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EXPERIMENTAL SIMULATION OF GAS-FLUID EFFECT IN HETEROGENEOUS POROUS MEDIUM

Abstract

The results of experimental investigations devoted to the search of new stimulation methods on oil reservoirs by gas fluid fringes are cited. The possibility of creation of gas fluid fringes system in the process of alkalini reagent reaction with hydrocarbons containing active acid components is shown.

A field method based on the effect of the leveling of displacement front and increase of coverage of weakly drained section of stratum at the expense of formation of gas-fluid system at stratum conditions is suggested.

One of effective methods of heavy, high-viscosity oil production is the bed stimulation by various physicochemical methods including both thermal technology and application of aqueous solution flooding of chemical agents as reagents. These methods allow to provide essential increase of oilrecovery factor. The efficiency of hydrocarbons production using such technologies is in sharp decrease of heavy oil viscosity, surface tension decline at interface, increase of temperature in a contact zone and etc [1-4].

Technologies based on the use of various chemical additives to water admitting to change the wetting characteristics of porous medium are already many years being used in oil-recovery practice alongside with thermal stimulation ways.

Aqueous solutions of alkalis used as injection agents in alkaline flooding of oil fields being at the late stage of development are widely used as displacement agents. The diluted aqueous solution of alkali changes the wetting characteristics of porous medium of oil-bearing collector and as a consequence creates favorable conditions for leaching and emulsification of asphaltene components of high-viscosity oils.

The effects of interaction of alkali with oil collector rocks and its saturating formation fluid are on the basis of technology of alkaline stimulation on depleted layer. High displacing ability of alkaline water, its influence on interphase properties of oil, water and rock is already known many years [1, 3, 5, 6].

Application of alkaline solutions in flooding of depleted oil fields is of significant interest in recent years because of investigations connected with organic and heteroorganic compounds having lower and mean molecular mass: high molecular pitch and asphaltenes and also various organic compounds in oil content.

It was shown [5] by the experiments that aqueous solutions of alkali in the boundary with oils of pays give a significant decrease of surface tension value and thus have great activity than the solutions of chemical agents traditionally used at present.

The data obtained by means of strain measuring indicate on surface tension decrease in the boundary with oil from 32,0 to 1,0 mH/m at alkali concentration in water equal to 0,1% .

The results of numerous papers devoted to alkaline stimulation say that in many cases the processes holding at interaction of aqueous solution of alkali on the bases of sodium carbonate (Na_2CO_3) with active acid components contained in high-pitch heavy oils are ignored.

During the carried out investigations it was assumed that the interaction between the alkalini solution and active acid components of oil essentially effects on the increase of oil recovery at alkaline flooding alongside with interphase tension decrease effects, oil emulsification, rock wetting alternation and etc. Experimental investigations were based on the assumption that during chemical reaction of aqueous solution of alkali with active components in heavy oils (naphtenic, carboxylic organic acids and others) it happens gas liberation (CO_2) and formations in a porous medium of a gas fluid system.

As an oil model the oil samples of Binagadi-north field (horizon ГД5ABCD) with the following characteristics we used: density 932-940 kg/m^3, viscosity -99,8-99,9 mPac; content of organic acids - 0,5-1 mg KON/g .

The investigations on definition of interfacial tension (6) of alkali solutions in the boundary with oil samples were carried out beforehand.

In fig.1 the isotherms of surface tension of soda ash and caustic soda solutions are represented.

For the considered dependencies of the value of surface tension on the type and alkali concentration it is seen that both investigated reagents lead to significant decrease of surface tension from 0,8 to 0,0014 mH/m. The greatest decrease of surface tension happens at concentration of alkali equal 0,5 mas.% and up to the values equal 2,0 mac.%. Then we observe the distinction in alternation of the quantity σ, namely, when we use caustic soda solution $NaOH$, beginning with quantity of concentration equal 2,0 mas.% it practically happens tenfold increase of σ to the values 0,01 mH/m, when by investigating the solution Na_2CO_3 and at high values of concentration the exponents of surface tension remain stably low.

The obtained results say that when the application of high concentrations (2-4 mas.%) of alkali solutions is justified from the point of view of wetting alternations of hydrophobic surfaces of porous media, the use of soda ash may be more effective as an alkali agent.

