Calculation of OIIP and Water Influx for Bottom Water Drive Reservoir (Sarir C-North field in Libya).

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Abstract

This paper is determine water influx using Fekovich method and the original oil in place of reservoir using method Havlena,D.,and Odeh .The material balance method is a powerful technique used to study reservoir performance and describing the important properties of the reservoir , including the estimates of original oil in place and the strength of aquifer.When people calculate water influx using the gas reservoir engineering method, they usually utilize three methods of van Everdingen-Hurst [(1)], Carter-Tracy [(2)] and Fetkovich[(3)]. Fetkovich [(3)] developed a method of describing the approximate water influx behavior of a finite aquifer for radial and linear geometries .The Fetkovich [(3)] theory is much simpler, and, like the Carter-Tracy [(2)] technique, this method does not require the use of superposition. Hence, the application is much easier, and this method is also often utilized in numerical simulation models. This approach begins with two simple equations. The first is the productivity index (PI) equation for the aquifer, which is analogous to the PI equation used to describe an oil or gas well .The results show that estimated value of water influx was 36762.86 bbl for one year and 3092857.415 bbl at the end of seven years and the original oil in place was 310 MMST .

Keywords: material balance equation ,Fetkovich equation ,Havlena -Odeh equation ,water influx, original oil in place

حساب حجم الزيت الاصلي وتدفق الماء لمكمن دفع مائي لحقل السرير، ليبيا

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المستخلص:

عند حساب تدفق الماء فى المكامن نستخدم ثلاث طرق وهي شائع الاستخدام طريقة تاريز وفان هورست وفتكوفتش. طور فتكوفتش سنة 1971 م طريقة لوصف سلوك تدفق المياه لطبقة المياه الجوفية المحدودة لشكل القطرى والخطى لسريان المائع. تعتبر طريقة فتكوفتش أبسط بكثير من طريقة تاريز لانها لا تتطلب استخدام التراكيب الجولوجية وغالبا مات ستخدم فى المحاكاة الرقمية. يبدأ هذا الاسلوب بمعادلتين بسيطتين. الأول هو معادلة مؤشر الانتاجية لطبقة المياه الجوفية والتي تشبه معادلة مؤشر الانتاجية لوصف بئر النفط او الغاز. المعادلة الثانية هى معادلة توازن المادة للخزان الجوفى بانضغاطية ثابته والتي تتناسب فيه تناقص الضغط للخزان مع معدل التدفق للمياه. فى هذا الورقة أستخدمنا طريقة فتكونتش لحساب تدفق الماء في المكمن. وايضا استخدمنا طريقة المعادلة الموزونة لحساب حجم الزيت الأصلي للمكمن. أدخلنا معادلة فتكوفتش فى المعادلة الموزونة وتحصلنا على حجم الزيت في المكمن.

الكلمات المفتاحية: معادلة اتزان المادة، معادلة فتكوفتش، معادلة اوداه، تدفق الماء، حجم الزيت الاصلي.

Overview

Sirt Basin Fields Producing reservoirs in the giant fields of the Sirt Basin range from Precambrian basement (igneous rocks) to Oligocene sands. Fracture porosity is important not only in the basement rocks but also in Cambro-Ordovician sandstone at Amal field. Pre-Upper Cretaceous sandstones are important reservoirs in the Sarir, Messlah, Bu Attifel, and Masrab fields. This basin is the youngest of the Libyan basins and contains all the major oil fields of Libya. The Sirt basin an interior fracture basin near the plate margin an axis at an angle to that margin. Commonly show horst-andgraben development. Common features of the three underexplored elements of the Sirt Basin are:

- Nearby oil production - Outstanding source rock (Upper Cretaceous Sirt-Rachmat Shale) - Large areal extent - Limited number of tests to pre-Upper Cretaceous unit.

1. Sarir Field

The Sarir field lies on the western margin of the Calanscio Sand Sea in Southern Cyrenaica. It is at present at the most southeasterly oilfield in Libya and lies some 420 km from the nearest

Mediterranean coast on the Gulf of Sirt (Figure: 1).

