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CO_2 Fracturing and Geologic Burial Studies in Tight Gas Reservoirs

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ABSTRACT

As global energy demand continues to rise and traditional energy sources become increasingly exhausted, tight gas reservoirs have become an important replacement resource. However, their development still faces challenges such as low efficiency and high energy consumption, and innovative technologies are urgently needed to realize efficient and green exploitation. This study focuses on the CO_2 fracturing technology, and systematically elaborates its principle, geological burial mechanism, adaptability of tight gas reservoirs and key influencing factors, so as to provide theoretical support for the popularization and application of CO_2 fracturing and storage technology.

KEYWORDS

Tight Gas Reservoir; CO_2 Fracturing; Factor; Geological Deposit.

1. INTRODUCTION

The extremely low permeability of tight reservoirs severely restricts the geological storage effect of CO_2, i.e., the slow injection rate and limited diffusion capacity make it difficult to effectively distribute CO_2 in the reservoir[1]. In response to this technical bottleneck, CO_2 fracturing technology has been developed, which not only significantly improves reservoir permeability, but also simultaneously realizes efficient CO_2 sequestration by constructing an artificial fracture network in tight formations through hydraulic fracturing, providing an innovative solution for carbon sequestration in unconventional reservoirs[2]. Currently, a series of representative demonstration projects of CO_2 fracturing technology have been carried out globally, including: the Illinois Basin Decatur Project (IBDP) in the U.S., which, as the world's first large-scale demonstration project of CO_2 sequestration in deep saline formations, has verified the key role of fracturing technology in improving the efficiency of sequestration; and Nagaoka CO_2 Sequestration Pilot Project (NOSPEP) in Japan, which focuses on exploring the advantages of CO_2 fracturing in complex geological conditions[3]. The Nagaoka CO_2 Storage Pilot Project in Japan focuses on exploring the adaptability of CO_2 fracturing under complex geological conditions; and the CO_2CRC Otway Project in Australia systematically researches the synergistic effect of CO_2 geological storage and enhanced gas recovery. The implementation of these demonstration projects has accumulated valuable practical experience for the large-scale application of CO_2 fracturing technology, and on September 1, 2013, the first pure liquid CO_2 fracturing test well in China was located in Changqing Sulige Gas Field, where CO_2 fracturing technology has been successfully applied to realize the high-efficiency exploitation of tight gas reservoirs. In terms of experiments, Wei Xinshan et al. [4]found that dense low-permeability sandstone has certain adsorption capacity through sandstone adsorption experiments, and the more dense the adsorption gas volume is, the higher the adsorption capacity is. Hao Yongmao et al. through mechanism analysis, numerical simulation and economic benefit evaluation, found that gas reservoir

CO2 injection can simultaneously realize the recovery rate improvement and CO_2 geological storage, which comprehensively demonstrates that the feasibility of this technology is high.

2. CO_2 FRACTURING AND GEOLOGIC BURIAL PRINCIPLES

2.1. Principles of CO_2 Fracturing and Geologic Burial

CO_2 fracturing is a technology that injects CO_2 into the borehole to create high pressure, thereby cracking the rock to increase rock fracture and porosity, thereby increasing the recovery of minerals, hydrocarbons and other minerals. CO_2 fracking is more environmentally friendly than traditional hydraulic fracturing. It uses renewable CO_2 instead of environmentally harmful chemicals and water. CO_2 fracking can also be used for geological storage of CO_2, sequestering CO_2 gas underground to mitigate climate change.

Pure liquid CO_2 fracturing, also known as dry CO_2 fracturing, differs from traditional hydraulic fracturing in that pure liquid CO_2 with high permeability and low viscosity is used as the fracturing medium to form tiny fractures in the rock, thus improving the recovery rate[5]. Liquid CO_2 will form a highly permeable “supercritical CO_2 phase” under underground temperature and pressure, which has very low surface tension and viscosity, and can form tiny cracks in rock to improve the permeability of rock. applications. In 1987, more than 400 dry fracturing operations were carried out in Canada, and were popularly applied to more than 30 formations, of which more than 95% were gas wells, which means that dry fracturing has reached a relatively mature stage of application[6].

In general, the application and research of pure liquid CO_2 fracturing technology in foreign countries have been relatively mature and achieved good results. People's knowledge of CO_2 fracturing has gradually deepened, and it is found that this fracturing fluid in supercritical state has two outstanding advantages that other fracturing fluids do not have: firstly, supercritical CO_2 has zero surface tension, which theoretically allows it to enter any size of cracks and pores, making it extremely capable of communicating with natural cracks and microfractures; secondly, compared with water, supercritical CO_2 can significantly reduce the pressure of rock fracture. These features make supercritical CO_2 fracturing a new type of fracturing technology that has attracted much attention and has a wide range of application prospects.

