PRESSURE TRANSIENT ANALYSIS FOR A RESERVOIR WITH A FINITE-CONDUCTIVITY FAULT

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Abstract - *The signature of the pressure spinoff curve for reservoirs with finite-conductivity faults is investigated to understand their behaviour and facilitate the interpretation of pressure information. Once a fault is reached by the disturbance, the pressure spinoff displays a negative unit-slope indicating that the system is connected to a formation, which means dominance of steady-state flow regime. Afterwards, a half-slope straight line is displayed on the pressure spinoff plot once the flow is linear to the fault. Besides, if at the same time a linear flow happens within the fault plane, then a additive flow regime takes place that is recognized by a 1/4 slope line on the pressure spinoff line. This paper presents the foremost complete analytical well pressure analysis methodology for finite-conductivity faulted systems victimisation some characteristics options and points found on the pressure and pressure spinoff log-log plot. Therefore, such plot isn't solely used as diagnosing criterion however additionally as a machine tool. The straight-line typical analysis is additionally complemented for characterization of finite- and infinite conductivity faults. Hence, new equations area unit introduced to estimate the distance to fault, the fault physical phenomenon and also the fault skin issue for such systems. The projected expressions and methodology were with success tested with field and artificial cases.*

***Key Words*: Radial flow, Bilinear flow, Fault conductivity, Steady state.**

1.INTRODUCTION

Many hydrocarbon-bearing formations area unit faulted and infrequently very little info is obtainable concerning the particular physical characteristics of such faults. Some faults area unit acknowledged to be waterproofing and a few others area unit non-sealing to the migration of hydrocarbons. whereas waterproofing faults block fluid and pressure communication with different regions of the reservoir, infinite conductivity faults act as pressure support sources and permit fluid transfer across and on the faults planes. Finite-conductivity faults fall between these 2 limiting cases of waterproofing and completely non-sealing faults, and area unit believed to be enclosed within the majority of faulted systems. A waterproofing fault is commonly generated once the throw of the fault plane is specified a leaky stratum on one facet of the fault plane is totally close against Associate in Nursing impervious stratum on the opposite facet. On the contrary, a non-sealing fault typically has Associate in Nursing short throw to cause a whole separation of productive strata on opposite sides of the fault plane. betting on the porousness of the fault, fluid flow might occur on the fault at intervals the fault plane or simply across it laterally from one stratum to a different. In general, a finite-conductivity fault exhibits a combined behaviour of flow on and across its plane. whereas unstable analysis will sight a fault distance to a well with a margin of error close to 2 kilometers, transient pressure analysis is that the best tool to sight the space well-fault with a margin of error of some feet. However, conventionally transient pressure analysis ways are solely used for detection distance fault-well while not taking under consideration such variables as conduction, harm of the fault and fault length. Before the current work, it absolutely was solely potential to estimate the fault conduction exploitation the straight-line standard analysis with Associate in Nursing equation planned by Trocchio (1990). Pressure transient analysis offers a potential thanks to verify the fluid transmissibility of faults. several models introduced within the literature facilitate characterize faults from pressure transient tests. the only of such models uses the well known methodology of pictures for waterproofing faults. This approach leads to doubling the slope of the line on a semilog plot of pressure take a look at knowledge. Extensions to intersectant or no intersectant multiple waterproofing faults have conjointly been reported within the literature. A finite-conductivity fault displays a common fraction slope on the pressure spinoff plot that is similar to be known as a line within the philosopher plot of pressure versus the common fraction root of your time. This behaviour was reported by Trocchio (1990) United Nations agency conducted a study on the Fateh Mishrif reservoir and provided a standard methodology for deciding fracture conductivity and fracture length.

1.1 PRESSURE BEHAVIOUR OF FINITE-CONDUCTIVITY FAULTS

In the finite-conductivity fault model employed by Anisur-Rahman et al. (2003), the fault porosity is larger than the reservoir porosity. Fluid flow is allowed to occur each across and on the fault plane, and the fault enhances the emptying capability of the reservoir. In their original answer, Abbaszadeh and Cinco-Ley (1995) allowed an amendment of quality and storativity in the two reservoir regions. during this study, it's assumed that the reservoir properties square measure a similar in each side of the fault. The typical influence of a semi-permeable fault is shown in Figure one within which we will observe that the response starts following the standard infinite-acting regime at associate early time. Once the finite-conductivity fault is felt by the pressure disturbance, the pressure spinoff drops on a line of slope -1. The fault provides a pressure support just like a constant-pressure linear boundary. Later, because the pressure drops within the fault, a flow is established within the thickness of the fault plane that results into a bilinear-flow regime, as delineated in Figure. One linear flow takes place within the reservoir once the fluid enters and exits the fault; the second linear flow describes the flux within the fault thickness. As seen in Figure 1, once the negative unit-slope line disappears as the time progresses, the ¼ slope line develops. Finally, the pressure spinoff response becomes once more flat describing the infinite-acting radial regime once the fault no longer has effects on the pressure response.

