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Experimental Investigation of CO_2 Flooding in Tight Oil Reservoirs Using CT Scanning Method

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Abstract

Tight oil reservoirs are characterized by ultralow permeability, causing hydrocarbons to be trapped in tiny pores and hinder the crude oil flow. CO_2 injection technology has been paid more attention in low-permeability reservoirs. In this work, the long core experiments of CO_2 flooding are conducted to study the displacement pressure and enhanced oil recovery, and CT scanning method is used to obtain the oil saturation profiles along the samples. The results show that the reservoirs pressure increases initially and decreases afterwards during CO_2 miscible displacement. The final reservoirs pressure is still much larger than the initial state, suggesting high energy supplement efficiency of CO_2 miscible displacement. At the initial stage (20 min), the pressure increases gradually, but oil saturation does not change very much. The initial oil flow is related to oil expansion induced by oil injection. After 20 min, the oil saturation at the inlet falls quickly. The oil saturation begins to decrease uniformly in the whole range of sections until the displacement front breakthrough. The sections near the inlet and outlet has larger residual oil saturation. The research is significant for understanding the microscopic mechanism of CO_2 flooding and enhancing oil recovery in tight oil reservoirs.

Keywords: Tight oil reservoirs, Enhanced oil recovery, CO_2 flooding, Residual oil saturation

1. Introduction

In contrast to conventional oil reservoirs, the tight oil reservoirs are characterized by more heterogeneous matrix, much lower matrix permeability and more complicated pore structure (Gao and Li, 2015). Horizontal-well drilling and multistage fracturing can result in network systems to justify economic production (Tian et al., 2015). The fast production decline is one of the most-intractable problems during tight oil development. The natural inability of oil flow refers to lower matrix permeability (<1.0 mD) and crude oil trapped by tiny pores. Globally, CO_2 flooding has been successfully used to recover crude from conventional oil reservoirs, but few investigations have examined tight oil reservoirs (Ben Salem et al., 2013). CO_2 can reduce interfacial tension, oil viscosity and residual oil saturation to recovers oil (Dong et al., 2012). In tight oil reservoirs, the oil and gas diffusion intensified by CO_2 is an important oil-recovery mechanism. In this paper, macro pressure distribution and micro oil saturation profiles are obtained to clarify the mechanism of CO_2 flooding in tight oil reservoirs

2. Experiments

The long core displace setup is used to conduct the CO_2 flooding experiments. The CT scanner in this experiment is developed independently by Research Institute of Petroleum Exploration and Development.

2.2 Experimental preparation and procedures

The CT values of dry and wet sample are given by

$$CT_{dry} = (1-\phi)CT_{grain} + \phi CT_{air} \tag{1}$$

$$CT_{wet} = (1-\phi)CT_{grain} + \phi CT_{oil} \tag{2}$$

According to Eq. (1) and (2), the porosity is given by

$$\phi = \frac{CT_{wet} - CT_{dry}}{CT_{oil} - CT_{air}} \times 100\% \tag{3}$$

where CT_{dry}, CT_{wet} are the CT values of dry and wet samples, respectively; CT_{grain}, CT_{air} is CT values of skeleton particle and air, respectively; CT_{oil} is CT value of oil.

The CT value of two phases is written as

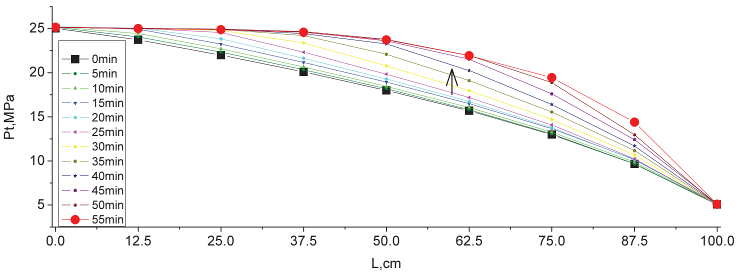
$$CT_{two\text{-}phase} = (1-\varphi)CT_{grain} + \varphi S_o CT_{oil} \tag{4}$$

The oil saturation is given by

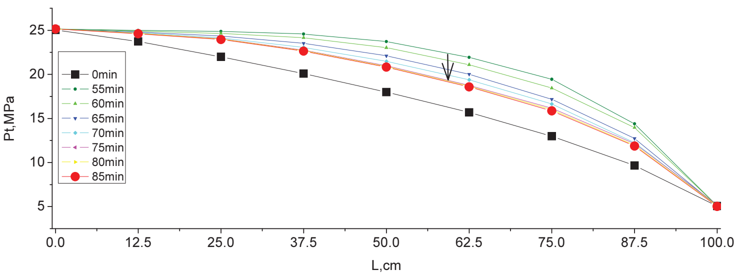
$$S_o = 1 - \frac{CT_{oil} - CT_{air}}{CT_{wet} - CT_{dry}} \cdot \frac{CT_{wet} - CT_{two-phase}}{CT_{oil} - CT_{CO_2}} \tag{6}$$

3. Results and discussions

3.1 CO_2 flooding pressure distribution



(a)



(b)

