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Analysis of production decline factors of fracturing horizontal wells in tight reservoirs and study of decline law

Zhang Chong

No.7 oil production plant, Daqing oilfield co., Ltd., Daqing 163517, Heilongjiang, China

Abstract: Horizontal well fracturing technology has been applied in tight oil reservoirs, and most horizontal wells show decline after high production period. In order to define the change law of horizontal well production based on the geological and engineering factors on the influence of the horizontal well production change, the paper uses Daqing region A block of the horizontal well production data in view of the analysis of the regressive method. Based on the analysis of each decline method, it is considered that the horizontal well production in this block is the exponential decline, which lays a foundation for the prediction of horizontal well production and the adjustment of the later development system.

1.Introduction

Horizontal well technology is an oilfield development of new technology developed in the 1940 s [1], at present, it has been applied in a variety of reservoir and achieved good development effect. However, after the stage of high and stable production, it soon enters the stage of production decline, which brings challenges to the benefit development of horizontal wells. Therefore, it is urgent to find out the production change rule of horizontal wells in different reservoirs to guide the future development and adjustment [2-14]. Based on the fracturing horizontal well development data of tight reservoir in daqing oilfield, this paper analyzes the production decline, summarizes the production change rule and application effect.

2.Analysis of horizontal well production decline factor

Daqing block A is the basic geological model. A typical ideal well is selected for the horizontal well productivity decline factor analysis.

(1) Reservoir impact on production

The effect of formation permeability on production: the production of a single well decreases with the decrease of formation permeability, which is equivalent to considering the stress sensitivity, and the permeability decreases with the continuous exploitation of the reservoir and the decrease of pressure.

Fluid viscosity effect on production: as fluid viscosity increases, well production increases as flow resistance decreases.

The effect of effective reservoir thickness on production: as fluid viscosity increases, the effective reservoir thickness increases, because the amount of oil the reservoir can supply increases.

(2) The effect of pressure on production

Impact of starting pressure on production: as the starting pressure increases, production per well decreases because the production pressure used for displacement has some capacity to overcome the starting pressure, resulting in lower production.

Formation pressure impact on production: as the formation pressure decreases, the production per well decreases and the energy available for displacement production decreases.

(3) Horizontal well technology factors

As the length of horizontal Wells increases, the output per well increases. Increasing the length of a horizontal well increases the amount of oil and gas flowing through the well, which in turn increases production per well.

The effect of horizontal well fracture length on production: as the fracture length increases, the output of a single well increases. But the increase is not that much because the overall length has little effect on the horizontal section of the well and the reservoir (explained from the model perspective).

3.Research on horizontal well production decline method

Evaluation of recoverable natural gas reserves in unconventional (low and ultra-low permeability) gas reservoirs has become an increasingly interesting topic.For tight gas reservoirs, due to the low and ultra-low permeability characteristics of reservoirs, the production data of such reservoirs often show a long unsteady percolation period, which leads to the situation that the recoverable reserves may be too high when using flow-time relations (such as exponential decline and hyperbolic decline relations). At present, the hyperbolic decline function of Arps is usually used to evaluate the reserves of tight gas reservoirs, but the hyperbolic decline equation of Arps is strictly applicable to the boundary control flow, so the hyperbolic decline function will cause great error in the calculation of dynamic reserves in unsteady seepage flow.

① Theoretical basis

Johnson and Bollens (1928) and Arps (1945) proposed the derivative functions of decline rate and decline rate, which can be defined as:

$$\frac{1}{D} = -\frac{q}{dq/dt} \tag{1}$$

$$b = \frac{d}{dt}\left[\frac{1}{D}\right] = -\frac{d}{dt}\left[\frac{q}{dq/dt}\right] \tag{2}$$

If D is a constant, then Arps' exponential decline equation can be derived from equation (1) :

$$q = q_i \exp\left(-D_i t\right) \tag{3}$$

The equation can also be obtained by solving the boundary control flow percolation equation of a well with fixed bottom hole flow pressure production in the center of a closed reservoir.The derivative of decline rate D and b can also be expressed by the cumulative yield-yield relation:

$$D = -\frac{dq}{dQ} \tag{4}$$

$$b = q\frac{d}{dQ}\left[\frac{1}{D}\right] \tag{5}$$

Blasingame and Rushing (2005) gave a detailed derivation for the Arps' hyperbolic regressive equation, and presented an expression for the change of the regressive rate D over time:

