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Pressure Transient Analysis using Generated Simulation Reservoir Data for Dual Porosity Model of Naturally Fractured Reservoir

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Abstract

A naturally fractured reservoir today plays a significant role in improved worldwide oil and gas production. More than half of the resource is mostly found in this reservoir. In this reservoir, there are two porous media: the matrix, which acts as the fluid source in this reservoir, and the fractures, which act as the fluid network that flows to the wellbore. Many authors have researched works to model this reservoir. There are two models are done in this study, such as Warren and Root model, where the fluid flow mechanism matrix to fractures is known as pseudosteady-state flow and the Kazemi-Gilman model is known as transient interporosity flow. Reservoir engineers generally utilize pressure transient analysis to determine this reservoir's characteristics. The purpose of this study is to assess whether it is feasible to verify the parameters of the reservoir for pressure transient analysis using a synthesis simulation model. It also aims to observe how reservoir parameters behave in relation to the characteristics of naturally fractured reservoirs by utilizing various values for porosity, permeability, and fracture spacing.

INTRODUCTION

Oil and gas reserves are discovered in Naturally Fractured Reservoirs (NFR). There are two porous mediums in this unique reservoir that are matrix and fractures. Whereas the fractures give a high flow rate but a low storage capacity, the matrix has a high capacity for storage but a low flow capacity. The purpose of this study is to determine fracture permeability and estimate average reservoir pressure through pressure well tests for naturally fractured reservoirs, as well as to verify whether the influence of storativity capacitance and interporosity coefficient might result in different behavior of the reservoir characteristic.

Naturally Fractured Reservoir (NFR)

An idealized model was created by (Warren & Root, 1963) to explore fluid rate of heterogeneous reservoirs (double porosity). The Warren and Root model's structure is made up of rectangular parallelepipeds, with the matrix represented by cubes and fracture represented by spaces amongst cubes. The interporosity flow in this model's is known as pseudosteady-state flow. A circular, finite reservoir with a well in the center and all fractures being horizontal was selected by (Kazemi, 1969) as a particular instance of the Warren and Root model. The idealized Kazemi model is seen in Figure 1. The Kazemi models have basic presumptions are: 1) single-phase; 2) unsteady in the radial and vertical directions; 3) fluid mobility from the matrix (which has high storage and a very low flow capacity) to fracture (which has a high flow rate and a small amount of storage); and 4) fracture that flow into the wellbore.

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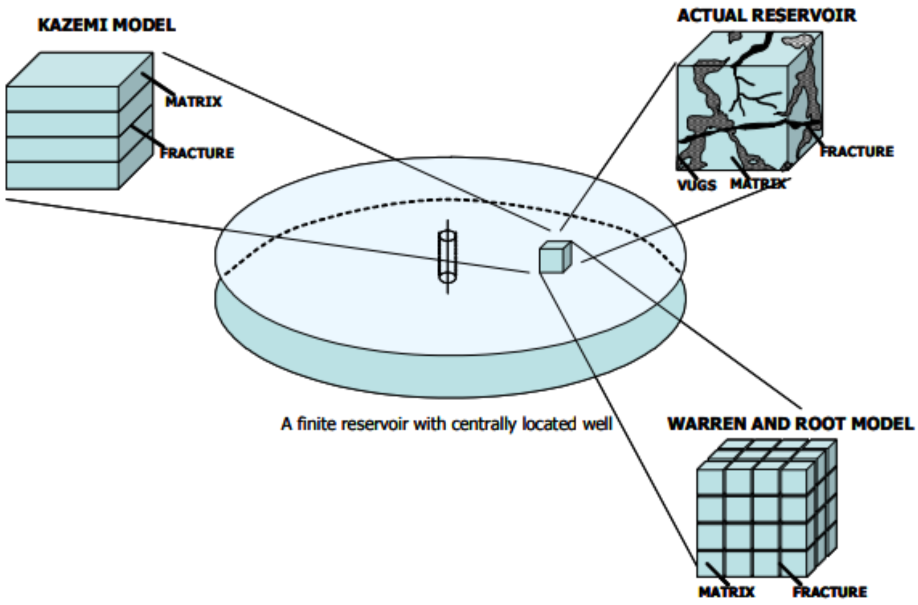

Figure 1. Idealization of a Naturally Fractured Reservoir (Kazemi, 1969)

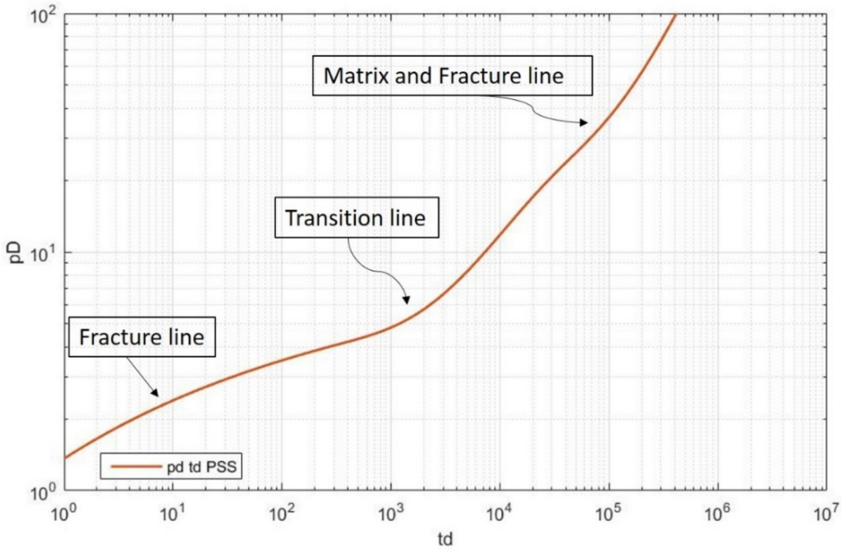

Figure 2. Pressure Dimensionless for Warren and Root Model

Figure 2 shows pressure analysis response displays two straight lines. The fracture media transient flow is represented by the first straight line, and the pseudo-steady state flow is represented by the second line. The slopes of the lines relate to the reservoir's flow capacity. The relative storage capacity of the fracture is related to the vertical separation of the two lines There are two important factors that how pressure transient identifying the behaviour in the two-porosity system. The first parameter is storativity capacitance (ω), is the ratio of the storage capacity of fracture to the total storage capacity of the system. The second parameter is interporosity flow coefficient (λ) is the ratio of permeability fracture to permeability matrix. The fluid mechanism of this reservoir usually flows dominantly from matrix to fracture, but its concern may depend on the heterogeneity of the system.

