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A TDS-Based Interpretation Method for Quantifying Fracture Connectivity from Pressure Interference Between Multi-Fractured Horizontal Wells

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Abstract

Pressure interference between Multi-Fractured Horizontal Wells (MFHW) provides direct evidence of hydraulic connectivity inside the Stimulated Reservoir Volume (SRV) and constitutes a key diagnostic indicator for characterizing unconventional reservoirs. However, conventional pressure transient analysis techniques based on type-curve matching or extended flow-regime identification often become difficult to apply under fracture-dominated interference conditions. This work presents an extension of the Tiab's Direct Synthesis (TDS) methodology for estimating fracture connectivity and transport parameters in hydraulically connected MFHW systems using characteristic features identified in pressure derivative log-log responses. The proposed formulation introduces direct analytical expressions for determining the interference coefficient, the degree of interference, the hydraulic fracture half-length, and the dimensionless fracture conductivity from diagnostic derivative points, including the minimum derivative within the interference region, the derivative maximum following linear flow, and the intersection between the 0.5 and 5/4 slopes.

The methodology is validated using synthetic interference responses generated from analytical solutions describing partially interconnected hydraulic fractures. Results show excellent agreement between input parameters and estimated values, confirming the robustness of the proposed interpretation workflow. Although only two representative examples are presented for clarity and space considerations, additional validation cases reported by [1] further support the applicability of the method across multiple fracture configurations.

The proposed approach provides a practical alternative to conventional interpretation techniques and extends the applicability of TDS to multiwell interference environments typical of unconventional reservoirs.

Introduction

Unconventional reservoirs have become a major contributor to global hydrocarbon production due to their large resource potential and the extensive use of multi-stage hydraulic fracturing in horizontal wells. In these systems, production performance depends primarily on the Stimulated Reservoir Volume (SRV), where flow occurs mainly through fracture networks rather than through the ultralow-permeability matrix. As a result, pressure interference between Multi-Fractured Horizontal Wells (MFHW) has emerged as a key indicator of fracture connectivity and reservoir communication within the stimulated region. Field observations in several shale developments have demonstrated that pressure interference between adjacent horizontal wells may occur much earlier than predicted by classical matrix diffusivity models. These early interference responses indicate that pressure propagation takes place preferentially through connected hydraulic fractures inside the SRV, providing direct evidence of fracture-driven communication between wells and highlighting the importance of fracture geometry and spacing in unconventional reservoir performance [2,3].

Numerical and semi-analytical studies further confirmed that interference behavior in shale reservoirs is strongly controlled by fracture-network connectivity rather than by matrix permeability. In particular, interference timing and pressure-derivative signatures depend primarily on fracture half-length, fracture conductivity, and interwell spacing, making interference testing a powerful diagnostic tool for evaluating hydraulic communication between MFHW systems, [4]. Analytical solutions describing pressure behavior between wells connected through a large hydraulic fracture demonstrated that pressure propagation along the connecting fracture generates characteristic linear-flow regimes identifiable in pressure-derivative responses. These regimes provide direct information about fracture connectivity and allow estimation of geometric fracture parameters governing interwell communication. Consequently, fracture-dominated interference responses differ fundamentally from classical radial interference observed in homogeneous reservoirs and require specialized interpretation methodologies adapted to unconventional systems, [4]. Pressure Transient Analysis (PTA) remains one of the most reliable techniques for estimating reservoir and fracture properties from well-test data. However, conventional straight-line and type-curve matching methods often become difficult to apply in unconventional reservoirs because multiple transient flow regimes -including bilinear and linear fracture flow- dominate early- and intermediate-time responses. To overcome these limitations, the Tiab's Direct Synthesis (TDS) technique was introduced as a practical interpretation methodology that allows direct estimation of reservoir parameters from characteristic features observed in pressure and pressure-derivative log-log plots without requiring iterative matching procedures, [5].

The extension of analytical interference solutions to fracture-connected horizontal wells created the possibility of interpreting pressure communication between wells using derivative-based diagnostics instead of numerical simulation or type-curve matching. In particular, the identification of linear-flow regimes associated with fracture-to-fracture communication provides a framework for estimating fracture length, conductivity, and connectivity directly from transient pressure responses [6]. More recently, these concepts were incorporated into the Tiab's Direct Synthesis (TDS) framework for unconventional reservoirs with multi-fractured horizontal wells. In this context, [1] derived interpretation expressions that allow estimation of connectivity-related parameters directly from interference signatures observed in pressure and pressure-derivative responses, extending the applicability of TDS to fracture-connected MFHW systems.

Building upon analytical interference models for fracture-connected wells and derivative-based interpretation techniques, the present work develops practical analytical expressions for reservoir characterization in unconventional formations. The proposed methodology provides a direct alternative for estimating fracture connectivity and flow parameters from transient pressure responses and extends the applicability of TDS to multiwell systems with hydraulic communication through connected fractures.

