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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

DEVELOPMENT AND SUBSTANTIATION OF PARAMETERS STIMULATORS OF HIGH-FREQUENCY HYDRODYNAMIC PULSES TO PREVENT COMPLICATIONS WHILE DRILLING WELLS

Speciality: 3313.02 – Machines, equipment and processes

Field of science: Technical sciences

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Baku – 2022

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GENERAL CHARACTERISTICS OF THE WORK

Relevance of the topic. After Azerbaijan gained independence development of its rich energy resources gained importance of state importance.

Realization of these programs set a number of problems before oil-gas industry, the need to solve which increased importance and stimulated extension of drilling activity during the last years.

In this connection stimulation of country fuel and energy complex development with the help of foreign investors and leading western oil companies has become a state policy. It became to master and develop the already explored oilfields in the deep-water part of the Caspian Sea shelf, the task to intensify exploration work both on the Caspian Sea shelf and on land was set, the prospectivity of and the state program of additional development of old land and sea deposits were mentioned.

This can be explained by the state of recoverable hydrocarbon resources in the system of "Azneft", the level of the Republic's own needs to load processing facilities, external obligations to load existing main product pipelines, etc., which requires careful study of all possible reserves to reproduce the mineral and raw material base.

It is necessary to note that restoration of mineral raw-material base could be realized on the basis of potential possibilities of 141 explored structures. Out of this number 113 are discovered structures, 22 structures are prepared for development and opening of drilling works front, where drilling works of different purpose are fulfilled. Thus the activity in the sphere of drilling works is the destiny of the country for a long term perspective and the researches aimed at raising their productivity will keep their relevance in the foreseeable future. In the nearest future taking into consideration the planned scope of drilling works in the fields of the national sector of the Caspian Sea the necessity of intensification, risk reduction, hence part of non-productive time of drilling programs and reduction of drilling cost in well construction becomes evident.

The cost of drilling works is determined by many factors of organizational, technical, technological, inn vesting and other nature.

Consequently, modernization of technical equipment, technological support and servicing of drilling works is an integral part of this program implementation.

One of the main tasks on the way of drilling works cost reduction, which are determined by many factors of organizational, technical, technological and investment nature, etc., is to improve the technological base of the drilling works. The main objective of drilling works is to improve their technical and technological support in order to decrease risks by preventing complications by means of research of complex influence of drilling modes on rock destruction process, drilling fluid parameters and compounding on drilling parameters and well development indexes.

One of such important factors is preservation of natural protectability of productive formations in technological processes of well construction, starting from initial drilling-in up to its workover[1]. Till now this component of the drilling programs is an acute problem despite the extreme need to solve this problem as well productivity of a well directly depends on it[2].

In the present dissertation on the basis of earlier works, carried out by the following specialists and scientists from different countries, such as F.A. Agzamov, M.M. Alexandrov, Angelopulo O.A., Bulatov A.I., Buslaev V.F., Gaivoron I.N., Gorodnov V.D., Zheltov Y.P., Koshelev A.T., Koshelev V.N., Krylov V.I., Krysin N.I., Kuznetsov Y.S., Mavlyutov M.R, Mirzajanzade A.H., Ovchinnikov V.P., Penkov A.I., Polyakov V.N., Potapov A.G., Ovtanatov G.T., Oganov A.S., Oganov G.S., Avetov R.V., Yasashin A.M., Sherstnev N.M., Rukavitsin V.N., Riabokon S.A, Sidorovsky A.M., Shurov V.N., Vadetsky Y.V., Dedusenko G.D., Kister E.G., Lipkes N.M., Sharipov A.U., Yagafarov R.G., Nigmatulina A.G., Tataurov V.G., Lugumanov M.G., Natsepinskaya A.M, Zozulya V.P.,

[1] Omelyanyuk M.V. Study of cavitation-outflow processes for energy-saving and environmental numerical technologies of oil and gas OTR, Moscow, 2021, p.129.

[2] Dolgikh L.N. Fixing, testing and development of oil and gas wells, Perm, 2009, p. 272.

Lushneeva O.A., Kostyanov V.M., Ganeyev R.F., Sannikov R.H., Akhmetshin E.A., Saltykov V.V., Galiagbarov V.F., Gilmashin I.G., Ahrens T.Y., Anderson A., Astrella L.A., Churchwell R., Dawies G.E, Behrmann L.A., Daneshy A.A., Bell V.T., Bihop S.R., Bond A.Y., Esk M.E., Halleck R.M., Mead D.A., Grames D.B., Grusbeck C.E., Hinds A.A., Pow- ter C.B., Stii-well C.T., Warpinski N.R., Webster G.A., Whit D.T., Huber K.Y., Collins R.E., Sausier R.Y., Karakas M., King G.E., Tarig S., Person C.M., Shmidt H.P., Santerelly F.Y., Outfel H., Zandel Y.P., Zimmerman P.K. and others presented the studies permitting to realize the drilling programs by means of efficient drilling, development and further exploitation of wells without complications and accidents in mountainous geological conditions of Baku and Absheron archipelagos.

The above-said confirms the relevance of the tasks and studies for the country's fuel and energy complex, and the results obtained and the recommended developments can be discussed for use in the practice of drilling by foreign, joint and national companies.

The object and the subject of the study. The object of the study is to improve the efficiency of the primary development of the drilling well.

The subject of the research:

1) development of methods of impact on the near-wellbore space;

2) Studying the methods for restoration of filtration-cost properties of the near-wellbore space;

3) development of technical means for realization of the primary well development;

4) Research of experimental characteristics, design of equipment for well completion and taking decisions for their performance improvement;

5) study of various technological options and appropriate downhole arrangements to prevent complications in the process of well development after drilling

Objectives and tasks of the research. The purpose of the research is to develop scientific foundations and practical methods of

technical and technological research to ensure efficient well drilling, development and subsequent operation without complications and accidents in mountainous-geological conditions of Baku and Absheron archipelagos.

In order to achieve this objective the following list of tasks has been presented in the dissertation work and is put forward for protection:

To estimate technological conditions in a well that contribute to complications during drilling jobs the problem of studying manifestation of relaxation phenomena in disperse systems (soils) to the class of which drilling circulating fluids are also assigned.

Study of relaxation phenomena in drilling muds as a result of their non-equilibrium for providing the implementation of pulling operations without the probability of gas slugs in the wellbore.

Working out the hydraulic way of preventing complications in the well on the basis of forecasting characteristics of possible bifurcations in the behavior of drilling mud with nonequilibrium-disperse and invert structure during the drilling process.

Development of the device for regulation of hydrodynamic influence on rocks of the near-wellbore area which makes it possible to improve hydrodynamic connection in the system "well - formation" for existing technological options realized by various downhole assemblies of drilling tools.

Experimental studies to assess the range of hydrodynamic oscillations of the fluid (P_2), their frequency (f) and vibration loads on the borehole section walls (nz_3) and specification of constructive features of exciters, which ensure filtration-capacitative properties restoration of near-wellbore space rocks.

