Determination of Drainage area in naturally fracture reservoir for vertical well:

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Abstract:

Today with the advances in scientific abilities in predicting the controllable factors in optimizing and success of industrial projects, the need to make a future with simulation and programming in the current important and influential industry in world finance is inevitably felt.

With the introduction of the related simulations and software in oil industry, it becomes utterly important to have precise information about what will happen before the digging process including the digging itself, production and reservoir simulation.

In this article, prediction of the physical shape of the reservoir, named Drainage area, is discussed. Knowing about the radius of investigation in wells we can find out useful information regarding the boundaries, distribution of pressure in boundaries and the way of direct usage of the basic simulation calculation equation.

The history of investigating this parameter goes back to 1960s. With the complementary efforts of Dietz a table was found for the shape of the reservoirs. However, based on the needs of the Persian Gulf countries that our oil reservoirs are placed in formations with natural fracture, calculating this parameter in this reservoir with the use of that table was wrong and will result in unreliable answer.

Therefore, we need to calculate this parameter for fractured reservoirs.

Generally, in fundamental equation in reservoir engineering, two parameters of C_A and A named Shape Factors and Drainage area, entered the equation simultaneously or the equation are defined based on r_e parameter that gives us the wrong understanding of the boundaries of the reservoirs with the simplification of a cylinder.

It worth noticing that the investigation of drainage is possible only if the shape of the reservoir is found. The method of finding C_A is using continuous equation of image wells that will not be investigated in this article.

Few studies were done on investigating A and C_A in NFR. However, the shortcoming of all these articles is using pure mathematical methods and transporting functions for forming fundamental equation or using converging reservoir method for the NFRs.

The purpose of this article is calculating A and C_A with the help of physical models and using regular experiments on wells to find A and C_A. We use IPR curve and well test in parallel.

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Keyword:

NFR: natural fracture reservoir, MBH method: Matthews, C.S, Browns F and Hazerbroek method, A: drainage area, C_A: shape factor

1. Introduction*:*

Prediction of production and shape of reservoir provide us with useful information about boundaries, distribution pressure and the place of nearby wells. Also, it affects reservoir characteristic equations which are the basis of simulators.

Generally, in the given fundamental equation in reservoir engineering, either the two parameter of C_A and A entered the equation simultaneously are the defined base on the r_e parameter.

The articles and methods presented to calculate C_A and A in homogenous reservoirs about NFR reservoir are problematic. These problems are related to the complex behavior and simulation assumption of doula porosity reservoir.

However, NFR reservoir is formed in the period that the pressure curve touched the boundaries and the flow is pseudo steady state. Luckily, The NFR [14] reservoir in this period performance like homogenous reservoir. The table for C_A in the continues equation of image well for superposition build up method is resulted by reservoir engineering which is registered by Dietz[8] and his colleagues, this is the main source for measuring C_A.

From 1970s on, some methods of calculating C_A have been registered and applied. Two of these methods are MBH [3] and MDH in that C_A and A are measured using well testing [5] and the slopes of liens in reservoir period.

Analysis MBH [3] method:

When a well in a stabilized reservoir is produced at constant rate Q (stb/day), the bottom hole pressure declines. At early times the pressure is given by [6]:

$P_{wf} = m. Log (t) + p_{1hr}$ …………………………………………………………………… (1)

Where

P_{wf}: flowing well pressure ;(psi)

T: production time; (hr)

[12], [5] $m = \frac{-162.6\, q\, \mu\beta}{kh}$ ……………………………………………………………….…. (2)

$Pw = p_i - \frac{70.6 q\mu\beta}{kh} . \left[ln\frac{0.000264kt}{\phi\beta\mu c_t r_w^2} + 0.80907 + 2s\right]$ ….……………………...……...…………... (3)

M (a negative number) is a slop of linear part of a plot P_w vs. $\log t$ and p_{1hr} is an intercept of the straight line portion of that plot at t =1 (hr)

