

Innovative technology for insulating the borehole absorbing horizons with thermoplastic materials

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Abstract. The purpose of the work is to increase the insulation work efficiency by using thermoplastic mixes based on polyethylene terephthalate. The tasks set were solved by a complex method of research, including the analysis and synthesis of the literary and patent sources, as well as conducting the analytical and experimental studies. The experimental data were processed on a PC using the methods of mathematical statistics. A method for insulating the absorbing horizons with thermoplastic materials has been developed and substantiated. To implement it, the following technological operations should be performed: supply of the thermoplastic materials to the borehole bottom, melting and squeezing of thermoplastic materials into absorption channels. For various geological and technical conditions of drilling, technological schemes of insulating the absorbing horizons with thermoplastic materials are proposed. The use of the household waste based on polyethylene terephthalate has been proposed as the plugging material to insulate the absorbing horizons of boreholes. For the first time, the possibility of using the household waste based on polyethylene terephthalate as the plugging thermoplastic material has been substantiated and proved. For the first time, a method for determining the efficient range of technology application for absorbing and unstable horizons insulation with thermoplastic materials through the use of bottom hole thermal sources has been substantiated analytically.

1 Relevance of the topic

Drilling, both exploration and production wells for the purpose of exploration deposits and mining in the area of iron ore and coal basins are being conducted to a high degree of development and metamorphism, in hard and fractured rocks [1 – 10]. Breeds of developed horizons are in a complex stress state [11 – 18]. This only decomposes the technology of

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the construction of mine workings [19 – 22].

The process of drilling wells is connected with geological problems. A common problem is the absorption of washing fluid [23]. On liquidation of absorptions a considerable amount of time and money are spent from the total cost of drilling wells. Absorption leads to an infraction of the technological regime of boring, the integrity of the wells walls and provokes accidents [24 – 28].

2 Analysis of last research and determination of unsolved problems

Research in the field of development of plugging materials and technologies of the prevention absorption of the drilling fluid is dedicated to the work Basaryhina Yu.M., Brazhenenka A.M., Bulatova A.I., Vasylieva M.I., Vakhrameieva I.I., Vozdvizhenskoho B.I., Haivoronskoho O.O., Dotsenka Yu.H., Ivacheva L.M., Kypka E.Ia., Kotskulycha Ya.S., Krylova V.I., Kudriashova B.B., Lipatova M.K., Martynenka I.I., Mysliuka M.A., Nikolaieva M.I., Polozova Yu.A., Rafienka I.I., Spsychaka Yu.N., Sudakova A.K., Stavychnoho Ye.M., Tershaka B.A., Tytkova N.I., Tiana P.M., Yakovlieva A.M., Yasova V.H. and other scholars. An analysis of their works was performed in [29 – 32].

The process of drilling wells is associated with geological complications. The most frequent type of complications that violates the technology of drilling is the absorption drilling fluid, at the same time, the annual cost of time in the overall balance for drilling increased to 23% and funds up to 10%.

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) [31]. In most cases, the elimination of absorption is ensured by the laying of channels. Absorption of washing fluid with hardening or non-hardening tampon mixtures creates a waterproof screen in the rock around the well. The use of plugging materials, which are prepared on a water-based basis with the infiltration of mineral or synthetic substances into their composition, are not sufficiently effective to eliminate the absorption of washing fluids. In our opinion, these materials and technologies have exhausted their potential of further improvement. Therefore, the only way is to design and apply technologies based on anhydrous materials, and other processes of formation of a plugging stone for the formation of insulation veils. These technologies include technology of creation of a plugging stone, based on the phenomenon of phase transition.

Mixtures of thermoplastic materials based on bitumen, sulfur and synthetic thermoplastics (polyethylene, polypropylene) have been used until nowadays [33, 34]. But due to the imperfection of technology, the use of thermoplastic materials was not widely used as plugging materials in isolation of absorbing horizons of drilling wells. In order to solve the problem of isolation of absorbing horizons, it is necessary to find fundamentally new solutions. Therefore, the development of technologies for the isolation of absorbing horizons with the use of more effective plugging materials is extremely important.