Interpretation of well test in Naturally Fractures Reservoir, Pressure and Pressure Derivative type curves that introduced by (Bourdet, 2002) for pseudosteady-state flow and transient interporosity flow and take into consideration the influence of wellbore storage and skin factor. An example of a Bourdet-type curve for a fractured reservoir (dual porosity) is shown in Figure 3 for pseudosteady-state flow, no wellbore storage, skin, and a closed boundary.

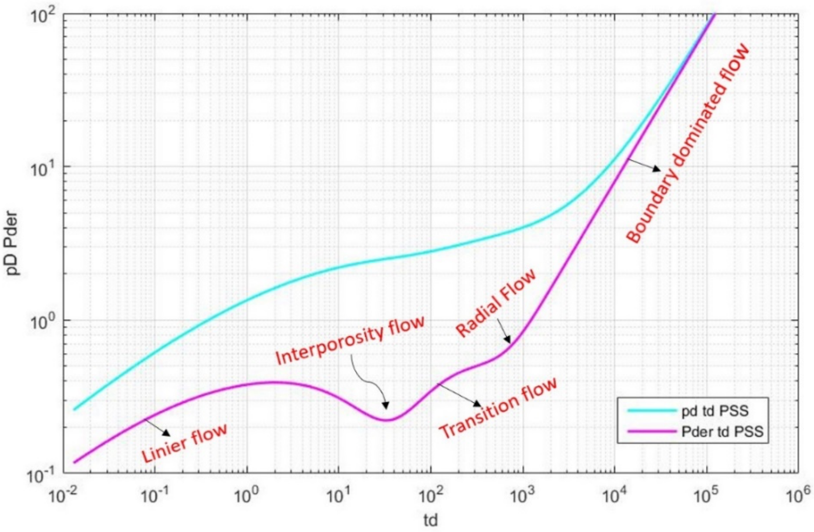

Figure 3. Bourdet Type Curve for Pseudosteady-state flow, no wellbore storage and skin, closed boundary

Pressure Transient analysis gives dissimilar character as compared to the single porosity (homogeneous reservoir). The derivative-type curve exhibits a valley form when the transition period is occurring, this is identification of characteristic of double porosity model. The derivative indicates a constant value of 0.25 during the transition regime if the flow is transient.

The dual-porosity approach's incapacity to deal with more complex reservoirs has already been studied by researcher. (De Swaan O, 1976)presented analytical solutions methods for interporosity transient flow with various geometries that already done by Kazemi. Later, (Najurieta, 1980)extended the theory to include the transition period. (Cinco L et al., 1976) considered a theoretical circular model with a centrally located well and a vertical fracture nearby the well, and also considered the effect of fracture orientation on pressure response.

(Abdassah & Ershaghi, 1986) introduced the triple porosity model. Although the Warren and Root theory has been modified to account for various matrix-to-fracture flow regimes, wellbore storage, and skin, it is still the most popular well test analysis technique for naturally fractured reservoirs. As a result, the parameters are valid for describing those reservoirs.

Based on previous study, (Maulindani, S. F., Abdassah, Marhaendrajana, & Prakoso, 2021) presented a reservoir simulation study for characterizing the dual porosity of a naturally fractured reservoir. Then (Maulindani, S. F. et al., 2021) extended for application the type curve matching for the pseudo steady-state flow model using reservoir simulation data, and also verified the result of the pressure transient analysis. For more detail study literature review are presented in table 1.

Table 1. Literature review summary.

Author	Title of paper	Research Description
(Warren & Root, 1963)	The Behavior of Naturally Fractured Reservoirs	Pressure transient analysis that characterizes dual porosity behavior can be identified by two parallel straight lines on a semilog plot and the model of the reservoir that rectangular parallelepipeds, where the blocks represent the matrix and the fractures is shown in spaces among the blocks.
(Kazemi, 1969)	Pressure Transient Analysis of Naturally Fractured Reservoirs with Uniform Fracture Distribution	Pressure transient analysis for a naturally fractured reservoir that is radial/cylindrical where fractures are horizontal or called as slab, the research uses a numerical solution model for analyzing the behavior of this reservoir.

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(Cinco L et al., 1976)	Unsteady-State Flow Behavior for a Well Near a Natural Fracture	Analyzing the behavior of naturally fractured reservoir with a circular model where the well is in the center and vertically fractured nearby the well.
(De Swaan O, 1976)	Analytic Solutions for Determining Naturally Fractured Reservoir Properties by Well Testing	Characterizing fractures reservoir using the analytical solution for unsteady state model and the interporosity transient flow in various geometries
(Mavor & Cinco-Ley, 1979)	Transient pressure behavior of naturally fractured reservoirs	Analysis of pressure transient for NFR for pseudo steady-state flow and transient interporosity flow either for infinite acting reservoir also for boundary reservoir using algorithm stehfest method.
(Mavor & Cinco-Ley, 1979)	Theory for Pressure Transient Analysis in Naturally Fractured Reservoirs	Analytical solution for unsteady state model that influences the transient period or no flow boundary.
(Cinco-Ley & Samaniego V, 1982)	Pressure transient analysis for naturally fractured reservoirs	Characterizing the naturally fractured by influence the orientation on pressure transient analysis that influence of fracture orientation.
(Abdassah & Ershaghi, 1986)	Triple porosity models for representing naturally fractured reservoirs	Pressure transient analysis of naturally fractured reservoir for triple porosity model.
(Da Prat, 1990)	Well test analysis for fractured reservoir evaluation	Interpretation of dual-porosity model using the analytical solution, for PSS model and Transient Model with varying the parameter and boundary condition.
(Nelson, 2001)	Geologic Analysis of Naturally Fractured Reservoirs	Fractures is a proses of geological deformation or physical diagenesis, the characteristic of NFR can be classified from how much matrix and fractures exist in the reservoir.
(Bourdet, 2002)	Well test analysis: the use of advanced interpretation models	Pressure and pressure derivative for interpretation of reservoir using the type curve matching.
(Maulindani, S. F. et al., 2021)	Reservoir Simulation Study for Dual Porosity Model to Determine Characteristic of Naturally Fractured Reservoir	Modeling simulation for dual porosity suggested in this study is to represent the characteristic of the naturally fractured reservoir. The model of this study is using warren and root model (pseudo steady state interporosity flow) and the influence of reservoir parameters.
(Maulindani, Sri Feni et al., 2021)	Application of Pressure Type Curve Matching for Characterizing the Naturally Fractured Reservoir	Type curve matching analysis for naturally fractured reservoir using generated data from reservoir simulation. The result of this study is interpretation using the analytical solution for variation of omega, lambda, and boundary of the reservoir.

The main objective of this study is the characterization of this unique reservoir using generated data synthesis simulations that are built with the variation of the parameter that the most influence the behavior of the naturally fractured reservoir, and then identify this characteristic of this reservoir through pressure transient analysis to determine the value of fracture permeability, omega, lambda, boundary reservoir.

