International Journal of Electric Power and Energy Studies
ISSN: 3006-2004 (Print), ISSN: 3006-0826 (Online) | Volume 3, Number 1, Year 2024
DOI: https://doi.org/10.62051/ijepes.v3n1.03
Journal homepage: https://wepub.org/index.php/IJEPES/index

Research and Development of Effects of Asphaltene Deposition in Tight Oil Reservoirs on CO_2-EOR and CO_2 Storage

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ABSTRACT

CO_2 injection can improve oil recovery significantly in tight oil reservoirs, in addition, CO_2 injection after the use and storage reduce the amount of emissions into the atmosphere, so as to achieve the effect of emission reduction. However, in the process of production and storage, CO_2 will interact with crude oil, formation water and rocks and minerals in the reservoir and react, thus changing the reservoir balance and fluid physical properties, resulting in solid phase deposition. Asphaltene deposits have a significant impact on the reservoir, especially on tight reservoirs.In this paper, The effects of asphaltene deposition caused by CO_2 injection on oil recovery and CO_2 sequestration in tight reservoirs were studied, and the research progress in this field is summarized and prospected. This study can provide reference for the development of tight oil reservoir and promote the development of tight oil recovery technology.

KEYWORDS

Tight Oil Reservoirs; CO_2 Injection; Asphaltene Precipitation; CO_2 Storage; Damage Characterization.

1. INTRODUCTION

The development of tight oil reservoir is of great strategic significance to ease the contradiction between energy supply and demand and stimulate economic growth in China and other countries in the world [[1],[2]]. However, tight sandstone reservoirs are characterized by poor physical properties, strong heterogeneity, extremely complex microscopic pore structure, low natural energy and poor fluid mobility [[3]].CO_2 injection into the formation can make the crude oil expand, effectively reduce the viscosity of crude oil, CO_2 has a strong diffusion ability, faster diffusion into the depth of the reservoir, CO_2 injection effect is better, can effectively improve the oil field recovery [[4],[5]].

Geological storage of CO_2 refers to the permanent storage of CO_2 injected into underground structural reservoirs [[6]]. Reservoir and brine are ideal geological structures for CO_2 storage [[7],[8]]. CO_2 in the process of enhanced oil recovery, CO_2 geological storage can also obtain more crude oil. However, in the process of CO_2 injection, part of CO_2 will dissolve in the underground reservoir fluid, and the other part of CO_2 will return to the surface with the production fluid..According to statistics, the application effect of CO_2 injection to enhance oil recovery and storage technology in existing tight sandstone reservoirs is far less than expected, and the average CO_2 storage rate is less than 50% [[9],[10]].

Therefore, the deposition mechanism of CO_2 displacement asphaltene deposition and its effects on pore structure, recovery efficiency and CO_2 storage in tight oil reservoirs were summarized, which provided a strong basis for the effective implementation of CO_2 enhanced oil recovery technology.

2. MECHANISM AND CHARACTERISTICS OF ASPHALTENE DEPOSITION

In the process of CO_2 injection, CO_2 is continuously injected into crude oil as a precipitator, which destroys the stability of mutual solubility of each component in the crude oil system, and the reconstituted asphaltene is deposited in the form of solid (Fig. 1). With the increase of CO_2 injection, the amount of precipitated asphaltene in crude oil also increases. Monger et al. [[11]] found that CO_2 dissolved in crude oil broke the thermodynamic equilibrium state in crude oil, so the deposited asphaltene would quickly adsorb on the pore surface of the rock, making the reservoir rock more oily and wet through laboratory experiments. At the same time, the decrease of pore space leads to the damage of formation permeability and borehole blockage. Zhang et al. [[12]] 's research results showed that core permeability and initial asphaltene content of crude oil directly affected asphaltene deposition during CO_2 flooding. The asphaltene deposition during CO_2 diffusion dissolution in crude oil and the asphaltene deposition during dynamic oil displacement were measured by spectrophotometry. The results show that under the same conditions, the low permeability core has a better effect on the asphaltene deposition. Zanganeh et al. [[13]] used a new experimental setup to study the deposition of asphaltene on model rocks under reservoir conditions. The asphaltene deposition process was observed by microscope. Then image processing software was used to analyze the amount of asphaltene deposition and its particle size distribution under different conditions. The amount of asphaltene deposited during natural pressure exhaustion and CO_2 injection was measured experimentally and modeled by thermodynamic solid model. The results show that asphaltene particles dissolve easily in solution during pressure loss. The amount of asphaltene deposition increased with the increase of CO_2 injection. Cruz et al. [[14]] used a variation chamber equipped with a near infrared probe to study the process of CO_2-induced asphaltene deposition, evaluating the effects of pressure, temperature, asphaltene concentration, and system composition on asphaltene deposition. The asphaltene deposition process was simulated by three times positive correlation method. The results show that temperature and composition of oil model system are the main parameters affecting the stability of asphaltene.

