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Evaluation of Post-fracturing Imbibition Oil Displacement Efficiency in Shale Reservoirs

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ABSTRACT

In order to clarify the imbibition law of shale oil after fracturing with guanidine gum and nano-slickwater, this study quantitatively analyzed the imbibition efficiency of shale core under different time periods of two kinds of fracturing fluids through the imbibition experiment of natural shale core and nuclear magnetic resonance test technology, and preliminarily understood the microscopic crude oil production characteristics of pore throat of shale imbibition. The experimental results show that the imbibition oil removal efficiency of nano-slick water reaches 34.7 %, which is higher than that of guanidine gum fracturing fluid. In the high imbibition efficiency stage of rock samples, within 6 h of the beginning of the experiment, the small pore porosity reaches 20.8 %, the large pore and fracture reach 30 %, and the final imbibition oil displacement rate can reach 31.7% and 39.6 %. The development of micro-fractures and bedding fractures is beneficial to improve the imbibition efficiency. With the extension of time, the imbibition rate gradually decreases, and the utilization degree of pore throat is limited.

KEYWORDS

Shale; Imbibition Efficiency; Nano-slickwater; Nuclear Magnetic Resonance.

1. INTRODUCTION

Due to the characteristics of low porosity and low permeability, shale reservoirs generally have no natural productivity in the mining process, and industrial oil flow needs to be obtained through fracturing construction[1].After the fracturing operation, the target layer forms a complex fracture network. Combined with the developed micro-fractures and bedding fractures, an effective channel is established for the flow of crude oil. Under the action of capillary force, a complex oil-water seepage system is formed between the fracture-matrix, and the oil-water displacement is used to improve the recovery rate. This process is called imbibition. Under the action of fracturing fluid imbibition and oil displacement, the recovery rate of shale reservoir can be effectively improved[2].

In recent years, researchers have found that nanoparticles are easy to pass through narrow pore throats and are not easy to degrade under high temperature and high salinity conditions in reservoirs. Nanoparticles can reduce interfacial tension and change wettability, showing great potential in improving tight oil imbibition recovery[3].Sun Qinghao et al. studied the influence of shale fabric phase and imbibition method on the imbibition efficiency. The results show that the shale imbibition process can be divided into three stages : high-efficiency imbibition stage, transition stage and gentle stage, and the recovery of crude oil in large pores is greatly increased when imbibition under pressure[1].Therefore, two types of fracturing fluids used in this study are guanidine gum fracturing fluid and nano-lubricant water, and the improvement of the imbibition efficiency of nano-lubricant water after pressure is quantitatively analyzed.

The imbibition efficiency of shale is affected by many factors. Therefore, the experimental core of this paper is selected from the natural core of the same layer of the same well, aiming at reducing the influence of reservoir physical properties, wettability and other factors. Combined with nuclear magnetic resonance technology, the imbibition characteristics and crude oil production law under the two types of fracturing fluid formulations are quantitatively analyzed by imbibition experiments, which provides a basic understanding for the development and production of shale reservoirs.

2. EXPERIMENTAL SCHEME

2.1. Experimental Materials and Instruments

The oil used in the experiment is simulated oil (crude oil and kerosene are configured in a ratio of 1 : 3), simulated formation water (salinity is 25000mg / L, water type is NaCl type), and fracturing fluid is guanidine gum fracturing fluid and nano slippery water. The core is taken from the natural shale core of Chang 7 layer in Heshui area. The basic physical parameters of the core are as follows : Table 1-1. The experimental equipment mainly includes BCDQ-II multi-functional integrated displacement system and MiniMR-HTHP nuclear magnetic resonance instrument.

Table 1. Basic physical parameters of core

Core number	Length/cm	Diameter/cm	Porosity/%	Permeability/$10^{-3}\mu m^2$
1#	5.12	2.51	5.68%	0.1572
2#	5.04	2.53	5.14%	0.1685