METHODS

There are two scenarios that are built in this research for a reservoir model using a commercial simulator to produced synthetic data simulation for dual porosity. First scenario is using the shape factor of Warren and root model and second scenario is using the shape factor of Kazemi-Gilman model, IMEX simulator (black oil), single phase flow, the reservoir model is radial grid, closed boundary, with or without wellbore storage and skin are the main subjects of this study. The synthesis Simulation Scenario are shown in Table 2 and the reservoir properties for simulation model are shown in table 3.

Table 2. Synthesis Simulation Scenario

Properties Reservoir	Scenario 1 Warren and Root Model		Scenario 2 Kazemi-Gilman Model	
	Simulation Case 1	Simulation Case 2	Simulation Case 3	Simulation Case 4
Fracture Porosity, fraction	0.05	0.05	0.08	0.06
Fracture Permeability, mD	122	118	133	114
Fracture Spacing, ft	0.2	1	0.5	2

Table 3. Reservoir Properties

Reservoir Properties	Value	Unit
Initial reservoir pressure	4200	psia
Pressure Saturation	1600	psia
Wellbore Radius	0.25	ft
Reservoir radius	1000	ft
API Gravity	38	°API
Matrix Porosity	23	percent
Matrix Permeability	0.0001	mD
Fractures Compressibility	3.25×10^{-5}	1/psia
Matrix Compressibility	1.8×10^{-5}	1/psia
Thickness of Reservoir	100	ft
Specific Gravity Gas	0.78	scf/stb

The simulation study is using grid cylindrical with the size 50x1x10 as shown in the Figure 4. The layers have been completely perforated by the open well. The reservoir must be undersaturated and the production scenario for bottom-hole pressure must be set above the saturated pressure. The bottom hole pressure is maintained at 1600 psi while the initial reservoir pressure is set at 4200 psia. The simulation is run under constant pressure and constant rate conditions for around one year of production.

Correlations based on the API gravity used is 38, where the reservoir temperature is 150°F, and the specific gravity of gas is 0.75 were used to estimate the fluid characteristics. The Corey approach was used to measure the relative permeabilities of the matrix and the fractures. Capillary pressures were not taken into consideration for the matrix or the fracture when computing the permeability curves.

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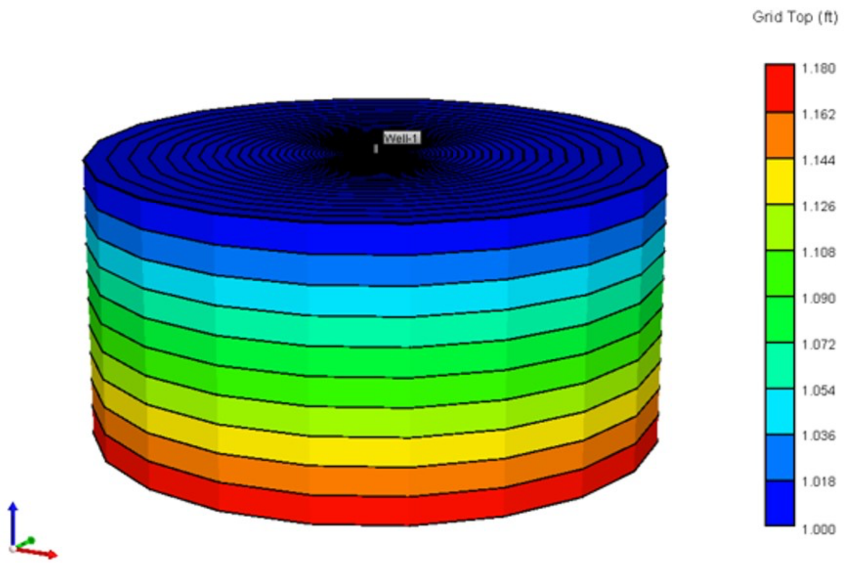


Figure 4. 3D Radial Grid for Reservoir Simulation Model

RESULTS & DISCUSSIONS

Pressure transient analysis is carried out to determine the effective permeability and average pressure after building the synthesis simulation. Whereas building simulation models, this well test has also been used as a validation tool by matching the pressure response from the model with well test data, regardless of whether the data is usually used as input for the simulation model. In this study, test analysis is being done with the aid of commercial software named KAPPA Saphir. The data pressure build-up test schematic was created in modeling simulation and loaded into KAPPA Saphir. Data for the reservoir were aligned with those in the simulation model. The pressure build up test is designed in two days of good production and then continues to shut in for a four or six day period of time, this is done for a short time as it assumed to have been reached the boundary of the reservoir.

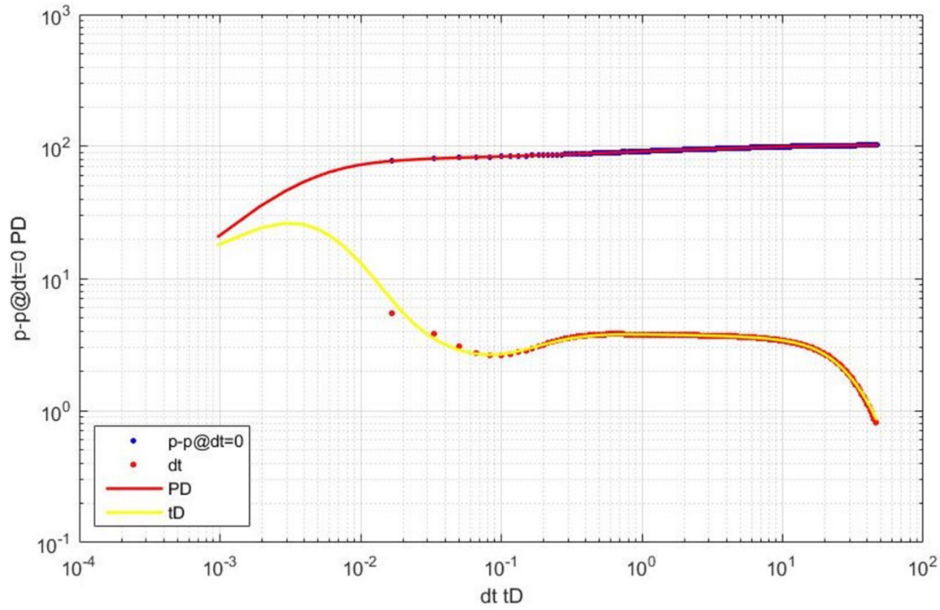
Pressure Transient Analysis for Pseudosteady-state Flow Model

There are two cases for interpretation of the behavior for pseudosteady-state flow with a different value of porosity fracture, permeability fracture, and fractures spacing. Figure 5a shows that type curve matching for synthesis simulation case-1, with porosity fracture is 5%, permeability fracture is 122 mD, and fracture spacing is 0.2 ft. the interpretation of the good test analysis presents the v shape of indicating dual porosity after transient line then continues with the dominated flow by fractures and end of it an indication the end of boundary, in this case, is a closed boundary.