The stable low exponents of interfacial tension quantities when using soda ash may be also explained from the position of chemical reaction between the alkali solution and naphthene constituents of highly resinous oils. Liberation of carbonic acid gas CO_2 in this reaction is additional contribution to this process.

Visual observation for the blending of oil sample and aqueous solution of soda ash at the open volume also showed that gasliberation holds at the whole of the volume reducing to significant gassaturation that affirms the assumption on possibility of gas fluid medium forming at conditions of wide contact of oil and alkali solution in porous medium.

Thus, the observed process initiates the generation of so-called pseudoboiling gas-fluid system in formation in the capacity of displacing fringe that in its turn promotes to increase displacement efficiency of asphaltene and high resinous oils.

To affirm the introduced assumptions we carried out laboratory investigations on test model initiating a porous medium of productive stratum. A porous medium was represented by a two-layer model of stratum with permeable plate (with contacting homogeneous layers with ratio of permeabilities of layers 1:5).

To carry out laboratory tests an experimental installation was set up. Its scheme is in fig.2. The installation included the following elements: 1 - vacuum line; 2 - a column with two-layer model of a porous medium; 3 - a column shell; 4 - model manometers; 5 - valves; 6 - a PVT bomb; 7 - overflush fluid bucket; 8 - distributing manifold; 9 - proportioning pump; 10 - ultrathermostat; 11 - pressure controller; 12 - measuring tube.

The tests were carried out in the following sequence: high pressure column was filled with the mixture of silica sand (90%) and clay of montmorillonite group (10 %) by means of vertical vibrational plugging back; after fitting experimental installation, according the scheme (fig.2) at steady thermostability (T=323 K) vacuum compaction of the installation and water saturation of porous medium was performed during of which the volume of pour of a system equal to 0,3 m^3 was determined. Bomb PVT was filled with oil of Binaghadi (Azerbaijan) field ($\rho = 932-940$ kg/m^3, $\eta = 99,8-99,9$ mPac; the content of organic acids 0,5-1,0 mg/g) and it was pumped through the system. At practical absence of water in production the value of residual water saturation was defined about 20 %, oil saturation of the model assumed to be equal to 80 %.

In sequel, water displacement of oil was performed at constant pressure drop 0,15 MPa when the pressure in the entrance of column with porous medium is 8,0 MPa, in the exit - 7,85 MPa.

The experiments were carried out in three stages. At the first stage as background investigations oil displacement was performed by fresh water, at the second stage at similar conditions oil was displaced by 2% aqueous solution of caustic soda ($NaOH$) and at the third stage 2% aqueous solution of soda ash was used as a displacing fluid. At all cases the displacement was performed by continuous injection of solutions in 4-fold pore volume.

The results of investigations cited in fig.3 show the dependence of oilsaturation on the volume of fluid extracted from porous medium. As is seen from the figure, displacement of oil by fresh water, aqueous solution of $NaOH$ and aqueous solution of Na_2CO_3 the character of oilsaturation alternation is different. The alternation is characterized by the fact that by displacing the oil by aqueous solution of soda ash we observe a significant sharp decrease of oil-saturation that indicates to the best flushing of oil-saturated streak. In this case we can also observe comparatively high water-free oil-recovery coefficient.

To show the advantages and effects of alkaline flooding, first of all, a wide interface of injection and displaced fluids is necessary. It is possible to provide it only by continuous injection of large volumes of alkalini solutions that requires great pecuniary and fiscal expenditure. And at the conditions of development of exhausted reserves of hydrocarbous the application of traditional technologies of alkalini flooding doesn't give the desired result or differs by lower efficiency index.

In the context of recent investigations [9] the ability of stimulation efficiency increase on exhausted beds represented by the reservoirs that are nonuniform by permeability, by means of combined flowdeviating and gas generating technology of alkalini flooding is considered.

The developed method stipulates the creation of conditions for alternation of filtration direction of injected agent in bottom-hole part of injection well.

To this end, a composite controlled viscoelastic composition with supporting system is injected to the bottom hole zone of the bed. This composition forms impermeable barrier in porous medium of reservoir and obstructs the motion of injected alkalini solution to high permeable flushed sections.

