A New Triple Porosity Seepage Model in Coalbed

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Summary Based on the analysis of macro and micro structure of the coalbed and comprehensive research on dual-porosity and triple-porosity models at home and abroad, three new triple-porosity models were proposed by considering the geological characteristics of coalbed and desorption law of CBM in China. The triple-porosity contains coal matrix, micro-fracture and structural fracture/cleat. By analyzing the coal samples from different region in China, it concludes that coal was cut into different shapes of blocks, which consist of cube/sphere, layer and cylinder, by structural fracture/cleat. The blocks as basic unit of coal are referred to matrix 1. There are uniform micro-unit and miro-fracture within the matrix 1, and the micro-unit is called matrix 2. Two kinds of CBM desorption phenomena include steady and unsteady desorption.

INTRODUCTION

CBM(Coalbed methane) which is the associated resources of coal is a kind of unconventional gas with main component methane and exists in coalbed and surrounding rock. CBM mainly adsorbs on the surface of coal matrix and part frees in coal pores and a little dissolves in coalbed water. In the "post-petroleum era", CBM as a clean, efficient and safe new energy plays an important role in the aspects of energy replacement, energy structural adjustment, environmental protection and mine safety in China. To recognize the effect of desorption on fluid flow, the characteristics of fluid flow in different coalbed and the effect of coal structure on CBM development by researching on seepage law of CBM will be helpful for promoting the process of CBM industry.

In 1975, Closmann[1] first describe the triple-porosity in a fissured carbonate reservoir. The model included matrix and fracture. In 1981, Liu Ci-qun[2] divided system into matrix 1, matrix 2 and facture. the exact solution for the unsteady radial flow equations of the slightly compressible liquid through triple-porosity formation by using the decomposition method was obtained. In 1983, Wu Yushu and Ge Jiali[3] also regarded triple-porosity model as matrix 1, matrix 2 and fracture. This model was based on Warren-Root model too. And the analytical solution was obtained by Laplace transformation. In 1983, Liu Ci-qun[4] studied the line source solution of two-dimensional axisymmetric unsteady-state flow and point source solution of a limited closed formation for triple-porosity model. From those triple-porosity research, we can see crossflow mechanism is pseudo-steady state. In 2007, Wu Yushu[5] developed a analytical method to pressure transient test in naturally fractured cavity reservoirs in western China. Since many formations conform to triple-porosity model, the research of triple-porosity model is significantly important to guide the reservoirs development in China.

MODELS

Pysical Model

In this paper, on the basis of the analysis of macro and micro structure and combination of the research on dual-porosity and triple-porosity reservoirs at home and abroad, three new triple-porosity models were proposed in connection with geological characteristics and desorption law of CBM in China. The physic model assumes the coalbed consists of cube/sphere, layer and cylinder. The basic unit is cut by fractures which form through geological tectonization and coal-forming process. Each basic coal unit is made up of uniform shape of micro-unit. The flow between micro-unit and micro-fracture is unsteady state crossflow in basic unit. And the micro-unit as the source doesn't flow into structural fracture/cleat. The fluid flow from basic unit into structural fracture/cleat. At last, the fluid flow from structural fracture/cleat into wellbore.

The coalbed is cut into different size of unit by fractures as the geological tectonic movements as shown in Fig.1. With the help of the SEM microscopy, the microstructure could be seen after 500 times magnification is shown in Fig.1.

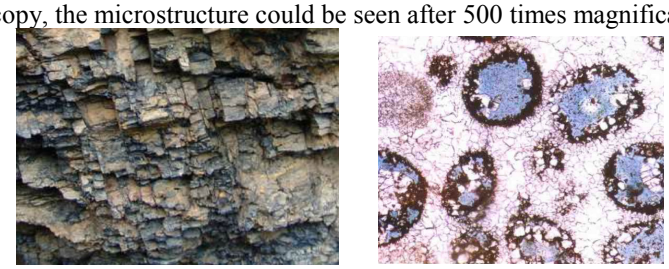

Fig.1 The macro-structure of cubic coal

The physical conditions of coalbed:(1) The coalbed is homogeneous, isopachous, isotropic. (2) The effects of wellbore storage and skin are taken into consideration.(3) The outer boundary conditions include infinite coalbed, cicular closed coalbed, circular constant pressure coalbed, rectangle closed coalbed and rectangle constant pressure coalbed.

