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Well Stimulation Technique Hydraulic Fracturing Method by PKN & KGD Models of Equations

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Abstract

Many wells are stimulated to enhancement productivity and recovery; two types of oil field stimulation procedures are typically used: hydraulic fracturing and acid fracturing. Well stimulation technology has been successful in improving hydrocarbon recovery.

Hydraulic fracturing is a well stimulation technique that involves increasing the average permeability in the well's drainage area, the procedure involves injecting a fluid at a higher pressure than the formation fracture pressure into the surrounding formation to be treated, this research is based on existing hydraulic fracturing length and width models(PKN, KGD)

The goal of this study is to design a hydraulic fracturing well in the Zelten dolomite formation at Sirte basin in Libya, also evaluation of the reservoir characteristics and fluid treating properties, as well as treating circumstances that have the greatest impact on fracture dimensions(length, width and height)

We will be able to put up a unified design injection parameters and correct design model for fracturing future wells in this formation by researching diverse reservoirs in this formation.

Keywords: wells, oil field, Hydraulic fracturing, stimulation, PKN, KGD, Libya.

Introduction

Well stimulation is routinely conducted to increase productivity, many wells are either proppant or acid fractured.

The use of various fracturing methods for stimulation of routinely stimulated by fracture, Concurrent with the wells has become a common procedure in the oil and gas.

Hydraulic fracturing, commonly known as fracking, and hydro fracturing is a well stimulation technique that involves the use of a pressurized liquid to fracture bedrock formations and desire for increased production is the need to optimize treatment industry, fracturing treatments are performed on wells of design and to predict well response following treatment, varous potentials to help increase production or Injectivity.Hydroulic fracuring process are shown in figure 1.

In addition to modblling the growth of the hydraulic be expected. This is true regardless of whether the stimulation fracture, treatment design is further complicated by the fact that method Is hydraulic fracturing with proppants or fracture.[1]

