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PRELIMINARY

PETROLEUM AND GEOTHERMAL ENGINEERING

Reservoir simulation study for dual porosity model to determine characteristic of naturally fractured reservoir

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Reservoir Simulation Study for Dual Porosity Model to Determine Characteristic of Naturally Fractured Reservoir

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Abstract. Reservoir characterization of dual porosity system and simulation modeling of naturally fractured reservoir present unique challenges because it different from single porosity reservoir. This reservoir is complicated so its need to characterize because have two medium porous there are matrix and fracture and also have two drive mechanism of interaction matrix and fracture that need to be modeled accurately.This study focused on estimation pressure p_D and rate dimensionless q_D that generated from simulation model. Where the parameter that influence the characteristic of reservoir such as storage capacity ratio, interporosity flow coefficient and various drainage radius, reD is created to characterizing the behavior of naturally fractured reservoir. The result of this study yield different characteristic of behavior in naturally fractured reservoir.

Keywords: Naturally Fracture Reservoir, Pressure Dimensionless, Rate Dimensionless, Simulation Model.

INTRODUCTION

Naturally fractured reservoirs have been studied intensively for several decades in the Petroleum and reservoir engineering fields. For this study dual porosity model using Warren and Root model for pseudo steady state interporosity flow has been done in the reservoir modelling. Estimating the characteristic of this reservoir by pressure transient analysis and describing the behavior of naturally fractured reservoir by reservoir modelling simulation.

Naturally fractured reservoir has been developed in 1960 by Barenblatt and Zheltov, then Warren and Root extended into petroleum engineering for dual porosity model that commonly used for researchers for analysis this type of reservoir, the model of dual porosity is shown in figure 1. As can be seen that there are two medium that are matrix block as known as source or tank that supplies the fluid flow to the fractures network then fluid flow to the wellbore. Whereas the matrix has low permeability but higher porosity, but the fractures has high permeability but lower in porosity.

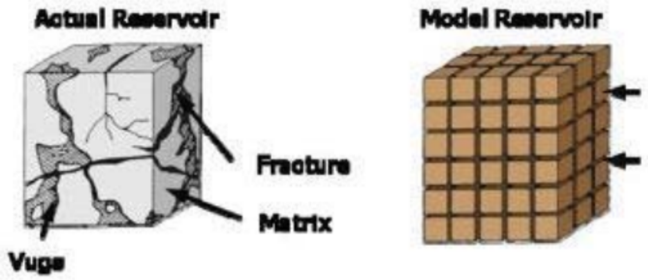

FIGURE 1. Warren and Root Idealization of Naturally Fractured Reservoir[2]

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Mavor and Cinco Ley (1979), Pressure transient analysis that characterize dual porosity behavior can be identify by two parallel straight lines on a semilog plot, whereas there are three part region such as : first region: represents the homogeneous behavior of the naturally fractured medium before the matrix medium starts to respond (transient radial flow),second region: describing interporosity flow; and third region: represents the homogeneous behavior of composite media (fracture permeability with the sum of matrix and fracture storages) when recharge from the matrix medium is fully established.

Giovani Da Prat (1980), Rate transient analysis that typical of naturally fractured reservoir be marked by early time fluid is flow dominantly from the fracture networks (transient flow), after the pressure in fracture decrease and the matrix pressure become dominant then finally at late time period the production the well become decrease sharply (pseudosteady state flow).

METHODOLOGY

The basic of partial differential equation for dual porosity system (Da Prat, 1981):

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

Matrix- fractures interaction is describing by instantaneous pressure steady state relations:

$$(1-\omega)\frac{\partial P_{mD}}{\partial t_D} = \lambda\left(P_{fD} - P_{mD}\right) \qquad (2)$$

Omega (storage capacity coefficient) is the dimensionless fracture storage parameter:

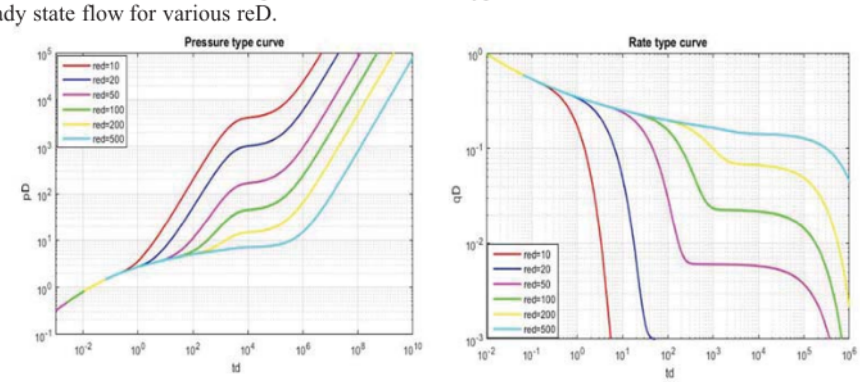
$$\omega = \frac{(\phi C_t)_f}{(\phi C_t)_f + (\phi C_t)_m} \qquad (3)$$