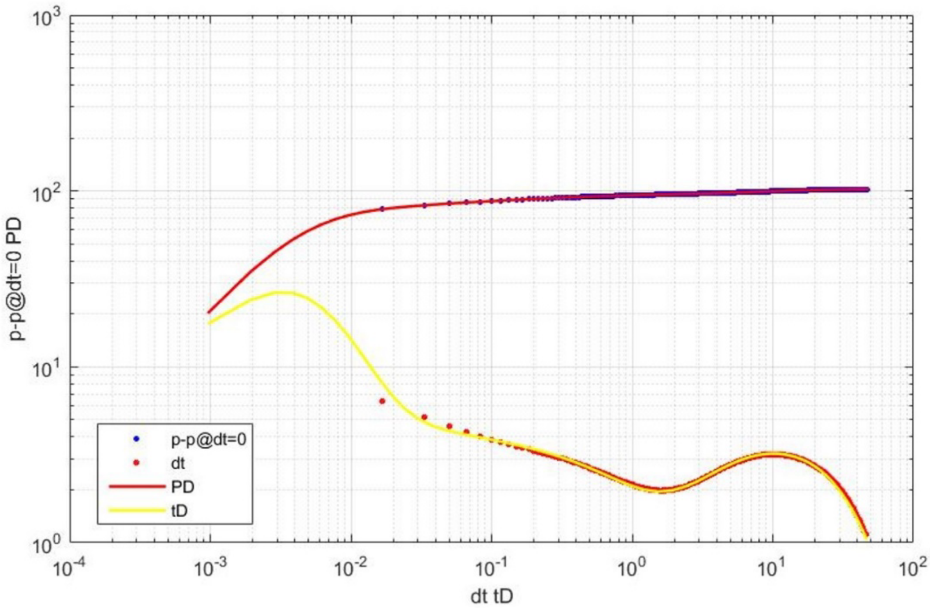
Figure 5b shows that type curve matching for synthesis simulation case-2, with porosity fracture is 5%, permeability fracture is 118 mD, and fracture spacing is 1 ft, as can we see from two cases that present how different behavior the dual porosity model also gives the different value of reservoir parameter omega and lambda. The result of the analysis pressure transient for the two cases is shown in more detail in Table 4.

Table 4. Simulation results from case pseudosteady-state flow model

Properties	Unit	Simulated Case-1	Simulated Case-2
Reservoir pressure, P	psia	4196	4197
Fracture permeability, k_f	mD	122	118
Drainage radius, r_e	ft	1010	963
Omega, ω		0.358	0.244
Lambda, λ		5.38×10^{-5}	2.4×10^{-5}



(a)



(b)

Figure 5. Pressure type curve matching of Synthesis Simulation Case-1 (a), Pressure type curve matching of Synthesis Simulation Case-2 (b)

Pressure Transient Analysis for Transient Interporosity Flow Model

The behavior of transient interporosity flow can be interpreted in two distinct ways depending on the porosity fracture, permeability fracture, and fracture spacing. The interpretation of the well test analysis presents the V shape of indicating dual porosity is not clear enough but acts as single porosity or homogenous reservoir, after transient line then continues with the dominated flow by fractures and end of its indication the end of boundary, in this case, is shown in Figure 6a. The porosity fracture is 8%, permeability fracture is 133 mD, and the fracture spacing is 0.5 ft.

As we can see from two cases that present how different behavior the dual porosity model also gives the different values of reservoir parameter omega and lambda, Figure 6b shows that type curve matching for synthesis simulation case-4, with porosity fracture is 6%, permeability fracture is 114 mD, and fracture spacing is 2 ft. Table 5 provides more specific information about the results of the examination of pressure transients for the Case-3 and Case-4.

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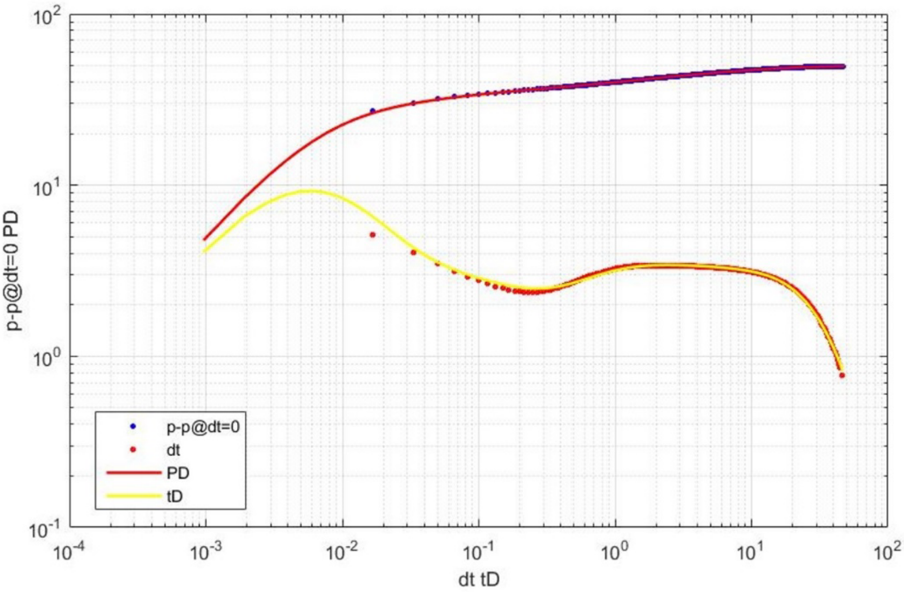
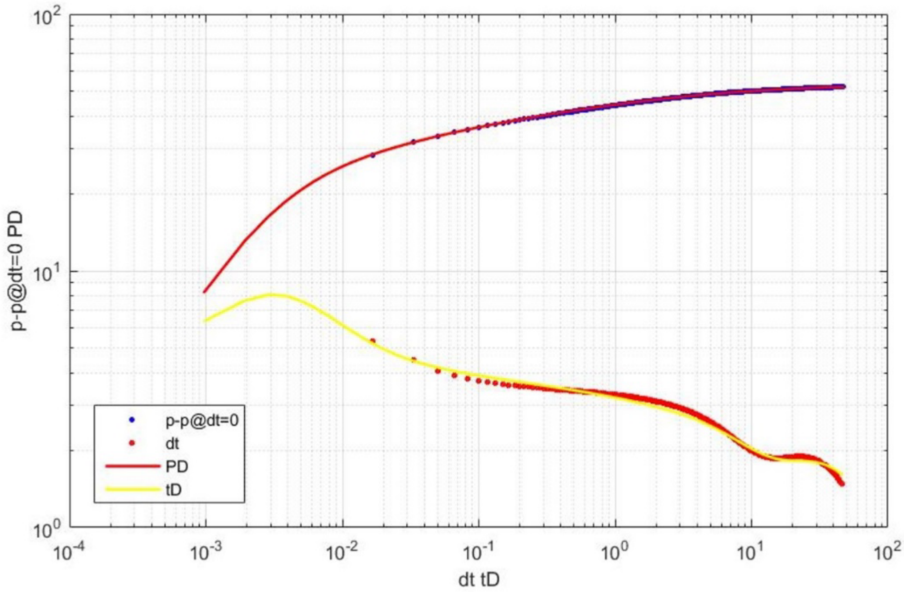
Table 5. Results obtained from case Transient Interporosity Flow Model

