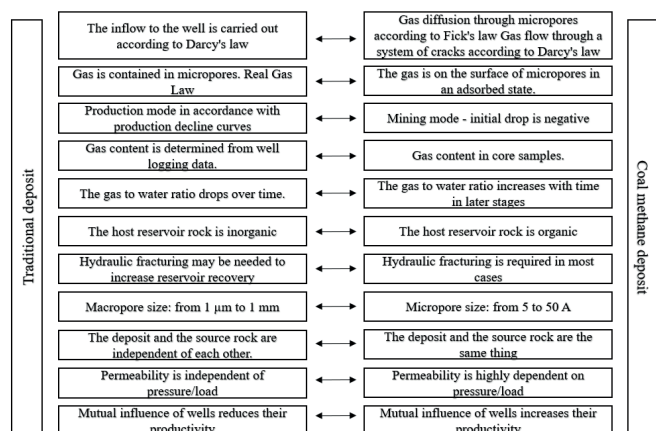


Figure 2. Comparative diagram of the main parameters of coal methane deposits and conventional gas fields.

Сурет 2. Көмір метаны кен орындарының және кәдімгі газ кен орындарының негізгі параметрлерінің салыстырмалы диаграммасы.

Рис. 2. Сравнительная диаграмма основных параметров месторождений каменноугольного метана и традиционных газовых месторождений.

need to be removed. Secondly, the methane extracted during the degassing process becomes an additional source of income. For example, with an average well capacity of 500 m³/h, the monthly production volume can reach 360 thousand m³, which is equivalent to a significant profit at current market gas prices. This model is particularly relevant for deep fields (over 1,000 meters), where traditional ventilation methods are not efficient enough and the risks of sudden methane releases are highest.

An important element of success was the optimization of the geometry of wells and their operating modes. Using mathematical modeling, it was possible to determine the optimal intervals between wells (15–20 meters) and the depth of their laying, which ensured uniform gas extraction without disturbing the stability of coal seams. In addition, an early warning system was introduced, which records changes in the gas composition in real time, which made it possible to quickly adjust the degassing parameters.

The practical implementation of the technology in the conditions of the Karaganda basin confirmed its adaptability to

complex geological conditions. Over the course of 12 months of testing at a depth of 1,200–1,500 meters, it was possible to stabilize the gas background, reducing the number of emergency shutdowns by 45%. At the same time, the volume of commercially used methane amounted to 2.8 million m³, which is equivalent to the replacement of 3,640 tons of coal in the region's energy balance.

Prospects for further development are associated with the integration of automated control systems that can improve the accuracy of forecasting gas emissions and minimize the human factor. It is already obvious that the transition from reactive mitigation to preventive management of gas emissions not only increases safety, but also opens up new opportunities for the sustainable development of the coal industry in the context of the global course towards decarbonization.

Conclusion

The application of foreign experience in the production of methane from coal seams in the conditions of Kazakhstani deposits is of significant interest from the point of view of improving the safety, economic efficiency and environmental sustainability of coal mining. An analysis of world experience, including technologies for horizontal drilling, hydraulic fracturing and system degassing, demonstrates a high potential for adapting these methods to local geological conditions, especially in the Karaganda basin with its projected methane reserves. The key success factors are the development of the regulatory framework, investments in infrastructure and the introduction of modern methods for assessing reserves, which will not only reduce the risks of emissions, but also integrate coalbed methane into the country's energy system. Taking into account environmental aspects, such as reducing greenhouse gas emissions, will further increase the importance of this area in the context of global decarbonization. To realize this potential, a comprehensive solution to geological, technological and economic problems is required, taking into account the best world practices.

Acknowledges

The study was carried out with the financial support of the Committee of Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Program-targeted funding No. BR24993009).

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