Mathematical Model

The analytical well interference models that describe the dimensionless bottom-hole pressure for two wells with two partially-interconnected hydraulic fractures are given by:

$$\bar{P}_{wD,A} = \frac{2\pi}{F_{CD,A}}\left(\frac{1}{s\sqrt{\lambda_A(s)}}\cdot\frac{f_1(s)+f_2(s)+f_3(s)}{f_4(s)+f_5(s)+f_6(s)}\right) \quad (1)$$

$$\bar{p}_{wD,B} = \frac{2\pi}{F_{CD,A}}\left(\frac{1}{s\sqrt{\lambda_B(s)}}\cdot\frac{g_1(s)+g_2(s)+g_3(s)+g_4(s)}{g_5(s)+g_6(s)+g_7(s)}\right) \quad (2)$$

where;

$l_A(s)$, $l_B(s)$ are spectral functions associated with the coupled problem
$f_i(s)$ y $g_i(s)$ are define in Table 1 & 2 from [4]

Other related variables and dimensional quantities are provided below:

Diffusivity coefficient in field units

$$\eta_{i,j} = 2.637\times10^{-4}\frac{k_{ij}}{(\phi c_t)_{i,j}\mu} \quad (3)$$

Dimensionless diffusivity coefficient, $\eta_i D_{,j}$

$$\eta_{iD,j} = \frac{\eta_{i,j}}{\eta_{I,A}} \quad (4)$$

where $\eta_{I,A}$ is the diffusivity coefficient of the inner reservoir associated with well A, and $\eta_{i,j}$ is the diffusivity coefficient of subregion i associated with well j.

Dimensionless time, pressure and pressure derivative

$$t_D = \frac{0.0002637\eta_{IA}t}{x_{FA}^2} \quad (5.a)$$

with t in hours, η_{IA} en ft^2/hr and x_{FA} in ft.

$$P_D = \frac{kh(P_i-P_{wf})}{141.2q\mu B} = \frac{kh\Delta P}{141.2q\mu B} \quad (5.b)$$

$$t_D * P_D' = \frac{kh(t*\Delta P')}{141.2q\mu B} \quad (5.c)$$

Dimensionless vertical distance

$$y_{eD,j} = \frac{y_{e,j}}{2x_{FA}} \quad (6)$$

measured from the horizontal symmetry boundary to the outermost boundary in the y-direction, $y_{e,j}$.

Dimensionless horizontal distance

$$x_{eD,j} = \frac{x_{e,j}}{2x_{FA}} \quad (7)$$

measured from the fracture to the outermost boundary in the x-direction, $x_{FD,j}$.

Dimensionless fracture width

$$w_{D,j} = \frac{w_{F,j}}{2x_{FA}} \quad (8)$$

Dimensionless fracture conductivity:

$$F_{CD,j} = \frac{K_{F,j}w_{F,j}}{K_{I,j}x_{F,j}} \quad (9)$$

Degree of interference coefficient:

$$\delta_w = \frac{\delta}{n_f} \quad (10)$$

defined as the ratio between fracture interference (*d*) and the total number of fractures.

Interference coefficient (*a*): is the well interference coefficient. α is a diagnostic parameter intended for history-matching data obtained from pressure-transient testing. α will be related to the number of fracture hits present in a given dual-MFHW system to obtain a normalized measurement of the degree of well interference. Mass flux from fracture A into fracture B occurs when *a*>0. Similarly, *a*<0 indicates flux from fracture B into A.

In this study, several dual Multi-Fractured Horizontal Well (MFHW) configurations were analyzed by generating pressure-versus-time data with the mathematical model proposed by [4]. Pressure-transient analysis in unconventional reservoirs allows the identification of different flow regimes governing system behavior throughout the productive life of the well.

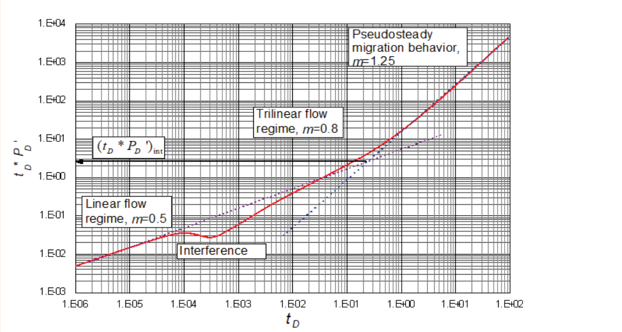

Figure 1: Dimensionless pressure derivative versus dimensionless time log-log plot displaying the different flow regimes.

This work presents an analytical model for evaluating interference between multi-fractured horizontal wells as a based to extend the TDS technique, in which several characteristic flow regimes are typically observed in pressure-derivative plots and can be used as diagnostic indicators of fracture connectivity and well-to-well interference behavior. Typically, different flow regimes are observed in the pressure-derivative plot, which help identify:

1. Fracture flow
2. Fracture-to-fracture or well-to-well interference
3. Matrix flow
4. Flow in unstimulated boundary regions

Figure 1 displays the possible flow regime found with [4] model. From this plot, the following observations are drawn:

Linear flow: The characteristic 1/2 slope observed in the pressure derivative helps estimate the effective fracture conductivity and fracture spacing, where fluid moves perpendicularly toward the hydraulic fracture. This regime is common in unconventional reservoirs and indicates that flow behavior is dominated by the geometry of the hydraulic fractures.

Fracture interference: When hydraulic communication exists between fractures, a V-shaped distortion appears in the pressure-derivative curve, indicating interference between adjacent fractures from different wells. This phenomenon occurs when fracture drainage areas overlap, affecting the pressure distribution and modifying the transient response of the system.

4/5 slope (0.8): This slope is not commonly reported in standard pressure transient analysis literature, as it is associated with a trilinear flow regime in which three types of flow coexist:

1. Linear flow within the fracture
2. Linear flow perpendicular to the fracture in the nearby matrix
3. Linear flow in the matrix farther away from the well

This slope of 4/5 (0.8) observed in the pressure derivative response is interpreted here as corresponding to a trilinear flow regime, consistent with the coexistence of linear flow within the fracture and linear flow contributions from adjacent matrix regions.

