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Experimental study of wettability alteration to gas wetness method to enhance coal bed methane production

It is of great importance and significance to study the production improvement technology for coal bed methane. Wettability alteration technology has been successfully applied to enhance oil production and recovery. However, literature on wettability technology used to enhance production of coal bed methane has not been reported. In this paper, a physical model was developed to describe the mechanism of wettability alteration technology to enhance coal bed methane. Gas-water displacement test was conducted in coal samples with and without the wettability alteration to gas wetness. Comparison of gas-water relative permeability curve before and after wettability alteration showed that wettability alteration technology could increase gas phase relative permeability, and reduce water residual water saturation in the gas-water displacement. The experimental results demonstrated that the wettability alteration to gas wetness technology can enhance the production of coal bed methane.

Keywords: *Coal bed methane, enhance production, wettability alteration.*

1. Introduction

Wettability alteration is described as a phenomenon that wettability of solid surface could be changed with the adsorption of active substance. In 1941, Buckley and Leverett [1] realized the importance of wettability on oil-water flow in the reservoir. The wettability alteration in porous media surfaces caused by adsorption of surfactants was reported by Spinler and Somasundaran et al. Later [2-4], many study demonstrated that wettability plays an important role in many field, such as capillary pressure, electrical properties of reservoir rocks, relative permeability, initial and residual water saturation. Wagner and Leach suggested enhancing recovery by alternating the reservoir wettability during water flooding. Li and Firoozabadi [5] reported that wettability of rocks could be changed from strongly liquid-wetness to preferential gas-wetness after chemical treatment. Their experimental result also showed that the oil recovery and gas phase relative permeability could be increased significantly after wettability alteration. Generally speaking, wettability alteration technology has been widely used in oil industry. The main purpose of this paper was to verify the feasibility of using wettability alteration method on enhancing coal bed methane production by experiment.

2. Mechanism of wettability alteration

Coal bed methane was developed by pressure depletion and initial water in coal bed must be drained first. Absorbed gas desorped from the coal matrix due to the pressure decrease[6-9]. Thus the development of coal bed methane can be considered as the process of water displacement by gas, where gas is the displacing phase and water is the displaced phase.

The gas-water flow performance in coal bed is inevitable affected by capillary pressure, which can be obtained as follow [10]:

$$P_c = \frac{2\sigma \cos\theta}{r} \quad \ldots \quad (1)$$

where P_c is the capillary pressure, r is the radius of a capillary tube, σ is the surface tension and θ is contact angle. From Eq.1, it can be seen that the capillary pressure could be very large in the low porosity and permeability formation where pore size is extremely small. Based on above analysis, capillary pressure has a great impact on gas-water flow performance in coal bed.

A physical model was developed to describe the mechanism of wettability alteration technology to enhance coal bed methane production, as shown in Fig.1. Note that the direction of capillary pressure was defined as wet phase to non-wet phase. Fig.1 depicts the direction of fluid flow and capillary pressure are opposite in water wet coal bed, where capillary pressure serves as an opposing force for fluid transport. However, the direction of fluid flow and capillary pressure are the same in gas wet coal bed, where capillary pressure serves as a driving force for fluid transport as shown in Fig.2. As discussed above, wettability alteration to gas wetness method could alter the capillary pressure from opposing force to driving force, which could enhance coal bed methane production and recovery. Note that the

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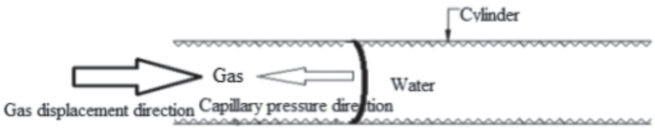


Fig.1 Capillary pressure direction and fluid flow direction in the water wet coal

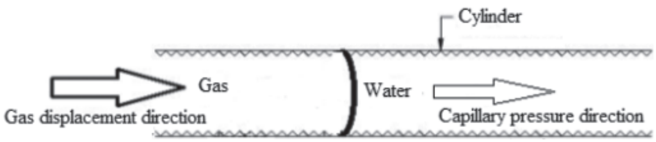


Fig.2 Capillary pressure direction and fluid flow direction in the gas wet coal

wettability may not alter to gas wetness after chemical treatment, which means the contact angle is still less than 90°, but an increase of contact angle can reduce the opposing force in gas-water flow after chemical treatment.

