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Determination of Reservoir Parameter of Naturally Fractured Reservoir at SF Field using Rate Type Curve Analysis

Sri Feni Maulindani[1*], Pauhesti Rusdi[2], Andry Prima[3], Djunaedi Agus Wibowo[4], Harin Widiyatni[5]
[1-6] Petroleum Engineering Department, Faculty of Earth Technology and Energy, Universitas Trisakti, Indonesia

ABSTRACT: This Naturally Fractured Reservoir (NFR) is become challenging to identify the behavior of performance in fluid flow in producing well at SF oil Field. Generally, this unique of mechanism that cannot be treated as homogenous reservoir, because has two porous media in this reservoir such as matrix and fracture, the dominantly fluid flow comes from the networks of fractures, but for matrix porous media as function of source that transfer fluid to the fractures. This complexity of reservoir needs deepest investigate the characteristic of this reservoir and estimating the reservoir parameter such as permeability fracture, storativity coefficient ratio (omega) and interporosity flow coefficient (lamda) of SF production wells at SF oil Field are the main objective of this study. There are two wells that are analyzed in this study, and the result of this study yields significant interpretation by analyzing the production data in order to approximate the characteristic of dual porosity in naturally fractured oil reservoir by applying the decline rate type curve matching.

KEYWORDS: Decline rate type curve matching, Interporosity flow coefficient, Naturally fracture reservoir, Permeability fracture, Storativity coefficient ratio.

I. INTRODUCTION

Characterization of NFR (Naturally Fractured Reservoir) is widely common using Pressure Transient Analysis for reservoir engineer as a tool for analyzing reservoir properties such as permeability of fractured, storativity ratio coefficient (Omega) and interporosity flow coefficient (lamda) and drainage radius (red). This reservoir generally identity through well test interpretation and also can identify the boundary of the reservoir near the well production. (Warren & Root, 1963), Their study has been applied in many researchers for a decade in order to describing the behavior of dual porosity model in naturally fractured reservoir, which is this reservoir is different with homogenous reservoir but often makes a similar performance of behavior with single porosity. This reservoir has two porous media that are matrix as source of storage of fluid but has small permeability, on the other hand fracture act as network of seepage of fluid to flow to the wellbore and has large of permeability. The ideal of the naturally fracture according to Warren and Root model is shown in fig 1. The Warren and Root model known as pseudosteady-state interporosity flow, because the fluid flow mechanism is under condition pseudosetady-state, where the fluid flow from the matrix porous media modeled as cubes then to the fracture through those space between the matrix porous media and the fracture porous media. There are many studies that has been done for many researchers regarding for identify this characteristic using well test analysis, (Mavor & Ley, 1979), their studies for analysis of transient pressure for determine the behavior of naturally fractured reservoir using analytical solution method, both for transient solution and boundary dominated flow. (Kazemi, 1969), their research developed the dual porosity model under condition transient interporosity flow, where the shape factor is slab in order that the fractures in horizontally form and so with the matrix block. (Heber Cinco et al., 1976), they developed well test analysis by influence the vertically fracture in their model, (de Swaan O, 1976), extend the reservoir model of infinite and finite reservoir by analyzing characteristic of naturally fractured reservoir for variety of geometry. (Maulindani et al., 2023), pressure transient analysis using generated data simulated for dual porosity model to identify the behavior of the naturally fractured oil reservoir.

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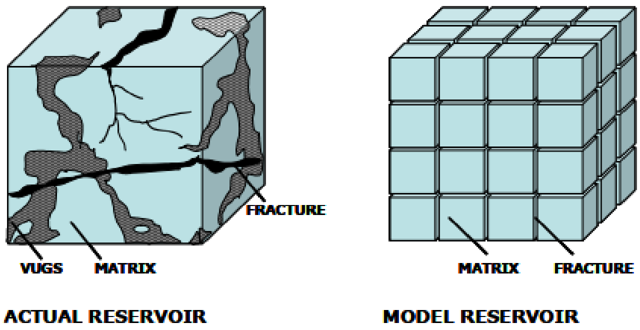

Figure 1. Ideal model for a natural fractured reservoir (Warren & Root, 1963)

Identifying this reservoir can be done using the Pressure transient analysis for dual porosity using Warren and Root Model as shown in figure 2. There are three-time region in Pressure Build Up test schema there are: early time region indicating the transient flow in the fracture media, and the second line represents as the pseudosteady state flow in the total system. The transition region is middle region as an indication end period for early time and beginning period for late time region, which is mostly influence by matrix subsidies the fractures.