The oil occurs at a depth of about 9,000 ft in a sand- stone reservoir of Upper Cretaceous age at the base of a Tertiary-Upper Cretaceous marine succession. The reservoir is capped by marine Upper Cretaceous shale's. The accumulation is trapped in a large, gently dipping fault-controlled structure. A field gathering system, a 34-inch pipeline and a marine terminal at Tobruk are at present under construction. The Sarir field occurs within but near the south- eastern margin of the Upper Cretaceous-Tertiary Sirt Basin.

2. Producing Areas

The Sarir oil field has three separate producing area:

- ✓ C-Main to the south of Sarir area.
- ✓ C-North in the middle.
- ✓ L-Field to the north of Sarir area.

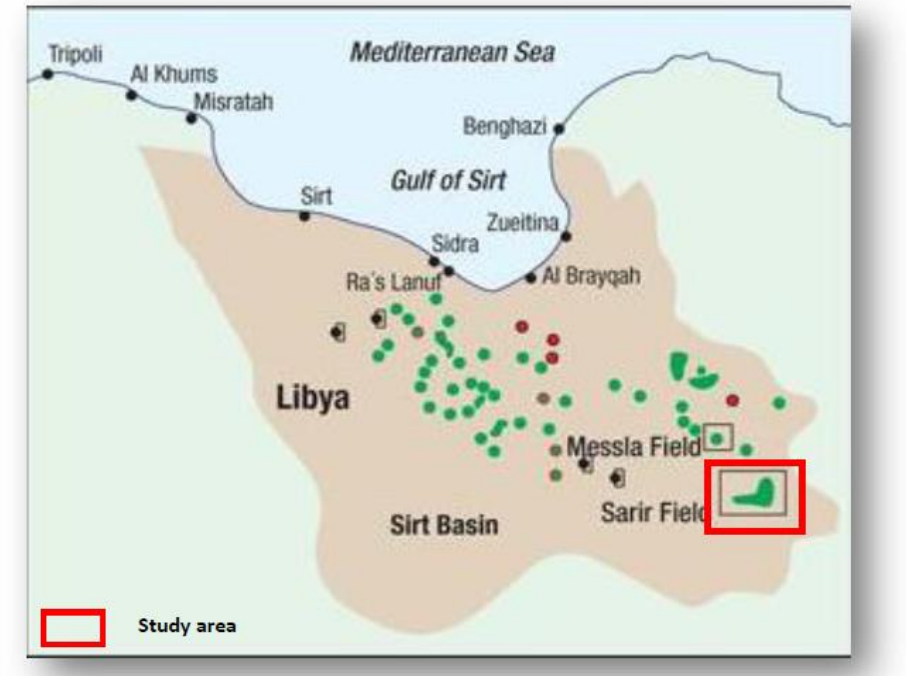

figure (1): Location Sarir oil field

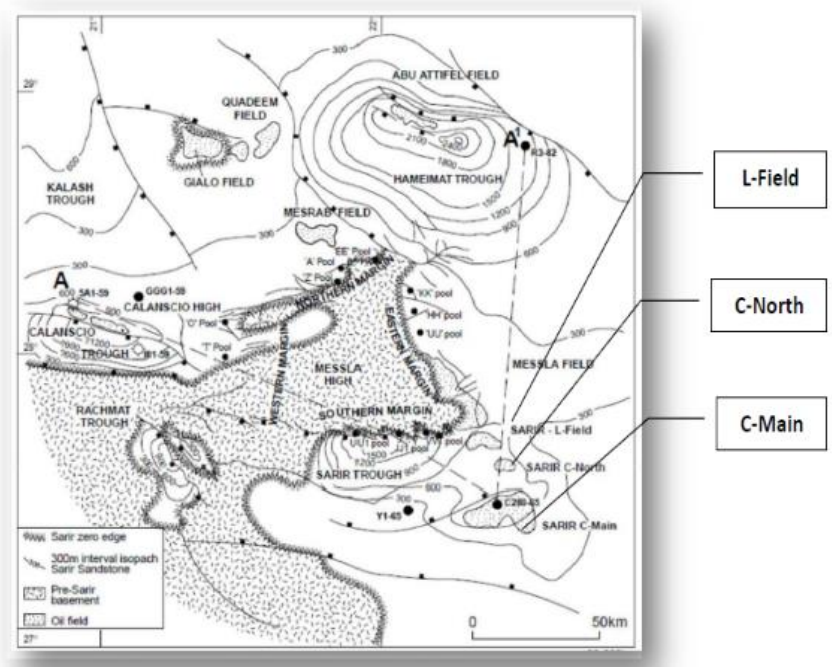

Figure (2): Location of oil fields within Sarir area

3. General information

The next tables summarize the information of Sarir field regarding the reservoir and the fluid contents.

SARIR SPECIFICATION	
Long	35miles (56 km)
Wide	25 miles(40km)
Area	146 miles squared(387km^2)
Size	95000 acre (38445 hacter)
Top of pay	Upper cretaceous sandstones at 8632 ft (2631m)
Drive mechanism	Water drive
Wettability	Good quality water wet
Field	No gas cap
Closure	300 ft large structure
Average porosity	18-19%

Porosity type	Inter-granular
Permeability average	Hundreds of milli-darcy`s with few 2-3 darcie`s streaks

Table (1): the specification of Sarir field (Arabian Gulf Oil Company)

PRODUCTION DATA	
Estimated ultimate recovery	6.5 billion bbl oil
Initial reserve in place	12 billion bbl oil
Initial production rate	8000 & some able to achieve max 2000 bbl/day
Wells spacing	2 km
Crude	Sweet oil &sulfur free &high paraffin content fairly light waxy crude
