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The Analysis of Dynamic Data of Multi-Fractured Horizontal Well Preliminary Application Research

ZHANG Xinke[a]; SUN Jingli[a]; WANG Wenquan[b],*; LI Jianjun[b]; WANG Liushen[c]

[a] Oil Recovery Engineering Research Institute, Zhongyuan Oilfield Company, Puyang, China.
[b] China Petroleum West-east Gas Pipeline Company, Zhengjiang, China.
[c] ESSCA Group, Beijing, China.
*Corresponding author.

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Abstract

Multi-fractured horizontal well's model is complicated, which have to consider lots of parameters and bring other difficulties for the analysis of dynamic data. This paper intends to identify the difference from a theoretical perspective first and consider the nonlinearity of numerical horizontal method can explain or evaluate for these wells. Then this paper based on an actual multi-fractured horizontal well of gas and utilize the new model to analysis of dynamic data of multi-fractured horizontal well with different analysis method, through contrast with each result concluded that the nonlinearity of numerical horizontal model is the most appropriate for the analysis of dynamic data of multi-fractured horizontal well. The nonlinearity of numerical horizontal method has considered interferences between fractures and nonlinearity PVT and other factors, which are advanced than other methods and this method is the most appropriate for the analysis of dynamic data of multi-fractured horizontal well up to now.

Key words: Multi-fractured; Horizontal well; Analysis of dynamic data

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INTRODUCTION

The horizontal well technology has developed rapidly since 1980s, with the production proceed, more paragraphs fracturing technology is applied to the horizontal well formed the multi-fractured horizontal well technology. As more and more of low permeability reservoirs have development, multi-fractured horizontal well technology have become more mature, however, intra-industry for this kind of production well data analysis mainly take the semi-log linear analysis method at present, this paper combined the semi-log linear analysis method, thematerial balance analysis method, analytical multi-fractured horizontal well method(MFHW), nonlinear numerical multi-fractured horizontal well method with each other to contrast analysis, and preference is given that the nonlinearity of numerical horizontal method is the most appropriate for the analysis of dynamic data of multi-fractured horizontal well up to now, and base on the living example to analysis its rationality, which for multi-fractured horizontal well's productivity prediction provide certain basis[2-4].

1. PHYSICAL MODEL

A horizontal well in different boundary reservoir, there are multiple vertical fractures along the direction of wellbore, and fractures completely throughout the reservoir. The flow of the horizontal wellbore and fractures are infinite diversion; The pressure drop in the fractures that produces only in fractures and at the crossroads of the well, don't consider skin factor; The horizontal well only in the fracture in perforation; The horizontal well produce with a constant production, but each fracture's production is not the same (Figure 1).

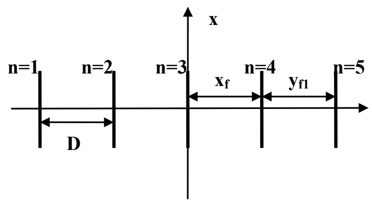

Figure 1
Multi-Fractured Horizontal Well's Physical Model

2. MATHEMATICAL MODEL

According to the direction of y produces multi-fractured line source, utilize Newman product, could obtain multi-fractured horizontal well system's pressure drop:

$$\Delta \mathrm{P}(x,y,\mathrm{t}) = \frac{1}{\varphi \mathrm{c}} \int_0^{\mathrm{t}} \mathrm{q}(\tau) S(x,y,\mathrm{t}-\tau)\, d\tau \tag{1}$$

On the dimensionless type, the pressure drop of fracture i is the summation of each fracture j:

$$p_{Di} = \sum_{j=1}^{n} q_{Dj}\, p_{Dij}\left(x_D, y_D, y_{\omega Dj}\right) \tag{2}$$

And the pressure drop of fracture j to fracture i can put it this:

$$p_{Dij} = \frac{\sqrt{\pi}}{4} \int_0^{t_D} S_{xD}(x_D, \tau) S_{yD}\left(y_{Di}, y_{\omega Dj}, \tau\right) d\tau \tag{3}$$

