COMPARISON OF SELECTIIVE SEMULTANEOUS WATER ALTERNATING GAS NITROGEN (SSWAG (N2)) BETWEEN SANDSTONE AND CARBONATE RESERVOIRS

(An experimental study)

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Abstract-The method selective simultaneous water alternating gas SSWAG is an enhanced oil recovery process. According to Nitrogen injection reservoir criteria, there are two rock types of reservoir that are suitable for nitrogen injection. Sandstone and carbonate are strongly advised in literature review; therefore, an experimental study to compare the two rocks is very useful. The mechanism of this process was to perform the selective (modified) simultaneous water alternating gas (SSWAG). The process was initially started with water flooding (WF), as a secondary recovery, to displace the possible producible oil original in Place (OOIP). When no more oil had been produced by WF, the developed SSWAG was applied, where the gas nitrogen (N_2) was injected at the bottom of the producing zone, while water was injected at the top of the producing zone. The results showed improvement in the Total Oil Recovery Factor, ORF%. Furthermore, the results illustrated that ORF% in Sandstone sand pack was slightly less than that in carbonate sand pack, where it was 73.43% and 73.72% in sandstone and carbonate respectively. Eventually, the gas break though (GBT) was earlier when SSWAG had been applied in carbonate compared with sandstone sand pack.

Key words: EOR, WF, WAG, SSWAG, ORF%, TORF%, GBT

1. INTRODUCTION

After depletion of the oil that can be recovered by primary recovery process, and after implementation of secondary recovery, Enhanced oil recovery (EOR) techniques are applied to recover the residual oil in the reservoir. Only one third of oil initial in place (OIIP) can be recovered by primary and secondary methods, therefore, developing methods of EOR plays a crucial role in the life of any oil field. Injecting fluids to the reservoir, (regardless to the classification; thermal such as hot water, steam; non-thermal such as chemicals, and gases) by sophisticated techniques, for the purpose of recovering the residual oil, is the usual procedure of EOR. The gas injection processes are aimed at improving recoveries by lowering the interfacial tension between the injected gases and the crude oil to minimize the trapping of oil in the rock pores by capillary forces. The mobility ratio between injected gas and the displaced oil bank by CO_2 and N_2 and other miscible/immiscible gas displacement processes is typically very unfavourable because of low viscosity of the injected phase. The unfavourable mobility ratio and the difference in density refer to viscous fingering and density tonguing, and consequently reduced sweep efficiency.

Water Alternating Gas (WAG) is a process of injecting water followed by gas, followed by more water, followed by more gas, etc. When the gas mixes with water ahead of it, it causes a reduction in gas mobility. WAG injection technique has been proposed and used since the late 50's of the last century, where different modifications of this technique were created and later developed. This process was by the combination of the two fluids injection, either alternately or simultaneously. The purpose was to avoid viscous fingering and density tonguing that occurs after gas injection. In addition, the mobility of gas is controlled by the WAG process. Although, water and gas are injected in the water alternating gas injection process, to solve these problems, the result is that injected fluids move towards the bottom and the top of the reservoir respectively due to their density difference with oil in the reservoir that caused to take place the under-riding and overriding phenomena. Therefore, large amount of oil remains in an area called Un-swept zone. Moreover, during the cycle of gas, the flow direction will be to the top of the reservoir, however, when the water cycle is implemented, the flow will be to the bottom as a result to gravity segregation of the fluids.

For the previous reasons, the main aim of this work was a necessity to develop the WAG technique to be much suitable for the resolution of the mentioned problems.

WAG process: WAG injection is a combination of two conventional EOR techniques; water flooding and gas injection. WAG process consists of the injection of water and gas either at alternate slugs or simultaneously in the well bore with the objective of reducing the impact of viscos fingering [1].

