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A. Sudakov[1], A. Dreus[2], Б. Ratov[3], O. Sudakova[4], O. Khomenko[1],
S. Dziuba[5], D. Sudakova[1], S. Muratova[6], M. Ayazbay[7]

[1]National TU Dnipro Polytechnic, Department of Underground Mining, Dnipro, Ukraine;
[2]Oles Honchar Dnipro National University, Dnipro, Ukraine;
[3]Satbayev University, Almaty, Kazakhstan;
[4]Pridneprovsk State Academy of Civil Engineering and Architecture, Dnipro, Ukraine;
[5]Institute of Geotechnical Mechanics named by N. Poljakov of National Academy of Sciences of Ukraine, Dnipro, Ukraine;
[6]Caspian University, Almaty, Kazakhstan;
[7]M. Kh. Dulaty Taraz State University, Taraz, Kazakhstan.
E-mail: sudakov@ukr.net, dreus@dnu.dp.ua, ratov.bt@gmail.com,
rudana.in.ua@gmail.com, svdzub@i.ua, sudakov@ukr.net, muratova@mail.ru, marat@mail.ru

SUBSTANTIATION OF THERMOMECHANICAL TECHNOLOGY PARAMETERS OF ABSORBING LEVELS ISOLATION OF THE BOREHOLES

Abstract. The aim of the work is to improve the thermomechanical absorption insulation technology horizons of drilling wells by the established regularities of change and the substantiation of its regime parameters from the composition and physical-mechanical properties strengthen thermoplastic composite material and, on this basis, development a technological regulation containing recommendations on the manufacture of composites and organizations laying work, designing and isolation of the absorption zones of the washing liquid in the drilling rigs wells. The tasks set were solved by complex method research that contains analysis and synthesis of literary and patent sources, conducting analytical, experimental and industrial research. Experimental processing data was carried out using methods of mathematical statistics. Experimental research is carried out using the provisions of the theory of scientific experiment and theory random processes. The evaluation of the effectiveness of the results was carried out in production conditions.

Key words: drilling of boreholes, isolation, absorbing level, melting, backfill materials.

Topicality. Drilling of both exploration and exploitation boreholes for exploration of deposits and extraction of minerals in the area of iron-ore and coal basins is conducted in a high degree of development and metamorphism, in strong and fractured rocks [1-10]. Rocks of mined levels are in complicated stressed state [11-18] that during construction of mine workings only complexify the technology of their installation [19-20].

Drilling of boreholes process involves geological complications. The most significant complication is the absorption of flushing water [20]. A significant proportion of the time and funds is spent on drilling of boreholes absorption. Absorption leads to disruption of drilling process mode, boreholes walls integrity, provokes accidents [10-20].

Analysis of recent research and identification of the unsolved problem. The works of Basarygin Yu.M., Brezhenenko A.M., Bulatov A.I., Vakhrameev I.I., Vozdvizhenskyi V.I., Volokitenkov A.A., Gaivoronskyi A.A., Dotsenko Yu.G., Ivachev L.M., Kipko E.J., Kotskulich Y.S., Krylov V.I., Kudryashov B.B., Lipatov N.K., Martynenko I.I., Thinyuk M.A., Nikolayeva N.I., Polozov Yu.A., Rafieko I.I., Spichak Yu.N., Sudakov A.K., Stavnaya E.M., Titkova N.I., Tana P.M., Yakovlev A.M., Yasov V.G. and other authors were devoted to research in the area of development of backfill materials and technologies for control of flushing water absorption. Analysis of their research is conducted in works [9].

Drilling of boreholes process involves geological complications. The most common types of complications that disrupted drilling technology were the absorption of drilling fluids. At the same time, annual time in the total balance sheet on drilling had been increased up to 23% and funds up to 10% in a proper way.

In most cases, absorptions isolation is ensured by backfilling of the flushing water absorption materials with solidifying or non-solidifying backfill mixtures by means of creating a waterproof shield in the rock around the borehole.

Insufficiently effective backfill materials are applied for the absorption of flushing water isolation, which are produced on a water base with addition of mineral-bearing or synthetic substances to its composition.