In this connection at the second stage of experimental investigations we studied the ability of controlling of coverage by displacement of two-layer bed model homogeneous by permeability zones, saturated by the above-mentioned oil samples. To this end we used the above described model of porous medium with permeable plate partitioning high and lower-permeable layers. After attaining the limiting values of water-free displacement regime, beforehand prepared portion (10% from the pore volume) of viscoelastic composition with controlled joint time was injected to the entrance of experimental column. The composition was prepared on the basis of aqueous solution of acrylic group polymers by adding jointing agent. The injection of the given volume provides its primary penetration into high-permeable zone of porous medium and formation there blocking barriers. The next injection of aqueous solution of soda ash to the column deviated it to the direction of low-permeable layer of filtrating column and led to further reflash of residual oil whose results are in fig.4

In the course of this stage of experiments it was established that combined use of controlled viscoelastic composition with alkalini solution leads to rereplacement of residual oil that ensures additional increase of oil-recovery coefficient.

Thus, laboratory investigations admitted to establish that interaction of injected alkalini agent with active acid components of high-pitch and asphaltene oils plays an important part in alkalini flooding processes alongside with interfacial tension decrease, oil emulsification, rock wetting alternation factors.

Incremental produced oil is provided by increasing the coverage by stimulation of oil-saturated steaks by means of blocking of high-permeable sections by controlled viscoelastic composition.

Necessary concentration of soda ash in alkalini solution is chosen so that to exclude the influence of alkalini solution adsorption to the flooding efficiency it is performed sequential injection of alkalini solution with stepwise alternation of concentration of Na_2CO_3 from 0,05-1,0% to $10,0\%$ to the fringe stratum.

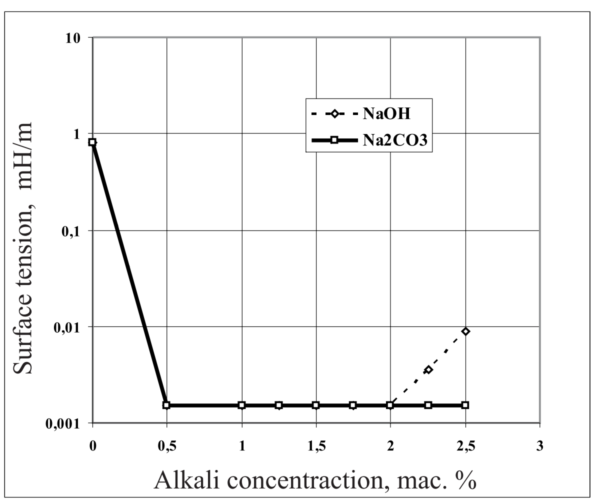

Fig.1. *Alternation of surface tension at the interface of "oil-alkali solution"depending on the concentration of $NaOH$ and Na_2CO_3.*

