Збірник наукових праць. Галузеве машинобудування, будівництво
Academic journal. Industrial Machine Building, Civil Engineering

http://journals.nupp.edu.ua/znp
https://doi.org/10.26906/znp.2020.55.2354

UDC 622.24

The efficiency increase of equipment work for the cleaning block of washing fluid

Surzhko Tetiana[1], Savyk Vasyl[2]*, Molchanov Petro[3], Kaliuzhnyi Anatoliy[4]

[1] National University «Yuri Kondratyuk Poltava Polytechnic» https://orcid.org/0000-0001-8095-3984
[2] National University «Yuri Kondratyuk Poltava Polytechnic» https://orcid.org/0000-0002-0706-0589
[3] National University «Yuri Kondratyuk Poltava Polytechnic» https://orcid.org/0000-0001-5335-4281
[4] National University «Yuri Kondratyuk Poltava Polytechnic» https://orcid.org/0000-0003-4768-1272
*Corresponding author E-mail: savycvasyl@ukr.net

The efficiency increase of equipment work for the cleaning block of washing fluid by the vibrating sieve modernization has been observed. The approach to the most acceptable values of constructive parameters of vibrating sieve using analytical methods and the usage of the rheological mixture model that allows determining the dynamic and technological characteristics of the vibrating machine and environmental impact on the form board and bottom has been implemented. The influence of the working body (grid) of the vibrating sieve on the rough cleaning of drilling mud from sludge has been investigated. A method for reducing complex hybrid systems to systems with a finite number of freedom degrees has been proposed, and the reduced parameters had the ability to adequately describe the wave processes of a continuous medium.

Keywords: the vibrating sieve, the drilling solution cleaning, the vibration exciter, the drilling solution, the rheological model, the working body, harmonic fluctuations, the resonant mode.

Підвищення ефективності роботи обладнання блоку очищення промивальної рідини

Суржко Т.О.[1], Савик В.М.[2]*, Молчанов П.О.[3], Калюжний А.П.[4]

[1,2,3,4] Національний університет «Полтавська політехніка імені Юрія Кондратюка»
*Адреса для листування E-mail: savycvasyl@ukr.net

Підвищення ефективності роботи обладнання блоку очистки промивальної рідини за рахунок модернізації вібросита. Зведення до найбільш прийнятних значень конструктивні параметри вібраційного сита за допомогою аналітичних методів та застосування реологічної моделі суміші, що дозволяють визначати динамічні та технологічні характеристики вібраційної машини, вплив середовища на борт і дно форми. Виявлено, що вібросита, які використовуються при очистці бурового розчину, конструктивно можуть ефективніше впливати на розчин при контрольованому режимі роботи робочого органу, що дозволить збільшити при цьому інтенсивність дії вібрації. Досліджено, що амплітуда напружень суттєво залежить від фізико-механічних характеристик суміші, частоти і амплітуди коливань, товщини оброблюваного шару і співвідношення частот вимушених і власних коливань системи. Вивчено динаміку роботи вібраційних систем, що представляють собою реологічну модель у вигляді інтегрального суцільного середовища, з урахуванням різних впливів на робочий орган. Досліджено вплив робочого органу (сітки) вібраційного сита на грубу очистку бурового розчину від шламу. Запропоновано метод зведення складних гібридних систем до систем з кінцевим числом ступенів свободи, при цьому редуковані параметри мають здатність адекватно описувати хвильові процеси суцільного середовища. На підставі отриманих результатів дослідження запропонована методика інженерного розрахунку визначення динамічних і конструктивних параметрів вібросит для очистки бурового розчину в насосно-циркуляційній системі бурової установки.

Ключові слова: вібраційне сито, очистка бурового розчину, вібрchoзбуджувач, буровий розчин, реологічна модель, робочий орган, гармонійні коливання, зарезонансний режим

Introduction

The work actuality is based on the importance of providing the high quality of wells drilling process in the oil and gas industry. It highly depends on the characteristics of re-generating systems (sifter-vibrating sieve, centrifuge, cyclones-sand separators, and others). The speed and quality of cleaning the drilling solution are up to constructive specialties of the vibrating sieve. Refining the cleaning drilling characteristics we offer to probe the vibrating sieve construction. Existing constructions have a row of disadvantages – particularly, an underdeveloped knot of imbalances that causes insufficiently qualified cleaning the drilling solution.