After sufficient time the pressure follows pseudo steady state for a given shape starts when the curve for that shape presented by MBH [3] method becomes linear. Dietz [8] tabulates the time for start of pseudo steady state for those shapes during the pseudo steady state period:

$$P_{wf} = m^* . t + p_{int} \quad \ldots (4)$$

Where:

[6] $$m^* = \frac{-0.23395\, q\, \beta}{\phi c_t h A} \quad \ldots (5)$$

[6][12] $$p_{wf} = p_i - \frac{70.6\, q\, \beta}{kh}\left[\ln\left(\frac{A}{r_w^2}\right) - \ln c_A + 0.80907 + 2s\right] \quad \ldots (6)$$

A: drainage area ;(ft^2)

C_A: Dietz shape factor [8]

p_{int} is the intercept of the straight line when it is extrapolated to t=0.

And the dimensionless time used by Dietz to define the beginning of pseudo steady state behavior is calculated from [6]:

$$(t_{DA})_{p.s.s} = 0.1833 \frac{m^*}{m} . t_{p.s.s} \quad \ldots (7)$$

$t_{p.s.s}$: time of start straight line of the plot of p_{wf} vs. t.

[2]Tiab direct:

Few articles in the field of fracture reservoir investigated some method including Tiab[2] direct. This method uses mathematical calculation, solving the movement of flux equation in doula porosity prose media, using transfer function of Laplace, modeling and drawing the two diagrams of P_D and $p_D{*}t_D$ vs. t_D Could come with some new equation that calculated A.

Tiab[2] works on the application of TDS technique for estimation of average reservoir pressure in vertical and horizontal well.

Be use to solve pressure solution under various matrix model [2]:

$$P_{WD} = 2\pi t_{DA} + \frac{1}{2}\ln\left(\frac{2.2458A}{c_A r_w^2}\right) + \frac{2\pi(1-\omega)^2 r_w^2}{\lambda A} + s \quad \ldots (8)$$

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$$P_{wf} = \bar{p} - \frac{141.2\, q\mu\beta}{kh} \cdot \left[\frac{1}{2} \ln \frac{2.2458 A}{C_A r_w^2} + s\right] \quad \text{..........} \quad (9)$$

$$\frac{k_f h\,(p_i - \overline{p}\,)}{141.2\, q\mu\beta} = \frac{2\pi(1-\omega)^2 r_w^2}{\lambda A} + 2\pi t_{DA} = \bar{p} \quad \text{..........} \quad (10)$$

$$t_{DA} \cdot p_{wD} = 2\pi t_{DA} \quad \text{..........} \quad (11)$$

$$\overline{P_D} = 2\pi t_{DA} \quad \text{..........} \quad (12)$$

Slop = 0.5

,[2] $$A = \frac{0.0002637 K_f\, t_{rst}}{(\phi c_t)_{f+m}\, \mu} \quad \text{..........} \quad (13)$$

Drainage with well testing:

This article is based on using IPR diagram and well testing reaches general solution for movement fluxes in prose media. It open new window to finding physical indices of reservoir by using two kinds of reservoir information.

Also, it is mentioned in the article that the new method is just an introduction to calculate Drainage [4] in wells and their C_A.

A crucial point is that this article provides the method which produce IPR equation using the fluid flow movement in reservoir. Additionally, due to its generalizability, this equation can be used for other fractured reservoirs. We are attempting to meet the need of IPR of the well suing this equation.