Lamda (Interflow porosity Coeficient) is the dimensionless matrix fractures permeability ratio:

$$\lambda = \alpha\frac{k_m r_{w^2}}{k_f h_{m^2}} \qquad (4)$$

Mavor dan Cinco Ley (1979) present the behavior of naturally fracture reservoir through analysis of pressure transient for infinite also for closed boundary dominated condition that included the effect of wellbore storage and skin factor. Also developed the type curve for wellbore pressure using analytical solution, which the real space solution for the reservoir pressure behavior as a function of time was obtained by evaluating the inverse transformation to the laplace space solution. This was accomplished with the numerical inversion scheme presented by stehfest algorithm as shown in the figure 2a for example the pressure type curve for the case where $\omega = 0.01, \lambda = 5x10^{-6}$pseudosteady state flow for various reD.

DaPrat developed the type curve for production rate using analytical solution, 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 was accomplished with the numerical inversion scheme presented by stehfest algorithm as shown in the FIGURE 2b for example the decline rate type curve for the case where $\omega = 0.01, \lambda = 5x10^{-6}$ pseudosteady state flow for various reD.



a

b

FIGURE 2a and 2b. Pressure and Rate Type Curve for Dual Porosity System (Analytical solution). Pseudo Steady State Interporosity Flow ω

$0.01, \lambda$

$5x10^{-6}$ for various reD

&7

Study that have been done by DaPrat (1981), shows that the trend of production for naturally fractured reservoir at closed boundary condition is early decline rapidly then become constant for long term of time and then Sageev, DaPrat dan Ramey (1985) has extended their research by included the effect of skin factor.

Analysis P_D Pressure Dimensionless and q_D Rate Dimensionless for Characterize Naturally Fractured Reservoir

Estimation pressure and rate dimensionless for naturally fractured reservoir with the following steps:

1. Calculate the Dimensionless wellbore Pressure:
   $$pD,\ Pressure\ dimensionless = \frac{k_f h p_i}{141.2\mu B} \quad (5)$$
2. Calculate the Dimensionless rate flow into wellbore:
   $$qD,\ rate\ dimensionless = \frac{141.2\mu B}{k_f h p_i} \quad (6)$$
3. Calculate the Dimensionless time:
   $$t_D = dimensionless\ time, \frac{2.637(10^{-4})k_f t}{[(\phi Vc)_m + (\phi Vc)_f]\mu r_w^2} \quad (7)$$
4. Calculate the Reservoir radius drainage dimensionless:
   $$r_{eD} = {}^{r_e}/_{r_w} \quad (8)$$
5. Plot pD *and* qD against t_D for various red

RESULT AND DISCUSSION

Numerical Simulation for Modelling Reservoir

The reservoir model was made with generated simulated data by a commercial pseudosteady state data simulator (CMG-IMEX). The parameters evaluated were OOIP and reservoir parameters (permeability fractures, omega, lamda and interporosity flow model). The numerical models are build using the following general considerations:

- Dual porosity system.
- Interporosity flow: Warren dan Root Model/ Pseudosteady State Flow.
- Cylindrical radial reservoir.
- Single phase fluid (oil and water).
- Constrain of well productions are Constant rate and Pressure wellbore constant.

This reservoir model is built with the well is vertical that placed at the center of the circular as shown in fig 4 and the reservoir pressure is above saturation pressure and so the reservoir is undersaturated condition through production. Additional reservoir information and well properties are presented in TABLE 1.

