Experimental study of CO₂ gas injection parameters on enhanced shale gas recovery under high temperature and pressure conditions

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Abstract

With the rapid development of social economy and industrialization, conventional energy has been unable to meet the social demand for energy. As a green and clean unconventional energy source, shale gas has received extensive attention. Shale gas has become an increasingly important development area to change the energy structure and move away from a reliance on conventional energy resources. At the present stage, the mainstay of shale exploitation is depressurization. However, due to the characteristics of shale gas, such as low yield of depressurization desorption, long exploitation time and low recovery rate, which is difficult to realize economic benefits in a short time. Therefore, an efficient and environmental-friendly production enhancement measure needs to be developed in imminent. The CO₂-enhanced shale gas recovery (CO₂-ESGR) technique has effectively solved the foregoing problems and defects. CO₂-ESGR is a new type of shale recovery technique that injects supercritical or liquid-phase CO₂ instead of pure water to fracture shale gas reservoirs, based CO₂-enhanced coalbed methane (CO₂-ECBM), and replaces CH₄ from shale reservoirs according to that CO₂ has a stronger adsorption capacity of shale than that of CH₄, thus improving the shale gas yield and production efficiency.

Previous studies have demonstrated that the adsorption capacity of CO₂ for shale is derived from spatial and thermodynamic effects, which is similar to the principle of CO₂-ECBM. Experimental and theoretical calculations on shale isothermal adsorption show that the adsorption capacity of CO₂ in shale matrix is 4-25 times higher than that of CH₄, and efficiency of displacement is positively correlated with total organic carbon (TOC) content, so CO₂ injection can effectively enhance shale gas recovery production and efficiency. With respect to the issues of enhancing shale gas recovery and geo-sequestration of CO₂, a series of lab experiments and numerical simulations conducted have confirmed the great recovery capacity of shale gas by CO₂-ESGR, however, most of the studies focused on marine shale and less on continental shale. In addition, most of the experiments conducted were based on crushed shale powder and could not meet the high temperature and pressure conditions of the reservoir, thus unable to present the actual production situation. In order to identify the shale gas recovery mechanism, it is necessary to have an in-depth analysis and study of the characteristics and influencing factors of CO₂-ESGR. It aims to enhance shale gas recovery rate and realize permanent CO₂ sequestration by understanding the characteristics and development methods of shale gas reservoirs.

In such context, this study firstly analyses the principle and feasibility of CO₂ injection to enhance shale gas recovery, then use the fracturing device to fracturing the experimental core, and finally investigate CO₂-ESGR using high temperature and pressure isothermal adsorption and the self-designed physical test platform (Fig.1.), analysing the effects of CO₂ injection concentration (pure group and hybrid components), injection rate and injection method.
flooding and huff-n-puff) on CH₄ recovery to identify the mechanism of shale gas recovery enhancement by CO₂ injection and the optimum CO₂ injection method. The preliminary study shows that CO₂ under high temperature and pressure conditions has a surface tension approximately to zero, low viscosity and high diffusivity, which effectively displaces CH₄ in shale reservoirs and improves shale gas recovery efficiency. The preliminary calculations show that the shale adsorption capacity of CO₂ is 4-20 times that of CH₄, and the CO₂ sequestration potential in shale gas reservoirs is 2-4 times that of shale gas reserves. Therefore, injecting CO₂ into shale gas reservoirs can improve shale gas recovery rate while achieving permanent geological storage of CO₂, which is in favour of both economy and environment.

**Keywords:** shale gas; supercritical CO₂; CO₂-ESGR; competitive adsorption; gas injection parameters; CO₂ geo-sequestration; carbon neutrality

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**Graphic abstract**

![Fig. 1. Schematic of core fracturing and CO₂ gas injection experiment device](image-url)