3. Experiments and results

Gas-water displacement test was conducted to obtain the relative permeability curves before and after wettability alteration. The experimental results was compared to verify the feasibility of using wettability alteration method on enhancing coal bed methane production. In this study, the gas-water relative permeability of original coal sample were measured firstly. After being dried, the coal sample was saturated with the chemical solution to change the wettability. The gas-water relative permeability was determined again after chemical treatment. The schematic of apparatus for measuring gas-water relative permeability was shown in Fig.3. The gas used in the experiment is methane and unsteady state method was used in this experiment.

The parameters of two coal samples were listed in Table 1. Contact angle of two coal samples were less than 90° in original condition, which represents preferential water-wetness. After chemical treatment contact angle of both coal samples were bigger than 90°, which demonstrated wettability alteration to preferential gas-wetness. Fig.4 shows the water droplets on the No.2 coal sample before and after the wettability alteration by the chemical treatments. It can he seen that contact angle increases from 75.12° to 96.53°, which indicates that the chemical agent can change the wettability of coal sample.

Figs.5 and 6 show the gas and water relative permeability

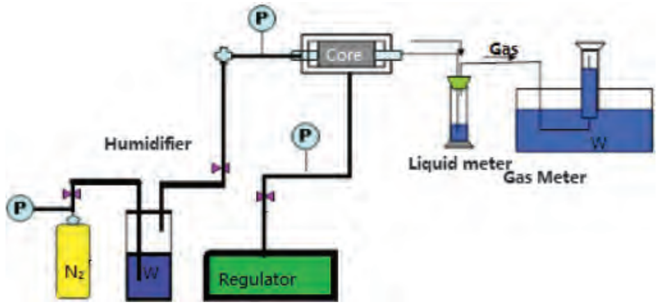
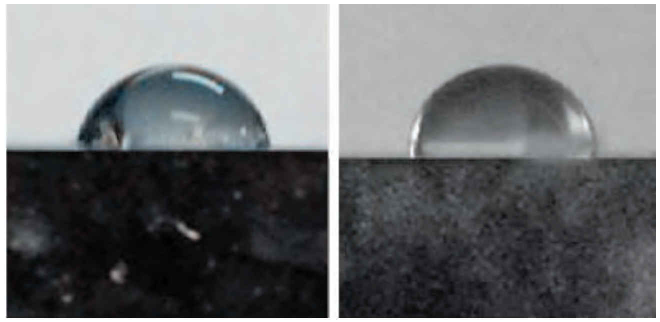


Fig.3 Schematic of the apparatus for measuring gas-water relative permeability



(a) Before chemical treatment (b) After with chemical treatment

Fig.4 Water dropletson the surface coal sample before and after the wettability alteration by the chemical treatments

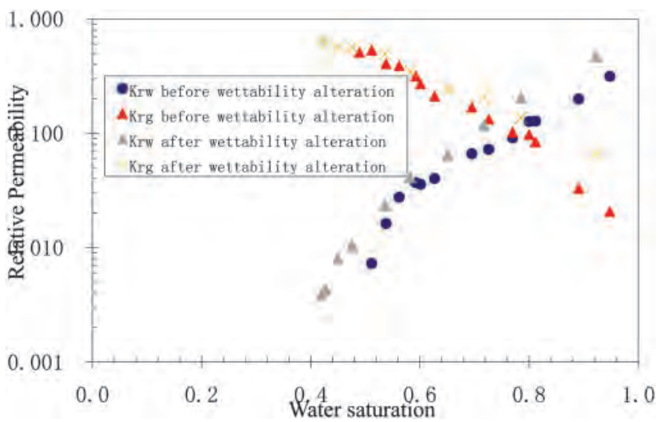


Fig.5 Gas-water relative permeability measured before and after wettability alteration (No.1 coal)

before and after the wettability alteration by the chemical treatments determined in two coal samples. The comparison shows that the residual water saturation by gas flooding was decreased from 48.91% to 41.98% in No.1 coal and from

