CSCanada
Advances in Petroleum Exploration and Development
Vol. 12, No. 1, 2016, pp. 31-34
DOI:10.3968/8659

ISSN 1925-542X [Print]
ISSN 1925-5438 [Online]
www.cscanada.net
www.cscanada.org

The Research and Application of New Horizontal Well for Offshore Oilfield Thin Reservoir Based on Pseudo Steady State Time

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Received 22 July 2016; accepted 9 September 2016
Published online 28 September 2016

Abstract
Fluids rate forecast of horizontal well are particularly important as horizontal well technology is widely used in bohai oilfield. According to the sector planning, horizontal well productivity is two to five times as much as directional well, combined with drawdown pressure, reservoir thickness and permeability to determine the horizontal well productivity. But this method lack of theoretical basis and need reservoir personnel has rich experience at the same time the compute number is the fixed value that can't reflect time dependent process of horizontal well productivity. In this paper a new mathematical model is constructed and introduced investigation radius. Based on these a new equation is derived. This theory can provide valuable for horizontal well productivity during a period of time, at the same time it can judgment whether the reservoir existing skin through production performance.

Key words: Horizontal well; Pseudo steady state time; Investigation radius; The law of equivalent percolation resistance

Zhang, Z. H., Liu, X., Zhang, J. M., Wu, C. X., & Jiang, C. (2016). The research and application of new horizontal well for offshore oilfield thin reservoir based on pseudo steady state time. *Advances in Petroleum Exploration and Development*, *12*(1), 31-34. Available from: URL: http://www.cscanada.net/index.php/aped/article/view/8659
DOI: http://dx.doi.org/10.3968/8659

INTRODUCTION

Analysis method and numerical simulation are two important approaches to research the deliverability of the horizontal well. Among them the most commonly used is analysis method[1-3]. Based on this point, domestic and foreign scholars propose made extensive research, a series production formulas were proposed. There are two methods on production formula, one is based on the mathematical model[4-5], through the appropriate assumption to simply the initial equation, the boundary condition, through this method obtain formula and it's analytical solution. The other is using conformal mapping[6-7], image mapping, the principle of potential superposition and the equivalent flow resistance method to obtain corresponding analytical solution.

With the development of the ocean engineering, horizontal wells that account for more than 30% of oilfield was applied cosmically in Bohai oilfield[8]. For the most oilfield in the south area of Bohai, because of reservoir thin is thickness, it's difficult to form ellipsoid percolation. Traditional productivity formula of horizontal wells exist too much error. Meanwhile horizontal well's oil drain that derivation from tradition productivity formula is regular-form, it can't reflect flow process of horizontal well. To solve these problems horizontal well productivity formula is improved and obtain a favourable effect on Bohai south area.

1. DEVIATION OF HORIZONTAL WELLS PRODUCTIVITY FORMULAS FOR THIN RESERVOIR

In the floating process, horizontal well's Percolation Characteristics is similar as ellipsoid. Because of this three-dimensional seepage field transformed into two-dimensional (Figure 1), it greatly simplified the solution process of equations by this way. However some reservoir is not thick enough it difficult to form ellipsoid percolation characteristics. For this condition ellipsoid can be reduced to a cuboid and two semi-circular. Besides Investigation radius is assigned into horizontal wells productivity formula.

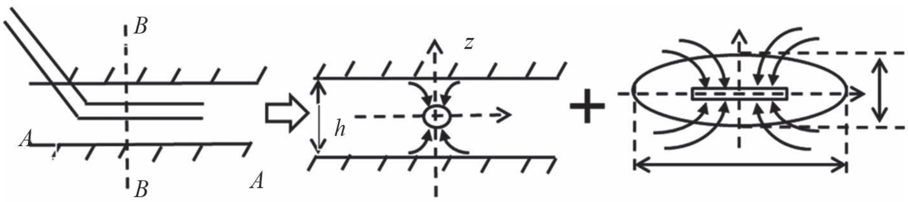

Figure 1
Horizontal Well Percolation Schematic Diagram

1.1 Horizontal Plane Percolation

As Figure 2 shows that well drainage area is equivalent to the cuboid and two semi-circular. The process of percolation was simplified by using this equivalent method.

