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ECONOMIC EFFICIENCY OF FAST WELL DRILLING IN DONBASS

(Reviewed by the editorial board member V. Mykhailov)

The main purpose of this paper is to study the optimal conditions for rational degassing during gas-hazardous mines operation and cost-effectiveness to ensure safe operation, to increase coal production and to use the produced gas commercially.

The work methodology is complex and combines mining-technological and economic components. The first step was to analyze the results of the project degassing, which was held directly in the field CG "Pokrovske", and define the main parameters affecting the efficiency of degassing. The parameters of drilling conducted on CG "Pokrovske" in 2012 were generalized. The next step was to establish a correlation between the parameters of drilling speed and lava promotion. The data on real drilling performance achieved in the implementation of degassing project showed that the average drilling speed was now about 100 m per day against the previous years' average of 500 m per month. The formulas for determining annuity from the drilling organization operations are given. The final stage of the research was to determine the optimum drilling performance for degassing at an economically favorable, rational expediency and efficiency level.

The obtained results revealed that the main parameters affecting the efficiency of degassing are drilling speed, optimization of degasification wells construction, as well as calculation of the effective well spacing and timing of their preparation for the lavas approach. It has been found out that the main factors to achieve efficiency of operation include cutting down on wages of the workers engaged in servicing rigs, due to drilling speeds, and decreasing investments into the construction of wells. Emphasis is laid on the need for integrated development of the existing fields, which combines degassing with coal mining.

Scientific novelty of the paper is in the development of formulas for calculating the drilling organization's annual income depending on drilling speed characteristics. Fast drilling technology offers clear advantages as compared to the conventional one.

The practical application of the paper is in determining the optimum speed and drilling conditions that ensure cost-effective degassing. The theoretical assumptions were confirmed by the results obtained from using the fast drilling operation technology developed by "Donetsksteel".

Problem definition and its relationship with important scientific and practical tasks.

Being under the influence of the gas factor, leading domestic mines have reached the limit of their output capacity. They need non-trivial solutions for safe and high efficiency coal mining operations. The preliminary degassing which is of preferential extensive use in the United States, Canada, Australia, China and other countries could be a solution; but about 10 years are required for 50-percent reduction in gas emissions; Ukrainian enterprises do not have so much time for that. That is why they are forced to find a combination of space and time performing coal mining operations and drilling, namely, to use wells drilled from the surface for degassing purposes. General mine ventilation ensures degassing of about 55% of the daily emissions in highly productive longwalls; this type of ventilation is followed by degassing by wells drilled from the development workings (25%), and finally, degassing by wells drilled from the surface (up to 20%).

Analysis of recent research and publications.

Conducted in recent years, research and its analysis in publications [1, 2, 3] are increasingly presenting arguments regarding the need for effective concomitant degassing. The conventional methods for underground degassing by drilling wells from excavations cannot provide the necessary safety conditions for gas factor in gas-hazardous mines. Equipping the mines with a modern coal-mining complex will increase labor productivity. Designed degassing pipes system, especially in old mines, are limited by bandwidth. It is necessary to create additional degassing systems that could provide the necessary working conditions in the mines and contribute to the rational use of the extracted gas. The solution to this problem could be drilling degasification wells from the surface, the advance of lava with forgery and gravitational unloading are an additional way to underground extraction

of gas from the coal-rock block. Degasification wells drilling should be conducted with the greatest possible speed.

Aspects of the problem to be solved.

Despite the fact that the method of degassing by wells drilled from the surface is the third in the row of the methods used for further development of Ukrainian mines, it is a crucial one, as all other resources have already been mobilized.

Degassing by wells from the surface requires drilling of a great number of wells. It has a direct impact on the economic aspect of coal mining. However, the focus had primarily been on the technical side [1, 2, 3]. Therefore, to improve the efficiency of coal mining in Ukraine, in this paper we set the goal to determine a rational scope of application of wells drilled from the surface.

Purpose of the article. The main purpose of this paper is to study the optimal conditions for rational degassing during gas-hazardous mines operation and cost-effectiveness to ensure safe operation, to increase coal production and to use the produced gas commercially.