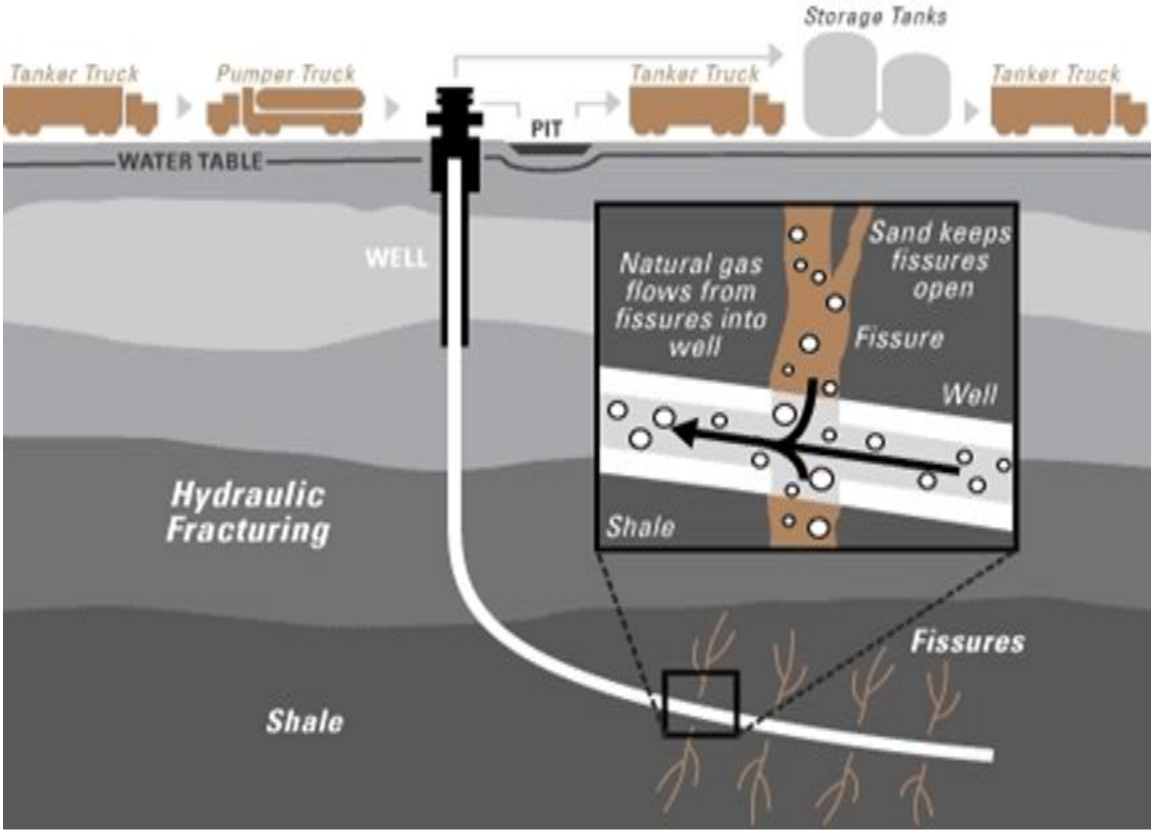

Figure 1. Hydraulic Fracture process.[1]

Hydraulic Fracturing Purpose:

- Increase the flow rate of oil and/or gas from low permeability reservoirs.
- Increase the flow rate of oil and/or gas from wells that have been damaged.
- Connect the natural fractures and/or cleats in a formation to the wellbore.
- Decrease the pressure drop around the well to minimize sand production.
- Decrease the pressure drop around the well to minimize problems with asphaltin or paraffin deposition.
- Increase the area of drainage or the amount of formation in con-tact with the wellbore. .[2]

Fracture Mechanism:

Fracture Mechanism can be divided into two steps:

1. Initiation Fracture.

2. Extension Fracture.

1- Initiation Fracture:

A hydraulic fracture treatment is accomplished by pumping a suitable fluid into the formation at a rate faster than the fluid can leak off into the rock.

Compressive stress of the rock when fracture initiation pressure depends on:

- Pressure of injection fluid.
- The rock type of formation.
- Pump at the surface.

2- Extension Fracture:

As injection of fracturing fluid continues, the fracture tends to grow in width as fluid pressure in the fracture, exerted on the fracture face, works against the elasticity of the rock material. .[2]

Hydraulic Fracturing Models:

In fracture modeling, the objective of the treatment must be kept in mind, do we want a long fracture, or do we need the fracture to be wide and short.

If a complete review of the reservoir flow and mechanical properties is conducted and realistic estimates of production have been forecasted, then the answers to these questions should be obvious accordingly, fracturing fluid, pumping rate, proppant/acid amount, and concentration are chosen. During this early period of hydraulic fracturing, two simple models were proposed to try to predict the shape and size of a hydraulic fracture.

Generally KGD and PKN models are essentially two dimensional plane strain formulations with fluid flow only along the length (or radius) of the fracture. [3]

Perkins and Kern Model of a Vertical Fracture (PKN):

Perkins and Kern (1961) assumed that a fixed height vertical fracture is propagated in a well confined pay zone; the stresses in the layers above and below the pay zone are sufficiently large to prevent fracture growth out of the pay zone. They further assumed the conditions as shown in Figure2, that the fracture cross section is elliptical with the maximum width at a cross section proportional to the net pressure at that point and independent of the width at any other point (i.e., vertical plane strain). Although Perkins and Kern developed their solution for non-Newtonian fluids and included turbulent flow, it is assumed here that the fluid flow rate is governed by the basic equation for flow of a Newtonian fluid in an elliptical section. [3] [4]