2.2. Geologic burial of CO_2

CO_2 geological sequestration is a technology for permanently sealing CO_2 in the subsurface[7], the mechanism of which is based on the characteristics of underground lithospheric confinement and the physical and chemical effects of CO_2. When a large amount of CO_2 is injected, the CO_2 penetrates into the trap and is isolated and sealed by the sealing layer of the trap.

The development of CO_2 geologic burial technology dates back to the 1960s. At that time, the U.S. Geological Survey (USGS) conducted a study called “Deep Geologic Storage” to explore the potential for underground storage of CO_2. In foreign countries, the practice of geological storage of CO_2 mainly includes two aspects: one is to utilize CO_2 to increase the production of oil and gas; the other is to store CO_2 directly in the ground. As more and more countries and regions begin to take actions to reduce emissions, CO_2 geological storage technology has been further promoted and applied. 2009, the European Union issued the Geological Storage Directive, which requires member states to formulate corresponding regulations on CO_2 geological storage, in order to promote the development and application of this technology. The Sleipner project in UK and Snohvit project in Norway are representative CO_2 geological storage projects.

China's CO_2 geological storage projects are mainly distributed in three fields: oil and gas fields, saline aquifers and coal seams. Among them, as the most mature field of CO_2 geological storage technology in China, oil and gas field is also the main place where CO_2 geological storage demonstration projects are implemented at present. The CO_2 geological burial demonstration project of the Jundong Oilfield located in the Tarim Basin of Xinjiang, which was carried out in 2014, adopts the direct injection of CO_2 to increase the crude oil recovery rate and CO_2 storage capacity through the dissolution, repulsion and adsorption of CO_2 in the oil reservoir, and the preliminary results show that the CO_2 recovery rate has reached more than 80%, and the project has achieved good results.

In addition to oil and gas fields, China has also carried out CO_2 geological storage projects in areas such as saline aquifers and coal seams. As China's first CO_2 storage project, Zouping CO_2 storage project started construction in 2011, completed construction and put into production in 2014, using CO_2 continuous injection method, has been injected more than 1 million tons of CO_2. In addition, China has also built a number of CO_2 geological storage demonstration projects in Changqing oilfield and Ordos Basin, etc., which are aimed at exploring and perfecting the CO_2 geological storage technology and management system of China. The aim is to explore and improve China's CO_2 geological storage technology and management system.

3. CO_2 FRACTURING AND GEOLOGIC BURIAL LAWS IN TIGHT GAS RESERVOIRS

3.1. Factors affecting CO_2 fracturing

With the increasing global energy demand and the depletion of traditional energy reserves, tight gas reservoirs have gradually become a new energy resource. In order to improve the recovery rate of tight gas reservoirs, CO_2 fracturing technology has been gradually developed in recent years. In tight gas reservoirs, CO_2 fracturing is affected by a variety of factors, including reservoir properties, CO_2 fracturing parameters, and rock pore structure[8].

3.1.1. Reservoir properties

Reservoirs with high porosity provide more storage space and reservoirs with high permeability have better liquid or gas mobility. Reservoirs with high porosity and permeability have better response to CO_2 fracturing. Therefore, for different types of reservoirs, the effect of their specific physical properties on the effectiveness of CO_2 fracturing needs to be considered. In addition, fracture is also a key factor affecting the effectiveness of CO_2 fracturing. The width and distribution of fractures have an important effect on the dispersion and propagation of CO_2, and fractures that are too wide or too dense have less control over CO_2 propagation.

3.1.2. CO_2 fracturing parameters

CO_2 fracturing parameters include injection pressure, injection volume, injection rate, and nature of fracturing fluid. Among them, injection pressure is one of the main control factors of CO_2 fracturing. To realize effective CO_2 fracturing, the pressure must be higher than the original pressure of the formation. A too fast injection rate may lead to problems such as high pressure, rising pore water level, and reduction of fracturing area, which affects the fracturing effect. Therefore, an appropriate injection rate can effectively control the distribution and diffusion of CO_2 in the formation.

3.2. Mechanism of CO_2 geological burial confinement

During the sequestration process, CO_2 needs to be effectively sequestered by a variety of mechanisms. These mechanisms can be used individually or in combination to ensure that CO_2 is buried without leaking into the atmosphere.