Properties	Unit	Simulated Case-3	Simulated Case-4
Reservoir pressure, P	psia	4196	4196
Fracture permeability, k_f	mD	133	114
Drainage radius, r_e	ft	1050	1010
Omega, ω		0.259	0.228
Lambda, λ		2.13×10^{-5}	5.98×10^{-5}



(a)



(b)

Figure 6. Pressure type curve matching of Synthesis Simulation Case 3 (a), Pressure type curve matching of Synthesis Simulation Case 4 (b)

CONCLUSIONS

This study is conducted in the simulation model and pressure transient analysis to integrate the behavior and identify the characteristic of this unique reservoir, and as a knowledge for verification of the reservoir parameter that influences the performance of the production of naturally fractured reservoir. Based on study, building the synthesis simulation model with a variation of fractures porosity, permeability fractures, and fractures spacing is needed to yield a more reliable model and accuracy.

There are two parameter reservoirs that the most important part indicates the characterization of this dual-porosity model is storativity ratio as the storage capacity and interporosity flow coefficient as the permeable of fluid to flow through the fractures, with pressure transient analysis is seen that with various porosity, permeability fracture and spacing give different behavior and characteristic the value omega dan lambda instead. This study is a validation to identify more clearly how to define the performance of production for naturally fractured reservoir. Subsequent research is proposed to apply the application of decline rate type curve for naturally fractured Reservoir.

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Naturally Fracture Reservoir, Pressure Transient Analysis, Reservoir Simulation, Fracture Flow, Transiet Flow.

Abstract

A naturally fractured reservoir today plays a significant role in improved worldwide oil and gas production. More than half of the resource is mostly found in this reservoir. In this reservoir, there are two porous media: the matrix, which acts as the fluid source in this reservoir, and the fractures, which act as the fluid network that flows to the wellbore. Many authors have researched works to model this reservoir. There are two models are done in this study, such as Warren and Root model, where the fluid flow mechanism matrix to fractures is known as pseudosteady-state flow and the Kazemi-Gilman model is known as transient interporosity flow. Reservoir engineers generally utilize pressure transient analysis to determine this reservoir's characteristics. The purpose of this study is to assess whether it is feasible to verify the parameters of the reservoir for pressure transient analysis using a synthesis simulation model. It also aims to observe how reservoir parameters behave in relation to the characteristics of naturally fractured reservoirs by utilizing various values for porosity, permeability, and fracture spacing.

INTRODUCTION

Oil and gas reserves are discovered in Naturally Fractured Reservoirs (NFR). There are two porous mediums in this unique reservoir that are matrix and fractures. Whereas the fractures give a high flow rate but a low storage capacity, the matrix has a high capacity for storage but a low flow capacity. The purpose of this study is to determine fracture permeability and estimate average reservoir pressure through pressure well tests for naturally fractured reservoirs, as well as to verify whether the influence of storativity capacitance and interporosity coefficient might result in different behavior of the reservoir characteristic.

Naturally Fractured Reservoir (NFR)

An idealized model was created by (Warren & Root, 1963) to explore fluid rate of heterogeneous reservoirs (double porosity). The Warren and Root model's structure is made up of rectangular parallelepipeds, with the matrix represented by cubes and fracture represented by spaces amongst cubes. The interporosity flow in this model's is known as pseudosteady-state flow. A circular, finite reservoir with a well in the center and all fractures being horizontal was selected by (Kazemi, 1969) as a particular instance of the Warren and Root model. The idealized Kazemi model is seen in Figure 1. The Kazemi models have basic presumptions are: 1) single-phase; 2) unsteady in the radial and vertical directions; 3) fluid mobility from the matrix (which has high storage and a very low flow capacity) to fracture (which has a high flow rate and a small amount of storage); and 4) fracture that flow into the wellbore.

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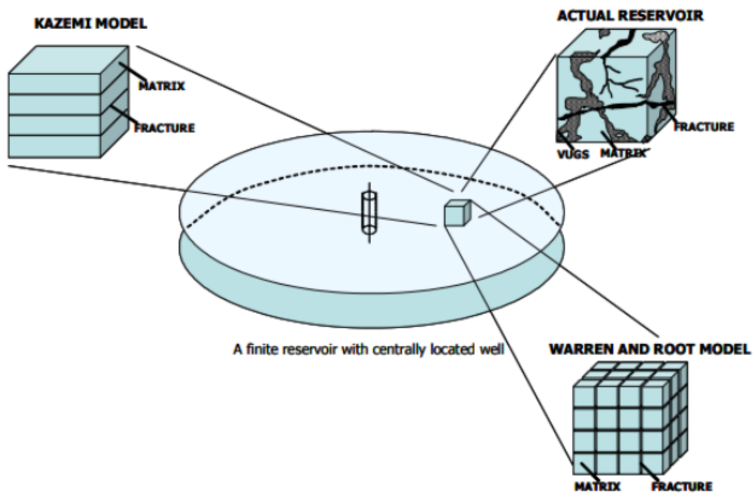

Figure 1. Idealization of a Naturally Fractured Reservoir (Kazemi, 1969)

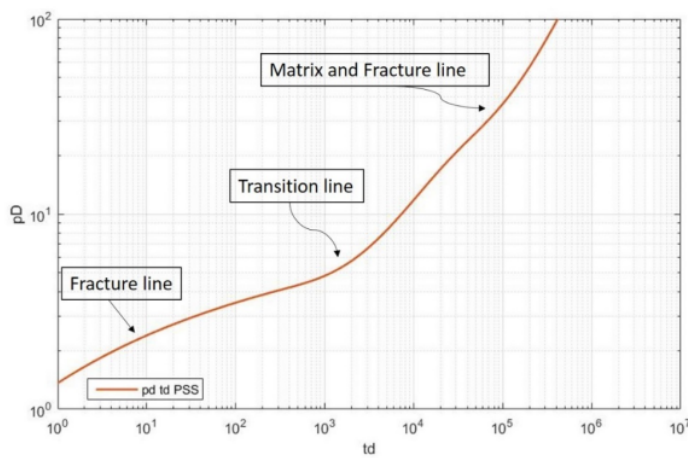

Figure 2. Pressure Dimensionless for Warren and Root Model

Figure 2 shows pressure analysis response displays two straight lines. The fracture media transient flow is represented by the first straight line, and the pseudo-steady state flow is represented by the second line. The slopes of the lines relate to the reservoir's flow capacity. The relative storage capacity of the fracture is related to the vertical separation of the two lines There are two important factors that how pressure transient identifying the behaviour in the two-porosity system. The first parameter is storativity capacitance (ω), is the ratio of the storage capacity of fracture to the total storage capacity of the system. The second parameter is interporosity flow coefficient (λ) is the ratio of permeability fracture to permeability matrix. The fluid mechanism of this reservoir usually flows dominantly from matrix to fracture, but its concern may depend on the heterogeneity of the system.