During wells drilling the cleaning of drilling solution from a drilled rock is the main operation. On its quality do physical and mechanical solution properties as well as the quality of prepared solution depend. During the rough solution, cleaning has been established that the most widespread way is using vibrating mechanisms of the set.

Cleaning the drilling solution it is actual to apply economic vibrating sieves with spacious fluctuations, for instance, a resonant type. But in existing vibrating sieves in the resonant of fluctuations, there is pulled the whole metal construction accompanied by the drilling solution in [1, 2] that needs big energetic expenditure. The effective mixture sealing is contributed by direct resonant fluctuations of form walls, which are here the active working body. For resonant fluctuations, we need less energy expenditure than for fluctuations of the whole set construction going along with the mixture. So, the development of cassette sets with the active working body is an actual and vital scientific and technical task. The circulating system of drilling sets includes ground devices and buildings that supply the wells washing by continuous circulation of washing fluid along the closed-circuit: pump – downhole – pump. The closed circulation prevents the pollution of natural habitat with drains of washing fluid that contains chemically aggressive and toxic components.

Circulating systems of drilling sets implicate mutually connected devices and buildings that are meant to implement the following functions:

– the preparation of washing liquids,
– the cleaning of washing liquid from drilled rock and other harmful additives,
– the pumping and operating the adjustment of physical and mechanical properties of washing fluid.

The composition of the circulating system includes sucking-in and pressure lines of drilling pumps, capacities to reserve the solution and needed materials for its preparation, gutters, settling tanks, equipment for solution cleaning, controlling-measuring appliances, and others. Circulating systems are mounted on detached blocks, which are involved in the suite of drilling sets. The block principle of manufacturing provides the compactness of the circulating system and eases its montage and technical service.

The most important requirements that are claimed to circulating systems of drilling sets – are the qualitative preparation and control as well as the sustainment necessary composition and physical-mechanic properties of washing fluid for given geological and technical conditions. While sticking to these requirements we can reach high speeds of drilling and forestall accidents and complications in the well.

Review of research sources and publications

The main parameters of a vibrating cleaning regime include the amplitude of vibrating displacements, fluctuations frequency, and time of vibrating influence on drilling solution. It is often the effect of vibrating sealing of mixture that is rated by the product of vibrating displacements amplitude and fluctuations frequency or vibrating displacements amplitude and square of fluctuations frequency, which are the vibrating speed and vibrating acceleration correspondingly [1, 2].

In his studies, V.I. Shmygalsiy [2] stated that the effect of vibrating impact is fully characterized by the criterion "intention of vibration", which is the product of vibrating displacements amplitude square and cube of fluctuations frequency, by the way, the technological effectiveness of vertically directed harmonic fluctuations remains unchangeable during different connection of amplitudes and frequencies if the mentioned product is unchangeable. Also in publications K.O. Olehnovych learning the intention of periodic motion of working bodies for different types of vibrating machines introduced the criterion "specific power of dynamic impact" (p. d. i.). There were theoretical dependencies of the vibrating process, realized experimental studies and done their processing, produced the construction and suggested the rough calculation of cassette vibrating set with the active working body, accomplished the research of the active working body and got with the varied way equation of fluctuations.

These issues are not watched as for vibrating sieves, but their usage will highly raise the efficiency of drilling solution cleaning. Losses of washing liquid rise with the volume increase of drilled rock and liquid leaks while it is cleaning [4-6].

At the bottom and in the open trunk of the well the washing fluid is contaminated by fragments of drilled rock, clay, and solid particles. Excessive containment of solid and rough clay particles in it leads to the decrease of drilling speeds. For example, while the increase of containment of solid phases in the washing fluid is on 1 % the figures of chisels operation decline by 7 – 10 %.

Definition of unsolved aspects of the problem

As a result of the abrasive influence of solid particles there accelerates the wearing-out and relevantly increases the expenditure of pumps, swivels, and downhole motors details. Consequently, there is increased workforce and material expenditures on repair, which impacts negatively on technical-economic figures of drilling. That's why cleaning devices must provide a thorough removal of drilled rock from the washing liquid. The washing fluid of optimal composition does not have to include particles of drilled rock, sand, and mud with the size 5 mkm and more. The admissible capability of cleaning devices must be not less than maximal pump giving.

Among requirements that are claimed to be circulating systems the most important are mechanization and automation of processes to prepare and clean washing fluids.

