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Research on ultrasonic excitation for the removal of drilling fluid plug, paraffin deposition plug, polymer plug and inorganic scale plug for near-well ultrasonic processing technology

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ABSTRACT

Near-well ultrasonic processing technology attracts more attention due to its simple operation, high adaptability, low cost and no pollution to the formation. Although this technology has been investigated in detail through laboratory experiments and field tests, systematic and intensive researches are absent for certain major aspects, such as whether ultrasonic excitation is better than chemical agent for any plugs removal; whether ultrasound-chemical combination plug removal technology has the best plugs removal effect. In this paper, the comparison of removing drilling fluid plug, paraffin deposition plug, polymer plug and inorganic scale plug using ultrasonic excitation, chemical agent and ultrasound-chemical combination plug removal technology is investigated. Results show that the initial core permeability and ultrasonic frequency play a significant role in plug removal. Ultrasonic excitation and chemical agent have different impact on different plugs. The comparison results show that the effect of removing any plugs using ultrasound-chemicals composite plug removal technology is obviously better than that using ultrasonic excitation or chemical agent alone. Such conclusion proves that ultrasonic excitation and chemical agent can cause synergetic effects.

1. Introduction

In recent years, enhance oil recovery remains to be a challenge throughout the world. Currently, the most commonly used technologies for enhanced oil recovery (EOR) are to inject chemical agents into the reservoir to enhance oil production [1]. It is obvious that such methods is limited by the cost of the chemical agents and their adsorption and loss onto the rock of the oil containing formation. The long-term use of chemical agents can not only often energy and labor intensive, but inevitably pollute the oil reservoir and reduce oil recovery [1,2]. Furthermore, other conventional methods for EOR, such as CO2 injection, steam injection and water flooding, also have the disadvantages of not being environmental friendly, requiring costly storage tanks and transportation infrastructure and may seriously damage the formation over time [3].

There is always a strong demand for enhance oil recovery techniques that are simple operation, high adaptability, low cost and no pollution to the formation. Some new methods have therefore been developed, such as EM (electromagnetic) and ultrasonic waves, inductive heating, and DC (Direct Current) heating [3]. The main advantage of them is that less amount of energy is required than conventional EOR [3].

Near-well ultrasonic processing technology, as one of the new EOR, has been attracted more attention in recent years [4,5]. This technology is better than conventional chemical methods no matter in terms of equipment investment or adaptable ability [6–9]. Ultrasonic technology has been prove to be an safe and energy efficient method for removal of oil–water emulsions which may appear in large tanks [10]. Besides, multiple ultrasonic actuators have been proved to improve the efficiency of ultrasonic based EOR effectively [11].

How to remove plugs has always been a technically difficulty for crude oil production. There are usually four kinds of plugs during normal oil production —— drilling fluid plug, paraffin deposition plug, polymer plug and inorganic scale plug. The conventional deplugging methods that inject chemical agents onto the rock of the oil containing formation have been proved to be a

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technique with huge construction difficulty, high cost and polluting oil reservoir [12–17]. Roberts et al. investigated the effect of removing paraffin deposition plug and polymer plug using ultrasonic excitation [18]. Research shows that ultrasonic excitation can remove paraffin deposition plug effectively, but is unsatisfactory for removing polymer plug. Results indicate that only ultrasound-chemical combination plug removal technology can remove polymer plug effectively. Adinathan Venkitaraman et al. studied the effect of remove drilling fluid plug by ultrasonic excitation [19]. Research proves that ultrasonic excitation can remove drilling fluid and the effect of it is influenced by ultrasonic power and frequency. The theory of ultrasonic plug removal was systematically studied by Brian Champion et al. [20]. Tom W. Bakker et al. systematically investigated the impact of cavitation caused by ultrasonic wave on deplugging effect [21]. In a word, although many references have been proved that ultrasonic excitation has a good effect on plug removal, systematic and intensive researches are absent for certain major aspects, such as whether ultrasonic excitation is better than chemical agent for any plugs removal; whether ultrasound-chemical combination plug removal technology has the best plugs removal effect.

In this paper, the comparison of removing drilling fluid plug, paraffin deposition plug, polymer plug and inorganic scale plug using ultrasonic excitation, chemical agent and ultrasound-chemical combination plug removal technology is investigated.

2. Experimental device and materials

Experimental setups for removing drilling fluid plug, polymer plug, paraffin deposition plug and inorganic scale plug is as Fig. 1 shows, which mainly consists of three parts: ultrasonic transducer, core gripper and man-made core. The parameters of six ultrasonic transducers for removing different plugs is as Table 1 shows.