Gravity	37 API
Wax content	19%
GOR	Vary 60-225ft^3/bbl

Table (2) : production data of Sarir field (Arabian Gulf Oil Company)

Introduction

-Material Balance Equation in Reservoir Engineering[4]

$$N_p\left[B_o + (R_p - R_s)B_g\right] + W_p B_w = N\left[(B_o - B_{oi}) + (R_{si} - R_s)B_g + (1+m)B_{oi}\frac{(C_f + S_{wc}C_w)}{(1 - S_{wc})}\Delta P + mB_{oi}\left(\frac{B_g}{B_{gi}} - 1\right)\right] + W_e + W_i B_w + G_i B_g$$

The equation above can be rearranged like this:

$$N_p\left[B_o + (R_p - R_s)B_g\right] + W_p B_w - W_i B_w - G_i B_g = N\left[E_o + E_{fw} + mE_g\right] + W_e$$

where;

Np = Net fluid production (Volume Produced – Volume Injection)

N = Oil in place

Et = Total expansion term (oil, water, gas cap and rock)

We = water influx

his simplified equation was presented by Havlena - Odeh [4]. With this equation form, graphical plots can be easily made and material balance evaluation is done more easily and accurately.

Aquifer Modelels

water influx models are mathematical models that simulate and predict aquifer performance .The are several popular aquifer models :

- Schilthuis model [5] .
- van Everdingen and Hurst (VEH) model [1] (radial and linear flow)
- Fetkovich model [3]
- Carter-Tracy[2] .

-Fetkovich's Method

(Fetkovich [1]) can be used to describe pseudo steady-state aquifers.

The following calculation illustrates this method.

1. To Calculate the initial volume of water in the aquifer is:

$$W_{ei} = c_t p_{aq,i} W_i$$

$$W_i = \frac{\pi(r_{aq}{}^2 - r_R{}^2) h \emptyset \frac{\theta}{360}}{5.615}$$

Calculate J. For radial flow in an aquifer with a finite no-flow outer boundary, from equation:

$$J = \frac{0.00708kh\left(\frac{\theta}{360}\right)}{\mu\left[\ln\left(\frac{r_{aq}}{r_R}\right) - 0.75\right]}$$

