The development effect evaluation of CBM reservoir in Hedong coalfield

Yanjun Yin[1], Xiuzhen He[2], Baojiang Duan[1], Wenshen Wang[1], Yi Feng [1]

[1]CNOOC EnerTech-Drilling & Production Co. Tianjin, 300452, China

[2] Yangtze University, Wuhan, 430100, China

Abstract

At present, the development of coalbed methane reservoir is a hot topic in China. For example, A test block of Hedong coalfield, combined with the actual situation of the coalbed methane,CBM reservoir seepage model is established based on the gas percolation mechanism of coalbed methane. This paper forecasted the CBM reservoir development effect, obtained the optimize theories of the development method and development mode in coal gas reservoir through comparing several development plans. The results shows that gas production increased rapidly after vertical Wells were fractured, obtained very good industry gas run of coalbed methane, the fracturing effect is obvious; The increase of the pre production mostly due to the desorption of methane within the scope of fracturing near wellbore, and quickly form a gas peak ,the late production stability is the methane desorption far from the wellbore transporting to the wellbore; The CBM reservoir contains very rich coalbed methane gas resources and has huge potential for exploration and development.

Keywords

coalbed methane,development method, Percolation model, fracture.

1. Introduction

As a new type of clean energy, coalbed gas is increasingly concerned all around the world. The resources of coalbed methane in depths Shallower than 2000 meters around the global is about 260 trillion cubic meters, which is more than two times the conventional natural gas proven reserves. The CBM resources are very rich in china, which is the third in the word, according to estimates, the coalbed methane resources within 2000 meters is trillion cubic meters that is equivalent to the conventional natural gas resources of the land and forms the good complementary in regional distribution. It is essential for china to develop CBM. However, it is not mature to develop the coal bed gas reservoir in our country, how to realize the reservoir comprehensively, and understand the mechanism of the coalbed gas in the reservoir, and develop reasonably and effectively are the urgent problems to be solved in the development of the coalbed methane reservoir [1-2].

2. Prediction model of coalbed methane well

The process of migration of CBM is desorption, diffusion and seepage.

2.1 Desorption and diffusion process of coalbed methane (CBM)

2.1.1 Desorption process of CBM

Coalbed methane (CBM) is adopted for the physical adsorption in coal. When the coal reservoir pressure is reduced, gas adsorbed on the surface of coal matrix pore will desorb, and flow to become a free state of gas in the pore, the process can be expressed in Langmuir isothermal adsorption equation:

$$V = \frac{V_L p}{p + p_L} \tag{1-1}$$

Where, V_L is Langmuir volume , m^3/t; V is Adsorption capacity of adsorbed gas when the gas pressure is p ; P_L is Langmuir pressure, MPa.

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2.1.2 Diffusion process of CBM

As the pore diameter of coal matrix block is too small, the permeability is very low, and the Darcy flow is quite weak and negligible. So it is generally believed that the transport or mass transfer in the porous matrix of coalbed methane is mainly diffusion [4-5]. Coalbed methane from matrix spreading cleat follows the Fick's first law, namely:

$$\frac{\partial C_m(t)}{\partial t} = \sigma D[V_E(P_g) - C_m(t)] = -\frac{1}{\tau}[C_m(t) - V_E(P_g)] \tag{1-2}$$

Where, σ is Shape factor; D is the gas diffusion coefficient of coal matrix, m^2/d ; $C_m(t)$ is the average concentration of adsorbed gas in coal matrix, m^2/t ; $V_E(P_g)$ is the matrix - fracture surface adsorption gas concentration of the gas pressure in balance, m^2/t ; τ is the adsorption time constant, $\tau = 1/\sigma D$.

When $P \geq P_d$, $V_E(P_g) = V_E(P_d)$, P_d is the critical desorption pressure

When $P < P_d$, Meet Langmuir equation:

$$V = \frac{V_L p}{p + p_L}$$

2.2 Simulation mathematical model of CBM reservoir

2.2.1 Basic hypothesis

(1) Coal seam is double porosity consisting of matrix pore system and fracture system; (2) The coalbed gas is saturated reservoir, no free gas and dissolved gas; (3) Coalbed is micro compressibility, fluid flow is isothermal flow; (4) The gas in the coal matrix is a non - equilibrium pseudo-steady state, obeying the first law of Fick diffusion; (5) Gas and water phase is incompatible to each otherp; (6) It is isothermal flow In the coal, ignoring the effect of gravity and capillary force.