Optimization of design characteristics of the hydrodynamic cavitation excitation node, namely determination of the required length, diameter of inlet and outlet sections (and their ratio) of its diffuser chamber. Development of an optimization model to simulate various hydraulic programs and make decisions on the exciter chambers design.

Development of optimization model for determination of pressure at the cavitation shock wave front, which is stimulated by cavi-

tation bubbles collapse for certain design of cavitation chamber and rheological properties of the pumped liquid, providing absence of complications on the wellbore walls and improvement of FES of the near-wellbore space during the process of its primary development.

Development of a recipe for a special drilling circulating fluid on the basis of new additives with the use of local natural, industrial and/or agricultural raw materials for implementation of the program of beefing up the space around the wellbore during drilling and at the stage of its primary development, As well as an estimation of their effectiveness in various recipes according to the certification and conformity to the requirements of the technological processes.

Improvement of the device for implementation of the technology "Drilling under Manipulated Pressure" (PMD), which enables to realize an automatic oscillating mode of pressure control to prevent downhole technological complications in various drilling regimes.

Creation of the technology of detecting inter-well flow rates of hydraulic fluid, which makes it possible to adjust water flooding projects for maintenance of the internal surface pressure.

Development of a device for running the tailing string for coating the pay zone, which allows to perform suffusion of colmatized borehole zone and thereby restore its fluid content and increase the efficiency of the borehole construction process and the stage of its primary development.

To develop, implement and estimate the economic efficiency of scientific and methodological support of regulations on constructing drilling wells and their development with different structural and technological designs by testing on SOCAR production sites.

Research methods. Experimental method, method of experimental data processing and logical method of information analysis, decision-making theory methods in definite, probable and uncertain conditions, mathematical optimization theory and different methods of mathematical physics problems solution have been used for the solution of the tasks.

The thesis statements which have been put to protection:

– Development of methods of influence on the near-wellbore space;

– Study of methods for restoring filtration capacitive properties of the near-wellbore space;

– Development of technical means for implementation of the primary well development;

– Research of experimental characteristics, design of equipment for the well development and taking decisions to improve their performance;

– Study of various technological options and corresponding downhole arrangements for preventing complications in the process of well development after drilling.

Research methods. Experimental method, method of experimental data processing, logical method of information analysis, decision-making theory methods in definite, probable and indefinite conditions, mathematical optimization theory, different methods of mathematical physics problems solution have been used for the solution of the above tasks.

Scientific novelty of the research. Taking into account the fact that according to the field statistical data by various oil and gas regions more than 10% of wells are out of operation due to the formation of the bottomhole zone and more than 16% have a significantly lower flow rate than their potential. Theses are aimed at the development of technical and technological measures to make decisions aimed at creating methods for the effective restoration of operational well characteristics which are of great scientific and practical importance for the industry. Ways of controlling the well hydrodynamic situation and stimulating this phenomenon by means of devices ensuring their geographical position in the necessary diapasons at the areas of the productive horizon with low petrophysical properties at the stage of drilling works and implementation of measures for their primary development have been worked out.

Scientific and practical significance of the research.

The scientific significance of the research boils down to the following:

1. Predictive characteristics of possible bifurcations in dynamic behavior of drilling mud with nonequilibrium-disperse and invert structure allow estimating fluctuations and their properties relaxation

manifestation, as a whole hydrodynamic well situation during drilling works and measures realization on primary development of productive horizon.

2. There has been developed a device for the drilling tools configuration to realize hydrodynamic influence on the near-wellbore space rocks in existing technological options of drilling works and implementation of measures for the primary development of productive horizon.

3. The solving rules developed on the basis of theoretical and experimental researches allow to determine the possibilities of vibroimpacts creation on the rocks of the near-wellbore area and can be used for designing of the compatibility of drilling works with the existing technological variants. These rules allow to define the possibilities to create vibration effects on rocks around the wellbore area and can be used for design of compatible combinations of technical and technological stimulators for various technological schemes of drilling works and implementation of measures on primary development of the productive layer.

4. The developed model of optimization of constructive parameters compatible with the steering cylinder metric properties allows to design the required combinations of hydraulic generators for various hydraulic programs.

5. According to optimization procedure of dynamic programming the problem of optimization of pressure at the cavitation shock wave front stimulated by cavitation bubbles collapse has been solved for design of cavitation chamber structure and rheological properties of processed liquid, to ensure the absence of complications on the wellbore walls and improvement of filtration-capacitive properties of the near-wellbore space in the process of its primary development.

6. The formula of the special drilling flushing fluid for realization of the program on suffusion for primary well development of the ringed near-well space in the processes of drilling works and implementation of measures for primary development of the productive horizon on the basis of new additives using local natural, industrial and/or agricultural raw materials has been developed.

7. The technology of detecting inter-well fluid flows of injection wells in the pulled-out formation zone by means of analysis of production wellhead on the basis of their resonance activity signals has been created and worked out.

Practical importance of the research can be explained by the following conclusions:

1. The received characteristics of hydrodynamic well formation are used in working out of programs on realizing round-trip operations, which reduce the probability of complications during drilling works and carrying out activities on primary development of productive horizon.

2. The possibility to stimulate hydrodynamic influence on the near-wellbore rocks allows ensuring the quality hydrodynamic system of the well - formation.

3. The impact on the rocks of the space around the borehole by the vibration loading using the hydrodynamic oscillations stimulators with the matching parameters can be used in various technological schemes to make decisions on the restoration of filtration-capacitive characteristics of the well - reservoir system.

4. The possibility of optimizing the pressure at the shock wave front, excited by collapsing cavitation-cavitation bubbles, depending on the well design and physical, mechanical and rheological properties of the drilling mud allows to provide and significantly increase the efficiency of well operation after development due to quality suflation of collimated borehole space in the process of drilling operations.

5. The evaluation of different drilling mud formulations in the presence of the offered component element has shown the efficiency of its use in different formulations in terms of its attestation characteristics and correspondence to the requirements of technological processes, which has confirmed their high potential for the oil and gas fields.

6. A device has been developed for carrying out drilling operations in different modes by means of maintaining control pressure in auto-collector mode, which is necessary for realization of technology

"Drilling under Controlled Pressure" (DCP) and prevention of possibility of wellbore technogenic complications.

7. The technology of interwell detection of fluid overflows allows evaluating the scanned hydrodynamic background and making decisions on improving the FES of the developed field and adjusting water flooding projects for maintaining the in-situ pressure.

8. A device for lowering the tailing string into the productive horizon zone has been developed, which allows to conduct suffosion of the annulus bottomhole zone and thereby guarantee the quality and efficiency of the wellbore construction process.

