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Study the Possibility of Application WAG Flooding on Libyan Oil Field

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Abstract

In this paper an EOR screening software has been appliedtochoose the best enhanced oil recovery methods and the ability of implementing this method on specific Libyan oil field in order to maximize oil recovery and field life as much as possible, this work has been done by using EORgui software, the results have been obtained and compared which concluded that the carbon dioxide flooding is the most viable options for this field. The result showed that applying CO_2injection using EORgui could be recovered 6.5 million barrels from 10 million barrel of the residual oil from the reservoir of this field.

Keyword: Enhanced Oil Recovery, Screening Criteria, EORgui, Miscible Flooding, Minimum Miscibility Pressure.

Introduction

The current renewed interest on research and development of EOR processes and their oilfield implementation would allow targeting significant volumes of oil accumulations that have been left behind in mature reservoirs after primary and secondary oil recovery operations. [1] During the life of a producing oil field, several production stages are encountered. Initially, when a field is brought into production, oil flows naturally to the surface due to existing reservoir pressure in the primary phase. As reservoir pressure drops, water is typically injected to boost the pressure to displace the oil in the secondary phase .[2] Lastly, the remaining oil can be recovered by a variety of means such as CO_2 injection, natural gas miscible injection, and steam recovery in the final tertiary or enhanced oil recovery (EOR) phase.[4]

The main parameter for determination of the possibilities to enhance oil recovery by e.g. CO_2 injection into a specific oil field is the measurement of Minimum Miscibility Pressure (MMP). This pressure is the lowest pressure for which a gas can obtain miscibility through a multi contact process with a given oil reservoir at the reservoir temperature. The oil formation to which the process is applied must be operated at or above the MMP. Before field trial this parameter is to be determined at the laboratory which traditionally is done by help of a slim tube or a raising bubble experiment.[3]

With production from many mature oil fields such as Hakim field, the declining and approaching tail production, the field owners have to consider enhanced oil recovery as a way of recovering more oil from the fields. Enhanced oil recovery through the injection of CO_2 as a tertiary recovery mechanism, preferably after water flooding, is one mechanism with which to recover more oil, extend the field life and increase the profitability of the fields.[5-6]

Miscible Flooding

Miscible injection uses a gas that is miscible (mixable) with oil and as the gas injection continues, the gas displaces part of the oil to the producing well. Injection gases include liquefied petroleum gases (LPGs) such as propane, methane under high pressure, methane enriched with light hydrocarbons, nitrogen under high pressure, flue gas, and carbon dioxide used alone or followed by water. LPGs are appropriate for use in many reservoirs because they are miscible with crude oil on first contact. However, LPGs are in such demand as marketable commodity that their use in EOR is limited.[7]

CO_2 flooding is carried out by injecting large quantities of CO_2 (15% or more of the hydrocarbon pore volume, PV) into the reservoir. Typically, it takes about 10 Mcf of CO2 to recover an incremental barrel of oil and about half of this gas will be left in the reservoir at the economic limit.[8] Although CO_2 is not truly miscible with the crude oil, CO_2 extracts the light-to-intermediate components from the oil, and, if the pressure is high enough, develops miscibility to displace the crude oil from the reservoir. [9] Basically, during CO_2 displacements miscibility takes place through in-situ composition changes resulting from multiple-contacts and mass transfer between reservoir oil and the injected CO_2. [10]

Data Collection

The case study was Hakim field that operated by Zuitina oil Company, Production Formation is Farha, total depth about 6700ft, average net pay thickness 46ft and the total wells completed 22 well. Average porosity is 21.6%, average permeability 27md, initial water saturation 25.1%, rock compressibility 3.0(E-6) psia^{-1}.Oil Formation Volume Factor at bubble point pressure is 1.265bbl/STB, oil gravity 48API, solution GOR 274scf/STB and oil viscosity at initial pressure 0.37cp.Initial Oil in Place 136.7MMSTB, Initial Oil Reserves 38.35MMSTB, Remaining Oil Reserves 9.453 and Recovery Factor is 28.05%.Initial Gas in Place 22.5Bscf, Initial Gas Reserves 10.46Bscf and Remaining Gas Reserves 1.464Bscf.Recovery mechanism is water injection. The average reservoir pressure is 2249 psia, initial pressure was 2693 psia and Bubble point pressure is 655psig.

