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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

DEVELOPMENT OF THE CONTROLLED TECHNIQUES ON THE FORMATION AND BOTTOMHOLE ZONE TO INCREASE THE EFFICIENCY OF TECHNOLOGICAL PROCESSES IN OIL AND GAS PRODUCTION

Speciality: 2525.01 – "Development and exploitation of oil and gas fields"

Field of science: Technical science

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GENERAL DESCRIPTION OF WORK

The actuality and study degree of the topic.

With the aim of enhancing production by considering the influence of extracted hydrocarbons in the dynamic development of the economy, the development and implementation of the controlled techniques on the formation and bottomhole zone have to be justified both theoretically and empirically in order to increase the efficiency in technological processes. It is an urgent issue to improve the operation of the fields for ensuring the effective operation of wells.

Drop of the reservoir pressure in the process of the development of oil fields causes watering of the wells, sand deposits and accumulation of the residual oil in the well. Accumulation of the residual oil reserves in the well is a negative phenomena and requires a serious control. For this reason, the dissertation study is assigned to avoid the above-mentioned problems and to eliminate the difficulties it causes on the basis of the conducted researches.

As the amount of the fluid produced from the field increases, the reservoir pressure drops, the liberation of the gasses solved in the fluid increases the viscosity of oil, surface tension increases, oil displacement by water in the oil and gas content becomes difficult and it causes the formation of the residual oil in the areas left beyond the development in the field.

To solve the aforementioned actual issue in the dissertation work, increase in efficiency and intensity of technological processes in oil and gas recovery, the development and the application of the controlled techniques on the formation and bottom hole zone are conducted in detail.

Object and subject of research.

To increase the efficiency of technological processes in oil and gas recovery, the investigation of the complex studies for the development of the controlled techniques on the formation and bottomhole zone and the development and elaboration of new methods.

The purpose and main objectives of the study.

- Displacement of oil with carbon gas in porous medium and studies of prospects.

- Obtaining CO_2 not on surface, but in the reservoir and studies of its impact to the fluid.

- Sand appearance in the production wells and ways to control this process.

- Identification of CO_2 role in the formation of sand phase appearance in production wells.

- Assessment of the unstable operation of wells during sand appearance, using mathematical and statistical methods.

- Studies of the technological characteristics of the production wells, factors that affect on the intensity of the watering in production wells.

- Development of the controlled techniques on the formation and bottomhole zone to improve the efficiency of technological operations.

Methods for solving the tasks.

The proposed problems should find their solution in the software by using the mathemetical-statistical methods and results of the laboratory analysis of the data, obtained from the laboratory experiments and field studies.

The main positions to be defended.

- Sudies of displacement of oil with carbon gas in the porous medium and its prospects.

- Studies of obtainment of CO_2 not on surface, but in reservoir condition and its effect on fluid in reservor.

- Sand phase appearance in production wells and ways to control this process.

- Identification of CO_2 role in sand deposits in production wells.

- Assessment of unstable operation of wells during sand deposits by using mathematical - statistical methods.

- Studies of operation characteristics of production wells, factors, stimulating watering of production wells, analysis of operation characteristics of wells.

- Development of the controlled techniques on the formation and bottomhole zone to improve the efficiency of technological processes.

The scientific recency of the research.

To improve the efficiency of the technological processes in the oil and gas recovery, the following scientific innovations were obtained by conducting complex researches for the development of the controlled techniques on the formation and bottomhole zone:

- Displacement of oil with carbon gas in porous medium and its prospects were investigated.
- Experimental researches were conducted to get CO_2 not on the surface, but in reservoir condition, about its impact to the fluid in the reservoir, its injection simultaneously with the surfactants and acid solution.
- Consilidation of the wellbottom area in the production wells and isolation of water invasion were analysed.
- Role of CO_2 in sand deposits in the production wells was identified;
- Formation of sand phase in the production wells and the ways to control this process were developed.
- It became possible to assess the unstable operation of wells during sand appearance by applying mathematical - statistical methods.
- Operation chareateristics of production wells, factors stimulating the watering of production wells were studied, operation characteristics of wells were identified.
- To improve the efficiency of technological processes, controlled methods on the formation and bottomhole zone have been proposed.

Theoretical and practical value of work.

To enhance the efficiency of the technological processes in oil and gas recovery, it consists of development of the controlled techniques on the formation and bottomhole zone and conducting a comprehensive analysis of their application.

More exact assessment of unstable operation of wells during sand appearance, using mathematical - statistical methods was applied.

More than 73.8 tons of oil was produced as a result of imlementation of the new technology, developed for obtaining carbon gas in porous medium for improvement of the displacement of oil in the reservoir and increas the oil recovery.

Approbation and application of the work.

The main provisions of dissertation were reported in the following International and Republic conferences:

1. "Consolidation of wellbottom area and isolation of water invasion" /Thesis/ Non-Newton systems in oil and gas areas. Materials of International Scientific Conference devoted to 85th anniversary of Academician Mirzajanzadeh Azad Khalil, Baku. 2013, pp. 196-198.

2. "About implementation issues of complex chemical solutions for stimulating the reservoir" /Thesis/ Devoted to memory of Gennadiy Vasilyevich Rassokhin, professor, doctor of technical sciences. Materials of international seminar, Ukhta, 2015, part 1, pp. 209-211.