Publication, approbation and application of the thesis. In total there have been published 14 scientific works on the subject of the thesis, of which 8 scientific articles, 3 local and international conferences 3 patents. Materials of dissertation have been presented at the international scientific conference "Breaking and metal-working tools - equipment and technology of their manufacture and application" (Kiev, 2019), at XLVII International scientific and practical conference "Fundamental and applied scientific research: Actual issues, achievements and innovations" (Penza, 2021) and at the III International Scientific Conference of Students and Young Scientists on "Oil-gas geology and engineering" dedicated to the 98th anniversary of national leader Heydar Aliyev (Baku, 2022).

The research was conducted in the trust of the “SOCAR-KBR” MMC. Real ecological and economic effect of 45 thousand manats was gained as a result of the measures carried out and the estimated annual ecological and economic effect amounted to 1.5 million manats. Corresponding acts for realization of measures in this regard were made and approved by the management of KBR trust.

Name of the institution where the dissertation work was carried out. Dissertation work was carried out at the department of "Mechanics" of the Azerbaijan State University of Oil and Industry and in the trust of the “SOCAR-KBR” MMC.

The structure and volume of the dissertation. The dissertation consists of 170 pages, an introduction, 5 chapters, including 7 tables, 29 figures and 23 graphs, a reference list of 156 titles, and 211,093 characters without tables, figures and reference list.

MAIN CONTENT OF THE WORK

In the introduction on experience of drilling works in different regions of the world the doctrine of Azerbaijan on development of its fuel and energy complex aimed at reducing the cost of development of onshore and offshore reserves with participation of target foreign operating and service companies-investors is substantiated.

The first chapter is devoted to the studying of prospects of increase of drilling works volume and increase of efficiency and profitability of their realization on land and sea fields considering the level of their development. For this purpose the current state of raw materials base and increase of oil production in the fields of Azerbaijan due to drilling of new wells have been considered, the anthropogenic hazards of drilling works process have been estimated, a classifier of possible complications at development of these fields by drilling has been worked out and the range of necessary measures to prevent them has been determined. The list of research works is defined according to these directions.

The second chapter is devoted to the influence of hydrodynamic behavior of drilling fluids on possible complications taking into account hydrodynamic conditions being a consequence of drilling fluids with the unequal weight-dispersed and inverted structure used in the process of well construction. Here in this connection in order to estimate the borehole hydraulic condition created by pumping of these drilling agents for drilling works their relaxation properties have been studied. There has been studied the phenomenon of "overlapping" in hydrodynamics of drilling mud with similar structural characteristics during well bore drilling and their influence on the effectiveness of round-trip operations.

The third chapter is devoted to the analysis and improvement of the ways to increase the efficiency of the first stage of well development after drilling by influence on its walls by non-stationary hydrodynamic fields. The possibility of creation of non-stationary hydrodynamic field in the near-wellbore space by stimulating the disruptive cavitation aimed at inflow recovery and putting the well into operation has been considered as one of the above directions. To

control the colmatation process by regulating the action (hydro mechanical, physicochemical and other) in the near-wellbore area. For the existing technological options there is a device designed for the existing technological options that can be realized by assembling the tools, including a hydraulic motor bit, a device for jet treatment of the wellbore area by a hydraulic cavitation stimulator, drilling pipes and a hydrodynamic cavitation tool. Compared with other devices designed for reproducing hydrodynamic cavitation the developed device has a number of advantages the main of which are simplicity of its operation and possibility of regulating the treatment process due to the absence of moving assemblies and details, rubber cup parts, which can wear out in the process of operation. The cavitation generator installed to the flushing nozzle uses the flushing fluid energy that is fed to the treatment area and transforms a stationary flow into a discrete pulse and creates high-frequency vibration accelerations in the supplied flow of fluid that affect the borehole walls in the treatment area.

To define the "range" values ($P_2 = P_{2max} - P_{2min}$) and frequencies of oscillations and vibration loads created by the hydrodynamic generator at the designed unit set up at the Logistics Department of SOCAR's KDB Trust, the experimental researches have been made (Fig.1).

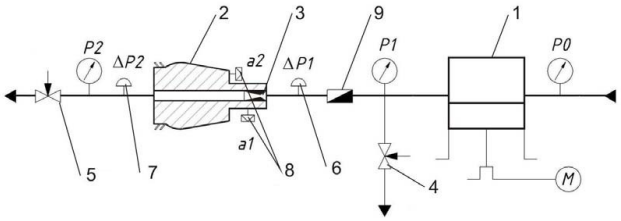


Fig.1. Schematic diagram of the hydraulic bench for testing for determination of hydrodynamic vibrator characteristics:
1 – pump; 2 – nozzle; 3 – cavitation generator;
4 and 5 – chokes; 6 and 7 – pulsation sensors;
8 – vibration acceleration sensor; 9 – flow meter

Pumping unit 1 with maximum pressure of 50 MPa, consumption rate of 26 l/min and electric motor power of 30 kW was the

source of high pressure. The technological liquid (water) through the high pressure hose through the turbine sensor of the liquid flow into the cavitation generator 3 and through the central channel of the nozzle 2 and the backwater choke 5 was discharged into the tank.

As a result of experimental research the dependencies of cavitation oscillations range P_2, their frequency f and vibro-load to the wellbore walls nz_3 on the ratio of average pressure P_2/P_1 for supply pressures P_1 = 5 MPa and P_1 = 10 MPa have been determined according to the results of the experimental studies and they are shown in Table 1 (Fig. 2):

Table 1

Results of experimental studies

P_i, MPa	P_2/P_1	P_2, MPa	f, Hs	nz_3, ms^{-2}
$P_1 = 5$	0.2	14.0	1400	16.0
	0.4	9.5	900	10.0
	0.6	4.0	400	5.0
	0.7	1.0	200	3.0
$P_1 = 10$	0.2	25.0	2400	27.0
	0.4	17.0	1800	18.0
	0.6	6.0	600	9.0
	0.7	2.0	150	6.0

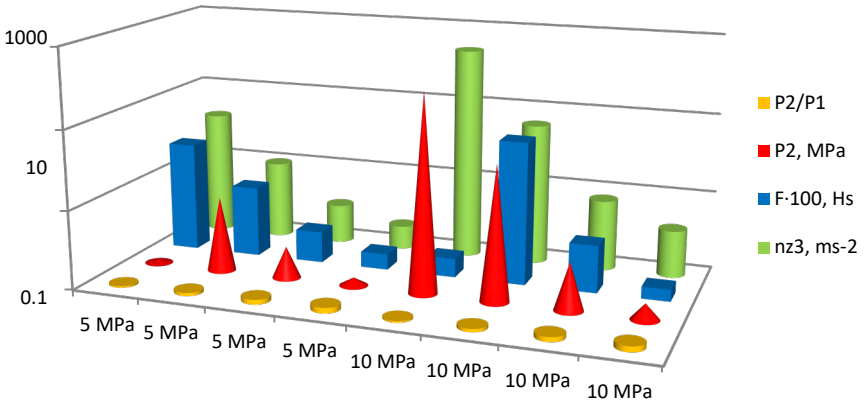


Fig.2. Results of experimental graphical representation (scale is logarithmic)

The fourth chapter is devoted to optimization of constructive characteristics of the hydrodynamic cavitation excitation node, namely determination of the required length and diameter of inlet and outlet sections (and their correlation) of the difuser chamber of the hydrodynamic exciter, where resistance forces are unknown at the initial stage and are determined by the optimum control method. With this purpose the problem of determination of an optimum function $F = \psi(T)$ at $0 \le t \le T$ providing uniform velocity change along the length of the nozzle **at the minimum losses** of hydraulic power has been set:

$$m\frac{d\upsilon}{dt} = p(t)F(t), \qquad p(t) = \frac{Q^2\gamma}{2g\omega^2F^2(t)}, \tag{1}$$

where m – mass of liquid inside the nozzle; υ – flow speed of the jet in the current point of the nozzle; $F(t)$ – current area of the nozzle channel; Q – flow rate of circulating liquid; γ – specific weight of flushing liquid; ω – flow coefficient.