The main research material.

Degassing efficiency depends on the well spacing density and the time factor. A proper combination of coal mining and well drilling operations is an important requirement: by the time of well completion, projection of well bottom on mined seam is to be at a distance of not less than 30 m ahead of the production face.

Thus, time provided for drilling and completion of a well shall satisfy the inequality:

$$T_{D1} \leq (L_1 - l_i) / m_{LW} , \qquad (1)$$

where T_{D1} – time of well drilling that is allowed by conditions of degassing technology, days; L_1 – spacing between wells within a single extraction panel, m; l_1 – minimum distance from the advancing face to the projection of well on the degassed seam at the time of well completion, m; m_{LW} – average daily advance of production face, m/day.

In order to stay within the stipulated time, commercial drilling speed is to be at least:

$$S_{1C} \geq nh_i / T_{D1c}, \qquad (2)$$

where S_{1c} – commercial drilling speed for a well, m/day; n – number of degassing wells that are to be constructed according to the plans by one drilling rig for the time T_{D1}; h_i – depth of i-th degassing well, m.

$$h_i = H_i - h_2, \qquad (3)$$

where H_i – depth of occurrence of the seam where degassing is performed, m; h_2 – project distance from the well shoe to the roof of the longwall, m.

The following parameters of well construction were taken as optimum ones for Project of Degassing that is being implemented in "Pokrovskoye" mine: L_1=300 m; l_1=30 m; h_2=15 m. If a degassed seam occurs at a depth of 800 m, the depth of the well is to be 785 m.

When average daily advance of a longwall is 7m (as it is in fact in case of mines characterized by high output capacity), for the construction of such a well not more than

$$\frac{300 - 30}{7} = 39 \; days \;\; \text{are to be spent.}$$

In the project of degassing that was developed for "Pokrovskoye" mine by a specialized organization "Donbassgeologiya", use of the Canadian drilling rig produced by National Oilwell Varco (Dreco) was assumed; while construction of wells from the surface was considered as rig-down and rig-up operations with a duration of 12 days and the actual drilling. Standard well drilling speed for a depth of 674 m was 40.5 days; 724 m – 43.5 days; 800 m – 48 days (drilling speed – 500 m per month per one drilling rig). Thus, in view of rig-down and rig-up operations for the well with a depth of 800 m, 60 days were required. It conditioned commercial speed of well construction of 13.3 m/day.

Drilling speed required under condition (2) is to be not less than 22 m/day. This means that the investment project for the creation and operation of the drilling organization, specialized in the construction of degassing wells drilled from the surface, would require more drilling rig complexes, and in case of simultaneous operation of several longwalls,

a number of drilling rigs would be increased in proportion to the number of concurrent mined panels. And it's not just arithmetic addition of pieces of equipment – significant increase in investment and operating costs is observed. Up-to-date drilling complexes are expensive ones (drilling rig produced by Dreco costs $ 9.7 million USD), each drilling rig is serviced by a separate crew, each drilling rig requires maintenance, including transportation from place to place, etc.

In order for the investment project for the foundation and operation of the drilling organization to be break-even, cash flow CF_t from its implementation represented in the form of annuity is to meet the following condition [1]:

$$CF_t \geq \frac{Inv}{\sum\limits_{1}^{T} \frac{1}{(1+m_1)^t}}, \qquad (4)$$

where CF_t – annual cash flow (annuity) from the activity of drilling organization, mln UAH; INV – cumulative amount of investments, mln UAH; m_1 – cost of capital, fraction unit; t – current year of project implementation; T – duration of the investment project.

The break-even condition (4) shows the amount of the annual cash flow that turns a net present value (NPV) under the project to zero for a given volume of investments and rate of capital cost. Condition NPV=0 gives very informative indicators for an investor – with their help, even roughly, the economic prospects of the project, its feasibility and, finally, efficiency can be estimated.

In 2012, in "Pokrovskoye" mine as a result of progressive fast drilling operations performed by one Ultra Single 150 drilling rig on three production panels, 36 degassing wells were drilled for 301 machine-days. According to the initial project, based on the traditional drilling technologies, 6 drilling rig complexes of Dreco type would have been involved to serve three longwalls. Individual parameters of drilling operations were summarized in the table.