For each time period, calculate the incremental water influx

$$\Delta W_{en} = \frac{W_{ei}}{p_{aq,i}}\left(\bar{p}_{aq,n-1} - \bar{p}_{rn}\right)\left[1 - exp\left(\frac{-Jp_{aq,i}\Delta tn}{W_{ei}}\right)\right]$$

$$\bar{p}_{aq,n-1} = p_{aq,i}\left(1 - \frac{W_{e,n-1}}{W_{ei}}\right)$$

$$\bar{p}_{rn} = \frac{p_{rn-1} - p_{rn}}{2}$$

Calculation procedure

Determining water-influx model parameters

Calculate the water influx at the end of the 7 years of production for Sarir C-North field in Libya. Reservoir, aquifer, fluid and rock properties are given below :

Table (3) , reservoir and fluid properties for Sarir C-North field (Arabian Gulf Oil Company)

Table (3) , reservoir and fluid properties for Sarir C-North field	
Property	
cw [1/psi]	2.32E-06
cf [1/psi]	4.42E-06
Swc	0.25
M	0
Bw	1.042
Fetkovich Aquifer Model	
Subtended Angle Theta	360
Permeability K [mD]	1
Thickness, h [ft]	325
Viscosity [cP]	0.3
Exterior Boundary Re [ft]	300000
Oil Zone Boundary, Ro [ft]	10000
Porosity	0.3

example for Fetkovich method

$$J = \frac{0.00708(1)(325)\left(\frac{360}{360}\right)}{0.3[\ln(30) - 0.75]} = 2.9 \text{ STB/D} - \text{psi.}$$

$$W_{ei} = \frac{p_i c_t \pi \left(r_{aq}{}^2 - r_R{}^2\right) h \emptyset \frac{\theta}{360}}{5.615}$$

$$W_{ei} = \frac{3985(6.74 \times 10^{-6})\pi(300000^2 - 10000^2)(325)(0.3)\frac{360}{360}}{5.615}$$

$$= 1.3 \times 10^{11} \ RB$$

At P_1 = 3878 *psi,*

n=1

$\bar{P}_{aq.0}$= 3985 ($1 - \frac{0}{1.3 \times 10^{11}}$) = 3985 *psi*

$\overline{Pr}$= $\frac{3985+3878}{2}$ = 3931.3 *psi*

$\Delta w_{e1} = \frac{1.3 * 10^{11}}{3985}(3985 - 3931.3)\ [1 - \exp\left(\frac{-2.9*3985*366}{1.3*10^{11}}\right)]$

Δw_{e1} = 36762.86 *bbl*s

Table (4) Water influx calculation using Fetkovich method

P , psi	$\frac{NP\ B_o}{B_{oi}\ c_e\ \Delta p}$	$\frac{w_e}{B_{oi}\ c_e\ \Delta p}$
3878	13.33	$31 * 10^6$
3740	358	$62 * 10^6$
3541	312	$82 * 10^6$
3478	409	$125 * 10^6$
3361	485	$159 * 10^6$
3346	556	$220 * 10^6$
3273	614	$271 * 10^6$

Table (5) : Calculation of material balance equation and Fetkovich method

Time , years	$\overline{P}aq$, n-1, *psi*	$\overline{P}r, n, psi$	w_{en},*bbls*
1	3985	3931.5	36762.86
2	3984.99	3809	243066.3688
3	3984.99	3640.5	607707.9488
4	3984.98	3509.5	1111002
5	3984.96	3419.5	1709539.636
6	3984.95	3353.5	2377916.895
7	3984.92	3309.5	3092857.415

