DOI: 10.31897/PMI.2018.6.647

UDC 62-133:622.79

DEVELOPMENT OF VIBROACOUSTIC MODULE FOR FINE FILTRATION OF DRILLING MUDS

Gennadii B. FEDOROV, Oleg L. DUDCHENKO, Dmitrii S. KURENKOV
National University of Science and Technology «MISIS», Moscow, Russia

The issue of drilling mud multiple use is problematic. To reuse, the solution must be efficiently cleaned from solid particles according to the class of 0.04-0.07 mm. An analysis of existing technologies and equipment has shown that drilling mud regeneration schemes are rather difficult to operate and expensive. In world practice there has been a tendency to create universal equipment, which allows most complete cleaning cycle for a drilling mud in fine grades.

The paper proposes an innovative vibroacoustic module for cleaning drilling muds from sludge. The creative element of the proposal is the impact of vibroacoustic oscillations on the drilling mud passing through the mesh element. At the same time, specific effects arise around the mesh, which increase the productivity and efficiency of the process. The design of the vibroacoustic apparatus and the principle of its operation are presented. An important element of the proposal is that the oscillation is created by pistons interconnected by rods and located on opposite sides of the mesh. This dipole system provides the excitation of variable pressures of different polarity before the mesh and after it.

The results of industrial tests of the vibroacoustic module when servicing the BU-75-BrE drilling rig are presented. The dependence of the installation performance and efficiency on the amplitude of oscillations was found. The optimal dynamic range of exposure (from 5.5 to 6.5 mm) was determined. Analysis showed that in the composition of the cleaned drilling mud, the maximum particle size of the solid phase did not exceed 0.04 mm. The conducted industrial tests confirmed the possibility of using the vibroacoustic module for cleaning the washing fluid and developing a pit-free drilling technology on its basis.

***Key words*:** vibroacoustic filtering; regeneration of drilling mud; dipole excitation of oscillations

***How to cite this article*:** Fedorov G.B., Dudchenko O.L., Kurenkov D.S. Development of Vibroacoustic Module for Fine Filtration of Drilling Muds. Journal of Mining Institute. 2018. Vol. 234, p. 647-651. DOI: 10.31897/PMI.2018.6.647

Introduction. Currently, there is an urgent need to reuse drilling mud when drilling wells. This is due to the high cost of drilling mud and the complexity of its disposal. For reuse, the solution must be cleaned of solid sludge according to the class of 0.04-0.07 mm. To clean drilling fluids from drilled rocks, vibrating sieves, developed by SWACO Geolograph and Derrick, centrifuges [2-4, 7] and flotation processes [8, 9] are used. For effective cleaning additional equipment is needed. In the Russian drilling practice, a three-stage cleaning system is used, consisting of a vibrating sieve, a battery of hydrocyclone-sand separators, and a battery of hydrocyclone-desilting. However, mentioned schemes for the regeneration of drilling mud are quite complex and expensive to operate.

Statement of the problem. In world practice, the following main optimizing directions of the existing circulating systems have been outlined:

- maximum reduction and simplification of the technological cleaning scheme;
- improving the efficiency and productivity of cleaning in the first stage – vibrosieves;
- the creation of universal equipment, which allows the most complete cleaning of the drilling fluid in fine grades in one processing cycle.

The use of vibroacoustic oscillations for the intensification and efficiency increase of the various technological processes (classification of solid particles, sewage treatment from suspensions, etc.) is known [1, 5, 6]. On the basis of these studies, scientific, technical, and experimental design works were carried out to create technical means for separating polydisperse suspensions using vibroacoustic technologies. One of the directions of these works is the development of multifunctional devices for fine cleaning and degassing of drilling fluids.

Results and discussion. The created vibroacoustic module (VAM) is a fundamentally new type of equipment for cleaning drilling fluids. The principle of module operation is based on the hydroacoustic effect of low-frequency oscillations on the fluid flow. Fluid flow, receiving oscilla-

