Study on the Adaptability of Depressurization and Injection of MD Film in Low Permeability Reservoirs

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Study on the Adaptability of Depressurization and Injection of MD Film in Low Permeability Reservoirs

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Abstract. Low-permeability reservoirs generally have poor physical properties and refer to reservoirs with low porosity and the radius of small pore in the reservoirs is large. In the process of water flooding development, due to the serious damage of pore water blocking, it is difficult to inject water or even impossible to inject water, which seriously reduces the development efficiency of water flooding. The MD film augmented injection techniques is an effective way to solve this problem. The laboratory tests show that the rock samples have the best effect of reducing pressure after being treated by the MD film and the water flooding flow rate is 0.05~0.10 mL/min. At the same time, the water saturation of the core pores increases and the water blocking damage of the pores is relieved after the MD film treatment, which is favorable for water injection. The results of the nuclear magnetic field show that the T_2 cutoff value of the rock samples treated by the MD membrane has decreased, and the porosity of flowable part core has increased. The molecular membrane agent could be apllied to the low permeability reservoir with the a pore throat radius greater than 0.01 μm.

1. Introduction

With the development of major oil fields, more and more low permeability reservoirs are currently being developed [1-3]. Research on the difficulties related to the production of low permeability reservoirs has attracted increasing attention. Due to the extremely low primary recovery of low permeability reservoirs, especially ultra-low permeability reservoirs, water flooding is required when supplying the formation energy. However, there are many problems with water flooding. Firstly, it will cause the clay minerals in the reservoir to hydrate and expand, resulting in a further reduction in the pore diameter. Secondly, low permeability reservoirs are usually characterized by a very small pore diameter and the injected water remains in the pores due to the capillary force; this blocks the pores, resulting in a cycle of water flooding [4-9].

The MD film technology is mainly used for water injection in low-permeability ($10\sim50\times10^{-3}$ μm^2) and ultra-low permeability ($1\sim10\times10^{-3}$ μm^2) reservoirs [10]. While studying its injecting mechanism and conducting field experiments, it is necessary to investigate the adaptation range in the pore size of low-permeability reservoirs and expand its application range. Therefore, this paper firstly analyzes the reasons for the low injection of low-permeability reservoir injection wells; According to the reasons and mechanism of the deficiencies, the effectiveness of the antihypertensive injection is evaluated by macroscopic and microscopic methods after treatment with the MD film augmentation technology. Finally, the NMR technique is used to determine the adaptation range of the pore radius of the MD film injecting technology in low permeability reservoirs.

2. Experimental

2.1 Analysis of under-injection

2.1.1 Low porosity and low permeability

Using Gas Permeameter Porosimeter LGPM70, the permeability of the rock sample after washing is less than 10×10^{-3} μm^2, and the porosity is 4 %~11 %, which comes from the reservoir with low permeability and low porosity (The experimental results are shown in Table 1.).

Table 1. Core porosity and permeability measurements.

Number	L(cm)	D(cm)	Φ(%)	K($10^{-3}\mu m^2$)
1	6.024	3.802	4.212	3.304
5	5.403	3.778	5.739	7.134
14	4.877	3.814	4.083	0.869
109	4.944	3.819	6.049	0.021
249	5.249	3.814	11.859	6.460

2.1.2 The small throat

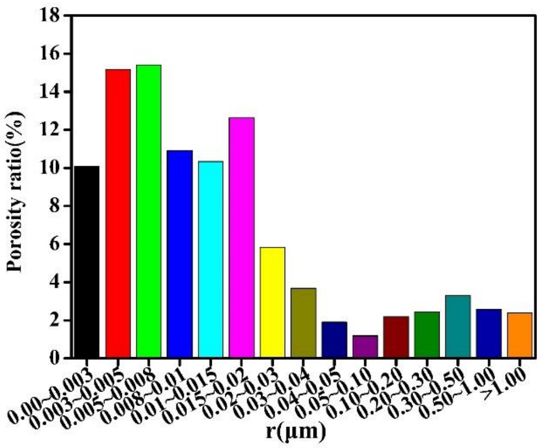

Figure 1. Histogram of core pore radius distribution.

As shown in figure 1, the porosity of reservoir core with pore radius less than 0.01 μm is 51.57 %, the proportion of pore radius between 0.01 μm~0.08 μm is 35.06 %, and the porosity with pore radius greater than 0.08 μm is only 13.37 %.

2.1.3 The damage of water bblockinging

As shown in figure 2(a), the water saturation of the rock sample in the saturated state is 4.50 %, and the water saturation after is placement of flowable water in the pores is 4.28 %, and the irreducible water saturation is as high as 95.11 %.It can be found from Figure 2(b) that the corresponding pores with a throat radius of less than 0.03 μm have almost no change in the pore water content after flooding, and serious water blocking damage has occurred.