On the dimensionless type, x,y direction of the source function can put it this:

$$S_{yD} = \sqrt{\frac{\alpha}{t_D}} \exp\left[\frac{\left(y_D, y_{\omega D}\right)^2}{4t_D}\right] \tag{4}$$

$$S_{xD} = erf\left(\frac{1+x_D}{2\sqrt{t_D}}\right) + erf\left(\frac{1-x_D}{2\sqrt{\alpha t_D}}\right) \tag{5}$$

$$t_D = \sqrt{\eta_x \eta_y}\, \frac{t}{x_f^2} \tag{6}$$

$$\alpha = \sqrt{\frac{\eta_x}{\eta_y}} \tag{7}$$

$$q_{Dj} = \frac{q_j}{q} \tag{8}$$

$$\eta = \frac{k}{\phi \mu c} \tag{9}$$

As each fracture connect with wellbore, the flow of the horizontal wellbore is infinite diversion, so the pressure drop of each fracture are same, and equal to the pressure drop of the horizontal wellbore. Add horizontal well's production is constantly, the following equations can be built:

$$\begin{bmatrix} p_{D11} & p_{D12} & p_{D13} & 1 \\ p_{D21} & p_{D22} & p_{D23} & 1 \\ p_{D31} & p_{D32} & p_{D33} & 1 \\ 1 & 1 & 1 & 0 \end{bmatrix} \begin{bmatrix} q_{D1} \\ q_{D2} \\ q_{D3} \\ p_D \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} \tag{10}$$

3. THEORETICAL RESEARCH

Intra-industry for this kind of production well data analysis mainly take the semi-log linear analysis method at present, this method based on the assumption that the fractured horizontal well intersecting n vertical fracture of 1/2 length x_f behave like a unique, large vertical fracture of half length $n \cdot x_f$. This method utilized the single fracture equivalent model which all fractures are represented by a single one. Interaction between fractures is not taken into account. Deviation is usually very large in the long-term productivity prediction. However, the method of material balance can not apply to the multi-fractured horizontal well, because the classical p/Z plot and other related material balance methods are based on the assumption that a pseudo-steady state flow regime is established, which is quite clearly not the case here: there is no indication of late time unit slope on the log-log and Blasingame diagnostic plots.

The analytical multi-fractured horizontal well method (MFHW) is based on the model for multi-fractured horizontal wells. And this model is based on two semi-analytical solutions that can simulate the transient flow behavior of multi-fractured horizontal wells. The current solutions were developed under the following assumptions: the well drain is strictly horizontal, the vertical or slanted section is not perforated; the horizontal drain crosses the vertical fractures perpendicularly; the distance between the fractures can be variable; the reservoir can either be homogeneous or heterogeneous (double-porosity); the fracture model can either be infinite conductivity, uniform flux or finite conductivity; each fracture can be individually described by its height, its length, skin and conductivity; the gas flows into the fractures only, the well drain only or both simultaneously. Fractures will be able to intersect the horizontal drain at any angle and it will be possible to combine the model with variable skin and external boundaries, among other things. This model has the advantage over the equivalent single fracture model to account for the real geometry of the system. The main difference is that it takes into account the interferences between the different fractures. The nonlinearity of numerical horizontal method is based on the method before, whose date is obtained from the analytical multi-fractured horizontal well method by non-linear regression. And it also takes into account the interferences between the different fractures (Table 1). As multi-fractured horizontal well can not apply conventional production data interpretation method, utilize Numerical well test technology can forecast Reservoirs boundary accurately, thus we can obtain the date that fit reservoir more actually, and contrast with each results from Numerical well test and analysis well test, mutual authentication[1].

Table 1
Different Analysis Method Contrast

	Semi-log linear analysis	Material balance analysis	Analytical MFHW	Numerical NL
Interference between fractures	no	no	yes	yes
Nonlinear PVT	no	no	no	yes

4. AN APPLICATION EXAMPLE

Some oil field a gas well is a multi-fractured horizontal well, The well is the oilfield that apply the horizontal well technology to improve deep low permeability of condensate gas reservoir development effect of the pilot test wells. Belong to oil and gas reservoir structure is multiple channel sand body for the sublacustrine fan, with low permeability and low porosity for features, reservoir space is primarily secondary pore, complicated pore structure, small radius is Larynx way, high capillary pressure, sandstone and mudstone thin interbed of vertical hydrocarbons, great interlayer discrepance, sand body phase change fast of horizontal performance, Thickness change is big, great interlayer discrepance, Connected degree is bad. This well actually horizontal directional drilled 476 m, and by six sections fracturing.

