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Intensification of the processes of preparation of drilling and cement mortars using vibration jet activation methods

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Abstract. The article presents the results of laboratory and field tests of vibro-jet magnetic activation (VJMA) technology in the technological processes of preparation of drilling and cement mortars. Studies have shown a significant improvement in the quality of the mortars, reducing the preparation time and energy intensity of the process. The use of VJMA technology for processing grouting mortar allows increasing the fluidity of the solution and increasing the strength of the cement stone. This facilitates the filling of cement mortar.

1. Introduction

Technological mortars must be prepared with certain properties and in large volumes. Each mortar has its own preparing technology, its recipes and its equipment. All of these preparing technologies are energy intensive. Chemical methods for obtaining the required parameters of process fluids are widely used to reduce production costs; however, this exacerbates the requirement for ecotoxicity. There are physical methods of influencing the initial components of process fluids, which can increase productivity and reduce the ecotoxicity of production. The “dry” activation of concrete components can serve as an example of such a physical method [1].

For the preparation and activation of process fluids, effects of various physical nature are used: mechanical, hydraulic, acoustic, thermal, magnetic, electrical. In this case, the main criterion for the degree of preparation can be considered the amount of energy spent on the process [2–7].

Vibration methods for the intensification of technological processes are used steadily in technology, providing a significant increase in productivity and product quality.

2. Research methods

In works [2-4, 8], an effective technology of vibro-jet magnetic activation (VJMA) of technological and raw fluids was developed, which include oil, cement mortars and drilling mud, polymer compositions, saline solutions, oil sludges and bottom sediments, as well as water-oil emulsions and hydrocarbon fuel. The aim of the proposed technology and devices for its implementation is the practical implementation of the principle of complex integration of a number of well-known physical factors of fluid activation in one device (acoustic field, shear flow of turbulent jets, magnetic processing of the medium), which has no analogues and is confirmed by patents and applications [2, 3].



The paper presents the results of laboratory, experimental and operational tests of devices and technology of VJMA.

2.1. Drilling mud preparation

Flushing fluids in drilling processes can have various physical and mechanical properties that have a significant impact on the entire drilling process and on the condition of the well. The quality of the flushing fluid should provide the maximum mechanical speed of drilling, high quality and minimum cost of drilling in specific conditions [9].

Comparative experiments were conducted in laboratory conditions to determine the feasibility of using VJMA technology of fluid to accelerate the preparation of drilling mud using clay from Dolmatovsky quarry (Tomsk).

Mixing the solution was carried out on a laboratory mixer in an open vessel with a rotation speed of 200 rpm. The radius of the mixer blade is 50 mm. All experiments were performed using distilled water. Assessment of the effectiveness of dispersion of quarry clay was carried out by sedimentation analysis. The density of the solution is 1060 kg/m³. According to sedimentation nomograms, the drilling fluid preparation time was reduced by 5-6 times with the use of VJMA technology (Figure 1) [2].

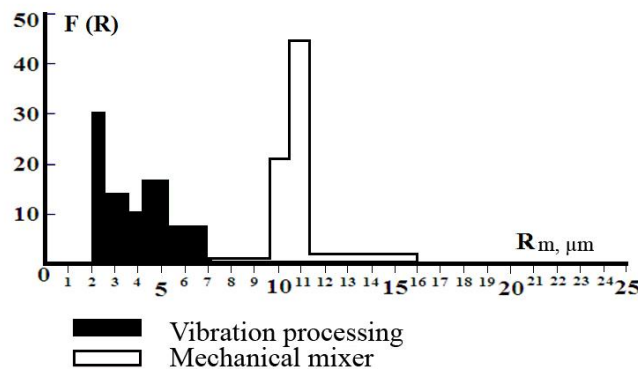
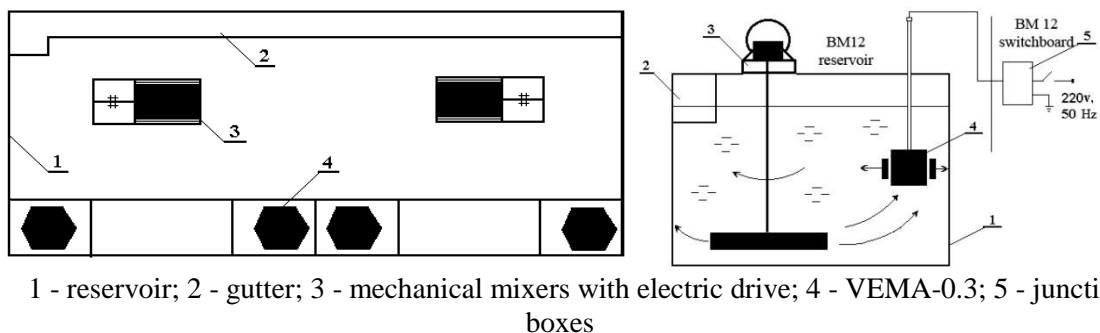


Figure 1. Distribution of particle sizes of clay when using a mechanical mixer and a laboratory vibrator VL-1

Field tests were conducted at well No. 69 BK on the offshore stationary platform OSP-3 of the "White Tiger" field of the "Vietsovpetro" joint venture (Socialist Republic of Vietnam) [10].