Interpretation of well test in Naturally Fractures Reservoir, Pressure and Pressure Derivative type curves that introduced by (Bourdet, 2002) for pseudosteady-state flow and transient interporosity flow and take into consideration the influence of wellbore storage and skin factor. An example of a Bourdet-type curve for a fractured reservoir (dual porosity) is shown in Figure 3 for pseudosteady-state flow, no wellbore storage, skin, and a closed boundary.

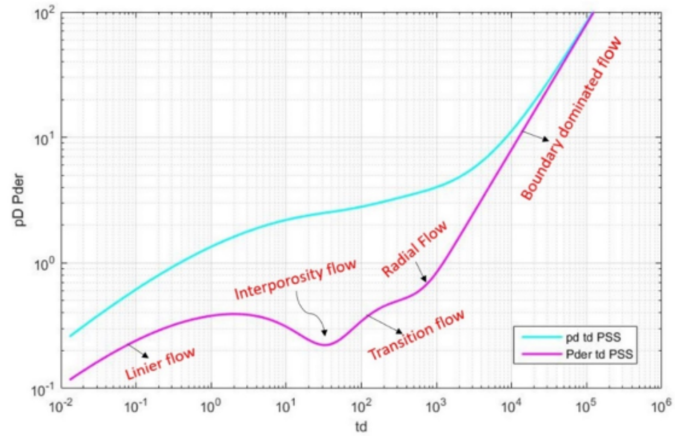

Figure 3. Bourdet Type Curve for Pseudosteady-state flow, no wellbore storage and skin, closed boundary

Pressure Transient analysis gives dissimilar character as compared to the single porosity (homogeneous reservoir). The derivative-type curve exhibits a valley form when the transition period is occurring, this is identification of characteristic of double porosity model. The derivative indicates a constant value of 0.25 during the transition regime if the flow is transient.

The dual-porosity approach's incapacity to deal with more complex reservoirs has already been studied by researcher. (De Swaan O, 1976)presented analytical solutions methods for interporosity transient flow with various geometries that already done by Kazemi. Later, (Najurieta, 1980)extended the theory to include the transition period. (Cinco L et al., 1976) considered a theoretical circular model with a centrally located well and a vertical fracture nearby the well, and also considered the effect of fracture orientation on pressure response.

(Abdassah & Ershaghi, 1986) introduced the triple porosity model. Although the Warren and Root theory has been modified to account for various matrix-to-fracture flow regimes, wellbore storage, and skin, it is still the most popular well test analysis technique for naturally fractured reservoirs. As a result, the parameters are valid for describing those reservoirs.

Based on previous study, (Maulindani, S. F., Abdassah, Marhaendrajana, & Prakoso, 2021) presented a reservoir simulation study for characterizing the dual porosity of a naturally fractured reservoir. Then (Maulindani, S. F. et al., 2021) extended for application the type curve matching for the pseudo steady-state flow model using reservoir simulation data, and also verified the result of the pressure transient analysis. For more detail study literature review are presented in table 1.

Table 1. Literature review summary.

Author	Title of paper	Research Description
(Warren & Root, 1963)	The Behavior of Naturally Fractured Reservoirs	Pressure transient analysis that characterizes dual porosity behavior can be identified by two parallel straight lines on a semilog plot and the model of the reservoir that rectangular parallelepipeds, where the blocks represent the matrix and the fractures is shown in spaces among the blocks.
(Kazemi, 1969)	Pressure Transient Analysis of Naturally Fractured Reservoirs with Uniform Fracture Distribution	Pressure transient analysis for a naturally fractured reservoir that is radial/cylindrical where fractures are horizontal or called as slab, the research uses a numerical solution model for analyzing the behavior of this reservoir.

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(Cinco L et al., 1976)	Unsteady-State Flow Behavior for a Well Near a Natural Fracture	Analyzing the behavior of naturally fractured reservoir with a circular model where the well is in the center and vertically fractured nearby the well.
(De Swaan O, 1976)	Analytic Solutions for Determining Naturally Fractured Reservoir Properties by Well Testing	Characterizing fractures reservoir using the analytical solution for unsteady state model and the interporosity transient flow in various geometries
(Mavor & Cinco-Ley, 1979)	Transient pressure behavior of naturally fractured reservoirs	Analysis of pressure transient for NFR for pseudo steady-state flow and transient interporosity flow either for infinite acting reservoir also for boundary reservoir using algorithm stehfest method.
(Mavor & Cinco-Ley, 1979)	Theory for Pressure Transient Analysis in Naturally Fractured Reservoirs	Analytical solution for unsteady state model that influences the transient period or no flow boundary.
(Cinco-Ley & Samaniego V, 1982)	Pressure transient analysis for naturally fractured reservoirs	Characterizing the naturally fractured by influence the orientation on pressure transient analysis that influence of fracture orientation.
(Abdassah & Ershaghi, 1986)	Triple porosity models for representing naturally fractured reservoirs	Pressure transient analysis of naturally fractured reservoir for triple porosity model.
(Da Prat, 1990)	Well test analysis for fractured reservoir evaluation	Interpretation of dual-porosity model using the analytical solution, for PSS model and Transient Model with varying the parameter and boundary condition.
(Nelson, 2001)	Geologic Analysis of Naturally Fractured Reservoirs	Fractures is a proses of geological deformation or physical diagenesis, the characteristic of NFR can be classified from how much matrix and fractures exist in the reservoir.
(Bourdet, 2002)	Well test analysis: the use of advanced interpretation models	Pressure and pressure derivative for interpretation of reservoir using the type curve matching.
(Maulindani, S. F. et al., 2021)	Reservoir Simulation Study for Dual Porosity Model to Determine Characteristic of Naturally Fractured Reservoir	Modeling simulation for dual porosity suggested in this study is to represent the characteristic of the naturally fractured reservoir. The model of this study is using warren and root model (pseudo steady state interporosity flow) and the influence of reservoir parameters.
(Maulindani, Sri Feni et al., 2021)	Application of Pressure Type Curve Matching for Characterizing the Naturally Fractured Reservoir	Type curve matching analysis for naturally fractured reservoir using generated data from reservoir simulation. The result of this study is interpretation using the analytical solution for variation of omega, lambda, and boundary of the reservoir.