DOI: 10.31897/PMI.2018.6.647

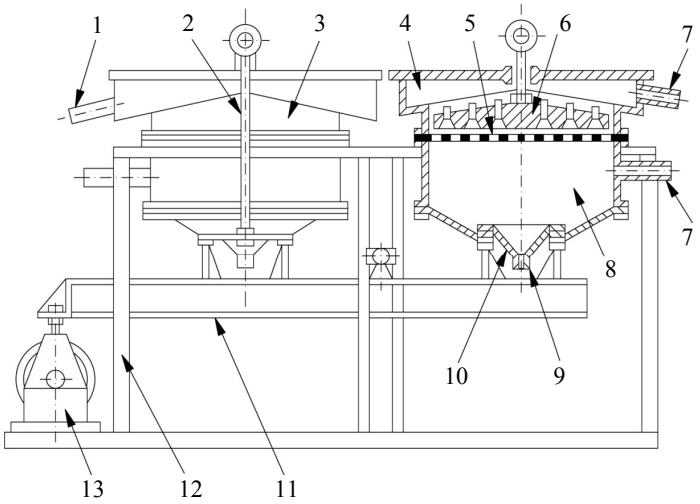

Fig.1. Vibroacoustic module for cleaning of drilling muds

1 – device for removal of the treated product; 2 – rods; 3 – metal case; 4 – treated product chamber: 5 – mesh partition; 6 – piston with holes; 7 – device for pumping the untreated product; 8 – tank for receiving the supply; 9 – a device for removal of the sludge; 10 – a piston in the form of a truncated cone; 11 – rocker; 12 – apparatus frame; 13 – vibration exciter

tion energy, becomes a multifunctional working mechanism, which increases the productivity and efficiency of the process. The whole process of cleaning drilling muds, in contrast to previously developed systems, is carried out in one stage. The schematic diagram of the vibroacoustic apparatus is shown in Fig.1.

The vibroacoustic apparatus has two sections with a common vibration exciter. Each section is made in the form of a metal case, the upper part of which is welded to the frame. Pistons are located at the ends of each section: the top one is flat with a system of holes, the bottom one is in the form of a truncated cone. The pistons are interconnected by rods and connected to the vibration exciter by a rocker. Pistons connected by a rod form a dipole oscillatory system, which excites pressures of different polarity on both sides of the mesh partition.

Each section is divided by a mesh partition into two chambers: the top one – of the fine treated product and the bottom one – of the untreated product inlet. The treated product chamber is equipped with an annular device for removal of the treated product. Receiving chamber has a device for feeding the untreated product. There is also a device for removal of sludge located in the center of the conical piston. Due to the oscillation of the conical piston, the sludge is compacted.

The mesh partition is the main working element of particles separation by size. In the vibroacoustic apparatus, Pyramid Plus meshes by Derrick are used, made of a sandwich-type mesh partition, which is two thin-mesh layers and a matrix of coarse mesh. Three mesh layers, joined together, are graphed and glued to a perforated base. Perforated meshes have a filtration degree of 45-50 microns, it is also possible to use spaltic sieves.

The design of the vibroacoustic module provides for the replacement of the mesh partition when it fails without disassembling the apparatus itself, which results in ease of replacement. The device for removal of sludge in the form of an oscillating truncated piston ensures reliable removal of sludge from the apparatus. Separate elements of the case (upper and lower chambers, partition) are rigidly connected with each other and with the frame of the apparatus. The upper and lower pistons are connected to the case with an elastic membrane. All detachable connections of VAM parts are sealed. The device provides for changing the frequency and amplitude of pistons' oscillation. Adjustment of these parameters ensures reliable operation of the apparatus with various physical and mechanical properties of the drilling mud being cleaned (particle size distribution, density of suspensions, etc.).

The separation process is as follows: after starting the vibration exciter and turning on the auger, the drilling fluid is fed into the receiving chamber of the untreated product, which fills all the chambers. Low-frequency elastic vibrations are excited in the drilling fluid. The effect is exerted from two sides. The drilling mud is divided into sands and cleaned drilling mud. Cleaned solution enters the chamber of the treated product. Sands accumulate in the chamber of the untreated product.

Due to the oscillation of the piston system, the surfaces are regenerated, sediment on them is destroyed, pushing solid particles to the middle of the chamber and transporting them downstream to the sludge removal unit, where the sands are cleaned. Passing through the precipitation plates,

DOI: 10.31897/PMI.2018.6.647

solid particles form a sediment on the bottom of the chamber. Next, the sediment is compacted and removed by the auger. The selected amplitude-frequency characteristic of the filter allowed changing the role of the sieve in the filtering process. The creation of countercurrents pushes the filtration zone itself from the mesh in the direction of the solution midstream. This also increases the service life of the filtrating mesh and the quality of cleaning. The cleaning process itself is a precise linked system, where each subsequent operation following from the previous one and strengthening it.

Industrial tests of the developed VAM. Industrial testing of vibroacoustic module VAM was carried out. For this purpose, drilling rig BU-75-BRE was chosen. The parameters of the drilling fluid at the drilling intervals: the interval of 260-1724 m – natural water suspension; interval of 1724-1826 m – clay mud with a density of 1140 kg/m^3. The flow rate of washing fluid $Q = 0.036$ m^3/s. Drilling was carried out by means of roller bits with a diameter of 215.9 mm, turbine and rotary methods.