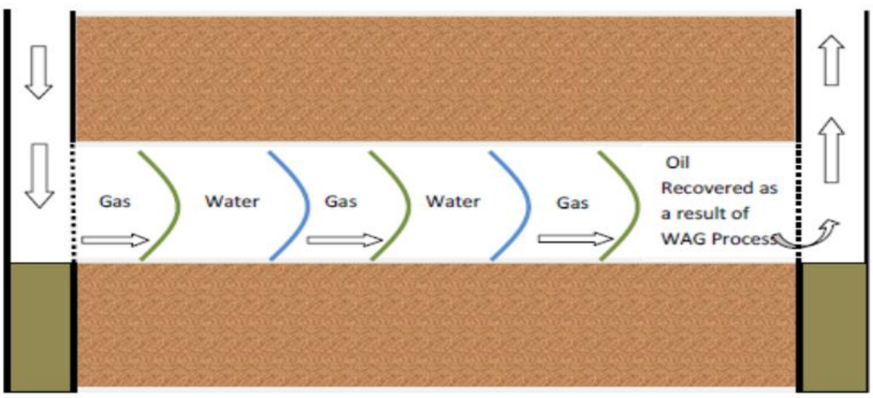

Figure 1: WAG PROCESS

Classification of WAG methods: In general, WAG can be classified to miscible (MWAG) and immiscible (IWAG) processes. Hybrid WAG (HWAG), and simultaneous WAG (SWAG) are among these classifications [2]. Some details are illustrated here.

Miscible WAG Injection: When the reservoir is re-pressurized, in order to bring the reservoir pressure above the minimum miscibility pressure (MMP) of the fluids. In many cases a multiple-contact gas/oil miscibility may have been obtained, but much uncertainty remains about the actual displacement process [3].

Immiscible WAG Injection: Even though, if the gas cannot develop miscibility with oil, still some compositional exchanges between gas and oil may important for the fluid characterization and oil recovery [2].

Hybrid WAG Injection: The process is referred to as hybrid WAG injection, When a large slug of gas is injected, followed by a number of small slugs of water and gas.

Simultaneous WAG (SWAG) injection: SWAG injection occurs when water and gas are injected in the reservoir at the same time through a single injection well. However, when the water and gas are mixed at the surface and then injected in to the reservoir, the process is referred as SWAG injection [3, 4, 5].

Selective Simultaneous Water Alternating Gas (SSWAG) Injection: when the gas and water are pumped separately using a dual completion injector without mix the two phases on the surface, the process is referred as selective or modified simultaneously water alternating gas (SSWAG) [6, 7]. Some authors considered that this technique requires two wells for injecting water and gas separately.

Gravity Assisted Simultaneous Water and Gas Injection (GASWAG): GASWAG technique is based on controlling the injection by turning off inactive perforation, increasing the number of wells and selective control of gas injection points (bottom of reservoir) and water (top of reservoir) [8].

Foam Assisted Water Alternating Gas (FAWAG): a process uses foam for improving the sweep efficiency during gas injection while reducing gas oil ratio GOR and maximizing production rate in the producer well. Foam can be injected in to the formation by co-injection of surfactant solution and gas, where alternating solution of surfactant and gas are injected into the formation. Another method for injecting foam in to the formation is, injecting surfactant solution into the upper region and gas is injected into the lower region of the formation [9].

2. LITERATURE REVIEW OF SSWAG

There is little literature about this specific type of WAG technique. Algharaib, et al. [5] presented a simulation study, a new design of SWAG process using CO_2, in which water is injected at the top of the reservoir and gas is injected at the bottom. From their conclusion, it was inferred that they injected water and gas not at the same time. The difference in water and gas densities provides a sweep mechanism in which water tends to sweep hydrocarbons down ward and the gas tends to sweep hydrocarbons upward. They investigated that for both homogeneous and heterogeneous reservoirs, several parameters such as mobility ratio between oil and gas phase's viscosity ratio between gas and oil phases, location of water and gas injection wells and injection rates of water and gas. The results also showed that the fractional oil produced by water is more than by gas. Barnawi (2008) performed a simulation study to verify Stone's simultaneous water and gas injection performance in a 5-spot pattern. Results showed that injecting water above gas may result in better oil recovery than WAG injection though not as indicated by Stone. Increase in oil recovery with SSWAG injection is a function of the gas critical saturation. The more gas is trapped in the formation, the higher oil recovery is obtained. SSWAG injection results in a steady injection pressure and less fluctuation in gas production rate compared to WAG injection.