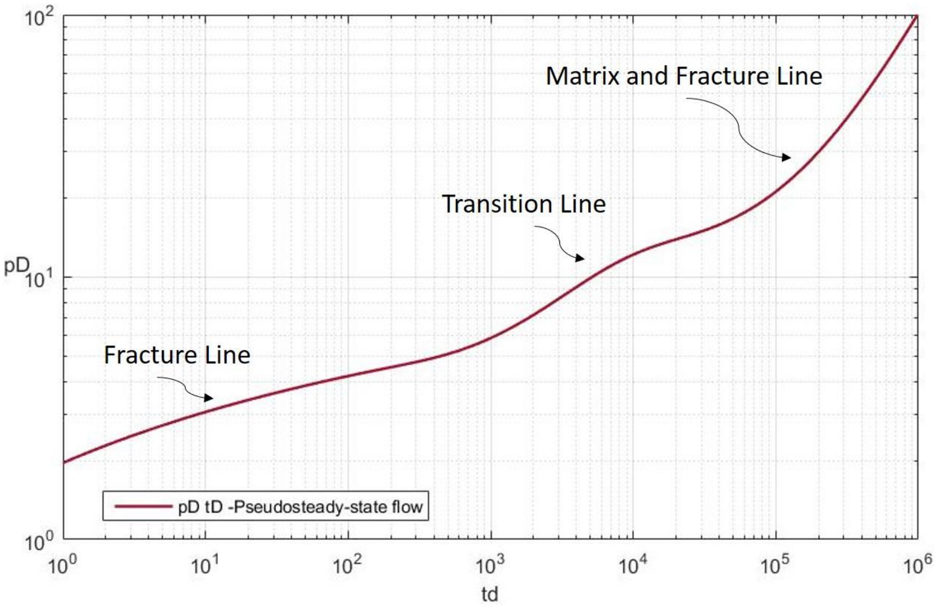

Figure 2. Log-log plot for pressure response in Naturally Fractures Reservoir

Beside pressure transient analysis for defining the characterization of dual porosity model, there are other method for determine this reservoir properties are using the Type Curve matching that many authors also have been applied this method for their research. In previous studies, (Maulindani et al., 2021), studies applied the Pressure type curve matching using numerical algorithm Gaver-Stehfest for estimating the reservoir parameter of double porosity using Warren and Root model for closed boundary and no skin, with the same methods, this study is using type curve (Da Prat et al., 1981), their method developed dimensionless rate and dimensionless time for analysing reservoir dual porosity model using analytical solution for infinite and finite reservoir with variety of omega, lamda dan red. This method is applied using daily production data and bottom hole pressure, then interpreted to the type curve that suitable for the reservoir. Production data analysis has been used for centuries for forecasting the performance of the well

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or field, where the data production and bottom hole pressure are available in daily operation data that are recorded in daily operation field.

There are many methods for analyzing production data, first of all, is pioneer by (Arps, 1945), He was pioneer for production analysis, by developed the method using empirical method. Which is very simple by plotting the data flow rate with time in logarithmic scheme. Then by making straight line between those data, can estimate the forecasting, ultimate recovery for the well as well field. There are three method that applied regarding the reservoir mechanism and characterization such as exponential method, hyperbolic method and harmonic method. (Fetkovich, 1980),(Fetkovich et al., 1987), he works extend the Arps by developed in log log type curve, then combine Arps equation with type curve using the analytical solution for constant pressure for analyzing oil and gas production in transient and pseudosteady-state flow regime, in format dimensionless variable. (Sageev et al., 1985), Their extend the study that has been done by Da-Prat et all, with adding the wellbore storage skin in the analytic solution, yield effecting the rate response, when usually at early time dominantly by well bore storage and skin, its initial rate is upper bounded it the 'film coefficient' phenomenon. Blasingame T. A., and Lee W. J. (1986), they study mainly based on a semi-analytical method for determining the drainage area and reservoir shape, using the variable rate in production data, when the pressure transient has reached the outer boundary.