3.2.1. Physical confinement

When CO_2 is injected into underground rock formations, a confined space, i.e., physical confinement, is formed due to geological formations. The mechanism of such confinement mainly depends on the pore and fracture structure of the rock, the geological structure and the sealing performance of the cap layer. When CO_2 is injected into oil or salt water layer, most of it will be transported upward due to buoyancy because the density is relatively small. Since the buoyancy of CO_2 is much smaller than the capillary pressure of well sealed cap layer or fault, it will stop transporting and gather together when it meets with it, thus playing the role of hydraulic barrier. As one of the most important CO_2 geological storage confinement mechanisms, physical confinement has high reliability and stability.

3.2.2. Dissolving captivity

Dissolutional confinement refers to the formation of dissolved confinement in the subsurface where CO_2 is dissolved in groundwater or oil and sequestered in the rock as the groundwater or oil is transported. In oil formations, dissolution in oil results in partial confinement in residual oil, while dissolution in saline formations increases the density of water and promotes CO_2 dissolution and further diffusion. Dissolution confinement usually requires instrumentation and methods such as rock properties and hydrodynamic modeling, etc. CO_2 dissolution confinement is important for CO_2 sequestration, as it allows better dispersion and stabilization of CO_2 in the subsurface, and reduces the risk of CO_2 leakage. In addition, CO_2 dissolution can also promote reservoir replacement and production increase.

3.2.3. Hydrate confinement

Carbon dioxide hydrate may be generated when the pressure is higher than 5 MPa and the temperature is lower than 10 ℃, whereas the generation of CH_4 hydrate requires the pressure to be higher than 10 MPa, so CO_2 hydrate is easier to generate than CH_4 hydrate. One way of storage is to bury CO_2 hydrate to the seabed or tundra where CH_4 hydrate exists, and replace CH_4 by injecting CO_2 into the CH_4 hydrate layer, so as to achieve the purpose of replacing and exploiting as well as sequestering CO_2 in the stratum.

In general, different forms of CO_2 storage can be combined with each other to form a multi-level storage mode, which improves the efficiency and safety of CO_2 storage. However, each form of storage has its own limitations and uncertainties, and it is necessary to consider different factors, such as geological conditions, groundwater dynamics, climate change, etc., to formulate a reasonable storage scheme and carry out risk assessment and monitoring.

4. SUMMARY AND OUTLOOK

(1) CO2 fracturing technology is an important means to improve the production capacity of tight gas reservoirs and promote the geological storage of CO_2. CO_2 fracturing can improve the permeability of reservoirs, increase the effective area of reservoirs and shorten the time of CO_2 transmission, thus improving the efficiency of geological storage of CO_2.

(2) As an effective measure to mitigate global climate change, CO_2 geological storage technology has been widely studied and applied. The mechanism of CO_2 underground storage mainly includes physical adsorption, chemical absorption and mineral solidification. Among them, physical adsorption is the most important mechanism.

(3) The application of CO_2 geological burial and CO_2 fracturing technology in the development of tight gas reservoirs has a broad prospect, but it needs to be scientifically and reasonably designed and adjusted according to the nature of the reservoir, geological conditions and burial parameters in the specific implementation process. Meanwhile, further in-depth research on the mechanism and influencing factors of CO_2 geological storage is needed to better guide and promote the development and application of CO_2 fracturing and geological storage technology.

REFERENCE

[1] Chen Huanqing.New progress of CO_2 flooding and storage technology[J].Petroleum Geology and Recovery Efficiency,2023,30(02):18-26.

[2] Wu Yangqing, Zhai Liang, Lu Shoufei, Hu Xiaoxi, Yang Weixin.Progress of CO_2 Flooding Technology in the Context of Carbon Neutrality[J]. Shandong Chemical Industry,2023,52(01):109-111.

[3] FREIBURG J T.AMER M,HENKEL K,et al. Ilitization in the Mt.simon Sandstone,linois Basin,USA:implications for carbon dioxide storage[J].Marine and Petroleum Geology,2022,146:2-22.

[4] Wei Xinshan, Hu Aiping, Zhao Huitao,et al.New geological understanding of tight sandstone gas[J].Lithologic Reservoirs, 2017,29(01):11-20.

[5] Tian Lei, He Jianjun, Yang Zhenzhou,et al.Application of CO_2 Energized Fracturing Fluid Technology in Jilin Oilfield[J]. Drilling Fluid & Completion Fluid,2015,32(06):78-80+84+109.

[6] Zhou Dongqiang, Wang Yi, Wang Yanqiu.Research Progress of Carbon Dioxide Fracturing Technology[J]. Shandong Chemical Industry, 2023, 52(01): 94-96.

[7] Liao Yin. Experimental research review of supercritical carbon dioxide fracturing technology[J]. China Mine Engineering, 2021,50(02):45-47.

[8] Li Haifeng, Wang Qiang.Study on utilization and geological storage of CO_2 in CCUS[J].Modern Chemical Industry, 2022, 42(10): 86-90+95.