To solve problems resulting by high and low permeability's in different zones, Saif S. Al Sayari [10] suggested injecting gas at the lower zone, referring to the main purpose of the technique of SSWAG. He added: there is no force to cause the injected gas to flow from the upper zone to the lower zone as it has lower or similar density as oil therefore, a method is required that confines the injected gas to the lower zone. A possible way of achieving this is by keeping the upper zone pressurized by continuous water injection and simultaneously injecting gas into the lower zone [10]. Although Al Sayari used Hydrocarbon in his WAG experiments and CO_2 for gas injection, he found that the flow of gas is to top zone as well to density force. Mohammad Javad Darvishnezhad and others performed a comparison between the different techniques of WAG such as Immiscible WAG (IWAG), Hybrid WAG (HWAG), Simultaneous WAG (SWAG) and Selective Simultaneous WAG (SSWAG) and water and gas injection to specify the appropriate injection method. Then ultimate oil recovery, residual oil saturation, daily and total oil production are compared in these scenarios. Also these scenarios in four and five spot injection patterns were compared. Results indicated that, SSWAG injection has the higher oil production and lowest residual oil saturation. In addition, among these scenarios, SSWAG in 4-spot pattern had the highest recovery and daily oil production. 4-spot pattern had the higher recovery and lower residual oil saturation than 5-spot pattern [11].

Oranat Santidhananon (2011), in his research, described SSWAG technique that it requires two wells for injecting water and gas separately. A gas injector is usually placed at the bottom of the formation while a water injector is placed at the top with another producer well on the other side of the reservoir opposite these two injectors. He found that SSWAG might not be suitable to implement in dipping reservoirs.

Bednarz and Stopa [8] made a world offshore review about EOR methods, They referred that the method of SSWAG, was used in Kuwait which by injecting water and gas selectively to prevent gravity segregation effects, indicating that this method is similar to Gravity Assisted Simultaneous WAG (GASWAG) technique.

3. SSWAN2 PROCESS MECHANISM

$SWAGN_2$ is a technique in which water and nitrogen are co-injected into a portion or the entire thickness of the formation, by using either a single wellbore or a dual completion injector where the two phases enter the pore zone at different depths (also called Selective SWAG - SSWAG). In fact, considering that injecting water and nitrogen at the same pressure, the injection process seems more uniform, gravity effects are less evident and, as a consequence, a better mobility control can be achieved. During injecting nitrogen at the bottom of the producing zone, the gas will displace the oil in the pores taking slight change in the direction, due to gravity effect, to the top. On the other hand, injection gas pressure would keep gas go forward if pressure was high enough. Contra versa, when water is injected at the top, the high pressure will keep water to flow forward, on the other hand, gravity is attracting water to the bottom Fig.2.

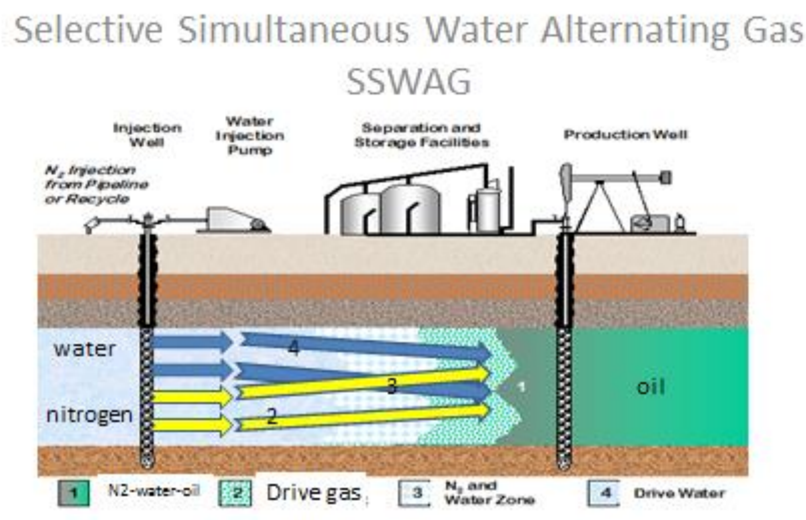

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Figure 2: An SSWAG process mechanism