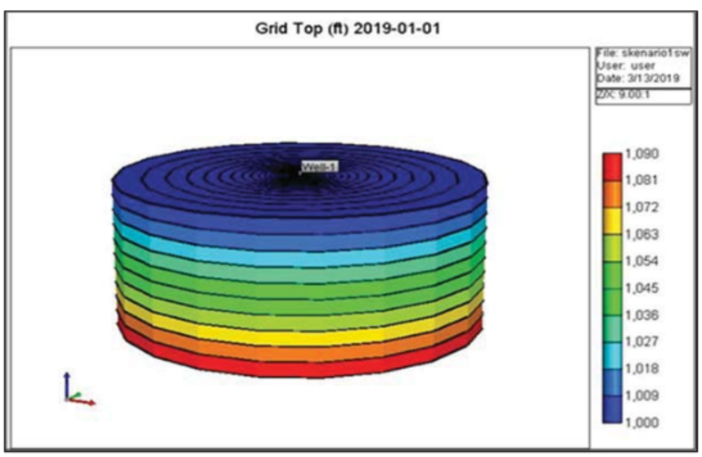


FIGURE 3. Reservoir Grid Model Cylindrical

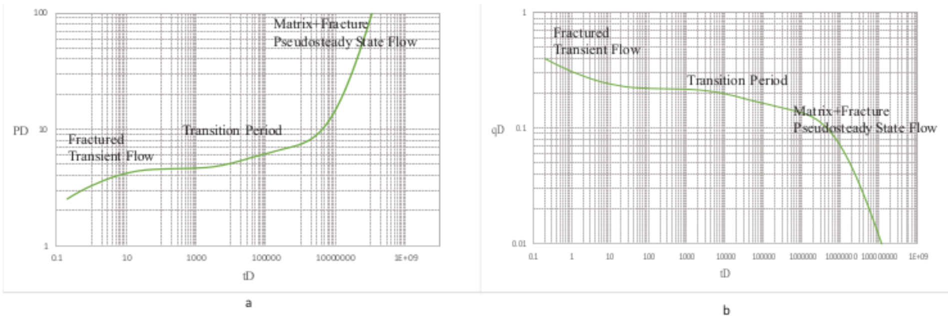


FIGURE 4a and 4b. Numerical Simulation case 2 pressure and rate dimensionless: Pseudosteady state Interporosity Flow $\omega = 0.09, \lambda = 1.51x10^{-5}$ reD = 1600

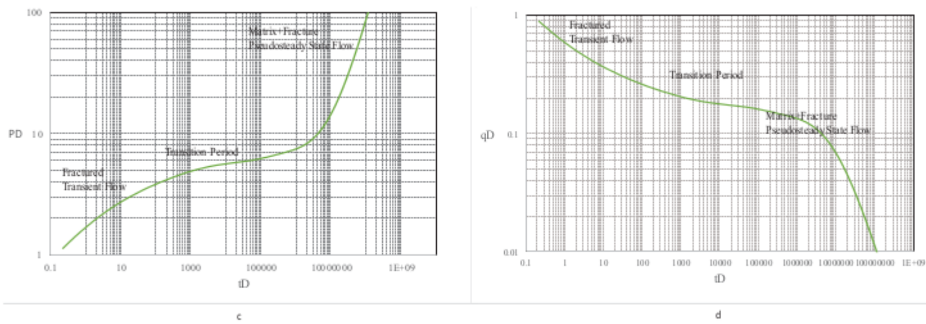


FIGURE 4c and 4d. Numerical Simulation case 2 pressure and rate dimensionless: Pseudosteady state Interporosity Flow $\omega = 0.09, \lambda = 1.51x10^{-5}$ reD = 1600

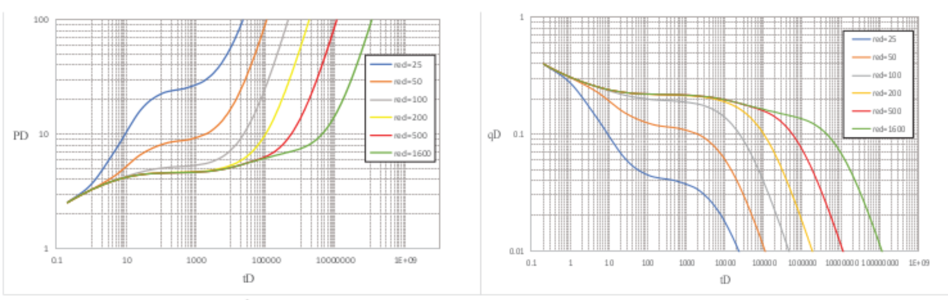


FIGURE 5a and 5b. Numerical Simulation case 1 pressure and rate dimensionless $\omega = 0.09, \lambda = 1.51x10^{-5}$ for various reD

