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RESEARCH PAPER

An enhanced oil recovery technique by targeted delivery ASP flooding

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Abstract: Aiming at the problem of the loss of the ASP flooding near the injection wells, this paper gives a new idea to enhance oil recovery called "Technique of Targeted Delivery", which combines the radial horizontal well with ultra-short radius drilled by high pressure water jet with the ASP flooding, the horizontal wells work as the "Target channel" transport the ternary composite system to the remaining oil enrichment area directly, to avoid the loss of the ternary composite system near the injection wells. The plate homogeneous experiment and numerical simulation show that the technique can significantly improve the sweep efficiency and the effect of the oil displacement, and greatly improve the oil recovery rate. The optimal flooding parameters of the target transport technique are: the right angle target, the length of the channel is about 15% of the well distance and the injection volume of the ternary composite system is 0.4 PV. Under such conditions, this technique can enhance recovery by 48.87% and 22.04% respectively, compared with the water flooding and conventional ASP flooding. The target transport technique solves the problem of high loss of chemical agent in near-wellbore area during the ASP flooding, and compensates for the high cost of ASP flooding and the limitation of application, and has a broad application prospect.

Key words: ASP flooding; targeted delivery; plate model; parameter optimization; enhanced oil recovery

Introduction

The ASP flooding is a kind of important tertiary oil recovery technology that can greatly improve the oil recovery rate[1–4], but the loss of ASP system in the formation has always been one of the bottleneck problems restricting the development of ASP flooding, especially near the injection well where the water saturation is high after water flooding, and a serious loss of ASP system could occur, negatively affecting oil recovery rate of the ASP system. A large number of researches have been done on the loss of ternary compound system at home and abroad[5–6] and the results show that physical and chemical adsorption, mechanical capture, shear degradation, chromatographic separation, diffusion and dispersion are some of the major factors affecting reservoir seepage of the ASP system in the reservoir. Liu Gang's research[7] showed that all components of the ternary compound system suffered severe losses when displacing in the second class oil layers: the surfactant loss rate reached 80% in the first 20% of migration distance and the loss rates of alkali and polymer were 23% and 12% respectively. At present, the two main methods to reduce the loss of ASP system are injecting front preflush slug before the injection of main slug or adding sacrificial agent directly in the main slug, but neither of them can effectively lower the loss of the ASP system, especially in near wellbore area, and both of them are high in cost. Therefore, how to reduce the loss of the ternary compound system near the injection well and improve the oil displacement efficiency of ASP flooding have become urgent technical problems to solve.

In recent years, with the ongoing development of oilfield and remaining oil tapping, the hydraulic jet drilling radial drilling technique based on high pressure water jet rock breaking technique has been used maturely. In 2007, several horizontal wells greater than 50.8 mm in diameter and 100 m in length were drilled using the hydraulic jet radial horizontal well technique in the Liujia coal mine[8]. In 2011, five 50-m long and one 90-m long radial horizontal wells were drilled in two layers of Well #1 of the Belayim oilfield in Egypt[9]. In 2012, several 100-m long horizontal radial wells were suc-

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cessfully drilled in Well M of the Yanchang oilfield[10].

To improve the utilization efficiency of the ternary compound system, by combining the high pressure water-jet radial drilling horizontal well technique with ASP flooding, an injection method called ASP system targeted transport technique was put forward, in which the high pressure water jet technique is employed to drill a ultra-short radius radial horizontal well from the injection well to the oil enrichment area after water flooding[11−14], also known as the targeted channel, through the targeted channel the ternary compound system is directly delivered to the oil enrichment area to reduce the loss of ASP system near the injection well, maximize the efficiency of the ternary compound system and enhance the recovery efficiency. To select the best displacement solution, the homogeneous core tablet model is used to carry out related physical displacement simulation experiment and the displacement parameters are also optimized by numerical modeling.