5/4 slope: The presence of a slope close to 5/4 (1.25) in the pressure derivative response is not commonly reported in the classical pressure transient analysis literature. However, in this study, this behavior was consistently observed under certain interference scenarios. It is important to note that the pseudo-steady migration regime associated with a 5/4 slope does not correspond to a physically classical flow regime. Instead, it represents an atypical diagnostic behavior identified within the analytical framework of the present model and is therefore treated here as an operational interpretation parameter rather than a conventional flow regime. As an interpretative hypothesis, this slope may be associated with complex flow behavior influenced by non-Euclidean geometries of the fracture system, possibly related to fractal-type structures. In this context, the 5/4 slope may be interpreted as the superposition of multiple flow regimes, where pseudo-steady-state flow components (unit slope) coexist with bilinear flow components (1/4 slope). Although this interpretation has not been explicitly reported in conventional literature, it is consistent with the complexity of flow behavior in highly fractured unconventional reservoirs. Nevertheless, this hypothesis requires further validation through numerical simulations or field data analysis and is therefore proposed here as a direction for future research.

Deviations from ideal late-time pressure behavior may occur under asymmetric or partially sealing boundary conditions, particularly when the reservoir is not fully closed and pressure communication with adjacent formations exists. These effects are consistent with boundary-dominated flow behavior as described in production and pressure transient analysis frameworks, [7].

TDS Technique Formulation

Interference Coefficient α. The interference coefficient αquantifies the degree of hydraulic communication between adjacent multi-fractured horizontal wells and represents a key parameter for characterizing fracture connectivity within the stimulated reservoir volume. In the analytical interference model of [4], this parameter controls the magnitude and direction of mass exchange between connected fractures and therefore governs the shape of the pressure-derivative response within the interference regime. Within the TDS framework, characteristic points identified on pressure derivative log-log plots can be used to derive direct expressions for reservoir parameters. In this work, a direct procedure was developed to estimate the interference coefficient from the minimum value of the pressure-derivative curve observed in the fracture-to-fracture interference region.

Dimensionless pressure derivative responses were generated for several values of the interference coefficient *a* = {0.2, 0.4, 0.6, 0.8}, Figure 2. Although the derivative curves exhibit different amplitudes, their geometric structure remains invariant within the interference regime. It was observed that multiplying the dimensionless pressure derivative by $a^{0.5}$ produces a geometric collapse of all curves into a single unified response in the interference region, see Figure 3. This invariance indicates that the interference minimum satisfies the scaling relation:

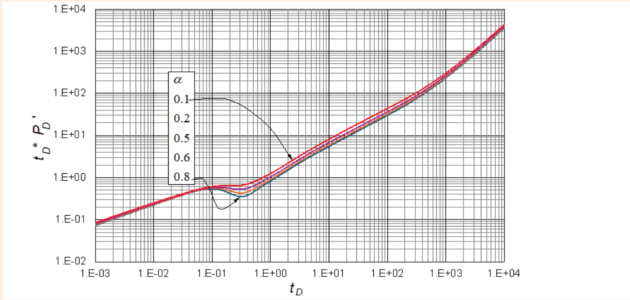

Figure 2: Dimensionless pressure derivative versus dimensionless time log-log plot for different *a* values.

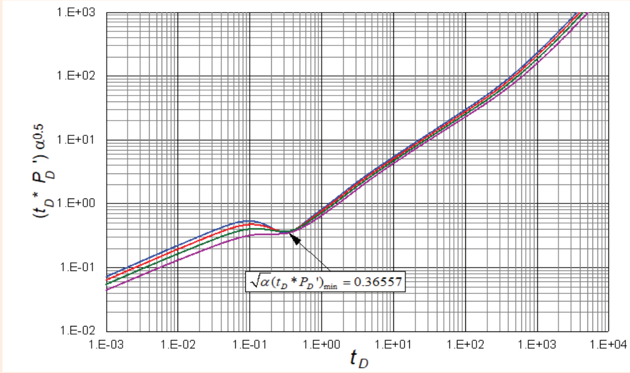

Figure 3: Unified dimensionless pressure derivative versus dimensionless time log-log plot for different values of *a*.

$$(t_D * P_D')\sqrt{\alpha}_{min} \quad (11.a)$$

Using the definition of the dimension\less pressure derivative (Eq. 5c), the interference coefficient can be expressed directly in field units as:

$$\frac{kh(t*\Delta P')_{min}}{141.2q\mu B\sqrt{\alpha}} \quad (11.b)$$

which provides a closed-form TDS expression for estimating the interference coefficient from the minimum derivative value without requiring type-curve matching or numerical inversion. This result establishes the minimum derivative point within the interference regime as a characteristic diagnostic feature for quantifying fracture-to-fracture communication in multi-fractured horizontal well systems.

$$\alpha = 2664.4179\left(\frac{q\mu B}{kh(t*\Delta P')_{min}}()^2\right) \quad (12)$$

Number of Connected Fractures. The number of fracture hits can be estimated from the interference coefficient using the following expression:

$$\delta_w = \delta / n_f \quad (13)$$

where:
d_w represents the effective fracture connectivity index,
d denotes the degree of interference (fracture his),
n_f is the total number of fractures.

