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To cite this article: Dan Huang *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **300** 022088

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Study on Production Decline Law of Multilateral Horizontal Well in Coalbed Methane Reservoirs

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Abstract. China is rich in coal-bed gas resources, however, because of the low abundance of coalbed methane, the low filtration ability of coal matrix and the complexity of gas streaming process, causing the single well productivity of conventional coalbed methane well is low. To improve the individual well producing rate and the economic effects of coal-bed gas reservoirs, the multilateral horizontal wells are being popularized on a large scale. Therefore, it is necessary to study the production decline law of multi-branch horizontal well in coalbed methane reservoirs. Based on the seepage physical model, a mathematical model based on resolution-diffusion-filtration was established. By using the point source function, the bottom pressure response function of single branch horizontal well was solved. By utilizing the theory of pressure superposition, mathematical model of production decline was gained, and the key elements influencing production decline were analyzed. The research results in this paper will have some guiding significance for efficient development of coalbed methane.

1. Introduction

Coalbed methane is gaseous hydrocarbon that stored in coal seams with methane as the main component, mainly adsorbed on the surface of coal matrix and partly dissociated among coal pores or dissolved in coal water. It is mineral resource associated with coal and belongs to unconventional gas. And it is clean, high quality energy and chemical raw materials rising nearly two decades in the international. The global coal-bed gas resources is $270 \times 10^{12} m^3$, which is half of the conventional natural gas reserves. China's coal-bed gas resources is $36.8 \times 10^{12} m^3$, and the theoretical constant yield is $633-935 \times 10^8 m^3$. At the end of 2012, there were more than 11,000 coalbed methane producible wells around the world, of which there were wells with industrial productions just over 6,000 (about 55% of the total production wells), and the average individual well producing rate in gas was only $1090 \sim 1700 m^3/d$ (that of US was $3000 \sim 6000 m^3/d$). Individual well producing rate is extremely low and the resulting comprehensive cost is difficult to reduce have become a serious obstacle to the development of coalbed methane in China. Fortunately, multi-branch horizontal well is the main technical approach to improve the single well productivity of coalbed methane, and recently, it is more and more widely applied on the exploitation of coalbed methane reservoirs. Therefore, it is necessary to study the production decline law of multi-branch horizontal well in coalbed methane reservoirs.



2. Physical model of multi-branch horizontal wells

Multi-branch horizontal wells in coalbed methane reservoirs, fundamental assumptions are following, 1) The coal-bed gas reservoir is composed of coal matrix, cleat and intrinsic fractures, the formation thickness is h , and the lateral radius is infinite or r_e ; 2) The fluid flowing obeys the law of resolution, diffusion and Darcy flow; 3) The gas well producing with a constant pressure and the output is q_{sc} under standard condition; 4) The gas follows isothermal seepage law, ignoring the gravitational effects; 5) The horizontal wellbore is in the y -axis direction and the z -axis direction is vertical; the separation of horizontal wells is $\Delta L_i (i = 1, \dots, m)$, and the intercept of the i -th horizontal well on the y -axis is y_i ; and its top half-length is L_{fRi} , the bottom half-length is L_{fLi} . The physical model is shown in Fig. 1.

