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Single Well Coning Problem and Applicable Solutions

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Abstract

One of the most important and common problems in petroleum engineering; reservoir, and production engineering is coning; either water or gas coning. Almost 75% of the drilled wells worldwide contains this problem, and in Iraq water coning problem is much wider than the gas coning problem thus in this paper we try to clarify most of the reasons causing water coning and some of applicable solutions to avoid it using the simulation program (CMG Builder) to build a single well model considering an Iraqi well in north of Iraq black oil field with a bottom water drive, Coning was decreased by 57% by dividing into sub-layers (8) layers rather than (4) layers, also it was decreased (Coning) by 45% when perforation numbers and positions was changed.

Key Word: Well coning, Iraqi well

Introduction

In simulation many problems can occur according to data and information user apply and water coning is the most common after a period of production. It is usually noted by the water oil ratio, respectively the gas coning is noted by the gas oil ratio in certain wells. Usually to avoid this problem in the oil fields or areas which are predicted to be a coning areas is to use directional drilling in the area or by valve controlling on the well-head, but sometimes it is impossible to predict that or there are some reasons like well depletion which happens after many years of production; in these cases other techniques should be used.

Water coning usually happens in oil fields with bottom water drive and it may affects the oil production economics due to water treatment and disposal issues [1]

Builder of CMG software is one of the most useful programs in analyzing this problem by simulation and it is used widely to predict and solve many reservoir and production problems like the problem we about to discuss.

Theoretical Background (Effect of simple coning)

Remember that all the formulas of the critical rate represent, as close experimental coefficient, the equilibrium between viscosity forces and gravity forces which characterize a cone. [2]

In the mobile face, Δp between exterior limit and the well, in radial circular flow [2]

$$\Delta p = B.Q.\mu \,\mathrm{Ln}\,(R/r) \quad \dots (1)$$

In the immobile phase Δp between the two limits

$\Delta p = \Delta\rho . g . Hc$ … (2)

The pressure is the same for the two phases along the interface, and combining eqts.(1) and (2) we obtain:

$$Q = \frac{2\pi . H . K . Hc . g \Delta\rho}{B . \mu . Ln\ R/r} \quad \dots (3)$$

Certain authors like Meyer and Shulga [3] have deliberately ignored real causes of instability of cone near the well. They supposed that the critical height is equal to the free height below perforations:

With: $Hc = Ht - Hp$ … (4)

Equation (3), become:

$$Qc = \frac{2\pi . \Delta\rho . g . Kh . Ht\ (Ht - Hp)}{B\circ . \mu\circ\ . Ln\ Re/r} \quad \dots (5)$$

Using above formula gives results 2 to 3 times below the reality.

Other authors like Sobocinsky and Bournazzel [3] used above formula and added a numerical coefficient deduced from experience done in laboratory:

$$Q\circ = \underline{\alpha} \frac{\Delta p . Kh . Ht\ (Ht - Hp)}{B\circ . \mu\circ} \quad \dots (6)$$

With: $\underline{\alpha} = 1.52 * 10^{-3}$ (Sobocinsky)
$= 1.42 * 10^{-3}$ (Bournazel)

Some Useful Data

The following data were used as an input data to the simulator [4]

1- PV T Data

Pressure Volume Temperature Data (PV T) are presented in english units in table (1)

Table (1), PVT Data

Pressure psi	Rs liberated scf/bbl	Rs insolution cf/bbl	B∘ vol/vol	Shrinkage factor vol/vol
3450	0	1249.6	1.619	1
3000	193	1056	1.536	0.949
2500	381.4	868.2	1.454	0.898
2000	540	709.6	1.388	0.857
1500	694.1	555.5	1.324	0.818
1000	838.8	410.8	1.266	0.782
650	942.7	306.9	1.233	0.755
200	1096	153.6	1.153	0.712 0.698
60	11662	83.4	1.13 1.049	0.648
0 at 60∘F	1249.6	0	1	0.618