In this article we will see that the general equation of fluid flow movement resulted from pore is separated for under the bubble point and the pressure-dependent parameters in the equation are made dependent again to the average pressure. Then, with well testing and Laboratory, the relative parameters and average pressure are calculated and substituted in the new equation. Afterwards, the transition pore or *P.S.S.* for the fluid flow condition is checked with a test point for the interested well. It will be revealed that it is *p.s.s*. Finally, the IPR equation is drawn for different r_e. By the same test point they can find out which r_e is the correct one and satisfy the equation [4] Transient:

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$$Q_o = \frac{0.00615 k_f h (p_i - p_w)}{\left(\log \frac{k_f h t}{r_w^2 \left(s_f + s_{wf} f(t,\varepsilon) \right) \left(\frac{k_{rf o}}{\mu_o} \right) p_{avr}} \right)} - 3.23 + 0.87 s \cdot \left(\frac{k_{rf o}}{\mu_o \beta_o} \right) p_{avr} \quad \text{.................................... (14)}$$

[4]Pseudo steady state:

$$Q_o = \frac{0.00708 k_f h (p_r - p_w)}{\ln\left(\frac{r_e}{r_w} \right) + s - 0.75} \cdot \left(\frac{k_{ro}}{\mu_o \beta_o} \right)_{p_{avr}} \quad \text{... (15)}$$

The previous studies on the reservoir equation ended in the entrance of A/C_A fraction to them. Based on this finding we have found that in all the resulted equations, the reservoir was assumed as a cylinder with the well inside it by a simplified assumption. Unfortunately, this process means replacement of the actual shape of the reservoir in a circle in mathematics which is very risky. Therefore, we get to the conclusion that we should find the actual shape of the reservoir based on the reverse engineering for image wells and use it in the original form of the equation with A/C_A. This method has fewer errors and results in more real answers. So, calculating A and C_A are important factors in this equation.

Methodology*:*

We generalize that we can use the physical models and the models which satisfy all the fluid flow in the reservoir in all pressures as the fundamental equation. In this equation, the IPR equation, rate equation and pressure are founded based on direct well testing [5]. Using j is both an advantage and the use of physical model of reservoir. Then we attempt to use well testing [5] and convergence method to find A/C_A fraction in IPR. To get to this aim, we found that, based on the aforementioned researches, there are equations to find drainage area and shape factor for homogenous reservoirs and that fractured models that touch the boundary pressure waves, the pseudo steady state behavior just like the homogeneous reservoirs. Therefore, we can use the process of finding drainage and shape factor. In this article we use the equations of MBH[3] and well testing[5] related to fractured reservoirs of warren and root (1)model and from it only C_A, which is not used directly from the equations with the aforementioned simplified assumption, is calculated and the shape of the reservoir is calculated from well testing.

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In this article the aforementioned method of MBH [3] is used to calculate the shape factors of fractured reservoirs that we know is very small and incorrect amount. We use the convergence method of these equations to reach the correct shape of the reservoir in which the A/C_A fraction is constant for each reservoir.

C_A resulted from well testing [5] will give us an amount of A in reservoir equation and A will give us another C_A. This method is repeated over and over again that only one answer with the interested regression will be found.

The goal of this method is determine simply and industry and fast way for shape factor that is essentially need to calculation reservoir equation and optimize placement of near well.

Step 1:

Plotting p_{wf} vs. T for long time that sure the pressure wave touches boundaries.

Step2:

Identify the slop of linear section of curve in Cartesian pepper that is m*.

Step3:

Found interception of this line pint that is p_{int}

Step 4[6]:

$$A = \frac{0.23396\, q_o \beta_o}{\varnothing h m^* c_t} \quad \ldots\ldots (16)$$

Step5:

Use general IPR equation [4],[12]:

$$Q_o = \frac{0.00708\, k_f h (p_r - p_{wf})}{\ln\frac{4A}{\gamma C_A r_w^2} + s - 0.75} \cdot \left(\frac{k_{rof}}{\mu_o \beta_o}\right)_{p_{avr}} \quad \ldots\ldots (17)$$

And determine shape factor from solution of A/C_A friction.

Result and discussion:

This method is developing for fracture reservoir that has no equation to determined shape factor and there isn't any method to find the location of near well and no sense about area and shape of reservoir.

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We want compare answer this method with another method that public for dreaming of shape factor.

We use the field data that for fracture reservoir from draw down test in table 2 and 3 in appendix.