In our view, these materials and technologies have exhausted their possibility of further improvement, so the only way is to develop and apply technologies that based on materials with non-water base and other processes of backfill stone formation for insulation of the boreholes. Such technologies include technologies for creating a backfill stone that are based on the phenomenon of phase transition.

The thermoplastic materials mixes on the base of bitumen, sulfur and synthetic thermo-layers (polyethylene, polypropylene) were applied up to the present moment.

However, the thermoplastic materials due to imperfections in technology, have not found widespread application as backfill materials during absorbing horizons isolation of drilling boreholes.

In order to solve the problem of absorbing levels isolation, it is necessary to find fundamentally new decisions. Therefore, the development of technologies for absorbing level isolation with application of more efficient backfill materials has utmost significance.

This work has a great practical importance. It is dedicated to solving of current scientific problem, which consists in establishing regularities of changing of axial load and rotation velocity during substantiation of mode parameters of effective thermomechanical technology of absorbing levels insulation from average strength limit for uniaxial compression, depending on: composite structure, ratio of components and type of filler; temperature of melting overheating, density, strengthening time and number of melts of backfill thermoplastic compound material.

Purpose and objectives of the research. The purpose of work is improvement of thermomechanical technology of absorbing levels isolation of boreholes by means of changing regulations and substantiation of its mode parameters from composition and physical-and-mechanical properties of backfill thermoplastic composite material. As well as development of technological regulation that containing recommendations for composite production and organization of backfilling operations, designing and zones of flushing water absorption isolation in boreholes on this base.

The idea of work is in establishment and application of regularities of physical-and-mechanical properties changing and advantages of backfill thermoplastic material for substantiation the mode parameters and to introduce into production effective thermomechanical technology of absorbing levels isolation of boreholes.

Statement of work. *The composition is chosen and substantiated due to results of physical-and-mechanical properties research of backfill thermoplastic composite material (TCM) on the base of secondary polyethylene terephthalate (PET) is chosen and reasonable. The technology of TCM production has been developed.*

PET is one of the most common domestic waste. According to statistical data, its volume is up to 20...25% of the total mass of domestic waste.

As the result of analysis of well-known physical-and-mechanical properties of PET, it is possible to apply it as binding material for absorbing levels isolation of boreholes [13-15]. Secondary PET.

Selection, substantiation and examination of the composition of TCM were conducted. Laboratory research allowed to develop an optimal formulation of TCM that protected by patents for an invention of Ukraine [16-18].

During laboratory examinations of physical and mechanical properties of TCM [12-20]:

- the necessity of filler entering into its composition is substantiated. Secondary PET in the molds was collapsed due to radial deep cracks formation. In the fracture of the samples, the structure is highly porous. All samples have a shrinkage phenomenon. Its size did not exceed 25%. On this basis, were made conclusions concerning to impossibility of PET application as backfill material. Therefore, with the “clean” secondary PET, the work has been stopped;

- type and optimal concentration of filler is determined;
- it is shown that TCM with filler size less than 0.5 mm in ratio 1:1;
- is “abrasive|” material despite the highest degree of wear and tear resistance.

Therefore, in order to the absorption flushing water isolation, it is recommended to apply PET- based TCM with a granulated filler of less than 0.5 mm. Generalized physical-and-mechanical properties are shown in Table 1.

PET-based TCM technology which consists of preparatory stage, production stage of a composite and formation is developed.

During theoretical examinations, approaches to modeling of thermophysical processes of melting and cooling at formation are considered. It is necessary for separation of rational thermophysical parameters of TCM production technology.

The calculations allowed to determine the duration of technological operations for TCM production, as well as the necessary energy costs.

Development of technology of absorbing levels isolation of boreholes with TCM application.

