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# BOTTOMHOLE FORMATION ZONE RESTORATION MECHANISMS AND METHODS

The importance of the choice of well exploitation methods is analyzed. Mechanical methods applicable in carbonate reservoirs are discussed. To maintain the efficiency of field development, it is important to maintain the productivity of wells at the planned level throughout the entire production period by increasing their productivity. Productivity increase, skin effect reduction is achieved with the help of acid treatment, the main principle of which is rock dissolution to form a man-made network of microchannels in the bottomhole formation zone, which allows maintaining the recovery rate at the planned level for a long period of time. Forecasting the flow rate of wells in fields with reserves of high-viscosity oil is one of the most difficult tasks in the development of oil fields. Acid treatments quality increasing through new working agent's usage and improving the technology analysis is performed. Acidizing a reservoir is inherently dual in nature in terms of the desired effect: while in some conditions it has a positive effect, in other conditions it may not be applicable at all.

**Key words:** production, productivity, oil and gas engineering, technologies, choice of well exploitation methods, bottom-hole formation zone

**Introduction**.

Increasing the efficiency of impact on the bottom-hole zone of wells using hydrochloric-acid solutions is one of the factors of effective development of oil deposits in carbonate reservoirs. To solve this problem, it is necessary to provide a geological and technological justification for the selection of wells and technological parameters of impact in specific geological conditions of deposits [1–7]. A significant number of technologies proposed to date for stimulating the bottomhole zone using hydrochloric acid indicates a wide variety of productive formations in terms of bedding conditions, geological-physical and physicochemical properties of reservoir rocks and fluids saturating them, differences in the development technology, which must be taken into account when impacting to increase its effectiveness.

The experience of carrying out hydrochloric acid treatments (HAT), highlighted in the literature by various researchers, shows that in different geological and field conditions, this method of influencing the bottomhole formation zone has different efficiency and its value is determined by the influence of a wide variety of factors, among which the main ones are:

- type of HAT (foam acid, thermoacid, regular HAT, etc.);
- technological parameters of HAT (acid volume, injection pressure, acid concentration, etc.);
- geological features of formations (porosity, permeability, fracturing, etc.);
- technological performance of wells and deposits (current reservoir pressure, water cut, frequency of HAT, etc.).

Acidizing a reservoir is inherently dual in nature in terms of the desired effect: while in some conditions it has a positive effect, in other conditions it may not be applicable at all. Speaking about the impossibility of a full-fledged study of the process, it cannot be argued that the preliminary design and modeling does not play an important role in the success of the operation.

HMO planning consists of the following five main steps.

1. Diagnosis of the reasons for the deterioration.
2. Selection of appropriate reagents for processing.
3. Selecting the agent injection mode into the reservoir (designing).
4. Modeling (calculation).
5. Forecasting the final productivity of the well.

As far as we know, drilling a well involves the formation of a mud filter throughout productive intervals in order to prevent drilling fluid from entering the formation and its subsequent clogging. At the same time, it is practically impossible to induce inflow without removing the filter cake. It allows to remove the mud cake and proceed with the operation to call inflow. For the designated purpose, acid is used as the injection agent. It in oil and gas wells is carried out in the presence of inorganic sediments, such as: calcium carbonate, iron carbonate, sulfate salts and iron oxides.

In such cases is carried out to remove inorganic sediments from the well. The most commonly used injection agent in the removal of inorganic sediments is acid, which, among other things, reduces the skin factor. There is another condition under which it is necessary to conduct it. At low reservoir permeability, there is extensive experience with the use of it to create wormholes in the rock by dissolving it, which increases the productivity or injectivity of the well (depending on whether it is producing or injecting).

**Identification of previously unsettled parts of the general problem.**

Acid treatment is a non-stationary non-isothermal three-dimensional process of injection of an agent into a pore medium, which is accompanied by chemical reactions. At the moment when the injection agent enters the reservoir, the rock begins to dissolve in acid, which results in irreversible changes in its reservoir properties (porosity and permeability). Acid consumption also implies mass transfer processes and changes in concentrations. In addition to the above, there is a change in the temperature of the entire system in accordance with the laws of an exothermic reaction that occurs with the participation of acid and rock.