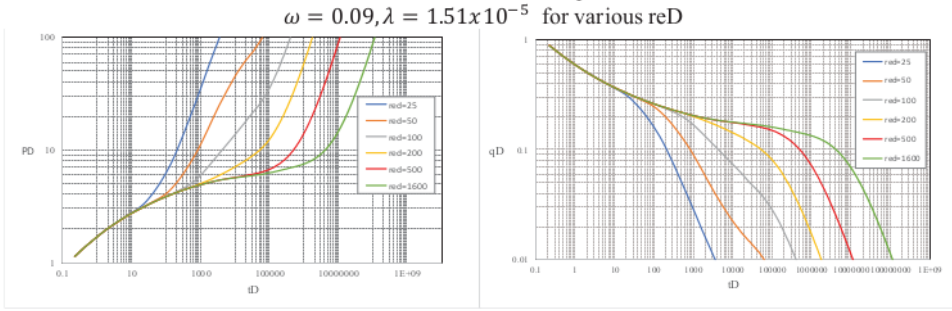


FIGURE 5c and 5d. Numerical Simulation case 2 pressure and rate dimensionless $\omega = \omega = 0.01, \lambda = 1.79x10^{-4}$ for various reD

TABLE 1. Reservoir Parameter of Simulated Data

Well Information		
Wellbore radius, r_w	0.25	Ft
Drainage radius, r_e	400	Ft
Reservoir Properties		
Formation Thickness, h	100	Ft
Matrix Porosity $\emptyset_m$	0.25	fraction
Matrix Permeability k_m	0.001	Md
Fracture Permeability k_f	100	Md
Matrix Compressibility c_m	$3.858x10^{-5}$	1/psia
Fracture Compressibility c_f,	$1.9x10^{-4}$	
Initial Condition		
Reservoir Pressure, P_r	4000	Psia
Pressure Saturation, P_b	1500	psia
Reservoir Temperature	150	°F
Gravity oil	38	API
Specific gravity gas	0.75	lb/cuft

For matrix and fractures relative permeabilities were generated from correlations as well. Fracture permeabilities curves were set as straight lines and capillary pressures were ignored for both the matrix and the fractures. Relative permeability of matrix and fracture are summarized in the TABLE 2.

TABLE 2 Relative Permeability Matrix and Fracture

Sw	Krw	Krow	Sw	Krw	Krow
0.2	0	0.8	0	0	1
0.246875	0.001172	0.703125	0.0625	0.0625	0.9375
0.29375	0.004688	0.6125	0.125	0.125	0.875
0.340625	0.010547	0.528125	0.1875	0.1875	0.8125
0.3875	0.01875	0.45	0.25	0.25	0.75
0.434375	0.029297	0.378125	0.3125	0.3125	0.6875
0.48125	0.042188	0.3125	0.375	0.375	0.625
0.528125	0.057422	0.253125	0.4375	0.4375	0.5625
0.575	0.075	0.2	0.5	0.5	0.5
0.621875	0.094922	0.153125	0.5625	0.5625	0.4375
0.66875	0.117187	0.1125	0.625	0.625	0.375
0.715625	0.141797	0.078125	0.6875	0.6875	0.3125
0.7625	0.16875	0.05	0.75	0.75	0.25
0.809375	0.198047	0.028125	0.8125	0.8125	0.1875
0.85625	0.229687	0.0125	0.875	0.875	0.125
0.903125	0.263672	0.003125	0.9375	0.9375	0.0625
0.95	0.3	0	1	1	0

Initial pressure reservoir is set at 4000 psi. The well is completed open hole and the bottom-hole pressure is kept constant at the value of 1600 psi. The simulation is run for an approximately 1 years of production on constant bottom-hole pressure condition. The producer well located in the center of the reservoir. The well was set to produce at a constant rate of 1000 BOPD/days. Simulation was run for different values of fracture porosity, fracture permeability, compressibility matrix and fracture that influence the characteristic of fractures reservoir, for details are summarized in table 3 for different scenario.

TABLE 3. Reservoir Properties for the Simulated Data

Reservoir Properties	Scenario 1	Scenario 2
Fracture Porosity, fraction	0.002	0.006
Fracture Permeability, fraction	$1x10^{-3}$	$1\ x10^{-8}$
Matrix Compressibility c_m, 1/psia	$3.858x10^{-5}$	$3.0x10^{-5}$
Fracture Compressibility c_f, 1/psia	$1.9x10^{-4}$	$1.9x10^{-4}$

After modeling simulated case is made and well test analysis have been carried out using commercial software using KAPPA – SHAPIRE, that we can estimate the value of parameter of this reservoir such as : Pressure reservoir, permeability fracture, storage capacity ratio, interporosity flow coefficient and radius of drainage. Modelling simulation case is confirmed with well test analysis and the result of pressure build up is accurately significant with the simulation case.