The method of absorbing level isolation with PET-based TCM application is developed and substantiated, for implementation of which it is necessary to perform the following technical and logical operations [11]: transportation of TCM to the absorbing level of the borehole, melting of TCM in the borehole and pressing of TCM into absorption channels. The technology of transportation of cylindrical briquettes of TCM along the borehole shaft and possibility of thermomechanical contact melting of TCM in the zone of flushing water removal are substantiated. The method of absorbing levels isolation with PET-based TCM application is defended by Ukrainian patents [1-11].

Technical advantages of the technology are following:

- possibility of TCM melting process management in the control area;
- possibility of TCM lag (jamming) isolation during transportation along the borehole shaft;
- absence of operation for removal of technological equipment from the borehole shaft and as a result, reduction in span time.

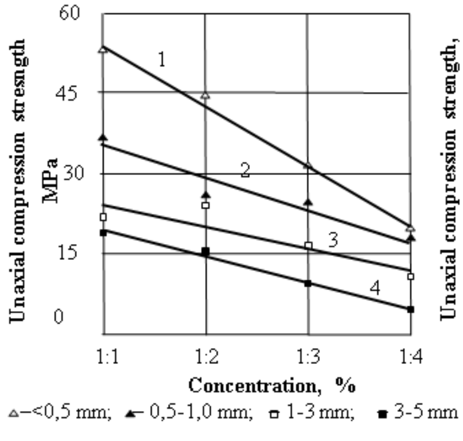

Figure 1 – Dependence of the average uniaxial compression strength from composition and concentration of granulated filler

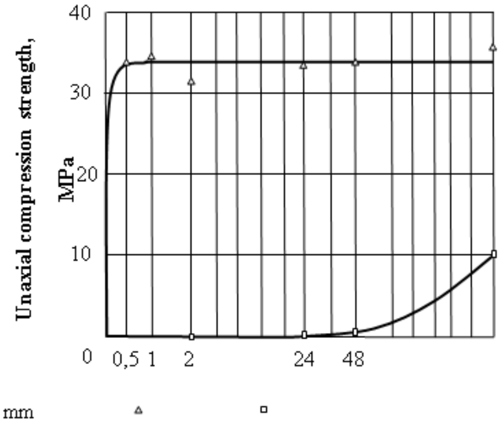

Figure 2 – Dependence of the average uniaxial compression strength on TCM solidifying time of and cement mixture during granulated filler concentration in the ratio of 1:3, gravel size < 0.5 mm

Table 1 – Generalized physical-and-mechanical properties of TCM

Composition	Density, kg/cu.m	Unaxial compression strength, MPa	Melting temperature, ^{0}C	Spreadability, ms	Hardness coefficient	Abrasion coefficient	Permeability of the sample, cu.cm
PET + Gravel. Ratio 1:1. d<0.5mm	1620	52.6	246	16-18	19.8	2.0	absent

The generated heat flux is extending into the body of the TCM briquette due to heat conduction. Under the influence of thermal energy, TCM is heated, and upon reaching the surface temperature, the phase transition value (melting temperature) melts up [18-19]. The molten part of the material is pressed into the porous walls of the borehole 1 due to the pressure that generated by the tool.

In this work we apply the heat-conduction equation to determine the parameters of the heating process in the form of

$$\frac{\partial t}{\partial \tau} = a\frac{\partial^2 t}{\partial y^2},\ \tau > 0,\ 0 \le y \le \infty, \tag{1}$$

with initial condition

$$t = t_0, \text{ at } \tau = 0 \tag{2}$$

and limiting conditions

$$-\lambda\frac{\partial t}{\partial y} = q_m,\ \text{ at }\ y = 0, \tag{3}$$

$$t = t_0,\ \text{ at }\ y \to \infty, \tag{4}$$

where t – temperature, τ – time, α – temperature conductivity coefficient, y – spatial coordinate, $t = t_0$ – initial temperature, λ – TCM heat conduction coefficient, q_m – surface flux into heat of the material.

