UDC 622.248.33

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ISOLATION TECHNOLOGY FOR SWALLOWING ZONES BY THERMOPLASTIC MATERIALS ON THE BASIS OF POLYETHYLENETEREPHTHALATE

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ТЕХНОЛОГІЯ ІЗОЛЯЦІЇ ПОГЛИНАЮЧИХ ГОРИЗОНТІВ БУРОВИХ СВЕРДЛОВИН ТЕРМОПЛАСТИЧНИМИ МАТЕРІАЛАМИ НА ОСНОВІ ПОЛІЕТИЛЕНТЕРЕФТАЛАТУ

Purpose. The aim is to increase the efficiency of insulation workings by using thermoplastic blends based on polyethyleneterephthalate.

Methodology. The tasks were solved by a multimeter method including the analysis and synthesis of the literary and patent sources, the analytical and experimental studies. Data interpretation was carried out using the methods of mathematical statistics.

Findings. Isolation method of swallowing horizons with thermoplastic materials was developed and validated. To realize it, the following production operations should be done: delivery of the thermoplastic materials to the downhole, the melting of thermoplastic materials and squeezing thermoplastic materials in absorption channels. The use the polyethyleneterephthalate-based domestic household waste was proposed as the plugging material to isolate the swallowing horizons of boreholes.

Originality. The possibility of using the domestic household waste based on polyethyleneterephthalate as the plugging thermoplastic material was proved and validated for the first time. Also for the first time, there was analytically proved the method of determining the efficient range of application of the isolation technology for swallowing and unstable horizons by thermoplastic materials using downhole heat sources.

Practical value. The results of this work is the development of technology and techniques of isolation of swallowing and unstable horizons, formula of tamping thermoplastic material, technology regulations of isolation of swallowing horizons.

Keywords*: drilling, hole, swallowing horizon, drilling liquid, absorption, isolation, plugging materials, downhole heat source, thermoplastic materials, melt*

Introduction. Analysis of the conducted research shows that there is now a great variety of technologies and materials for the dissolution of fluid loss (Fig. 1) [1]. In most cases, the elimination of absorption is provided with plugging the channels loss of circulation by solidifying and non-solidifying grouting mixtures by creating a watertight barrier in the formation around the well.

Generally, plugging materials used to eliminate fluid loss are insufficiently effective. They are prepared on water-base with integration of mineral binder or synthetic substances. The main disadvantage of these materials is that they have high sensitivity to watering - solutions are easily mixed with the drilling liquid and the reservoir waters, especially at cross-flows. Then dilution and sedimentary of cement slurry occur, leading to increasing thickening time, flowing over considerable distance from the well and, as a consequence, it leads to a waste of plugging materials, repetition of plugging operations.

In this regard, grouting mixtures based on thermoplastic materials (TPM) with low fusion point present significant interest as their melt can easily dive into the channels of lush liquid loss and settle down there.

Analysis of the recent research and unsolved aspects of the problem. Up to the present moment, different polymers and monomers belonging to the group of thermoplastics were used as plugging thermoplastic materials. Thermoplastics' main characteristics are that they melt when heated and solidify again when cooled. This process can be repeated many times, if the heating does not go beyond the limit at which the polymer decomposes.