Simulation Case 1

The result of calculated of pressure and rate dimensionless that generated using simulation model are presented in table 4 (case 1). Modelling simulation for case 1 is confirmed with well test analysis yield $\omega = 0.01$ and $\lambda = 1.79\ x\ 10^{-4}$ and reD = 1600. As can be seen in figure 4a for log- log plot of analysis pressure dimensionless for dual porosity model (pseudosteady state flow) at early time the behavior of this characteristic shown the linier fracture dominated flow then transition period which matrix transition flow and finally pseudosteady state flow (closed dominated boundary).

At figure 4b for log-log plot rate dimensionless for this reservoir shown characteristic at early time is dominated by fracture linier flow then goes to period transition time is fractured boundary dominated flow and finally at late time period is matrix linier+ fracture boundary dominated flow. The flow rate shows a rapid decline,then it becomes nearly constant for a certain period, and finally it falls to zero. Figure 5a and 5b shown the simulated case for $\omega = 0.01$ and $\lambda = 1.79\ x\ 10^{-4}$ for various drainage radius dimensionless (reD), which shown different characteristic of reservoir.

TABLE 4. Result obtained from the analysis Scenario 1

Method	Simulation Model	Pressure Transient Analysis	Analysis P_D or q_D
Original Oil In Place, N(MMSTB)	1.833	-	-
Cumulative Oil Production, NP (MSTB)	306.48	-	-
Recovery Factor, RF(%)	16.7	-	-
Resevoir Pressure (psia)	4000	3998.38	4000
Fracture Permeability, $k_f\ (md)$	80	85.8	85
Drainage radius,r_e	400	389	1600 (reD)
Storativity ratio, ω	0.01	0.01	0.01
Interporosity Flow Coefficient, λ	$1.79\ x\ 10^{-4}$	$1.79\ x\ 10^{-4}$	$1.79\ x\ 10^{-4}$
Compressibility total,C_T 1/psia	$7.8\ x\ 10^{-5}$	$7.8\ x\ 10^{-5}$	$7.8\ x\ 10^{-5}$

Simulation Case 2

The result of calculated of pressure and rate dimensionless that generated using simulation model are presented in table 5 (case 2). Modelling simulation for case 2 is confirmed with well test analysis yield $\omega = 0.09$ and $\lambda = 1.51\ x\ 10^{-5}$ and reD = 1600. As can be seen in figure 4c for log- log plot of analysis pressure dimensionless for dual porosity model (pseudosteady state flow) at early time the behavior of this characteristic shown the linier fracture dominated flow then transition period where matrix transition flow and finally pseudosteady state flow (closed dominated boundary).

At figure 4d for log-log plot rate dimensionless for this reservoir shown characteristic at early time is dominated by fracture linier flow then goes to period transition time is fractured boundary dominated flow and finally at late time period is matrix linier+ fracture boundary dominated flow. The flow rate shows a rapid decline,then it becomes nearly constant for a certain period, and finally it falls to zero. Figure 5c and 5d shown the simulated case for $\omega = 0.09$ and $\lambda = 1.51\ x\ 10^{-5}$ for various drainage radius dimensionless (reD), which shown different characteristic of reservoir.

TABLE 5. Result obtained from the analysis Scenario 2

Method	Simulation Model	Pressure Transient Analysis	Analysis P_D or q_D
OOIP, N(MMSTB)	1.833	-	-
NP (MSTB)	286.811	-	-
Recovery Factor, RF(%)	15.64	-	-
Resevoir Pressure (psia)	4000	3998.38	4000
Fracture Permeability, $k_f\ (md)$	80	85	85
Drainage radius,r_e	400	392	1600 (reD)
Omega, ω	0.09	0.09	0.09
Lamda, λ	$1.51\ x\ 10^{-5}$	$1.51\ x\ 10^{-5}$	$1.51\ x\ 10^{-5}$
Compressibility total ,C_T 1/psia	$7.27\ x\ 10^{-5}$	$7.27\ x\ 10^{-5}$	$7.27 x\ 10^{-5}$

CONCLUSION

Modelling simulation for dual porosity that suggested in this study is to represent the characteristic of the naturally fractured reservoir. Model of this study is using warren and root model (pseudosteady state interporosity flow) and the influence of storage capacity ratio, interporosity flow coefficient and red (drainage radius of dimensionless) has been main concern in characterization of naturally fractured reservoir.

The works of this study are improvement and evaluation from the previously researcher for analyzing pressure and rate for characterizing of dual porosity system specially in naturally fractured reservoir. The proposed of this study is applying the simulated cases for pressure and rate in dual porosity system, and yield different characteristic of behavior in naturally fractured reservoir.

SUGGESTION

Further study needs to applied using analytical solution for validation the numerical simulation for pseudosteady state flow and transient interporosity flow in naturally fractured reservoir.

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