The work is devoted to solve this urgent scientific task, which consists in the establishment of regularities changes in axial load and rotational speed when substantiating the regime parameters effective thermomechanical isolation technology of absorbing horizons from the middle limit strength on uniaxial compression depending on: composite composition, ratio components and type of filler; melt temperature overheating, density, time hardening and the number of melting plugging thermoplastic composite materials, which has a great practical importance.

The purpose and objectives of this research. The aim of the work is to improve the thermomechanical technology of isolation of absorbing horizons of drilling wells by establishing regularities of change and substantiation of its regime parameters from the

composition and physical and mechanical properties of the plugging thermoplastic composite material and, on this basis, to develop a technological regulation to contain recommendations on the manufacture of composites and the organization of plugging works, to design and to isolate an absorption zones of the washing fluid in drill holes.

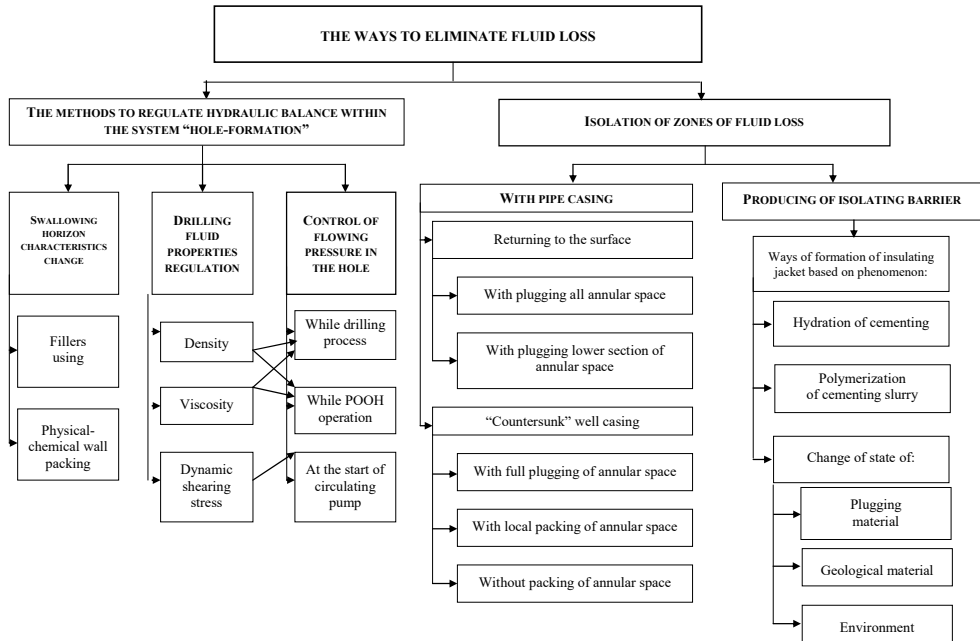


Fig. 1. Classification of the ways to eliminate the loss of drilling fluid.

The idea of the work is to establish and use the regularities of changing the physical and mechanical properties and advantages of the plugging thermoplastic composite material to justify the regime parameters and introduce into the production of an effective thermomechanical technology for the isolation of absorbing horizons of drill holes.

3 Basic material

A new technology for the isolation of TPM absorbing horizons based on the use of polyethylene terephthalate [35 – 39] is proposed to eliminate the disadvantages inherent in TPM application technologies. A distinctive feature of the technology is that the TPM delivered to the zone of complication in the form of a cylindrically-hollow cylinder, is melting under the influence of positive temperatures of the downhole contact type heat source, followed by crushing the polymer into the absorbing horizon and cooling it to form an impenetrable, low-volume insulation sheath [40 – 43] .

To implement the proposed technology, it is necessary to perform the following technological operations, step by step: transporting the TPM to the absorbing horizon through the wellbore, melting TPM and pushing the TPM into the absorption channels. Other ways for the implementation of this technology are given in Table 1. [44]

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.

The field of application of the technology is the isolation of absorbing horizons in boreholes for various purposes, represented by stable, crystalline rocks with complete, intensive or catastrophic absorption of washing fluid.

Table 1. Insulation technology absorbing horizons 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

It is proposed to use polyethylene terephthalate (PET) as a plugging thermoplastic material. The physical properties of polyethylene terephthalate are given in Table 2 [38, 39, 45 – 47].