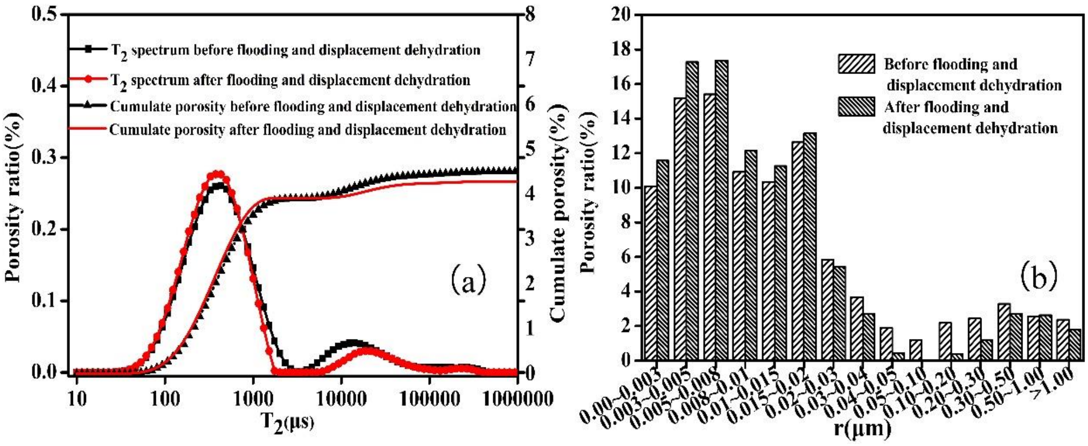

Figure 2. The MD film before and after treatment.

2.2 Analysis of the effect of the MD film depressurization

2.2.1 Experiment analysis

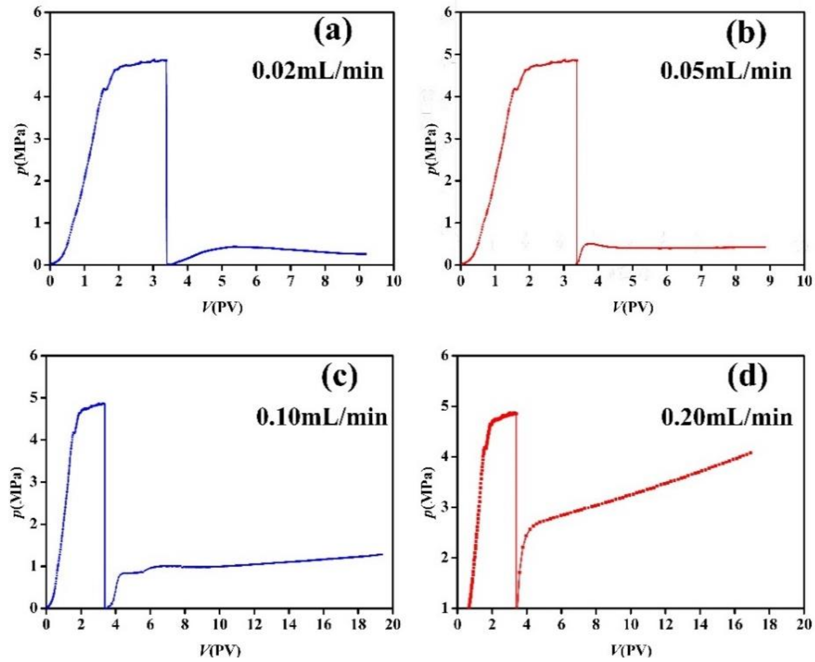

Figure 3. Water flooding injection pressure curve.

As shown in Figure 3, after the core is treated by the molecular membrane with the water flooding rate is 0.02 mL/min, 0.05 mL/min and 0.10 mL/min, the injection process is maintained under a relatively stable pressure condition. However, when the water flooding flow rate is 0.20 mL/min, the water flooding pressure increased with the amount of injection value and the injection time.

Table 2. Water flooding injection pressure parameter.

v(mL/min)	P_1(MPa)	P_2(MPa)	K_2/K_1
0.02	4.86	0.26	18.69
0.05	4.86	0.42	28.93
0.10	4.86	0.87	27.93
0.20	4.86	>4.07	<11.91

When the injection flow rate is 0.02 mL/min, the ratio of permeability before and after MD film treatment is equal to 18.69, and the injection pressure is only 0.26 MPa, but the water injection amount is relatively small, which cannot meet the dosage. When the injection flow rate is 0.20 mL/min, although the water injection amount is greatly increased, the injection pressure is relatively large. When the injection flow rate is 0.05~0.10 mL/min, K_2/K_1=28.93~27.93, the injection pressure is relatively small, and the water injection amount also increase.