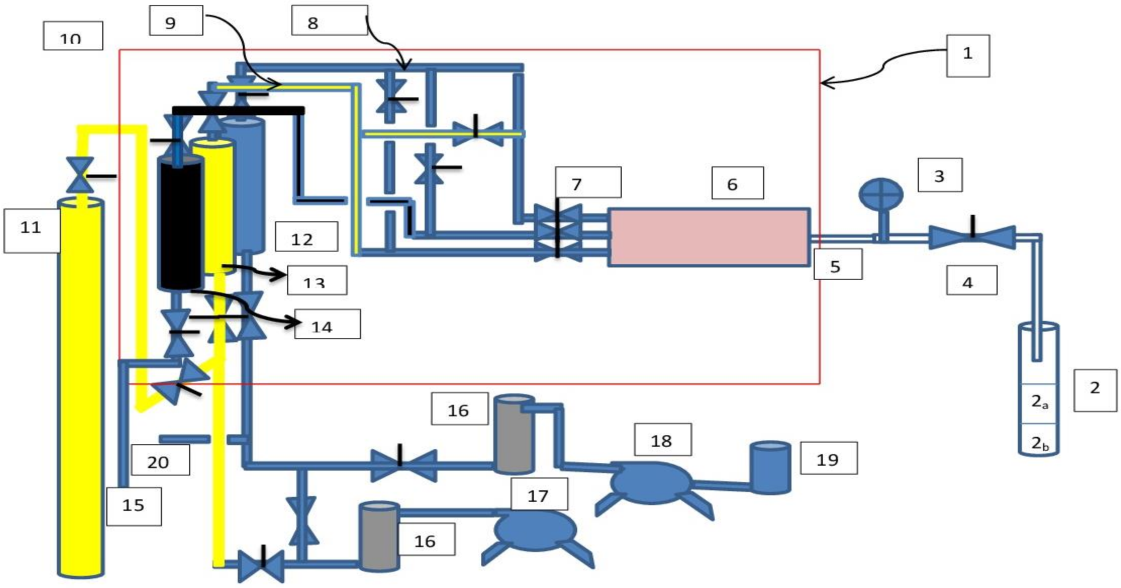
Advantages of SSWAG (Nitrogen) tichnique

1. This technique can be applied in miscible and immiscible manner.
2. This method is applicable in both sandstone and carbonate reservoirs.
3. The cost is very low. Compared to other techniques such as chemicals.
4. Two injection wells can be used; one for gas; one for brine.
5. By using nitrogen gas, corrosion is very low if not exist compared with carbon dioxide.

4. METHODOLOGY

Experimental setup

The flooding system is described in Fig.3., where all apparatus used in the experiments are labelled and below are named.



Lab experimental Setup Components

1- Oven border (all these equipment are in the oven to control Temperature)
2- Oil, water, and gas production graded cylinder. 2_a : produced oil, 2_b: produced water
3- Pressure Regulator, RP
4- Outlet valve
5- Sand pack core holder outlet
6- Sand pack core holder contains sandstone or carbonates
7- Core holder inlet valves
8- Water line
9- Gas line
10- Oil saturating line
11- Gas supply cylinder
12- Water accumulator
13- Gas accumulator
14- Oil accumulator
15- Oil supplier
16- Mercury cylinder
17- Mercury pump
18- Water pump
19- Water resource for pump
20- Brine resource

Figure 3.:The experimental setup that was used in the lab

Equipment Describtion

Nitrogen gas, cylinder and injection dystem

Nitrogen gas cylinder: the gas cylinder was set as pressure of 200 bar (2940 psi) to supply the injection system with N_2 to be used in the different methods of flooding. The N_2 was pure 99%. The prperties of nitrogen at 70C^o were mentioned below in table 1.