PET is one of the most common polymers. About 65 million tons of various products (fibers, threads, films, bottles, etc.) are produced from PET in the world. One of the important reasons for such a rapid development of PET production is that of all types of synthetic polymers its production is the most environmentally friendly, since the only by-product of the process of its production is the reaction water. The main stages of the manufacturing process are carried out in a vacuum, and therefore there are practically no emissions to the environment.

Table 2. Physical properties of polyethylene terephthalate.

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	1.41·10 ⁴
Ultimate elongation	%	12 – 55
Impact elasticity	kJ/m ²	30
Brinell 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		6.55·10 ⁻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 dioxins are not released when incinerated, since PET does not contain chlorine. The toxicity of PET when burning is identical to burning firewood.

In connection with the separate collection of municipal solid waste introduced in Ukraine, the use of recycled PET should sharply increase, from which about 50 thousand tons / year of various types of textile products are already produced in Ukraine.

Polyethylene terephthalate is a synthetic linear thermoplastic polymer belonging to the class of polyesters. Polycondensation product of terephthalic acid and monoethylene glycol. Polyethylene terephthalate has the ability to exist in amorphous or crystalline states, and the degree of crystallinity is determined by the thermal history of the material.

With rapid cooling, polyethylene terephthalate is amorphous. Amorphous polyethylene terephthalate is a solid transparent material. Commercial polyethylene terephthalate is usually produced in the form of granules with a granule size of 2-4 millimeters.

PET has high mechanical strength (Table 2) and impact resistance, abrasion resistance and multiple deformations under tension and bending. It retains its high impact and strength characteristics in the operating temperature range from -40 °C to +60 °C. PET has a low coefficient of friction and low hygroscopicity. The total operating temperature range of polyethylene terephthalate products is from -60 °C to +170 °C.

PET is a good dielectric. The electrical properties of polyethylene terephthalate at temperatures up to +180 °C, even in the presence of moisture, change slightly. By its resistance to aggressive environment, PET has a high chemical resistance to acids, alkalis, salts, alcohols, paraffin, mineral oils, gasoline, fats, ether. It has increased resistance to water vapor. At the same time, PET is soluble in acetone, benzene, toluene, ethyl acetate, carbon tetrachloride, chloroform, methylene chloride and methyl ethyl ketone.

PET is characterized by excellent plasticity in a cold and heated state.

Thermal destruction of PET occurs in the temperature range + 290 °C ... +310 °C. Destruction occurs statistically along the polymer chain. The main volatile products are terephthalic acid, acetaldehyde and carbon monoxide. At +900 °C a large number of various hydrocarbons is generated. Mostly volatile products consist of carbon dioxide, carbon monoxide and methane.

To increase thermal, light, fire resistance, friction and other properties, various additives are introduced into PET. The methods of chemical modification with various dicarboxylic acids and glycols, which are added during the synthesis of PET into the reaction mixture, are also used.

Plugging materials must comply with certain technical and technological requirements. Their compliance largely determines the technical and economic efficiency of the work. Comparison of the compliance of well-known plugging materials and PET with these requirements (Table 3) allows us to conclude that PET may well be recommended for use to isolate absorbing horizons.

The analysis of used plugging materials allows us to divide them into three groups (Fig. 2). The presented classification of plugging materials is based on the processes that result in a plugging stone or gel of hydration, polymerization or phase transition.

Analysis of all technological operations and methods for their implementation shows that the choice of the necessary technological scheme can be made on the basis of the method of delivery of the TPM to the zone of complication [48 – 57].

Upon delivery of the TPM along the well, three schemes of technological operations are possible. In the diagrams shown in fig. 3 and fig. 4 TPM is melted by the heat of the drilling fluid, and in Fig. 5 – by contact method.

The first scheme (Fig. 3) provides for performing six operations in a certain sequence. Here, between heating the drilling fluid and melting of the TPM, it is necessary to perform operations for lifting the heater and delivering the TPM, which will lead to loss of heat and

time. Therefore, when determining the heating temperature of the drilling fluid, it is necessary to introduce a correction factor for these losses. In the second technological scheme, the delivery of the TPM is allowed before the heater is lifted to the surface, i.e., the delivery and heating operations can be combined in time.