In Multi-Fractured Horizontal Well (MFHW) systems, reservoir drainage efficiency is directly influenced by fracture connectivity. Based on the interference coefficient *a*, an analytical expression was developed to estimate the fraction of hydraulically connected fractures, allowing quantification of the impact of fracture interference on production performance. The relationship between the interference coefficient *a*, and the connectivity parameter d_w described using a Michaelis-Menten-type model, [8] as given by the following equation:

$$\delta_w = \frac{11.31\alpha}{F_{CD}^{0.1} x_f^{0.25} (0.50+\alpha)} \quad (14)$$

where F_{CD} is the dimensionless fracture conductivity and x_f is the fracture half-length.

This expression provided the best fit to the experimental data, achieving a coefficient of determination of R^2=0.9999 □ 1 (Figure 4). However, in order to adapt the equation to the specific characteristics of the system under study, additional adjustments were introduced to incorporate fracture-related properties. In particular, the model was multiplied by the fracture half-length x_f raised to the power of 0.25 and by the dimensionless fracture conductivity F_{CD} raised to the power of 0.1, see Figure 5. These modifications allow a more accurate representation of both geometric and transport effects governing system behavior.

Although empirical, these exponents reflect the sublinear influence of fracture geometry and conductivity on inter-fracture communication, consistent with diffusion-dominated flow and distributed pressure propagation within complex fracture networks. This adjustment ensures that the model preserves its capability to describe the characteristic rapid initial growth and subsequent saturation behavior of the interference coefficient *a*, while simultaneously incorporating the influence of fracture length and conductivity, thereby improving its applicability for reservoir characterization.

This equation makes it possible to distinguish between:

1. Connected fractures: fractures that exhibit effective pressure communication and actively contribute to hydrocarbon flow.
2. Partially connected (fractal-type) fractures: fractures with reduced hydraulic conductivity or limited interaction with other fractures within the system.

Furthermore, this equation allows:

1. evaluation of fracture interference in dual MFHW systems with 5, 10, 20, and 50 fracturing stages per well,
2. determination of optimal fracture spacing to maximize recovery,
3. identification of fractures with low connectivity and the design of optimization strategies for hydraulic fracturing treatments.

Degree of interference coefficient: For the evaluation of the degree of interference, the parameter *a*, the fracture half-length x_f, and the dimensionless fracture conductivity F_{CD} were correlated using the technical data reported by [4]. The interference coefficient *a*, which relates fracture length to stage spacing, was used to classify different interference scenarios. Based on the tabulated values extracted from [4], Table 1, several representative values of the interference coefficient *a* were selected to characterize low-moderate-and high-interference conditions and plotted in Figure 4. To validate the degree of interference estimated using Equation (14), the results were compared with those predicted by the analytical interference model proposed by [4].

Table 1: Different values of δ_w, [4].

F_{CD}	2055	F_{CD}	822	F_{CD}	548	F_{CD}	685
x_f	200	x_f	500	x_f	750	x_f	600
δ_w	α	δ_w	α	δ_w	α	δ_w	α
0.2000	0.0729	0.1000	0.0438	0.1000	0.0486	0.1000	0.0450
0.4000	0.1720	0.2000	0.0975	0.2000	0.1070	0.2000	0.1020
0.6000	0.3120	0.3000	0.1630	0.3000	0.1790	0.3000	0.1690
0.8000	0.5250	0.4000	0.2440	0.4000	0.2720	0.4000	0.2550
1.0000	0.8900	0.5000	0.3480	0.5000	0.3920	0.5000	0.3660
		0.6000	0.4820	0.6000	0.5580	0.6000	0.5150
		0.7000	0.6720	0.7000	0.7770	0.7000	0.7250
		0.8000	0.9490	0.8000	1.1600	0.8000	1.0400
		0.9000	1.3980	0.9000	1.8600	0.9000	1.5900
		1.0000	2.2470	1.0000	3.5240	1.0000	2.7800

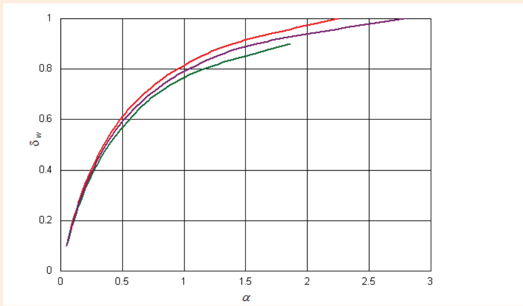

Figure 4: *a* versus d_w from Table 1.

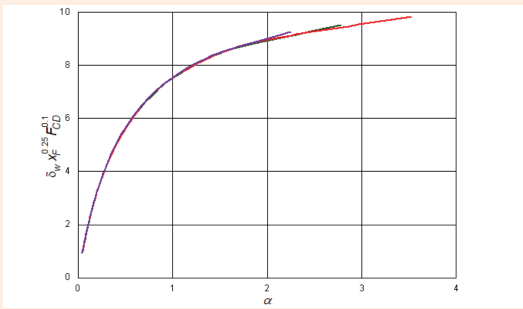

Figure 5: Unified curves for parameters x_f y F_{CD}.

Estimation of Hydraulic Fracture Half-Length. During the detailed analysis of the pressure and pressure-derivative responses obtained from the analytical simulations, a consistent local maximum in the pressure-derivative curve was identified after the linear flow regime characterized by a 1/2 slope on the log–log diagnostic plot (Figure 6). This feature appears systematically across the evaluated interference scenarios and fracture configurations. This behavior indicates that the derivative maximum represents a characteristic transition point in the system dynamics. Physically, this point corresponds to the progressive depletion of the dominant linear inflow toward the hydraulic fracture and the onset of a transition regime influenced by the effective fracture half-length and the evolving drainage geometry around the stimulated region. Figure 7 presents a unified pressure derivative behavior obtained from multiplication of the pressure derivative times de square root of the half-fracture length.