The main objective of this study is the characterization of this unique reservoir using generated data synthesis simulations that are built with the variation of the parameter that the most influence the behavior of the naturally fractured reservoir, and then identify this characteristic of this reservoir through pressure transient analysis to determine the value of fracture permeability, omega, lambda, boundary reservoir.

METHODS

There are two scenarios that are built in this research for a reservoir model using a commercial simulator to produced synthetic data simulation for dual porosity. First scenario is using the shape factor of Warren and root model and second scenario is using the shape factor of Kazemi-Gilman model, IMEX simulator (black oil), single phase flow, the reservoir model is radial grid, closed boundary, with or without wellbore storage and skin are the main subjects of this study. The synthesis Simulation Scenario are shown in Table 2 and the reservoir properties for simulation model are shown in table 3.

Table 2. Synthesis Simulation Scenario

Properties Reservoir	Scenario 1 Warren and Root Model		Scenario 2 Kazemi-Gilman Model	
	Simulation Case 1	Simulation Case 2	Simulation Case 3	Simulation Case 4
Fracture Porosity, fraction	0.05	0.05	0.08	0.06
Fracture Permeability, mD	122	118	133	114
Fracture Spacing, ft	0.2	1	0.5	2

Table 3. Reservoir Properties

Reservoir Properties	Value	Unit
Initial reservoir pressure	4200	psia
Pressure Saturation	1600	psia
Wellbore Radius	0.25	ft
Reservoir radius	1000	ft
API Gravity	38	°API
Matrix Porosity	23	percent
Matrix Permeability	0.0001	mD
Fractures Compressibility	3.25×10^{-5}	1/psia
Matrix Compressibility	1.8×10^{-5}	1/psia
Thickness of Reservoir	100	ft
Specific Gravity Gas	0.78	scf/stb

The simulation study is using grid cylindrical with the size 50x1x10 as shown in the Figure 4. The layers have been completely perforated by the open well. The reservoir must be undersaturated and the production scenario for bottom-hole pressure must be set above the saturated pressure. The bottom hole pressure is maintained at 1600 psi while the initial reservoir pressure is set at 4200 psia. The simulation is run under constant pressure and constant rate conditions for around one year of production.

Correlations based on the API gravity used is 38, where the reservoir temperature is 150°F, and the specific gravity of gas is 0.75 were used to estimate the fluid characteristics. The Corey approach was used to measure the relative permeabilities of the matrix and the fractures. Capillary pressures were not taken into consideration for the matrix or the fracture when computing the permeability curves.

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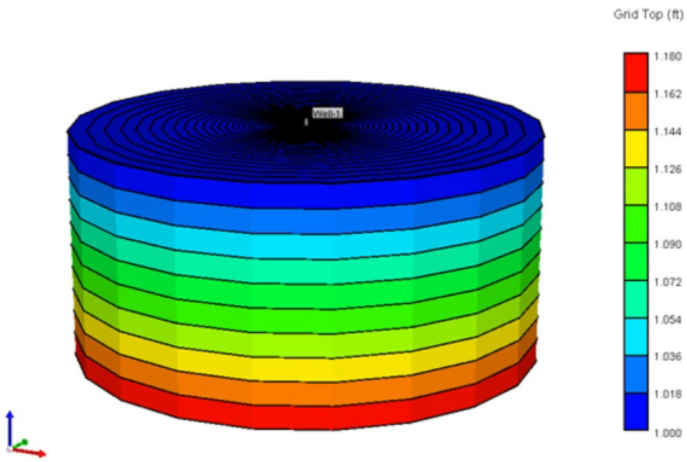


Figure 4. 3D Radial Grid for Reservoir Simulation Model

RESULTS & DISCUSSIONS

Pressure transient analysis is carried out to determine the effective permeability and average pressure after building the synthesis simulation. Whereas building simulation models, this well test has also been used as a validation tool by matching the pressure response from the model with well test data, regardless of whether the data is usually used as input for the simulation model. In this study, test analysis is being done with the aid of commercial software named KAPPA Saphir. The data pressure build-up test schematic was created in modeling simulation and loaded into KAPPA Saphir. Data for the reservoir were aligned with those in the simulation model. The pressure build up test is designed in two days of good production and then continues to shut in for a four or six day period of time, this is done for a short time as it assumed to have been reached the boundary of the reservoir.

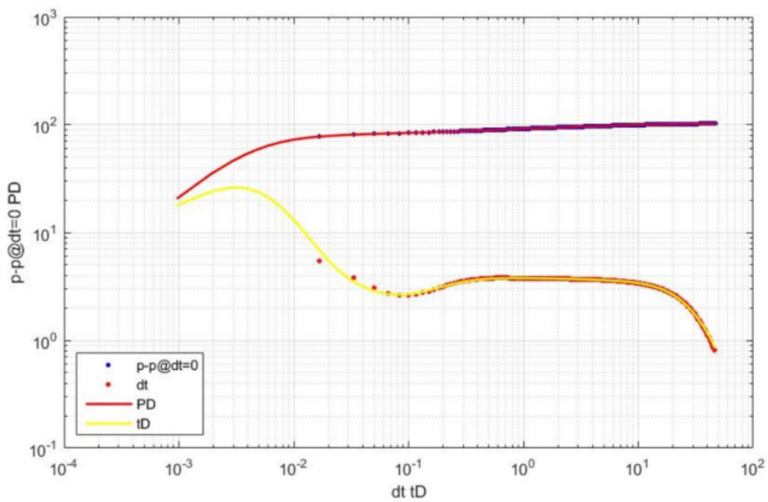
Pressure Transient Analysis for Pseudosteady-state Flow Model

There are two cases for interpretation of the behavior for pseudosteady-state flow with a different value of porosity fracture, permeability fracture, and fractures spacing. Figure 5a shows that type curve matching for synthesis simulation case-1, with porosity fracture is 5%, permeability fracture is 122 mD, and fracture spacing is 0.2 ft. the interpretation of the good test analysis presents the v shape of indicating dual porosity after transient line then continues with the dominated flow by fractures and end of it an indication the end of boundary, in this case, is a closed boundary.