3. "Inreasing efficiency of development of carbonaceous reservoirs on the basis of synergetic approach. /Thesis/ International scientific and practical conference "Condition and prospects of operation of mature fields". Aktau, 2019, volume I, pp. 443-447.

The results of the conducted analysis were implemented in 3 water injection wells in Oil and Gas Production Site-2 named after A.J. Amirov of "Azneft" Production Union of State Oil Company of Azerbaijan Republic (SOCAR).

Acts on the application of measures are attached to the dissertation.

The main results of the thesis were published in 14 publications which are listed at the end of the abstract. 11 of them are articles, 3 are reports and abstracts of conferences.

The structure and scope of the work.

The dissertation work consists of introduction, 3 chapters, conclusions and recommendations, the list of references, consisting of 107 titles and applications. The volume of work is 170 computer printed text including 26 figures, 17 diagrams, 20 tables and 1 appendices. Total volume of dissertation is 201191 symbols.

Brief content of the work.

The introduction describes the main provisions of the dissertation, the relevance of the research conducted on the dissertation topic is demonstrated, as well as the scientific innovations of the work, the key provisions to be defended and the methods of solving the issues are explained.

The first chapter some technical shortages and restrictions were revealed in increasing the efficiency of oil and gas production in the direction of improving the efficiency of oil and gas production by stimulating the reservoirs and wellbottom areas, taking into account the results obtained from external and local researches, from the existing geolocical and engineering conditions.

In the process of development of oil fields the watering of production wells is observed after certain period. Watering phenomena in the production wells in the proces of development and operation of fields is a negative occurence and requires a serious control. For this reason, the conducted studies aim at prevention of watering in the production wells and elimination of the associated difficulties

One of the problems of oil and gas production is destruction of the well operation equipment by sand coming with fluid entering through the reservoir into the wellbottom and at the same time forming blockages by deposition in the wellbottom. Elimination of sand blockages requires to apply hard labor and sometimes may causes oil loss in big volumes; also causes the destruction of the sustainability of formation in the wellbottom area, destruction of rocks and distortion the operation pipeline.

As the majority of the oil wells in operation offshore in Azerbaijan consist of poorly-cemented reservoirs that are operated for a long period, one of the main problems of the wells operated in those fields is related to the damage of the wellbottom area, destruction of the operation pipeline, penetration of sand and formation water from the reservoir into wellbottom area; it causes in its turn the drop of conductivity capacity of the wellbottom area, decreases intervals between workovers and as a resut increases cost of produced oil.

Because of this reason while stimulating the reservoirs it is required to study the selection of the correct working agent and reagent and their effect on the viscosity of oil in heterogeneous and homogeneous systems, to the surface tension, flow characteristics and other factors.

The most effective, widely applied method in stimulating the reservoir, is water injection. Despite the advantages of water injection, it also has disadvantages. There are certain and unsolvable difficulties in stimulating the reservoir with gas. Both these methods lead to extreme residual oil build-up in the wells. This issue, i.e. existence of minimum amount of residual oil reserves in the reservoir and not full operation of the field preserves priority of application of new mechanisms and technologies even in these days. It is considered more appropriate to remove oil from the reservoirs of the existing rocks of oil fields more than exploring new oil fields. For this reason injection of carbon gas to the reservoirs, displacement of oil with carbon gas are considered as more comprehensive system. As carbon gas is a better solvent and it is solved well, it changes the physical properties of oil while contacting it. It requires theoretical justification of implimentation of controlled reservoir and wellbottom area stimulation methods to produce residual oil, built-up in dead zones of the field.

In order to solve the researched issue, in the dissertation scientific studies were conducted in 4 main directions:

- Analysis of the work done in sand wells and the obtained results.

- Analysis of the work done and the results obtained during the during water injection.

- Analysis of the work done on the acid treatment of the bottom zone of production wells and the obtained results.

- To increase oil production, non-conventional in our country experiments and foreign researchers' practice study with following analysis of obtained results.

The main factor in the research of methods of impact on the well bottom zone is the collection, systematization and analysis of field data. Each field data obtained at certain time intervals determines the current condition of the wellbore zone and the field at the indicated times, and a complete analysis of the data provides information about the condition of the field at a later stage. For this purpose, we must use the concept of understanding the processes occurring in oil and gas fields.

The first chapter of the dissertation covers the different activities of different foreign and local scientists and researcers for increasing the oil production and broad analysis of the obtained results and what advantages and disadvantages these activities have in the solution of the common problem, by taking all these mentioned factors into account

The second chapter shows the selection of conditions and methods capable for ensuring the efficiency of technological processes in oil and gas production, development of the methods of increasing recovery potential depending on the specific conditions of the reservoir and the ways to select proper facility to conduct technological operations.

In the work, the displacement of oil by carbon dioxide is given a lot of space. Information about carbon dioxide, its physical and chemical properties during contact with oil, current and future perspectives of this method is provided here.

Of course, carbon dioxide injected into the layer dissolved in liquid and water cannot retain its original properties. This is caused by the physical and chemical properties of the rock and formation water. Depending on the pressure and temperature, the dissolution of carbon dioxide in water allows to explain the process of oil displacement more clearly and to obtain more realistic results.

