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Scientific note

Dry Gas Injection for Miscible Displacement on Žutica Oil Field

PROCEEDINGS

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Key words: Gas injection, Miscibility condition, Enhanced recovery, Displacement, Vaporizing gas drive, Multiple contact.

Ključne riječi: utiskivanje plina, uvjeti miješanja, povećanje iscrpka, istiskivanje, otparavanje u plinsku fazu, višekontaktni proces.

Abstract

By the process of gas injection under miscible conditions, the total oil recovery also includes vaporized hydrocarbons from the residual immobile oil, in addition to the oil produced by direct displacement. The process is complex and involves the influence of the interaction of extracted hydrocarbons and in-situ oil at the displacement front. Therefore, the final oil recovery under miscible conditions is higher than the "conventionally" displaced oil. Methods of calculating multiple contacts miscibility with an Equation of State (EOS) determine the miscibility conditions by simulation processes as a vaporizing gas drive or condensing gas drive. The aim of this study was to determine a degree of miscibility.

Sažetak

Pri procesima utiskivanja plina ukupni iscrpak nafte uključuje osim nafte proizvedene izravnim istiskivanjem i ugljikovodike otparene iz zaostale, nepokretne nafte. Mehanizam procesa je složen i obuhvaća efekte interakcije otparenih ugljikovodika i nafte na frontu istiskivanja. Zato je konačni iscrpak nafte uz proces miješanja veći od "konvencionalno" istisnute i otparene nafte.

Metode računanja višekontaktnog otparavanja s nekom od jednadžbi stanja određuju uvjete miješanja simulacijom procesa; mehanizmom otparavanja ili mehanizmom kondenzacije. Cilj simulacije procesa proizvodnje nafte polja Žutica režimom podržavanja slojnog tlaka bio je određivanje karaktera procesa, tj. stupnja približavanja uvjetima miješanja izraženog veličinom iscrpka nafte.

1. INTRODUCTION

When a fluid is injected into a reservoir to displace oil towards the production well, oil recovery is not complete. One method to improve recovery is to reduce or suppress the interfacial tension between the oil and injected fluid. This happens when injected fluid, hydrocarbon gases for example (dry natural gas, mainly methane, carbon-dioxide) are miscible with oil (BLACKWELL et al., 1959; BENHAM et al., 1960; STALKUP, 1984).

2. METHODS AND RESULTS

The aim of this research was to simulate the process of oil production in the Žutica field by maintaining reservoir pressure, and to define process characteristics (miscibility or immiscibility conditions). To simulate the process, a unidimentional reservoir simulator COMP3 was used (Scientific Software Intercomp). A 9-component system was required in the formulation of fluid composition (adjusted to PR EOS). It was also assumed that the pore space contains only saturated oil (the criterion for fluid mobility calculated by multiple contact vaporization), and does not consider either the influence of petrophysical heterogeneities of the reservoir rock, or the viscous fingering of fluid. In fact, only the thermodynamic aspect of the process is investigated.

The sequence of calculations is correlated with the practical procedure of oil production which consists of:

1. Gas injection (SLOBOD & KOCH, 1963; CAUDLE & DYES, 1958) into a reservoir until a certain pressure is attained, and

2. Maintenance of constant reservoir pressure with a given value of oil production. Part of the injected dry gas is dissolved in the reservoir oil and the consequences are:

- increasing oil volume (oil-swell);
- changes in phase composition, density and viscosity of oil;
- changes in composition and density of equilibrium gas phase.

Changes of these properties of Žutica oil calculated for various pressures ranging from the initial saturation pressure P_{bi} = 128.5 bar up to 200 bars are shown in Fig. 1. In this particular case, injected dry gas is poorly dissolved in already saturated oil and swelling of oil is 6%, while oil density decreases by 3% from 0.687 to 0.665 g/cm^3. Simulation of the dynamics of displacement pro-

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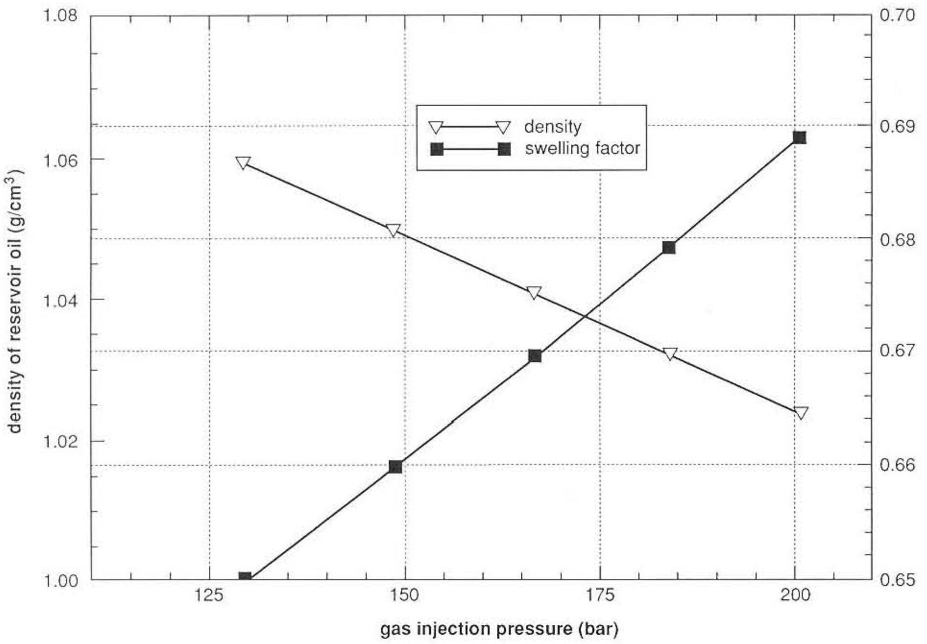

