P220 RHEOCHEMICAL TECHNOLOGIES TO IMPROVE OIL RECOVERY AND STIMULATE OIL PRODUCTION

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ABSTRACT

The efficiency and reliability of IOR techniques and production stimulation methods wholly depend on the quality level and amount of stimulation and isolation repair works and on the reasonable choice of chemicals used for oil recovery operations.

The low efficiency of such operations is mainly due to the following factors:

- complicated wellbore profile;
- wellbore aggressive environment (salts, BS&W, waxes and other hard particles);
- high colmatage of the bottom-hole zone;
- sealing defects in casing and tubing;
- flow losses in some parts of the wellbore;
- high GOR;
- high injectivity (over 500 cum per day at 10 MPa wellhead pressure);
- low injectivity (below 500 cum per day at 10 MPa wellhead pressure);
- abnormally high/low formation pressure;
- defective sealing in rubber and synthetic parts and joints of wellbore equipment;
- simultaneous impact of factors mentioned.

More than 30% of oil wells in Russia have been shut down for many years because of above-mentioned factors. It impacts negatively on the strategy of oil field development and the objectivity of estimates as far as the efficiency of IOR methods is concerned.

Apart from the direct losses this situation may lead to the artificial reservoir heterogeneity, the irregular oil displacement, the formation of zones with premature increase of water production, and finally to the depletion of oil recovery.

The objective of this report is to introduce some new rheochemical technologies using specific multifunctional chemical compositions as well as methods and means of their application.

INTRODUCTION

The statistics which have been accumulated with regard to unsuccessful application of chemicals in oil production operations suggest that all researchers concerned with new chemical-oriented technologies be aware of corresponding requirements in this area.

The authors of the following report have managed to develop specific chemical compositions which have a wide range of structural and mechanical properties, necessary adhesive power, density, polymerization cycle and capacities for dissolution and retention of free gas. To avoid the impact of gravitation and sedimentation phenomena these compositions also make it possible to regulate their density under overall pressure conditions and to ensure high thermal stability characteristics of them. It also became possible to supply an adequate solution for the utilisation and environmental security problems which may arise in connection with developed viscoelastic compositions.

The newly developed rheochemical technologies were used in such technological operations as:

- emergency well killing before repair works;
- cleaning of bottom-hole zone;
- increase of productivity and inter-repair time in deep-well pumping operations;
- lowering of water cut in production wells;
- setting of combined cement plugs in wellbore;
- isolation of oil/gas, oil/water parts of formation and other operations.

LABORATORY AND FIELD TEST RESULTS

Compositions designed for application in the technological process of well killing are prepared on the basis of water solution of polyacrylamid with crosslinkers and filling agents. The evaluation of dynamic viscosity and maximum shear effort was carried out according to flow curves established for compositions running through the capillary tube which had 2,37 m in length and 5,92 mm in diameter. Values of maximum shear effort and dynamic viscosity for the viscoelastic compositions vary within a wide range.

Investigation of thermal stability was conducted as follows. Five drying boxes were put to constant temperatures of 60⁰ C, 70⁰ C, 80⁰ C, 90⁰ C and 100⁰ C respectively. Each box hosted 4 samples of the aforesaid compositions measuring 200 cucm which were under observation during 30 days. The beginning of structural destruction was observed at 100⁰ C for all 4 compositions. Density evaluation tests were carried out in PVT cell under overpressure of 1 MPa, 5 MPa and 10 MPa by hydraulic press. On the basis of test results one comes to the conclusion that introduction of the filling agents makes it possible to create compositions with enhanced thermal stability, viscosity and maximum shear rate which permits to regulate their density.

Field tests were conducted in the multilayer Samotlor oil field. Productive formations in the trial zone are at the depths of 1700...2300 meters. Permeability ranges from 100 to 450 mDarcies, porosity - from 0,2 to 0,28, GOR - from 50 to 300 Ncum/cum. 50% of wells in trial zone have been shut-down for a long time because of abnormal geological and technical conditions caused by free gas and abnormally high or low reservoir pressure.

Newly developed compositions and killing technologies were tested during workover and current remedial subsurface operations.

1. EMERGENCY PRODUCTION WELLS KILLING

In the process of well killing a special viscoelastic composition was preliminary injected into the well. With gas being dissolved in the composition its density diminishes, and the hydrostatic pressure of viscoelastic column is lowered.

On the basis of field tests it was found that dispersing filling agents included into viscoelastic systems served for better dissolution of maximum amounts of gas. Moreover, the maximum depletion of composition density by adding of filling agents at the rate of 10% of volume has increased gas solubility as well. For instance, with gas dissolved in the composition its density which was initially of $\rho = 0,8 \text{ g/cucm}$, went down after trial to $\rho = 0,4 \text{ g/cucm}$ on the well outlet.

If the initial density was $\rho = 1,05$ g/cucm, the density of aerated viscoelastic composition with filling agent was $\rho = 0,9$ g/cucm as measured at the well outlet, and for the initial density of $1,11$ g/cucm the density at the outlet was $\rho = 1,10$ g/cucm. I.e. with increase of initial density of composition gas dissolution power in it is considerably reduced.

It should be stressed that during well killing operations period of time must be scheduled for keeping the composition at high pressure to ensure maximum and high quality dissolution of gas and to attain the homogeneity of aerated viscoelastic composition as required.

According to field test results, the filling agent is in some way "a guide" contributing to better dissolution of gas in viscoelastic compositions. With test results available one can see that both newly developed compositions and corresponding amendments to repair procedures proved to be highly efficient. Owing to new compositions and well killing techniques one could happily bring to completion all workover and current subsurface remedial operations in oil wells with abnormal geological, technical and technological conditions.