2.2.2 Gas, water two-phase flow equation of fracture in the Coal seam

Seepage velocity of gas phase and water phase in cracks can be expressed as respectively [6-7]:

$$v_g = -(\frac{86.4KK_{rg}}{\mu_g}\beta_g \nabla p + \frac{D_f}{C_f}\nabla C_f) \tag{1-3}$$

$$v_w = -\frac{86.4KK_{rw}}{\mu_w}\beta_w \nabla p \tag{1-4}$$

v_g ,is seepage velocity to gas , v_w is seepage velocity to water, m/d; K is absolute permeability, μm^2 ; K_{rg} is relative permeability to gas, K_{rw} is relative permeability to water, μm^2 ; μ_g is Gas viscosity, μ_w is water viscosity, $mPa \cdot s$;P is Fracture pressure, MPa; D_f is Gas diffusion coefficient in fracture, m^2/d; C_f is gas concentration in fracture, kg/m^3, ($C_f=\rho_g\phi_g S_g$, ρ_g is gas density, kg/m^3; ϕ_g is Fracture porosity; S_g is Gas saturation) ; β_g is Darcy law correction coefficient to gas, β_w is Darcy law correction coefficient to water.

The gas spreading to the fractures constantly sees as he source of the gas phase flow, the gas continuity equation of fractures can be expressed as:

$$24\frac{\partial}{\partial t}(\rho_g\phi_f S_g)-q_m=-\nabla(\rho_g v_g) \tag{1-5}$$

And

$$q_m=-24F_G\frac{\partial C_m(t)}{\partial t} \tag{1-6}$$

Where, q_m is flow of matrix block, $kg/(m^3 \bullet d)$; F_G is Geometrical factor; t is flow time; $C_m(t)$ is average content of adsorbed gas in matrix, kg/m^3.

Water phase continuity equation in fractures:

$$24\frac{\partial}{\partial t}(\rho_w\phi_f S_w)=-\nabla(\rho_w v_w) \tag{1-7}$$

Where, S_w is water saturation; ρ_w is water density, kg/m^3.

Will type (1-3) into (1-5) , gas seepage equation is obtained:

$$24\frac{\partial}{\partial t}(\frac{\phi_f S_g p}{Z})=\nabla[\frac{p}{Z}\cdot\frac{86.4KK_{rg}}{\mu_g}\beta_g\nabla p+\frac{D_f}{C_f}\nabla(\frac{RT}{Z})]+\frac{RT}{M_g}q_m \tag{1-8}$$

Z is gas deviation factor; R is gas constant, $KPa\bullet m^3/(mol\bullet K)$; T is temperature of coal seam; M_g is gas molar mass, kg/mol.

Will type (1-4) into (1-7), water seepage equation is obtained:

$$24\frac{\partial}{\partial t}(\frac{\phi_f S_w}{B_w})=\nabla(\frac{86.4KK_{rw}}{B_w\mu_w}\beta_w\nabla p) \tag{1-9}$$

B_w is volume factor of water phase.

2.2.3 Numerical model and its solution

As well as the center of seepage area by plane radial grid, adopts the difference discrete method available [8]:

$$q_w=\frac{172.8\pi h}{0.5\Delta x}\bullet\frac{K(p_1)K_{rw}(S_{g1})}{\mu_g B_w}(\beta_w)_{1/2}(p_1-p_w) \tag{1-10}$$

$$q_g = \frac{172.8\pi h}{0.5\Delta x} \bullet \frac{K(p_1)K_{rg}(S_{g1})}{Z(p_1)\mu(p_1)}(\beta_g)_{1/2}(p_1^2 - p_w^2) + \frac{2\pi h}{0.5\Delta x} D_f \frac{p_1 - p_w}{Z(p_1)} \frac{M_g}{\rho_{sc}RT} \quad (1\text{-}11)$$

3. Prediction scheme design

The coalbed methane reservoir is a monoclinal structure striking west or south slope. There are no. 4 and no. 8 coal seam in the Exploration and development layers, the coalbed seams are stable, the thickness is large, the depth is moderate, and the gas bearing property is good, all are minable seam. The neral trend of the change of Coal seam gas content increases with the increase of the depth of the coalbed, and the gas content in the southeast is higher. No. 4 coal seam has fractured 2 wells, and the No. 8 coal seam has fractured 4 wells. After 2-3 months of drainage, the 2 wells of No. 4 coal seam was in the rise of gas production, the 4 wells of No. 8 coal seam began to produce gas, after a period of rise and gradually reach the stable yield with breakthrough production of 1000 m^3/d. The main physical parameters are shown in table 1. The permeability of hydraulic fracture is 1D, the fracture half-length is 90m, and the fracture width is 6mm. The bottom pressure is known, fitting the gas production and water production, the situation of fitting as shown in figure 1.