2.2.2 Nuclear magnetic analysis

As shown in Figure 4, the results of nuclear magnetic measurements before and after treatment with the MD film indicate that: the water-filled porosity were 4.50 % and 5.56 % before and after the MD film treatment, respectively. When T_2<2.656 ms, pore radius is less than 0.05 μm, the pore portion are significantly increased compared with that before the MD film treatment.

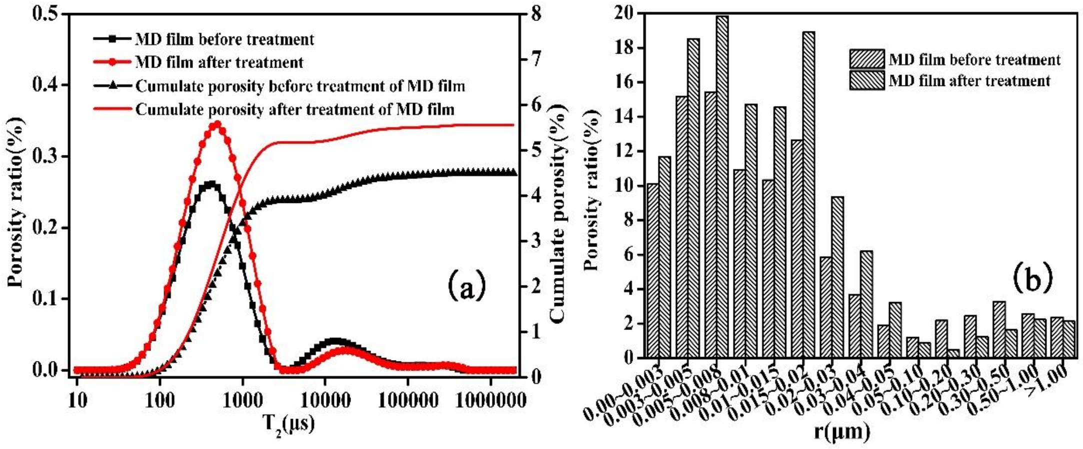

Figure 4. Core NMR measurements; (a) T_2 relaxation spectrum; (b) pore radius histogram.

The reservoir pores in original state are as shown in Figure 5(a), and the pore throat has a certain connectivity. When the external fluid is injected into the core, a layer of water film is gradually attached to the surface of the reservoir rock, which reduces the pores radius of the core and even cause the water blocking, and makes it difficult for the subsequent injected water to enter the deep pore of the core (Figure 5(b)). After the core is injected with the MD film, the water film attached to the rock surface peels off, the water blocking releases, and the connectivity between the pores is newly restored (Figure 5(c)). After the core pores restore connectivity, the extraneous water can reach the deep pores of the core again. The results of nuclear magnetic measurements show that the both the water-filled porosity and the porosity ratio increased and the peak value became larger after film washing.

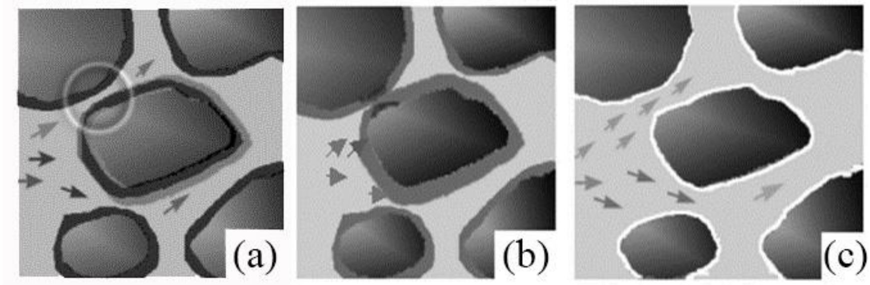

Figure 5. Pore throat water blocking release diagram;
(a) Original state; (b) Water blocking status; (c) Release the water blocking.

2.3 Adaptive study

As shown in Figure 6, the water-filled porosity after dehydration before the MD film treatment was 5.46 %, and the T_2 cutoff value was 2.48 ms. After the MD film treatment, the water content after dehydration was 4.46 %, the T_2 cutoff value was 1.63 ms. The water content after dehydration decreased and the flowable part porosity increased compared with before the MD film treatment.