Four vibrators of electromagnetic activation VEMA were located in the reservoir for the preparation of the drilling mud (Figure 2). The tests were carried out after the descent of the 245 mm casing in the process of transferring the drilling mud with a density of 1.16-1.19 g/cm³ to the drilling mud with a density of 1.7-1.73 g/cm³. The total electric drive power of the mixers is 15 kW. The total electric power of VEMA is 1.2 kW. The control preparation of the drilling mud was carried out in a separate reservoir, where two traditional mechanical mixers were installed.



1 - reservoir; 2 - gutter; 3 - mechanical mixers with electric drive; 4 - VEMA-0.3; 5 - junction boxes

Figure 2. Scheme of the vibrators installation in the reservoir

An analysis of the test results shows that all parameters of the drilling mud prepared with VJMA technology are better than the parameters of the drilling fluid prepared in the traditional way. The density in the reservoirs is the same, but in the reservoir with vibrators the basic viscosity is 1.8 times lower. This is explained by the fact that due to the high shear rates and the acoustic field created by the VEMA, a better dispersion of the drilling fluid occurred. Water loss decreased by 11%.

Structural and mechanical properties of the drilling mud are characterized by the thixotropy coefficient $K_t = SShS_{10}/SShS_1$, where $SShS_1$ is the static shear stress at rest, $SShS_{10}$ is the static shear stress after 10 minutes. According to the recommendation given in [10], the value of K_t should not exceed 2. When using the technology of vibrojet magnetic activation, the value of K_t is 2.

To prevent possible complications when drilling wells in clay and clay-containing rocks, it is proposed to limit the maximum value of the pH of the flushing fluid to 9.2 [10]. When using VJMA, $pH = 9.0$.

The mud preparation time in the control reservoir was 30% longer than in the reservoir with vibrators. The reduction in drilling mud preparation time using 4 VEMA vibrators was 1.8 hours in relation to 6 hours in the control reservoir. The increase in the number of VEMA will allow reducing the preparation time to a greater extent and increasing the dispersion of the drilling fluid. Comparative parameters of the drilling mud before the experiment and after the experiment with and without vibrators are presented in Table 1.

Table 1. Drilling mud parameters.

Drilling mud parameters	Before testing	After testing	
		Control reservoir	Reservoir with vibrators
Density (g/cm ³)	1.19	1.73	1.72
Viscosity (sec)	50	61	34
Water loss (cm ³)	4.5	4.5	4.0
Crust (mm)	1.0	1.0	1.0
SShS, 1/10	20/50	35/71	20/40
$K_t = SShS_{10}/SShS_1$	2.5	2.028	2
pH	10.5	9.5	9.0

According to the results of field tests, the dependence of reducing the time for preparing the drilling mud $T = f(N)$ is obtained. Using this dependence, it is possible to estimate the required amount of VEMA to reduce the time required to prepare the drilling mud (Figure 3). Figure 3 shows the dependence of the decrease in energy intensity of the drilling mud preparation process $\Delta W = f(N)$. The energy intensity of the process of preparation (weighting) of the drilling mud using four VEMA decreased by $\Delta W = 22$ kWh.

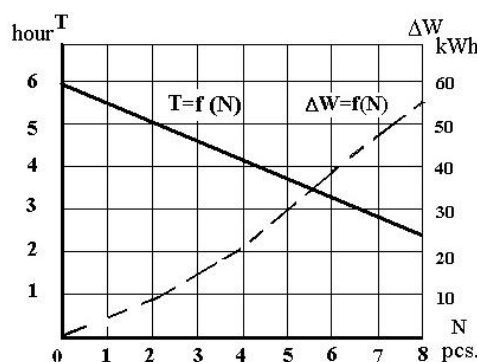


Figure 3. Experimental dependences of reducing the preparation time and reducing energy intensity on the number of vibrators in the process of preparing the drilling mud.

2.2. *Vibration processing and preparation of cement mortar*

One of the most complex processes for fixing wells is their cementing, which includes: preparing a grouting mortar, pumping it into a pipe string, and forcing it into the annulus of the well.

Cementing of oil and gas wells is the final stage of the preparation of the oil rig for operation. The scope of work is aimed at ensuring the maximum service life of the structure. This is due to the following reasons: a) the need to isolate each oil and gas region; b) the need to exclude the possibility of mixing raw materials and water from different layers; c) compliance with the requirements governing the protection of a metal pipe surface [1, 12, 13].