**The main purpose of this paper is**: to investigate the peculiarities of the bottomhole formation zone restoration mechanisms and methods. Conducting understands the understanding of the types and kinetics of chemical reactions occurring with the participation of acid and breed. During the process there is a continuous change in the concentration of acid.

**The main part.** The rate of depletion of acid is equal to the constant change in the concentration of acid in the superficial conditions, erected to the degree of coefficient, taking into account the change in thermobaric conditions. The function of the concentration of acid depends on the two variables: the reaction time and the distance from the bottom of the well. There are two types of chemical reactions: homogeneous and heterogeneous. If the acid reacts with the breed, then this is a heterogeneous reaction in which the acid is a liquid phase, and the breed is a solid phase. Hydrogen ion should first differ in the breed, react with it, and then the reaction product diffuses back into volume (dissolves). Thus, there are two stages of diffusion and one step of reaction, which cannot belong to a homogeneous reaction, which implies that both phases are liquid. It is obvious that in the process is accompanied by a heterogeneous reaction between the acid (liquid phase) and the breed (solid phase).

Technologies for carbonate and terrigenous collectors are fundamentally different. Carbonate breeds (limestone and dolomite) actively react with hydrochloric acid, and reaction products are well soluble in water. In general, there are two modes for oil and gas collectors:

1 – impact on the last environment (matrix);

2 – acid hydraulic rupture of the layer (hydraulic fracturing).

When exposed to the pore medium, the injection pressure should not exceed the hydraulic fracturing pressure. The use of acid compositions are mainly aimed at increasing productivity (reducing the skin factor) by removing the bridging agent and creating channels of increased conductivity (wormholes).

When comparing carbonate and terrigenous reservoir treatment approaches, as mentioned above, the chemistry of clay reservoir treatment is much more complicated. However, despite the simplicity of describing chemical reactions in carbonate reservoirs, the physical model of the process of carbonate rock dissolution is much more complicated than in clayey rocks. In sandstone, the dissolution process is slow, which means that the acid front moves evenly. In carbonates, the kinetics of the reaction of acid with rock is characterized by a high rate, which leads to uneven dissolution of the rock.

Below is a list of the most commonly used acid compositions for carbonate reservoirs.

As you can see, weak acids are used mainly for bottomhole treatment and cleaning of perforations; hydrochloric acid is used to treat the collector, despite the fact that the deeper the clogging zone extends, the more concentrated the acid must be applied. Thus, the use of highly concentrated hydrochloric acid is well suited for treatment in carbonate reservoirs.

Table 1. Recommended types of acid compositions for treatment of carbonate reservoirs

| Purpose of treatment | Recommended acid and concentration |
|---|---|
| Bottom hole treatment | 5% acetic acid |
| Treatment of perforations | 9% formic acid<br>10% acetic acid<br>15% hydrochloric acid |
| Deep penetrating treatment | 15% hydrochloric acid<br>28% hydrochloric acid<br>Acid emulsion |

Due to its high solvent power, hydrochloric acid is the most common reagent in carbonate reservoirs. There are two risk factors associated with the use of hydrochloric acid: high reaction rate and high corrosiveness. To reduce the level of corrosive activity, organic acids are added to the acidic composition. In addition to this, the low solvent power of organic acids makes it possible to reduce the level of uneven reaction front of the acid composition in the rock (formation of wormholes).

In light of the above description of the properties of organic acids, there is a practice of creating acid compositions based on hydrochloric acid with the addition of organic acids to achieve a moderate level of formation of high-permeability channels, which as a result positively affects the increase in well productivity. Organic acids are used for carbonate reservoirs many years.

Experience shows that the use of highly concentrated organic acids will not be effective, due to the possible precipitation of insoluble precipitates during the reaction of the reagent and rock. Permissible concentrations for formic and acetic acids are 13% and 9%, respectively.