Six ultrasonic transducers are as Fig. 2 shows. These transducers can bear a temperature of 110 °C and a pressure35 MPa. Experimental samples are man-made cores with a diameter of 2.5 cm and a length of 7 cm. They are divided into three types (30, 60, 120 mD) according to gas logging permeability, as Fig. 3 shows. Component proportion: $NaCL:CaCL_2:MgCl_2{\cdot}6H_2O$ = 7:0.6:0.4. Porosity is 18.9–21.9%.

The core permeability recovery (P_{RR}) can be taken as an index for evaluating the effect of plug removal. $P_{RR} = (P_t - P_d)/P_0$, where P_t represents core permeability after ultrasonic excitation, P_d represents core permeability after plug deposition, P_0 is the initial core permeability.

3. The influence rules of ultrasonic frequency on the effect of plug removal

The effect of ultrasonic frequency on removing drilling fluid plug, paraffin deposition plug, polymer plug and inorganic scale plug for the cores with different gas logging permeability is investigated. Experiment results are as Figs. 4–6 shows.

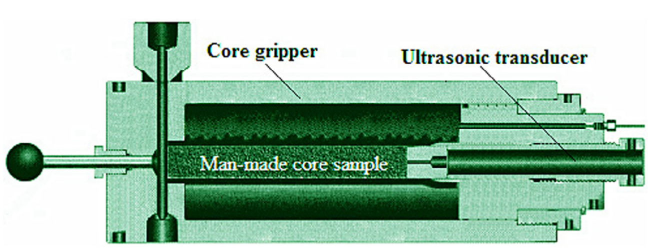

Fig. 1. The experimental flow diagram of ultrasonic plug removal.

Fig. 2. Ultrasound transducers.

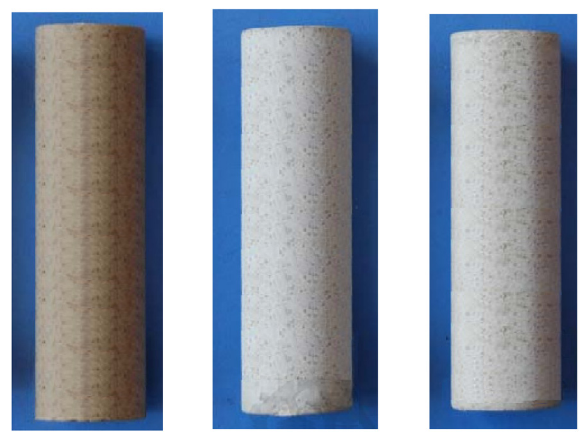

Fig. 3. Three type man-made cores.

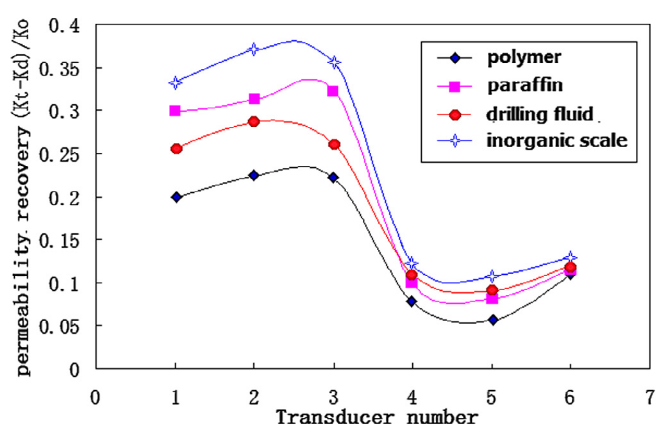

Fig. 4. The effect of ultrasonic frequency on removing drilling fluid plug, paraffin deposition plug, polymer plug and inorganic scale plug for the core with a gas logging permeability of 30×10^{-3} μm^2.

Overall, it can be seen in the above three figures that the plug removal effects using transducer No. 1–3 are better that using transducer No. 4–6. Transducer No. 6 has a better effect for the four plugs removal than transducer No. 5 and transducer No. 4. It also can be seen form the above three figures that the optimum range of removing four plugs using ultrasonic excitation is 30–40 Khz. Form Table 1, the power of transducer No. 1–3 (1000 W) is 10 times as big as that of transducer No. 4 and No. 5 (100 W), the power of transducer No. 6 is 200 W. Therefore, it can be concluded that power has a strong impact on ultrasonic plug removal: the