2.2. Experimental Procedure

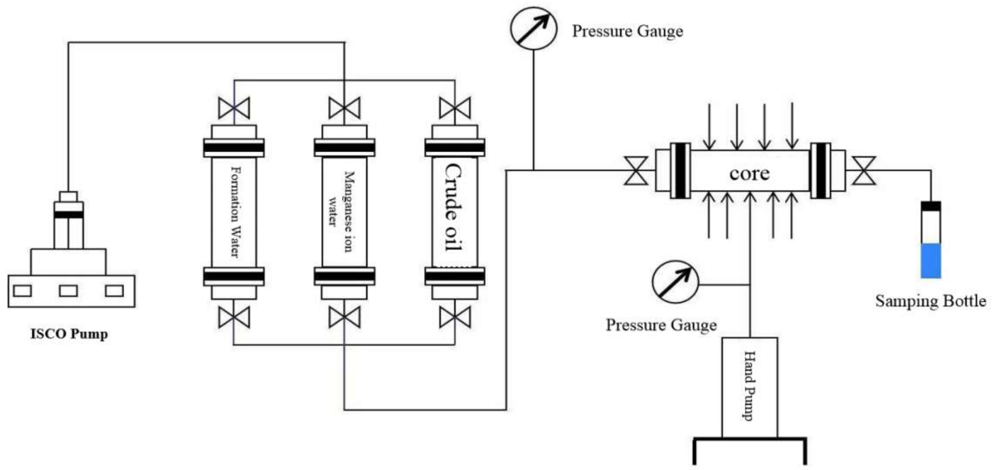

Fig.1 Displacement equipment

(1)Two typical cores were selected and cut into standard rock samples with a diameter of 2.5cm and a length of 5cm by anhydrous cutting technology.

(2)The core is washed with oil, and the gas permeability is measured after the core is dried ; the simulated formation water was saturated by vacuum pressure for 24h, and its porosity was tested. The manganese water with a concentration of 30000mg/L was displaced at a speed of 0.05ml / min to eliminate the water ion signal.

(3)Using the displacement device, the core is fully saturated with the simulated oil at a rate of 0.05ml/min, and the outlet end flows out 5PV to consider the saturation is complete. The NMR T_2 spectrum scan is performed to establish the original oil-water distribution of the core;

(4)Two kinds of fracturing fluid were prepared. The fracturing fluid was mixed with Mn^{2+} solution to eliminate the hydrogen signal in the fracturing fluid sample.

(5)Under reservoir conditions, the core samples were placed in two types of fracturing fluids, and the core was scanned by nuclear magnetic resonance T2 spectrum when the imbibition time reached 6h, 12h, 24h and 36h. The T2 spectrum of each stage is compared, and the characteristics of crude oil production are quantitatively analyzed.

3. RESULT

3.1. Initial Characteristics of Shale Core

The microscopic pore structure and scale characteristics of shale can largely determine the seepage capacity and imbibition efficiency of shale samples. Based on the nuclear magnetic resonance test, the T_2 spectrum of the two rock samples is drawn (Fig.2). The curve is the initial oil distribution of the two shale core samples. Quantitative evaluation of pore throat characteristics of rock samples shows that the microscopic pore throat characteristics of the two rock samples are similar, and the peak type is high on the left and low on the right. The T_2 relaxation time of the main peak is mainly between 0.01 and 1, mainly matrix pores. The secondary peak is between 1 and 1000, mainly large pores and fractures. According to the T_2 spectrum peak type, the pore size of the core is divided into two categories, among which the small pore interval $T_2 < 1$ms, the large pore and fracture interval : $1\text{ms} \le T_2 < 1000\text{ms}$[6].

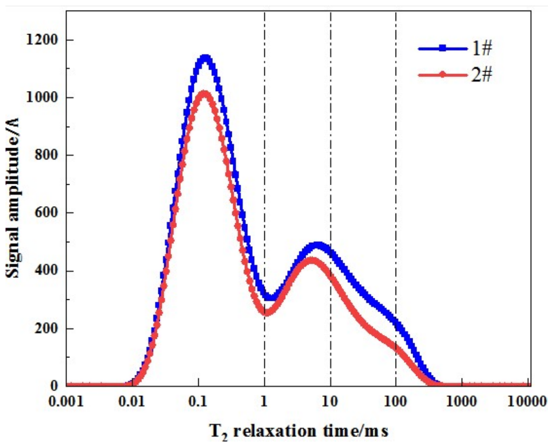

Fig.2 T_2 spectrum of original oil-bearing distribution of rock samples

3.2. Characteristics of Crude Oil Utilization

Figs 3 and 4 are the comparison of the original oil distribution of the two cores with the NMR T_2 spectrum of the oil displacement efficiency of the fracturing fluid at different times, and the characteristics of the oil displacement of the rock samples under different fracturing fluids are clarified. The 1# rock sample uses nano-slickwater, and the 2# rock sample uses guanidine gum fracturing fluid. It can be seen that the rock sample has the fastest imbibition rate in the first 6h, which belongs to the high imbibition stage. Between 0~6h, the pore throat signal amplitude of different sizes has a greater degree of decline. With the continuous effect of imbibition, the imbibition rate is significantly reduced within 6~36h, and the T_2 spectrum curve is slightly decreased. It shows that with the increase of the soaking time after shale reservoir pressure, the degree of pore utilization is limited. Therefore, selecting the appropriate soaking time after pressure can effectively improve the productivity after pressure.