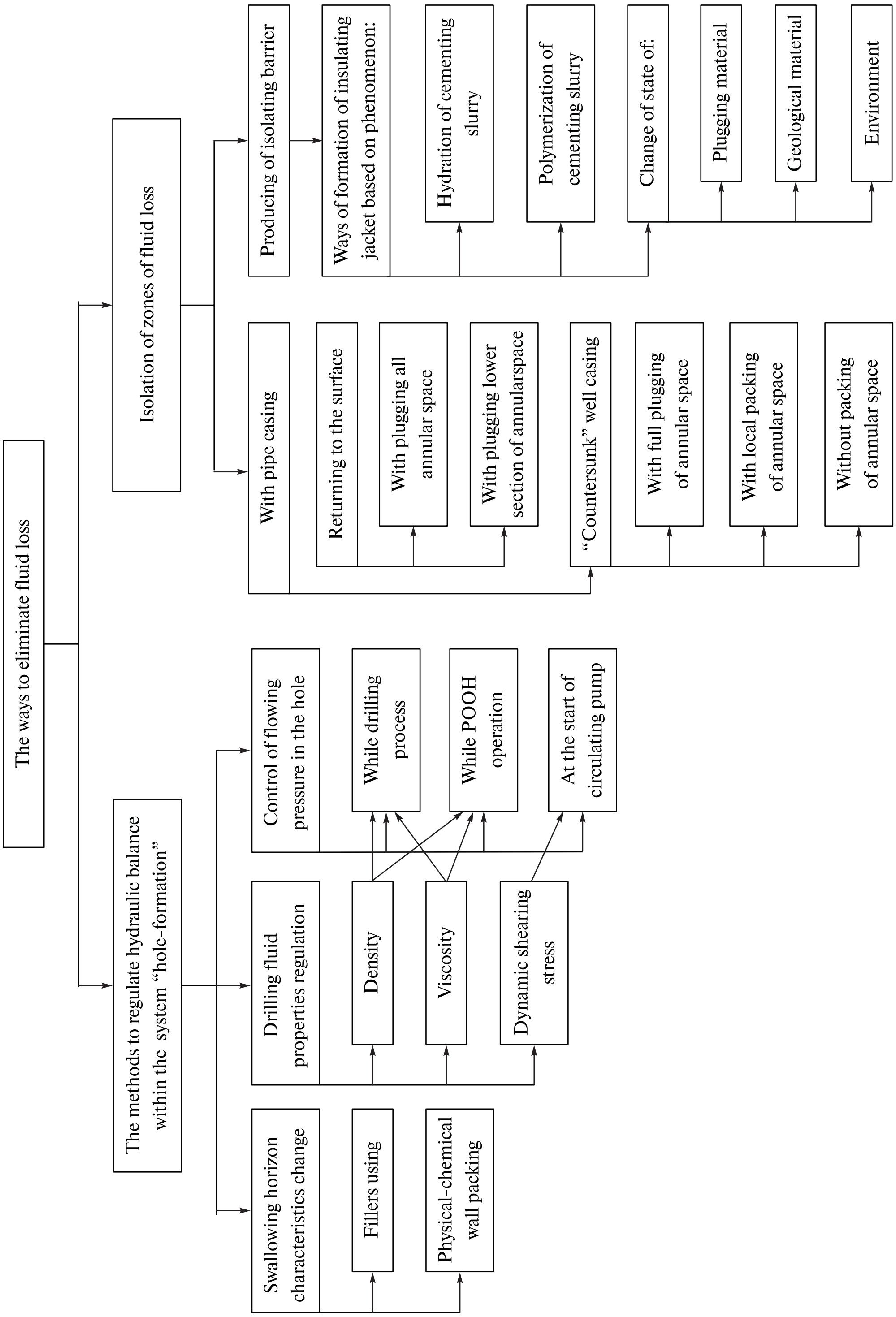

Fig. 1. Classification of the ways to eliminate fluid loss

Up to the present moment, on an industrial scale, only bitumen was used as TPM. The main disadvantage of bitumen, as the plugging material, is its ability to run down in time: when a differential pressure is between 0.3–0.5 MPa it is still able to flow even at a temperature of +15 °C. The bitumen melt has density which is close to the water density and in the operating environment of the drilling liquid it is able to delaminate and float. Bitumen is drilled out low and is capable to foul drilling tool. There are known facts about its carcinogenicity and deleterious environmental impact. Because of these and other disadvantages, bitumen is not widely used as a plugging material.

For the purpose of minimizing disadvantages typical to the bitumen-based mixtures, at the same time in the National Mining University – under A. M. Brazhenenko's guidance [2], and in St. Petersburg State Mining Institute – under V. S. Litvinenko's guidance [3], there were made development works of fundamentally new and innovative plugging technologies of swallowing horizons.

A distinctive feature of the proposed technologies is that TPM with low temperature of melting is delivered to the problem zone in solid granulated form, where it is heated to a liquid state by downhole heat source, with following squeezing in the pore space of the swallowing or unstable horizon.

In the first case [2], sulfur was proposed to be used as the TPM. Solid sulfur is chemically inert, corrosive water does not act destructively on it. Sulfur is easily drilled out and does not wad to the technological tool. Shelf life of granulated sulfur doesn't impact on its physical and mechanical properties. The cost of sulfur is comparable to the cost of cement, and far fewer than the cost of synthetic resins. Due to the low viscosity of melt of both pure sulfur and sulfur containing plasticizer additives, it can easily penetrate the rocks with low crack opening displacement. Fragility of sulfur can be eliminated by the addition of plasticizers. Strength of plugging stone procured by cooling the molten sulfur is comparable to the strength of the cement stone, and in the early stages of solidification, strength of sulfur is much higher than strength on uniaxial compression of the cement stone. The melting point of plugging thermoplastic material can be regulated by plasticizers.