The main objective of this study is to determine the characterization of this unique reservoir using analysis of daily production data of SF well by applying the decline rate type curve matching that developed by Da-Prat type Curve for pseudosteady state flow interporosity flow mechanism that are built with the variation of the parameter that the most influence the behavior of the naturally fractured reservoir, and then estimating the value of fracture permeability, omega, lambda, boundary reservoir for SF Well at SF Field.

2. METHODS AND DATA

Diffusivity Equation for Double Porosity in Pseudosteady-State flow

The fundamental partial differential equation (Da Prat et al., 1981),for describing the fluid flow naturally fractured reservoir is:

$$\frac{\partial^2 P_{fD}}{\partial r_D^2} + \frac{1}{r_D}\frac{\partial P_{fD}}{\partial r_D} = (1-\omega)\frac{\partial P_{mD}}{\partial t_D} + \omega\frac{\partial P_{fD}}{\partial t_D} \quad (1)$$

The most common reservoir parameter in NFR is the influence of storativity capacitance and interflow coefficient in the reservoir. Where this is the indication of matrix and fractures contributes the fluid of production performance of the well. The equation for those two parameters is presents in Eq.2 and Eq.3.

Omega (storage capacity coefficient) is dimensionless parameter are:

$$\omega = \frac{(\phi C_t)_f}{(\phi C_t)_f + (\phi C_t)_m} \quad (2)$$

Lamda (Interflow Coeficient flow) is dimensionless matrix to fracture permeability ratio are:

$$\lambda = \alpha \frac{k_m r_{w^2}}{k_f h_{m^2}} \quad (3)$$

Boundary of Reservoir r_{eD} are:

$$r_{eD} = {}^{r_e}/_{r_w} \quad (4)$$

Decline Rate Type Curve for Double Porosity Model Pseudo Steady-State Flow

Estimating the reservoir characterization specially for Double Porosity Model is challenging, because this happens difficulties to identify the behavior of this unique reservoir. The Decline rate type curve for double porosity (Da Prat et al., 1981), developed the dimensionless date with dimensionless dime using analytical solution approximation, which the real space solution for the flow rate behavior as a function of time was obtained by evaluating the inverse transformation to the Laplace space solution. This is achieved with the numerical inversion scheme by Gaver-Stehfest algorithm. Figure 3 shows the dimensionless flow rate with dimensionless time. The Rate Type Curve are build using commercial Software MATLAB.

Flow rate dimensionless and time dimensionless are define as:

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$$q_D = \frac{141.2qB\mu}{k_f h(p_i - p_{wf})} \quad (5)$$