Annual cash flow on break-even condition of the project was calculated based on 20 years of operation of drilling complexes and the rate of 12% per annum.

Table 1

Actual and Estimated Indicators of Drilling Operations

Indicator	Measurement Unit	Value
Wells constructed in 2012	pcs	36
Average duration of well construction	days	8±2
Deductions for salary payment for drill site	thous. UAH/day	18.5
Costs excluding depreciation when using one Ultra Single 150 drilling rig	mln UAH/well	1.0±0.1
Wage and salaries fund for drill site when using one Ultra Single 150 drilling rig	mln UAH/year	5.5
Wage and salaries fund for drill site when using six Dreco drilling rigs	mln UAH/year	32.9
Total costs when using one Ultra Single 150 drilling rig	mln UAH/year	37.3
Total costs when using six Dreco drilling rigs	mln UAH/year	64.7
Unit costs excluding depreciation when using six Dreco drilling rigs	mln UAH/well	1.8
Investments when using one Ultra Single 150 drilling rig	mln UAH	192
Investments when using six Dreco drilling rigs	mln UAH	466
Annual cash flow on break-even condition of the project when using one Ultra Single 150 drilling rig	mln UAH	26
Annual cash flow on break-even condition of the project when using six Dreco drilling rigs	mln UAH	62

When comparing the projects, design identity of wells was assumed; increase in costs of maintenance of drilling complexes in case of their greater amount etc. was not taken into account. As major factors in achieving economic efficiency, only savings on salaries of personnel directly engaged in drilling rigs maintenance, and reduction in amount of investments due to reducing the time of a well construction.

The value of the annual income of the drilling organization on break-even condition of the investment project (taking into account appropriate annuity of cash flow) is to satisfy the following condition:

$$G \geq CF_t + C_{dr}, \qquad (5)$$

where G – average amount of annual income of drilling organization, mln UAH; C_{dr} – cost of the construction of

wells drilled from the surface without depreciation deductions, mln UAH.

Conclusions. In the case of fast drilling technologies, the above mentioned 36 wells constructed for "Pokrovskoye" mine would have cost for coal production enterprise more than 62 mln UAH taking into account the requirement to ensure break-even condition of the project; in case of conventional drilling technologies – more than 127 mln UAH.

In the past, artillery-type weapons were cast with the Latin inscription "Ultima ratio regum", which had the following meaning: "The final argument of kings". For owners of the leading Ukrainian mines such a "final argument" is degassing wells drilled from the surface. But, according to the assessment performed by the Institute of

Industrial Economics of National Academy of Sciences of Ukraine, the basic project is not economic. Degassing of Coal and Gas Deposits by wells drilled from the surface can be economic providing the commercial drilling speed exceeds 22 m/day and enables using one drilling complex.

While acknowledging the importance and effectiveness of the process of preliminary degassing by wells drilled from the surface, it should be recognized that degassing combined with mining operations will be of immediate interest to the existing mines for at least another 15-20 years. It determines the topicality and value for the domestic coal industry of the progressive fast drilling operations technology developed by "Donetsksteel".

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ЕКОНОМІЧНА ЕФЕКТИВНІСТЬ ШВИДКІСНОГО БУРІННЯ СВЕРДЛОВИН В УМОВАХ ДОНБАСУ

Головною метою даної роботи є дослідження оптимальних умов раціонального проведення дегазаційних робіт при експлуатації газонебезпечних шахт та їх економічної ефективності для дотримання безпеки робіт, нарощування видобутку вугілля та використання вилученого газу у господарчих цілях.