Heat flux on the working surface is determined from

$$q_m = \frac{\mu k_m \pi F D n}{S}, \tag{5}$$

where μ – friction coefficient, k_m – coefficient that taking into account the fraction of friction heat for TCM heating and melting, F – axial loading, D – diameter of friction surface, S – surface area of friction, n – rotation frequency of the tool.

a

b

Figure 3 – Radius of TCM extent in the crack with opening of 30 mm: *a* – backfill stone in the level model, *b* - overhead view

From the solution of task (1) - (4) with the help of Fourier’s law $q = -\lambda\frac{\partial t}{\partial y}$ and condition (5), an expression is obtained, which establish relationships between mode parameters of technological process and parameters of thermophysical processes during tool operation [18-20]

$$Fn = \frac{\lambda D}{2\mu k_m\sqrt{\pi a \tau_f}}\left(t_f - t_0\right), \tag{6}$$

where τ_f – time of surface heating to melting temperature, t_f – TCM melting temperature.

The equation of heat balance is applied for determination of thermomechanical drilling velocity in the form of

$$q_m = q_{melt} + q_\lambda, \tag{7}$$

where q_{melt} –heat for melting of a layer surface of the material with thickness $d\xi$ for the time $d\tau$; q_λ –heat flow to warm up inner layers of material, determined by Fourier's law. Heat flux q_{melt} is defined by the expression

$$q_{melt} = \rho L \frac{d\xi}{d\tau}, \tag{8}$$

where L – internal melting heat of TCM. The velocity of thermomechanical drilling is defined as $V=d\xi/\tau d$.

Therefore, from the equation (7), using the solution of a task (1) – (4) and defining τ_f through mode parameters of drilling, expression for the velocity of thermomechanical drilling is received

$$V = \frac{1}{\rho L}\left(\frac{4\mu k_m Fn}{D} + \frac{\lambda(t_f - t_0)}{\sqrt{\pi a \tau}}\right). \tag{9}$$

Analyzing (9) at $\tau\to\infty$, we will get a formula for the velocity limit of thermomechanical drilling

$$V_{lim} = \frac{1}{\rho L}\left(\frac{4\mu k_m Fn}{D}\right). \tag{10}$$

Average velocity of thermomechanical drilling for the time T we will define as

$$V_{av} = \frac{1}{T}\int_0^T V(\tau)d\tau, \tag{11}$$

where T – drilling time; $V(\tau)$ – is determined by equation (10).

After integration (10) on time ranging from 0 to T with taking into account a condition $\xi=0$ at $\tau=0$ we will receive expression for drilling depth during period T

$$h = \frac{1}{\rho L}\left(\frac{4\mu k_m Fn}{D}T + \frac{2\lambda(t_f - t_0)}{\sqrt{\pi a}}\sqrt{T}\right). \tag{12}$$

Results of performed analysis of calculation algorithm, as well as design dependencies of changing the depth and rate of thermomechanical melting of borehole in time (Figure 6) are presented in the form of alignment chart of dependence of mode parameters on rate of thermomechanical melting of TCM at borehole face. Therefore, during an axial loading of 700 daN and a rotation velocity of 700 min^{-1}, the design thermomechanical melting velocity of the instrument volume with a diameter of: 46 mm will be equal to – 1.2 m/h; 59 mm – 1.0 m/h; 76 mm – 0.84 m/h; 93 mm – 0.74 m/h; 269 mm – 0.46 m/h.

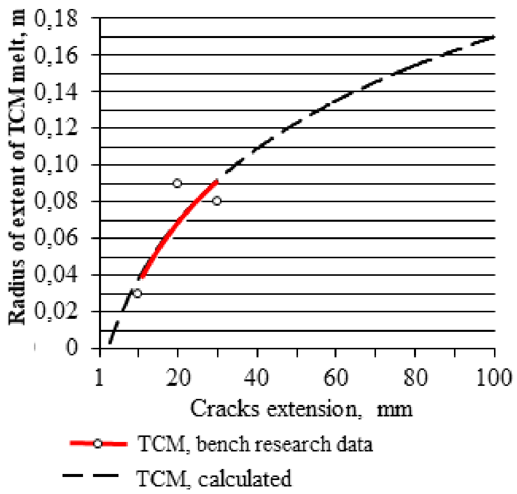

Figure 4 – Dependence of radius of TCM melt distribution on cracks extension for the borehole with a diameter of 59 mm