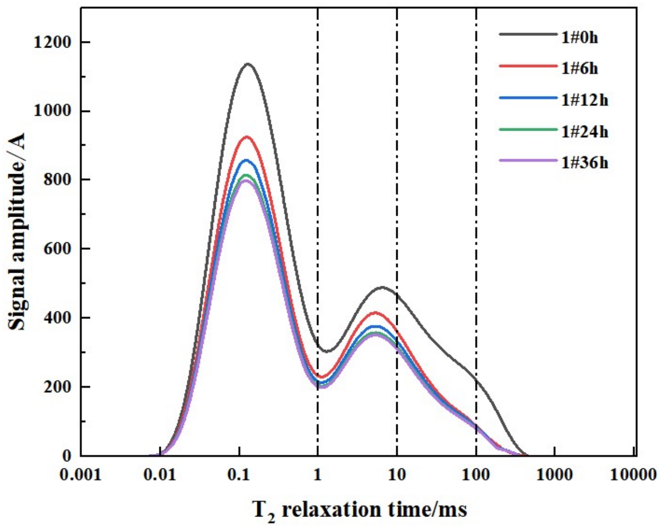

Fig.3 Microscopic changes in crude oil production of 1 # rock sample

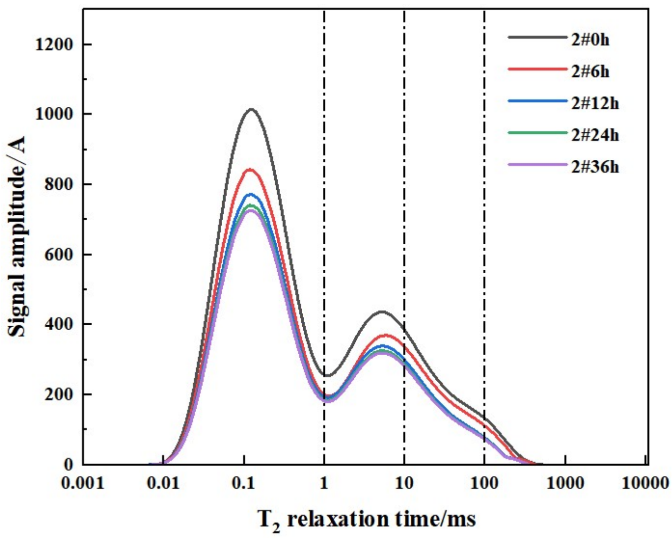

Fig.4 Microscopic changes in crude oil production of 2# rock sample

The total imbibition efficiency of the 1# rock sample is 34.7 %, and the 2# rock sample is 29.3 %. Compared with the rock sample under the guanidine gum fracturing fluid, the nano-slickwater fracturing fluid shows better imbibition oil removal efficiency. It is found from Fig.5 that under the infiltration of nano-slippery water, the oil drainage efficiency of small pores is 20.8% at 0~6h, and the cumulative oil drainage efficiency reaches 31.6% at 36h, indicating that nano-slippery water can effectively replace oil in small pores. When the imbibition time reaches 36 h, the cumulative imbibition oil displacement efficiency of macropores and fractures reaches 39.7%, indicating that the reservoir shale with microfractures and bedding fractures has higher imbibition oil displacement efficiency, and after fracturing, it is more helpful for the fracturing fluid to enter the micro-nano pores for oil-water replacement, so as to improve the total recovery rate.

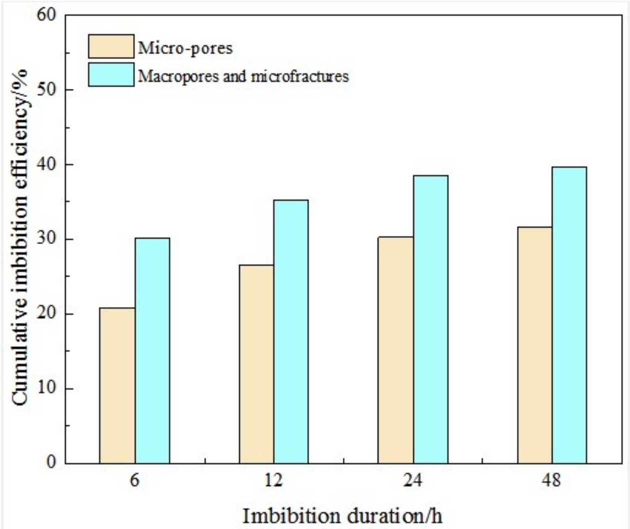

Fig.5 1# cumulative imbibition efficiency

4. SUMMARY

(1)In the first 6 hours, the imbibition rate of shale samples in the study area is the fastest, the small pore pore reaches 20.8 %, the large pore and fracture reaches 30 %, and the final imbibition oil displacement rate can reach 31.7 % and 39.6 %. The development of micro-fractures and bedding fractures is conducive to improving the imbibition efficiency.

(2)The imbibition efficiency of nano-slickwater is significantly higher than that of guanidine gum fracturing fluid, which can effectively act on shale reservoirs and improve oil imbibition recovery.

(3)With the extension of the experimental time, the imbibition rate gradually decreases, and the degree of pore throat utilization is limited. The appropriate soaking time can be optimized on site to achieve economic and effective improvement of productivity.

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