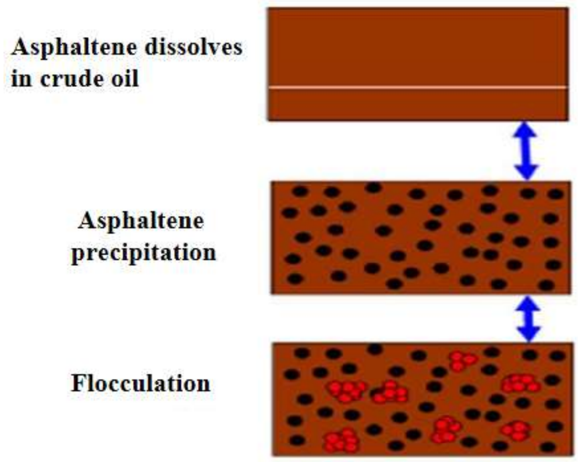

Fig. 1 Diagram of asphaltene deposition process

3. MECHANISM OF ASPHALTENE DEPOSITION ON MICROSCOPIC PORE STRUCTURE

Early studies on the effect of asphaltene deposition on microscopic pores were all conducted from the perspective of permeability reduction It is found that the reason for the decrease of permeability caused by solid phase deposition is the pore throat blockage caused by precipitated particles in the process of CO_2 flooding. When the size of precipitated particles is close to or exceeds the size of pores and throats, they will be trapped in the narrow pore throat in the reservoir rock, resulting in blockage and poor pore throat connectivity, thus reducing the permeability of the reservoir (Fig. 2). After that, the influencing factors mainly include the scale of asphaltene precipitation in reservoir crude oil, the particle size distribution of solid precipitation, the pore size distribution of reservoir rock, and the adsorption and resolution degree of solid precipitation in reservoir rock. Civan [[15]] studied the damage of asphaltene deposits to reservoirs, and he believed that the deterioration of reservoir physical properties and the loss of permeability were the result of the combined effect of the reduction of pore size and the blockage of pore throat. Leontaritis et al.[[16]] used the 1/3 bridging rule to determine the ratio of pore throat radius to the size of asphaltene precipitate particles causing pore throat blockage. Zhao Fenglan et al. [[17]] found that the variation amplitude of reservoir permeability during CO_2 flooding is not only related to the scale of asphaltene precipitation in crude oil, but also influenced by CO_2 injection rate, the particle size of asphaltene precipitation particles and the initial permeability of reservoir core in the process of CO_2 flooding through core displacement experiments.