Pumps: There are two pumps used during the SSWAG. The used pumps were (dual piston pump, model 12-6) used to inject water from the top of mercury cylinder to push mercury through 1/8” stainless steel pipes. Both pumps are pressing murcury which compressed either gas or water to perform the process. The pumps were used separately in WF, WF, and WAG processes. However both pomps were used simultaneosly in SSWAG.

Oil/Gas/Water accumulators : there are three accumulators of size of 680 cc, for each fluid. All accumulator inlests were connected to the pumps, while the outlets were connected to the medeum inlet of th core holder for oil, in order to perforn oil saturation before starting flooding processes. Water and gas accumulators outlets were conneceted to all core holder inlets in order to carry out water saturation or to perform W.F, and SSWAG.

Core holder and out let system

Core holdre: the sand pack coreholder was made of stainless steel which could withatand a pressure of 3000 psi. it had three inlets ond outlet holes. The three inlets were made to receive the injected fluids while the outlet was for producing oil, gas, and water. The core holder was 35.29 cm in length and the inside diameter was 3.8 cm, while the hole diameter was 1/8".

Core holder confinement pressure: the core holder outlet was connected to a pressure regulator (PR). The purpose of this pressure regulator was to maintain the core holder , which represents the reservoir coditions, at a certain pressure and temperature.

Production reciever (separator): this separator was connected to the outlet of pressure regulator (PR), in order to receive and separate the fluids: gas, water, and oil.the separator was actually a graded cylinder to record the volume of oil and water produced by each process. The gas was ventiled at the top of the cylinder. There was not a necessisity to record the volume of the gas produced.

Tubing and fitting system: All the setup system was connected to each other by 1/8” stainless steel pipes, and valves that they could withstand upto 2500 psi. on the other hand.

Materials

Brine: Sodium chloride (NaCl) was used to make the synthetic brine solution. 35 grams of NaCl were used in the total of 1000 ml of distilled water to make 35,000 PPM brine water.

Crude Oil: crude oil was taken from Kemaman Crude Oil Terminal, Malaysia, supplied by UMP lab stores.

Gas Nitrogen: The gas nitrogen that had been used in the all processes was with purity of 99%. The cylinder was provided by pressure regulator to press the gas accumulator cylinder with the pressure desired.

Preparation of sandpack for both sandstone and carbonate cores

Five micro meter filter cloth was lowered at the outlet of the core holder bottom hole to prevent sand escape from the core holder during flooding experiment experiments. The sandstone (glass beads, size of 90-150 micron meter) or carbonate (lime stone, size 150-250 micro meter) grains were washed and then regularly pushed into the core holder using deionized water to ease filling sand pores with water and to make the grains very homogenously compacted. Another filter cloth was put at the inside outlet of the holder. The outlet cover was tightly sealed. This procedure was done for both types of rocks.

Core flooding runs for SSWAG were carried out in the laboratory, using rig as shown in Fig 3. It consisted of gas (nitrogen) and water (brine), as they were simultaneously injected. We were working on a light crude oil 38.77 API, while brine to be injected was similar to sea water, 35,000 PPM. Sandstone and carbonate core properties as well as reservoir fluid properties were already taken. They were as figured in this table 1.

Calculation of porosity (ϕ), and permeability (k) of the sand pack core samples: Sandstone and Carbonate

Porosity measurement

To measure porosity (ϕ), of the Core, the core holder was filled with sandstone/carbonate and compacted then the weight of the core holder was recorded. the sand was saturated of deionized water and vibration had been applied on the core for water saturation through sand pores. This operation was contiued until saturation was completed. Then the weight of the core holder with sand and water in it was taken. The diffrence in the weight readings gave the weght of the water in the core. Since the density of deionized water is 1 g/cc therefore, water weight represents the pore volume of the sand pack, then.