$$t_D = \frac{0.0002637k_f t}{(\phi C_t)_{m+f} r_w^2} \quad (6)$$

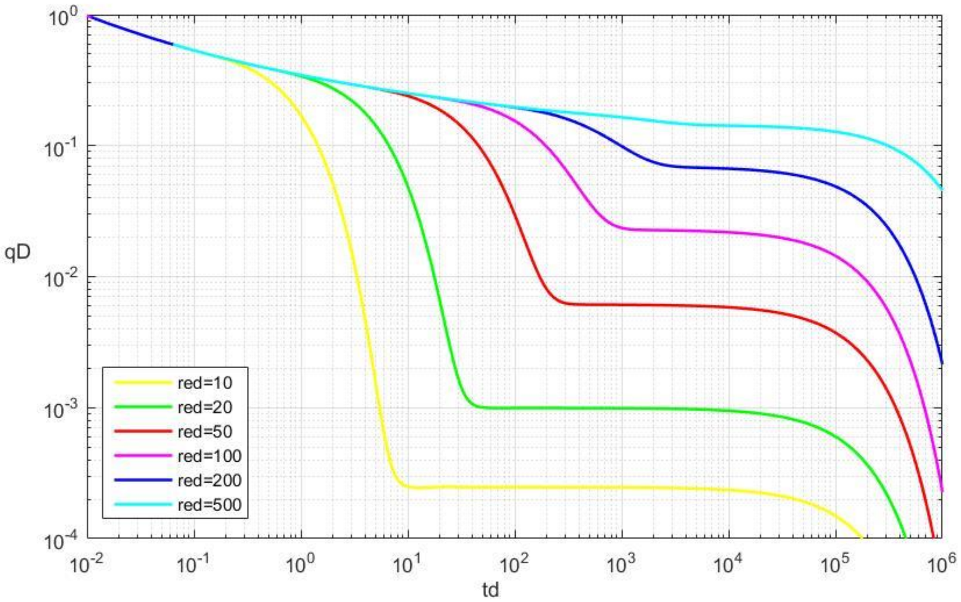

Figure 3. Rate Type Curve for Double Porosity System PseudoSteady- State Interporosity Flow $\omega = 0.01$, $\lambda = 5x10^{-6}$ for various reD[1&7]

Reservoir Parameter of Dual Porosity in Naturally Fractured Reservoir

Estimating the fracture permeability and total storativity using decline rate type curve matching using eq. 7 and eq.8, the match point from the analysis is done by overlay the data production of the well to the type curve that suitable for the reservoir.

Estimate fracture permeability:

$$k_f = \frac{141.2\mu B}{hpi} \frac{[q]_{MP}}{[q_D]_{MP}} \quad (7)$$

Estimate total storativity:

$$[(\phi Vc)_m + (\phi Vc)_f] = \frac{2.637(10^{-4})k_f}{\mu r_w^2} \frac{[t]_{MP}}{[t_D]_{MP}} \quad (8)$$

2.3 Reservoir Data of Well SF

The reservoir of SF Field has 3 layer that perforated and mostly all layers are open produce, the oil production with water cut around 75% and solution of gas 300 SCF/STB. The daily production is 1800 Bopd, reservoir pressure is 1500 Psia, for more details the reservoir data for SF Well is shown in table 1.

Table 1. Reservoir Data of Well SF

2Well Information		
Wellbore radius, r_w	0.25	ft
Drainage radius, r_e	125	ft
Reservoir Properties		
Formation Thickness, h	55-100	ft

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Matrix Permeability k_m	0.0001	md
Fracture Permeability k_f	53-79	md
Reservoir Data		
Reservoir Pressure, P_r	1500 - 1600	psia
Pressure Saturation, P_b	1200	psia
Reservoir Temperature	170	°F
Gravity oil	35	API
Specific gravity gas	0.82	lb/cuft

The pressure Build up test for SF well has been analysis for well SF#1 and SF#2, to give the information of characteristic in the naturally fractured reservoir for both well such as permeability fractures, omega, lamda, drainage area, boundary of the reservoir. For more details the well test analysis for SF Well is present in table 2.

Table 2. Data Pressure Transient Analysis of Well SF

Properties	Unit	SF#1 Well	SF#2 Well
Reservoir pressure, P	psia	1500	1600
Fracture permeability, k_f	mD	79	53
Drainage radius, r_e	ft	125	125
Omega, ω		0.03	0.01
Lambda, λ		$1.54\ x\ 10^{-5}$	$1.79\ x\ 10^{-4}$

Table 3. Data Production history of Well SF#1

t, days	q. Bopd	t, days	q. Bopd
0.00512	10685.6	0.0714	7091.45
0.0058	10451.4	0.0867	6897.7
0.0071	10336.2	0.1060	6709.23
0.0087	10109.6	0.1254	6598.6
0.011	9942.98	0.16268	6525.9
0.0139	9617.8	0.2055	6382.8
0.0167	9252	0.2559	6347.6
0.0201	9049.2	0.3130	6242.9
0.0248	8704.96	0.3893	6174.18
0.0301	8467.11	0.4634	6072.4
0.0368	8235.7	0.5631	5906.4
0.0410	7878.69	0.6717	5777.02
0.0511	7663.42	0.7618	5619.18
0.0594	7412.85		

The data daily production for wells SF are present in table 3 and 4. The Production history data has been selected to be smooth to create data that can be interpreted in significantly better to analyze.