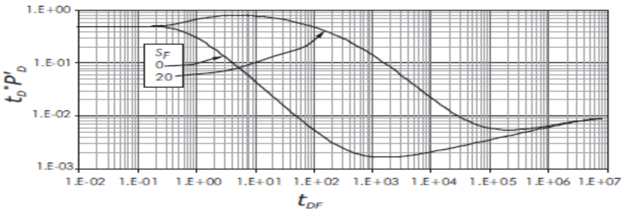

Figure 1. Dimensionless pressure derivative for a well near finite-conductivity fault. s_F = 0 and 20.

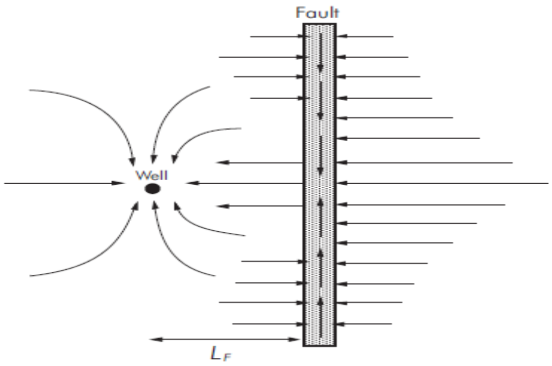

Figure 2. Schematic of a typical fault system and flow lines, after Abbaszadeh and Cinco-Ley (1995).

Figure three shows the pressure and pressure by-product behaviour once the skin issue across the fault plane is equal to zero and also the reservoir properties on each side of the fault are an equivalent. Wellbore storage and wellbore skin effects don't seem to be enclosed. many pressure by-product curves as a operate of physical phenomenon of the fault plane, ranging from zero.1 to 107, ar shown on this figure. At early times, the pressure by-product is flat representing infiniteacting radial flow within the left-side of the reservoir. At a dimensionless time, tDF, of 0.25, the pressure by-product curves deviate from the radial flow once the pressure transient reaches the fault plane. The deviation degree depends upon the physical phenomenon of the fault plane. For fault conductivities but zero.1, the pressure by-product essentially remains on radial flow regime indicating that there is no flow on the fault plane which fluid transfer occurs solely across the fault. this can be thanks to the very fact that very low fault conductivities produce an outsized flow resistance along the fault plane, whereas a zero skin issue creates no resistance to flow across the fault. Therefore, fluid flow comes from the right-side to the left-side of the reservoir across the fault, as if the fault plane wouldn't exist. For high-conductivity cases, the fault plane at the start acts as a linear constant-pressure boundary and also the pressure derivative becomes a line with a slope of minus unity. As time progresses, pressure within the fault plane decreases, fluid enters the fault linearly from the reservoir, moves linearly on it, and exits from the fault plane toward the manufacturing well. This flow characteristic is seen as a quarter-slope straight-line additive flow regime on the pressure by-product curves. At later times, when the disturbance much has passed the fault system, the behaviour reflects the complete reservoir response and also the by-product curves asymptotically reach the radial flow regime again. it's attention-grabbing to notice that the pressure-transient behaviour for intermediate values of fault physical phenomenon is similar to it of naturally cracked reservoirs. Thus, in a pressure take a look at, one semiconducting fault will provide the appearance of a naturally fractured reservoir. Figure four shows pressure by-product behaviours for finite-conductivity faulty systems beneath fault skin issue conditions. The reservoir properties area unit an equivalent everywhere. for sure, the skin creates further resistance to flow inside the fault plane for a few amount of time, resembling a scenario kind of like a protection fault for all physical phenomenon values. Pressure derivatives once the onset of the fault effects tend to approach the well-known behaviour of doubling of the semilog straight- line slope (dimensionless pressure by-product equals 1) for sF > 100. At larger times, once pressure on the left aspect of the fault becomes low enough to permit for considerable flow to cross the fault plane, the pressure waves propagate through the right-side of the reservoir and also the behaviour becomes just like the unmutilated fault case, S_f = 0. The negative unit-slope line of the constant-pressure linear boundary and also the quarter-slope line of the bilinear-flow regime characteristics ar developed for top conduction values, and eventually the dimensionless pressure derivative curves approach the worth of 0.5 (combined reservoir behaviour).