In Tiab[2] direct with long determination and plotting we can found:

$$A = \frac{0.003318\, k_f\, t_{min\,s}}{(\phi c_t)_{f+m}\mu} = \frac{0.003318 \times 7 \times 20 \times 58}{0.048 \times 0.0000245 \times 0.362} = 3164365\ (ft^2)$$

That if use

[9], [12] $$t_{DA} = \frac{0.000264\ k\, t}{\phi \mu c_t A} = \frac{0.000264 \times 7 \times 178}{0.048 \times 0.0000245 \times 0.362 \times 3164365} \approx 0.2$$

to identify shape factor that answer is .22 that this answer is so wrong

From old method C_A get from this formula[6],[11],[10]

$$C_A = 5.456\, \frac{m}{m^*} \cdot exp\left(\frac{2.3(p_{abr} - p_{int})}{m}\right) = 5.465\, \frac{-300}{-4.5}\, exp\left(\frac{2.303\,(10359 - 9784)}{-300}\right) = 4.3$$

That answer 4.39 is small and incorrect because this way is for conventional reservoir not fracture.

But in method that explain above we identify slop m*= -4.5 from plotting and determine A from equation (13) equal 3348570.055(ft^2) In this section we use general equation of fluid flow IPR to determine A/C_A and with knowing a we can determine c_A that equal 10.8[11],[10].

$J = 0.87$

$$0.87 = \frac{7 \times 66}{141.2 \times 0.362 \times 1.8235 \times \left(\frac{1}{2} \ln \frac{4 \times 3348570.05}{1.78 \times (0.8817)^2 C_A} - 4.7\right)}$$

$C_A = 10.8$

This answer is correct and valid.

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Conclusion:

1. Using IPR and well testing [5], which are two tests of wells, gives us more real information to obtain fundamental equation of reservoir.
2. Using equation with fewer errors gives us better predictions for the future of production.
3. The shape and environment of reservoir are important information to categorize and recognize the reservoir.
4. Results of this article relate the fractured reservoir to the homogeneous reservoirs whereas it doesn't interfere with their solution process.
5. The resulted answer is precise and has fewer mathematical functions.

Nomenclature:

NFR: *natural fracture reservoir*

A: *reservoir area*

C_A: *shape factor parameter*

P_D: *dimensionless pressure*

P_i: *initial reservoir pressure psi*

P_{wf}: *wellbore flowing pressure psi*

P_{avr}: *average reservoir pressure psi*

K_f: *fracture permeability md*

K_m: *matrix permeability md*

H: *formation thickness ft*

Q: *flow rate stb/d*

B: *formation volume factor rb/stb*

μ: *oil viscosity cp*

Ø: *Porosity fraction*

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$C_{t:}$ *total formation compressibility psi*$^{-1}$

R_w: *wellbore radius ft*

$T_{d:}$ *dimensionless time*

ω : *Storability ratio fraction*

λ*: inter porosity transfer coefficient*

s: *skin factor*

table 2:

$c_t = 24.5 \times 10^{-6} psi^{-1}$

$\emptyset = 0.048$

r_w =0.2917 ft

p_i =11347 psi

h =65 ft

q =2700 stb/d

β =1.8235 rb/stb

µ = 0.362 cp

K from plotting =7 md

S from plotting = 4.7

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t(hr)	pw(psi)	t(hr)	pw(psi)
0.25	10989	55	9647
0.5	10630	66	9487
0.75	10486	67	9479
1	10359	69	9463
1.25	10343	71	9455
1.5	10271	74	9447
1.75	10215	77	9431
2	10183	80	9423
2.5	10136	84	9406
3	10112	88	9382
3.5	10080	92	9358
4	10056	96	9342
4.5	10048	100	9326
5	10040	104	9302
5.5	10032	108	9294
6	10016	112	9270
7	10000	116	9246
8	9984	120	9230
9	9968	131	9150
10	9960	132	9142
12	9936	134	9134
14	9920	136	9125
16	9904	138	9117
18	9880	143	9109
20	9864	148	9085
24	9832	153	9061
28	9816	158	9037
32	9792	163	9021
36	9795	168	9013
40	9735	173	9005
45	9703	178	8981
50	9679		