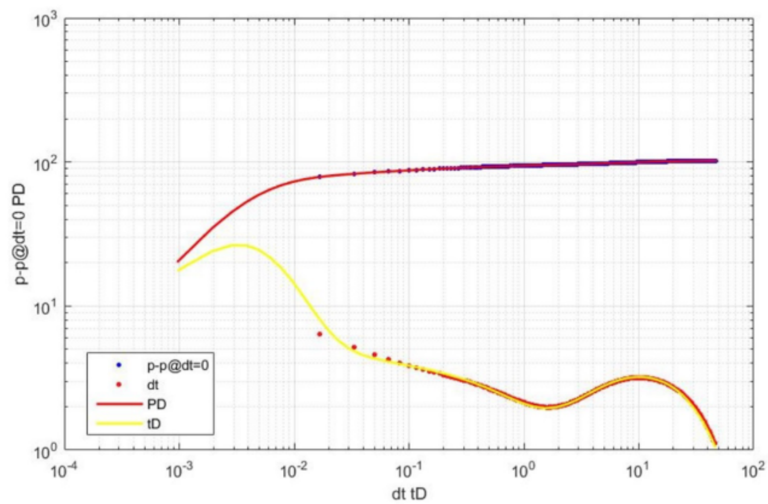
Figure 5b shows that type curve matching for synthesis simulation case-2, with porosity fracture is 5%, permeability fracture is 118 mD, and fracture spacing is 1 ft, as can we see from two cases that present how different behavior the dual porosity model also gives the different value of reservoir parameter omega and lambda. The result of the analysis pressure transient for the two cases is shown in more detail in Table 4.

Table 4. Simulation results from case pseudosteady-state flow model

Properties	Unit	Simulated Case-1	Simulated Case-2
Reservoir pressure, P	psia	4196	4197
Fracture permeability, k_f	mD	122	118
Drainage radius, r_e	ft	1010	963
Omega, ω		0.358	0.244
Lambda, λ		5.38×10^{-5}	2.4×10^{-5}



(a)



(b)

Figure 5. Pressure type curve matching of Synthesis Simulation Case-1 (a), Pressure type curve matching of Synthesis Simulation Case-2 (b)

Pressure Transient Analysis for Transient Interporosity Flow Model

The behavior of transient interporosity flow can be interpreted in two distinct ways depending on the porosity fracture, permeability fracture, and fracture spacing. The interpretation of the well test analysis presents the V shape of indicating dual porosity is not clear enough but acts as single porosity or homogenous reservoir, after transient line then continues with the dominated flow by fractures and end of its indication the end of boundary, in this case, is shown in Figure 6a. The porosity fracture is 8%, permeability fracture is 133 mD, and the fracture spacing is 0.5 ft.

As we can see from two cases that present how different behavior the dual porosity model also gives the different values of reservoir parameter omega and lambda, Figure 6b shows that type curve matching for synthesis simulation case-4, with porosity fracture is 6%, permeability fracture is 114 mD, and fracture spacing is 2 ft. Table 5 provides more specific information about the results of the examination of pressure transients for the Case-3 and Case-4.

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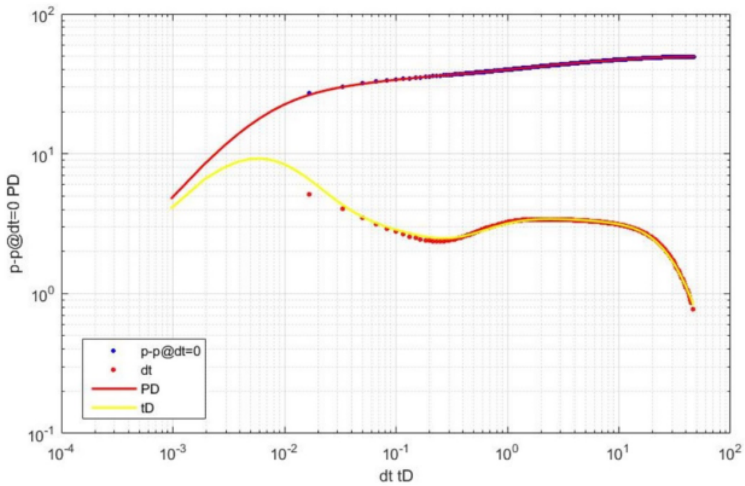
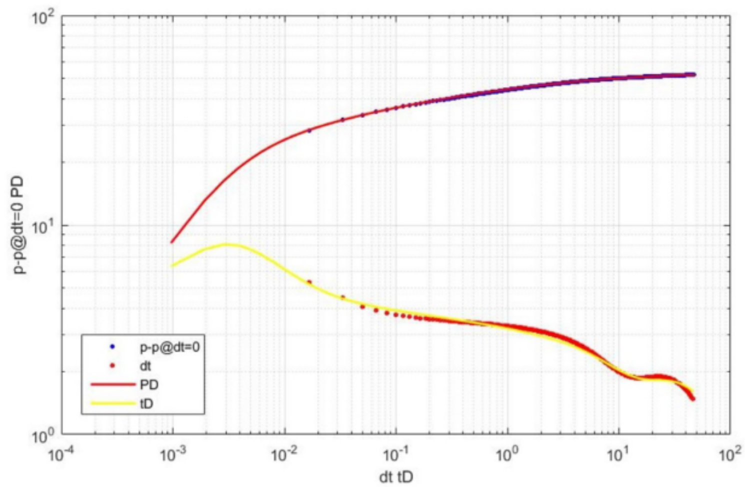
Table 5. Results obtained from case Transient Interporosity Flow Model

Properties	Unit	Simulated Case-3	Simulated Case-4
Reservoir pressure, P	psia	4196	4196
Fracture permeability, k_f	mD	133	114
Drainage radius, r_e	ft	1050	1010
Omega, ω		0.259	0.228
Lambda, λ		2.13×10^{-5}	5.98×10^{-5}



(a)



(b)

Figure 6. Pressure type curve matching of Synthesis Simulation Case 3 (a), Pressure type curve matching of Synthesis Simulation Case 4 (b)

CONCLUSIONS

This study is conducted in the simulation model and pressure transient analysis to integrate the behavior and identify the characteristic of this unique reservoir, and as a knowledge for verification of the reservoir parameter that influences the performance of the production of naturally fractured reservoir. Based on study, building the synthesis simulation model with a variation of fractures porosity, permeability fractures, and fractures spacing is needed to yield a more reliable model and accuracy.

There are two parameter reservoirs that the most important part indicates the characterization of this dual-porosity model is storativity ratio as the storage capacity and interporosity flow coefficient as the permeable of fluid to flow through the fractures, with pressure transient analysis is seen that with various porosity, permeability fracture and spacing give different behavior and characteristic the value omega dan lambda instead. This study is a validation to identify more clearly how to define the performance of production for naturally fractured reservoir. Subsequent research is proposed to apply the application of decline rate type curve for naturally fractured Reservoir.

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