TABLE 1: PARAMETER OF COAL SAMPLE

Coal no.	Length (cm)	Radius (cm)	Porosity (%)	Permeability (md)	Contact angle before wettability alteration (°)	Contact angle after wettability alteration (°)
1	5.46	2.45	21.18	51.95	81.23	98.34
2	6.32	2.52	8.18	8.34	75.13	96.53

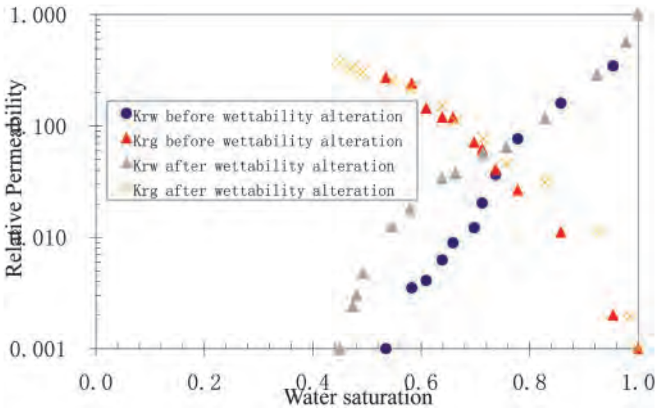


Fig.6 Gas-water relative permeability measured before and after wettability alteration (No.2 coal)

53.49% to 44.968% in No.2 coal respectively. There is a little difference between water relative permeability before and after wettability alteration, but the gas relative permeability increased after wettability alteration. The gas relative permeability at residual water saturation was increased from 0.51 to 0.66 in No.1 coal and from 0.27 to 0.37 in No.2 coal respectively. The residual water saturation was decreased and gas relative permeability was increased after coal wettability was changed from water wetness to gas wetness.

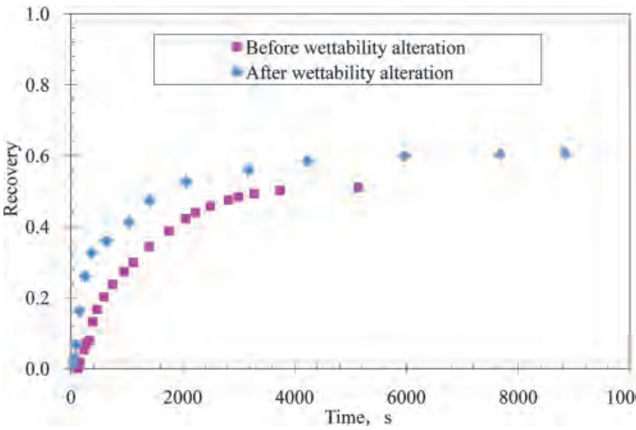


Fig.7 Recovery measured before and after wettability alteration (No.1 coal)

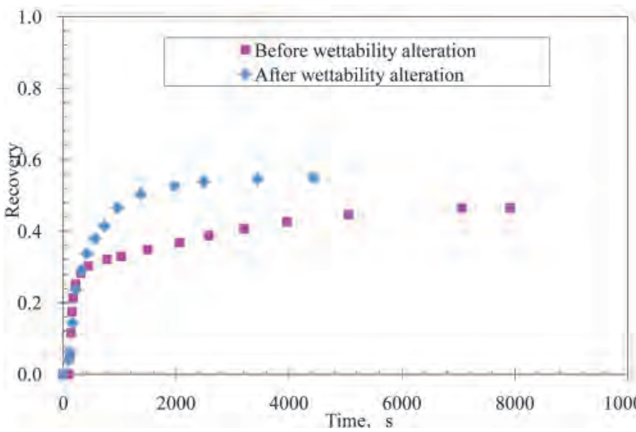


Fig.8 Recovery measured before and after wettability alteration (No.2 coal)