So, in well № 37058 the GOR was reached 250 Ncum/cum before the killing operations started, the injectivity was 70 cum/day and wellhead pressure 15 MPa. Several attempts to kill the well using traditional technologies were not successful. With application of new technology the well was successfully shut down and first quality remedial maintenance of subsurface equipment could be done thereafter.

Also successful was the killing of the well № 31110 with abnormal reservoir pressure of 23,5 MPa at depth of 1780 m.

It has to be noted that all gas-lift wells that were shut down with application of new well killing technologies and repair procedures came back to their production mode 2-4 hours after the operation was completed. Using traditional technologies, if successful, such wells came to previous production mode after several days (Fig.1).

2. CLEANING OF BOTTOM-HOLE COLMATANTS

Proposed technology consists in pumping the viscoelastic composition into the reservoir and lifting it back to surface with colmatants by means of repressuring. The repressurization can be achieved either by reducing the hydrostatic pressure in reservoir or by usage of a special hydraulic bailer. The bailer is used when the reservoir pressure is low, i.e. $P_{res} < P_{h.s.}$ In low pressure wells the wellbore sections between two neighbouring perforations was generally plugged with sludge. So that prior to the injection of the viscoelastic composition to bottom-hole zone one has first to remove from the wellbore the residual sludge sediments which are mainly the remnants of destroyed productive formation skeleton, as well as chemical and mechanical increments that might have been left in the hole after workover or current subsurface repair operations. This work can be done with special hydraulic bailer which. Compared to other bailing equipment, has the advantage to provide for the regulation of repressuring values and of speed of incoming fluid in the tubing. The regulation of repressuring values is made by choosing the appropriate location for the bailer in the tubing. The choice of location is made also with regard to limits of compression for tubing. The speed of incoming fluid charged with sludge is regulated by opening a corresponding number of perforations available in bailer's inlet section. It is important as the sludge "cup" may be of different size, and prevents the formation skeleton from additional destruction.

After removing the sludge cup from the wellbore the viscoelastic composition is injected into formation in distance of 1,0-1,5 m around the well. It remains that wellhead pressure with annulus closed should not be higher than destructive casing damage pressure, less hydrostatic pressure supplied by blow-down liquid.

Using time needed for polymerization of composition the tubing with bailer and packer can be taken up and down the hole. As the speed (not instantaneous) of composition with colmatants coming into tubing can be regulated, there is no such negative effects as water breakthrough into the wellbore. If $P_f \geq P_h$, the cleaning of bottom-hole zone is performed simultaneously with the well killing. The repressurization of the productive formation is then made either by using well pumps or by compression of well fluid.

3. INCREASE OF WELL PRODUCTIVITY AND INTER-REPAIR TIME IN PUMPING OIL PRODUCTION

It is known that in the process of discharging well fluids in pumping production mode oscillatory motions due to inertia forces in mobile parts of the drive are generated. The oscillations' amplitude may be very important and produce a sharp effect as regards mechanical load in rods. Longitudinal oscillations in tubing are likely to cause vibrations, bendings and destruction of pumping rods.

To avoid emergencies, it is proposed to inject into annulus a viscoelastic composition that serves to compensate longitudinal oscillations according to law of communicating vessels. Figure 2 represents the dynamometer chart before and after installation of hydraulic packer in the well. Using the hydraulic bailer for this purpose it became possible to sensibly reduce oscillations and increase the well output by 65-70%.

4. LOWERING OF WATER PRODUCTION IN OIL WELLS

Admittedly, the increase of repressuring in oil formations should increase the well productivity too. Still, for so called "floating" deposits the growth of repressuring values may lead to a sharp rise of water cut due to piezoconductivity of formation oil and water is about 50 times different. Such formations are generally developed either by putting them on intermittent production or by exerting minimum repressuring efforts on productive formation.

To enhance the productivity of oil wells on such oil sites it is proposed to use lightened viscoelastic compositions with controlled density that remains stable under overall pressure going up to 25 MPa. These compositions are injected into the water part of reservoir. Owing to the fact that viscosity of such compositions is lower than that of formation water but higher than oil viscosity, injected composition find themselves in intermediate position between oil and formation water. Since they have better structural and mechanical properties than oil itself, there is a possibility to increase repressuring values and to improve oil output. Absolute values of repressuring are selected for each oil well case by case.

This technology may also find applications on production sites of multilayer deposits where one is confronted with serious problems concerning inter-column transfer flows when it's coming on to work in upper layers. Yet, the efficiency of existing methods of setting cement plugs is very low. Special plug compositions on the basis of epoxy resins allowing to considerably improve the results of isolation repair works in whole have been also developed.

CONCLUSIONS

1. Special compositions and highly-efficient technologies for technological operations of oil production have been also developed as well as special multifunctional viscoelastic compositions with enhanced thermal stability, density, shear stress limit, elasticity and optional viscosity for the needs of stimulation and isolation repair works have been also developed.
 2. Using a variety of inert and non inert filling agents one could attain the required density of composition which ensures the maximum dissolution and retention of gas in this composition.
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3. Composition and application method for creating equilibrium conditions in oil wells in view of well killing operations and further repair works on sites with abnormal geological, technical and technological conditions have been proposed.
4. New compositions and well killing technologies have been tested with success in the Samotlor, Urievsky and Pokamassky oil fields in Western Syberia and proved to be highly-efficient from the technological and economical point of view.
5. Environmental standards for maximum allowable concentrations of chemical agents being used and means of their utilization have been established.

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Fig. 1 Coming back to production mode:

1. Application of traditional technology of well killing and repair works;
2. Application of rheochemical technology of well killing and repair works.

Fig. 2 Dynamometer chart of well before (a) and after (b) installation of hydraulic packer.