According to the optimality condition

$$\frac{dx_1}{dt} = \frac{1}{m}p(t)F(t) = f_1,$$
$$\frac{dx_0}{dt} = k_1x_2^1 + k_2F^2(t) = f_\circ \tag{2}$$

and the procedure of Pontryagin's optimization method, referred to as the "maximax principle," the Hamiltonian is compiled:

$$H = \sum_{i=1}^{n}\psi_i f_i; \qquad H = -\left(k_1x^2 + k_2F_{(t)}^2\right) + \psi_1\frac{Q^2\gamma}{2gm\omega^2}F(t). \tag{3}$$

Converting (3) and using the following boundary conditions (4)

$$\upsilon(t=0) = \upsilon_0, \qquad F(t=0) = F_0$$
$$\upsilon(t=T) = \upsilon_{\text{out}}, \qquad F(t=T) = F_{\text{out}}, \tag{4}$$

The friction forces at the inlet and outlet of the channel are defined as

$$F(t) = \frac{F_0F_{\text{out}}shBT}{F_{\text{вых}}shBTchBt + F_0shBT - F_{\text{out}}shBtchBT},$$
$$\upsilon(t) = \upsilon_0(chBt - chtBTshBt) + \frac{shBt}{shBT}\upsilon_{\text{out}} \tag{5}$$

Using the theorem of change of motion of liquid along the length of the nozzle and the boundary condition $T_y(t = T) = 1$ to determine its length, the following expression is obtained

$$l = \left(shBT - \frac{ch^2 BT}{shBT} \right) \frac{F_{out} \upsilon_{in}}{F_0 B} + \frac{\upsilon_{out} chBT}{BshBt} + \\ + \frac{F_{out} \upsilon_{in}}{BF_0} chBT - \frac{\upsilon_{out}}{BshBT}. \quad (6)$$

$$F(t) = \frac{\left(2\omega^2 Q - \upsilon_{out} F_{out}\right) F_{out} shBT}{2\omega^2 QshBt + \upsilon_{out} F_{out} [shB(T-t) - shBt}, \quad (7)$$

$$\upsilon(t) = \left(chBt - shBtcthBT\right) \frac{F_{out} \upsilon_{out}}{F_0} + \upsilon_{out} \frac{shBt}{shBT}. \quad (8)$$

The expression (7) is a profile of longitudinal section of the nozzle. Velocity changes in any section of the nozzle are determined by formula (8). The results of calculation by formulas (7) and (8) for certain cases (Q = 0,04 m^3/h; F_{out} = 6,410-3 m^2; B = 198 s^{-1}; υ_{out} = 70 m/s) are presented on Fig.3. Therefore, to ensure minimum values of local resistance and maximum flow coefficient (ω = 1) the optimum nozzle profiles are set[3,4].

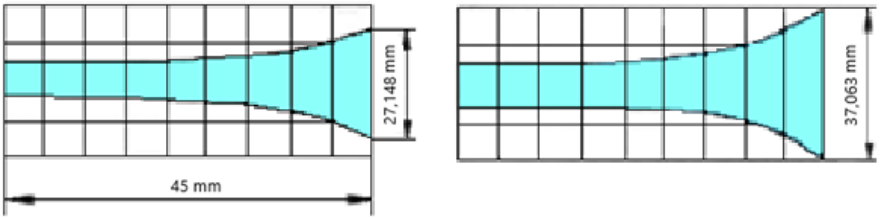


Fig. 3. Nozzle profiles at the flow coefficient ω:
a) ω = 1; b) ω = 0.75

It follows from the picture that if the nozzle length is 45 mm, the inlet diameter of the nozzle profile starts increasing in the middle of the nozzle and its outlet size increases approximately 2.5÷3 times

[3] Al-Hameedi A.T., Alkinani H.H., Dunn-Norman et al. Using Machine Learning to Predict Lost Circulation in the Rumaila Field, Australia, 2018.

[4] Longde S. Development characteristics and orientation of tight oil and gas in China, 2019, 46 (6), – p.1073-1087.

or more. It means that the diffusor chamber length can be taken as being within 30 mm and the inlet and outlet diameters d_{out}/d_{in} should have the correlation of 2.5÷3. These parameters can be changed for the other hydraulic program.

This chapter also considers the problem of determining the magnitude of the hydraulic shock at the shock wave front, which is caused by the hydrodynamic stimulator.

The process of hydrodynamic cavitation treatment of near-wellbore space in the process of primary development is realized by a special device – hydrodynamic cavitator due to directed and regulated conversion of potential and kinetic energy of liquid flow, forcibly pumped by the hydraulic pump through the cavitator diffusor chamber. Occurrence and support of the process of forming gas or gas vapor cavitation bubbles (caverns) in special areas of hydrodynamic cavitator, which close (collapse) as a result of increase of local hydrostatic pressure in liquid is the consequence of mentioned energy transformation. Closing of cavitation bubbles is corresponded by intensive shock wave processes with appearance of local zones of extremely high thermobaric parameters (hundreds of thousands atmospheres and ^{0}C, accordingly) and cumulative impact action on the nearby areas of liquid surrounding their zone of collapse.

Heat and mass transfer processes accompanying cavitation as well as jet currents occurring further along the liquid flow contribute to intensive cleaning of the wellbore space. High-hours hydrodynamic influence is made by the device of special construction that provokes cavitation phenomenon. Cavitator is lowered into the wellbore using drill pipes and its body has special inserts that stimulate periodically disruptive cavitation thus creating hydraulic loads on the wellbore walls and favorable conditions for bottomhole zone cleaning due to the improvement of hydraulic conductivity of rocks composing the zone.

Implementation of such programs in real time and processing time for each interval depends on the specific conditions and purpose of the well, namely for production wells – their production capacity, and for injection wells – their injectivity. That is why the state of bottomhole zone for the period of cavitation treatment is very important. That requires geophysical surveys for evaluation of filtration-volu-

metric properties (FVP) of rocks in bottomhole zone.