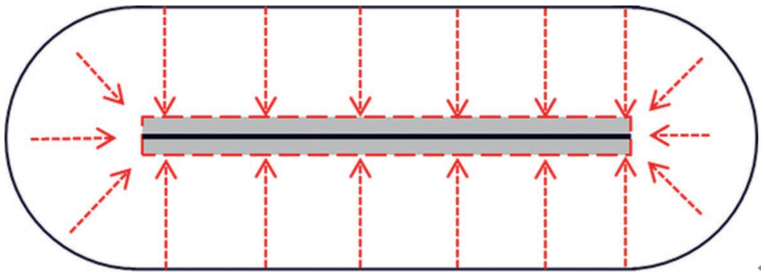

Figure 2
Equivalent Drainage Area

1.1.1 The Liner Flow

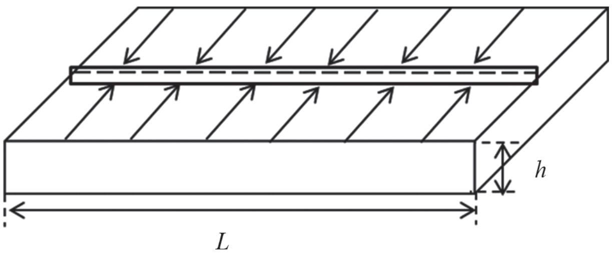

Figure 3
Schematic Diagram of Linear Seepage

According to the Darcy law (Figure 3). The formula for productivity of liner flow is

$$q_{hl} = \frac{2KhL\Delta p_1}{\mu B\left(\frac{a}{2} - \frac{h}{2}\right)} = \frac{4KhL\Delta p_1}{\mu B(a-h)}. \quad (1)$$

Percolation resistance of liner flow is

$$R_{hl} = \frac{\mu B(a-h)}{4KhL}. \quad (2)$$

1.1.2 The Radial Flow

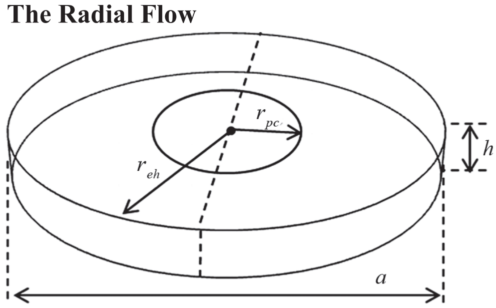

Figure 4
Schematic Diagram of Radial Flow

According to the equivalent processing of Figure 4. The productivity formula for the stage of plane radial flow is

$$q_{hr} = \frac{2\pi KhL\Delta p_1}{\mu B \ln\left(r_{eh}/r_{pc}\right)}. \quad (3)$$

Percolation resistance of radial flow is

$$R_{hr} = \frac{\mu B}{2\pi Kh}\ln\left(r_{eh}/r_{pc}\right). \quad (4)$$

The total flow of plane radial flow is superposition of liner and radial flow $q_h = q_{hl} + q_{hr}$. Equivalent percolation resistance is $R_h = \triangle q / q_h$. So the total resistance of horizontal plane is

$$R_h = \frac{R_{hl} R_{hr}}{R_{hl} + R_{hr}}. \quad (5)$$

1.2 Radial Flow for Vertical Direction

Horizontal well entered vertical and horizontal flow when the plane radial flow is end .The fluid from near borehole zones to well bore and form the vertical and horizontal flow.

