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To Interpret Rate Transient Analysis for the Determination of Reservoir Properties

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Abstract: ***Rate-time decline curve analysis is a major technique which is mostly used in petroleum engineering. Many methods are used for the determination of the decrease in the production rate within a given period of time. The main disadvantage of Arp's decline type curve analysis is that it is only used for boundary dominated flow period; it is not used for transient flow period. The analysis of the Fetkovich is to determine the log-log type curve for both the transient flow period (early time period or infinite) and boundary-dominated flow period (late time period). Arps developed the type curve which shows the production rate decline with time for the finite reservoir or late time period. The exponential or constant flow decline, hyperbolic decline, and harmonic decline according to the value of decline curve exponent (b) is given by Arps. After that Fetkovich improved on earlier work done by Arps in predicting decline production rate of wells over a given period of time. The main objective of this study was to plotting the rate transient analysis curve. I will plot the Fetkovich type curve (combined early and late times region). The graph will be plotted between the dimensionless decline flow rate (q_{Dd}) and the dimensionless decline time" (t_{Dd}). This will be the objective of the study.***

Keywords: Decline curve analysis, Dimensionless Decline flow rate, Dimensionless decline.

I. INTRODUCTION

Decline curve analysis (DCA) is used to evaluate the decline production rate with respect to time and also estimating the future performance of wells (*J. Pet. Tech.* Jan.1972). Over the course oil and gas production rates decline with time and changing relative volumes of produced fluids in a given period of time. The objective of the decline curve analysis concept is to determine a decrease in the production rate by plotting a log-log type curve between the dimensionless flow rate (and time)(Arps, J. J.; 1945).

Another function of Decline curve analysis is to determine oil and gas reserves and their properties. According to the value of decline curve exponent (b) there are three basic types of models available which are known as exponential (b=0), harmonic (b=1) and hyperbolic decline (0<b<1) (Arps, J. J.; 1945). There are several type of decline curve methodologies available which predicts the changes in a well condition throughout its working span. One of the oldest method is Arps decline method, which shows that the value of b-varies between 0 and 1. Value of b is not possible greater than 1 (b>1). Arps decline curve method is used for only the late time period. The major drawbacks of Arps method is that it is only applied for boundary dominated flow (BDF). Due to this, the early production data i.e. transient flow during the infinite acting period cannot be determined by Arps method.

To overcome this limitation Fetkovich developed a new form of type curve which is extended the Arps' type curves into the early-time i.e. infinite flow. In Fetkovich model the advanced production data analysis has been consider with respect to rate transient analysis (RTA). The rate transient analysis is an extension of well testing (Fetkovich, 1980a). The main objective of rate transient analysis is that without shut-in a well evaluation of reservoir have been performed by using pressure and transient rate. Further the rate transient analysis is used to determine information about reservoir characteristics, effectiveness of well completion and initial oil and gas in place.In this methodology the Fetkovich decline type curve analysis is used for matching production data by the help of correlating of various types of curve which were obtained over the course of time with ambient flow rate condition. Fetkovich type curves are generated from the combined the solutions of transient region (infinite flow) or early period radial systems at the constant bottom hole flowing pressure (p= constant) and the boundary-dominated flow period or late time period which is initially developed by Arps. The left-hand side region of the Fetkovich type curve is called the early-time region and the right-hand side region is called the late-time region (Fetkovich, 1980). The early-time period is determined from transient flow equations which will come from the well-test analysis concept and the late-time portion (boundary dominated flow) is determined by the Arps decline type curve. Fetkovich type curve is the plot between the dimensionless decline rate (q_{Dd}) and the dimensionless decline time (t_{Dd}).The exponential decline curve is common for both early and late time region.

In this study the Fetkovich type curve analysis is used to estimate the performance of the wellbore, when a well is producing at a constant bottom hole flowing pressure (BHFP). From this analysis we can able to determine the permeability of reservoir and wellbore skin factor which is helping to predict the reservoir characteristics and useful to determine the future performance of the reservoir.

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II. METHODOLOGY

There are different types of the decline curve is use for determine the decrease in the production rate with respect to the time. In this Fetkovich is one of the most important methods to calculate the permeability of reservoir and wellbore skin. Fetkovich combined the early-time region i.e. transient flow and the late-time region i.e. boundary dominated flow of Arps decline curve. The Fetkovich early-time curve shows that the infinite-acting reservoir which is a solution of the transient flow equations and late-time data can be determined by the Arps decline type curve. Arps decline curve equations are determined by using boundary dominated flow equations.The Figure (1) shows on a single dimensionless curve for the exponential, harmonic and hyperbolic decline solutions (Fetkovich, M.J.; 1980a). For the early and late-time region, the exponential or constant percentage decline is common.