General view of the design of the vibration generator (structural design) is shown below, which includes three structural elements:

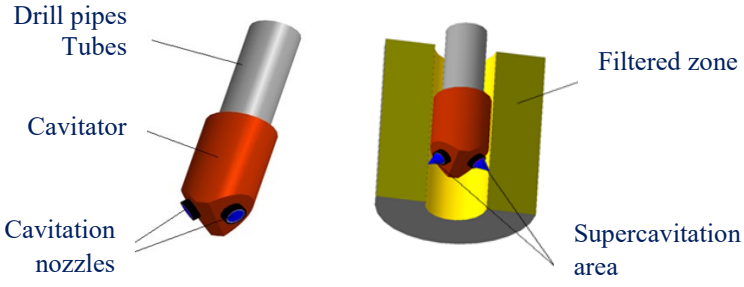


Fig.4. Structural piping (*a*) and arrangement (*b*) in the pipeline of the generator with cavitation nozzles

During periodic disruptive cavitation wave propagation of hydrodynamic oscillations occurs according to the Markov process represented by the biological process of birth, multiplication and death. The process of birth is the emergence of gas bubble, the process of reproduction is the process of bubble increase and their separation, the process of death is the process of bubble collapse (Fig.5*b*)

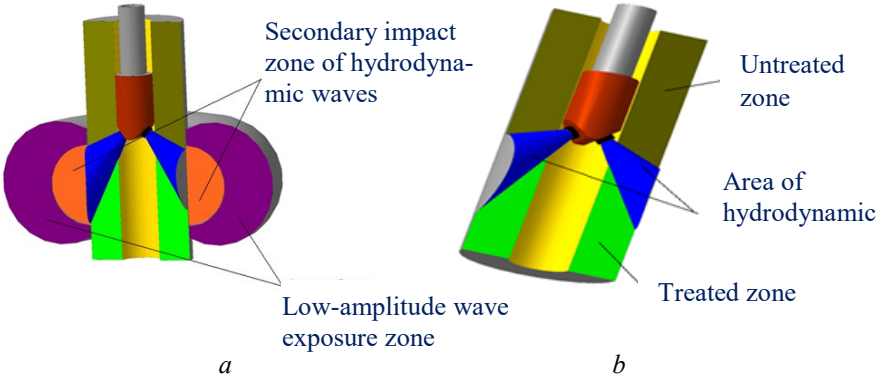


Fig.5. Location of the treated and untreated sections of the borehole, separated by the area of hydrodynamic cavitation (*a*) and scheme of the wave propagation zones from periodic disruptive cavitation (*b*)

In order to avoid damage to the integrity of the pump piping, the capacity should be increased gradually, while observing the pressure on the manometer.

When the working agent flows from the elevator pipeline into the cavitator body through the cavitation nozzles, the treated area of the borehole wall under the bubbles collapse experiences loads in the form of shock waves from the liquid, which have the property of being short-term (due to their death) and repeated many times (due to their multiplication) and their influence on the borehole wall becomes smaller with every other borehole wave and in some time completely dies out. In the absence of control over the size of the excited shocks (as the results of the bench tests showed) the damage of the borehole walls and their hydrofracturing take place, which leads to the absorption of drilling mud and deterioration of rocks FVP. Therefore when creating the exciter design the possibility of shock loads which do not damage the integrity of the borehole bottom part is of a great importance. It should be noted that the preservation of the integrity of the borehole bottom part during the excitation of shock loads is determined not only by the size of the acting load, but also by the speed of its application, i.e. the so-called specific impulse, which is determined by

$$i = \int_0^{t_{\max}} P_{\max} dt \tag{9}$$

where t – specific impulse; $t_{\max}$ – shockwave time; $P_{\max}$ – shockwave pressure.

The load from the shockwave pressure with a certain rate of its application, acting on the column of drilling fluid, contributes to deformations with a certain rate of the borehole section, created by cavitation bubbles in the column of drilling fluid, which is determined from the following relationship, which includes the shockwave pressure:

$$u = \sum \frac{P_{\text{sh.w}}}{\rho_{\text{d.f.c.}} D_0} \tag{10}$$

where $P_{\text{sh.w}}$ – pressure at the shock wave front; $\rho_{\text{d.f.c.}}$ – mass density

of the drilling fluid column during shock wave passage; D_0 – velocity of shock wave propagation in the drilling fluid column.

Therefore it is possible to minimize possible deformations created by cavitation bubbles in a column of drilling fluid and ensure the absence of complications on the borehole walls by controlling the pressure of the wave (this can be done by selection of corresponding parameters of cavitation chamber design and rheological properties of the fluid). For this purpose the following task is set.

It is required to find the minimum deformation velocity of the wellbore walls when cavitation formation is excited:

$$J = \int_0^{t_{\max}} u dt$$

or the same thing

$$J = \int_0^{t_{\max}} \sum \frac{P_{\text{sh.w}} dt}{\rho_{\text{d.f.c.}} D_0} \qquad (11)$$

for the shock wave action time under the restriction, in the form of partial differential equations, which are the equations of motion of an incompressible fluid in the Euler formula[5]:

$$\frac{d\upsilon}{dt} + \upsilon \frac{dP}{dt} = -\frac{1}{\rho_0}\frac{dP}{dr}; \quad r\frac{d\upsilon}{dr} + 2\upsilon = 0, \qquad (12)$$

where ρ_0 – the density of the working agent of the exciter; P, υ – respectively, the pressure and mass velocity of the liquid.

This system of equations is transformed into a system of differential equations of the I-st order with the following notations of the form:

$$z_1 = \upsilon; \qquad \frac{dz_1}{dr} = z_2; \quad \left(= \frac{d\upsilon}{dr}\right)$$

$$\frac{dz_1}{dt} = -z_1 z_2 \left(1 + \frac{2k}{\rho_0}\right). \quad \left(= \frac{d\upsilon}{dt}\right)$$

[5] Nyunyaykin V.N. Regulation of filtration characteristics of rocks in the near-bottom zone at the late stage of field development, 2002, p.44-45.