In the second case [3], organic binders based on synthetic thermoplastics allow to achieve hard and affordable pipeless barring. Polyethylene and polypropylene have no environmental limitations during barring and conducting isolation works. Granulated compositional speciation with an organic matrix and mineral fillers comply with the terms of sustainable pipeless mounting and isolation of complicated intervals of holes.

The disadvantages of this technology are: the lack of safe downhole source of heating basic material and squeezing (transporting) the TPM melt to the swallowing horizon; considerable time expenditures during TPM melting in borehole conditions, conditioned by great thermal losses; the proposed plugging materials are multicomponent, which requires previous mixtures treatment and, as a consequence, increases costs.

Plugging materials used for isolation of swallowing horizons during solidifying must not shrink with fracturing or spread in cracks, must have good cohesion to the rocks, and must be resistant to water and differential pressure. In addition, these materials must be single-component, processable upon delivery to the plugging zone, and be easily drilled out and washed off drilling tool, and must have density higher than the density of the scouring agent.

The objective of the article is to increase the efficiency of insulation works by using thermoplastic blends based on polyethyleneterephthalate.

Presentation of the main research. In order to eliminate the disadvantages of using the TPM technology, a new isolation technology of swallowing horizons has been offered. It is based on using polyethyleneterephthalate. The distinctive feature of this technology is that the TPM, delivered in the trouble area in the form of a cylindrically hollow cylinder, melts under the influence of positive temperature of downhole contact type heat source with the following squeezing of polymer to the swallowing horizon and its cooling, thus forming a fluidproof and low-volume insulated casing.

To implement the proposed technology, the following process steps should be taken stage-by-stage: transport the TPM to the swallowing horizon along the hole, melt TPM and squeeze TPM to the swallowing channels. Possible variants of this technology are shown in Table 1.

The application of the designed technology is the isolation of swallowing horizons in the boreholes of various purposes, presented by stable crystalline rocks with a full, intense or catastrophic fluid loss.

To implement the proposed technology, it is proposed to use polyethyleneterephthalate (PET) as plugging thermoplastic material. The physical properties of polyethyleneterephthalate are shown in Table 2 [4, 5].

PET is one of the most widespread polymers. Approximately 65 million tons of different products in the world (fibers, filaments, films, bottles, etc.) are made from PET. One of the important reasons of such a rapid development of PET production is that among all types of synthetic polymers its production is the most environmentally friendly, as the only by-product of its production is the water of reaction. The main process steps of its manufacturing are carried out in vacuum; therefore the environmental emissions are nearly non-existent.

Table 1

Swallowing horizons isolation technique using TPM

Process steps	Possible variants of steps
Transporting the TPM to the swallowing horizon	Along the hole
	On the drill-stem
	Along the drill-stem
	In in pod
TPM melting	By fire
	By chemicals
	By bottom-hole electrical heater
TPM squeezing	By bottom-hole electrical heater
	By increasing hydrostatic pressure in the hole

Table 2

Physical properties of polyethyleneterephthalate

Property	Unit	Value
Density:		
amorphous PET	g/cm^3	1.33
crystalline PET	g/cm^3	1.45
both amorphous and crystalline PET	g/cm^3	1.38–1.40
Break point:		
ultimate tensile strength	MPa	172
transverse strength	MPa	50–70
compressing strength	MPa	80–120
Modulus of tensile elasticity	MPa	$1.41 \cdot 10^4$
Ultimate elongation	%	12–55
Impact elasticity	kJ/m^2	30
Brinnel hardness	MPa	100–120
Water adsorption for 24 h	%	0.3
Temperature of fusion	°C	255–265
Softening point	°C	245–248
Breakdown temperature	°C	350
Factor of thermal expansion		$6.55 \cdot 10^{-4}$
Thermal conductance	W/mK	0.14
Freezing resistance	°C	–50
Dielectric capacitivity at 10^6 Hz		3.1

PET waste belongs to class 5 (the safest) and their burning does not emit dioxin, as PET does not contain chlorine. PET`s toxic level while burning is identical to the burning of wood.

In view of introduction of the separate household solid wastes collection in Ukraine, PET`s recycling should rise steeply, it is used now in Ukraine for producing about 50 thousands of tons of various kinds of textile products per year.

Polyethyleneterephthalate is a synthetic linear thermoplastic polymer which belongs to the polyester class. Polycondensate of terephthalic acid and monoethylene glycol. Polyethyleneterephthalate can exist in amorphous or crystalline states, where the degree of crystallinity is determined by thermal prehistory of the material.

After quick cooling, PET is amorphous. APET is a solid transparent material. Commercial PET is usually produced in granulate form with the size of 2–4 mm.