Problem statement

The tasks of research in this work are the analysis of existing cleaning technologies and the next development of recommendations for the effectiveness assessment of usage in industrial conditions to raise the efficiency of drilling solution cleaning.

Basic material and results

The cleaning of washing fluids is carried on by the way of successive removal of big and tiny fragments of drilled rock and other additives, which are included in the washing fluid that comes from the well. For full cleaning of washing fluids circulating systems are equipped with a complex of cleaning devices. The primary cleaning is done by the vibrating sieves, with the help of which there are done big particles away (with the size of more than 75 mkm). Tine ones are removed with the sand separator (40 mkm), mud separator (25 mkm), and centrifuge (5mkm), which are used in the next stages of cleaning.

The solution must correspond with the following requirements:

– remove destroyed rock to the surface;
– cool and smear a drilling chisel and equipment;
– transmit energy on placement at the bottom of machine and turbine;
– sustain and stabilize well walls;
– create hydrostatic pressure on the layer full of fluid and gas;
– decrease the weight of the pipes due to the effect of buoyancy;
– serve as the habitat while conducting logging;
– warn the disruption of well trunk while turbulent flow or partial dissolution of rocks;
– be compatible with overdrilled rocks and filled with their liquid and gas;
– warn the corrosion of chisel, drilling column, casing pipe, and surface equipment;
– prevent the filtration properties escalation of the productive layer.

The containment of the solid phase in the drilling solution characterizes the clay concentration (3 – 15 %) and weighting material (20 – 60 %). To provide the drilling efficiency (depending on precise geological-technical conditions) the properties of the drilling solution are adjusted by the correlation change of dispersed phase containment and dispersed habitat one and the addition of special materials and chemical reagents to them. To warn the water-oil-gas appearance during anomaly high layer pressures there is increased the density of drilling solution by adding special weighting materials or decreased it by the aeration of drilling solution or addition of foam-generators to it. The containment of the solid phase in the drilling solution is regulated by the three-step system of cleaning on vibrating sieves, sand separators (cyclones), and mud separators (sedimentary centrifuges); gas-like agents are separated in degassers. Besides it, to adjust the containment of solid-phase we add selective flocculants to it.

While being cleaned on vibrating sieves particles of drilled rock are sieved under the impact of vibrations that are arisen by eccentric or inertial vibrators. The most widespread are inertial vibrators, which permit to adjust easily the amplitude of the fluctuations by changing the imbalances position. The vibrator drive consists of electro-machine and V-belt transmission. Particles of washing fluid being bigger than net cells of vibrating sieve anchor on it and are delivered to the dump (the sludge capacity) through the transporting gutter. The cleaning solution having overcome the sieve reaches receiving capacities of the circulating system.

According to the number of vibrating frames there are allocated one-, double and tripled vibrating sieves with one-, two- and three-tier horizontal or incliningly situated sieves. Vibrating frames are set with individual vibrators and equalizers for equal sharing of solution along the width of the sieve. In multi-tier vibrating sieves washing fluid comes from the well to the higher sieve with larger cells and then to lower ones with fewer cells. Consequently, the productivity on the unit of surface increases, and simultaneously, its wearing-out declines.

For washing fluids of high viscosity, the cleaning effectiveness rises during the increase of vibrations amplitude and inclining angle of the sieve. Multi-tier sieves are provided with the device for independent regulation of inclining angle of sieves. To soften hits and protect from big loadings the vibrating frame is hung to the prop frame with the help of spiral springs or rubber shock absorbers. Vibrating frame fluctuations happen along with the closed round or elliptic trajectory. The facing motion of the vibrating frame and washing fluid contributes to the self-cleaning of the sieve. The recovery of permissible capability in vibrating sieves occurs by periodical cleaning of the sieve with water or blowing with cramped air.

The permissible capability and cleaning depth of washing fluid depends on the surface and size of net cells. The biggest surface is on wicker sieves of steel wires or nylon threads. The sieve longevity is up to the wearing-out and corrosion-fatigue tightness of used wires and treads as well as the equality of sieve strain in the vibrating frame. While boosting the thickness of wires there is an increase in their toughness and wearing-out. But, synchronously, there is the decrease of sieve surface and, decently, the permissible capability of the vibrating sieve.