According to this (Figure 5) it can derive the formula of vertical and horizontal flow.

$$q_c = \frac{2\pi KL\Delta p_2}{\mu B \ln\left(h/2r_w\right)}. \quad (6)$$

Percolation resistance of vertical and horizontal flow is

$$R_c = \frac{\mu B}{2\pi KL}\ln\left(h/2r_w\right). \quad (7)$$

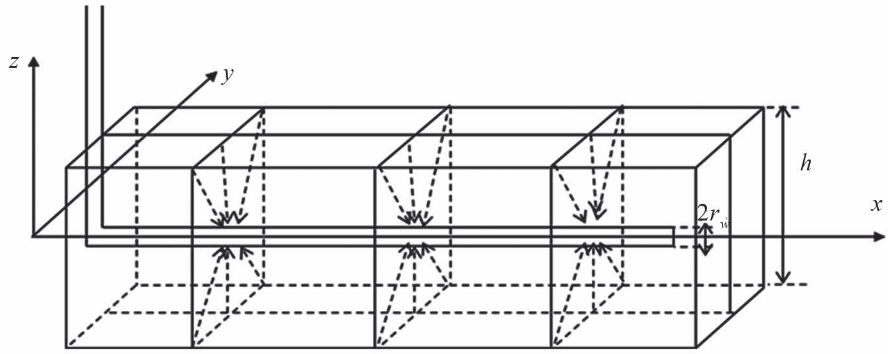

Figure 5
Schematic Diagram of Radial Flow for Vertical

The flow of two stage are equal because there is continuity between vertical and horizontal flow and plane flow. The total of percolation resistance can be derived according to the equivalent flowing resistance method:

$$R_t = R_s + R_c = \frac{R_{sx}R_{sj}}{R_{sx}+R_{sj}} + R_c . \quad (8)$$

The relationship among the productivity drop of producing pressure and percolation resistance is

$$Q = \frac{\Delta p}{R_t} . \quad (9)$$

Let Equation (8) substitute (9),

$$Q = \frac{2\pi Kh\Delta p}{\mu_o B_o\left[\frac{\ln(a/h)\cdot a/4L}{\ln(a/h)/2\pi + a/4L} + \frac{h}{L}\ln\left(h/2r_w\right)\right]} . \quad (10)$$

1.3 Influence of Investigation Radius

Not only the flowing bottom hole pressure is gradually decreased when the well is starting production. But also the formation pressure dropping near bottom hole. In other words horizontal well's pressure wave is changed with the variation of time. It's not reach the boundary in a minute. So investigation radius is assigned to characterize the control boundary of horizontal well.

According to the Muskat and Van Poolen. Investigation radius is

$$r_{eh} = 0.12\sqrt{\frac{Kt}{\phi\mu C_t}} . \quad (11)$$

Through Figure 4 it can obtained a=2r_{eh}, put it into (11):

$$a = 0.24\sqrt{\frac{Kt}{\phi\mu C_t}} . \quad (12)$$

Let Equation (12) substitution into (10):

$$Q = \frac{2\pi Kh\Delta p}{\mu_o B_o\left[\frac{\ln\left(0.24\sqrt{\frac{Kt}{\phi\mu C_t}}\Big/h\right)\cdot\sqrt{\frac{Kt}{\phi\mu C_t}}\Big/L}{\ln\left(0.24\sqrt{\frac{Kt}{\phi\mu C_t}}\Big/h\right)/2\pi + \sqrt{\frac{Kt}{\phi\mu C_t}}\Big/L} + \frac{h}{L}\ln\left(h/2r_w\right) + S\right]} . \quad (13)$$

2. EXAMPLE APPLICATIONS

A01H is a horizontal development well of X oil Field in Bohai, and its foundation parameter as shown in Table 1.

The relationship between A01H specific productivity index and time which calculated by new formula is shown in Figure 6.