Mathematical Model

The dimensionless governing equation in fractures: $$\frac{\partial^2 p_{fD}}{\partial r_D^2}+\frac{1}{r_D}\frac{\partial p_D}{\partial r_D}-\frac{\lambda_{m1}}{5}\frac{\partial p_{m1D}}{\partial r_{m1D}}\bigg|_{r_{m1D}=1}+\alpha_{1D}+\alpha_{2D}(p_{fD}-P_{CD})=\omega\frac{\partial p_{fD}}{\partial t_D} \quad (1)$$

The dimensionless governing equation in matrix 1: $$\frac{\partial^2 p_{m1D}}{\partial r_{m1D}^2}+\frac{2}{r_{m1D}}\frac{\partial p_{m1D}}{\partial r_{m1D}}-\frac{\lambda_{m2}}{5}\frac{\partial p_{m2D}}{\partial r_{m2D}}\bigg|_{r_{m2D=1}}=\frac{15\omega_{m1}}{\lambda_{m1}}\frac{\partial p_{m1D}}{\partial t_D} \quad (2)$$

Initial condition of matrix 1: $$p_{m1D}(t_D=0)=0 \quad (3)$$

Inner boundary condition of matrix 1: $$\frac{\partial p_{m1D}(0,t_D)}{\partial r_{m1D}}=0 \quad (4)$$

Outer boundary condition of matrix 1: $$p_{m1D}(r_{m1D},t_D)\big|_{r_{m1D}=R_D}=p_{fD}(r_{m1D},t_D)\big|_{r_{m1D}=R_D} \quad (5)$$

The dimensionless control equation of matrix 2: $$\frac{\partial p_{m2D}^2}{\partial r_{m2D}^2}+\frac{2}{r_{m2D}}\frac{\partial p_{m2D}}{\partial r_{m2D}}=\frac{225\omega_{m2}}{\lambda_{m1}\lambda_{m2}}\frac{\partial p_{m2D}}{\partial t_D} \quad (6)$$

Initial condition of matrix 2: $$p_{m2D}(t_D=0)=0 \quad (7)$$

RESULTS AND DISCUSSION

In terms of the solving results, the curves about pressure, pressure derivative and time are drawn. To research the triple-porosity characteristics of CBM, it needs to analyze the effects of storage coefficient, crossflow coefficient and desorption coefficients.

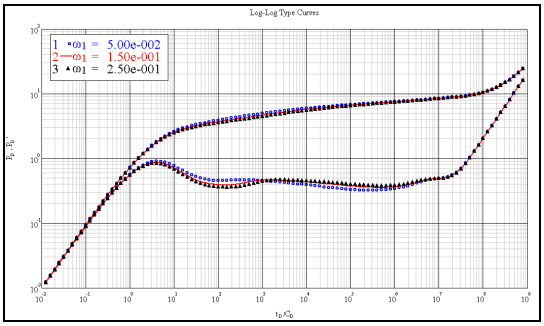

Fig.2 The effect of storage coefficient of matrix 1 and matrix 2

Fig.2 shows that the prophase and anaphase of the curves coincide. The prophase of curves is wellbore storage and skin effects stage, and the anaphase is boundary effects stage. In intermediate period, the first valley has greater concave margin and the second valley has smaller concave margin with the greater storage coefficient of matrix 1 and the smaller of matrix 2. Triple-porosity characteristic is clearly shown: firstly, the fluid flow from matrix 2 to matrix 1; then the fluid flow from the matrix 1 to the fractures; at last, the system reaches a steady state.

CONCLUSIONS

In according to the characteristic of coalbed in China, a new triple-porosity models have been developed for evaluation of reservoirs made out of matrix 1, matrix 2 and fractures by considering the steady and unsteady desorption. They are triple-porosity spherical unsteady crossflow model and triple-porosity strata unsteady crossflow model. The steady and unsteady desorption coefficients impact on the anaphase of type curves. The smaller the steady and unsteady desorption coefficients are, the greater the pressure derivative curve go down.

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