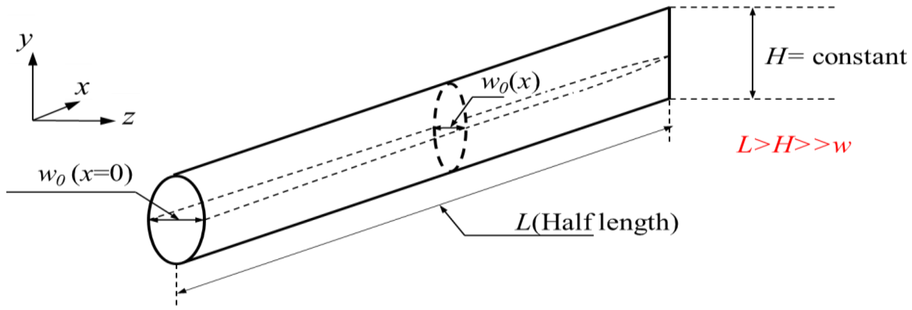

Figure 2: PKN fracture schematic diagram. [4]

Khristianovich-Geertsma-De Klerk Model (KGD):

Khristianovich and Zheltov (1955) generalized to a medium with stress contrast, and the original P3D model. TheKGD fracture model is shown in Figure3.

considers plane-strain conditions in cross sections orthogonal to the fracture front. It is commonly referred to the initial stage of fracture propagation, the second, known as the PKN model, assumes plane-strain conditions in cross sections parallel to the front; it is applicable at distances far enough from the front. Emphasize that the both models employ the same plain-strain elasticity equation by Muskhelishvili, which connects the opening of a straight crack with traction on its shores and stresses at infinity.[3] [4]

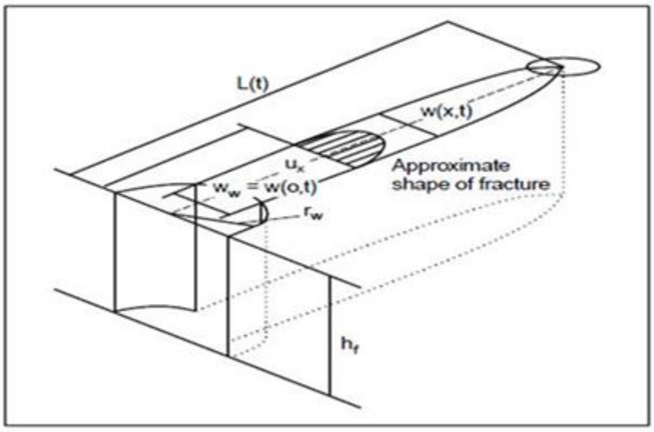

Figure3: KGD fracture model [3] [4]

Types of Hydraulic Fracturing:

Hydraulic fracturing is used to create additional passageways in the oil reservoir that can facilitate the flow of oil to a producing well.

There are two types of Conventional Hydraulic Fracturing:

- Vertical fracture
- Horizontal fracture

Wells used for hydraulic fracturing are drilled vertically, vertically and horizontally, or directionally

Wells may extend to depths greater than 8000 feet or less than 1000 feet, and horizontal sections of a well may extend several thousands of feet away from the production pad on the surface. [5] [6]

Hydraulic Fracturing Fluids:

The fracturing fluid is a critical component of the hydraulic fracturing treatment, fracturing fluid pumped during the process is generally in a turbulent flow in the well bore and perforations, and in laminar flow in the fracture. [7]

To select the fracturing fluid for a specific well, it is necessary to understand the properties of the fluid and how these properties may be modified to accomplish desired effects. [8] [9]

The fracturing fluid has two major functions:

1- Open and extend the fracture.
2- Transport the proppant along the fracture length.

Hydraulic Fracturing Proppants:

Proppants are used to hold the walls of the fracture apart to create a conductive path to the wellbore after pumping has stopped and the fracturing fluid has leaked off.

The ideal propping agent will be strong, resistant to crushing, and resistant to corrosion, have a low density, and readily available at low cost moreover the propping agent will be higher in permeability than the surrounding formation. [10] [11]

Proppants have the following primary functions

1- Used to prevent the fractures from closing when the injection of the pump has stopped
2- Used to allow the ease of reservoir fluid to flow into the wellbore.