The last oil flow rate of the field is 1558 bbl/day, Water cut 80%, GOR 1570 cf/bbl and cumulative oil production 28 MMbbl, cumulative gas production 8.8 Bscf.

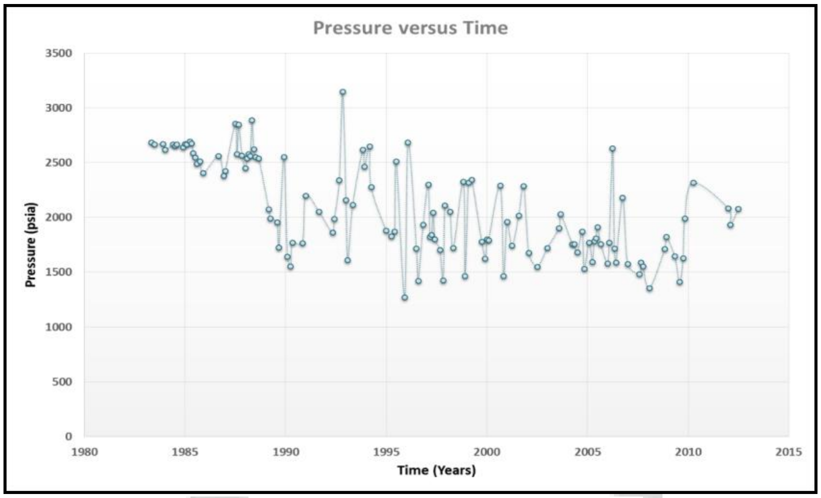


Figure 1: Hakim oil field Pressure History

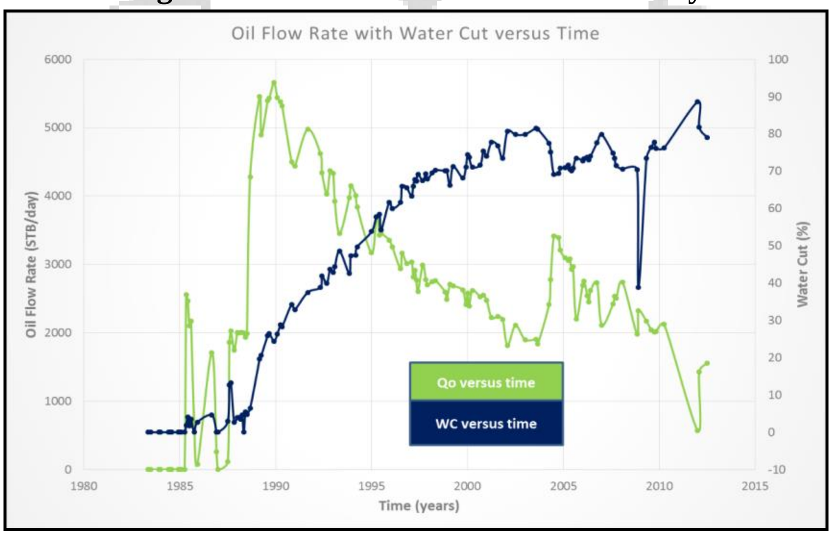


Figure 2: Oil Flow Rate and Water Cut versus Time

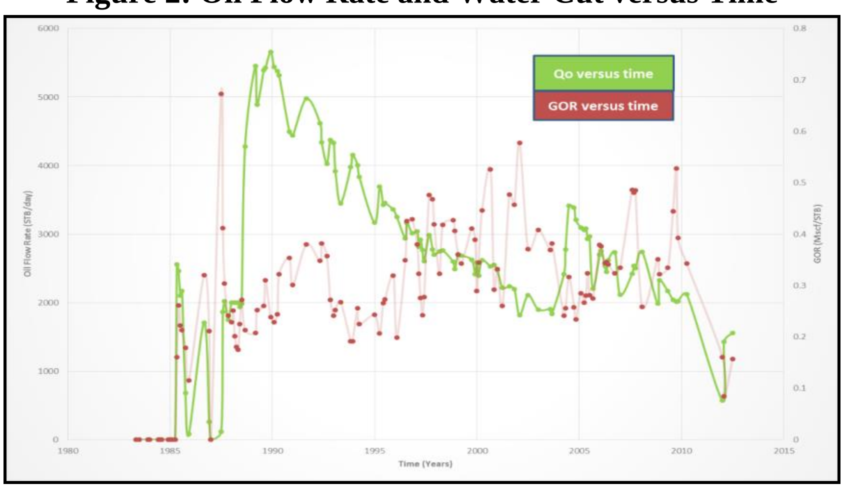
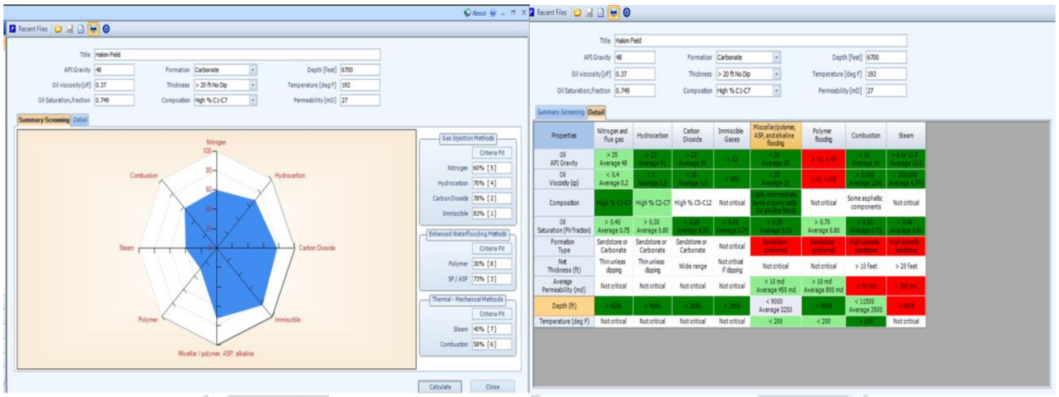


Figure 3: Oil Flow Rate and Gas Oil Ratio versus Time

Results and Discussion

Screening Criteria

Starting with screening criteria to select the optimum EOR method to applying, by using EORgui software.



Red block means the property out of limitation of method, Green block means the property in limitation of method, light green block means slightly effect of property on method and whit block means no effect of property on method. The above screens for EORgui screening show high ability to applying Miscibility flooding for this field, the chemical and thermal methods are not recommended for this field.

