Fuel 233 (2018) 354–360

Contents lists available at ScienceDirect

Fuel

journal homepage: www.elsevier.com/locate/fuel

Full Length Article

Simulations on recoverability performances for a coalbed methane field in SE edge of Ordos basin, China

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ARTICLE INFO

Keywords:
Geological modeling
Recoverability performance
Field simulation
Space optimization
Historical matching

ABSTRACT

This paper mainly studies the recoverability performances for a coalbed methane (CBM) field located in the southeastern edge of the Ordos basin of China. Geological models are established, and drainage performances for four typical wells are described in detail. Single well simulations for the four wells are conducted to check accuracies of parameters and predict well drainage performances, and optimizations of well spaces are simulated to determine the most suitable well space. Results indicate that the reservoir parameters used in this study are quite accurate, and the well space of 350 × 300 m is most suitable in this area. Furthermore, the fifteen years' field simulation under the well space of 350 × 300 m is conducted, which shows that the well number, average production and cumulative production are 1944, $7.01 \times 10^8\, m^3/d$ and $105.22 \times 10^8\, m^3$, respectively. To validate the well space used in this study, analyses of recoverability and economic profit are conducted, both of which demonstrate that the well space of 350 × 300 m is most suitable in this area and can bring a stable drainage performance for a long time and get a high gas production.

1. Introduction

Coal is a source, reservoir and trap for significant quantities of methane and minor amounts of other gases [1,2]. This gas, referred to as coalbed methane (CBM), is potentially an important economic resource, and has received worldwide attentions as a clean and unconventional energy [3–6].

Before CBM exploration and exploitation, numerical simulation is always used to predict well recoverability performance, parameters optimization, CO_2 enhanced CBM, CO_2 geosequestration, and coal mine gas migration and emission [7–12], all of which can be the bases for both delineating a target exploitation area, and designing a reasonable drainage system [13,14].

As a result, simulations on well recoverability performances have been extensively conducted in recent years [15–17]. Meanwhile, many simulation models have been developed, as described and compared in Law et al. [13,16] and Wei et al. [18], among which, the dual porosity/single permeability models proposed by Warren and Root [19], Kazemi [20], de Swaan [21] and Gilman [22] are most widely used. Relevant cases can be found in the following researches. King and Ertekin [23,24] reviewed CBM models which had been developed and published from literatures. Young [15] presented simulation examples of multi-seam fractured wells and open-hole cavity wells. Gentzis and Bolen [25] conducted numerical simulations on a coal seam, and indicated that the multiple but parallel horizontal wells had positive impacts on recovery performances. Yang et al. [26] simulated gas productions for wells with different peak yields and initial rates. Zou et al. [17] simulated gas productions for three wells in southern Qinshui basin of China by using the COMET3 reservoir simulation software. Ziarani et al. [27] simulated the effect of non-equilibrium sorption time on gas production in CBM reservoirs. Zou et al. [28] simulated well performances for different types of coal reservoirs, and presented the exploitation mode for each type.

In some studies, a new model with triple porosity and dual permeability has been adopted to decouple desorption and diffusion processes in matrix blocks [29], of which accuracy has been validated by Wei and Zhang [3] and Zou et al. [30]. Besides, Thararoop et al. [31] amended Langmuir equations and developed a CBM simulation software based on the triple porosity/dual permeability model, and then used the software to simulate recovery performance of a well. Although this model is more accurate than the conventional dual porosity/single permeability model, it is quite difficult to obtain parameters of different pore systems, which leads to a limited usage [30].

CBM recoverability performances have been simulated for a long time, and the used models show great maturity. However, the simulated target mainly aims at one well or a few wells. Nowadays, to obtain large amounts of gas productions and cause intense well interferences, hundreds or thousands of CBM wells are always arrayed in a gas field.

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https://doi.org/10.1016/j.fuel.2018.06.071
Received 10 February 2018; Received in revised form 15 April 2018; Accepted 19 June 2018
0016-2361/