Case Study

Initially three wells B01, B03 and B04 were drilled in Zelten-A formation and put them on production early in 2003. B16 was drilled in April 2008 as a first development well in ZELTEN-A suggested by Phase II Development Plan study.

Between 2008 and 2009, six wells had been drilled namely; B18, B19, B20, B21, B22 & B23.

B18 and B19 have been completed as PADF and dumping in total 900 PWPD, B20, B21 & B22 are completed initially as Producers. B20 started producing in September 2010 with initial oil rate of 700 BPD, the well then stabilized at rate of 420 BPD with no water cut, whereas both B21 and B22 were producing about 350 BOPD for few months before stopped producing any fluid to the surface, artificial lift was suggested for these wells to be produced for another period of time before it can be finally converted to PADF wells. Figure4 Shows wells of Zelten-A formation

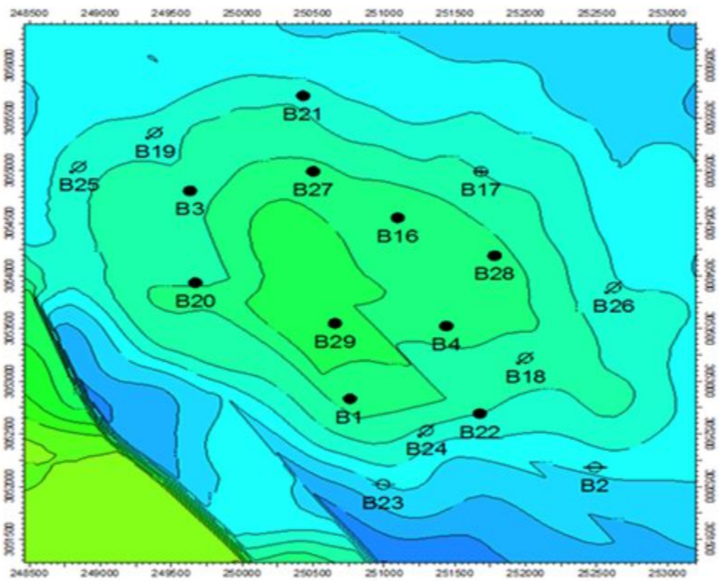

Figure 4. Wells of Zelten-A formation

Field Location Map

The En Naga North and West fields are situated in a sub area of the old concession NC177, in the En Naga sub basin of the Sirte Basin, Libya, 200km south of Ras-Lanuf. The En Naga Field can be split into En Naga North and West, this sub area is now referred to as the Exploitation Area NC177. It has been producing oil from the Eocene and Palaeocene reservoirs that comprise the field since February 2003.

The En Naga North field has three major pools,In the north, there are the Gir-North and Zelten A reservoirs and in the west is the Gir-West reservoir, which is the smallest of the three. Field Location Map is shown in Figure 5.