1. Experimental design of targeted delivery ASP Flooding

1.1. Experimental materials

(1) The alkali used in this experiment was analytically pure NaOH. (2) Sodium alkyl benzene sulfonate compound with effective content of 50% was used as the surfactant. (3) The polymer used in the experiment had a relative molecular mass of $2\ 400\times10^4 - 2\ 600\times10^4$ (on average $2\ 500\times10^4$), effective solid content of 90% and a hydrolysis degree of 22%. (4) The water used in the experiment was water simulated Daqing oil field formation water with a salinity of 6 778 mg/L (including 20 mg/L KCl, 3 488 mg/L NaCl, 114 mg/L Na_2SO_4, 564 mg/L $MgCl_2{\cdot}6H_2O$, 64 mg/L $CaCl_2$ and 2 828 mg/L $NaHCO_3$). (5) The experimental oil was prepared with degassing and dehydrated crude oil from the No.2 Daqing Oil Plant and aviation kerosene, with a viscosity of 7.9 mPa·s (measured by Brookfield Viscometer under 45 °C and 7.34 r/s). (6) The ternary compound system was prepared with 1 500 mg/L polymer (HPAM) solution (made up by simulated water) as the base liquid and 1.2% alkali (NaOH) and 0.3% effective mass fraction surfactant. The apparent viscosity of ASP flooding system was 36.8 mPa·s (The measuring method was the same as that in (5)). The interfacial tension between the simulated oil and ternary complex system was 2.05×10^{-3} mN/m at 45 °C. (7) The tablet core model (Fig. 1), homogeneously casted, had an injection well, a production well, electrodes and saturated oil wells and saturated water wells (used when saturated oil and water). Electrode was used to test the resistivity and calculate the oil saturation and then draw the oil saturation distribution diagram. The size of the model is 50×50×3 cm and its permeability is 500×10^{-3} μm^2.

1.2. Experimental apparatus

The displacement experimental apparatus included HDH-100C high temperature and high pressure constant speed pump, quiet air pump, HW-II type incubator, high pressure vessel, resistance test device, SVT20N type spinning drop interfacial tension meter, DV - II + Pro type Brookfield viscosity meter and measuring cylinder.

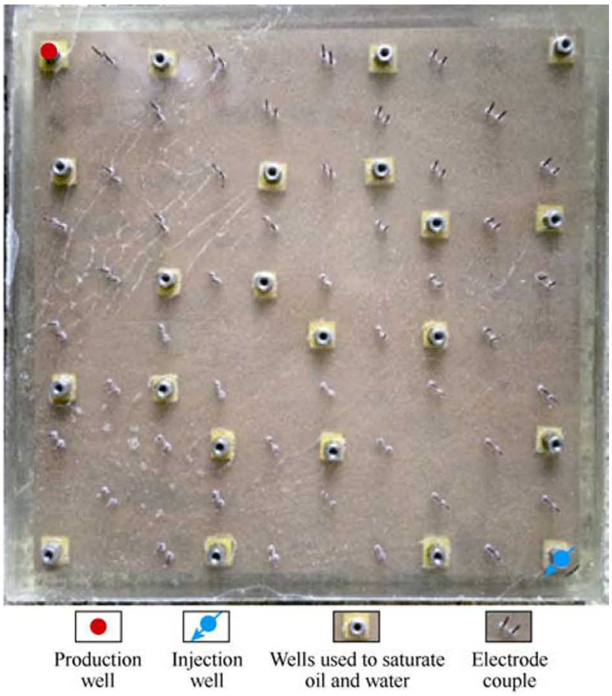

Fig. 1. The tablet core model.

1.3. Experimental steps

To facilitate the set of the targeted channel, a quarter of the five-spot pattern with one injection well and one production well was adopted as the injection-production pattern of the tablet model. Limited by the model and the experimental condition, a hole with 25 cm in length and 3 mm in diameter was drilled (instead of water-jet drilled) to simulate the targeted channel.

The experiment steps: (1) The model was evacuated and saturated with water. (2) The model was saturated with oil and aged. (3) Oil was displaced by water to the outlet with water cut of 98% and then the water drive recovery rate was calculated. (4) Conventional ASP flooding: 0.3 times pore volume ternary compound system was injected after water flooding and then water flooding was followed till 98% water cut at the outlet. (5) The resistance values of all parts of the tablet model was tested after repeating steps from 1 to 3 and the oil saturation was calculated to draw the oil saturation distribution diagram. (6) After water flooding, according to the distribution of oil saturation, the targeted area was selected. (7) The targeted channel was drilled (in right angle or opposite angle) and 0.3 times pore volume of ternary compound system was injected through the targeted channel, and water flooding was followed to the water cut of 98% at the outlet and then the recovery rate was calculated. (8) The distribution chart of oil saturation after the final water flooding was plotted and compared with that of the conventional displacement.