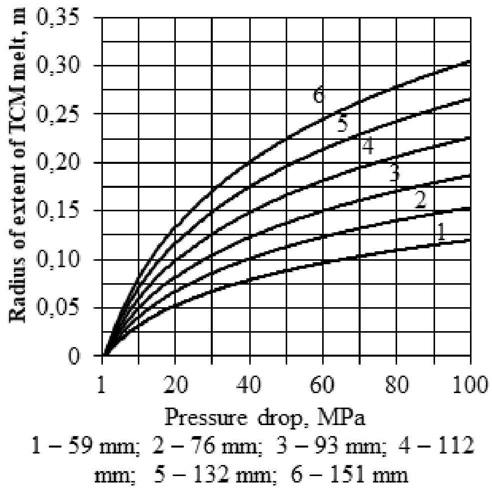

Figure 5 – Dependence of radius of TCM melt distribution on pressure drop in "seam-borehole" system

- developed thermomechanical technology of flushing water absorption isolation with TCM application has made it possible to reduce time consumption in the areas of Havrilovka village up to 15 h, Romanki village – up to 8 h. The total costs at the first site respectively amounted to 24.2 thousand UAH, at the second one is 12.1 thousand UAH (prices of March, 2018) with taking into account the cost of materials, energy inputs and backfilling;
- developed technology allows to isolate absorbing level from borehole space qualitatively, with minimum expenses.

The economic effect of the implementation of the developed method of backfilling in absorbing levels isolation with TCM application is equal to 1.65 - 2.64 million UAH per year with the volume of backfilling operations drivage in 100 wells.

Conclusions. The main scientific and practical results, conclusions and recommendations or executed research:

1. The theory about conditions under fractured rock the application of water-based backfill mixtures using various mineral-bearing and synthetic substances reached its limit of perfection has been further developed. In recent decades, the work to improve the properties of backfilling materials has been limited to solving local problems, rather than isolation, so the main disadvantage of it is dilution. As a result of water-based backfilling solutions, there is their reduction, significant losses of backfilling materials and time for flushing water isolation, and in general increasing the cost of boreholes by more than 20%. It is possible to reduce these losses by filling the channels with non-diluted in-seam waters by melt of thermoplastic material to form the isolation shell;

It is substantiated that applied thermoplastic materials due to imperfections of technologies, instability of physical-and-mechanical properties, cancerogenity of their components have not found widespread application as backfill materials during absorbing levels isolation of boreholes;

2. The necessary technological parameters of backfilling and dimensions of the isolation shell have been established, which made it possible to substantiate and develop the “Technological Regulation of Absorbing Levels Isolation of PET-based TCM” that acting as a normative document in the production organizations of the State Service of Geology and Subsoil of Ukraine;

3. The results of the complex of theoretical and experimental research that was performed in PhD thesis found practical application during conducting of experimental-industrial implementation of the technology of flushing water isolation of TCM in the conditions of the commercial enterprise of LLC Industrial and Geological Group “Dniprohydrostroi”

А. Судаков[1], А. Дреус[2], Б. Ратов[3], О. Судакова[4], О. Хоменко[1], С. Дзюба[5], Д. Судакова[1], С. Муратова[6], М. Ауезбай[7]

[1]Ұлттық техникалық университеті «Днепровская политехника», Днепр, Украина;
[2]О. Гончар атындағы Днепр Ұлттық университеті, Днепр, Украина;
[3]Satbayev University, Алматы, Қазақстан;
[4]Днепр құрылыс және сәулет академиясы, Днепр, Украина;
[5]Н. С. Полякова атындағы Геотехникалық механика институты
Украина Ұлттық ғылым академиясы, Днепр, Украина;
[6]Каспий университеті, Алматы, Казахстан;
[7]М. Х. Дулати атындағы Тараз мемлекеттік университеті, Тараз, Казахстан;