The vibroacoustic module VAM was included in the circulating system of the drilling rig BU-75-BRE instead of the block of VS-1 vibrating sieves and hydrocyclone. In the process of drilling, the drilling fluid was supplied to the vibroacoustic module, where it was regenerated. The cleaned drilling fluid was fed back into the well. Dried sludge was removed from the bottom of the apparatus with a discharge auger. The cleaning process was carried out at a pressure drop of 0.3 atm. Mesh partitions with a cleaning class of 0.071 and 0.094 mm were used. In the course of the experiment, the device performance and the cleaning efficiency were measured depending on the oscillation amplitude and frequency. The amplitude of oscillations varied from 2 to 8 mm, and the frequency of oscillations from 10 to 25 Hz. The choice of the frequency range was done due to the fact that the results of preliminary laboratory studies on mud cleaning with a change in frequency from 5 to 100 Hz showed the greatest efficiency of the process in the specified range.

As a criterion of cleaning efficiency, the coefficient of filtration degree was chosen, which was calculated by the formula

$$\varphi = \frac{n_0 - n}{n_0} \cdot 100\ \%,$$

where n_0 and n – mass content of suspensions in the treated and the untreated suspension.

The results of VAM industrial tests are presented in Fig.2, 3.

Obtained results revealed that the performance and cleaning efficiency depend on the amplitude of oscillations. There is a dynamic range of exposure (from 5.5 to 6.5 mm), in which device's parameters are maximum, what corresponds to the highest performance of VAM with a pressure drop of 0.3 atm and using meshes with filtration degree of 45-50 microns. The dependence of these parameters on the frequency in the range of frequency studies was not found. Analyzes showed that maximum size of the solid phase particles in the composition of the cleaned drilling mud did not exceed 0.04 mm. The moisture content of the condensed product was 15-20 %. The presence of maximum cleaning efficiency regarding the amplitude of oscillations is explained as follows. When the amplitudes of oscillations are less than 5.5 mm, the complete

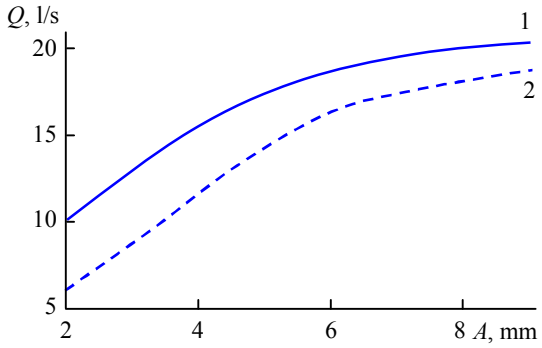

Fig.2. Device performance dependence on the amplitude of oscillations at $f = 15$ Hz
Cleaning class 0,094 (1); 0,071 (2)

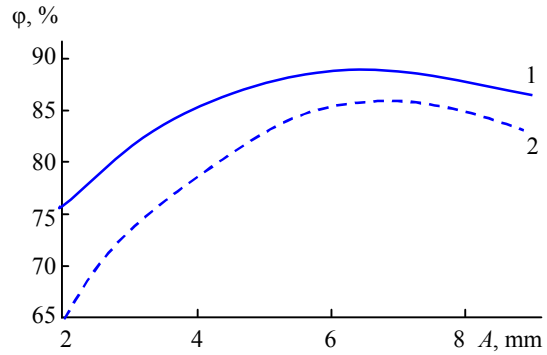

Fig.3. Dependence of cleaning efficiency on the amplitude of oscillations at $f = 15$ Hz и $Q = 20$ l/s
Cleaning class 0,094 (1); 0,071 (2)

DOI: 10.31897/PMI.2018.6.647

destruction of the filter layer does not occur, particles with sizes smaller than filter cells are retained in it. At large amplitudes, not all small particles have time to pass through the filter.

The tests showed that the VAM productivity with a reserve (there was no need for the overflow system) provided the necessary flow rate of the washing fluid (0.036 m^3/s) for the conduction of technological processes associated with drilling wells.

Conducted industrial tests confirmed the possibility of using a vibroacoustic module for cleaning washing fluid and developing on its basis a pit-free drilling technology. Qualitative and quantitative indicators of drilling mud cleaning with the use of VAM correspond to those of a three-stage drilling fluid cleaning technology with a significant (7-10 times) reduction of electricity consumption.

The design of VAM is simple, reliable in work and does not require expensive equipment. According to its technical and economic characteristics, the vibroacoustic module surpasses the best of the well-known three-stage cleaning systems, for example, the company «SWACO». The table shows the characteristics of cleaning by «SWACO» and VAM.