Porosity,ϕ (%) = $\frac{pore\ volume}{Bulk\ volume}$ X 100

Where Bulk volume is the total volume of the sand back. It was calculate by this formula
Bulk volume = л r^2 L
Where
л = 3.14
r = inside core radious, cm
L = inside length of the core, cm
Porosity values for sandstone and carbonate sand packs are recorded in table 1.

Callculation of permeability

After taking the porosity measurements of sandstone and carbonate samples, permeability (K) was also calculated. The sand pack was subjected to a differential pressure between inlet and outlet during water flow rate. It was calculated by recording the differential pressure between inlet and outlet points of the sandpack at different flow rates. Then Darcy law was applied.

$$Q = -\frac{KA\Delta P}{\mu L}$$

Where
Q = flow rate,
μ = viscosity,
A = area,
ΔP = differential pressure and
L = core length.
Then

$$K = \frac{Q\mu L}{A\Delta P}$$

K was calculated several times with different values of Q and the aveage K was recorded.
The values for ϕ and K were recorded in table 1
By applying this formula we can find the slop of this curve which gives the value of K, therefore

$$Q\mu/A = K\ \Delta P/L$$

Where slope, m is K here
The calculated values of porosities and permeabilities are in table 1

Table 1: Sandstone and carbonate sand packs, rock and Fluid (oil, nitrogen, and water at 70C°) properties

No	**properties**	**Values**
1	Oil viscosity (at 70 C°), Cp	2.4
2	Oil density (at 25 C°), g/cm^3	0.812
3	Oil density (at 15 C°), g/cm3	0.83
4	Oil density (at 70 C°), g/cc	0.79
5	API gravity° (at 15 C°)	38.77
6	Water salinity, PPM	35,000
7	Water Brine viscosity, at 25C°, cp	0.959
8	Water Brine viscosity, at 70 C°, cp	0.4413
9	Water Brine density, at 25C°, g/cc	1.023387
10	Water Brine density, at 70 C°, g/cc	1.003215
11	Nitrogen gas viscosity at 70 C°, cp	0.000022378
12	Nitrogen gas density, at 70 C°, g/cm^3	0.129821

13	Nitrogen gas viscosity at 25 C°, cp	0.00002104216
14	Nitrogen gas density, at 25C°, g/cm3	0.152675
15	Sandstone (glass beads) sandpack permeability, md	3350
16	Sandstone (glass beads) sandpack (porosity), %	37.5
17	Sandstone (glass beads) sandpack size, miron meter	90-150
18	Carbonates (Limestone) permeability,md	3054
19	Carbonates (Limestone) sandpack porosity, %	40.75
20	Carbonates (Limestone) sandpack grain size, micron m	150-250

Procedure of the experiments

Two types of reservoirs Sandstone and carbonates have been tested using SSWAG process.
These steps must be taken in each experiment

Sandstone Sample

Brine and Oil Saturation

- Brine, which was prepared earlier, was pumped to accumulator 12 (see Fig.3) crude oil into accumulator 14 and N_2 in accumulator 13.
- solution of brine was injected to the sandpack core until confirming complete saturation (saturation must take 24 hrs)
- After core had been saturated with brine crude oil was injected to find saturation of oil S_o in core and with this irreducible water saturation, S_{wi} was also calculated (also oil saturation must take 24 hrs.)

Experiment

SSWAG nitrogen application (gas is injected at the bottom and water at the top)

The experiment was conducted at inlet pressure (2000 psi), outlet pressure (1990 psi), and the overburden was set to be 2000 psi and a temperature of 70 ºC was maintained. The core was saturated for 24 hrs. in brine before the run. The following steps were followed:

- Brine solution was injected to determine the volume recovered by secondary recovery (W.F.) to calculate irreducible oil saturation, S_{oir}.
- The SSWAG (nitrogen) process was applied by by injecting gas (N_2) from accumulator 13 at the bottom injection inlrt and brine solution from accumulator 12 at the top inlet. They were injected simultaneously to recover the remaining crude from the core.
- Produced Oil and water are collected at the outlet manually and the reading is noted.
- The times when gas breakthrough and water break through were recorded during the experiment.