Figs.7 and 8 show the significant increase in water productivity after the wettability alteration by the chemical treatments in two coal samples. The comparison shows that the water recovery by gas flooding was increased from 51.09% to 60.78% in No.1 coal and from 46.51% to 55.04% in No.2 coal respectively. The experimental result shows that wettability alteration technology can enhance water productivity.

One can see the significant increase in gas production rate after dealing with the chemical agent in two coal samples, as shown in Figs.9 and 10. Take the gas production rate at residual water saturation as example, the value increased from 4.56 to 5.88 ml/min in No.1 coal and from 2.96 to 3.56 ml/min in No.2 coal respectively.

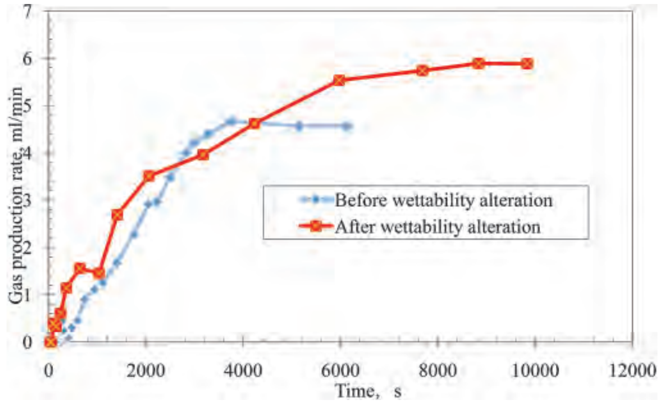


Fig.9 Comparison of the gas production rates before and after wettability alteration, (No.1 coal)

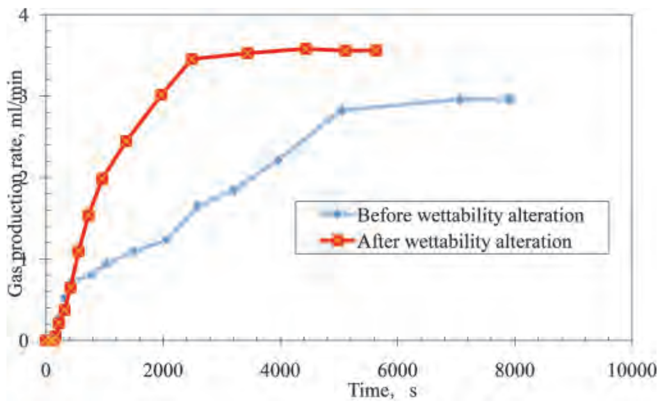


Fig.10 Comparison of the gas production rates before and after wettability alteration (No.2 coal)

In summarizing, the experimental results demonstrate that the wettability alteration technology can increase gas production rate as well as water recovery by gas flooding, and decrease residual water saturation in coal sample.

Conclusions

Based on the present study, the following conclusions may be drawn in the cases studied:

1. A physical model was proposed to explain the mechanism of wettability alteration technology to enhance coal bed methane production. This is because wettability alteration to gas wetness method could change the capillary pressure from opposing force to driving force.
2. The wettability of coal sample was changed from water wetness to gas wetness after chemical treatment according to the contact angle determination .
3. The experimental result demonstrated that both gas production rate and water recovery by gas flooding were increased, and residual water saturation was decreased after wettability alteration. It is possible to use the wettability alteration technology to enhance coal bed production.

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