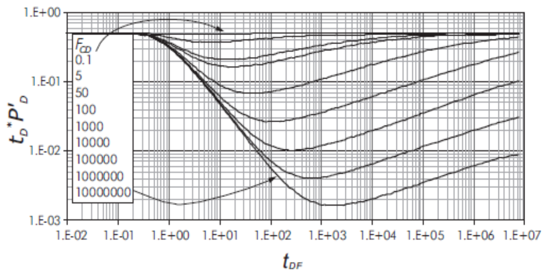

Figure 3. Effect of fault conductivity on pressure derivative dimensionless. s_F = 0.

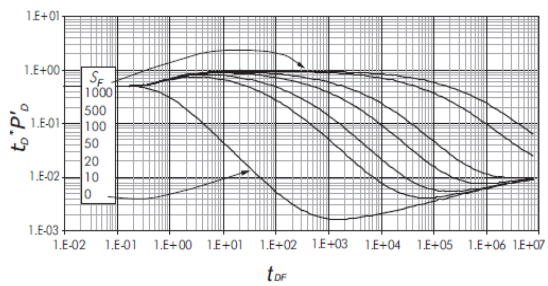

Figure 4. Effect of fault skin factor on pressure derivative dimensionless, h_D = 1.

Figure 5 shows dimensionless pressure by-product curves at many dimensionless pay thickness. At low h_D, the negative-unit slope line is a lot of visible than at higher values.

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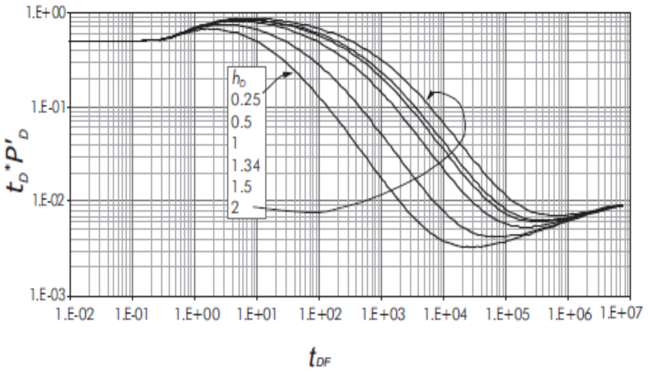

Figure 5. Effect of h_D on pressure derivative dimensionless, s_F = 20.

1.2 MATHEMATICAL FORMULATION

The dimensionless quantities utilized in this work are defined as:

$$P_D = \frac{kh}{141.2 q\mu B}\Delta P \qquad (1)$$

$$t_D{}^* P_D' = \frac{kh(t^*\Delta P')}{141.2\, q\mu B} \qquad (2)$$

$$t_{DF} = \frac{0.0002637 kt}{\phi\mu c_t L_F^2} \qquad (3)$$

$$h_D = \frac{h}{L_F} \qquad (4)$$

$$F_{CD} = \frac{k_f w_f}{k L_F} \qquad (5)$$

The formulation of the equations follows the philosophy of the TDS technique, Tiab (1995). It means. several specific regions and "fingerprints" found on the pressure and pressure by product behaviour are dealt with:
1) porousness and skin factors are found by victimization the following equations, Tiab (1995):

$$k = \frac{70.6\, q\mu B}{h(t^*\Delta P')_r} \qquad (6)$$

$$s = \frac{1}{2}\left(\frac{\Delta P_r}{(t^*\Delta P')_r} - \ln\left(\frac{k t_r}{\phi\mu c_t r_w^2}\right) + 7.43\right) \qquad (7)$$

2) The early radial flow end at:

$$t_{DFer} = 0.25 \qquad (8)$$

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2) The early radial flow end at:

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Putting *Equation 3* into the above expression and solving for the distance from the well to the fault:

$$L_F = 0.0325\sqrt{\frac{k t_{er}}{\phi\mu c_t}}$$

3) The governing dimensionless pressure derivative for the steady-state flow caused by the fault is:

$$(t_D{}^* P_D')_{SS} = \frac{1}{2}\left(1 + s_F h_D\right)^2 \frac{1}{t_{DF}} \qquad (10)$$

Replacing the dimensionless quantities given by *Equations 2, 3* and *4* into *Equation 10* and solving for the fault skin factor will result:

$$s_F = \frac{L_F}{h}\left[\sqrt{\left(\frac{3.7351\times 10^{-6} k^2 h t_{ss} (t^*\Delta P')_{ss}}{q\mu^2 B\phi c_t L_F^2}\right)} - 1\right] \qquad (11)$$