Fig. 1 The pressure distribution during CO2 flooding experiments

3.2 Oil saturation profiles

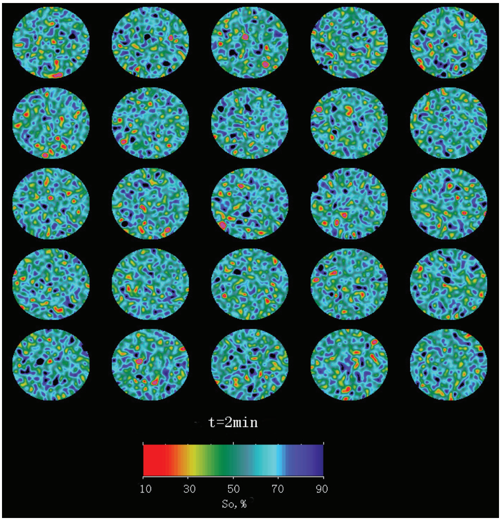


Fig. 2 The oil saturation profiles at 2 min

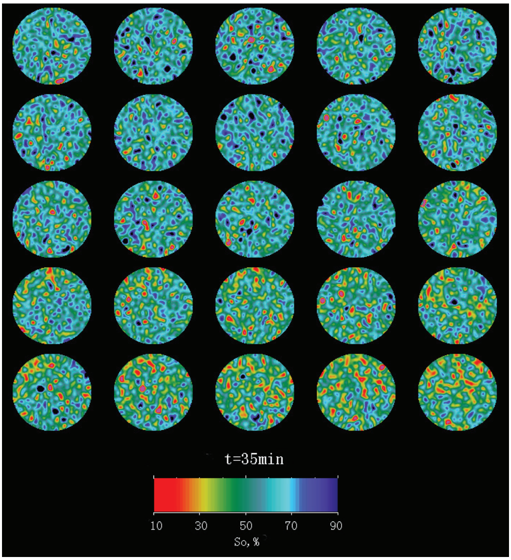


Fig. 3 The oil saturation profiles at 35 min

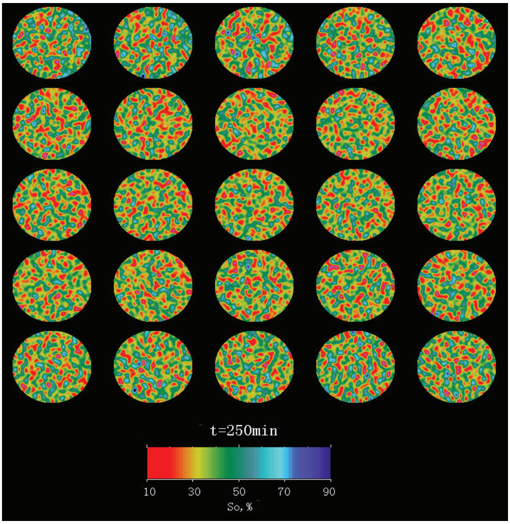


Fig. 4 The oil saturation profiles at 250 min

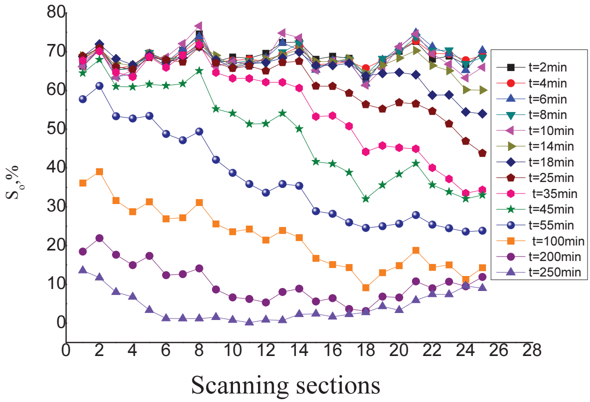


Fig. 5 The oil saturation profiles at different scanning sections.

4. Conclusions

(1) The reservoirs pressure increases initially and decreases afterwards during CO_2 miscible displacement. The final reservoirs pressure is still much larger than the initial state, suggesting high energy supplement efficiency of CO_2 miscible displacement.

(2) At the initial stage (20 min), the pressure increases gradually, but oil saturation does not change very much. The initial oil flow is related to oil expansion induced by oil injection. After 20 min, the oil saturation at the inlet falls quickly. The oil saturation begins to decrease uniformly in the whole range of sections until the displacement front breakthrough.

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References

Ben Salem, I., Cantat, I., Dollet, B., 2013. Response of a two-dimensional liquid foam to air injection: swelling rate, fingering and fracture. J. Fluid Mech. 714, 258–282.

Dong, X., Liu, H., Sun, P.,eta.., 2012. Air-foam-injection process: an improved-oil-recovery technique for waterflooded light-oil reservoirs. SPE Res. Eval.Eng. 15 (4), 436–444.

Gao, H., Li, H., 2015. Determination of movable fluid percentage and movable fluid porosity in ultra-low permeability sandstone using nuclear magnetic resonance (NMR) technique. J. Pet. Sci. Eng. 133, 258–267.

Tian, X., Cheng, L., Cao, R.et al. 2015. A new approach to calculate permeability stress sensitivity in tight sandstone oil reservoirs considering micro-pore-throat structure. J. Pet. Sci. Eng. 133, 576–588.