Numerical Simulation Study on Coal Bed Methane Development

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Abstract

In order to find out the advantages and disadvantages of various development methods of coal bed gas, the experimental block provided by the field is studied, the component calculation model is established by CMG numerical simulation software on the basis of fine geologic modeling. Four development schemes are designed which are depleted development, development of hydraulic fracturing, development of nitrogen injection, and development of carbon dioxide injection respectively. Numerical simulation results are shown that the hydraulic fracturing technology that has good effect in increasing production of conventional oil and gas field is not applicable development of coal bed methane in the experimentation area. As gas injection development program, the scheme of carbon dioxide injection is improved by 11.4 percentage points compared with the development of nitrogen injection. This is related to the strong adsorption ability of coal bed methane to carbon dioxide.

Keywords

Coal bed methane, numerical simulation, hydraulic fracturing, carbon dioxide injection.

1. Introduction

Coal bed methane (CBM), which is occurred in coal seam with methane as a main component, mainly absorbed on the matrix of coal particle surface, partially dissociate in coal pores or dissolved in coalbed water. It is the associated mineral resources of coal, and It belongs to unconventional natural gas[1]. CBM is gas source rock as well as reservoir rock and is a double porosity reservoir with low porosity and low permeability. Its characteristics is low tensile strength, low Young's modulus and large volume compressibility[2-3]. The coal gas recovery rate of foreign oilfieldscan reach 30%~80%. Although the domestic coal-bed methane development later, It made good progress, and the prediction of recovery rate is up to 40%~55%[4-5]. Especially since the first time to exceed 10×10^9 m^3 for coal bed methane production in 2011, China's coal-bed methane industry has entered a stage of rapid development[6-7]. In this paper, the development of coal bed gas is studied by numerical simulation software.

2. General situation

2.1 Geologic general situation

The overall structure is a monocline structure that turns gradually from NNE to nearly NWW direction. On this basis a series of wide and slow fold nearly ns-trending, north east-north east trending developed. The dip angle of strata is generally not more than 15°. There is a large normal fault, and the fault that turn generally NE trend in the block, and broken leng is about 100 m.

2.2 Rock physical property of reservoir

Core data show: the true density of coal seam is 1.48~1.58, and apparent density is 1.4~1.5. Porosity is 3.96%~5.92%, So it is Low porosity and compact reservoir. Permeability is $0.72\sim2.06\times10^{-3}$ μm^2. Coal seam pressure is 3.8~6.71 MPa, and pressure coefficient is 0.69~0.82, so it belongs to the under pressure reservoir.

2.3 Fluids Physical Properties

The content of dry ash free base gas in coal bed is 10.2~22.1m^3/t, Gas component analysis results show that The methane concentration in coal bed methane is higher, which can reach 80.12%~98.32% With a small amount of carbon dioxide and nitrogen.

3. Geological model construction

Fine geological model is established by PETREL geological modeling software. The grid division should follow the following principles: The well number of grid partition of the relative concentration area should be more dense, The number of grids among the wells should be appropriate, and the grid can be slightly sparse from the far zone of the well; In order to ensure the production authenticity of four-boundary mesh in the simulation process, we add 2 rows empty grid with no attribute Outside the well grid. In accordance with the modeling requirements, we applied of 40 m × 40 m model to build the grid In plane. So grid number is 185×200. In the longitudinal direction, 3 sedimentary layers were established according to the different of sedimentary period of microfacies and sedimentary environment. In the whole reservoir geological model, the total number of grids is 111000. Three dimensional map of coal seam is as follows.

