Well killing and stimulation at oil well servicing with hydrophobic emulsion compositions

Dmitriy Vladimirovich Mardashov, Mikhail Konstantinovich Rogachev

Federal Government Budgetary Institution of higher education
"National Mineral Resources University (University of Mines)"
21-st line, 2, Saint-Petersburg, 199106, Russia

Abstract. Experience of oil field development indicates that during processes of well killing, as well as during their exploitation filtration characteristics of the bottomhole formation zone deteriorate gradually. The cause of this process is the use of water-based process fluids, which are most widely used at this stage of evolution of the oil industry. Alternative systems in this respect are hydrocarbon-based compositions, namely hydrophobic emulsions. This article presents results of laboratory studies and field tests of new technologies of well killing and stimulation of oil wells in well servicing using hydrophobic emulsions under field development conditions in Western Siberia. These technologies allow conserving, remediating and enhancing filtration characteristics of bottomhole formation zone during well servicing.
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Introduction

Analysis of oil field development indicates a deterioration of reservoir properties of the bottomhole formation zone due to the negative impact of process fst-otpravka n completing, well servicing and oil well exploitation. Use of commonly used water-based compositions of process fluids leads to a significant reduction in the permeability of producing formation by the hydrocarbon phase and, consequently, to lowering of oil production rates [1, 2].

There are two basic ways to prevent negative effects of traditionally used process liquids onto productive reservoir [2]:

- mechanical - use of technologies that prevent contact of aqueous compositions of process fluids with rocks of bottomhole formation zone (downhole safety valves);
- physicochemical - use of hydrophobic chemical compositions of process liquids [2, 3].

The second method is the most promising in the oil industry [2, 4, 5]. In domestic and foreign practice, hydrophobic emulsion compositions (inverse emulsions) of well killing fluids for well servicing are most widely used [2, 3].

Experience of hydrophobic emulsion compositions application indicates that they possess the following adjustable properties, which distinguish them from conventionally used water based well killing compounds [1, 2, 3, 6]: density, viscosity, thermal stability, filterability, etc. These parameters may be adjusted by content, salinity and type of aqueous (dispersion) phase; aqueous solutions of inorganic salts ($CaCl_2$, KCl, NaCl, $ZnCl_2$) are usually used as this phase. However, when aqueous solutions of acids (e.g., hydrochloric acid HCl) are used as the dispersion phase, hydrophobic emulsion can act as stimulating compositions, improving conditions of oil inflow to bottomhole zones of oil producing wells [4].

Therefore studies related to development of new hydrophobic well killing fluids formulations and technologies of their application to conserve, remediate and enhance bottomhole zone filtration characteristics during well servicing are considered relevant in the oil and gas industry.

The essence of the developed technologies consists in application of listed hydrophobic emulsion compositions during well killing before well servicing:

- inverted water-oil emulsions (IWOE) - "blocking compositions" injected into well with coverage of perforation interval or with squeezing into reservoir bottomhole zone, ensuring preservation of its filtration characteristics, and as a consequence, preservation of well productivity;
- inverted acid-oil emulsions (IAOE) - "stimulating compositions" injected into the well with squeezing into reservoir bottomhole zone ensuring improvement of its filtration properties and, consequently, increase of well productivity.

High aggregate stability of the developed process fluids is provided by use in their composition an emulsifying agent "Yalan-E2" [7], which is designed and implemented in industrial production together with "Synthes-TNP" LLC (Russia, Ufa, Rep. Bashkortostan). Currently, this emulsifying agent is supplied to a number of oil and gas companies in Western Siberia.

Main part

As the basic chemical reagent in development of new processing liquids was used a synthetic nonionic surfactant (emulsifying agent) "Yalan-E2" provided by "Synthes-TNP" LLC.

In developing of formulations of a new process fluid compositions the optimal concentrations of the reagent-emulsifier were determined (Table 1). It should be noted that the hydrophobic emulsion compositions stabilized with emulsifying agent "Yalan-E2", possess high thermal stability, i.e. 100% aggregate stability at 80 ºC, which allows recommending this type of surfactant for use under conditions of high reservoir temperatures, particularly in the oil fields of Western Siberia [1, 8, 9].

Table 1. Composition and technological properties of hydrophobic emulsions

Composition name	Hydrophobic emulsion composition, vol.%			Characteristic of the disperse phase		Density, g/cm³	Thermal stability at 80 °C, days.
	"Yalan-E2"	diesel oil	disperse phase	concentration, %	solution type		
IWOE	3	47	50	10	$CaCl_2$	0,95	6
	3	37	60	40	$CaCl_2$	1,16	10
IAOE	1	49	50	12	HCl	0,94	1
	1	19	80	24	HCl	1,06	1

One of major advantages of the developed emulsion compositions compared to traditionally used water-based process fluids is the ability to control their processing properties by changing the amount and type of dispersed (aqueous) phase. So IWOE density is a controlled variable and may vary within a wide range (0,95-1,16 g/cm3). IWOE and IAOE compositions represent liquids with non-Newtonian flow pattern. Dynamic viscosity in such systems depends on shear stress and is a function of shear rate. At changing the content of the dispersed phase in compositions from 50 to 70 vol%., emulsion viscosity varies in a wide range (200-3000 mPa·s at shear rates 14,6-73,2 s^{-1}), which allows adjusting degree of its penetration into formation, depending on purpose of treatment [1].