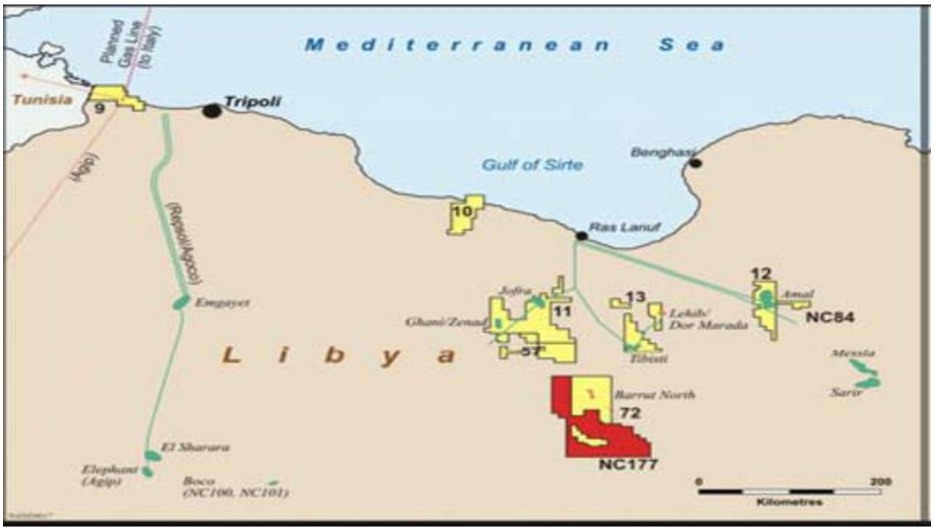

Figure 5. Field Location Map

Producion history

The wells, which is part of the Zelten-A formation, began producing in July 2009 at a rate of 350 BPD with no water cut. Production History of Zelten-A formation is shown in Figure 6.

Six wells were drilled between 2008 and 2009, notably B18, B19, B20, B21, B22, and B23. B20 began producing in September 2010 with an initial oil rate of 700 BPD, before stabilizing at 420 BPD with no water cut. The maximum oil rate was 700 BPD with increasing W.C. The last known oil rate was roughly 350 BPD.

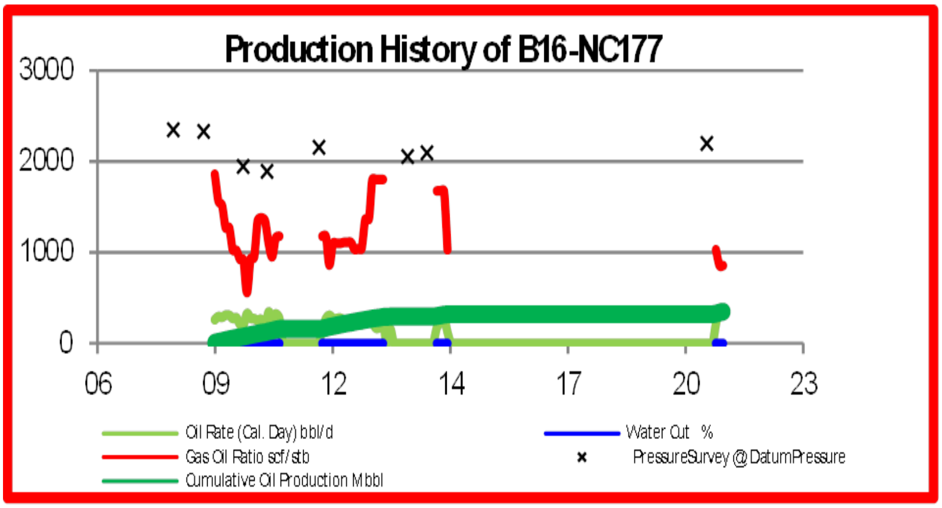

Figure 6. Production History of Zelten-A formation

The Methodology of the process:

The data that was received was used to calculate and compare the bottom hole pressure and the producing rate of oil for this well, before and after a hydraulic fracturing operation:

- Hydraulic Fracturing Design Procedure
- Calculation of Minimum Fracturing Pressure
- The Fracture Volume (Fracture Dimensions)
- The Well's Production Analysis (IPR Curves)
- Calculation of Production Increase (McGuire & Sikora)
- Fracture Conductivity using Propped Fracture Permeability Curves
- Calculation of Wellhead Injection Pressure (Pw)

Data Required for Hydraulic Fracturing Design:

Input data are shown in Table1.This data is then used to design and optimize fracture treatment, During the optimization process, sensitivity studies on placement of perforations, treatment size and fluid and proppant volumes are performed.

