P209 IMPROVED OIL RECOVERY FROM THE WATERED PRODUCTIVE STRATA IN THE CARBONATE RESERVOIRS

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ABSTRACT

The zones having poor reservoir properties remain unrecovered in flooding of the carbonate producing formations characterized by presence of many fractures in combination with low-permeability matrix. To solve the problem the technology for the treatment of the oil- and water-saturated reservoirs based on an increase of filtration resistance of the high-permeability watered reservoir zones using the polymer-dispersion systems (PDS) consisting of water-soluble polymers, dispersion rock particles and modifying additives has been developed.

When polymers and dispersion rock particles are injected into the reservoir their interaction in the fractures and large pores results in formation of the polymer-mineral systems substantially reducing their size. The residual flow resistance factor increases as the size of water-containing channels increases restricting water flow through the high-permeability intervals. Simulation of the formation processes indicates that PDS injection into the carbonate reservoirs at high water content of produced fluids provides an increase of oil recovery by 2.2...10.3.

The results of pilot trials in the oil fields of Stock Companies "Tatneft", "Kombineft" and "Udmurtneft" verified the feasibility of efficient PDS application in the carbonate reservoirs. For 6 years of the technology application in 25 test areas additional oil recovery totaled 28444 t and averaged 1153 t per one treatment.

INTRODUCTION

One of the basic problems of effective development of the oil fields having the carbonate producing formations is complete sweep efficiency of the producing formation which depends on a number of factors connected with geological structure of the reservoir, its reservoir properties and properties of formation fluids. Higher level of the carbonate reservoir fracturing as compared

with the terrigenous reservoirs is one of the causes of low efficiency of the flooding methods (1, 2, 3). The well-known hydrodynamic and physical-and-chemical methods for improved oil recovery using surfactants, alkalies, polymers and other reagents become low-effective during breakthrough of formation and injected water through the high-permeability reservoir zones into the producing wells. The problem has been solved by development of the methods and agents for restricting water flow in fractures and other high-permeability parts of the oil- and water-saturated reservoir. With that end in view we suggest to increase filtration resistance of the watered zones of the producing formation using PDS the application of which in the terrigenous reservoirs provides an increase of ultimate recovery (4). The paper presents the results of further studies for adapting PDS to the conditions of the carbonate producing formations by varying PDS technological characteristics and modifying them with various additives.

RESULTS AND DISCUSSION

Experimental studies involved:

study of PDS and their modifications' effect on the filtration characteristics and oil recovery from the carbonate reservoirs by simulating formation processes;

testing of the technology for PDS application under the conditions of actually developed oil fields.

Clay suspension, polyacrylamide DKS-ORPF-40NT, chromium acetate (III), formation and injected water having salt content 232 g/l and 130 g/l respectively have been tested.

Experimental studies aimed at developing the effective technology for

treatment of the producing formations in carbonate deposits on the basis of the patterns specified in the tests with terrigenous rocks (4).

Interaction of clay particles having the size 2...6 mcm and PAA results in formation of the clay-and-polymer systems having the size 10...150 mcm that is sufficient for filling the largest pores and microfractures of sandstone and carbonate deposits (4). We used more concentrated PAA or injected modifying additives taking into account the high adsorption properties of carbonate rocks as compared with sandstones.

All experiments for studying PDS effect on the filtration characteristics of porous medium and oil recovery have been carried out in the coupled cylindrical patterns simulating the stratified-heterogeneous reservoir with two isolated layers having different permeability. Porous medium was prepared out of grinded extracted carbonate core (for carbonate reservoirs) or grinded quartz

sand (for terrigenous reservoirs). It was saturated with formation water and oil of the applicable oil field diluted with kerosene up to required viscosity. The temperature was 303 K. The patterns have been flooded at constant flow rate of injected water up to 100% water content of produced fluids recovered from the high-permeability layer and stabilization of the filtration characteristics. Then the reagent slugs have been successively injected followed by water drive. The efficiency of treatment was evaluated on the basis of the residual flow resistance factor and increase of recovery factor as compared with flooding.

Test results indicated that:

residual flow resistance factor originated in carbonate porous medium by PDS as well as for sandstones increases as permeability increases (Fig.1);

plugging of the high-permeability layer with PDS and its modifications results in redistribution of filtration rate in the layers and increase of oil recovery (Fig.2);

recovery factor growth increases as heterogeneity increases (Fig.3);

PDS efficiency can be increased by modifying it with chemical reagents (Table 1, Fig.4).

Thus the tests indicated that recovery of additional oil from the heterogeneous carbonate reservoirs is feasible by increasing filtration resistance of the watered zones (fractures) by injecting of PDS and its modifications.

The technology for PDS application has been tested in the oil fields of Tatarstan, Republic of Komi and Udmurtiya. 28444 t of additional oil was recovered in 25 test areas by applying PDS and on the average 1153 t was recovered per 1 treatment (Table 3).