Studies of corrosive activity of the developed IWOE and IAOE compositions showed its high protective properties to metals compared with traditionally used water-based process fluids. According to analysis of laboratory tests results (Table 2), emulsion compositions have lower corrosion rate in comparison with aqueous solutions of $CaCl_2$, and HCl (IWOE - 3 times and IAOE - 30 times) [10]. Such effect is explained by the fact that the disperse medium of these compositions is a hydrocarbon liquid (diesel or crude oil) which in contact with a metal surface reduces the degree of interaction between the dispersed phase of the emulsion (aqueous solution of $CaCl_2$ or HCl) with the metal. At the same time protective effect of the compositions is enhanced due to the presence of emulsifying agent "Yalan-E2".

Table 2. Corrosive activity of hydrophobic emulsions in comparison with aqueous solutions of salts and acids at temperature of 80 °C

No.	Studied composition	Corrosion rate, g/m²·hour
1	IWOE	0,14
	Aqueous solution of $CaCl_2$ (30 %)	0,42
2	IAOE	1,11
	Aqueous solution of HCl (12%)	33,0

To study the influence of IWOE on the filtration characteristics of reservoir rocks laboratory tests simulating a process "well killing - well development" in thermobaric conditions were conducted using natural terrigenous deposit core on a formation damage evaluation system FDES-645(Coretest Systems Corporation).

According to the results of experimental studies the IWOE composition during penetration into a porous medium of a reservoir rock showed hydrophobic properties, which resulted in preservation of permeability by hydrocarbon phase (coefficient of permeability restitution (CPR) was 80-100%) and in an increase of filtration resistance in relation to the aqueous phase (CPR in this case was 50% on average). It is reasonable to assume that use of this hydrophobic composition as a well killing fluid before well servicing will provide preservation of oil flow rates and decrease of water cut.

Influence of the IAOE composition on porous medium of reservoir rock was estimated by filtration studies results when interacting with a carbonate rock sand packed tube. The study results showed that the developed composition in comparison with a conventional aqueous HCl solution contributes to slow rates of interaction between its dispersed phase (aqueous HCl solution) with hydrocarbon- and water-saturated samples of reservoir rocks up to 2-3 times. As a result, use of IAOE as an intensifying process fluid allows increasing the depth of the bottom hole formation zone treatment with an active acid, providing a uniform penetration of the emulsion into a productive reservoir.

Thus, in order to improve the operational efficiency of the production wells new compositions of process fluids are recommended for controlled regulation of bottom hole formation zone filtration characteristics in well servicing. The developed compositions have hydrophobic properties, which distinguishes them from traditionally used water-based systems. Considering high periodicity of well servicing (1 well servicing per 1-1.5 years on average), a new approach to solve the problem of conservation, remediation and enhancement of the filtration characteristics of bottom hole formation zone was proposed, the essence of this approach lies in combination of each well killing operation before well servicing with bottom hole formation zone

treatment using developed hydrophobic emulsion process fluids [2]. Information about the technologies and areas of effective application of these compounds is shown in Table 3.

Table 3. Application technologies for the developed compositions of process fluids

Parameters	Developed composition	
	IWOE	IAOE
Composition characteristic	Inverted water-oil emulsion - blocking hydrophobic composition	Inverted acid-oil emulsion - intensifying hydrophobic composition
Effective application area	Low-, medium-permeable terrigenous reservoirs	Medium-, high-permeability carbonate reservoirs
Application technology	Perforation interval coverage or squeezing into a bottom hole formation zone	Squeezing into a bottom hole formation zone based on calculation of 1.0-1.5 m^3 per 1 m of productive formation effective thickness

Effectiveness of the technology of a bottom hole formation zone blocking with IWOE composition before well servicing which was developed jointly with «Oil Technology Overseas» LLC was confirmed by results of field tests conducted on several wells of Western Siberia oil fields. The test results showed high efficiency of application of this technology in the form of production rates increase by an average of 5-10 m^3/day, shortening of time of well putting into operation mode to 1-3 days and reduction of water cut by 20-30%.

Conclusion

Implementation of these technologies will allow: maintaining and increasing producing wells oil rates, reducing a water cut, reducing development time and time of well putting into operation mode, protecting oilfield equipment from harsh reservoir and waste waters.

Summary

1. Technologies of killing and stimulation of oil wells at well servicing to ensure conserving, remediating and enhancing filtration characteristics of bottomhole formation zone were developed. The technologies are based on application of hydrophobic emulsion compositions of well killing fluids.

2. A new approach to solve the problem of conservation, remediation and enhancement of the filtration characteristics of bottom hole formation zone was proposed, the essence of this approach lies in combination of each well killing operation before well servicing with bottom hole formation zone treatment using developed hydrophobic compositions of process fluids.

3. The following well killing fluid compositions and its application technologies are proposed:

- Inverted water-oil emulsions (IWOE) – "blocking compositions", injected into well with coverage of perforation interval or with squeezing into a bottomhole formation zone providing conservation of its filtration characteristics and, consequently, conservation of well productivity.
- Inverted acid-oil emulsions (IAOE) – "stimulating compositions", injected into well with squeezing into a bottomhole formation zone providing improvement of its filtration properties and, consequently, increase of well productivity.

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Corresponding Author:

Dr.Dmitriy Vladimirovich Mardashov

Federal Government Budgetary Institution of higher education

"National mineral resources university (University of Mines)"

21-st line, 2, Saint-Petersburg, 199106, Russia

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