In vibrating sieves there are applied nets with such sizes of cells: 0.16×0.16; 0.2×0.2; 0.25×0.25; 0.4×0.4; 0.9×0.9 mm. While choosing the cell size it is worth considering the necessary stage of cleaning, the permissible capability of vibrating sieve, and density of washing fluid.

The net is attached to the vibrating frame with the help of a cassette or two drums situated at the frame ends. At one end the net is wound with the saving of length, which is used for permission of injured while exploiting fields of the working surface of the net.

The cassette attachment supplies the equal strain of the net in longitudinal and transverse directions. The waving of the working surface in the net and its non-touch connection to the vibrating frame lead to premature injuries. Vibrating sieves allow cleaning fully washing fluids from particles with the size of more than 0.125 mm and removing it to 50 % of the drilled rock.

For widespread vibrating machines with resonant harmonic fluctuations the criterion can be shown in such a way:

$$N_0 = \left(\frac{m_0 r_0}{M_n}\right)^2 \frac{\omega^3}{2\pi} , \quad (1)$$

where m_0r_0 – the static moment of imbalances;
M_n – the got mass of fluctuation system that is the masses total of the working body, form, and some part of the mixture;
ω – the angle speed of fluctuations.

This criterion has an energetic character, is conveniently linked with dynamic and constructive parameters of vibrating-forming machines, and allows to correlate their technological effectiveness at the stage of projecting.

Having multiplied the denominator and numerator of dependence (1) and the angular speed of fluctuations ω and mentioned while it $m_0r_0\omega = F_0$, we have got the correlation of made powers for different frequencies of fluctuations while unchangeable power of dynamic impact

$$\frac{F_{01}}{\omega_1} = \frac{F_{02}}{\omega_2} \quad \text{or} \quad F_{01} = F_{02} = \sqrt{\frac{\omega_2}{\omega_1}} \quad . \quad (2)$$

Shown dependencies (2) demonstrate the advantage of low-frequent fluctuations, which means that having declined the frequency of fluctuations while having the same power of dynamic impact we can get "softer" vibration regimes on record to the made power and amplitude value of vibrating acceleration.

Browsed above criteria of vibration intensity permit considering technological possibilities of the vibrating set, but have not obtained the general and full recognition from scholars and builders.

The development of machine formation has led to the fact that now the vastest are vibrating sets with vertically directed fluctuations with the frequency of fluctuations f = 50 Hz and amplitude A = 0,3 ... 0,7 mm.

Processes, which perform while vibrating, depending on the viscosity of habitat as well as the shape, size, character of the particle's surface, amount of solid phase, and the most important – the value and frequency of impulses that are transmitted by mixture fragments [6, 9].

There has been a row of studies to define the mixture impact on the operation dynamics of the working body in vibrating systems. In publications [25, 26, 50, 63] the accountability of mixture impact on the working body is calculated by the coefficient of connection α, which is up to work parameters of vibrating compeller:

$$M\frac{d^2y}{dt^2} + b\frac{dy}{dt} + Cy = F \quad , \quad (3)$$

where M – the got mass of system vibrating particles that is determined from the dependence:

$$M = M_{st} + M_f + \alpha M_b, \quad (4)$$

where M_{st} – the mass of moving trunk;
M_f – the form mass;
α – the coefficient of connection;
M_b – the mixture mass;
C – the given coefficient of tightness for spring elements;
b – the given coefficient of movement prop of the working body;
F – the made power.

The dependence (3) is right when observing the mixture as the system with focused parameters.

Accounting for the waving fact the definition of fluctuations regimes, which go on in the mixture, is dedicated to publications [1-11], the solution of which is done according to the internal properties of the system.

In the work, there have been learned the spread of waves spring-plastic deformations and defined rheological characteristics of mixture considering tensions of sealing layer. Therefore, the tension that arises in the sealing layer is determined according to the formula:

$$\sigma(x,t) = \rho g(H - x) + \sigma(x)\cdot\sin[\omega(t + \gamma x) - \beta_3], \quad (5)$$

where ρ – the mixture toughness;
g – the acceleration of free fall;
H – the product, which is forming;
x – the current value of height;
$\sigma(x)$ – the amplitude of tensions in the sealing layer;
ω – the frequency of the fluctuations;
t – the current time;
γ – the coefficient of the extra slide;
β_3 – the complex coefficient that includes dynamic parameters of vibrating machine and habitat.