Based on this observation, the time associated with the derivative maximum, t_{max}, is proposed as a diagnostic parameter for estimating the hydraulic fracture half-length, x_f, using an expression analogous to the dimensionless-time formulation employed in the Tiab's Direct Synthesis (TDS) technique:

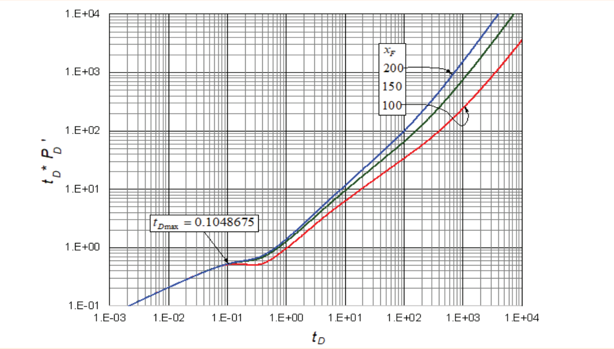

Figure 6: Dimensionless pressure derivative versus dimensionless time log-log plot for different values of X_f.

$$x_f \ \alpha \ \sqrt{\frac{kt_{max}}{\phi\mu c_t}} \quad (17)$$

Application of this formulation to the simulated datasets showed that the estimated values of x_f are in close agreement with the fracture half-length defined in the analytical model and remain consistent with those previously obtained from the linear-flow diagnostic window. This confirms that the derivative maximum provides a complementary and robust criterion for fracture-length estimation, particularly in cases where the 1/2-slope regime is poorly defined, shortened, or affected by interference effects between fractures or wells.

Therefore, the use of t_{max} extends the applicability of the TDS methodology by providing an alternative fracture-length estimator under complex multi-fracture interference conditions typical of MFHW systems. Then, from Figure 6:

$$t_{Dmax} \quad (18.a)$$

Replacing Equation (5.a) into Equation (18.a) yields:

$$\frac{0.0002637kt_{max}}{\phi\mu c_t x_f^2} \quad (18)$$

Solving for x_f:

$$x_f = \sqrt{\frac{0.002514Kt_{max}}{\phi\mu c_t}} \quad (19)$$

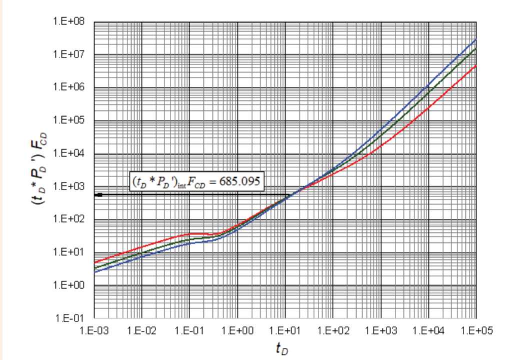

Figure 7: Unified dimensionless pressure derivative versus dimensionless time log-log plot for different values of x_F displaying a maximum point.

Dimensionless Fracture Conductivity (F_{CD}). It is a parameter that quantifies the relative capacity of a hydraulic fracture to transmit fluids compared with the ability of the formation to supply flow into the fracture. This parameter allows evaluation of whether well productivity is controlled primarily by fracture conductivity or by matrix permeability. Mathematically, F_{CD} is defined as:

$$F_{CD} = \frac{k_f \omega_f}{k_i x_f} \quad (20)$$

To reduce the uncertainty associated with identifying the linear flow regime, a graphical criterion based on slope intersection was applied following the classical Tiab's Direct Synthesis (TDS) framework. On the pressure-derivative log-log plot provided in Figure 1 & 7, two reference straight lines are constructed: (a) a line with slope 1/2, corresponding to linear flow, and (b) a line with slope 5/4 (1.25), associated with the transition toward the pseudo-steady migration regime. The intersection of these two lines defines a unique characteristic point of the system. From this point, a vertical projection is drawn to the pressure derivative curve, allowing direct determination of the corresponding dimensionless pressure-derivative value, $(t_D{*}P_D')_{int}$.

According to the Tiab's Direct Synthesis formulation, the dimensionless fracture conductivity can then be calculated from the dimensionless derivative evaluated at the slope-intersection point using the following expression:

$$(t_D * P_D')CD \frac{kh(t*\Delta P')_{int}}{141.2q\mu B_{CD}}_{int} \quad (21)$$

$$F_{CD} = \frac{96735.4179q\mu B}{h(t*\Delta P')_{int}} \quad (22)$$

where $(t{*}\Delta P')_{int}$ is the pressure derivative value read directly from the log-log plot at the characteristic point defined by the intersection of the 0.5 and 5/4 slopes. The application of this procedure allows estimation of F_{CD} with high accuracy, minimizing the subjectivity typically associated with the visual identification of extended flow-regime intervals. In addition, this approach is particularly robust in scenarios where the 1/2 slope exhibits oscillations or is observed over limited time windows, as commonly occurs in multi-fractured systems or in the presence of well interference.

The identification of characteristic points on the pressure derivative curve, rather than relying on extended regime intervals, enables extension of the TDS methodology and improves the estimation of key parameters such as fracture half-length and dimensionless fracture conductivity, even under conditions where interwell interference is present.