PET has high mechanical strength (Table 2) and impact value, abrasion resistance and repeated deformation during stretching and deflection, and keeps its high impact-resistant and strength characteristics in the operating temperature range from –40 to +60 °C, PET has a low index of friction and low water-absorbing capacity. The total operating temperature range of PET products is from –60 to +170 °C.

PET is a good dielectric material, the electrical properties of the polyethyleneterephthalate at temperatures up to +180 °C change slightly even in the presence of moisture. By resistance to severe environment PET has high chemical resistance to acids, alkalis, salts, spirits, paraffin, mineral oils, gasoline, grease, carboxethyl ester. It has augmented stability to water vapor. At the same time, PET is soluble in acetone, coal naphtha, toluene, ethyl acetate, carbon tetrachloride, chloroform, methylene chloride and methyl ethyl ketone.

Polyethylene is characterized by excellent ductileness in the cold and hot state.

Thermal degradation of PET occurs at a temperature range from +290 to +310 °C. Degradation goes statistically along the polymer chain. The main volatile products are terephthalic acid, acetaldehyde and carbon monoxide. At +900 °C a large number of different hydrocarbons is generated. The volatile products are mainly carbon dioxide, carbon monoxide and methane.

To improve thermal-, light-, fire resistance, friction behavior and other properties, various additives are introduced into PET. Also the methods of chemical modification are used: by various dicarboxylic acids and glycols, which are added in the course of PET synthesis in the reaction-mixture.

Plugging materials should meet the specified technical and technological requirements. This compliance largely determines the technical and economic efficiency of the work. Comparison of the compliance of known plugging materials and PET with these requirements Table 3 suggests that PET may be recommended for using to isolate the swallowing horizons.

Table 3

The compliance of plugging materials with technical and technological requirements

Requirement to	Plugging material			
	cement	bitumen	sulfur	PET
Matrix (melt)				
Good fluidness	+	+	+	+
The ability to dive into fractures	+	+	+	+
Sedimentation stability	–	–	+	+
Inactivity in environment	–	+	+	+
Adjustability of rheology	+	+	+	+
Plugging stone				
Good adhesiveness with rocks	–	–	–	–
Stability to scouring action of stratal waters	+	+	+	+
High drillability	+	–	+	+
Ability to relax	+	–	+	+
Water tightness	+	+	+	+
High physical and mechanical properties	+	–	–	+
Low friction coefficient	–	–	–	+
Raw material stock				
Be abundant	+	+	+	+
Price per ton, UAH	2000	8000	2900	2000
Properties do not deteriorate with time	–	–	+	+
Environmentally-friendly	+	+	+	+

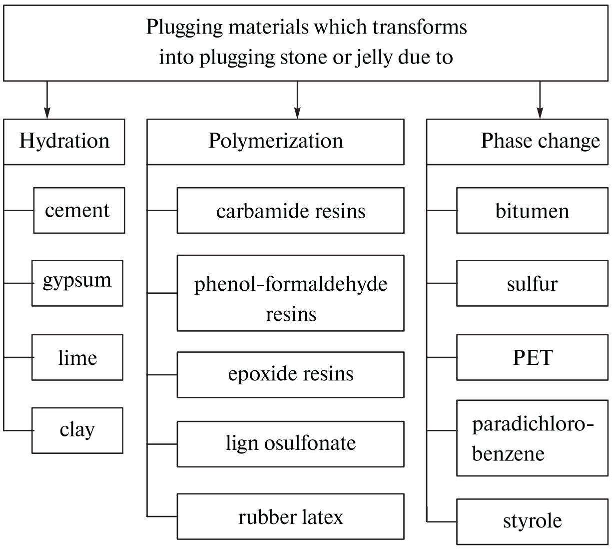

Fig. 2. Classification of plugging materials

The analysis of used plugging materials allows to divide them into three groups (Fig. 2) [6, 7]. The presented classification of plugging materials is based on the processes resulting in the formation of plugging stone or hydration-gel, polymerization-gel, or gel of phase change.

Conclusions and perspectives. This work considers the isolation technology of swallowing TPM horizons. For its implementation, the following operations should be done: TPM delivery to the downhole, TPM melting and squeezing to the swallowing channels. The possibility to use PET as plugging material is proved.

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Тампонаж горных пород при бурении геологоразведочных скважин легкоплавкими материалами / [Бражененко А. М., Гошовский С. В., Кожевников А. А. и др.] – Киев: УкрГГРИ, 2007. – 130 с.

Мета. Підвищення ефективності ізоляційних робіт за рахунок застосування термопластичних сумішей на основі поліетилентерефталату.