The applying WAG is recommended for this field, due to good screening for CO2 and water flooding performance.

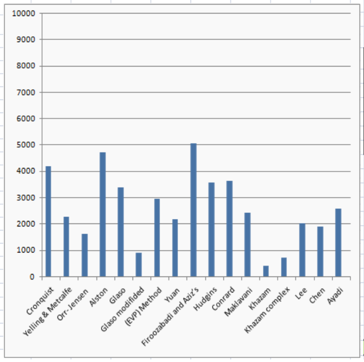
Minimum miscibility pressure (MMP) calculation

To ensure miscibility between injection gas and oil, the pressure should be higher than MMP that can be measured at laboratory by using slim tube test, but when test is miss, the correlation and EOS modelling can be used.In our study, we building black oil modelling by using published empirical correlation as presented in chapter three to calculate MMP.

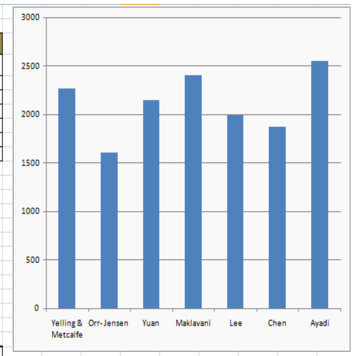
The methodology of estimation be filter the results that obtained from correlations and compare the results and match the nearer results as will present below. Finally taken the average from the last correlation as will present and the minimum miscibility pressure estimated as 2120 psia and its less than reservoir pressure 2249 psia.