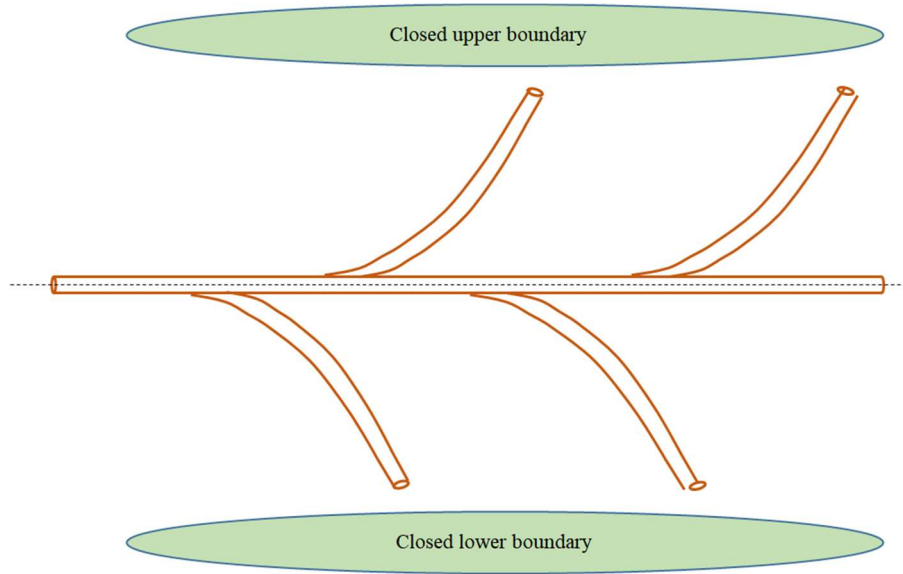


Figure 1. The seepage physical model of multi-branch horizontal wells.

According to previous derivations, the dimensionless mathematical model with dual-porosity and single-permeability of coalbed methane reservoirs is:

$$\begin{cases} \frac{1}{r_{id}^2} \frac{\partial}{\partial r_{id}} \left(r_{id}^2 \frac{\partial c_D}{\partial r_{id}} \right) = \lambda \frac{\partial c_D}{\partial t_D} & \text{(matrix diffusion)} \\ \frac{1}{r_D^2} \frac{\partial}{\partial r_D} \left(r_D^2 \frac{\partial \Delta \psi}{\partial r_D} \right) + \frac{(1-\omega)}{\lambda} \frac{\partial c_D}{\partial r_{id}} = \omega \frac{\partial \Delta \psi}{\partial t_D} & \text{(cleat seepage)} \end{cases} \quad (1)$$

Where $c_D = c - c_i$ is dimensionless diffusion concentration; $t_D = \frac{3.6kt}{\theta L^2}$ is dimensionless time; $\Delta \psi = \psi_i - \psi$ is pseudo-differential pressure; $\omega = (\phi c \mu) / \theta$ is storage ratio; $\lambda = \frac{3.6k\tau}{\theta L^2}$ is diffusion coefficient; $\tau = \frac{R^2}{D}$ is adsorption time; $r_D = \frac{r}{L}$ is dimensionless radius; $\theta = \phi c_i \mu + \frac{6p_{sc}T}{q_D T_{sc} \psi_i}$.

Drawing support from previous derivation, the basic solution of transient point source of the equation is:

$$\bar{r}_D = \frac{1}{4\pi\rho_D} \exp\left(-\rho_D \sqrt{u}\right) \quad (2)$$

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3. Features of multi-branch horizontal wells production decline

The branch numbers of horizontal wells is an important parameter that affects yield of horizontal wells. Fig. 2 is the relationship graph of branch numbers and dimensionless rate, and it reflects that the more the branch numbers are, the more the connected reservoirs are, the huger the drainage area is, the larger the dimensionless deliverability is; on the contrary, the less the branch numbers are, the smaller the discharge area is, and the smaller the dimensionless rate is.

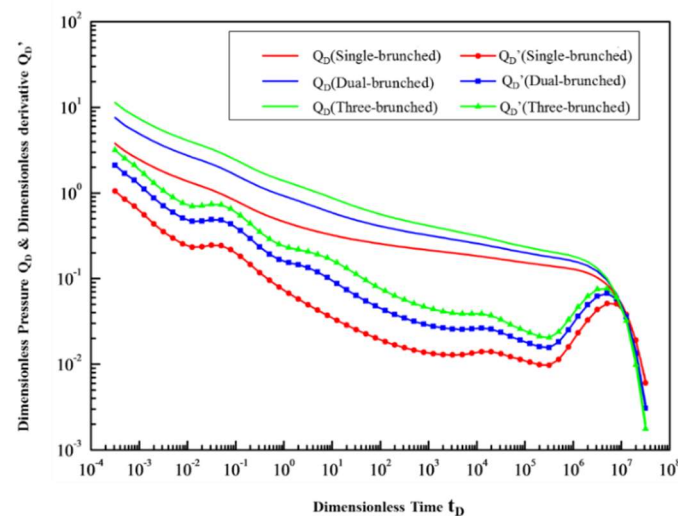


Figure 2. The comparison diagram between single and multi-branch horizontal wells