Методика. Поставлені завдання вирішувалися комплексним методом дослідження, що включає аналіз і узагальнення літературних і патентних джерел, проведення аналітичних, експериментальних досліджень. Обробка експериментальних даних проводилася на ПЕВМ з використанням методів математичної статистики.

Результати. Розроблено та обґрунтовано спосіб ізоляції поглинаючих горизонтів термопластичними матеріалами, для реалізації якого необхідно виконати наступні технологічні операції: доставку термопластичних матеріалів на вибій свердловини, плавлення термопластичних матеріалів і вдавлювання термопластичних матеріалів у канали поглинання. У якості тампонажного матеріалу для ізоляції поглинаючих горизонтів бурових свердловин запропоноване використання побутових відходів на основі поліетилентерефталату.

Наукова новизна. Уперше обґрунтована й доведена можливість застосування у якості тампонажного термопластичний матеріал побутових відходів на основі поліетилентерефталату. Уперше аналітично обґрунтована методика визначення раціональної сфери застосування технології ізоляції поглинаючих і нестійких горизонтів термопластичними матеріалами з використанням забійних теплових джерел.

Практична значимість. Полягає в розробці технології та технічних засобів ізоляції поглинаючих і нестійких горизонтів, рецептури тампонажного

термопластичного матеріалу, технологічного регламенту ізоляції поглинаючих горизонтів.

Ключові слова: *буріння свердловин, поглинаючий горизонт, промивальна рідина, поглинання, ізоляція, тампонажні матеріали, вибійне теплове джерело, термопластичні матеріали, розплав*

Цель. Повышение эффективности изоляционных работ за счёт применения термопластичных смесей на основе полиэтилентерефталата.

Методика. Поставленные задачи решались комплексным методом исследования, включающим анализ и обобщение литературных и патентных источников, проведение аналитических, экспериментальных исследований. Обработка экспериментальных данных проводилась на ПЭВМ с использованием методов математической статистики.

Результаты. Разработан и обоснован способ изоляции поглощающих горизонтов термопластичными материалами, для реализации которого необходимо выполнить следующие технологические операции: доставку термопластичных материалов на забой скважины, плавление термопластичных материалов и вдавливание термопластичных материалов в каналы поглощения. В качестве тампонажного материала для изоляции поглощающих горизонтов буровых скважин предложено использование бытовых отходов на основе полиэтилентерефталата.

Научная новизна. Впервые обоснована и доказана возможность применения в качестве тампонажного термопластичного материала бытовых отходов на основе полиэтилентерефталата. Впервые аналитически обоснована методика определения рациональной области применения технологии изоляции поглощающих и неустойчивых горизонтов термопластичными материалами с использованием забойных тепловых источников.

Практическая значимость. Состоит в разработке технологии и технических средств изоляции поглощающих и неустойчивых горизонтов, рецептуры тампонажного термопластичного материала, технологического регламента изоляции поглощающих горизонтов.

Ключевые слова: *бурение скважин, поглощающий горизонт, промывочная жидкость, поглощение, изоляция, тампонажные материалы, забойный тепловой источник, термопластичные материалы, расплав*

Рекомендовано до публікації докт. техн. наук О. М. Давиденком. Дата надходження рукопису 17.11.15.

UDC 622.281 (574.32)

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TECHNOLOGY OF TWO-LEVEL SUPPORTING WORKING CONTOURS

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ТЕХНОЛОГІЯ ДВОРІВНЕВОГО КРІПЛЕННЯ КОНТУРІВ ГІРНИЧИХ ВИРОБОК

Purpose. Developing a technology with rope anchors hardening a roof of workings supported with steel-polymeric anchors which will exclude the roof collapse cases in zones of the increased mining pressure.

Methodology. Solving problems is based on systematic analysis and generalization of theoretic and industrial domestic and foreign experience in the field of development of technological schemes of mining roadways in stratified and ore mineral deposits; data modeling of strata pressure allocation, defectiveness and stability of rock massif; analytical researches of efficient application of technological innovations; experiments in real industrial conditions.

Findings. The two-level technology of supporting extraction workings based on accounting geomechanics of stressed-and-strained state of rocks around the workings with determining the optimum parameters of roof bolting depending on the influencing mining technological factors.

Originality of the methods proposed in the work consists in the following:

- the design capability to perceive loading without delays, a great load bearing capacity, prevention of the shift and stratification of the roof rocks, formation of domes and rock inrushes;
- reducing methane gas emission into the working, enhanced durability of the support and increased between-repairs resource, as well as the reached economic efficiency due to the cost reduction for working support and repair.