$$q = q_i \frac{1}{\left(1 + bD_i t\right)^{1/b}} \tag{6}$$

D can be written as a function of time:

$$D = \frac{D_i}{1 + bD_i t} \tag{7}$$

Cumulative output is expressed as:

$$G_p(t) = \frac{q_i}{(1-b)D_i}\left[1-(1+bD_i t)^{1-(1/b)}\right] \tag{8}$$

According to the definition of Arps, the domain of derivative b of decline rate is 0-1. If b is greater than 1, the cumulative production tends to infinity over time. When the hyperbolic decline function is used to evaluate unconventional (tight gas) reservoirs, it can be found that b is often greater than 1, which makes the estimation result of recoverable reserves relatively large.

For a given hyperbolic decreasing function, b is a constant, and the decreasing rate is D. Parameters D and b can be calculated using either production-time data or production-cumulative production data. It is generally better to use production-cumulative yield because the production-cumulative yield data is much smoother than the production-time data.

②Power rate exponential decline model

According to the production data of tight gas reservoir (production-time data), the curve of decline rate D over time was calculated and plotted on a log-log graph. It can be found that the curve presented a linear trend in the later period. Therefore, the decline rate D is redefined as:

$$D = D_\infty + D_1 t^{-(1-n)} \tag{9}$$

Put it into formula (1) to get the exponential decline model of power rate:

$$q = \hat{q}_i \exp\left(-D_\infty t - \frac{D_1}{n}t^n\right) = \hat{q}_i \exp\left(-D_\infty t - \hat{D}_i t^n\right) \tag{10}$$

$$b = \frac{n(n-1)\hat{D}_i t^{(n-2)}}{\left(D_\infty + n\hat{D}_i t^{-(1-n)}\right)^2} \tag{11}$$

In which: D_∞—The decreasing constant, defined in the formula (9) (t goes to infinity)

$\hat{q}_i$—Initial flow, as defined in formula (10) (as t approaches 0)

D_1—Decreasing constant, defined in formula (9) (t=1day)

$\hat{D}_i$—The decreasing constant is defined as D_1/n

n—Time index, defined in formula (9).

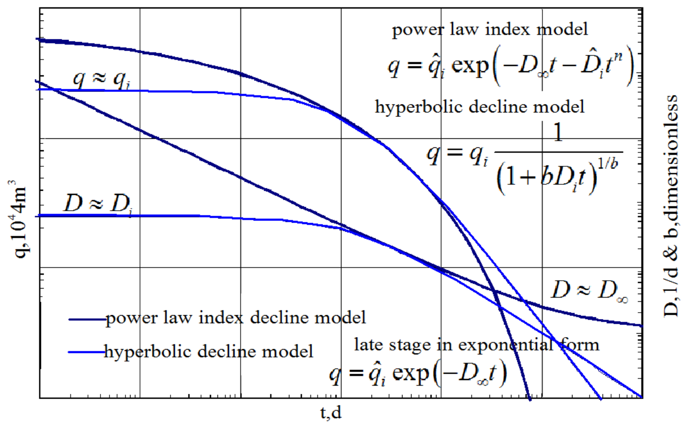

FIG. 1 comparison of characteristics between hyperbolic decline model and exponential decline model

FIG. 1 is a comparison diagram of the characteristics between hyperbolic decline model and power

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exponential decline model. It can be seen from the figure that the power exponential decline model can be well fitted to the entire production history (including unsteady flow, transition flow and quasi-steady flow). In the late period, that is, the boundary control flow period, the curve characteristics are controlled by D_∞ parameters.

4.Power rate exponential decrement application

Daqing block A produced 9 horizontal Wells with an average daily output of 46.8t of liquid, 27.1t of oil and 45.5% of water. Well X is the earliest horizontal well in production, with 23 clusters in the 7th stage of fracturing. In the initial stage, a single well produces 21.2t of oil per day. In the first three months, the production declines rapidly, and after nine months, the production tends to be stable.

5.Conclusions

Based on the analysis of the decline factors of horizontal wells in the block and the study of the law of decline, it is concluded that the output of horizontal wells per well decreases with the increase of the starting pressure because some energy is used to overcome the starting pressure. Horizontal well production is affected by fracturing fractures in the early stage, and the production is relatively high. As production progresses, oil around the fracture is slowly extracted, and the subsequent supply by the matrix is slow, and the production decreases gently. The method of power rate exponential decline can be well applied to the law of horizontal well production decline in block A.

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