ҰҢҒЫЛАРДЫ БҰРҒЫЛАУДЫҢ ГОРИЗОНТТАРЫН ИЗОЛЯЦИЯЛАУДЫҢ ТЕРМОМЕХАНИКАЛЫҚ ТЕХНОЛОГИЯСЫНЫҢ ПАРАМЕТЕРЛЕРІН ПАЙДАЛАНУ

Аннотация. Жұмыстың мақсаты "Ұңғымаларды бұрғылау көкжиектері" термомеханикалық абсорбциялық оқшаулау технологиясын өзгертудің белгіленген заңдылықтары бойынша жетілдіру және оның режимінің параметрлерін беріктендіретін термопластикалық композициялық материалдың құрамы мен физикалық-механикалық қасиеттері бойынша негіздеу және осы негізде композиттер жасау және салу жұмыстарын ұйымдастыру, ұңғымалардың бұрғылау қондырғыларында жуу сұйықтығын сіңіру аймақтарын жобалау және оқшаулау бойынша ұсынымдарды қамтитын технологиялық регламент әзірлеу болып табылады. Қойылған міндеттер әдеби және патенттік көздерді талдау мен қорытуды, аналитикалық, эксперименттік және өнеркәсіптік зерттеулер жүргізуді қамтитын кешенді зерттеу әдісімен шешілді.

Деректерді эксперименттік өңдеу математикалық статистика әдістерін қолдану арқылы жүргізілді. Эксперименталды зерттеу ғылыми эксперимент теориясының ережелерін және кездейсоқ процестер теориясын пайдалана отырып жүргізіледі. Алынған нәтижелердің тиімділігін бағалау өндірістік жағдайларда жүргізілді.

Термопластикалық композициялық материалдан (ТКМ) төгудің құрамы мен физикалық-механикалық қасиеттері бойынша оны пайдалану шарттарын негіздеу және өзгерту заңдылықтарын белгілеу арқылы ұңғымалардың сіңіру деңгейлерін оқшаулаудың термомеханикалық технологиясын жетілдіру. Осы негізде композитті дайындау және ұңғымалардағы жуу суының абсорбция аймақтарын жабу, жобалау және оқшаулау бойынша жұмыстарды ұйымдастыру жөніндегі ұсынымдарды қамтитын технологиялық регламент әзірленеді.

Қойылған міндеттер коммуникацияның кешенді әдісі арқылы шешілді, оған әдеби және патенттік көздерді талдау және қорыту, сондай-ақ аналитикалық, эксперименттік және өнеркәсіптік зерттеулер жүргізу кіреді. Тәжірибелік деректер математикалық статистиканы қолдана отырып, ДК-де өңделді. Эксперименталды зерттеулер ғылыми эксперименттің жалпы теориясын және кездейсоқ процестер теориясын қолдана отырып жүргізілді. Алынған нәтижелердің тиімділігін бағалау өндірістік жағдайларда сынау жолымен жүргізілді.

Байланыс әзірленген және негізделген; ТСМ қолдану мүмкіндігі расталған. Брикеттелген ТЦМ өндіру мүмкіндігі теориялық және эксперименттік түрде көрсетілген. Бастапқы эталондық отын (ПЭТФ) негізінде ТСМ өндіру технологиясы әзірленді. ТКМ өндірісінің ұтымды технологиялық режимдері негізделген. ПЭТ негізінде ТКМ қолдану арқылы жұтылу деңгейін оқшаулау технологиясы әзірленді және негізделген. Сіңіргіш деңгейлерді оқшаулаудың техникалық негіздері жағдайлардың кең ауқымында жылуалмасу процестерін есептеуге мүмкіндік беретін бағдарламалар жиынтығын құру үшін алгоритмі бар балқытуды қолдана отырып әзірленген.