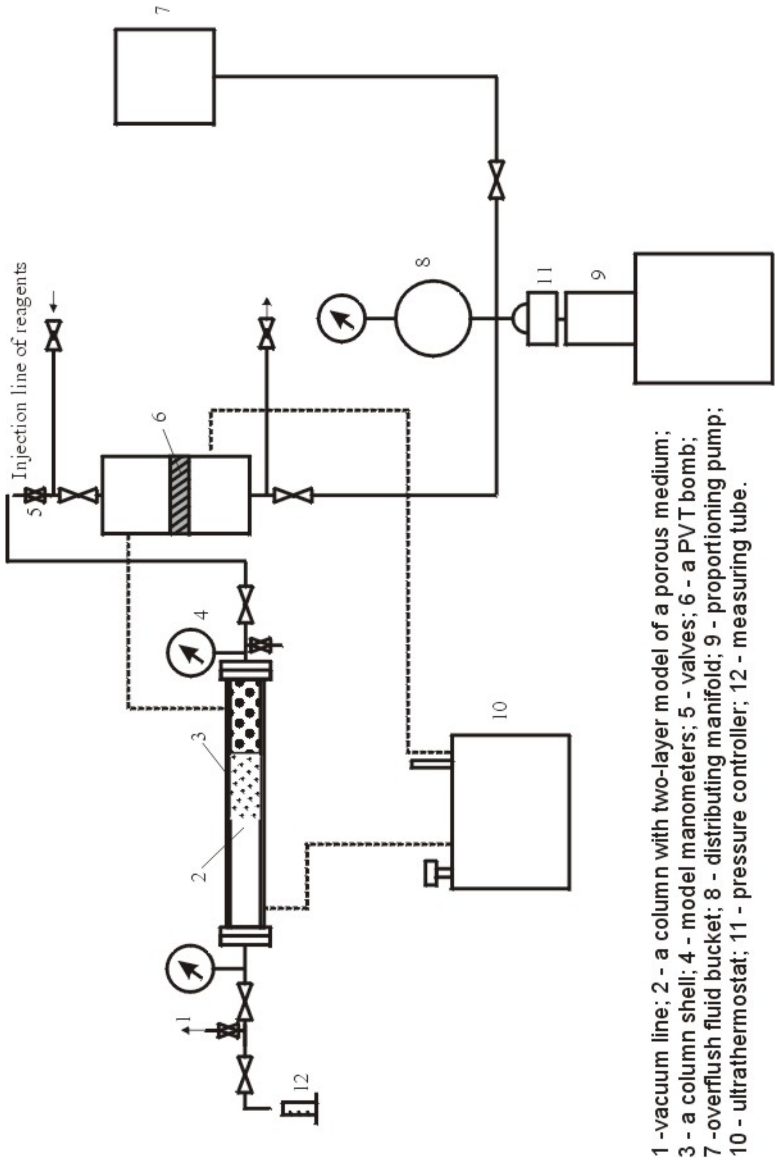

Fig.2. *The scheme of experimental installation.*

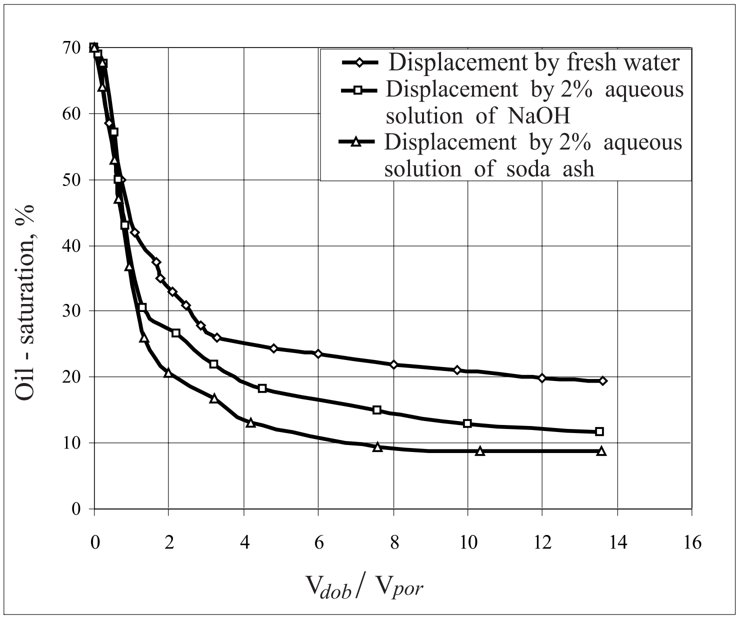

Fig.3. *Dependence of oil-saturation on the volume of recovered fluid.*

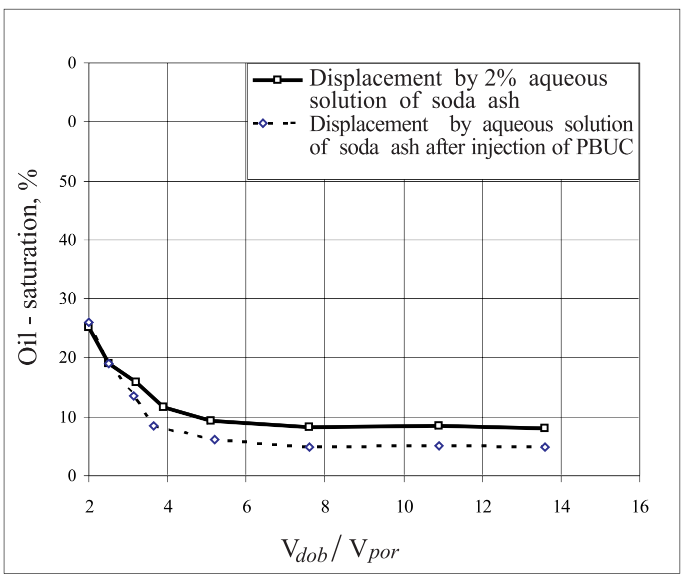

Fig.4. *Dependence of oil-saturation on the volume of recovered fluid by reflushing a porous medium.*

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