Table 1:Data Required

Producing Interval:	**5561-6310**	**ft**
Formation Thickness:	**46.0**	**ft**
Depth:	**6310**	**ft**
Average Reservoir Pressure:	**2,195.0**	**psi**
Horizontal Tensile Strength of Rock:	**705**	**psi**
Reservoir Oil Compressibility:	**1.253E-05**	**psi^{-1}**
Reservoir Water Compressibility:	**2.300E-05**	**psi^{-1}**
Reservoir Gas Compressibility:	**5.300E-04**	**psi^{-1}**
Oil Saturation	**72.4**	**%**
Water Saturation	**27.6**	**%**
Gas Saturation	**0**	**%**
Formation Porosity:	**23**	**%**
Formation Permeability:	**4**	**md**
Matrix Compress. Transient Time (Δt_{ma}):	**55.5**	**μsec**
Matrix Shear Transient Time (Δt_{sma}):	**88.0**	**μsec**
Fracturing Fluid Viscosity:	**40**	**cp**
Fracturing Fluid Density:	**8.36**	**ppg**
Reservoir Oil Viscosity:	**0.298**	**cp**
Area of Filter Medium:	**22.8**	**cm^2**
Slope of Fluid Loss Curve at Lab.:	**1.80**	**$cm/min^{½}$**
Filtration Pressure at Lab.:	**100**	**psi**

Casing Outer Diameter:	9.625	in
Wellbore Diameter:	12.25	in
Drainage Diameter:	2565	ft
Proppant Size and Type:	20/40	mesh
Porosity of Packed Proppant:	35	%
Specific Gravity of Proppant:	2.63	#
Fracturing Fluid Fpurt Foss	0.010	gal/ft^2
Tubing Inner Diameter	2.991	in
Tubing Depth	6,257	ft
Gas Oil Ratio	821	scf/bbl
Bubble Point Pressure	1,818	psi
Bottom Hole Temperature:	176	°F
Skin Factor before Fracturing (assume):	20	#
Perforation Diameter:	0.25	in
Perforation Discharge Coefficient:	0.87	#
Number of Perforations:	100	#
Closure Stress:	6,710	psi
Well Spacing:	70	acres
Frictional Pressure Gradient inside Tubing:	0.1501	psi/ft
Oil Formation Volume Factor:	1.6751	bbl/STB

Assume: hf=h, qi= bbl/min Vi= bbls

Type of Completion is a Cased Hole.

Hydraulic Fracturing Design Procedures:

In this section will present the main data required for hydraulic fracture design and design procedure steps; (i. e. step by step).

Calculation the Formation Fracturing Pressure including

1-Initiation Fracturing Pressure (P_f):

- The overburden pressure ($P_{ob} = \sigma_v$):

$$P_{ob} = G_{ob} \times D$$

- The minimum fracturing pressure (P_f):

$$P_f = \frac{2 \times \left(\frac{\nu}{1-\nu}\right)(P_{ob} - P_P) + T_o}{2 - \alpha\left(\frac{1-2\nu}{1-\nu}\right)} + P_P$$

2-Calculation of Minimum Fracturing Pressure (P_f):

- The extension pressure ($P_{frac} = \sigma_{h(min.)}$):

$$P_{frac.} = \left(\frac{\nu}{1-\nu}\right) \times (\sigma_V - P_P) + P_P$$

3-Calculation the Effective Fracturing Fluid Coefficient:

$$\Delta P_{\,(closure\ stress)} = P_f - P_P$$

4-The Fracture Volume (Fracture Dimensions):
Assume (q_i = bbl/min), and (V_i = bbls):

- Pumping time (t_p):

$$t_p = \left(\frac{V_i}{q_i}\right)$$

5-Calculation of Fracturing Efficiency (Eff):

- Calculate fracture volume (V_f):

$$V_f = \left(\frac{\pi}{2}\right) L\, W_W\, h_f$$

Vf = 313 ft^3

- The fracture efficiency (Eff):

$$Eff = \left(\frac{V_f}{V_i}\right) \times 100$$

Eff = 31.0 %

6-The Well's Production Analysis (IPR Curves):

Production of (IPR) Curve before Fracturing:

- Productivity Index ($PI=J_o$) by using Darcy's law:

$$q_o = \frac{7.08 \times 10^{-3} \, k \, h (P_e - P_{wf})}{\mu_o B_o \left[Ln(r_e / r_w) \right]}$$

PI = 0.77 BPD/psi

Fracture half-length VS fracture width (KGD) is shown in Figure 7.