In view of the obtained dependences the task of pressure optimization at the shock wave front stimulated by cavitation bubbles collapse was set and solved by the dynamic programming method, for which the Bellman functional equations were composed[6]:

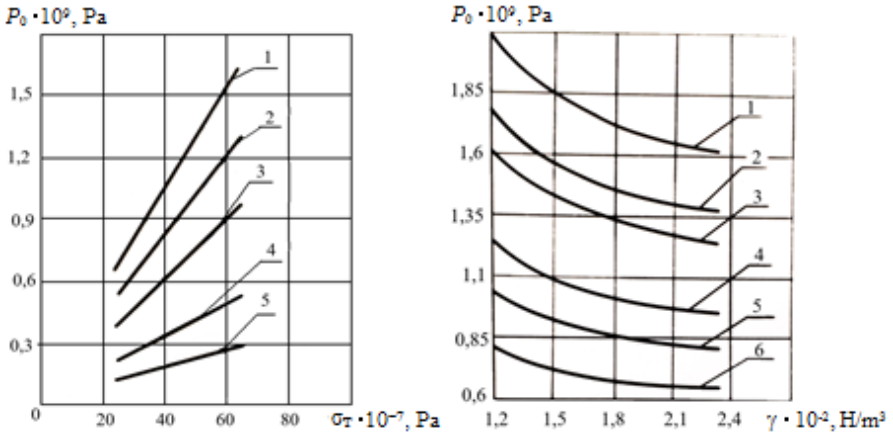
$$V + \sum_{i=1}^{n} f_i(x, z_1) \frac{dS}{dz_i} = 0\,;$$

$$\frac{dV}{dz_1} + \sum_{i=1}^{n} \frac{f_i(x, z_1)}{dz_1} \frac{dS}{dz_i} = 0,$$

whose solution allowed us to obtain the following expression:

$$(P_{max})_0 = \frac{2}{\sqrt{3}} \frac{r_1}{r_0}^{\frac{8\rho_0}{k}} \frac{k\sigma_T r_1 exp[-\alpha(r_1 - r_2)]}{8\eta\rho_0 r_2}\,. \qquad (13)$$

The resulting equation (13) allows us to choose such a cavity nozzle, in which by pumping flushing fluid through it the improvement of FVP of bottomhole zone will be ensured.



a *b*

Fig.6. Dependence of $(P_{max})_0$ on mud column height (σ_T) and rock strength (γ) (b)

[6] Orekhov V.V. Regulation of the energy state of the deposit by the example of the Kolgan object of the Vakhitovskoye oil field, Moscow, 2010, p. 75-79.

Thus, by stimulating hydrodynamic shocks on the borehole section the effect of suffosion of the ringed near-wellbore space can be improved and the technical and economical characteristics of drilling production wells at the stage of development can be increased.

This chapter also contains researches for development of the special drilling fluid concept for implementation of the program on suffusion for primary development of the well of the ringed near-wellbore space in the process of drilling works.

In this connection the classification of existing drilling muds according to various functional and technological specifications depending on the technological operations and thermobaric properties of their implementation conditions is given and the requirements to their specifications and component composition are formulated. It is pointed out that all these factors have a significant impact on the investment of large investments into the import of drilling mud additives due to the inconsistency of their properties with the technological processes to be implemented and the resulting loss of their volumes. Full or partial replacement of additives will allow you to save a significant amount of money per year. When replacing only 10% of imported additives to compensate the loss of liquid for a year you can get real economy of money which in its turn justifies development of new additives in the country using local natural, industrial and/or agricultural raw materials.

In the work preliminary results of tests of loss-of-liquid additive made with the use of agricultural wastes are considered. The results of the experiments show that the fluid loss additive is equally applicable to both clay-free freshwater and saltwater-based drilling fluids. Thus, they demonstrate the suitability of the additive for current and future exploration and exploitation of oil and gas resources. When drilling in porous and permeable zones there is a high probability of losing a huge volume of the liquid phase of the drilling fluid during the drilling process.

Currently, there is an expansion of drilling operations to highly sensitive marine and deep water environments around the world. In order to preserve marine flora and fauna the researches are focused

on the development of a new generation of "green" additives to drilling fluids, which are ecologically pure, non-toxic and easily biodegradable, which allows to avoid short-term and long-term ecological consequences in highly sensitive deep-water marine environment.

That is why effective control of fluid losses when drilling a well is very important both at the stage of drilling and oil and gas production during well operation. In the future the development of highly effective drilling mud additives with high quality physical and chemical properties compared to conventional drilling mud additives will help to solve this problem.

In this work the problem of application of ecologically clean additive for compensation of fluid losses obtained from local raw materials was solved. This additive is applicable both for clay-free brown.

The additive is applicable for clay-free drilling muds on fresh and salt water base and is able to control the fluid loss while drilling without negative influence on the environment, ecosystem, environment of the application and so on. The output fluid loss compensation additive has the inclusion size smaller than 150 microns and is easily dispersed in the aqueous medium at low to moderate shear rate. Suitability of our petroleum-based local additive was evaluated by working out clay-free muds on fresh and salt water base with additive and then we made the following tests

1) tests at room temperature and overpressure up to 10 MPa;

2) liquid loss tests at high pressure and high temperature (at 100^0C and overpressure of 30 MPa).

Preliminary test results showed that local fluid loss reduction additive could significantly mitigate clayless system changes in fluid loss reduction. Initial results also demonstrate the suitability of local raw materials for localization of product development in the country within the oil and gas industry.

In order to choose the appropriate raw material for technical and economical justification of produced additive we made an assessment of several agricultural wastes available from different local sources. The brief analysis of effectiveness of research of operational characteristics of chosen accessible product showed its suitability as an additive

for struggle against losses of liquid at use of drilling muds on a fresh and salty basis. Preliminary estimate of easily accessible initial material showed the availability of this material in hundreds of thousands tons per year. Fig.7 shows a diagram of the developed technological process of additive preparation to control the loss of liquid.

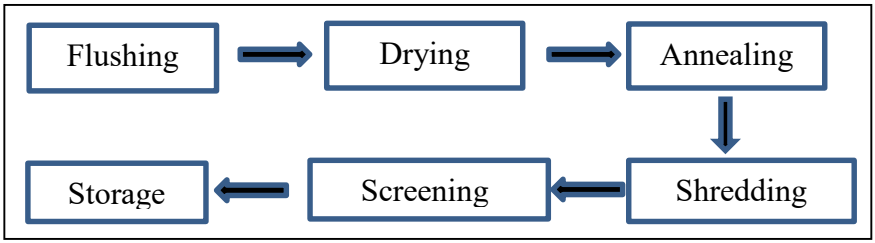


Fig.7. Diagram of technological process of preparation of an additive to control the loss of liquid

Initial processing consists of cleaning the raw material from the shell and all external impurities to separate the original product, and then washing it with fresh water to remove the sticky substance from the seeds. Then the seed is subjected to heat treatment to remove excessive moisture and make it more fragile for fast and easy crushing. The next step is to cool the seeds down to room temperature and make them ready for grinding. For this purpose they are placed in the sample chamber of the milling machine. Finally the shredded powder is sieved to separate particles under 150 microns in size for storage.

Various experimental evaluations of drilling muds of different formulations in the presence of the offered component element have been made and the efficiency of their use in different formulations according to attestation characteristics and correspondence to the requirements of technological processes under implementation has been shown. All these data makes us conclude that the offered additive based on agricultural waste has a high potential for being used as an available local raw material for the development of drilling mud compounding for oil and gas fields.

The fifth chapter is devoted to presentation and characteristic of developments for increase of efficiency of the process of primary development of wells after construction of their wellbore. On the ba-

sis of the analysis of existing technologies of drilling works it has been noticed that the technology of drilling works at the steerable borehole pressure is safer and as a result more profitable and allows developing and realizing more progressive combined drilling programs in different layouts (Fig.8).