Also, in the experimental study of the displacement of oil by carbon dioxide in a porous medium, it is clearly explained how this process occurs in laboratory conditions. Although the application of the CO_2 system for oil displacement is highly effective method, this technology has a number of technical shortcomings and limitations.

Although the application of a perfect CO_2 system for oil displacement is a highly effective method, this technology has a number of technical drawbacks and limitations. Currently, many modifications of the carbon dioxide application method are known. In this regard, improvement of the oil production coefficient in formations is based on the unique ability of carbon dioxide to disperse (disappear) in oil as well as in water. However, the search for scientific research works to create new technologies while maintaining the positive aspects of the efficiency of CO_2 is continued. The depletion of exploited and developed fields, as well as the increase of oil waste materials in the country's raw material base in general, require an increase in the final oil yield coefficient.

When CO_2 solves in water, viscosity of water increases, but when CO_2 solves in oil, it improves the fluidity properties of oil more. The acquisition of CO_2 in formation water and its injection into the reservoir is more effective than producing it on the surface and injecting into reservoir. In this case the produced CO_2 solves in water and oil in the reservoir and paves the way to direct the process in the form we want.

Heavy oil (paraffin-asphaltene-resins) is taken from well 1149 of “Neft Dashlary” (“Oil Rocks”) offshore field and its geophisical properties were studied in rotational viscosimeter “Rootest-2” for researches. The obtained results were developed on the basis of Cross metodology. During the experimental studies 1 – 10% solution of $NaHCO_3$ was used.

The shapes of the vessels and equipment were located as shown in Figure 1 for the experiment. The unit is called an experimental unit as it is used for 3 (three) different experiments separately.

The experiment for obtaining CO_2 is conducted both in formation water and in natural water (fresh water).

When CO_2 solved in oil, there were not water and solid particles in oil at the end of the laboratory studies as it reduces the viscosity of oil when it solves in it and as it reduces the surface tension in the boundary of water.

The results of studies conducted in formation water were higher than those in normal water. It may be explained by the factor that naphthenic acids are more in formation water and when they react with the alkalines, milonaft is formed. Milonaft is considered a better degasing element. As the starting slipping tension reduces, formation water degases faster than the sea water or normal water.

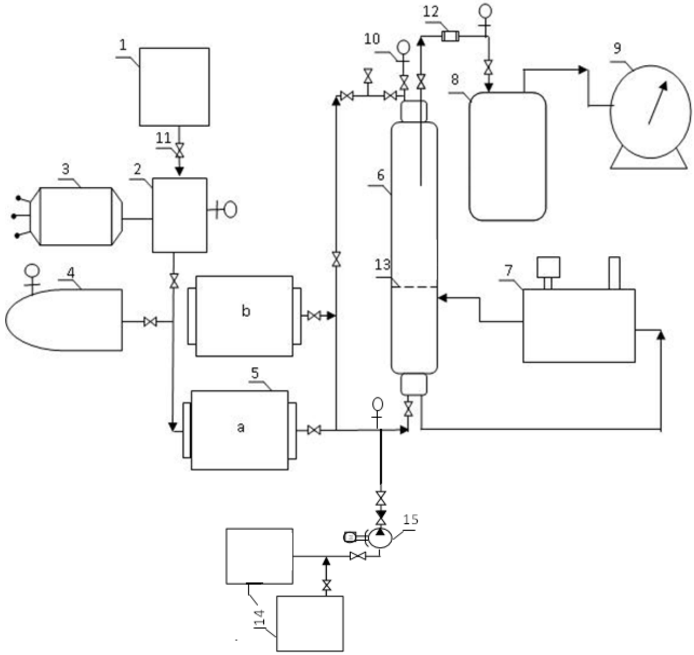


Figure1. Schematics of the experiment unit

1 – vessel for preparation of mixture for obtaining CO_2 , 2 - manifold, 3 – manual press, 4 – gas bottle containing CO_2, 5 - PVT-bombs, 6 – reservoir model with porous medium, 7 - thermostat, 8 – measuring tank, 9-flowmeter, 10 – pressure gauge, 11 – control valves, 12 - controller,13-water-oil contact, 14 – vessels for preparation of mixture to obtain (sulphanol), 15 – batching pump.