Fig. 1 Changes in properties of reservoir oil during gas injection (after JÜTTNER, 1995).

cess at set constant pressure of gas injection has already been performed under various pressure values. Typical curves of oil recovery versus volume of injected gas are shown in Fig. 2. Oil recovery is not a distinct function of injection pressure, therefore the oil recovery at a pressure of 135 bars (pressure close to actual reservoir conditions) is a little lower than oil recovery at 180 bars pressure. Gas injection of one pore volume (P.V.) at a pressure of 135 bar gave a recovery of 51%, while at a pressure of 180 bar the recovery is 55% of the original oil in place.

A practical method of defining a characteristic multiple contact miscibility between injected fluid and oil is the "slim-tube" test from which the minimum miscibility pressure (MMP) was determined. According to the criterion (YELLING & METCALFE, 1980) the minimum miscibility pressure (MMP) is that particular gas injection pressure when 1.2 P.V. of injected gas displaced over 90% of present oil. Results of the "slim-tube" test are shown in Fig. 3 which showes that the miscible conditions in the system (saturated oil Žutica - methane, respectively dry natural gas), can be achieved only after application of very high pressure (MMP of a system is 500 bar). In other words, in oil production from the Žutica field, the regime of pressure maintenance should make modest contributions by the mechanism of multiple contact vaporization to oil displacement, since in the interval of real applicable pressures of gas injection the process will proceed under immiscible conditions.

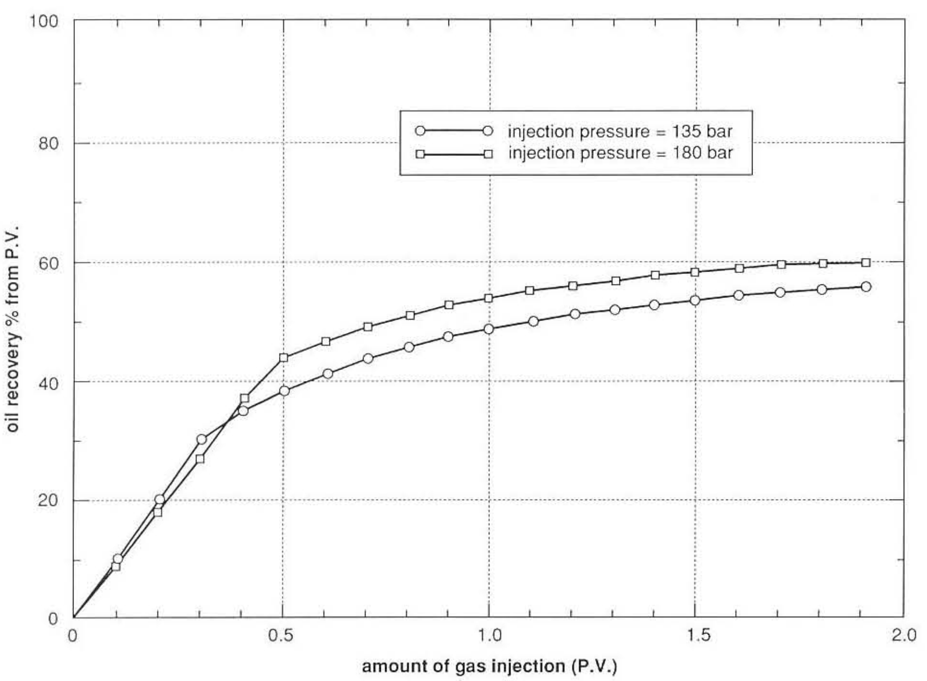

Fig. 2 Oil recovery by multiple-contact process (after JÜTTNER, 1995).