Synthetic Examples

Example 1

The simulated pressure derivative curve provided in Figure 8 was built with information from Table 2. The purpose of this example is to evaluate the interference coefficient between wells, varying within the range from 1 to 0.4.

The following information was read from Figure 8:

t_{max}=0.0001 days $(t*\Delta P')_{min}$= 0.02437 psi $(t*\Delta P')_{int}$=0.652 psi

Table 2: Input simulation values.

Parameter	Value	Parameter	Value
c_{tF}, 1/psi	$1x10^{-3}$	T, °R	640
c_t, 1/psi	$5x10^{-5}$	q_A, BPD	350
ϕ_F, %	15	q_B, BPD	200
μ, cp	0.7	k_{oF_A}, md	7000
k_{mA}, md	$1x10^{-5}$	k_{oF_B}, md	6000
h, ft	100	w_{FA}, ft	0.07
k_{o1}, md	10	w_{FB}, ft	0.06
ϕ, %	5	x_{FA}, ft	100
k_{o2}, md	10	x_{FB}, ft	150
B, rb/STB	1.35	η_{FA}	175800
C_{FDA}	4.9	η_{FB}	150685.7
C_{FDB}	2.4	X_{eA}, ft	5000
η_A	7534.286	X_{eB}, ft	5000
η_B	7534.286	Y_{eA}, ft	4000
η_M	7.534286	Y_{eB}, ft	2800
α	0.5		

Equation (12) allows calculation of the interference coefficient.

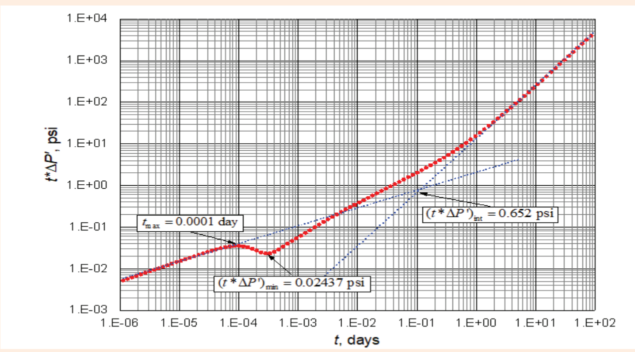

Figure 8: Pressure derivative versus time log-log plot for example 1.

$$\alpha = 2664.4179\left(\frac{(350)(0.7)(1.35)}{(7000)(100)(0.02437)_{min}}\right)^2 = 1.00$$

The degree of interference is calculated using Equation (14).

$$\delta_w = \frac{11.31(1.00)}{(490000)^{0.1}(100)^{0.25}(0.50+1.00)} = 0.6432$$

Next, the effect of the interference degree and the interference coefficient was evaluated for several MFHW configurations by varying the number of fractures, n_f, to 5, 10, 20, and 50. The parameter *d* was then calculated using Equation (13).

$$0.6432 = \frac{\delta}{5} \rightarrow \delta = 3.216$$

$$0.6432 = \frac{\delta}{20} \rightarrow \delta = 12.864$$

$$0.6432 = \frac{\delta}{10} \rightarrow \delta = 6.432$$

$$0.6432 = \frac{\delta}{50} \rightarrow \delta = 32.160.6432 = \frac{\delta}{50} \rightarrow \delta = 32.16$$

The estimation of the fracture half-length, x_f, is achieved with Equation (19).

$$x_f = \sqrt{\frac{0.002514(7000)(0.0001)}{(0.05)(0.7)(0.000005)}} = 100.28 \text{ ft}$$

The estimation of the dimensionless fracture conductivity F_{CD} is performed using Equation (22).

Table 3: Comparison for results for example 1.

Parameter	Input value	This study	Error (%)
α	1.00	1.00	0
x_f, ft	100.00	100.279	0.278
F_{CD}	490000	490724.532	0.1476

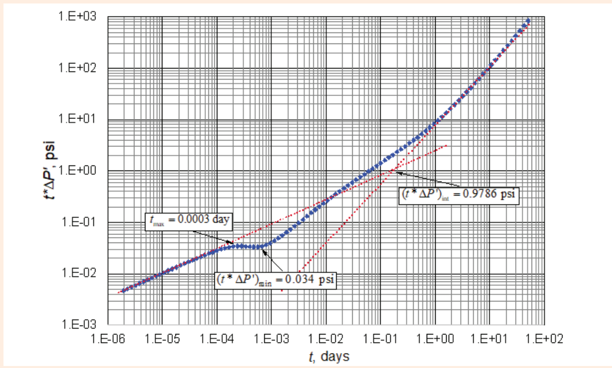

Figure 9: Pressure derivative versus time log-log plot for example 2 with x_f =150 ft,

$$F_{CD} = \frac{96735.4179(350)(0.7)(1.35)}{(100)(0.652)} = 490724.532$$

Results from this example are given in Table 3.