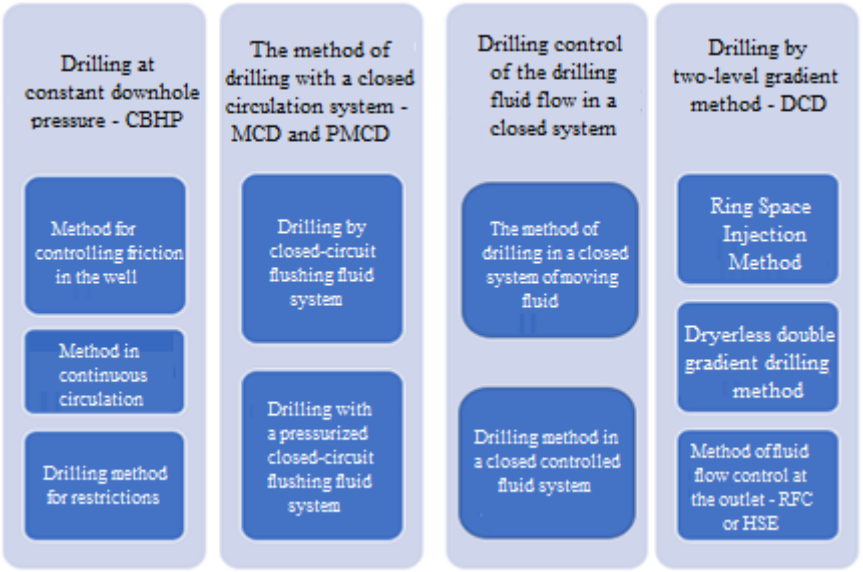


Fig.8. Categories and subcategories of drilling operations of drilling operations with controllable downhole pressure

The general layout of the technology "Drilling under the controlled pressure" (PMD), realization of drilling works process includes a unit that allows to realize the process of drilling works in different modes due to the maintenance of the control pressure in an oscillatory mode to prevent the possibility of well technological complications (Fig.9).

Two interconnected chambers, designed for control pressure, at which they are unloaded, do not allow to go beyond the limits of the set value and thus maintain the desired mode of operation of the whole plant (Fig.10).

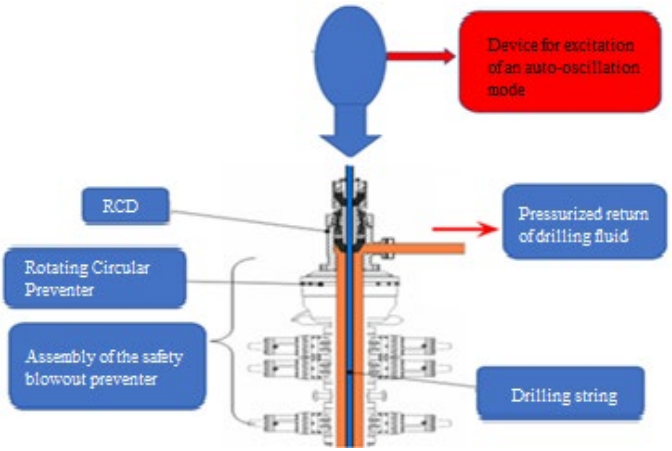


Fig.9. Typical location of a rotating of a closed-loop control device (RCD) drilling fluid circulation system

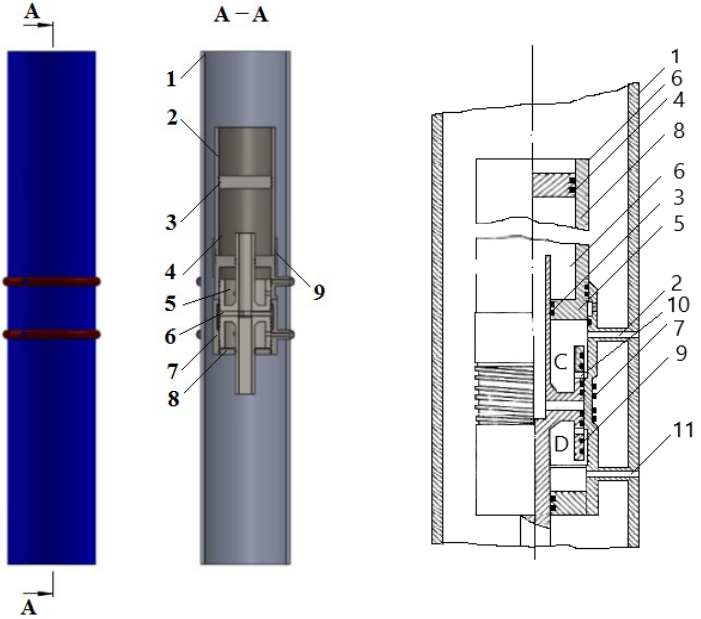


Fig.10. Control device of the closed loop system drilling fluid circulation system control device:
1 – body; 2 – nipple; 3 – socket; 4 – hydraulic cylinder; 5 – hydraulic chamber; 6,10 – piston; 7 – rod; 8,11 – radial bore; 9 - sleeve

The chapter also presents the technology of detecting injection wells fluid flows for hydrodynamic background scanning and determination of hydraulic conductivity in the field under development. The technology includes a number of operations that boil down to treatment of injection fluid with suspended magnetic nanocomposite containing spun macroheterocycle in the ratio of 1:1000 and injection of certain volume of fluid prepared and treated by adding surfactant, corrosion inhibitor and anti-spin additive through the injection well. After pumping from production of the producing wells samples are taken at the wellhead and subjected to the EPR (electrosteam resonance) analysis. Then according to the resonance activity signals of the producing well products the map of their interaction with the injection wells is made and the corresponding interroutine flows are defined. For studying the requirements to reservoir fluid displacement by the injection fluid the so-called "contact corner" is used that eventually characterizes the possibility to increase the efficiency of formation fluid displacement due to reservoir fluid wetting. For the purpose of research to estimate the importance and suitability of this parameter for reservoir conditions the corresponding tests were done on specially made samples (Fig.11).

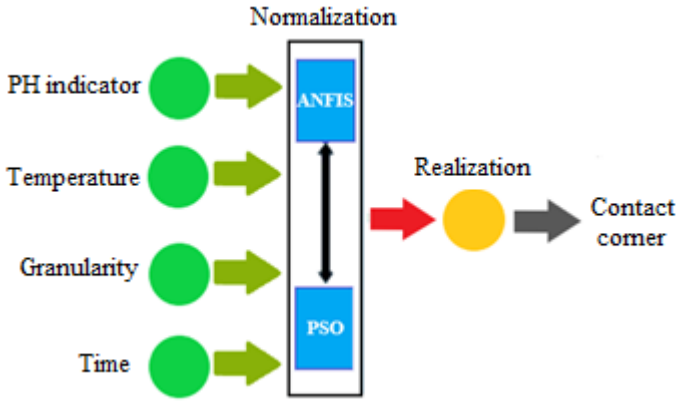


Fig.11. Model of experimental studies

According to the test results it was found that the parameters of injecting fluid preparation and established limits of its change pro-

vide the efficiency of formation product displacement in reservoir conditions and on the whole create favorable conditions for adjustment of flooding projects aimed at increasing the volume of production and the oil recovery factor of the area.