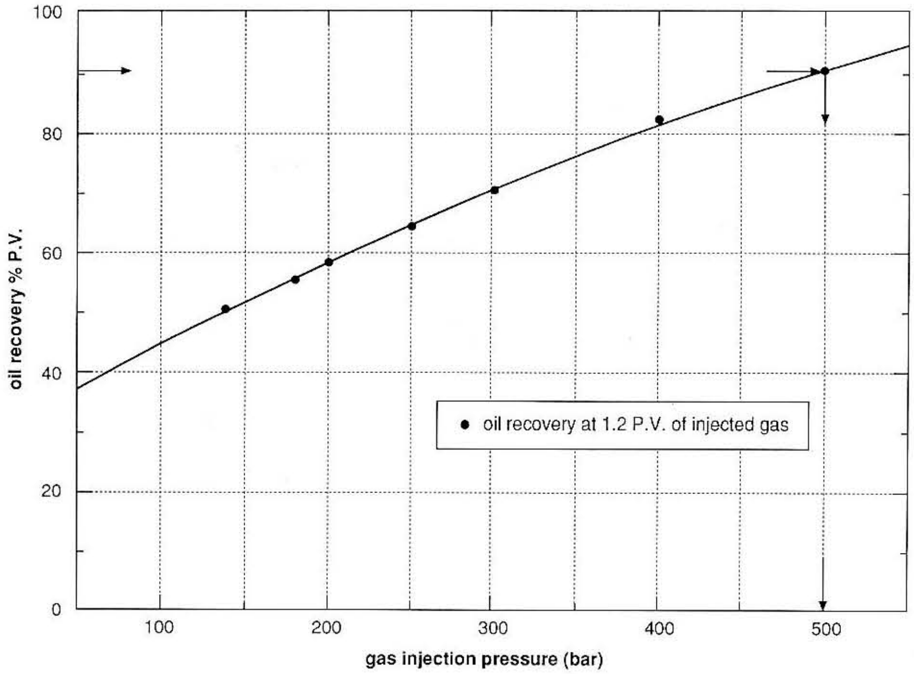

Fig. 3 Determination of minimum miscibility pressure (MMP) ("slime-tube" test) (after JÜTTNER, 1995).

Quantitative dynamic changes of composition with dependence on quantity of injected gas is shown in Fig. 4. The enrichment of dry gas with for example ethane is about 80% at the first contact and about 50% at the 16th contact (which equals the total injected volume from 0.8 P.V.). It must be noted that these data relate to processes of gas injection into saturated oil. The gas cap in the reservoir has not been considered. In this particular process, composition of the existing gas cap affects the phase equilibria and final composition of the produced gas phase.

3. CONCLUSION

By processes of gas injection into a reservoir, the composition of fluids in the area near the critical point distinctly differ from the composition of the original reservoir fluid. Therefore it is necessary to create a good model of a fluid from 9 to 15 components adjusted with one Equations of State (EOS).

To produce more oil, the pressure in the reservoir must be maintained by injecting another fluid. Oil displacement in the Žutica oil field by maintaning reservoir pressure by gas injection at an actual pressure of 130 bar occurs under immiscible conditions in accordance with the expected phase behaviour of a methane-oil system, because the minimum miscibility pressure (MMP) of injected gas in reservoir oil, determined by the "slim-tube" test, is about 500 bar. If the process should be performed at higher pressure (up to maximum possible reservoir pressure of 200 bar), it cannot be expected to produce a greater contribution to misci-

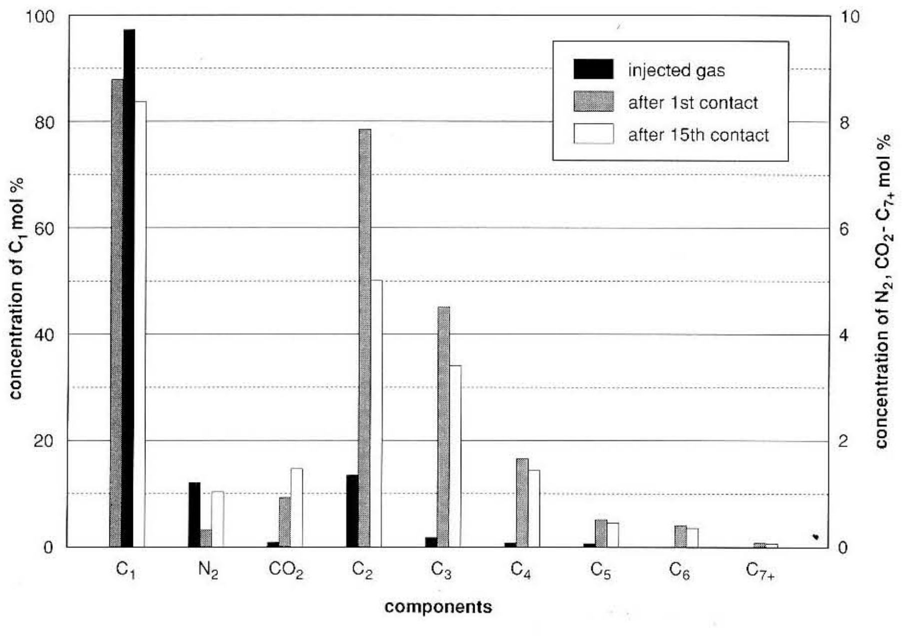

Fig. 4 Composition of equilibrium gas (after JÜTTNER, 1995).

bility displacement in the total production. At the present production regime, injection of the dry gas leads to enrichment of gas phase by multiple contact vaporization of light hydrocarbons. Low volumes of methane dissolve in the oil in place, so changes in the properties of the saturated oil are indistinct. The contribution of multiple contact mechanism of hydrocarbon vaporizing in total oil displacement is negligible.

Acknowledgment

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