Comparative technical and economic characteristics of «SWACO» and VAM

Parameter	three-stage cleaning system «SWACO»	vibroacoustic module
Flow rate, not less than, m^3/s (l/s)	0.045 (45)	0.045
The smallest particle size removed from drilling mud by 90% or more, m (mm)	0.00005 (0.05)	0.00005 (0.05)
Loss of drilling mud, no more than, % of flow rate	3.0	2.5
Mass, ton	3.5	2.8
Required space, m^2	35	15
Power consumption, kWt/h	50	6.5
Overall cost, thousand USD	150	15
The cost of equipment and technical adjustments annually, thousand USD	20-30	3-4

The vibroacoustic module is 2 tons lighter than the «SWACO» system with the same productivity, it occupies an area of 2.3 times less, and its cost is 10 times lower. The device is structurally simple and reliable in operation. Annual technical adjustments and configurations will cost 10 times less than traditional cleaning system. Vibroacoustic module, intended for cleaning of unweighted drilling fluids from drilled rocks, is a fundamentally new equipment, has obvious advantages compared with traditional schemes and technologies and has no analogues in drilling practice.

Conclusion. The following conclusions can be drawn. The vibroacoustic module is designed for cleaning drilling solutions from solid sludge according to the class of 0.04-0.07 mm and provides:

- high performance and guaranteed cleaning of drilling fluids on sieves and filter materials;
- development and implementation of non-waste technologies;
- effective thickening and utilization of sludge;
- solving problems of cleaning the drilling fluid in one cycle;
- constructive simplicity and reliability in operation.

The use of vibroacoustic technology opens up wide possibilities not only for cleaning drilling fluids, but also for solving a whole range of complex tasks related to fine separation of suspensions, and, first of all, for creating highly efficient local installations for cleaning circulating and mine waters, filtering industrial waste drains.

REFERENCES

1. Agafonov Yu.G., Dudchenko O.L., Fedorov G.B. Infrasound technics and technology – an innovative direction in the intensification of mining processes. *Naukovii visnik natsional'nogo girnichogo universitetu*. 2014. N 2, p. 99-104.

2. Kozlov V.A. The method of calculating the moisture of coal sludge sediment in filter centrifuges. *Ugol'*. 2016. N 6, p. 12-15. DOI: 10.18796/0041-5790-2016-6-12-15

3. Kozlov V.A. The process of dewatering fine coal and coal sludge in filter centrifuges. *Ugol'*. 2016. N 5, p. 91-93. DOI: 10.18796/0041-5790-2016-5-91-93

4. Kozlov V.A. Filtration theory in the application to filtration centrifuges. *Ugol'*. 2016. N 7, p. 76-78. DOI: 10.18796/0041-5790-2016-7-76-78

5. Agafonov J.G., Dudchenko O.L., Fedorov G.B. Infrasonics for intensification of mining practices. Scientific Reports on Resource Issues Innovations in Mineral Resource Value Chains: Geology, Mining, Processing, Economics, Safety, and Environmental Management. Freiberg, 2014. Vol. 1, p. 176-183.

6. Drebenstedt C., Agafonov J.G., Fedorov G.B. Research and development of waste waters vibroacoustic purification methods for mining enterprises. Proc. IMWA. 2016. Mining Meets Water – Conflicts and Solutions, p. 859-866.

7. Chen L., Qian Z., Wen S., Huang S. High-gradient magnetic separation of ultrafine particles with rod matrix. *Mineral Processing and Extractive Metallurgy Review*. 2013. Vol. 34 (5), p. 340-347. DOI: 10.1080/08827508.2012.695304

8. Lima N.P., Valadao G.E.S., Peres A.E.C. Effect of amine and starch dosages on the reverse cationic flotation of iron ore. *Minerals Engineering*. 2013. Vol. 45, p. 80-84. DOI: 10.1016/j.mineng.2013.03.001

9. Boom A.D., Degrez M., Hubaux P., Lucion C. MSWI boiler fly ashes: magnetic separation for material recovery. *Waste Management*. 2011. Vol. 31, p. 1505-1513.

***Authors*: Gennadii B. Fedorov,** *PhD*, *Associate Professor*, *gbfedorov1947@gmail.com* (*National University of Science and Technology «MISIS»*, *Moscow*, *Russia*), **Oleg L. Dudchenko,** *PhD*, *Associate Professor*, *dionis_4444@mail.ru* (*National University of Science and Technology «MISIS»*, *Moscow*, *Russia*), **Dmitrii S. Kurenkov,** *Postgraduate Student, kurenkov@misis.ru* (*National University of Science and Technology «MISIS»*, *Moscow*, *Russia*).

The paper was received on 28 March, *2018.*
The paper was accepted for publication on 18 October, *2018*.