Example 2

Figure 9 reports a simulated pressure derivative curve which was built with information from Table 1. The purpose of this example is to evaluate the effect of F_{CD} and x_f. The following information was read from Figure 9:

t_{max}= 0.00028 days $(t*\Delta P')_{min}$= 0.034 psi $(t*\Delta P')_{int}$= 0.9786 psi

Equation (19) was used for the calculation of the fracture half-length x_f.

$$x_f = \sqrt{\frac{0.002514(7000)(0.0003)}{(0.05)(0.7)(0.00001)}} = 122.8 \text{ ft}$$

The estimation of the dimensionless fracture conductivity F_{CD} was performed using Equation (22).

$$F_{CD} = \frac{96735.4179(350)(0.7)(1.35)}{(150)(0.9786)} = 326949.67$$

The interference coefficient was calculated using Equation (12).

$$\alpha = 2664.4179\left(\frac{(350)(0.7)(1.35)}{(7000)(100)(0.034)}\right)^2 = 0.51$$

Next, a parametric analysis of the TDS methodology is performed, followed by the calculation of the degree of interference using Equation (14).

$$a_w = \frac{11.31(0.51)}{32666^{0.1}60^{0.25}(0.5+0.51)} = 0.458$$

Subsequently, the influence of both the interference degree and the interference coefficient was analyzed for several MFHW configurations by considering fracture counts, n_f, of 5, 10, 20, and 50. The corresponding values of the parameter *d* were then determined using Equation (13).

$$0.458 = \frac{\delta}{5} \rightarrow \delta = 2.29$$

$$0.458 = \frac{\delta}{10} \rightarrow \delta = 4.58$$

$$0.458 = \frac{\delta}{20} \rightarrow \delta = 9.16$$

$$0.458 = \frac{\delta}{50} \rightarrow \delta = 22.9$$

Results from example 2 are provided in Table 4.

Table 4: Comparison for results for example 2.

Parameter	Input value	This study	Error (%)
α	0.50	0.51	2.00
x_f, ft	150	122.8	18.1
F_{CD}	326666	326949.67	0.086

Results Analysis

Identification of characteristic diagnostic points in the pressure-derivative response

The interpretation methodology proposed in this work is based on the identification of characteristic points in the pressure-derivative response associated with fracture-to-fracture interference between Multi-Fractured Horizontal Wells (MFHW). Unlike conventional pressure transient analysis, which relies on extended flow regimes, the Tiab's Direct Synthesis (TDS) approach allows parameter estimation directly from diagnostic derivative features observed on log-log plots.

As illustrated in Figure 1, the derivative response exhibits a sequence of characteristic slopes associated with fracture-dominated flow behavior. In particular, the linear-flow regime identified by a slope of 0.5 provides the reference framework for estimating fracture-related parameters, while the interference region is characterized by a V-shaped distortion that reflects hydraulic communication between adjacent fractures. The transition toward later-time responses frequently includes a diagnostic behavior approaching a slope near 5/4, which is interpreted here as an operational indicator of pseudo-steady migration effects within the connected fracture network. These characteristic derivative signatures define the diagnostic points used throughout the present methodology for estimating the interference coefficient, the number of connected fractures, the fracture half-length, and the dimensionless fracture conductivity.

Estimation of the interference coefficient

The interference coefficient *a* quantifies the degree of hydraulic communication between fractures belonging to adjacent horizontal wells and represents one of the key parameters controlling the derivative response within the interference regime. Dimensionless derivative curves generated for several values of *a* demonstrate that, although their amplitudes vary, their geometric structure remains invariant within the interference region (Figure 2). When the dimensionless derivative is multiplied by $a^{0.5}$, all curves collapse into a single unified response (Figure 3), confirming the existence of a scaling relation governing the interference minimum.

This invariant behavior allows the minimum derivative value to be used as a characteristic diagnostic point for estimating the interference coefficient through Equation (12). Application of this formulation to Example 1 produced values of *a* consistent with the connectivity conditions imposed in the analytical interference model, confirming the reliability of the minimum derivative as a robust estimator of fracture communication intensity.

Estimation of the number of connected fractures

Once the interference coefficient is determined, the number of fracture hits can be estimated through the connectivity index d_w using Equation (13). This parameter represents the fraction of hydraulically connected fractures relative to the total number of fractures present in the system. The relationship between *a* and d_w follows a Michaelis-Menten-type functional behavior, as expressed by Equation (14), incorporating both fracture geometry and transport effects through the fracture half-length and the dimensionless fracture conductivity.

Application of this formulation to the first example allowed estimation of the effective number of connected fractures for several assumed fracture distributions. The results confirm that the connectivity index increases consistently with the interference coefficient, reflecting the progressive overlap between fracture drainage regions as hydraulic communication intensifies.

Estimation of fracture half-length

The fracture half-length x_f was estimated from the characteristic maximum observed in the pressure derivative response following the linear-flow regime. This diagnostic point represents the transition from fracture-dominated linear flow toward a geometry-controlled flow regime influenced by the effective fracture extension within the stimulated reservoir volume. The corresponding estimation was performed using Equation (19), which relates the fracture half-length to the derivative maximum through the dimensionless time formulation consistent with the classical TDS framework.

Application of this procedure to Example 2 yielded fracture half-length values in close agreement with those defined in the analytical model used to generate the synthetic derivative response. This result confirms that the derivative maximum constitutes a reliable diagnostic feature for estimating fracture geometry, particularly in scenarios where the 0.5 slope associated with linear flow is partially obscured or limited in duration due to interference effects.

Estimation of dimensionless fracture conductivity

The dimensionless fracture conductivity F_{CD} was determined from the characteristic intersection point between the 0.5 and 5/4 slopes identified on the pressure-derivative log-log plot. This intersection defines a unique diagnostic point representing the transition between linear-flow-dominated behavior and interference-controlled migration effects within the connected fracture system.

According to Equation (22), the dimensionless fracture conductivity can be expressed directly as a function of the pressure-derivative value evaluated at this characteristic point. The use of slope intersection criteria reduces the uncertainty associated with visual identification of extended linear-flow intervals and provides a more stable estimation procedure under complex interference conditions. Application of this formulation to the analyzed examples produced conductivity values consistent with the transport characteristics imposed in the analytical interference simulations, confirming the robustness of the proposed interpretation workflow.