Қайталама ПЭТФ негізінде ТКМ қолдану негізделген және алғаш рет дәлелденген. Екінші рет ПЭТФ қолдануға негізделген ТСМ ұңғымасының проблемалық аймағында термомеханикалық балқыту мүмкіндігі негізделген және дәлелденген. ТСМ термиялық балқыту кезінде жылу алмасу процесін сипаттауға мүмкіндік беретін әлеуетті негізделген және эксперименталды расталған температуралық үлгі одан әрі дамуды алды. Алғаш рет ТЦМ балқытудың термомеханикалық процесінің моды параметрлері мәндерінің оның жылу физикалық қасиеттері мен техникалық сипаттамаларына тәуелділігі анықталды. Бірінші рет ПЭТ негізінде тцм-ның сіңіру қабілеттілігінің жарықшақтардың ашылуынан тәуелділігі анықталды.

Қайталама ПЭТФ негізінде ТКМ қолдана отырып сіңіру деңгейін оқшаулау технологиясын қолдану саласын негіздеу. ПЭТ негізінде ТСМ деңгейін абсорбциялық оқшаулауға арналған технологиялық параметрлерді таңдау бойынша перспективалы ұсыныстарды әзірлеу. Қайталама ПЭТФ негізінде ТКМ сіңіргіш горизонттарын оқшаулаудың принципті жаңа технологияларын әзірлеу. ПЭТФ негізінде ТКМ жасау технологиясын әзірлеу. Зерттеу бағдарламалары мен әдіснамаларын әзірлеу. ТЦМ негізінде ПЭТ оқшаулаудың сіңіргіш горизонттарын сіңіруге арналған технологиялық регламентті әзірлеу.

Түйін сөздер: Ұңғымаларды бұрғылау, оқшаулау, сіңіру деңгейі, балқыту, материалдарды жабу.

А. Судаков[1], А. Дреус[2], Б. Ратов[3], О. Судакова[4] , О. Хоменко[1],
С. Дзюба[5], Д. Судакова[1], С. Муратова[6], М. Аязбай[7]

[1]Национальный технический университет «Днепровская политехника», Днепр, Украина;
[2]Днепровский национальный университет им. О. Гончара, Днепр, Украина;
[3]Satbayev University, Алматы, Казахстан;
[4]Приднепровская академия строительства и ахитектуры, Днепр, Украина;
[5]Институт геотехнической механики им. Н. С. Полякова
Национальной академии наук Украины, Днепр, Украина;
[6]Каспийский университет, Алматы, Казахстан;
[7]Таразский государственный университет им. М. Х. Дулати, Тараз, Казахстан;

ОБОСНОВАНИЕ ПАРАМЕТРОВ ТЕРМОМЕХАНИЧЕСКОЙ ТЕХНОЛОГИИ ИЗОЛЯЦИИ ПОГЛОЩАЮЩИХ ГОРИЗОНТОВ БУРОВЫХ СКВАЖИН

Аннотация. Целью работы является совершенствование технологии термомеханической абсорбционной изоляции «Горизонты бурения скважин» по установленным закономерностям изменения и обоснование параметров ее режима по составу и физико-механическим свойствам упрочняющего термопластичного композиционного материала и, на этой основе, разработка технологический регламент, содержащий рекомендации по изготовлению композитов и организации укладочных работ, проектированию и изоляции зон поглощения промывочной жидкости в буровых установках скважин. Поставленные задачи были решены

комплексным методом исследования, содержащим анализ и обобщение литературных и патентных источников, проведение аналитических, экспериментальных и промышленных исследований. Экспериментальная обработка данных проводилась с использованием методов математической статистики. Экспериментальное исследование проводится с использованием положений теории научного эксперимента и теории случайных процессов. Оценка эффективности полученных результатов проводилась в производственных условиях.

Совершенствование термомеханической технологии изоляции поглощающих уровней скважин путем установления закономерностей изменения и обоснования условий ее эксплуатации по составу и физико-механическим свойствам засыпки из термопластичного композиционного материала (ТКМ). На этой основе разрабатывается технологический регламент, содержащий рекомендации по подготовке композита и организации работ по засыпке, проектированию и изоляции зон абсорбции промывочной воды в скважинах.

Поставленные задачи решались с помощью комплексного метода коммуникации, который включает анализ и обобщение литературных и патентных источников, а также проведение аналитических, экспериментальных и промышленных исследований. Экспериментальные данные обрабатывались на ПК с применением математической статистики. Экспериментальные исследования проводились с применением общей теории научного эксперимента и теории случайных процессов. Оценка эффективности полученных результатов проводилась путем испытаний в производственных условиях.