Методика робіт є комплексною та поєднує гірничо-технологічну та економічну складові. Першим етапом був аналіз результатів проекту дегазації, проведеного безпосередньо на родовищі ШУ "Покровське" та визначення головних параметрів, що мали вплив на результативність дегазаційних робіт. Узагальнено параметри бурових робіт, що були проведені на ШУ "Покровське" у 2012 році. Наступним кроком було встановлення взаємозв'язку між параметрами буріння свердловини та швидкістю посування лави. На прикладі реальних показників буріння, які досягнуті при реалізації дегазаційного проекту, розрахована середня швидкість буріння, яка складає біля 100 м/добу при середніх показниках минулих років 500 м/місяць. Наведено розрахункові формули для визначення щорічного грошового потоку від діяльності бурової організації. Кінцевою стадією у роботі було визначення оптимальних показників буріння для проведення дегазаційних робіт на економічно вигідному, раціонально-доцільному та ефективному рівні.

Отримані результати дозволили встановити, що основними параметрами, що впливають на результативність дегазації, є швидкість буріння, оптимізація конструкції дегазаційних свердловини, а також розрахунок ефективних відстаней між свердловинами та визначення часу їх підготовки до підходу лав. Визначено, що основними факторами для досягнення ефективності робіт є економія на заробітних платах робітників, що зайняті на обслуговуванні бурових установок, за рахунок швидкостей буріння та скорочення обсягу інвестицій для будівництва свердловини. Підкреслено необхідність комплексного освоєння існуючих родовищ, що поєднує проведення дегазації з видобутком вугілля.

Наукова новизна роботи полягає у виведенні формули для розрахунку річного прибутку бурової організації у залежності від швидкісних характеристик проведення бурових робіт. Встановлено переваги технологій швидкого буріння свердловин у порівнянні з традиційними.

Практична значимість роботи полягає у визначенні оптимальної швидкості та умов буріння, за яких проведення дегазації є доцільним та економічно вигідним. Висновки підтверджені результатами, отриманими при використанні на практиці технології швидкісного буріння, розробленої ПрАТ "Донецьксталь".

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ЭКОНОМИЧЕСКАЯ ЭФФЕКТИВНОСТЬ СКОРОСТНОГО БУРЕНИЯ СКВАЖИН В УСЛОВИЯХ ДОНБАССА

Главной целью данной работы является исследование оптимальных условий рационального проведения дегазационных работ при эксплуатации газоопасных шахт и их экономической эффективности для обеспечения безопасности работ, наращивания добычи угля и использования добытого газа в хозяйственных целях.

Методика работ является комплексной и объединяет горно-технологическую и экономическую составляющие. Первым этапом был анализ результатов проекта дегазации, который проведен непосредственно на месторождении ШУ "Покровское" и определение главных параметров, влияющих на результативность дегазационных работ. Обобщенны параметры буровых работ, проведенных на ШУ "Покровское" в 2012 году. Следующим шагом было установление взаимосвязи между параметрами бурения скважины и скоростью продвижения лавы. На примере реальных показателей бурения, достигнутых при реализации дегазационного проекта, рассчитана средняя скорость бурения, которая составляет около 100 м/сутки при средних показателях прошлых лет 500 м/месяц. Приведены расчетные формулы для определения ежегодного денежного потока от деятельности буровой организации. Конечной стадией в работе было определение оптимальных показателей бурения для проведения дегазационных работ на экономически выгодном, рационально-целесообразном и эффективном уровне.

Полученные результаты позволили установить, что основными параметрами, влияющими на результативность дегазации, являются скорость бурения, оптимизация конструкции дегазационных скважин, а также расчет эффективных расстояний между скважинами и определение времени их подготовки к подходу лав. Определено, что основными факторами для достижения эффективности работ является экономия на заработных платах рабочих, занятых на обслуживании буровых установок, за счет скоростей бурения и сокращение объема инвестиций для строительства скважины. Подчеркнута необходимость комплексного освоения существующих месторождений, сочетающего проведение дегазации с добычей угля.

Научная новизна работы заключается в выведении формулы для расчета годовой прибыли буровой организации в зависимости от скоростных характеристик проведения буровых работ. Установлены преимущества технологий быстрого бурения скважин по сравнению с традиционными.

Практическая значимость работы заключается в определении оптимальной скорости и условий бурения, при которых проведение дегазации целесообразно и экономически выгодно. Выводы подтверждены результатами, полученными при использовании на практике технологии скоростного бурения, разработанной ЗАО "Донецксталь".