Carbonate (lime stone) sample

The same steps and procedure had been done for sandstone was repeated for carbonate for SSWAG (N_2), and all results were recorded.

5. RESULTS

Results are illustrated in the tables 2, 3, 4, and 5. They are classified as per type of rock and different processes

Sandstone sand pack results

Water flood process

Table 2: parameters and results of water flood experiment

Pore Volume, PV, cc	Water Saturation, S_{wi}, %	Oil Initial In place, OIIP, cc	Water Injection Pressure (W. I. P.), psi	Inj. Time, hours	Recovered. oil Volume, cc	R.F %
151	15.23	128	2000	4.	85	66.4

SSWAG process

Table 3: parameters and results of SSWAG experiment

OIP (oil remaining), cc	G. I. P., psi	W.I. P., psi	W.I. time for 1/2 P.V., hrs	G. I. time. for 1/2 P.V, hrs	R. oil, cc	R.F,% (related to OOIP)	R.F % (related to the rem. Oil (OIP)	Total R.F.%
43	2000	2000	1:00	2:00	9	7.03	20.93	73.43

Carbonates sand pack results

Water flood process

Table 4: parameters and results of water flood experiment

Pore volume P.V, cc	Water saturation, S_{wi}, %	Oil Initial In Place, OIIP, cc	Water Injection Pressure, W. I. P. , psi	Inj. Time, hours	Recovered oil, cc	R.F %
162	15.43	137	2000	4:30	87	63.50

SSWAG process

Table 5: parameters and results of SSWAG experiment

OIP (oil remaining), cc	Gas. I. P., psi	W.I. P., psi	W.I. time for ¼ P.V., cc	G. I. time. for ¼ P.V, cc	R. oil, cc	R.F,% (related to OOIP)	R.F % (related to the rem. Oil (OIP)	Total R.F.%
50	2000	2000	2:15	2:15	14	10.22	18.00	73.72

All results in one table

Table 6: ORF, % regarding to rock type before and after developing SSWAG process

Rock type Recovery Factor, RF	Recovery factors (RF), %	
	Sandstone	Carbonate
ORF related to OIIP, %	7.03	10.22
ORF related to OIP, %	20.93	18
Total Oil Recovery Factor, %	73..43	73.72
Gas break through(GBT), minuts	39	35

A. Results discusion

Each Experiment starts with W.F then SSWAG. The comparison between sandstone and carbonate for the recovery is shown in the results table 6. From the point of view of applying the SSWAG as a an EOR method to avoid the problems that occur during implementation of water alternating gas (WAG), such as gas gravity ride, and gas water segregation, that usually occur after some time of starting water injection. Water and gas trend to separate. Water goes down and gas goes up. Therefore, it was necessarly to find a way how to avoid this problem. Selective simultaneous water alternating gas (SSWAG) could have partialy a solution to this problem. But the segregation and the separation and the gravity on gas and water still can affect. developed SSWAG can prolong the time before gas break through occur. Table 10 shows that by using the developed SSWAG the total recovery factor TRF had increased in both sandstone and carbonates sandpacks from 66.4% by using WF to 73.43% in sandstone, and from 63.5% by using WF to 73.72% in carbonate sand pack.. Furthermore, the time of gas breakthrough (GBT) in SSWAG process, was earlier in carbonate (35 min), while it was 39 min. during sandstone process injection.

In sandstone, the increament of production after W.F, was the higher in sandstone 20.93%, compared with 18% in carbonate when the reference of evaluation was the values of oil remaining in place (OIP).

Fig.4 shows applying SSWAG processe, on sandstone sand pack.

Fig.5 shows the applying SSWAG processe, on carbonates sandpack.

B. Interpretation of results

Water flooding process, which is usually the first step in every EOR method, is a method of secondary recovery processes. The mechanism is to displace the oil by taking the benefit of viscous forces.

Conventional oil recovery involves improving volumetric sweep efficiency via a variety of technologies and practices.