Соединение было разработано и обосновано; Возможность применения ТСМ была подтверждена. Возможность производства брикетированного ТЦМ показана теоретически и экспериментально. Разработана технология производства ТСМ на основе первичного эталонного топлива (ПЭТФ). Обоснованы рациональные технологические режимы производства ТКМ. Разработана и обоснована технология изоляции уровня поглощения с применением ТКМ на основе ПЭТ. Технические основы изоляции поглощающих уровней разработаны с применением плавки с алгоритмом для создания набора программ, позволяющих рассчитывать процессы тепломассообмена в широком диапазоне условий.

Применение ТКМ на основе вторичного ПЭТФ было обосновано и доказано впервые. Обоснована и доказана возможность термомеханического плавления в проблемной зоне скважины ТСМ, основанной на применении вторичного ПЭТФ. Потенциально обоснованная и экспериментально подтвержденная температурная модель, позволяющая описать процесс теплообмена при термическом плавлении ТСМ, получила дальнейшее развитие. Впервые установлена зависимость значений модовых параметров термомеханического процесса плавления ТЦМ от его теплофизических свойств и технических характеристик. Впервые установлена зависимость проникающей способности ТЦМ на основе ПЭТ от раскрытия трещин от уровня поглощения.

Обоснование области применения технологии изоляции уровня поглощения с применением ТКМ на основе вторичного ПЭТФ. Разработка перспективных рекомендаций по выбору технологических параметров для абсорбционной изоляции уровня ТСМ на основе ПЭТ. Разработка принципиально новых технологий изоляции поглощающих горизонтов ТКМ на основе вторичного ПЭТФ. Разработка технологии изготовления ТКМ на основе ПЭТФ. Разработка исследовательских программ и методологий. Разработка технологического регламента для поглощения поглощающих горизонтов изоляции ПЭТ на основе ТЦМ.

Ключевые слова: бурение скважин, изоляция, поглощающий уровень, плавка, засыпка материалов.

Information about authors:

Sudakov Andrey Konstantinovich, National TU Dnipro Polytechnic, Department of Underground Mining, Dnipro, Ukraine; sudakov@ukr.net; https://orcid.org//0000-0003-2881-2855

Dreus Andrey Yulevich, Oles Honchar Dnipro National University, Department of Fluid Mechanics and Energy and Mass Transfer, Dnipro, Ukraine; dreus@dnu.dp.ua; https://orcid.org//0000-0003-0598-9287

Ratov Boranbay Tovbasarovich, Satbayev University, Almaty, Kazakhstan; ratov.bt@gmail.com; https://orcid.org/0000-0003-4707-3322

Sudakova Oksana Ivanovna, Pridneprovsk State Academy of Civil Engineering and Architecture, Department of Economics and Entrepreneurship, Dnipro, Ukraine; soi2@i.ua; https://orcid.org//0000-0002-8547-6176

Khomenko Oleg Evgenievich, National TU Dnipro Polytechnic, Department of Underground Mining, Dnipro, Ukraine; koordi@rudana.in.ua; https://orcid.org//0000-0001-7498-8494

Dzuba Serhii, Institute of Geotechnical Mechanics named by N. Poljakov of National Academy of Sciences of Ukraine, Dnipro, Ukraine; svdzuba@i.ua; http://orcid.org/0000-0002-3139-2989

Sudakova Diana Andreevna, National TU Dnipro Polytechnic, Department of Underground Mining, Dnipro, Ukraine; sudakov@ukr.net; https://orcid.org//0000-0002-8676-4006

Muratova Samal Karimbaevna, Caspian University, Almaty, Kazakhstan; muratova@mail.ru; https://orcid.org/0000-0002-6805-334X

Ayazbay Marat Dildabekovich, M. Kh. Dulaty Taraz State University, Taraz, Kazakhstan; marat@mail.ru

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