Validation of the proposed methodology

The proposed TDS-based interpretation procedure was applied to multiple MFHW interference scenarios during the development of the analytical formulation. However, only two representative examples are presented here due to space limitations. These examples illustrate the complete workflow required to estimate fracture connectivity parameters directly from pressure-derivative diagnostic features.

A more extensive set of application example, including additional fracture distributions and inter-ference configurations, is documented in [1], where the consistency of the proposed interpretation expressions was verified across multiple synthetic scenarios generated with the analytical interfer-ence model of [4].

The agreement observed between analytical model inputs and TDS-estimated parameters confirms that characteristic derivative points provide reliable estimators of fracture half-length, connectivity intensity, and dimensionless fracture conductivity in hydraulically connected MFHW systems. Overall, the results demonstrate that the extension of Tiab's Direct Synthesis to fracture-connected horizontal wells provides a practical and physically consistent methodology for interpreting interference behavior in unconventional reservoirs without requiring type-curve matching or numerical inversion procedures.

Conclusion

This work presents an extension of the Tiab's Direct Synthesis (TDS) methodology for interpreting pressure interference between hydraulically connected Multi-Fractured Horizontal Wells (MFHW) in unconventional reservoirs using characteristic features identified in pressure-derivative log-log responses. Based on the results obtained, the following conclusions are drawn:

1. The minimum pressure-derivative value observed within the interference regime provides a reliable diagnostic point for estimating the interference coefficient *a*, which in turn allows determination of the connectivity index d_w and the number of effective fracture hits *d*, This approach enables direct quantification of fracture-to-fracture hydraulic communication without requiring type-curve matching or numerical inversion.
2. The maximum observed in the pressure-derivative response after the linear-flow regime constitutes a robust diagnostic criterion for estimating the hydraulic fracture half-length x_f, particularly in scenarios where the classical 0.5 slope interval is partially masked or shortened by interference effects.
3. The intersection between the diagnostic slopes 0.5 and 5/4 in the pressure-derivative log-log plot defines a characteristic transition point that can be used to estimate the dimensionless fracture conductivity F_{CD}, reducing uncertainty associated with the identification of extended linear-flow regimes in complex interference environments.
4. Application of the proposed methodology to representative MFHW interference scenarios demonstrates that characteristic derivative points can replace conventional regime-matching procedures and provide physically consistent estimates of fracture connectivity and transport parameters. Although only two representative examples are presented here for clarity and space limitations, additional validation cases covering multiple fracture configurations are documented in [1], confirming the robustness and applicability of the proposed interpretation framework.

References

1. Sánchez-Murcia W (2026) Application of Tiab's Direct Synthesis (TDS) in the characterization and optimization of unconventional reservoirs with Multi-Fractured Horizontal Wells (MFHW) [Universidad Surcolombiana]. Universidad Surcolombiana, Facultad de Ingeniería, Colombia.
2. Awada A, Santo M, Lougheed D, Xu D, Virues C (2016) Is that interference? a work flow for identifying and analyzing communication through hydraulic fractures in a multiwell pad. SPE Journal 21(05): 1554-1566.
3. Yu W, Wu K, Zuo L, Tan X, Weijermars R (2016) Physical models for inter-well interference in shale reservoirs: Relative impacts of fracture hits and matrix permeability. URTEC-2457663-MS.
4. Molina O, Zeidouni M (2017) Analytical approach to determine the degree of interference between multi fractured horizontal wells. SPE Europec Featured at 79th EAGE Conference and Exhibition. D031S007R003-682.
5. Tiab D (1995) Analysis of pressure and pressure derivative without type-curve matching-Skin and wellbore storage. Journal of Petroleum Science and Engineering 12(3): 171-181.
6. Escobar FH, Prada-Moreno EF, Suescún-Díaz D (2021) Interpretation of pressure interference tests for wells connected by a large hydraulic fracture. Journal of Petroleum Exploration and Production Technology 11: 3255-3265.
7. Blasingame TA, Lee WJ (1988) The variable-rate reservoir limits testing of gas wells. SPE-17708-MS.
8. Michaelis L, Menten ML (1913) Die kinetik der invertinwirkung. Biochemische Zeitschrift 49: 333-369.

Nomenclature

c_t	Total sistema compressibility, psi^{-1}
F_{CD}	Dimensionless fracture conductivity
k	Permeability, md
h	Reservoir thickness, ft
n_f	Number of fractures
P	Pressure, psi
q_t	Total Flow rate, bpd
r_w	Wellbore radius, ft
t	Time, hr
P_{wf}	Well-flowing pressure, psi
x_e	Horizontal distance, ft
y_e	Vertical distance, ft
s	Laplace parameter
x_F	Fracture length, ft
Y_E	Reservoir length, ft
$t^*\Delta P'$	Pressure derivative, psi
$t_D{}^*P_D{}'$	Dimensionless pressure derivative

Greek

α	Interference coefficient
Δ	Drop
d	Fracture interference
*d*w	Degree of interference coefficient
h	Diffussivity
ϕ	Porosity
m	Viscosity, cp

Sufixes

A	Well A
B	Well B
D	Dimensionless
F	Fracture
i	Sub-region, initial

I	Inner
int	Intercept
j	Well number
L	Linear
max	Maximum
min	Minimum
pss	Pseudosteady-state
o	Outer
wf	Well-flowing