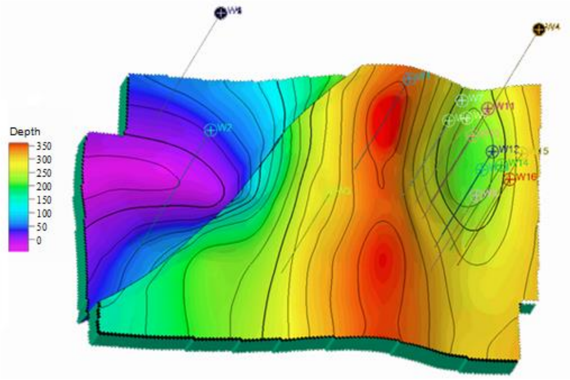

Fig.1 Three dimensional structure map of coal seam

4. History matching of numerical simulation

The calculation model of the component is established by using CMG numerical simulation software. the Production data is from May 2014 to June 2015. Therefore, it is needed to fit the numerical model according to the known production data when the geological model is established. The fitting results of the numerical simulation and the actual production data are generally match, and the fitting effect is better.

5. Scheme and scheme prediction

On the basis of the current depleted development, four schemes are designed by eclipse numerical simulation software. scheme 1 continue to maintain the depleted development which is regarded as the basis scheme; scheme 2 is Hydraulic fracturing development; scheme 3 is nitrogen injection development; scheme 4 is development by injecting carbon dioxide. The three schemes regard the beginning of 2016 as the initial time of development.

The depleted development can make full use of the natural elastic energy of gas reservoir. Numerical simulation results are shown that: by the end of August 2023, the scheme 1 stops developing because the formation pressure was reduced to abandonment pressure. The recovery rate was 19.6%.

The hydraulic fracturing technology has remarkable effect on the increase production of conventional oil and gas reservoirs. Numerical simulation results are shown that: by the end of May 2026, the scheme 2 stops developing because the formation pressure was reduced to abandonment pressure. The recovery rate was 26.6%. Relative to the basis scheme, recovery rate of scheme 2 increased by 7 percentage points, but there is no good effect similar to conventional oil and gas. t is determined by the distinctive geological characteristics of chinese coal seam which is the low strength and loose of the skeleton. The permeability and fracturing of coal seams will be poor when fracturing, so the extended distance of the fracture in the coal seam is limited after fracturing. When drainage is carried out, the coal bed methane extraction is only near the well bore. Therefore, hydraulic fracturing has little effect.

Gas injection development is actually an increase of gas reservoir saturation and gas desorption rate by injecting N_2, CO_2, flue gas and other gas into coal reservoir. Its essence is to change the pressure conduction characteristics and to keep the diffusion rate constant by injecting energy into the coal seam. Numerical simulation results are shown that: by the end of May 2032, the scheme 3 stops developing because the formation pressure was reduced to abandonment pressure. The recovery rate was 38.5%. By the end of March 2035, the scheme 4 stops developing because the formation pressure was reduced to abandonment pressure. The recovery rate was 49.9%. Relative to the basis scheme, scheme 3 and scheme 4 had significant effect on increasing production. However, for the same gas injection development, the scheme 4 is improved by 11.4 percentage points compared with the recovery ratio of scheme 3. The main reason is the higher boiling point, the ability to be adsorbed is stronger, for CO_2, CH_4 and N_2, their ability to be adsorbed decrease in turn. It is precisely because of different adsorption capacity, when CO_2 is injected into the coal seam, it will compete with the CH_4 in the coal matrix, which will replace the original adsorption of methane in the coal seam. For N_2, it can merely affect its adsorption isotherm by reducing the partial pressure of free methane, so that adsorbed methane is replaced. In contrast, the ability of CO_2 to replace methane in coal is better than that of N_2.

Numerical simulation results show that the stimulation results of carbon dioxide injection is the best in the four schemes, but this is just limited to theoretical studies. On the spot, we need to consider the vulnerability and sensitivity of the coal seam, so we need to further exploration and research in oil field.

6. Conclusion

(1) The hydraulic fracturing technology that has good effect in increasing production of conventional oil and gas field is not applicable development of coal bed methane in the experimentation area.

(2) As gas injection development program, the scheme of carbon dioxide injection is improved by 11.4 percentage points compared with the development of nitrogen injection. It is mainly because carbon dioxide adsorption ability of coal seam is better than methane, and methane is better than nitrogen. So carbon dioxide is more likely to drive out coal bed methane whose main component is methane.

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