The screenshot from the work using Excel sheet shows that the Glaso, Aziz, Khazme's correlations get higher and smaller value from the other correlations. The average MMP from all correlation that used with outlier correlations were 2600 psia.

	Results
Cronquist	4186.898969
Yelling & Metcalfe	2264.503164
Orr- Jensen	1607.618803
Alston	4710.642408
Glaso	3373.045665
Glaso modifided	880.2696646
(EVP) Method	2918.786965
Yuan	2151.333645
Firoozabadi and Aziz's	5035.102272
Hudgins	3538.58141
Conrard	3618.632119
Maklavani	2403.683778
Khazam	391.5677545
Khazam complex	691.6073829
Lee	1989.332095
Chen	1868.200087
Ayadi	2549.783679
AVG	2598.799404



	Results
Yelling & Metcalfe	2264.50316
Orr- Jensen	1607.6188
Yuan	2151.33365
Maklavani	2403.68378
Lee	1989.33209
Chen	1868.20009
Ayadi	2549.78368
AVG	2119.207893



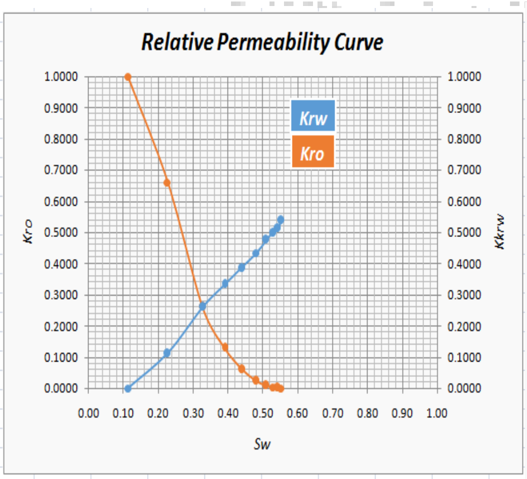
Prediction of future oil production after applying WAG

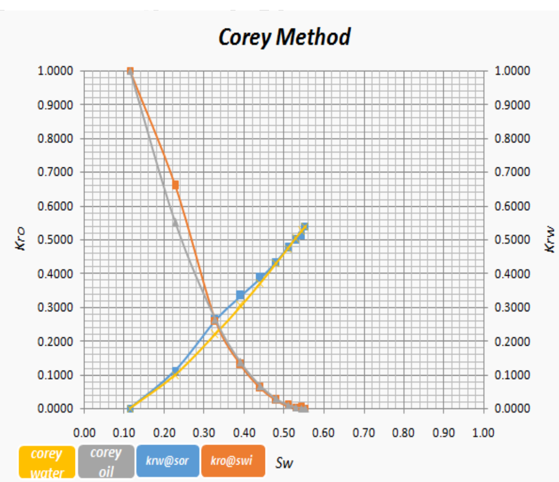
Enhanced oil recovery through the injection of CO_2 as a tertiary recovery mechanism, with water flooding as Water altering gas (WAG), will be studying to predict the amount of oil that can be produced.

The main factors that may be effect on this process are injection fluid rate and WAG ratio, so the sensitivity will be run to investigate the optimum injection rate and WAG ratio that gives high Recovery factor. (5)

The prediction of production and optimization need more of reservoir parameter to can use EORgui, such as relative permeability, Dykstara person, Corey and Koval factors.

Co	2.00	Swc	0.1140	Krw	0.5390
Cw	1.25	Sor	0.4470	Kro	1.0000





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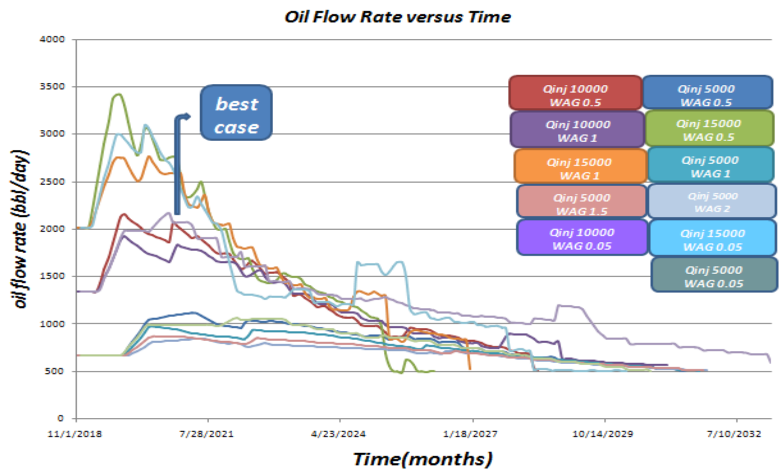
Sensitivity Analysis