Watercut of the production wells with the water injected to the reservoir untimely causes the drawdown of production. Watercut factors may be divided into two groups as natural and unnatural factors. Natural factors are also called as geological and physical factors. These factors depend on the structure of the field, lithological and mineralogical content of reservoir, physical properties of the reservoir, chemical properties of oil and water in porous medium and their flow mechanism. Unnatural factors are called as technological (process) factors and location system of wells, field development mode and well operation indicators refer to them. The watercut of reservoirs with good filtration capability progresses without problems in homogenious oil fields, having anticlinal structure. In non-homogenious reservoirs water enters the areas with high conductivity capacity first, in the areas with low conductivity capacity the stagnation of oil and water contact or delay is observed. Water penetration into to the reservoir layers with poor lithological collector is uneven and as a result of this stagnant oil areas appear in the reservoir. Reservoir area non-homogeneity and geometric dimentions affects on the dymanics of the production wells. Water entering period of production wells depends on the ratio of the thickness of layers soaked in water and oil in the layered reservoirs. As the thickness of the watercut layer increases, water invasion probability of the oil wells also increases. Viscosity of oil in reservoir depends on the quantity of real surface components present in its content. When components prevail, production wells get watercut untimely and oil recovery factor reduces. The studies of lithological and physical properties of oil fields show that the reservoirs with non-homogeneous layers can be interrelated with each other or can have different thicknesses. The factors stimulating water invasion of the reservoirs with low viscosity are the reservoir non-homogeneity, density of location network of wells and their production volume. When the oil is displaced with water in non-homogeneous reservoirs, the occurence of penetration of fluids from one layer to another under the effect of capillary and hydrodynamic forces causes the reduction of conductivity ratio of these layers and oil activity and leads to water invasion of the production wells. The absence of hydrodynamic communication among the layers in the non-homogenous reservois causes water conductivity in the size of one volume of the environment and formation of annular hydrocarbon fluid residues in the watercut area of the layer with higher penetration level. The watercut percentage of the wells operating non-homogeniously layered reservoirs with hydrodynamic communication is lower than the watercut percentage of reservoirs without hydrodynamic communication (table 1). It should be noted, that oil content also plays a considerable role in the untimely watering of the production wells. When the oil with active components in the content is displaced from the porous medium, layer with abnormal properties appears on the water particles. As this established layer has higher viscosity, it is necessary to apply certain force to move it.

Table 1.

Characteristics of the used reservoir model samples

L.m	N,m	b,m	h_1,m	h_2,m	h_1 /h_2	K_1, mkm^2	K_2, mkm^2	K, mkm^2	p,%	K_1 /K_2
0,81	0,078	0,019	0,039	0,039	1	14,2	1,6	8,0	30,0	9,0
0,81	0,078	0,019	0,039	0,039	1	10,0	1,6	5,8	29,5	6,2
0,81	0,078	0,019	0,039	0,039	1	8,0	1,6	4,8	29,0	5,0
0,81	0,078	0,019	0,039	0,039	1	5,1	1,6	3,3	28,5	3,1

Prevalance of the active components in hydrocarbon fluid affects the watercut of non-homogeneous reservoir model. The impact of the conductivity ratio (K_1/K_2/) of the layers were studied in non-homogeneous resorvoir (diagram 1).

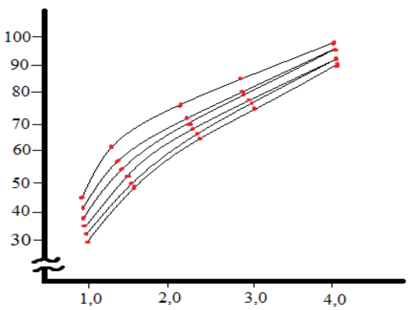


Diagram 1. Watercut ratio of layers in non-homogeneous medium

1-homogeneous porous medium with low conductivity; 2,3,4,5-non-homogeneous porous medium with 3,1;5,0;6,2;9,0 conductivity ratio accordingly; 6-homogeneous porous medium with high conductivity

In the small values (K_1/K_2 <5,0) of the ratio K_1/K_2, the flow rate is practically equal in high and low conductivity layers of the reservoir model. Maximum watercut is observed in the first reservoir model having high conductivity (14,2 mkm^2). On the basis of the conducted experiments we can draw a conclusion that the drop of the conductivity ratio of layers from 9,0 to 3,1 reduces the water invasion.

Displacement of oil with water in the reservoir improves the oil recovery factor. The main factor affecting this is the contact of the base floor of oils with non-newtonian properties to the big water area in homogeneous reservoirs. The efficiency of oil produced at the account of water injection into the reservoir for increasing the oil reovery is about 20-25% in high viscosity fields and not more than 10% in the reservoirs with base floor contacting big water area. The reason for this, is the water invasion of reservoirs in a short time interval.

It is more appropriate to dwell on the wellhead pressure changing mechanism which is a momentarily changing parameter in order to learn sanding-up mechanism in the well in a fast track manner. The reason for this is to get the needed figures in a short time in order to conduct our statistical calculations. In the wells operating with gushing metod, the change of the wellhead pressure divirges from the regularities and its acquisition of chaotic situation quickly draws attention.

For the purposes of study about 10 different oil wells drilled and put into operation in Deep Water Gunashli Field and about 64 oil wells operating from Fasila Suite reservoir were initially analysed. In order to make the research work conducted in the analyzed wells more prompt, the research in 54 compressor gas-lift oil wells was stopped. The reason for this is the large number of factors that influence the change of parameters in mechanically operated oil wells. An example of this, is that the amount of gas injected to the well as a working agent is not stable regulated. If the average daily quantity of the working agent injected to the oil well, which is a mechanical method and works with a compressor method, is 10,000 m^3, then a limit is set for it from 9,500 m^3 to 10,500 m^3.

This means that depending on the amount of fluid flow from the reservoir to the bottom of the well and the pressure at the bottom of the well, the oil well will receive gas in the indicated boundary interval. As a result, the compressor well analysis will be calculated with a minimum error of 10%. In this case, it will be difficult to correctly predict the sand that comes with the fluid from the formation to the bottom of the well.