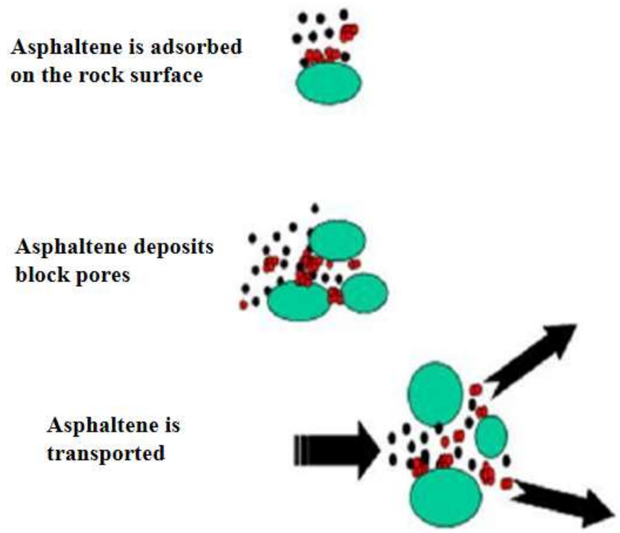

Fig. 2 Diagram of asphaltene deposits in reservoir pores

At present, experimental means such as nuclear magnetic resonance, scanning electron microscopy, CT scanning, visualization experiment and numerical simulation can understand the law of asphaltene deposition under the microscopic pore throat, not only from the permeability analysis, but also from the analysis of wettability, pore size, pore throat structure and distribution, so as to more clearly define the mechanism of asphaltene deposition on the microscopic pore throat. Mohamed Khather et al. [[18]] conducted CO_2 displacement experiments using carbonate cores, nuclear magnetic resonance, CT scanning, scanning electron microscopy and chemical analysis of produced oil. The research results show that asphaltene deposition will lead to a decrease in permeability. The most important factors for asphaltene stability are the initial concentration of asphaltene and the concentration of CO_2 at the time of injection, and more asphaltene deposition is generated in high-permeability cores. Sherif Fakher et al. [[19]] found that asphaltene plugging in nanopores is very serious because the size of pores is closer to the size of asphaltene clusters through the asphaltene visualization experiment and asphaltene filtration experiment. Asphaltene deposits and pore plugging are a serious problem in both conventional reservoirs with large pores and unconventional reservoirs with nanopores. Asphaltene deposits occur not only in heavy oils, but also in light oils. Qi et al. [[20]] carried out core displacement experiments under CO_2 injection pressure based on the core NMR T_2 spectrum testing principle. The results show that the damage rate of asphaltene deposition and permeability increases rapidly at first and then tends to be stable with the increase of CO_2 injection pressure. Asphaltene deposition will cause wettability reversal. With the increase of asphaltene deposition, the wettability reversal index increases, and the core wettability continuously changes to the direction of strong oil moisture. Shi [[21]] found that the higher the asphaltene content of crude oil, the greater the deposition rate of asphaltene during CO_2 huff and huff. In the process of CO_2 huff and puff, asphaltene deposition has a greater degree of damage to reservoir permeability, but a relatively small degree of damage to porosity.

4. EFFECT OF ASPHALTENE DEPOSITION ON CO2 DISPLACEMENT EFFICIENCY

In the process of CO_2 displacement, the injected CO_2 dissolves in the crude oil, resulting in changes in the composition of the crude oil, resulting in asphaltene precipitation in the crude oil, resulting in changes in the physical properties of the reservoir. The precipitation of asphaltene in the reservoir will lead to the decrease of reservoir permeability and adsorption on the surface of rocks and minerals, and the wettability will be reversed, further reducing the flow capacity of crude oil, resulting in the decrease of crude oil production. Duan et al.n [[22]] used the pressure drop method to determine the effects of the initial content of asphaltene and pressure changes on the solubility and diffusion coefficient of CO_2 in crude oil. The experimental results show that the diffusion coefficient of CO_2 in crude oil increases linearly with the increase of pressure, and the solubility first increases and then decreases. However, when the content of asphaltene in crude oil increases, the diffusion coefficient of CO_2 decreases and the solubility increases. Khurshid et al. [[23]] developed a simulator to simulate CO_2 flooding at different depths, temperatures and pressures. The research results show that asphaltene concentration and rock properties have a significant impact on CO_2 dissolution and asphaltene precipitation in the process of CO_2 flooding. Due to asphaltene deposition, CO_2 cannot be transported, and effective permeability of oil and water will be reduced, resulting in lower oil recovery.