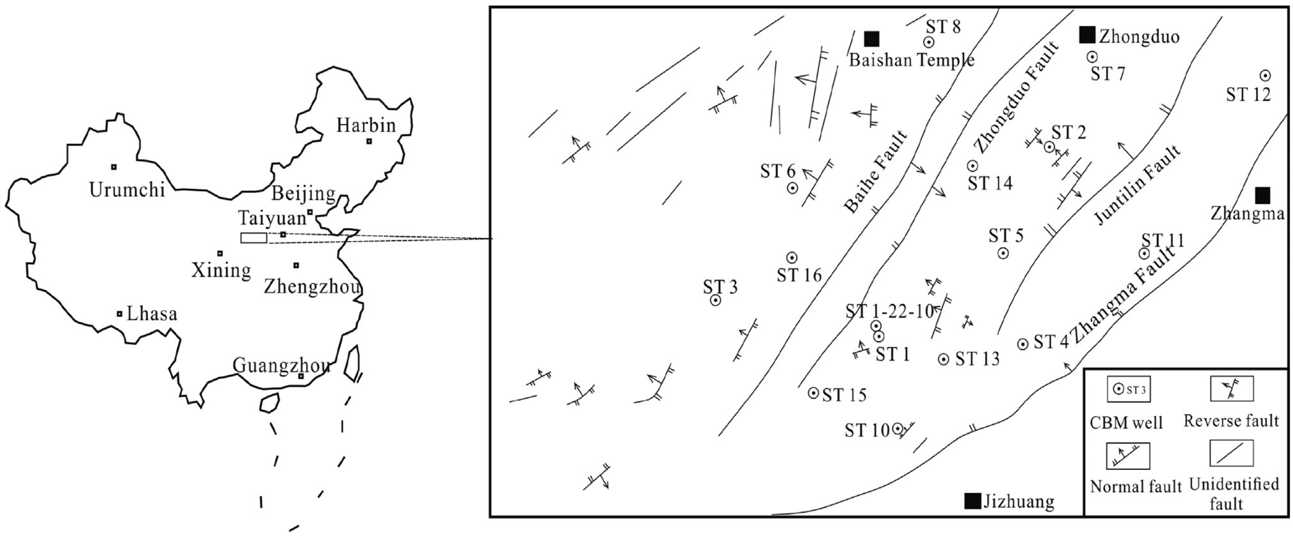

Fig. 1. Structural outline and well locations of the study area.

Therefore, it is essential to conduct simulations for an entire gas field, yet it has been rarely studied. This paper selects a hotspot CBM field located in the southeastern edge of the Ordos basin of China as an example, builds the geological models for this area, uses numerical simulation method to determine well space and well number, and simulates recoverability performances for all the wells arrayed in this area finally.

2. Geological setting, modelling and simulation

2.1. General information

A hotspot CBM field located in the southeastern edge of the Ordos basin of China is selected as a case in this paper. The target coal seam is coal seam No. 2, and its buried depth decreases from southeast to northwest. Faults and folds are both developed in this area, and the trends and inclinations of faults are generally southeast and southwest, respectively. CBM wells are mainly east of Baihe and Zhongduo Faults, while much fewer in the west, as shown in Fig. 1.

2.2. Well descriptions

Drainage curves of nineteen wells in this area are collected, among which, wells of ST1, ST4, ST5 and ST13 perform well, as described follow.

It should be noted that there are two outlets for a CBM well, and one is for water and the other one for gas. During drainage, gas and water are separated in the well bore by using a gas-liquid separator first and then pumped out from the corresponding outlet. Then, both gas and water productions can be measured at the outlets under the standard state, of which temperature is 0 °C and pressure is 100 kPa. Meanwhile, all gas volumes mentioned in this pape is measured under the standard state.

Fig. 2 shows the drainage histories of four typical wells of ST1, ST4, ST5 and ST13, as detailedly described below. Remains of wells do not perform well. Their gas productions are quite low (wells ST3, ST6, ST7, ST8, etc.) or none (wells ST2, ST11, ST12, etc.), which is not helpful for the later simulations. Therefore, drainage curves of those wells are not listed.

Drainage history of well ST1 can be divided into two stages. The first stage refers to the early 250 days. There are some sudden decreases for gas production in this stage, which is caused by man-made flow interventions. In this stage, the maximum gas production rate reaches 2632 m^3/d, and the water rate varies between 0 and 7 m^3/d. Remaining time is the second stage. Water production rate decreases gradually from 3.6 to 0.1 m^3/d, and gas rate gradually increases to the maximum value of 12746 m^3/d and then keeps quite stable. Cumulative gas and water productions are 381981 m^3 and 666.5 m^3, respectively.

Drainage history of well ST4 can also be divided into two stages. The initial 200 days is the first stage. In this stage, gas production rate is quite low, with a maximum value of 500 m^3/d, and water production rate keeps quite stable at about 3 m^3/d from day 60 to 190. After 200 days, the drainage history goes to the second stage. Water production rate decreases from 4.7 to 2 m^3/d, and then keeps quite stable; while gas production rate increases firstly, and keeps quite stable at about 1200 m^3/d afterwards.

For well ST5, no gas produces in the first 120 days, while water production rate gradually increases to 9.5 m^3/d. After 120 days, gas starts to be desorbed, which is a new stage. Gas production has repeated variations of increase first and stabilization afterwards, with the final rate of 1840 m^3/d. Water production rate decreases gradually from 9.5 to 0.4 m^3/d. Cumulative gas and water productions in this stage are 171451 m^3 and 798.19 m^3, respectively.

As for well ST5, water production rate changes from 0.84 to 5.46 m^3/d, and its cumulative and average values are 697.1 m^3 and 3.29 m^3/d, respectively. Gas starts to be desorbed at day 115. After that, it increases to a maximum rate of 1585 m^3/d fist, and then decreases to 1012 m^3/d. The cumulative gas production is 87521 m^3.

2.3. Geological modeling

Geological models for the research area should be established before simulation, such as buried depth, coal thickness, gas content, etc. For single well simulation, these models are always flat in space, with only one value for one parameter, which is because that the research area is quite small and can be thought that the value of each parameter in the area is constant. While for field simulation, the research area is quite large, in which the value of each parameter is various. With helps of well testing, well drilling, etc., values of parameters at different places can be obtained, and geological models including buried depth, coal thickness, gas content and permeability can be thereby built, as shown in Fig. 3. All of the models will be input in the software during the later simulations.

A fault model also needs to be considered during simulation, because it is very important to decide well location and well space. Another model considering the buried depth and fault is build, as shown in Fig. 4.