The sensitivity analysis were based on change and measure the effect of changes the injection rate and WAG ratio and the figure below will present the cases that run from the model that built in our study to investigate the optimum recovery factor that can get by applying the miscibility flooding.



The summary of results that obtained from each case were collected and comparing the results based on cumulative oil production, recovery factor increasing and the date to reach to economic rate. The results show that the increase in water ration in WAG and increase in injection rate didn't get good production and the optimum case was with injection rate 10,000 bbl/day with WAG ratio zero that means only CO2 rate these conditions reach the RF to 25.22%.

Injection Rate (STB/d)	WAG	Abandoned Date	Cumulative Oil (MMSTB)	Recovery Factor (%)
5000	0.5	01/10/2031	3.789	2.77
10000	0.5	01/07/2028	4.601	3.36
15000	0.5	01/04/2026	4.885	3.57
10000	1.0	01/02/2031	5.113	3.74
5000	1.0	01/10/2031	3.529	2.58
15000	1.0	01/02/2027	5.083	3.71
5000	2.0	01/12/2031	3.294	2.40
5000	1.5	01/12/2031	3.367	2.47
5000	0.05	10/01/2030	3.514	2.57
10000	0.05	04/01/2033	6.550	4.79
15000	0.05	04/01/2030	6.001	4.39

Conclusions

- After production performance monitoring, the last oil flow rate of the field is 785 bbl/day, Water cut 88%, GOR 1500 cf/bbl and cumulative oil production 29 MMbbl, cumulative gas production 32.2Bscf
- Screening criteria shows high ability to applying Miscibility flooding for this field, the chemical and thermal methods are not recommended for this field. The applying WAG is recommended for this field, due to good screening for CO_2 and water flooding performance.
- By building black oil modeling used correlations to estimate MMP and the MMP is about 2120psia.
- The effect of injection rate on prediction of oil production was great, but the effect of WAG ratio as decrease as RF increase.
- The field is water flooded and the WAG flooding has poor effect on flooding and the CO2 flooding is more effective.
- The optimum injection rate is 10,000 STB, by WAG ratio 0.05, to reach to 25.22% recovery factor.
- The main recommendation that should be mention in last work of this study that the application of WAG flooding on reservoirs with highly water cut is very poor application so should prepare the water problems before start the WAG flooding.

Nomenclatures

K_{rw}= relative Permeability to water (md)

K_{ro} = relative Permeability's to oil (md),

μ_o = oil viscosity (cp)

μ_w = water viscosity (cp)

*N*c = capillary number (Fractional)

ν = interstitial velocity of the displacing fluid (i.e. water)

K =Koval factor (Fractional)

E = "effective" viscosity ratio (Fractional)

S_e = viscosity solvent (cp)

H_k = Dykstra–Parsons (Fractional)

P_i = Initial pressure (psia)

B_{oi}= Oil formation volume factor at initial pressure (bbl/STB)

h= Average net pay thickness (ft)

ϕ_{avg}= Average porosity (Fractional)

k_{avg} = Average Permeability (mD)

S_{wi} = Initial Water Saturation (Fractional)

$K_{ro(s_{wmin})}$ = Oil Relative Permeability at Minimum Water Saturation (mD)

S_{wmax} = Maximum Water Saturation (Fractional)

S_{wmin}= Minimum Water Saturation (Fractional)

S_w = Water Saturation (Fractional)

S_{orw} = Residual Oil Saturation to Water (Fractional)

c_o = Corey Oil Exponent

c_w = Corey Water Exponent

$K_{rw(s_{orw})}$ = Water Relative Permeability at Residual oil Saturation (mD)

S_{wcr} = Critical water Saturation (Fractional)

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