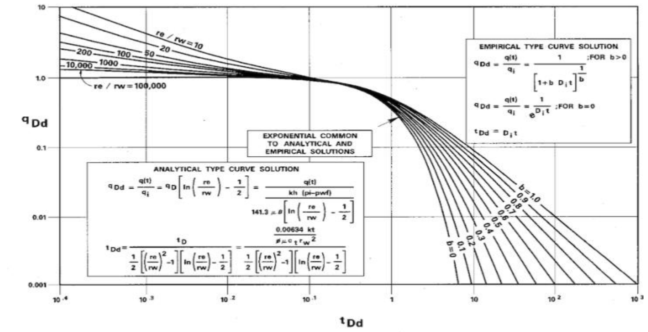

Figure 1: Fetkovich Type curves – Combined Early and Late-Time region(Fetkovich, 1980a)

Fetkovich Early Time Curves: Fetkovich type curve use for an infinite and finite reservoir, the single phase radial flow and slightly compressible fluid. The Fetkovich early-time curve shows that the infinite-acting reservoir which is a solution of the transient flow equations. Hence the transient flow is not depending on the reservoir size. The results of early time region were represented in terms of a dimensionless decline flow rate and a dimensionless decline time in graphical form on the log-log plot.

The dimensionless time in term of declined curve of reservoir variables:

$$t_{Dd} = \frac{t_D}{\frac{1}{2}\left[\left(\frac{r_e}{r_w}\right)^2 - 1\right]\left[ln\left(\frac{r_e}{r_w}\right) - \frac{1}{2}\right]}$$

The decline curve dimensionless rate q_{Dd} in term of q_D:

$$q_{Dd} = \frac{q_t}{q_i} = q_D\left[ln\left(\frac{r_e}{r_w}\right) - \frac{1}{2}\right]$$

At the early time i.e. transient flow all reservoirs would follow the same curve and it will deviate when the reservoir is reached at the boundary (Fetkovich, M.J.: *J. Pet. Tech.* July 1971). If the reservoir size is increased, the transient flow ends and it has deviated. After the transient flow, the boundary-dominated flow will occur.

Fetkovich Late-Time Curves: Late-time data can be determined by the Arps decline type curve. Arps decline curve equations are determined by using boundary dominated flow equations when the decline curve dimensionless time is greater than 0.3 (Fetkovich, M.J.; 1980a). These two dimensionless equations are used in the Arps decline curve are:

The dimensionless flow rate q_D can be expressed as:

$$q_D = \frac{141.3\, q_{(t)}\, \mu\, B}{kh\,(p_i - p_{wf})}$$

The dimensionless time t_D can be expressed as:

$$t_D = \frac{0.00634kt}{\emptyset \mu c {r_w}^2}$$

Where,

q_D = dimensionless flow rate

t_D = dimensionless time

q_{Dd} = dimensionless decline rate

t_{Dd} = D_i*t = dimensionless decline time

The solution of Van Everdingen and Hurst during late time region i.e., when reached at a reservoir boundary using by Fetkovich, is to determine "the dimensionless decline flow rate" (Van Everdingen, W. Hurst, 1949). The "decline curve dimensionless flow rate" is expressed in term of the decline curve dimensionless time by an exponential function. Then the equation is:

$$q_{Dd} = e^{-t_{Dd}}$$

The hyperbolic decline equation is:

$$q_t = \frac{q_i}{(1 + b * D_i * t)^{1/b}}$$

The resulting dimensionless equation is:

$$q_{Dd} = \frac{q_t}{q_i} = \frac{1}{(1 + b * t_{Dd})^{1/b}}$$

III. RESULTS AND DISCUSSION

The reservoir permeability and wellbore skin for a particular field is calculated with the help of Fetkovich type decline curve. There the production rate data with time are given for East side Coalinga field which is shown in Table-1(Fetkovich, M.J 1980).

Table 1- Rate time data from East side Coalinga filed:

Time(years)	Production Rate, q (BOPY)	Time(years)	Production Rate, q (BOPY)
0.5	52000	11.5	5600
1.5	42500	12.5	4550
2.5	34500	13.5	3800
3.5	28500	14.5	3200
4.5	23000	15.5	2750
5.5	18600	16.5	2176
6.5	15000	17.5	1780
7.5	12500	18.5	1456
8.5	10500	19.5	1191
9.5	8500	20.5	975
10.5	6900	-	-

The data plot of the actual rate-time are plotted on log-log scale. This plot is called the "data plot".

The plot is shown in Figure (2).