For ensuring the accuracy of the study about 10 oil wells, operating with gushing method are selected and 6 out of them are located on deep water offshore platforms. They are oil wells 26, 228, 289 on platform 8, oil well 3440 on platform 10, oil wells 168, 210, 344 on platform 11, oil well 308 on platform 13, oil well 306 on platform 14 and oil well 279 on platform 15, operating with gushing method. Taking well parameters, coordinates of location in the field, appearance of sanding up in some cases, well running for a long time without sanding up after the performed maintenances and absence of water traces in the well production as basis in the result of analysis, well 210 is selected, which is running with gushing method and is located on deep water platform. Sanding up is observed in this well from time to time. The records of wellhead parameters which are taken continuously at points 121 and 124 are collected when there was no sanding up, when sand appearance was in the progress and when there was a deposited sand amounts already in this well for the study, frequency, amplitude and phase change analysis were conducted with the Furye analysis.

In the first case, when there was no sand in the well, the fluctuations of the change of the wellhead pressure corresponds to a certain pattern. Fluctuations periodically repeat after each other.

In the second case, when sanding up was in progress, the fluctuations of the wellhead pressure change starts not to correspond to the defined pattern and it leads to chaotic dancing movements. In this period sand does not affect the operation of the well considerably.

In the third case, ther is already a settled sand deposits in the well and in this period the fluctuations of the wellhead pressure change does not correspond to the defined pattern and it makes full chaotic fluctuative movements. Such change in the wellhead pressure shows the increase of sand mass percentage in the well production and decrease of the volume of oil production of the well.

When analysing the changes of the fluctuations of the wellhead parameters as shown in the diagrams, we notice that during the normal operaion of the gushing wells it runs with certain fluctuations, corresponding to the pattern, but when these fluctuations do nor repeat, we notice that the conformity to the pattern violates. And this does not allow to predict the existence of any pattern in the later periods of its operation.

To solve this issue, we applied Furye spectral analysis method.

We observed the change of frequency in the wellhead pressure (P_1), in differencial pressure ($\Delta P=P_{x+1}-P_x$) and in pressure gradient ($\Delta P'=\frac{\Delta P}{P}=\frac{P_{x+1}-P_x}{P_x}$) with Furye analysis when there was no sanding up in the well, when sanding up was in progress and when there was a settled sand deposits in the well and corresponding amplitude and phase changed according a certain pattern.

For predicting the current situation of the reservoir system and different factors affecting it, entropy analysis is used which is the measure of uncertainty of the situation. If the last set of the random measuremet values $x_1, x_2 ... x_n$ ($p_1, p_2 ... p_n$), p_i are given with probable distribution, in this case the distribution entropy is defined as follows using Shennon formula:

$$S = -\sum_{i=1}^{k} p_i \log_2 p_i \qquad (1)$$

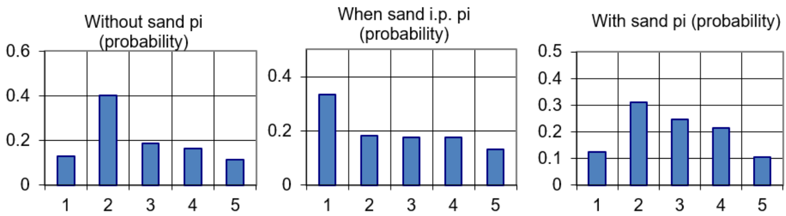
Table 2.

Entropy of the well

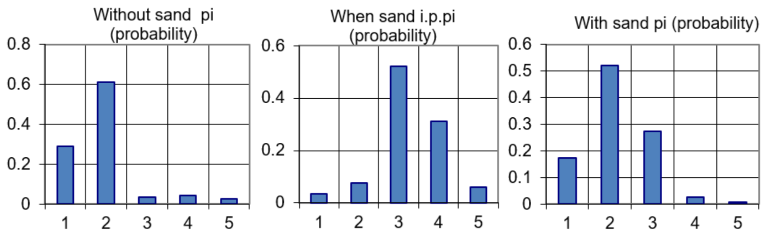
	Without sand	When sand is in progress	With sand
P	2,153	2,213	2,245
$\Delta P=P_{x+1}-P_x$	1,436	1,629	1,701
$\Delta P'=\frac{\Delta P}{P}=\frac{P_{x+1}-P_x}{P_{x+1}}$	1,359	1,584	1,607

The entropy icnreases in wellhead pressure (P), differencial pressure ($\Delta P=P_{x+1}-P_x$) and pressure gradient ($S_x=\ln(\frac{P_x}{P_{x-1}})$) when there is no sanding up in the well, when sanding up is in progress in the well and when there is a settled sand deposits in the well (Table 2).

P



$\Delta P=P_{x+1}-P_x$



$\Delta P'=\frac{\Delta P}{P}=\frac{P_{x+1}-P_x}{P_{x+1}}$

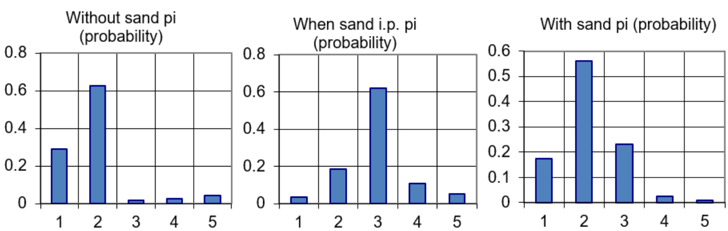


Figure 2. Entropy of the well

So we can come to such conclusion that it is possible to predict sanding up prosess beforehand on the basis of the dynamics of the wellhead pressure change. It is identified on the basis of the study that the entropy value increases during sanding up (Figure 2).