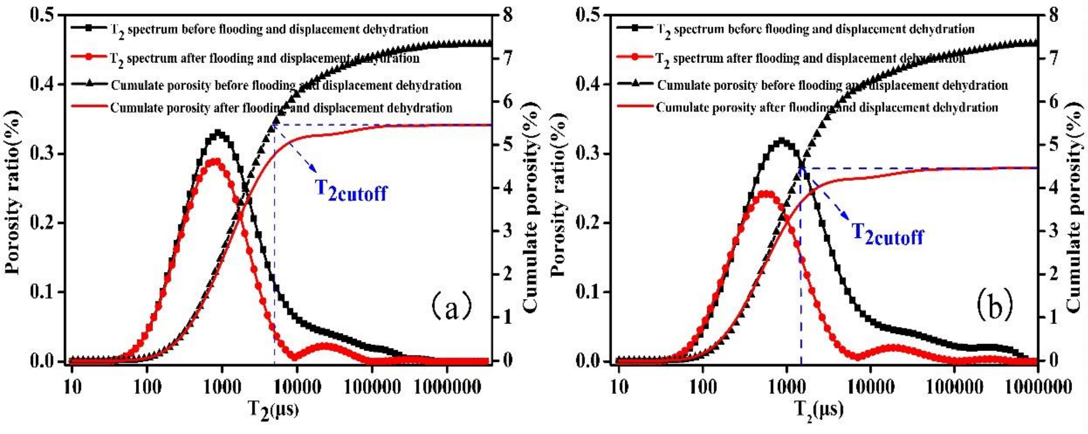

Figure 6. Rock sample nuclear magnetic resonance measurement T_2 relaxation spectrum; (a) Before treatment of MD film; (b) After treatment of MD film.

As shown in Figure 7, both the porosity of the pores with a pore radius r>0.08 μm before and after the treatment of the MD film were significantly reduced, and only a small amount of residual water was contained after the displacement. Because the pores have a relatively large radius and still have connectivity which allows water to flow through, even if water film is adsorbed on the rock surface. However, the water film on the rock surface is difficult to be peeled off. After the core is treated by the MD film, although the water film on the rock surface can be stripped, part of the water is caught by the small pore throat nearby, and then flows back to the pore after the displacement pressure disappears. Therefore, the nuclear magnetic measurement results in both states show that there is a small amount of water remaining in the pores.

After the core treatment by the MD film, the proportion of porosity with pore radius between 0.01μm and 0.08μm was reduced compared with before the MD film treatment, and the residual water content in the pores was relatively large. First, after the core is treated by the molecular membrane, the molecular membrane is adsorbed on the surface of the rock, which changes the wettability of the rock surface and reduces the adhesion between the water and the rock surface, result in benefit to the flow of water in the pores. Secondly, since the pores with a pore radius r>0.08 μm are the main channels when the water in the partial pores is driven out, gas channeling occurs, resulting in water in the pores having a relatively small pore radius being difficult to be affected.

After the core is treated by the MD film, the proportion of porosity of the pore radius r<0.008μm has a small increase. The core has a thick water film attached to the pore surface of the rock before the MD film treatment, causing water blocking damage to some of the pore throats, leading to the pores could not to be completely filled with water. After the core is treated by the MD film, the water-blocking damage of the pore throat is released, and the pores are further filled with water. However, due to the small pore radius, the displacement pressure is less than its starting pressure, and the water in the pores of this part cannot flow.

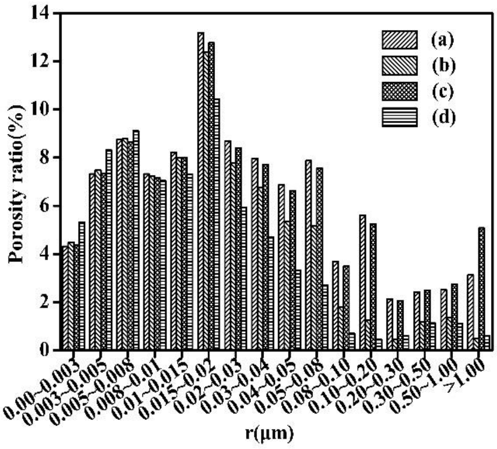

Figure 7. Pore size distribution histogram;
Before treatment of the MD film:(a) Before flooding and displacement dehydration; (b) After flooding and displacement dehydration;
After treatment of the MD film:(c) Before flooding and displacement dehydration; (d) After flooding and displacement dehydration.

3. Conclusions

The experimental results and nuclear magnetic analysis show that the rock samples have the best augmented injection effect when increasing the injection rate with 0.05~0.10 mL/min after the MD film treatment, and it could significantly increase the proportion of water porosity in the small throat pores.

After the molecular sieve treatment, the T_2 cutoff value of the rock sample decreased from 2.48 ms to 1.634 ms, which indicated that the porosity of the flowable part of the rock sample increased and the swept volume was increased. Therefore, the suitable rage of MD film according to pore radius distribution within low permeability reservoir: flowable partial pore required the throat radius greater than 0.01μm and there is no flowable ability within pore throats with a radius less than 0.008μm.

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