Production of (IPR) Curve after Fracturing:

- Productivity ratio (J_f / J_o):

$$\frac{J_f}{J_o} = 3.33$$

$$\frac{J_f}{J_o} = \left(\frac{q_f}{P_e - P'_{wf}} \right) \Big/ \left(\frac{q_e}{P_e - P_{wf}} \right)$$

The Process of Output Data:

This section introduces the main results obtained from this study and discussions from this study was divided into:

1- The Formation Fracture Pressure:

A- Calculation of Initiation Fracturing Pressure (Pf):

» The minimum fracturing pressure (Pf):

Pf = 3,884 ps

2- The Effective Fracturing Fluid Coefficient:

» The total control coefficient (CT):

CT = 0.00215 ft/min½

3- The Fracture Volume (Fracture Dimensions):

» The fracture width (W_W) and length (L) by using **KGD** Model:

Ww= 0.265 In L =385 ft

» The fracture volume (V_f):

Vf= 615 ft

» The fracture width (W_W) and length (L) by using **PKN** Model:

W_W =0.17 in L =415 ft

» The fracture volume (V_f):

V_f =425 ft^3

Fracture half-length VS fracture width (PKN) is shown in Figure 8.

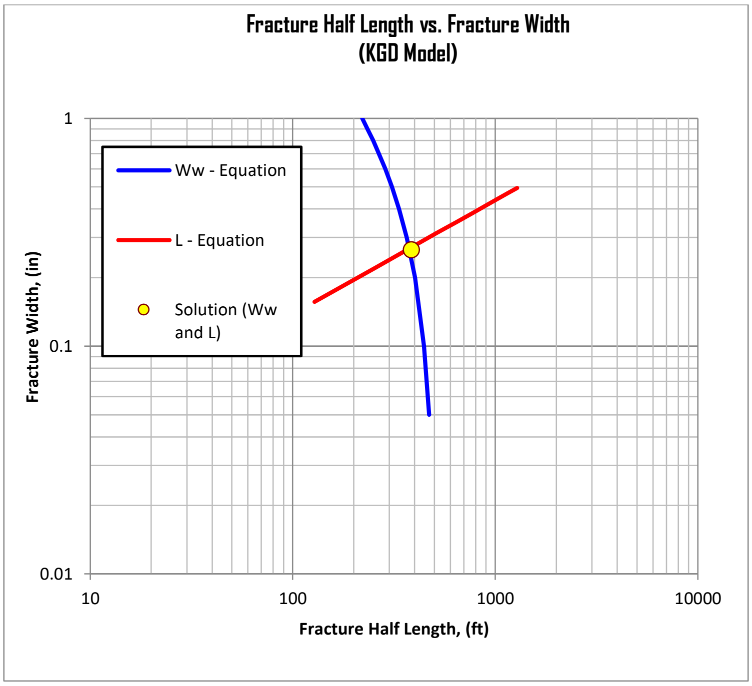

Figure7: Fracture half-length VS fracture width (KGD)