If we carry out Furye spectral analysis in the wells operating by means of compressor or pump, which is considered as mechanical operation method, there will be great errors in obtaining the correct results. So that, depending on whether working agent of compressor wells is gas or air, along with the existing errors, the results of this method of analysis will lead to doubts and questions as sometimes the control of the working agent cannot be exact. The results of Furye spectral analysis will give much more errors in the wells, operating with centrifugal or deep-water pumps.

As a result of a number of conducted experimental studies, CO_2 injection is shown as the most efficient method of impact to the oil fields. Taking this into concideration, the prospects of CO_2 application to Gunashli field is analized. So that the prevalance of Ca^{+2} and HCO_3 ions and volume of CO_2 in the content of oil and reservoir existing in this field, that constitute Fasila Suite and Balakhani reservoir set which are the main operational facilities of this field provides certainty that stimulation with CO_2 will be more effective. As it is known that obtaining CO_2 in big volumes and its injection into the reservoir will ensure a great efficiency, the difficulty in obtaining CO_2 still preservs its criticality. Taking into account all the details, in order to expand the area of stimulation of water injection, to improve and to perfect oil displacement with water, it is required to benifit maximum from the capabilities of active ions in the content of formation water and that of the rocks that constitute reservoirs. For this, by using the existing water injection process in Gunashli field and depending on the content of the rocks, constituting the reservoir, it alows us to obtain CO_2 in reservoir conditions and to improve the efficiency of reservoir stimulation. Injection of the carbonated water always presents difficulties both technically and economically. For this reason it is required to obtain CO_2 inside the reservoir, to solve it in reservoir water or in treated sea water and oil, to ensure its operation in the reservoir without losses.

We can solve this problem by injecting surfactants (sulphanol) and acid (HCL) into the reservoir in the defined percentage ratio. During the process of impacting wellbottom and reservoir, the conductivity of the injection well recovers or increases. Acid, penetrating into the wellbottom area or into the reservoir reacts with the rock pores, solves sandstone, limestone and dolomite and increases the diameter of the channels and conductivity of porous medium.

$$4HCL+CaMg(CO_3)_2= CaCL_2+MgCL_2+2H_2O+2CO_2$$
$$2HCL+CaCO_3=CaCL_2+CO_2+H_2O$$

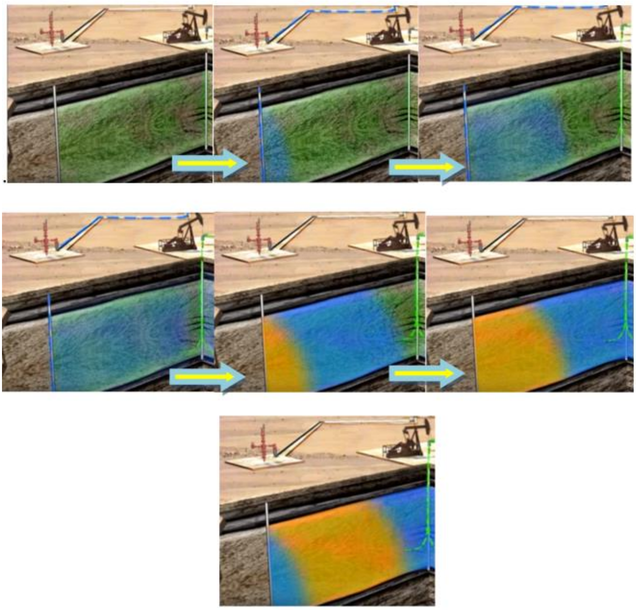


Figure 3. Movement of oil, water, acid and sulphanol contact between injection and production wells when injecting HCl into the reservoir through the injection well

It is possible to apply the results of the above-mentioned reactions for increasing the efficiency of water injection process into the reservoir (Figure 3). So that while conduction water injection process both in limestone and dolomite rocks, it is possible to achieve in obtaining CO_2 straight away in the reservoir conditions and in displacing oil in the reservoir efficiently with the obtained volume without losses by adding chloric acid to water which is periodically injected. When the consentration of the carbon dioxide which is solved in oil increases, solubility of carbon dioxide decreases. When carbon dioxide solves in water, viscosity of mixture increases along with increase of consentration.

Table 3.

Report table about the injection of chloric acid

Horizons	FLD	X horizon	IX horizon
Calculated volume of HCl compound to be injected per horizons, in m^3	62,45	56,94	20,35
Avarage volume of water injected daily into the reservoir, in m^3/day	449	532,6	458,9
Injection period of the calculated volume of HCl compound into each horizon, in hours	3,34	2,57	1,06
Radius of the sweep area of HCl compound per horizons, in m	12,12	12,37	12,81
Avarage impact period of the injection of HCl compound into horizons, in hours	54,5	43,6	19,6
Periodical injection number of HCl compound (per horizons)	163	130	292
Breakthrough period of HCl compound as intermideate layer into the production wells , in days	370,1	236,2	238,5

When impacting the reservoir with inhibited chloric acid depending upon the porosity of the rock in the limy fields, the consumption of chloric acid is calculated for full progress of reaction in 1 m thickness of filter and for full and efficient use of chloric acid.