2- Following Table (2) shows the chemical composition of Oil vs. Weight percent

Table (2), Composition and weight%

Composition	Weight%
C1	0.3
C2	0.32
C3	0.51
iC4	0.97
nC4	4.86
iC5	7.75
nC5	9.4
C6+	75.89

3- Formations depths (tops and bottom) from RTKB (m) and reservoir formations top as shown in table no.3 below [6]

Table (3), Tops and bottoms of different layers

Layer	Top from RTKB/ m	Bottom from RTKB/ m	RTKB m	Top m
Jeribe	2804	1868.5	284.05	1804
Dhiban	18868.5	1913.8		1868.5
Euphrates	1913	1926		1913.8
Serikagni	1926	1955		1926
Basal Anhydrite	____	____		___
Jaddala	-------	--------		-------

4- As shown in table number 4 the oil density versus reservoir pressure

Table (4) Oil density vs. Pressure

Pressure psi	Oil density lb/ft3
500	0.6783
4500	0.6751
4000	0.6719

5- Water saturation and porosity versus different reservoir layers, thickness are presented in table (5) below [6]

Table (5), Thickness, Water Saturation and Porosity versus Reservoir Layers

Layer	Thickness m	Water Saturation fraction	Porosity fraction
Jeribe	18	0.4	0.19
Dhiban	25	1	0.07
Euphrates	18	0.3	0.2
Serikagni	10.5	0.2	0.1
Basal Anhydrite	9.5	0.2	0.2
Oligocene	25	0.8	0.1
Jaddala	20	1	0.05

Building the Model and Finding a Solution

In order to build the model a suitable simulator must be used depending on the types of fluids in the field by determining to use a black oil field then Builder of CMG simulator should be used. Using PVT[4] information related to the X-well for our study to build the model using 4 layers totally of 400 meter and 100 meter of radius [6] perforated in the production zone (layer 3) given in the final well report[6] of the well chosen.

The water coning problem appeared after running the simulator for 35 years and many steps were taken to avoid this problem. Then next step were taken to avoid the water coning, and these steps are related to each other and were done consequently,

1- Divide the 4 main layers to sub layers, totally 8 layers it help in minimizing the water coning. It was 13.24 mstb with layer 4 layered model and become 5.87 mstb, so it was minimized by 57% approximately ant this result is due to the decrease in water encroachment from limited aquifer size in one coning well model
2- Change the perforation interval number instead of one layer perforation. 2 layers (the 4th and 6th) were chosen to be perforated (in the 4 layers model, layer 3 was perforated) . This step made the perforation interval much less and on a higher level/ the water production was 5.87 mstb before this step and after it became 4.1 mstb, approximately it was minimized by 31%
   It is not effective as the previous one as a second step, but if this step were taken to be the first step the result will be minimizing the 13.24 mstb to 6.98 mstb, about 45%
3- This step must be done within limit, not to exceed the original perforation depth.
4- Using one perforation area instead of two, but in this case the oil percentage will be minimized as well, so it is not a preferable step.
5- Trying to minimize the production period for the well, not to exceed 25 years in simulator, predicting for more than 25 years can cause many problems to occur while it might be unrealistic due to limited aquifer size in our one well model.

Conclusions

1- Dividing the model to sub layers 8 layers instead of 4 layers result In decreasing water coning by 57% can avoid and minimize the water coning
2- Changing perforations place and number (within limit) led to decrease coning by 45%.
3- Minimizing the production time in the simulator and increasing production period beyond 25 years resulted in many problems which is unrealistic.

Nomenclatures

mstb: million standard barrel,
PVT: pressure, volume and temperature,
ΔP: Pressure difference (Kg/m^3),
B: formation volume factor (vol/vol),
Q: Flow rate (m^3/day),
μ: viscosity (cp),
Ln: natural logarithm,
R: outer radius (m),
r: well radius (m),
g: acceleration= 9.81 (m/sec^2),
Qo: oil rate (m^3/day),
Δρ in gm/cm^3,
K: permeability (md),
μo: oil viscosity (cp),
Ht: total bed thickness (m),
Hp: perforated height (m) and
Ht: immobile phase height (m).

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