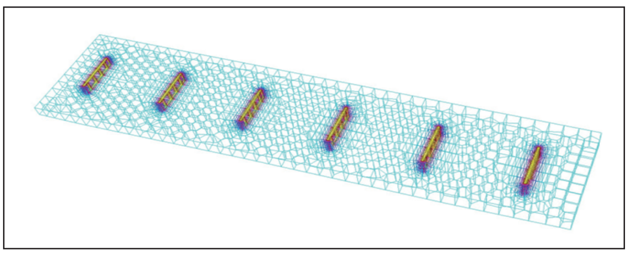

Figure 2
The 6 Section Fracture in Use of Numerical Analysis of the Well

We achieved the fractured well's production data of beginning six months, then use the nonlinearity of numerical horizontal method to analysis these dates, and achieved sensationally production history fitting curve and log-log graph, blasingame curve(Figure 2, Figure 3). Thus we can get that this well's permeability is very low, and only nearby the fracture have pressure drop, in other words, the extraction gas only around the fracture as half a year's production, reserves producing small. So it should to play longer horizontal well, and more fractures are need, and this is fitted with the practical production data of this well. We predicted the next two months' production, which is well fitted with the practical production data we got later.

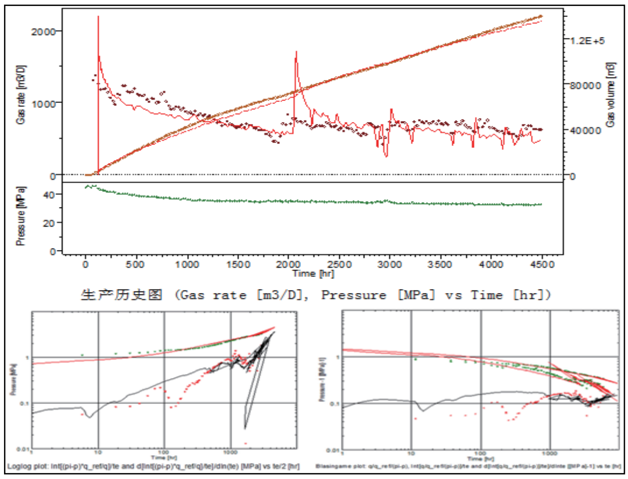

Figure 3
The Well's Production History Fitting Curve, Log-Log Graph, Blasingame Curve

5. COGNITION AND CONCLUSION

(1) Multi-fractured horizontal well's model is complicated and lots of parameters, this bring a lot of difficulties in production data analysis. Except horizontal section length, gas thickness, permeability anisotropic, xf that affect horizontal well's productivity, we have to consider the case of fracture, like different fracture's quality, can lead to different flow period in multi-fractured horizontal well, fracture's number influence the big or small of pressure cone of depression, fracture's space between each other can influence the time of pseudoradial flow appear. With multi-fractured technology's development, we have to consider more complicated factors, like phase change, complex fracture nets, adsorption-desorption and so on. As the lots of factors can influence multi-fractured horizontal well's test curve form, there is a big difficult in production data analysis.

(2) Through analysis and contrast in theory, we know that as there is no productivity, conventional vertical well can not apply to develop low permeable reservoirs, especially tight gas reservoir, so multi-fractured well is necessary. However, as these wells could not reach pseudosteady-state flow, so decline analysis is inappropriate, and as pressure gradient is high, PVT parameter variation have to consider, only use adsorption-desorption method is also inappropriate. The nonlinearity of numerical horizontal method with new models have

considered these factors, so this method is the most appropriate for the analysis of dynamic data of multi-fractured horizontal well up to now.

(3) Some oil field a multi-fractured horizontal well of gas utilized this method to analysis dynamic data and productivity prediction, results of our analysis and actual data obtained are basically same, successfully explained the well, and proved this method is appropriate for multi-fractured horizontal well's interpretation in turn.

In allusion to the technology for multi-fractured horizontal well's production data analysis, semi-log linear analysis method is not taking interaction between fractures into account, so the productivity prediction will inevitably deviate from reality, but it can however be used as a method for finding an initial range of parameters of the analytical MFHW model. In turn, the fractured horizontal well analytical model can correctly capture the interferences between fractures, but its simplified PVT assumptions make it miss the actual problem of nonlinearity induced by the gas properties, hence its pessimistic production forecast. The nonlinear numerical fractured horizontal well model is not affected by those limitations. It has considered interferences between fractures and nonlinearity PVT and other factors, and got a good validation that applied on site. Although this method is complicate and more time-consuming, it is the most appropriate and newest technology for the analysis of dynamic data of multi-fractured horizontal well up to now.

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