Table 1:

Drawdown pressure data

Reference:

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2. Engler T and Tiab D''Analysis of pressure derivative without type-curve matching

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5. A simple build up analysis method to determine well drainage area and draw down pressure for stabilized well’’ spe

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11. R.C Earlougher JR spe-AIME ‘’estimation drainage shape from reservoir limit test’’parer 3357

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13. C.s Matthews, and DG Russell ‘’pressure build up and flow test in well’s reprint series

14. Van golf

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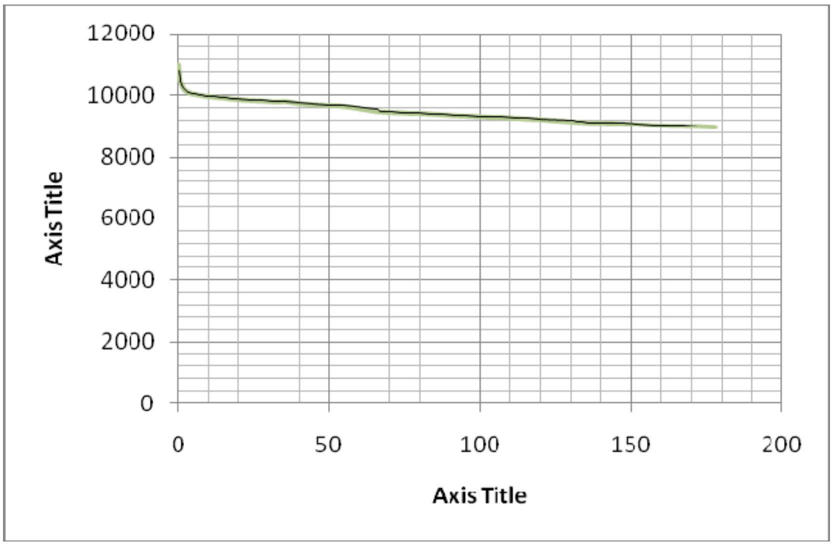

Table .2 (drawdown curve)

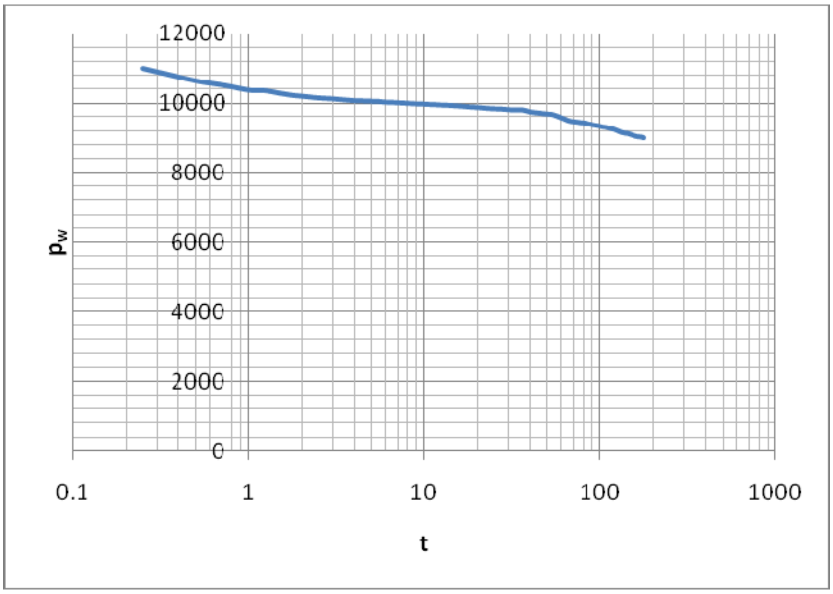

Table .3 (Horner plot build up curve)

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