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Table 4. Data Production History of Well SF#2

t, days	q. Bopd	t, days	q. Bopd
0.00024	12288.1	0.0047	11576.4
0.00028	12046	0.00585	11348.4
0.00034	11966.5	0.00744	11423.9
0.00042	11966.5	0.00982	11124.9
0.00053	11808.9	0.01267	11273.4
0.00065	11808.9	0.015526	11051.4
0.00086	11730.9	0.0206	10978.4
0.00109	11653.4	0.0272	10833.8
0.00138	11653.4	0.0272	10620.5
0.0018	11576.4	0.0399	10480.6
0.00229	11730.9	0.0493	10206
0.0028	11576.4	0.0603	10071.9
0.0035	11423.9	0.0865	9551.6

4. RESULTS AND DISCUSSION

Analysis of Decline Rate Type Curve Matching for Well SF#1

After collecting data Reservoir, data history production of well SF#1 in order to estimating the reservoir parameter, by applied the Decline Rate Type Curve for well SF for Pseudosteady-state flow for variety of boundary of reservoir. Based on the well test result, the type curve for this well are analyzed with reservoir parameter omega 0.03, Lamda $1.54x10^{-5}$ with variety of reD, by plotting the production data of SF well over lay with the Type Curve Matching. From the match point can estimate fracture permeability and total storativity, as shown in figure 4 and 5. Calculate the fracture Permeability using the eq.7 and Total Storativity using eq.8 for Well SF#1 are:

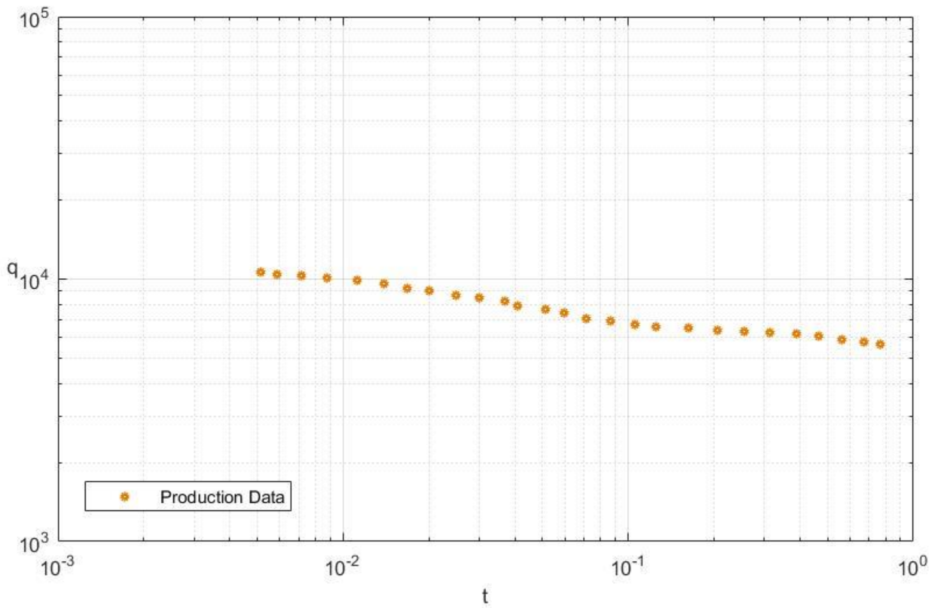

Figure 4. Production data in log log curve for Well SF#1

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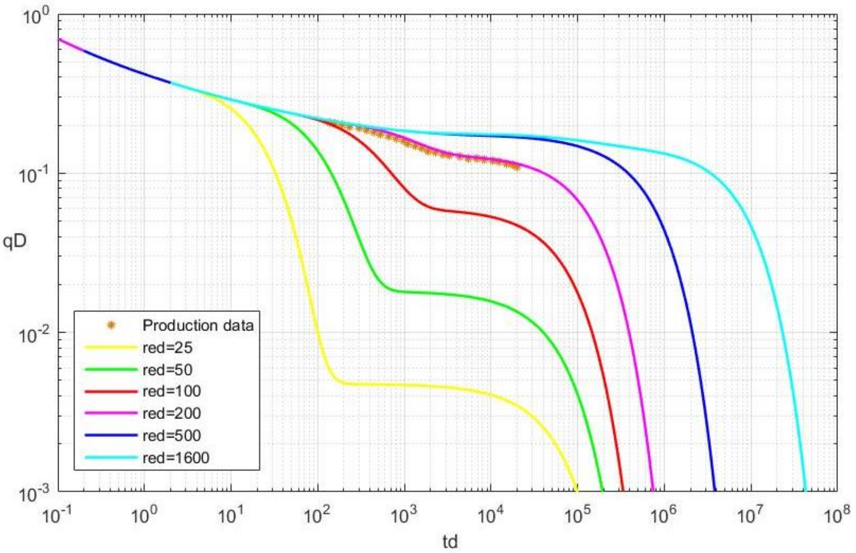