During the analysis of the literature on the selection of acid compositions applicable to carbonate rock types, a list of recommendations for the use of hydrochloric acid was summarized and identified, taking into account the temperature of the medium:

$T \leq 149^\circ C$ 15% HCl or 28% HCl

$149^\circ C < T \leq 204^\circ C$ 15% HCl or HCl – Acetic acid

$T > 204^\circ C$ 10% HCl or HCl – Acetic acid

It is important to take into account the fact that the reaction of hydrochloric acid with rock and the reaction of organic acids with rock do not occur simultaneously. In the presence of strong and weak acids in the CS, the weak one enters into the reaction only after the strong one has been worked out.

First to react hydrochloric acid, and only after reaching the minimum concentration of hydrochloric acid, a weak acid reacts with the rock.

This is a kind of delayed action system that allows you to increase the depth of penetration and processing.

Another means of prolonging the reaction is to increase the viscosity of the reactant. In this case, the slowing down of the reaction is provided by slowing down the diffusion of the hydrogen ion into the rock, which is achieved by increasing the viscosity of the acid solution.

One approach to increase the viscosity of an acid is to polymerize its solution. The polymer must be compatible with the acid solution and do not interact with the acid. Viscosity is controlled by adjusting the polymer concentration in the acid formulation. The addition of a polymer to the acid composition reduces its diffuseness and, as a result, the reaction rate (prolongation of the action of the acid on the rock). In addition to adding polymers, viscoelastic surfactants and gels are also used to increase the viscosity.

The second method of increasing the viscosity is fundamentally different from the first. It is based on the ability of a hydrochloric acid solution to mix with oil.

Acid-oil emulsion has a high viscosity and is used for carbonate reservoirs. Such an emulsion is called an acid emulsion.

Acid emulsion, in addition to the possibility of using it in deep-penetrating P treatment, has low corrosion-active properties. Acid emulsion reduces the rate of rock dissolution, has a high displacement capacity and, as a result, allows creating deep-penetrating channels connecting the bottomhole zone and the well. The mechanism of the reaction of rock with acid when using acid emulsion is slightly different from the standard. There is no uniform diffusion of hydrogen ions, and the acid, as an oil-insoluble phase, is represented by small bubbles in the emulsion.

To prepare an acid emulsion, there are some requirements:

1.Acid solution and oil are insoluble. To form a stable oil-acid emulsion, it is necessary to use an emulsifier, the action of which is aimed at reducing the interfacial tension between immiscible liquids.

2. The more energy transferred to the liquids during the mixing process, the more stable the emulsion will be. The best emulsifier in this case is a cationic surfactant, due to the positive charge of the carbonate rock. Like-charged media will repel and the emulsifier will not be able to be absorbed on the rock surface, which will ensure long-term stability of the acid emulsion and ensure deep penetration of the reagent into the formation.

3. Another important aspect in the mechanics of the reaction of the acid emulsion and the rock is the fact that the emulsion is unevenly distributed over the volume of the injected agent, respectively, the reaction rate slows down both with the rock and with the well equipment, which increases the depth of penetration into the reservoir and low corrosive activity of the acid composition.

To achieve the maximum effect, the following conditions must be met: the reagent must be completely delivered to the contaminated reservoir zone, and the reaction products must be completely removed after surgery. Selective injection becomes really necessary in interbedded reservoirs with unstable reservoir properties, since a homogeneous fluid will flow into reservoirs with higher permeability, and low-permeability interlayers will remain untreated and, subsequently unused.

One of the most significant factors is to ensure that the acid composition enters the plugged formation zones. This is especially important in wells that open several productive horizons with different permeability. Since the high-permeability formation absorbs the main part of the acid and the low-permeability formations remain not involved in the acid treatment process.

The area of penetration of the acid composition into the formation is an important component of the success of the treatment. Colmatation, which, among other things, depends on the interaction of fluid and rock, can be distributed unevenly throughout the entire thickness of the formation. In this case, the initial permeability of the reservoir can also be uneven and distributed with a large spread throughout the reservoir. Under such conditions, during matrix treatment of the formation, the behavior of the reagent, which consists in choosing the path with the least resistance (bypassing the most clogged zones along the most permeable or less contaminated ones), ultimately has a detrimental effect. And each subsequent pumped volume of acid continues to go through the already treated zones, getting into the layers that least need acid exposure.