Table 1
Reservoir Physical Parameter of X oilfield in Bohai

Permeability (mD)	Thickness (m)	Porosity (%)	Oil viscosity (mPa·s)	Coefficient of compressibility	Wellbore radius (m)	Volume factor	Horizontal well length (m)
2,682	10	0.33	15.5	0.000822	0.11	1.1	270

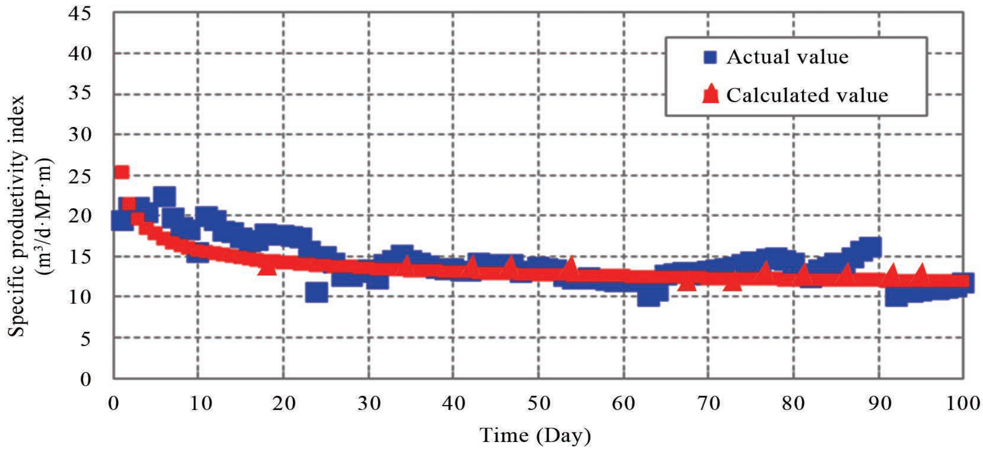

Figure 6
The Specific Productivity Index Contrast of X Oilfield in Bohai

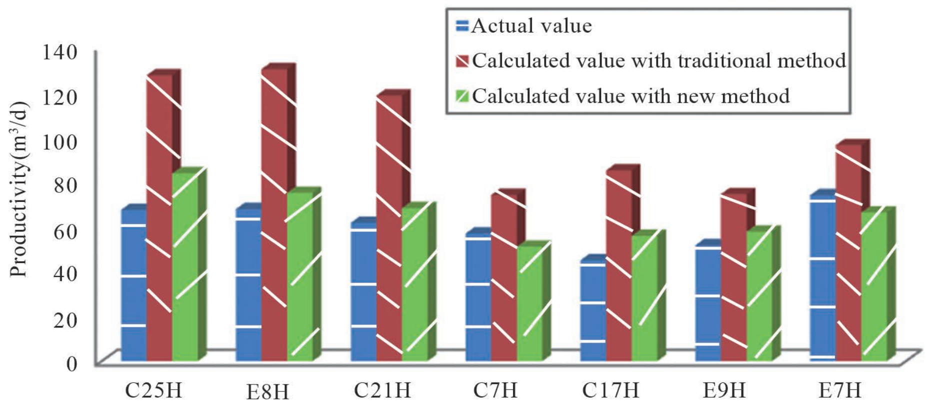

Figure 7
The Well Productivity Contrast of X Oilfield in Bohai

Figure 7 is well productivity contrast of X oilfield in Bohai, it can be shown that, compared with the traditional method, the horizontal well production accuracy which using pseudo-steady-state production is significantly improved, and the formulas has a good application effect in the field.

CONCLUSION

Based on horizontal well actual seepage pattern of Bohai oilfield, the vertical plane radial flow remains the same, and horizontal flow process is changed. After simplifying and decomposing the thin drainage body, the flow field equivalent characterization is made, the detection radius is introduced to characterize the drainage radius horizontal well, and the new formula is established. The application result show that, the formula has certain promotion and application value for horizontal wells production forecasting in offshore oilfield thin reservoir.

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