The chapter also contains information about a device for running down the tailing string with a filter part for casing the productive horizon area, which allows suffocating the ringed bottom-hole zone. The disconnector that connects the transport head string and the lower section (countersunk part) of the tailgate is designed as a head part and connects it with the descending string of two coupling adapters with the left external thread at the end made on the surface with a 10o bevel and has a mounting surface of the responding support surface with the left internal thread of the descending tailgate. Execution of the connector in the form of the head and two muff reducers with the lower left nipple thread executed on the surface with a 10o bevel and the landing surface, It connects trunk pipes with the muff end of the descending (countersunk) pig tail and allows the required space between pipes (an order of magnitude bigger than the existing analogues) and make the quality cementation of the descending part of the pig tail without complications and then its upper part through the joint nipple.

The end of the chapter contains attempts and is devoted to the implementation of the research results and evaluation of the annual economic efficiency of the research results.

MAIN RESULTS

1. The paper studies the manifestation of relaxation phenomena in dispersed systems, which class includes drilling muds, in order to estimate the technological conditions in the borehole contributing to complications during drilling operations. It has been found out that relaxation phenomena in drilling muds reduce quantitative indexes of their dynamical behavior due to the absence of fluctuation sources due to their non-equilibrium and can provide running and lifting operations which reduce the possibility of gas slugs formation in the wellbore.

2. On the basis of the conducted research the hydraulic hydraulic method of well complications prevention has been developed taking into account and based on the forecast characteristics of possible bifurcations in the drilling fluid behavior with nonequilibrium-disperse and invert structure in the process of drilling works.
3. The device has been designed for controlling influence on rocks in the near-wellbore zone in order to improve hydrodynamic connection in the system well - formation. The device is designed for existing technological options which are realized by tools arrangement including hydraulic motor bit, hydrodynamic cavitation stimulator for blasting of near-wellbore part, Drill pipe.
4. Experimental device was used to carry out investigations which made it possible to determine the dependencies of cavitation oscillations range P_2, their frequency f and vibration loading on the borehole section walls nz_3 on the ratio of average pressure P_2/P_1 values for supply pressures P_1=5 MPa and P_1=10 MPa.
5. The results of experimental studies confirmed the possibility of obtaining different vibration loads on rocks of the near-wellbore space when using the stimulators of hydrodynamic vibrations by using the developed device in various technological schemes, which can be used to restore its filtration-capacitative characteristics, which requires research and specification of design features of the stimulators.
6. Corresponding mathematical expressions for optimization of design characteristics of the hydrodynamic cavitation excitation node, namely determination of necessary length, diameter of inlet and outlet sections (and their correlation) of the diffuser chamber of the hydrodynamic exciter have been obtained on the basis of optimization model solution. The simulation for a concrete hydraulic program on the base of the obtained expressions showed that the input diameter of the nozzle profile at the 45 mm long has begun to increase already to its middle and at its output the size increases approximately 2.5÷3 times or more. It means that the diffusive chamber length can be taken within 30 mm, and input and output diameters d_{out}/d_{in} should have the relation equal to 2.5÷3. These parameters can be changed for another hydraulic

program, since there is a possibility to make simulations for its various modification.

7. The problem of optimization of pressure at the cavitation shock wave front stimulated by cavitation bubbles collapse for design of cavitation chamber construction and rheological properties of pumped fluid has been set and solved by dynamic programming method, That ensures the absence of complications on the borehole walls and improvement of filtration-capacitative properties of the wellbore space in the process of its primary development. This opportunity, which depends on the borehole design and physical-mechanical and rheological properties of drilling fluid, allows to provide and increase significantly the efficiency of well operation after completion due to quality suffusion of annular space in the process of borehole drilling.
8. There has been developed a formula of special drilling circulating fluid for realization of the program of well suffosion during initial development of the space around the wellbore. The formula is based on new additives using local natural, industrial and/or agricultural raw materials. According to the estimates of different drilling mud formulations in the presence of the offered component element their efficiency has been shown in different formulations according to the attestation characteristics and correspondence to the requirements of technological processes which confirms their high potential for oil and gas fields.
9. A device has been developed for performing the technology "Drilling under Manipulated Pressure" (PMD), which makes it possible to carry out drilling operations in different modes by maintaining the control pressure in the auto-oscillating mode, which is designed to prevent the possibility of wellbore technogenic complications.
10. The technology has been created for detection of interwell cross-flow of the fluid injected through the injection wells into the drained reservoir space by analyzing at the wellhead the production of the producing wells on the basis of their resonance activity signals, which allows getting estimates according to the scanned hydrodynamic background and making decisions on improvement

of FES of the developed field and adjustment of flooding projects for maintaining the internal surface water pressure.

11. A device for running the tailing string for casing the productive horizon zone, allowing to carry out suffusion of colmatized bottomhole formation zone by increasing the gap between the production string and the drill pipe string by more than five times, which allows to guarantee the quality and thereby the efficiency of the wellbore construction process, has been developed.
12. According to the results of the research the technique for processing the walls of the drilled wells of different constructions and technological designs has been developed. The main suggestions of the method have been used for wall processing and prevention of problems at wells № 330 and 491 drilled at production areas of KBR of SOCAR and the real and expected economic benefits amounting to 120 thousand and 5.0 million AZN were received. Carried out calculation of annual economic efficiency of researches has confirmed possibility of reception of economy at a rate of 200 thousand AZN.

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Personal contribution of the applicant in the published scientific works in connection with the research:

Works [2], [3], [12], [14] were made by the author independently.

In [1], [4], [5], [6], [7], [8], [10] the formulation of the research problem, their implementation and processing of the results, making suggestions, analysis of the proposed devices and compiling their drawings, the design of articles in the article format were made by the author.

Works [9], [11], [13] were written as a result of joint discussion of the authors on the recommendation of the supervisor to master the theoretical part of the problem.

The defense will be held on 21 October 2022 at 13^{00} at the meeting of the Dissertation council ED 2.02 of Supreme Attestation Commission under the President of the Republic of Azerbaijan operating at Azerbaijan State Oil and Industry University.

Address: AZ 1010, Baku city, Azadlig Avenue, 34.

Dissertation is accessible at the Azerbaijan operating at Azerbaijan State Oil and Industry University Library.

Electronic versions of dissertation and its abstract are available on the official website of the Azerbaijan State Oil and Industry University

Abstract was sent to the required addresses on 21 September 2022.

Signed for print: 19.09.2022

Paper format: A5

Volume: 42849

Number of hard copies: 100