Table 3. 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 striatal waters	+	+	+	+
High drill ability	+	-	+	+
Ability to relax	+	-	+	+
Water tightness	+	+	+	+
High physical and mechanical properties	+	-	-	+
Low friction coefficient	-	-	-	+
Raw material stock				
Be abundant	+	+	+	+
Price per ton, UAH	1500	8000	12500	3000
Properties do not deteriorate with time	-	-	+	+
Environmentally-friendly	+	+	+	+

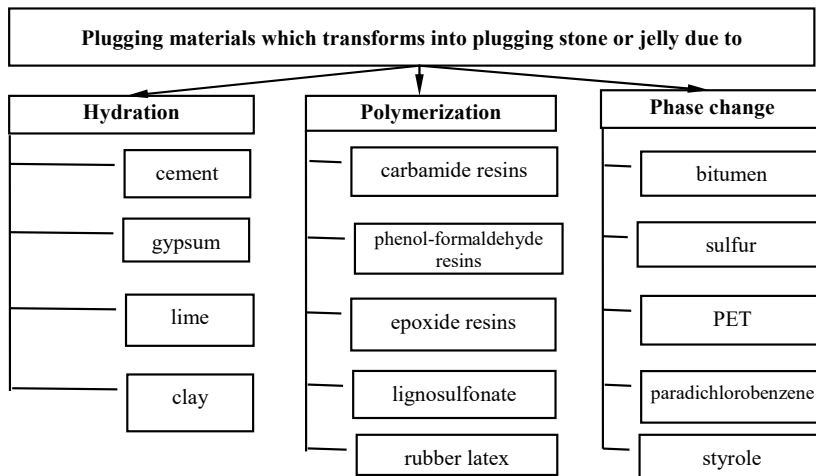


Fig. 2. Classification of plugging materials.

In this case, more favorable conditions are provided for melting TPM. Implementation of the second technology is possible with sufficient gap between the walls of the well and the walls of the heater case. The case must be made of materials resistant to aggressive environments. When applying the third technology, in case of absence of the column of liquid in the well, contact type of electric heaters are used.

The second scheme. As in the previous case, there are three options of completing delivery of pipes along the string (Fig. 4). To implement the first two technologies heaters of small diameter are needed so that they can be transported along the drill string. In the first case the heater is removed from the well after heating drilling fluid and then TPM granules are poured through the drill string. This sequence of operations leads to a specific loss of heat in drilling fluid at the bottom hole. In the second case, these losses can be eliminated. However the lift of heater body inside the pipe string becomes more complicated because of the remains of the melt of TPM. The third method requires fewer operations. In this case the heater of large diameter can be used as it is pulled down into the well after lifting the drill string. In this technology TPM melts due to contact method.

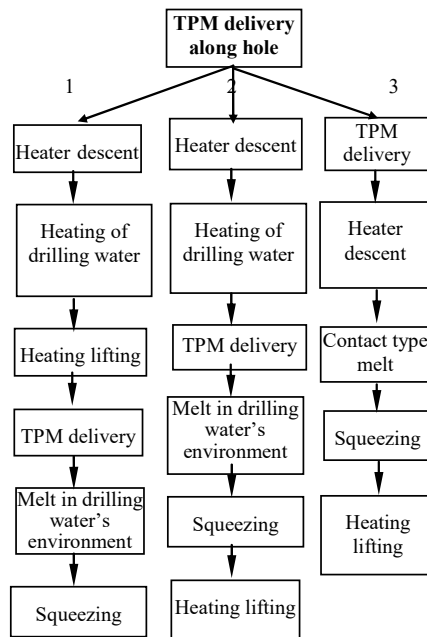


Fig. 3. Isolation technology of absorbing horizons during TPM delivery along the hole.

The third scheme. During TPM delivery in the container (Fig. 5), there are two methods of completing an activity. In the first case, the container is pulled down into the borehole and then it unleashes TPM after landing. After removing the container from the hole the heater is pulled down to begin melting the TPM by contact method. A special device is required to follow the technological steps of the second technological scheme. It is pulled down into the well on a cable that combines the heater, the container and a fill valve of releasing the melt on the bottom hole.

After the analytic and experimental research, with regard to the geological and technical conditions of drilling, the technological schemes discussed in Figs. 3 – 5, based on the presented technological schemes of conducting plugging operations, the method can be recommended for use in industrial environment. In this case, general requirements lodged to the technology of plugging of absorbing horizons using TPM are to be met.