Figure 5. Decline Rate Type Curve Matching for Well SF#1

Estimate fracture permeability

$$k_f = \frac{141.2\mu B}{h(pi - pwf)}\frac{[q]_{MP}}{[q_D]_{MP}} = \frac{141.2 * 0.8 * 1.125}{55 * 1500}\frac{34.19}{1} = 79\ md$$

Estimate Total Storativity

$$\left[(\phi Vc)_m + (\phi Vc)_f\right] = \frac{2.637(10^{-4})k_f}{\mu r_w^2}\frac{[t]_{MP}}{[t_D]_{MP}} = \frac{2.637(10^{-4})*79}{0.8*0.25^2}\frac{3.01x10^{-5}}{1} = 1.175\text{x}10^{-6}\ 1/\text{psi}$$

Analysis of Decline Rate Type Curve Matching for Well SF#2

After collecting data Reservoir, data history production of well SF#2 in order to estimating the reservoir parameter, by applied the Decline Rate Type Curve for well SF for Pseudosteady-state flow for variety of boundary of reservoir. Based on the well test result, the type curve for this well are analyzed with reservoir parameter omega 0.01, Lamda $1.79x10^{-5}$ with variety of reD, by plotting the production data of SF well over lay with the Type Curve Matching.

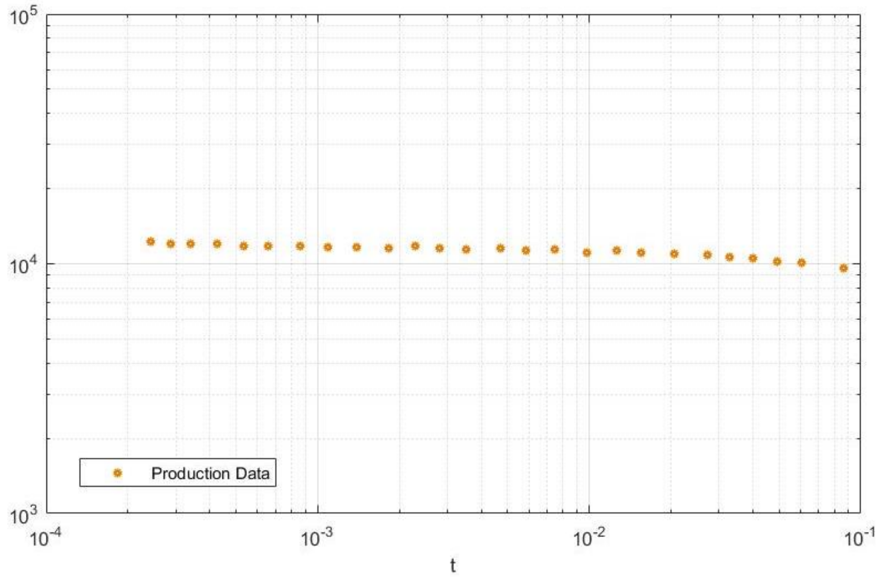

Figure 6. Production data in log log curve for Well SF#2

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From the match point can estimate fracture permeability and total storativity, as shown in figure 6 and 7. Calculate the fracture Permeability using the eq.7 and Total Storativity using eq.8 for Well SF#2 are:

Estimate fracture permeability

$$k_f = \frac{141.2\mu B}{h(pi - pwf)} \frac{[q]_{MP}}{[q_D]_{MP}} = \frac{141.2 * 0.75 * 1.25}{80 * 1600} \frac{32.03}{1} = 53\ md$$