**Conclusions and ideas for further investigation.**

There are some physical means of diverting the injected acid composition for selective treatment, which include: the use of rubber-coated balls that are added to the composition of the injected fluid to plug the receiving perforations, and the use of packers that isolate the zone required for treatment during the operation from the rest of the wellbore. Mechanical methods of selective treatment differ from the rest in that they completely cover non-target intervals, directing the entire flow of the reagent into an open area [8–14].

Another available mechanical selective treatment method is coiled tubing (or injection of a reagent using coiled tubing). Flexible pipes allow directional injection of acid into specific reservoir intervals.

In addition to the above mechanical methods of selective acids, there is another specific method applicable in carbonate reservoirs. The method includes the injection of a high-viscosity acid composition (gelled or self-diverting), the viscosity of which varies depending on the fluid velocity. The effect of varying viscosity of the CW depending on its filtration rate makes it possible to uniformly treat the entire productive interval with acid, regardless of the range of change in reservoir properties throughout its entire length. This selective SCR method has recently been introduced into production and shows good results. It should be mentioned that there are two main methods of intensification of inflow – and hydraulic fracturing. Treatment of the bottomhole formation zone, which is mainly represented by acid treatment technologies, was described in detail earlier in the current chapter. In the last paragraph, a brief description of the fracturing technology will be presented.

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**МЕХАНІЗМИ ТА МЕТОДИ ВІДНОВЛЕННЯ ПРИБІЙНОЇ ЗОНИ ПЛАСТУ**

Проаналізовано важливість вибору методів експлуатації свердловин. Обговорюються механічні методи, застосовні в карбонатних колекторах. Для підтримки ефективності розробки родовищ важливо підтримувати продуктивність свердловин на плановому рівні протягом усього періоду видобутку за рахунок збільшення їх продуктивності. Підвищення продуктивності, зменшення скін-ефекту досягається за допомогою кислотної обробки, основним принципом якої є розчинення породи з утворенням техногенної мережі мікроканалів у привибійній зоні пласта, що дозволяє підтримувати видобуток на плановому рівні протягом тривалий період часу. Прогнозування дебіту свердловин на родовищах із запасами високов'язкої нафти є однією з найскладніших завдань розробки нафтових родовищ. Проведено підвищення якості кислотних обробок за рахунок використання нових робочих речовин і вдосконалення технології аналізу. Підкислення резервуару за своєю природою має подвійний характер з точки зору бажаного ефекту: хоча в одних умовах воно має позитивний ефект, в інших умовах воно може бути незастосовним взагалі.

**Ключові слова:** видобуток, продуктивність, нафтогазове машинобудування, вибір методів експлуатації свердловин, технології, привибійна зона пласта

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**МЕХАНИЗМЫ И МЕТОДЫ ВОССТАНОВЛЕНИЯ ПРИБОЙНОЙ ЗОНЫ ПЛАСТА**

Анализируется важность выбора способов эксплуатации скважин. Обсуждаются механические методы, применимые в карбонатных коллекторах. Для поддержания эффективности разработки месторождений важно поддерживать продуктивность скважин на запланированном уровне в течение всего периода добычи за счет увеличения их производительности. Повышение производительности, снижение скин-эффекта достигается с помощью кислотной обработки, основным принципом которой является растворение породы с образованием техногенной сети микроканалов в призабойной зоне пласта, что позволяет поддерживать дебит на запланированном уровне в течение длительный период времени. Прогнозирование дебита скважин на месторождениях с запасами высоковязкой нефти является одной из самых сложных задач при разработке нефтяных месторождений. Проведен анализ повышения качества кислотных обработок за счет применения новых рабочих агентов и совершенствования технологии. Кислотная обработка пласта носит двоякий характер с точки зрения желаемого эффекта: если в одних условиях она дает положительный эффект, то в других условиях может вообще не применяться.

**Ключевые слова**: добыча, продуктивность, нефтегазовое дело, технологии, выбора способов эксплуатации скважин, призабойная зона пласта.