The length of horizontal wells is an important parameter that affects production of horizontal wells. Fig. 3 shows the relevance between the length and dimensionless rate, which reflects that the longer the horizontal wells are, the more the connected reservoirs are, the huger the drainage area is, and the larger the dimensionless productivity is; conversely, the shorter the wells are, the smaller the drainage area is, and the smaller the dimensionless rate is.

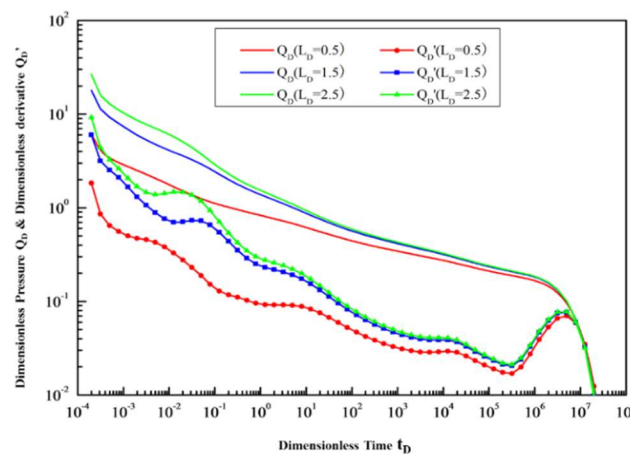


Figure 3. The comparison diagram of different horizontal wells length

The interval of multilateral wells is also an important parameter that affects the output of horizontal wells. Fig. 4 shows the relationship of the separations and dimensionless production, we can see that the

larger the separation is, the connected reservoirs are, the huger the discharge area is, and the greater the dimensionless productivity is; conversely, the smaller the interval is, the smaller the discharge area is, and the smaller the dimensionless deliverability is.

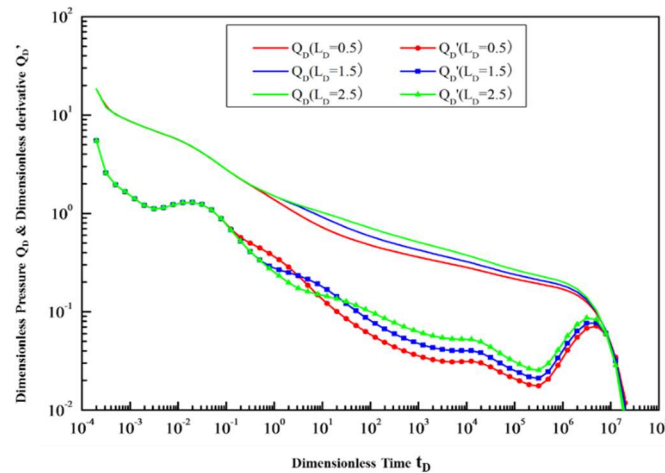


Figure 4. The comparison diagram of different intervals of multilateral wells

4. Conclusion

(1) According to the theory of dissolution-diffusion-seepage of coalbed methane reservoirs, the seepage mathematical model was established and the transient point source solution of coalbed methane reservoirs was gained. Through Laplace transform, the integral formula transformation and pressure superposition principle, the mathematical model of multi-branch horizontal wells production decline analysis was obtained.

(2) The more the branch numbers are, the more the connected reservoirs are, the huger the drainage area is, and the greater the dimensionless deliverability is. The longer the horizontal wells are, the more the connected reservoirs are, the huger the drainage area is, and the greater the dimensionless deliverability is. The bigger the intervals are, the more the connected reservoirs are, the huger the drainage area is, and the greater the dimensionless deliverability is.

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