One of the ways to improve the quality of casing cementing during well drilling is to maintain the specified technological parameters of the grouting mortar during its preparation and pumping into the annulus. The use of VEMA in the technological chain will eliminate the drawbacks of the preparation of the mortar, not only by eliminating stagnant zones in the averaging tank, but also by improving the properties of the cement mortar (increasing the spreadability of the mortar, hardening the cement stone).

The amount of mechanical energy for vibration exposure depends on the amplitude of the vibrations, the frequency of the vibrations and the exposure time. According to the hypothesis P.A. Rebinder there is a limit value of the shear rate during vibration, causing the transition of concrete mixture from a state of elastic-plastic to a state of temporary fluidity. Upon reaching a certain impact energy, a transition to a state of temporary fluidity is observed. With the extension of the exposure time, the structural viscosity will decrease even more, but a further increase in shear will not cause a decrease in viscosity, but will lead to destruction of the structure of the cement mortar. Therefore, it is necessary to control the time and energy of the vibration effect on the cement mortar [11].

2.2.1. Laboratory tests. 1. Laboratory of SpetsUBR OJSC (Nizhnevartovsk, 1997). The spreadability index on the cone of the AzNII was: when using the VL-1 vibrator – more than 25 cm; when using a traditional mixer – 23 cm. The strength of cement stone increased by 8%. The experimental results depending on the processing time are presented in table 2. As a result of studies, it was determined that during vibration processing, the spreadability of the mortar increased, but during vibration processing for more than 10 minutes, the spreadability of the mortar decreased.

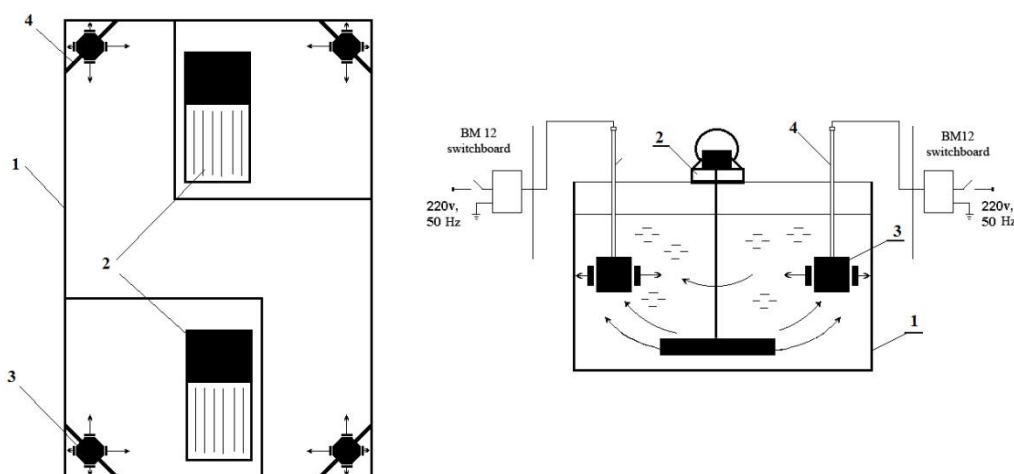
Table 2. Laboratory test results.

Cement mortar	Without vibration processing		Vibration processing time (min)		
	From cement aggregates	From averaging reservoir	10	20	30
Spreadability (cm)	18	23	25	21.5	19.5

2. Laboratory NIPImorneftegaz JV Vietsovpetro (Vung Tau, Socialist Republic of Vietnam, 1997). The cement mortar was prepared using a standard laboratory mixer and a laboratory vibrator VL-1 according to the formulation of the Scientific and Production Company Exbourg & Co. The spreadability of the solution was: when using a vibrator VL-1 – 25.5 cm; when using a standard mixer – 22 cm.

2.2.2. Field tests. NIPImorneftegaz JV Vietsovpetro (Vung Tau, Socialist Republic of Vietnam, 1997). Preparation of cement mortars in the process of completion of well No. 69 on the offshore stationary platform OSP-3, cement slurry LCH (lightweight cement for hot wells). The arrangement of mechanical mixers and VEMA is presented in Figure 4.

The density of the cement mortar is 1.52 g/cm³. The spreadability of the mortar was: when using a VEMA vibrator – 27 cm; when using a standard mixer – 25 cm. It was established that due to the use of VEMA-0.3, stagnant zones disappeared in the averaging reservoir.



1 - averaging reservoir; 2 - mechanical mixers; 3 – VEMA; 4 - vibrator suspension fittings

Figure 4. Scheme of the experiment for the preparation of cement mortar at OSP-3 JV "Vietsovetro".

3. Conclusion

1. The use of VEMA for the preparation of drilling mud significantly reduces the preparation time, reduces the energy intensity of the technological process and significantly reduces the ecotoxicity of flushing fluids.

2. The use of VJMA technology in the process of preparing cement mortars can increase the homogeneity and spreadability (decrease in viscosity) of the mortar while increasing the strength of the cement stone.

3. The time of vibration processing must be selected by the quality of the process fluid or by the amount of energy reported to the medium.

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