According to some researchers, the usage of inert materials for plugging the porous rocks does not cause much difficulty. The proposed technology is recommended to be used for plugging fractured absorbing horizons with a minimum opening of cracks 0.5 mm. Process water and clay mud can be used as drilling fluid.

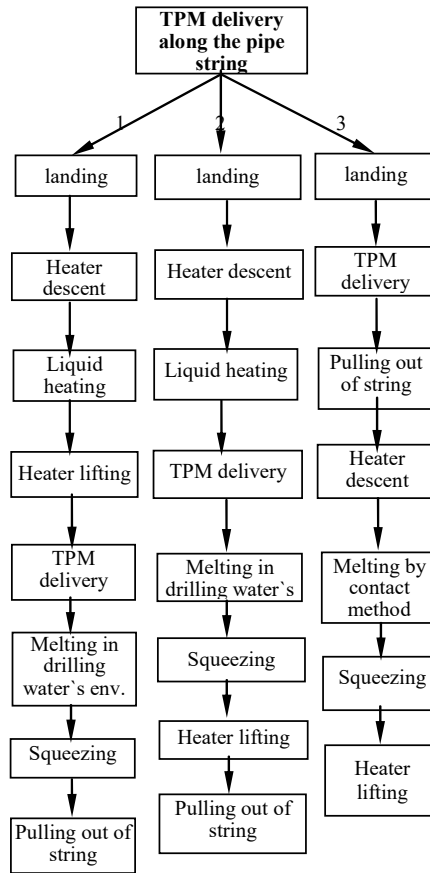


Fig. 4. The technology of isolation of absorbing horizons during TPM delivery along the drill string.

For the conditions: the well is piled up by the pipe string with its open part which not exceeds 50 m, the well is vertical and not deeper than 150 – 200 m, and there are no cavities, the column of drilling fluid is above of the roof of the absorbing horizon at least for 20 – 25 m. In this case it is possible to use the technological scheme with TPM delivery along the borehole (Fig. 3). This technological scheme is the most appropriate for these conditions because its technological operations are consistent, and because emergency situations related to the tool pulling are impossible in the well.

During the process of drilling wells, particularly in the Donbas, there are cases when the well is drilled with complete fluid loss. This caused by intensive development, high fracturing and permeability of the rocks which form the walls of the well. At the same time, at the bottom hole there is an insignificant amount of drilling fluid or its full absence. For these types of wells it is recommended to use the technological scheme shown in Fig. 3. At the same time, it is possible to do the delivery of the material by its backfill through the top of borehole, and at great depth – along the drill string (Fig. 4). While performing this technological scheme, there should be no core fragments in the core tube. For melting granulated TPM, downhole heat sources of contact type are applied.

The most functional, simple and technological way of plugging is the method of TPM delivery in the container (Fig. 5).

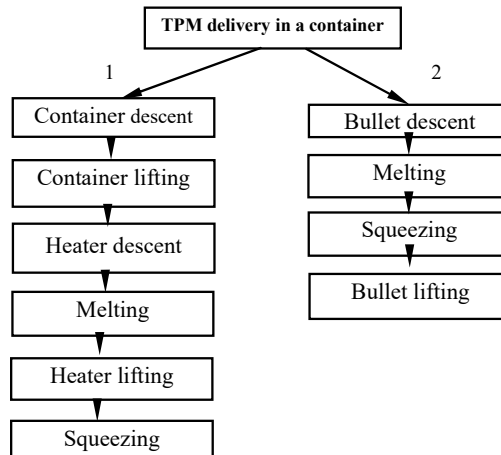


Fig. 5. The technology of isolation of absorbing horizons while TPM delivery in a container.

Melting is realized by way of contact. The disadvantage of this method is the limited volume of the container. In this case, the minimum number of process steps will be required for isolation the absorptive horizon. The method of TPM delivery to the downhole in a container with attached cable has the best perspectives. It can be used for wells up to 9000 meters long with minimal waste of time and energy.

4 Conclusions

This work considers the isolation technology of absorption TPM horizons. For its implementation, the following operations should be done: TPM delivery to the downhole, melting and strangulation TPM to the absorbing channels. For various geological and technical conditions of boring, technological schemes of isolation of the absorbing TPM horizons are proposed. The possibility to use PET as plugging material is proved.

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