Asphaltene deposits have a greater impact on tight reservoirs with smaller pores and complex pore throat structures, and the recovery rate declines faster. Shen et al. [[24]] used the numerical reservoir simulation method to simulate the CO_2 huff and huff process and the precipitation and deposition of asphaltene in shale hydraulic fracturing reservoirs. The results show that asphaltene deposits in rock matrix are formed during injection and production, while asphaltene deposits in fracture network are only formed during CO_2 injection. By reducing throughput pressure, asphaltene deposition can be reduced, but at the same time, crude oil production will decrease significantly, resulting in a significant reduction in oil recovery. Controlling throughput time is more effective in controlling asphaltene deposition. Lee et al. [[25]] studied the formation of asphaltene and the nanolimiting effect during CO_2 huffing and huffing in shale reservoirs, established a reservoir simulation model that took both the formation of asphaltene and the nanolimiting effect into account, and quantifies the effects of asphaltene deposition and nanolimiting effect on the output of shale oil. This study shows that in order to accurately predict oil and gas production during CO_2 huff and huff in shale, the effects of asphaltene formation and nanoconfined effects should be considered. Huang et al. [[26]] found that asphaltene deposits in immiscible CO_2 state mainly occur in larger pore throats, while asphaltene deposits in miscible CO_2 state mainly occur in smaller pore throats. The amount of asphaltene precipitation, the degree of plugging, and the recovery efficiency have mutual influence and restriction. The higher the recovery efficiency, the higher the amount of asphaltene precipitation, and the higher the degree of pore plugging. Elturki et al. [[27]] conducted CO_2 huff and puff experiments by using filter membranes and shale cores. Studies have shown that when CO_2 reaches the miscible state, asphaltene deposition decreases, and asphaltene will change core wettability to oil wetness, affect pore structure and block pores, resulting in reduced recovery.

5. EFFECT OF ASPHALTENE DEPOSITION ON CO2 SEQUESTRATION

Asphaltene deposits resulting from changes in pressure, temperature or oil composition not only affect the performance of CO_2 flooding, but also affect carbon capture and storage by reducing porosity, permeability and altering wettability. At present, the mechanism of asphaltene deposition on CO_2 storage is studied based on numerical simulation. The current study believes that asphaltene deposition will absorb more CO_2 in microscopic analysis, and due to hysteresis effect, asphaltene deposition will plug CO_2 in small pores and increase CO_2 capture. For depleted reservoirs, asphaltene may restrict or even block the effective zone of rock used for gas storage. Cho et al. [[28]] established a comprehensive solid deposition model, including adsorption, pore-throat plugging, etc., to predict the amount of asphaltene precipitation under dynamic conditions. The research results show that the deposition of asphaltene in reservoir conditions will cause pore plugging, porosity and permeability reduction, wettability change and other formation damage, and increase the residual CO_2 capture to 39% through hysteresis effect. Residual CO_2 replaces fluid in pore space, and asphaltene deposition damage reduces gas mobility, resulting in more carbon dioxide capture. Reduced oil recovery. Alafnan [[29]] used molecular simulation software to reconstruct the asphaltene structure and assess its CO_2 storage capacity. The results of the study showed that confirming the carbon dioxide storage capacity of asphaltene as an absorbed (dissolved) and adsorbed phase, the presence of asphaltene increased the storage capacity of the pore space by a factor of 4. In addition, the adsorption capacity has a lag, which is conducive to the retention of adsorbed phase. Espinoza Mejia et al. [[30]] used a novel pressure-volume-temperature unit and solid detection system to measure phase behavior, asphaltene initial pressure, and asphaltene precipitation and modeled the fluid phase using a Peng-Robinson equation of state model, while the solid phase equilibrium was modeled using a solid model. The results showed that the asphaltene precipitation increased with the increase of CO_2 injection amount and decreased with the increase of temperature. It has been proved that the process of asphaltene deposition is reversible, which can reduce the production of asphaltene deposition and increase the effective zone of rock used for gas storage in depleted oil reservoirs, and a new correlation of the molar volume of asphaltene is proposed.

6. CONCLUSION

(1) There are many methods to measure the amount of asphaltene precipitation, such as gravity precipitation, acoustic resonance and light scattering. The study of asphaltene deposition mechanism should be combined with the current advanced scanning technology to observe the mechanism of asphaltene deposition in pores of tight oil reservoirs.

(2) The effects of asphaltene deposition on microscopic pore structure and reservoir physical properties were characterized by CT, NMR, visual displacement equipment and numerical simulation.In the CO_2 immiscible and miscible stages, the influence of asphaltene deposits on pores of different sizes is different in tight oil reserviors.

(3) At present, there are few relevant studies on the influence of asphaltene deposition on CO2 storage in the process of CO_2 flooding, and most of them are based on numerical simulation to study CO_2 storage. The future research direction is to study the influence of asphaltene deposition on CO_2 storage through specific experiments.

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