Estimate Total Storativity

$$[(\phi Vc)_m + (\phi Vc)_f] = \frac{2.637(10^{-4})k_f}{\mu r_w^2} \frac{[t]_{MP}}{[t_D]_{MP}} = \frac{2.637(10^{-4})53}{0.75*0.25^2} \frac{7.256x10^{-6}}{1} = 2.031x10^{-7}\ 1/psi$$

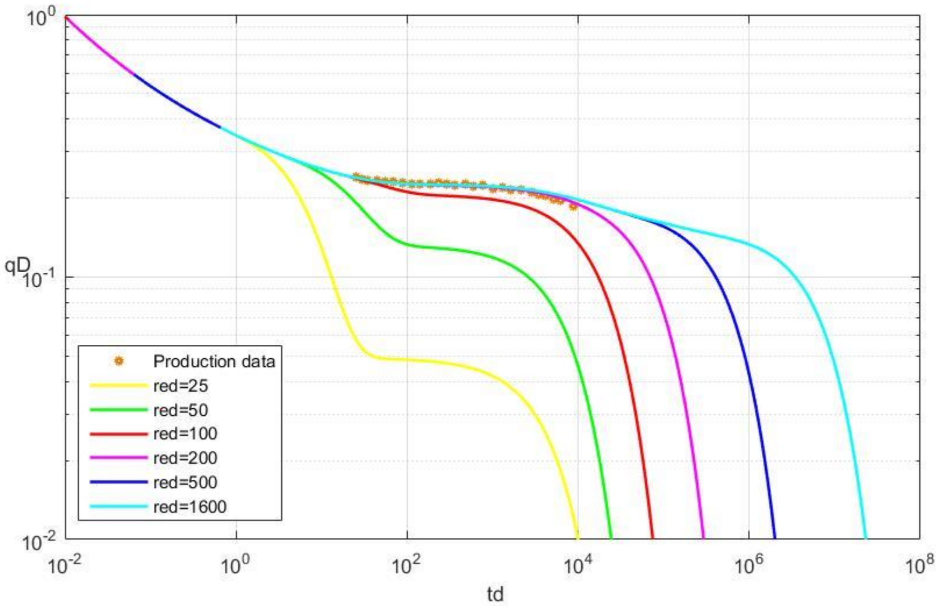

Figure 7. Rate Type Curve Matching for Well SF#2

The summary of resulted of the analysis that yield significant value for analyzing production data for naturally fractured oil field with decline rate type curve analysis are shown in the table 5.

Table 5. Result obtained from the analysis of SF Well

Parameter Reservoir	Rate Type Curve Matching Well SF#1	Rate Type Curve Matching Well SF#2
Reservoir Pressure (psia)	---	----
Fracture Permeability, $k_f\ (md)$	79	53
Drainage radius, r_e	125	125
Dimensionless boundaries, r_{eD}	200	200
Omega, ω	0.03	0.01
Lamda, λ	$1.54\ x\ 10^{-5}$	$1.79\ x\ 10^{-5}$
Total storativity, $[(\phi Vc)_m + (\phi Vc)_f]$ 1/psia	$1.175\ x\ 10^{-6}$	$2.031\ x\ 10^{-7}$

5. CONCLUSION

Nowadays, many researchers using the pressure transient analysis to characterize the reservoir, in case has to shut in the well production, with this decline rate type curve method have the benefit to estimate the reservoir parameter using the daily production data without loss of production. Even though, analysis production data for naturally fractured reservoir is rarely discussed, because the complexity and complicated reservoir to identify the behavior of double porosity model in application of field.

The study focuses on two well in SF Field that have characteristic of dual porosity, pseudosteady-state and bounded dominated flow reservoir. Application type curve matching for well SF#1 and SF#2 yield significant analysis. The result of this interpretation of data production with decline rate type curve can estimate fracture permeability, storativity capacitance, interflow coefficient, boundary of reservoir.

SUGGESTION

For future works, this study proposed for applied Pressure Transient Analysis and Inversion Data production analysis for estimating OOIP, ultimate recovery of naturally fractured oil field in indonesia.

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