Hence it becomes clear that when the porosity is about 15%, the calculated volume for 1 m is about 1,06m^3 and for the rocks with porosity about 10%, 0,701 m^3 acid is required. In accordance with this calculations, the results of the obtained volume of chloric acid which will be injected as an intermediate layer into the reservoirs through the injection wells, operating from FLD (Fasila Suite) of Gunashli field and from IX and X horizons of Balakhani Suite are given in Table 3.

It should be noted, that the condition in which the calculated volume of the proposed intermediate layer fully reacts and solves lime sholud be considered as condition when the termination of the reaction is awaited after the intermediate layer is injected and the well is closed.

If we take into account that immediately after the injection of intermideate layer, consisting of chloric acid into the resrvoir, it is displaced by water and moves towards the deep layers of reservoir and reacts with the top layers of the lime sections of rocks, it causes increase of conductivity in the deep layers of the reservoir and in this way it both increases water absorption of the reservoir (increase of conductivity in the depths of reservoir decreases resistance), and also separated CO_2 gas solves in water and it helps for better displacement of oil. Knowing the volume of injected water into reservoir through the injection wells in the above-mentioned horizons and its movement in the reservoir approximately (it is impossible to identify it exactly), it is also possible to identify approximately the period of injection of chloric acid into reservoir as intermediate layer.

In order to limit the movement of water from the remote zones of the formation, the surfactant solution injected into the fluidized formations mainly enters the small permeability area of the formation.

The rheological characteristics of oil with anomalous viscosity behind the compression front increase due to the diffusion of the aqueous solution of the surfactant into the oil. Due to the formation of "oil-water" emulsion, the viscosity of the compressing agent increases at the compression front. This increases the degree of compression coverage of the layer. One of the factors that positively affect the kinetics of oil displacement is the improvement of the permeability of carbon dioxide, which dissolves the calcium carbonates that make up the rock. When carbonated water is injected into the liquefied layers, a part of the oil is removed due to the decrease in the viscosity of the residual oil and the expansion of its volume. Due to the fact that the injected water penetrates the oil, it is impossible to effectively maintain the formation pressure and ensure the compression of the oil. Injection of acid along with water injected into carbonate rocks leads to formation of CO2 system in the formation, changes in their parameters as dissolved in oil and water, increase of oil yield coefficient, reduction of mass percentage of water in the produced liquid and increase of oil production.

In the third chapter of the dissertation we have shown the assessment of the economic efficiency on the basis of the change of the main factors and obtained results before and after the implementation of the developed methods of the obtained results in the field conditions.

Three oil fields – Gunashli, Chilov and Puta - Gushkhana - Lockbatan were analysed as the subject of studies. Data about Gunashli and Chilov fields was presented at the beginning of the dissertation and also the date about the conducted studies was provided. Lokbatan field which is in the last phase of development and on the verge of depletion is selected for solving the problems put forward in the dissertation and for showing the achievement of reflection of the presumptions clearly.

For the implementation of presumptions of dissertation, i.e. for implementing them in the field conditions, out of 18 operating wells in Puta – Gushkhana – Lockbatan developed and operated by

OGPD named after A. Amirov, 5 water injection wells 57, 81, 730, 1133 and 1804 of OGPS-2 were selected. Out of 5 wells 3 water injection wells – 57, 81 and 730 were selected which are considered fast reacting ones for the activities during the studies. As a result of multiple researches we conducted, about 12 oil wells which are in the affection area of these water injection wells were selected out of 472 wells comprising operating asset of OGPD named after A. Amirov. For exact identification of the efficiency of the activities to be conducted and for analyzing and for drawing real conclusion about the results, 6 oil production wells were selected which have closer hydrodynamic communication to the injection wells and 2 oil production wells are assigned for each water injection well.

Acid solution (HCl 21%) was injected to the reservoir through the injection wells for obtaining carbon gas. Acid was fully displaced into the reservoir without losses, using surfactants (sulphanol) as chaser. The process of water injection into the reservoir was continued through the initial water injection wells for obtaining the desired efficiency along with the movement of acid solution in reservoir. There was a change both in the rate of flow, in the volume of the displaced solution and oil between the production wells during and after the experiment.

Daily parameters of wells were taken and analyzed per each water injection well before and after the experiment. It became clear from the parameters taken before the experiment that water absorption of each well was different in different days. The main reason for this is related to the formation of different salts in the filter area of the reservoir resulting from the water injection and to decrease of conductivity of that area. It also makes difficulties in stable water injection into the reservoir in its turn.

Before the experiment the expected indicators per each water injection well separately, i.e. how the daily water absorption capacity will change in each well was estimated. So that it was estimated that daily water absoption would increase 18.4% per well 730, 16.8% per well 57 and 19.6% per well 81. It means 18.27% increase of water volume in the above-mentioned 3 wells in avarage during the normal operation of wells.

If we analyze the conducted activities separately per water injection wells, we can see that:

- If the volume of the daily injected water was 140-187 m^3/day in well 730 before the experiment, it changed to 160-240 m^3/day after the experiment.

- If the volume of the daily injected water was 4-5 m^3/day in well 57 before the experiment, it changed to 90-170 m^3/day after the experiment.