The amplitude of tensions is highly up to physical and mechanical characteristics of the mixture, frequency, fluctuations amplitude, layer thickness, which is being processed, and frequencies correlation between made and own system fluctuations.

The observation of operation dynamics in vibrating systems, which are the rheological model being shown as a one-piece integral environment considering diverse impacts on the working body (harmonic, hitting-vibrating, and poly-phase ones), is given in the publications [1, 2, 10] where there has been offered the method of knowledge between compounded hybrid systems and systems with the eventual number of freedom stages while reductive parameters have the ability to describe adequately waving processes of one-piece habitat.

The equation of the dynamic system "machine-habitat" has the sight:

$$(m + m_b a_1)x + (b + m_b\omega d_1)x + Cx = F\cdot\sin(\omega t), \quad (6)$$

where m – the mass of moving particles;
a_1 and d_1 – coefficients of reactive and active resistance of mixture correspondingly that implicate parameters of waving process and are defined according to the dependence [1, 2]:

$$a_1 = \frac{\alpha \cdot sh2\alpha \cdot h + \beta \cdot \sin 2\beta \cdot h}{h \cdot (\alpha^2 + \beta^2) \cdot \left[ch2\alpha + \cos 2\beta \cdot h\right]}$$
$$d_1 = \frac{\alpha \cdot sin2\beta \cdot h + \beta \cdot sh2\alpha \cdot h}{h \cdot (\alpha^2 + \beta^2) \cdot \left[ch2\alpha + \cos 2\beta \cdot h\right]}, \qquad (7)$$

where h – the height of the mixture layer,
α – the coefficient that defines the extinguishment of the wave,
β – the coefficient that determines the length of the wave.

The dynamic pressure in such a case is defined on record to the formula:

$$\sigma = \rho H X_0 \ \omega_2 \ \alpha_1^2 + d_1^2, \qquad (8)$$

In publications [7, 9, 11] the rheological model of the mixture is shown by the body Shofild-Skott-Bler, which is the successive connection of the models belonged to Bingham and Kelvin:

$$\eta_1\eta_2\gamma + \eta_1\gamma = (\tau - \tau_0) + \left(n_1 + n_2 + \frac{n_2}{\xi}\right)\tau + n_1 n_2, \qquad (9)$$

where n_1, n_2 – the time of relax and time of spring deformation postponement relevantly;
ξ – the dimensionless coefficient of viscosity;
η_1 – the coefficient of real viscosity, which characterizes the flow of mixture sample;
τ – the tangential tension;
τ_0 – the maximal tension of slide.

While $\tau > \tau_0$ the model (9) is like the spring-viscous-plastic body that explains the mechanism of mixture vibration dilution, which allows revealing regularities of switching the last one to diluted state and establish parameters of the dynamic tense state that supply such transmission.

As shown above, rheological models of mixture allow us to define the dynamic and technological characteristics of vibrating machines and environmental impact on the form board and bottom.

The solution of the given task is shown in the publications [3, 11], in which the rheological model is shown as the researched partly-line function and has the sight:

$$\begin{cases} x - \frac{1}{\rho}\left(\frac{d\sigma_x}{dx} + \frac{d\tau_{xy}}{dy}\right) = \frac{dV_x}{dt} + V_x\frac{dV_x}{dx} + V_y\frac{dV_y}{dy}; \\ y - \frac{1}{\rho}\left(\frac{d\tau_{xy}}{dx} + \frac{d\sigma_y}{dy}\right) = \frac{dV_y}{dt} + V_x\frac{dV_y}{dx} + V_y\frac{dV_y}{dy}; \\ \frac{1}{\rho}\left(\frac{d\rho}{dt} + V_x\frac{d\rho}{dx} + V_y\frac{d\rho}{dy}\right) + \frac{dV_x}{dx} + \frac{dV_y}{dy} = 0 \\ \frac{2\tau_{xy}}{\sigma_x - \sigma_y} = \frac{\frac{1}{2}\left(\frac{dV_x}{dy} + \frac{dV_y}{dx}\right) \pm \frac{dV_x}{dx}tg\varphi}{\frac{dV_x}{dx} \mp \frac{1}{2}\left(\frac{dV_x}{dy} + \frac{dV_y}{dx}\right)tg\varphi} \end{cases}, \qquad (10)$$

where x, y – relevant projections of masses powers;
σ, τ – normal and tangential tensions relevantly;
ρ – the toughness of habitat.