Figures 5 and 6 show the results of PDS injection into the injection wells N 4621 and 4643 in Arkhangelsk oil field of Stock Company "Tatneft". Injection of 2000 m³ and 1200 m³ of PDS respectively into the reservoirs resulted in reduction of well injectivity by a factor of 1.5 (Table 2). Isobar lines considerably varied in the reservoir indicating filtration redistribution (Fig.5). Because of fracture plugging sweep efficiency increases (Fig.6,a) decreasing water content of produced fluids and increasing oil production rate (6,b). 360 t of additional oil has been produced in the well N 4621 area for 12 months and 4635 t - in the well N 4643 area for 6 years while the action has been still efficient.

Conventional oil field equipment, ecologically safe polymers and cheap clay suspensions have been used for PDS application providing from 10 up to 50% of profit in combination with achieved technological effect.

CONCLUSIONS

1. Interaction of polyacrylamides and rock dispersions in the carbonate reservoirs results in an increase of filtration resistance of the high-permeability zones and fractures. In addition the residual flow resistance factor originated by PDS increases as permeability of porous medium increases.

2. Plugging of the high-permeability and fractured zones by the successive injection of clays and polyacrylamides results in the increase of reservoir sweep and ultimate recovery.

3. Recovery factor growth increases as heterogeneity of the carbonate reservoir increases.

4. The polymer-dispersion systems and their modifications are the effective agents for improved oil recovery from the carbonate reservoirs - additional oil recovery totaled 28444 t in 25 treated areas in the oil fields of SC "Tatneft", "Kombineft" and "Udmurtneft" and averaged 1153 t per 1 treatment.

5. The high economic efficiency of the technology for PDS application is based on additional oil recovery using conventional oil field equipment and ecologically safe polymers and cheap rock suspensions.

REFERENCES

1. B.F.Sazonov, V.S.Kovalev, V.A.Shabanov etc. Development of the carbonate reservoirs of porous type. Neftyanoye khozyaistvo, N 9, 1987, pp. 25-30.
 2. N.I.Lisin, D.V.Konovalov, A.K.Tsekhmaistryuk etc. Carbonate reservoirs of Timano-Pecherskaya province. Neftyanoye khozyaistvo, N 9, 1987, pp.31-33.
 3. R.Kh.Muslimov, R.G.Abdulmazitov. Improvement of the technology for development of low-effective oil fields of Tatariya. Kazan:Tatar publishing house, 1989.
 4. A.Sh.Gazizov. PDS application for improved oil recovery. Transactions of the 6-th European Symposium on improved oil recovery. 21-23 May 1991, Stavanger, v.2.
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1 - for terrigenous reservoirs
2 - for carbonate reservoirs

Fig.1. Relation of a residual resistance factor and porous medium permeability.

Fig.2. Dynamics of oil displacement from the carbonate heterogeneous formation model.

Fig.3. Relation of the recovery factor increase and level of the carbonate reservoir heterogeneity.

Fig.4. Filtration resistance variation of high-permeability layer porous medium after PDS injection.

Fig.5. Isobar map in the test area of Arkhangelsk oil field (Bashkir stage) before and after PDS injection.

Results of oil displacement simulation from the heterogeneous reservoirs
($K_1/K_2 = 3,0 \text{ mcm}^2/0,25 \text{ mcm}^2$)

Table 1

Characteristics	Average values	
	quartz sand	carbonate
Porous medium		
Viscosity of oil at 30°C, mPa·s	3,87	19,7
Residual water saturation, %	25,5	34,8
Characteristics by the end of primary flooding:		
- recovery factor, %	37,1	42,3
- waterflood displacement efficiency in high-permeability layer, %	68,0	41,9
- residual oil saturation, %	23,8	37,9
- mobility of water filtered through the high-permeability layer, $\text{mcm}^2/\text{mPa}\cdot\text{s}$	0,893	0,282
PDS efficiency:		
- residual flow resistance factor	1,60	1,27
- increase of recovery factor, %	3,5	2,2
Modified PDS efficiency:		
- residual flow resistance factor	4,41	3,22
- increase of recovery factor, %	14,3	7,4

Technical characteristics of PDS injection

Table 2

Characteristics	№ of injection wells	
Well injectivity, (m^3/day)/injection pressure, MPa:		
- before injection	880/0,5	960/0
- after injection	860/2,0	310/2,5
PDS flow rate, m^3	2000	1200

Results of PDS application in oil fields having carbonate reservoirs

Table 3

Stock company	Number of treatments	Form of well for injection	Additional oil production, t	
			total	on the average per 1 treatment
Tatneft	15	injection	16197	1080
Udmurtneft	1	injection	800	800
Komineft	9	producing	11447	1431
Total:	25		28444	1153

Fig. 6. Results of PDS injection into well 4346 of Arkhangelsk oil field.