Table (5) : Calculation of material balance equation and Fetkovich method

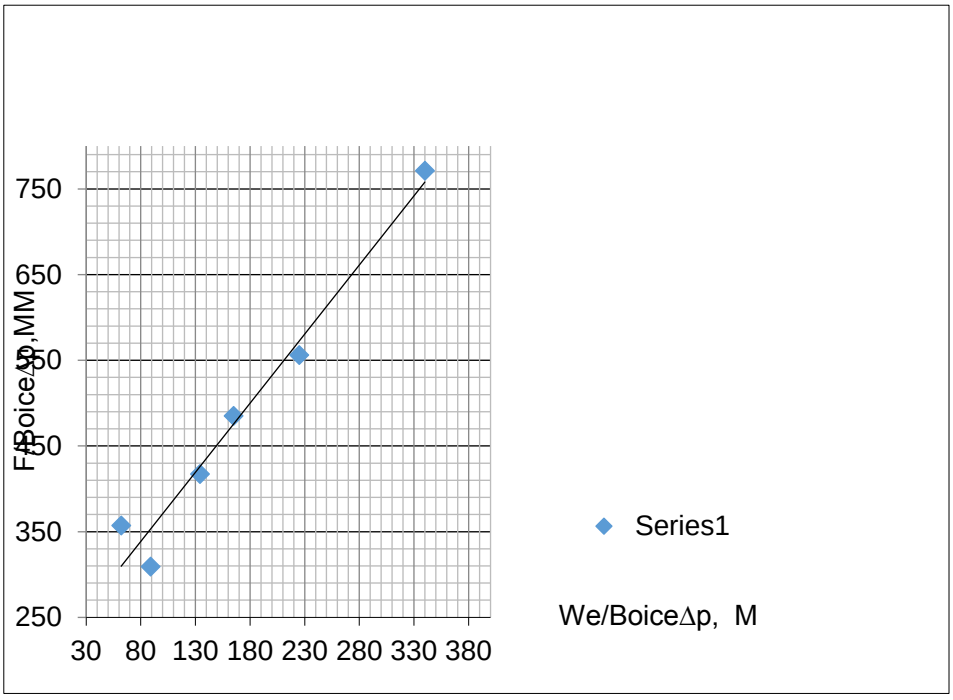

Figure (3) ,results of original oil in place ,N ,MMstb.

from figure (3) ,N =310 MMSTB

conclusion:

1- the aim of the work is to determine water influx using Fetkovich model and the original oil in place using material balance equation (Havlena,D.,and Odeh)
2- The results show that estimated value of water influx was 36762.86 bbl for one year and 3092857.415 bbl at the end of seven years and the original oil in place was 310 MMSTB.
3- The Fetkovich model described the aquifer properties .
4- the material balance method is powerful technique used to study reservoir performance and describing the important properties of the reservoir (Havlena,D.,and Odeh)
5- This will assist the reservoir engineers and production managers in during reservoir management .

Recommendation

The following recommendation for further research work have been made :

1- The model can be compare with Carter-Tracy method .
2- I also recommend that the model should be compared with Van Everdigen-Hurst model.

Nomenclatures

N = oil initially in place (STOIIP) in reservoir (stb)

Np = cumulative oil production (stb)

Boi = oil volume factor at initial reservoir pressure (rb/stb)

Bo = oil volume factor at current reservoir pressure (rb/stb)

Rsi = solution GOR at initial reservoir pressure (scf/stb)

Rs = solution GOR at current reservoir pressure (scf/stb)

Rp = cumulative produced gas oil ratio (scf/stb)

G = gas volume initially in place (GIIP) in reservoir (scf)

m = ratio of initial gas cap volume to initial oil volume (rb/rb)

Bgi = gas volume factor at initial reservoir pressure (rb/scf)

Bg = gas volume factor at current reservoir pressure (rb/scf)

Swc = connate water saturation (fraction or %)

Cw = water compressibility (1/psi)

Cf = formation (rock) compressibility (1/psi)

Wp = cumulative water production (stb)

We= cumulative water influx from aquifer (rb)

Bw = water volume factor at initial reservoir pressure (rb/stb)

Wi = cumulative water injection (stb)

Gi = cumulative gas injection (scf)

Gp = cumulative gas production (scf)

Eg = gas expansion term (rb/stb)

Eo = oil expansion term (rb/stb)

Efw = formation and connate water expansion term (rb/stb)

ø =porosity

r_r = reservoir radio

h = thickness

J = productivity index

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