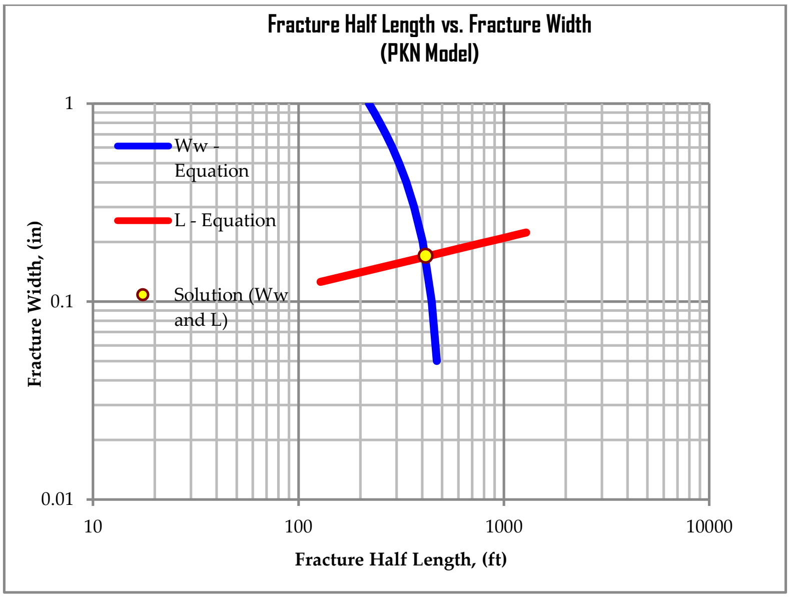

Figure: 8 Fracture half-length VS fracture width (PKN)

» Production of IPR Curve after Fracturing:

Productivity ratio (J_f / J_o):

Jf / Jo = 4.11 ratio

Production of IPR Curve after Fracturing is shown in Figure 9.

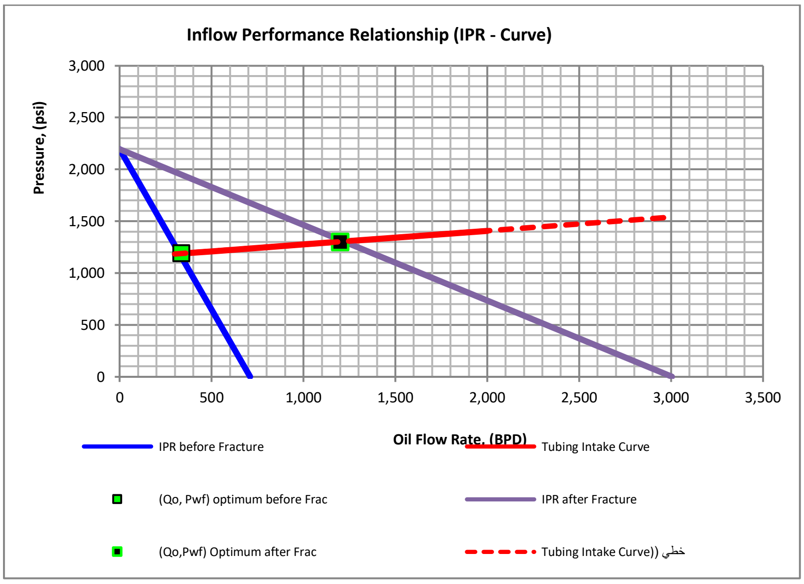

Figure9:Production of IPR Curve after Fracturing

Conclusion:

Evaluating the hydraulic fracturing for this study has indicate that production rate was increased by comparing the flow rate and bottom flowing pressure. the producing rate and the bottom hole flowing pressure before fracturing was:

- $Q_{optimum}$ (before fracturing) $= 335\ bbl/day$

- $P_{wf_{optimum}}$ (before fracturing) $= 1190\ psi$

After the hydraulic fracturing treatment was applied, the producing rate was greatly increased to a value of:

- $Q_{optimum}$ (after fracturing) $= 1200\ bbl/day$

- $\acute{P}_{wf_{optimum}}$ (after fracturing) $= 1300\ psi$

The increase in productivity is = 3.6 times better.

Recommendations

We should study various reservoirs in this formation to be able to develop a unified design injection parameters and a correct design model for fracturing future wells in this formation.

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