4) The pressure and pressure derivative dimensionless expressions for the bilinear-flow regime are:

$$P_D = \frac{2.45}{\sqrt{F_{CD}}} t_{DF}^{0.25} + s_{BL} \qquad (12)$$

$$t_D{}^* P_D' = \frac{0.6125}{\sqrt{F_{CD}}} t_{DF}^{0.25} \qquad (13)$$

Replacing the dimensionless quantities given by Equations 2, 3 and 5 into Equation 13 can end in an expression to estimate fault physical phenomenon using an arbitrary purpose on the pressure spinoff throughout the bilinear-flow regime;

$$k_f w_f = 121.461\left(\frac{q\mu B}{h(t^*\Delta P')_{BL}}\right)^2 \left(\frac{t_{BL}}{k\phi\mu c_t}\right)^{0.5} \quad (14)$$

5) using the minimum pressure spinoff coordinate, we get another expression for the fault conductivity:

$$k_f w_f = \frac{a + c(t_D{*}P_D')_{min} + e(t_D{*}P_D')^2_{min} + g(t_D{*}P_D')^3_{min}}{1 + b(t_D{*}P_D')_{min} + d(t_D{*}P_D')^2_{min} + f(t_D{*}P_D')^3_{min} + h(t_D{*}P_D')^4_{min}} (kL_F + S_F kh) \quad (15)$$

Where the constants are a = 11198700, b = -1235. 2895, c = 256626000, d = 71204.381, e= -491990000, f= 64974400, g = -154650000 and h = 116739000.

The dimensionless pressure derivative lines obtained from the radial flow and the steady-state flow regimes intercepts at:

$$0.51 = \frac{1}{2}(1 + s_F h_D)^2 \frac{1}{t_{DF}} \quad (16)$$

$$t_{DFrssi} = (1 + s_F h_D)^2 \quad (17)$$

Replacing the dimensionless time into *Equation 17* and solving for the well distance to the fault will result in:

$$L_F = \sqrt{\frac{0.0002637\, k\, t_{rssi}}{\phi \mu c_t}} - s_F h \quad (18)$$

The line corresponding to the steady state and the bilinear flow line of the dimensionless pressure derivative intersect at:

$$\frac{0.6125}{\sqrt{F_{CD}}} t_{DF}^{0.25} = \frac{1}{2}(1 + s_F h_D)^2 \frac{1}{t_{DF}} \quad (19)$$

$$t_{DFssBli} = \left[\frac{(1 + s_F h_D)^2 \sqrt{F_{CD}}}{1.225}\right]^{0.8} \quad (20)$$

Replacing the dimensionless time defined by *Equation 3* into *Equation 20* and solving for the conductivity fault will result in:

$$k_f w_f = 1.694 \times 10^{-9} kL_F \left(\frac{k\, t_{ssBLi}}{\phi \mu c_t L_F^2}\right)^{2.5} 1 \Big/ \left(1 + s_F \frac{h}{L_F}\right)^4 \quad (21)$$

If the dimensionless fault physical phenomenon is larger than 2.5x108, the linear flow disappears and therefore the linear flow seems exhibiting a ½-slope line on the pressure spinoff curve. during this case we've got Associate in Nursing infinite-conductivity fault. The dimensionless pressure derivative expression for the higher than mentioned linear flow regime is:

$$t_D{}^* P_D = 2.8 \times 10^{-6} \sqrt{t_{DF}} \quad (22)$$

Replacing the dimensionless quantities given by Equations a pair of and three into Equation twenty two can lead to another expression helpful to estimate the gap from the well to the fault;

$$L_F = 6.42 \times 10^{-6} \frac{qB}{h(t^*\Delta P')_L} \sqrt{\frac{\mu t_L}{k\phi c_t}} \quad (23)$$

2. RESULTS ANALYSIS

The results agree quite well with the input values for simulation and also the fault's conduction estimated by typical analysis. Pressure by-product behaviour for a well settled close to finite-conductivity fault was studied and expressions to estimate the space from the well to the fault, fault conductivity and fault skin issue were introduced and successfully tested with artificial and field examples. These were conjointly compared to the straight-line typical technique that complemented this work. It was found that for fault conductivities larger than 2.5x108, the pressure by-product exhibit a half-slope line, since linear flow happens from the fault to the reservoir. a brand new expression for this flow regime was introduced, as well as one to estimate the fault length.

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