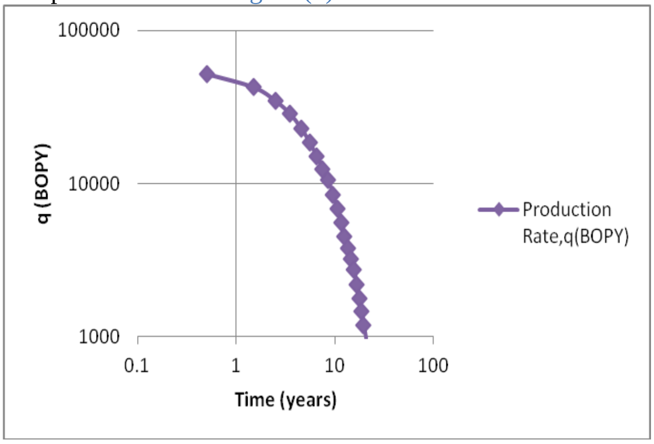

Figure (2) Rate-time data plot

This data plot is moved over the Fetkovich type curve plot which is shows in Figure (1) and good match is determined. From that match point determine the value of "r_e/r_{wa}" and b on Fetkovich decline type curve.

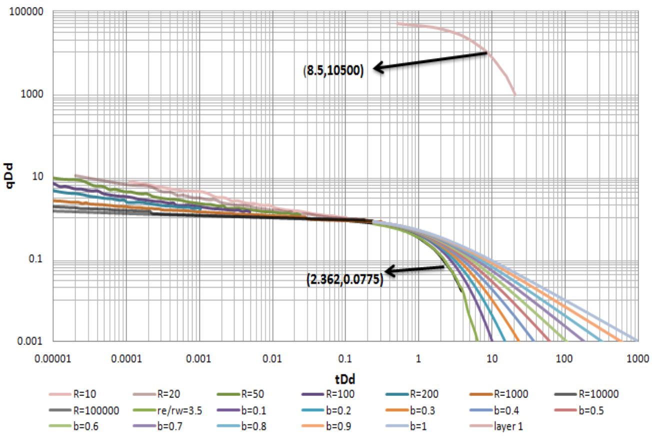

Figure 3: Rate-time data for Coalinga field well move over Fetkovich decline type curve

Given data:

$h = 100$ ft $\qquad \mu_0 = 1$ cp

$B_0 = 1.50$ bbl/stb $\qquad C_t = 20\times10^{-6}$ psi^{-}

$r_w = 10.53$ inch

After obtaining the good match point, the value of (q_t and $t)_{match}$, $(q_{Dd})_{match}$ and $(t_{Dd})_{match}$ is determined. From the data plot on Fetkovich type decline curve, these values are obtained:

$b = 0$ $\qquad t_{Dd} = 2.362$

$$\left(\frac{r_e}{r_{wa}}\right)_{match} = 20 \qquad q_{Dd} = 0.0775$$

$t = 8.5$ years $\qquad q_t = 10500$ BOPY

Initial flow rate and decline curve exponent is calculated by:

$$q_i = \frac{(q_t)_{match}}{(q_{Dd})_{match}} = \frac{10500}{0.0775} = 135483.87 \text{ BOPY}$$

$$D_i = \frac{(t_{Dd})_{match}}{(t)_{match}} = \frac{2.362}{8.5} = 0.278$$

Reservoir permeability and wellbore skin can be determined by:

$$K = \left(\frac{q_t}{q_{Dd}}\right)_{match}\left(\frac{141.2B_o\mu}{h(P_i - P_{wf})}\right)\left[ln\left(\frac{r_e}{r_w}\right)_{match} - \frac{1}{2}\right]$$

$$K = \left(\frac{10500}{0.0775}\right)\left(\frac{141.2 * 1.5 * 1}{100 * (4000 - 1000)}\right)\left[\ln 20 - \frac{1}{2}\right]$$

K= 238.72 md

Effective wellbore radius is:

$$r_{wa} = \sqrt{\left(\frac{t}{t_{Dd}}\right)_{match} * \frac{0.01268K}{\Phi\mu Ct\left[\left(\frac{r_e}{rwa}\right)^2 - 1\right]\left[\ln\left(\frac{r_e}{r_{wa}}\right)_{match} - \frac{1}{2}\right]}}$$

$$r_{wa} = \sqrt{\left(\frac{8.5}{2.632}\right)\frac{0.01268 * 238.72}{0.2 * 1 * 20 * 10^{-6} * [20^2 - 1] * \left[\ln 20 - \frac{1}{2}\right]}}$$

$$r_{wa} = 52.3 \text{ inch}$$

Wellbore skin is:

$$S = \ln\left(\frac{r_w}{r_{wa}}\right)$$

$$S = \ln\left(\frac{10.53}{52.3}\right) = -1.6$$

Wellbore Skin is negative and reservoir permeability is high so it is clear that the well is stimulated.

IV. CONCLUSION

Advantages of Rate Transient Analysis (RTA) are that it is used to measure the reservoir using rate and pressure data without the need to shut in wells. From this study, it is clear that the Fetkovich type decline curve is used to generate the type curve by combine the transient period i.e. infinite reservoir and the late time region (boundary dominated reservoir) which is developed by Arps. It is clear from the above well data, we can find out the reservoir permeability and wellbore on the Fetkovich type curve by data plot match. From the above field data, the reservoir permeability is high (K=238.72 md) and wellbore skin is negative (S= -1.6), so the well is stimulated.

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