Firstly, vertical Wells for fracturing and non- fracturing are predicted. Forecast for 20 years, gas production curves are shown in Figure 2. From Figure 2 it can be seen that after fractured, the gas production increases quickly, and the effect is obvious. Then 3 Schemes of fractured wells are predicted, the cumulative gas production curves of the 3 schemes are shown in Figure 3. Plan 1 with 300 * 300 pattern, 20 years of recovery is 55.2%; Second scheme adopts 300 * 400 pattern, 20 years of recovery is 59.1%; the third is 400 * 500 pattern, 20 years of recovery is 53.5%. In comparison with the three schemes, the 300*400 well pattern is the best one at present.

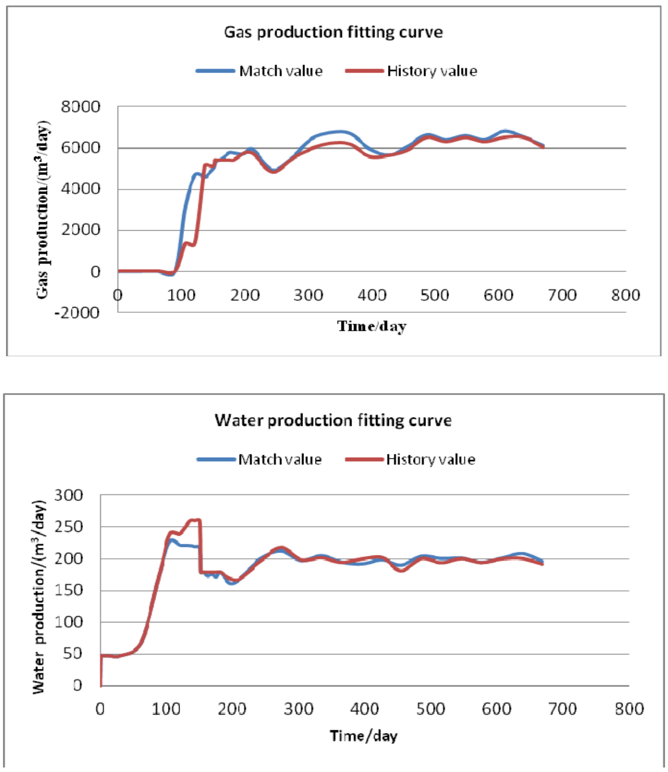

Figure 1. The gas production rate and water rate curve fitting

Table 1 Main physical parameters

Reservoir parameters	No.4 coal seam	No. 8 coal seam
formation temperature(℃)	25	25
Buried depth(m)	700~1100	700~1100
Thickness(m)	2.28~8.6	3.8~15.52
Original gas content(m3/t)	4.49~8.6	4.30~8.80
Langmuir volume(m3/t)	10.9～18.07	8.31～16.40
Langmuir pressure(MPa)	2.19～5.02	1.66～2.87
Coal seam density(t/ m3)	1.4	1.38
Permeability(10-3μm2)	0.24~0.94	0.19~4.9
Porosity (%)	1~3	1~5

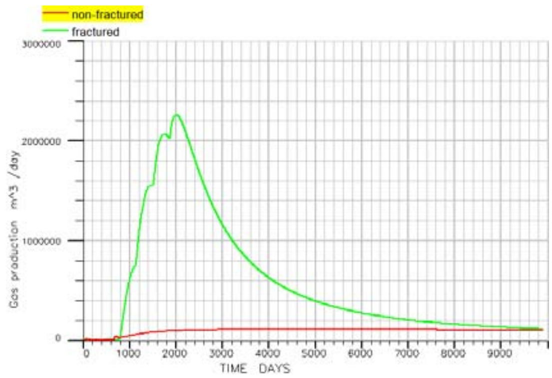

Fig. 2 Gas production curves of fractured and non-fractured

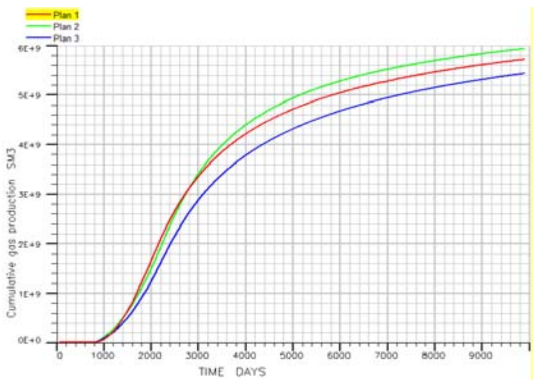

Fig. 3 Cumulative gas production curves of Scheme 1, 2, 3

Acknowledgments

(1) The distribution of No. 4 coal seam is stable, gas content is greater than 4m3/t, with a high degree of saturation and good permeability, good coalbed methane industry airflow can be got through the appropriate measures and process on increasing production.

(2) The 300*400 well pattern is the best one in comparison with the three schemes.

(3) The increase of the pre-production mostly due to the desorption of methane within the scope of fracturing near wellbore, and quickly form a gas peak, the late production stability is the methane desorption far from the wellbore transporting to the wellbore.

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