The task solution for the vibrating sealing (10) leads to the following: there is the lining with the method of characteristics, then it is shown in a canonical view and solved with the method of ultimate odds. With the help of this method as the result of defining initial and limited conditions, we can observe the whole process of sealing as well as the loadings that influence the machine and form board [3].

Conditionally the process of sealing is divided into several stages. In the publication [7] there is shown the three-step division of the sealing process, while which at the first step there is the intensive convergence of mixture particles and fast air removing that remains between them in an uncompressed state; at the second one there is removed the part of compressed air as the result of cement dough dilution; at the third step, there is the thixotropic dilution of cement dough with the remnants dispersion of compressed air and free water as well as the filling of free space in the form. In the works [7, 8] there have been proposed to pick out the next processes that occur while processing the mixture: at the first one there is the re-compacting of components, at the second stage there appear shells and liquid phase on the surface of big filler and at the last one, there is the compressing cramp of the mixture.

In the work [6] there have been offered to allocate two phases: the first – there is the re-compacting of big components (rubble) and creation of macrostructure and the second includes the deeper thixotropic change in the small dispersed (cement) system and formation of microstructure. This approach bases on the imagination of mixture as a composting material that has macro and micro peculiarities [6].

In the works [6, 12] there is demonstrated the explanation of fluctuations regimes for the mixture. At the first stage, there are recommended fluctuations of low frequency with the big amplitude of fluctuations while overcoming the powers of dry friction clutch in mixture particles. For this, we do not need small amplitudes (1 ... 5 mm) and the acceleration (1,5 ... 3,5) g to subdue the limited tension of the slide depending on habitat properties and sizes of big filler [7, 14]. At the second step, there is the extra sealing, which will go intensively while big thixotropic changes. To dilute the dissolved component there are actual high frequencies or the introduction of plasticized additives.

Using harmonic fluctuations to process mixtures, one or another stage dominates. So, the flow is faster on the first stage with low frequencies and big amplitudes, but during high frequencies and small amplitudes, it is on the contrary (the second one) [7]. This change can be removed by using asymmetric fluctuations regimes that are realized with the frequency of 25 Hz and lower, and big amplitudes, near which there arises a row of high frequencies and small amplitudes. As the result of an asymmetric regime there happens the connection of two stages, which means intensifying the process [1, 6, 9, 10].

During the impact of low-frequent regimes, there is the less intensive dilution of dissolved components. On the other hand, big amplitudes facilitate mutual displacement of particles, and the general time of sealing decreases [6, 12, 13].

For moving mixtures in conditions of low frequencies, powers of viscous resistance will be higher than while middle frequencies, but not important. In studies to find out rational accelerations for diverse frequencies, it has been established that while increasing the vibration frequency we need to raise the high acceleration. Therefore, for frequencies 10 ... 15 Hz the rational acceleration is (1,5 ... 3,0) g, but for frequencies 40 ... 50 Hz it is (3,0 ... 4,0).

While applying moving mixtures it is especially important to remove the stratification. The usage of asymmetric fluctuations regimes with the frequency from 10 to 25 Hz and acceleration in limits of 10-35 m/s2 decreases the stratification at 2 ... 2,5 times for moving and at 3 ... 3,5 ones for very moving mixtures comparing to symmetric regimes of vibrating (f = 50 Hz, A = 0,2 ... 0,5 mm) [6, 8]. While there appears the possibility to use effectively additives and plasticizers, decrease the cement expenditure and decline the noise level and vibration while contracting the sealing regime to 15 ... 30 s [1, 3, 10].

The sealing is functionally dependent on the acceleration that is accepted as one of the main factors, which define this process, which is essential during creating the vibrating set. The fewer values of acceleration and scopes for rational frequencies and amplitudes are, which will allow the highest effect of sealing, the more optimal the vibrating system will be [6, 7, 8]. Besides the acceleration, the efficiency of vibration impact was also rated by the vibrating speed, specific power, intension, and other connections of displacement and fluctuations frequency [1, 3, 6-16].

Conclusions

1. There has been a possibility to increase the efficiency of equipment work for the cleaning block of washing fluid.

2. There have been observed processes happening during the vibration, which are dependent on the environment viscosity.

3. There has been learned the dynamics of vibrating systems work that are the rheological model being shown as a one-piece integral environment.

4. There have been explained the fluctuations regimes for the solution.

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