- If the volume of the daily injected water was 10-12 m^3/day in well 81 before the experiment, it changed to 115-230 m^3/day after the experiment. Also it was impossible to increase the volume of injected water into the well as the wellhead pressure increased above the set pressure during water injection in this well.

- As the main purpose of the conducted work was to obtain carbon gas in the reservoir and to improve oil recovery in the production wells, we can tell the compete results about the efficiency of experiment after analyzing the production wells in the same way. For this it is required to analyze the figures of daily oil production of 2 production wells per each water injection well, 6 production wells in total before the experiment and after it.

- In water injection wells selected for obtaining active CO_2 in the reservoir conditions by injecting acid solution (HCl) and surfactants (sulphanol) together (number of wells 57, 81, 730) and in 2 production wells 152 and 1140 out of 6 production wells, having hydrodynamic communication with these wells (number of wells 7, 83, 89, 152, 1140, 1216), it is proved that wells 152 and 1140 have no hydrodynamic communication with the corresponding water injection wells and as a result of implementation in 4 wells, about 0.202 tons of efficiency was achieved during 12 months in total.

CONCLUSIONS

1. CO_2 , obtained in reservoir conditions both decreases the viscosity of residual oil in the oilbearing areas and considerably improves the filtration properties of oils soaked on the rocks by removing them from their surfaces, helps to improve the separation of oil from water and its free movement in the reservoir conditions. Used glucose ensures longer duration of the reaction and also ensures displacement of oil present in the reservoir in bigger volumes. So that, it is possible to control the separation of carbon gas any time. It is also possible to control carbon gas separation with this method. CO_2 separates steadily for 14-15 days and it gradually starts to decrease. It is more efficient to solve and inject the compounds used in the study in the formation water injected into the reservoir. So that as solving CO_2 in formation water increases viscosity of water, it will also pave the way to prevent the formation of lateral coning.

2. It is possible to reduce sand formation by reducing the viscosity of the produced oil, the contact stress of oil, friction force and it is possible to reduce sand formation in the production wells by reducing surface tension. When oil flows through the pores of the rocks, which are poorly semented or medium semented, the rock structure of the reservoir and wellbottom area are not exposed during the impact with the carbon gas, obtained in reservoir contitions. Sand formation is relatively less in the wells with low viscosity rather than the wells with high viscosity during high depression.

3. It is possible to reduce the viscosity of oil with CO_2 in reservoir conditions. Injection of CO_2 into the reservoir through the injection wells requires very big financial resources. Solved CO_2 gas undergoes losses until it enters the reservoir during the injection of carbonated water into the reservoir. But CO_2, obtained in the reservoir conditions makes maximal job in the well without undergoing losses. This is a more simple method from the technological point of view and requiring less financial expenditures.

4. Water injected into the reservoir improves oil recovery index by CO_2 changing the parameters of oil and water along with maintaining the reservoir pressure stable.

5. Acid pumped into the injection water may be pumped in doses or periodically.

6. When chloric acid is injected into the reservoir as an intermediate layer, displacement of oil from the reservoir improves as a result of separation of CO_2 gas and oil recovery of reservoirs increases. CO_2 gas injected into the reservoirs as an intermediate layer of chloric acid through the injection wells and separated in the depths of reservoir penetrates into the hard components of oil soaked on the rocks in those areas causes decrease of the viscosity of residual oil in these areas and helps increase the volume of displaced oil.

7. When chloric acid is injected into the limy rocks as an intermediate layer, expansion of pores take place both in wellbottom area and in the depths of reservoir and resistance forces reduce because of the increase in the reservoir conductivity and it ensures the intensity of water injection into the reservoir.

8. As a result of better solution of CO_2, obtained in the reservoir and as it causes piston-type of movement of oil and water contact in the reservoir, it leads to decrease of water invasion along with increase of displacement of oil by water.

9. Depending upon the geological properties of the rocks, comprising the field, it is recommended that the implementation of the method after every 3 or 6 months will be more profitable. It will be possible to control both the acquisition of carbon gas and the volume of water injected into the reservoir in this way.

10. It will be possible to predict the sand formation process on the basis of analysis of the dynamics of wellhead pressure change.

11. It is identified that the quantity of entropy increases during sand formation. \

12. The proposed method paves the way to develope prompt and controlled stimulation methods to the wellbottom area for preventing problems in the lifting pipes and in the filtration area of the wells during sand formation.

Main content of dissertation reflected in the following works:

1. Osmanov B.A., Mustafayev K.İ. Consolidation of wellbottom area and isolation of water invasion // "OGGOC" SRI, Scientific works. – Baku: - 2013. Volume XIV, pp. 84-90.

2. Osmanov B.A., Mustafayev K.İ. Consolidation of wellbottom area and isolation of water invasion. Materials of the International Scientific Conference devoted to the 85th anniversary of Acadenician Mirzajanzadeh Azad Khalil, Baku: - 2013. pp.196-198.

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14. Mustafayev K.I., Development of methods for the improvement of efficiency of water injection into the reservoir //Azerbaijan Oil Industry, - Baku: - 2020. № 5, pp. 57-60.

In the works carried out with co-authors, the personal work of the author:

[10], [14] – performed on my own.

[1], [2], [3], [4], [5], [6], [7], [8], [9], [11], [12], [13] – presentation of problem, conduction of experiments and field studies, analysis of the results, data collection.

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