In SSWAG, the difference in water and gas densities provides a sweeping mechanism in which water tends to sweep the hydrocarbons downward and the gas tends to sweep the hydrocarbons upward. It is expected that the two displacement mechanisms will work together to enhance the overall sweep efficiency and thus the oil recovery.

During the injection of water from the top zone, water displaces the remaining oil as well as water used in W.F. pushing the oil before starting the effect of gravity that makes water goes down after the decline of injection pressure. However, injecting gas from the bottom will make the gas pushing the oil remaining before tonging as affected by gravity of gas.

In sandstone sample WF gave better results compared with carbonate, while carbonate was much better when using SSWAG technique. The difference in total oil recovery factor between the two types of rocks was only 0.29 %.

The literature review showed that wetting properties of the reservoir played a very important role for the efficiency of water flood. Experimental results clearly indicate improvement of the oil recovery without wettability alteration. Because about 80% of these geologic formations are oil-wet carbonate reservoirs pose a problem in oil recovery. The negatively–charged carboxylic acid anions in oil are attracted to positively-charged carbonate surfaces, thus generating oil-wet surfaces.

The ORF%, that gained from SSWAG process without involving WF in sandstone, was higher than in carbonate, while the quantity gained in WF was greater in sandstone. On the other hand ORF% by SSWAG, was greater in carbonate (10.22%), while it was 7.03% in sandstone.

By applying SSWAG in carbonate, GBT was after 35 minutes in sandstone, while it was after 39 minutes in carbonate sand pack see Fig 4 and Fig 5. That is because of difference in effective porosity. In carbonate, the porosity was 40.5% while it was only 37.75%, in sandstone see table 1. The mud in limestone (carbonate) was too much which made delay in case of WF and because of limestone is oil-wet. In sandstone case, and because it is water-wet, the sand absorbs water, which makes the gas delaying before reaching the outlet. In case of gas and due to the low density and viscosity, it moved faster in carbomate than sandstone.

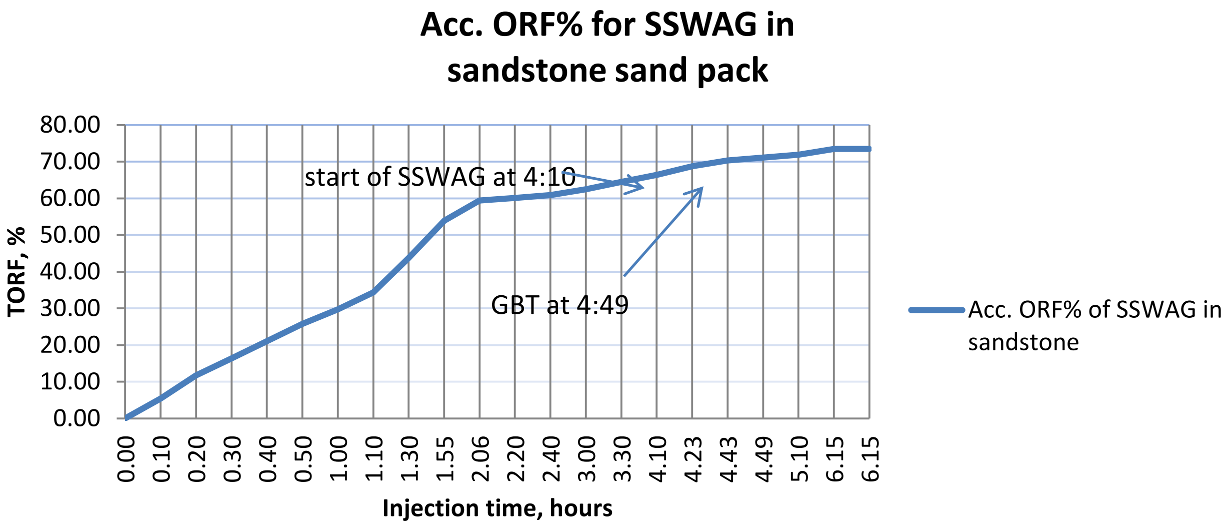


Figure 4: SSWAG (nitrogen) process (sandstone) ; Injection Time V.S. Acc. TRF%

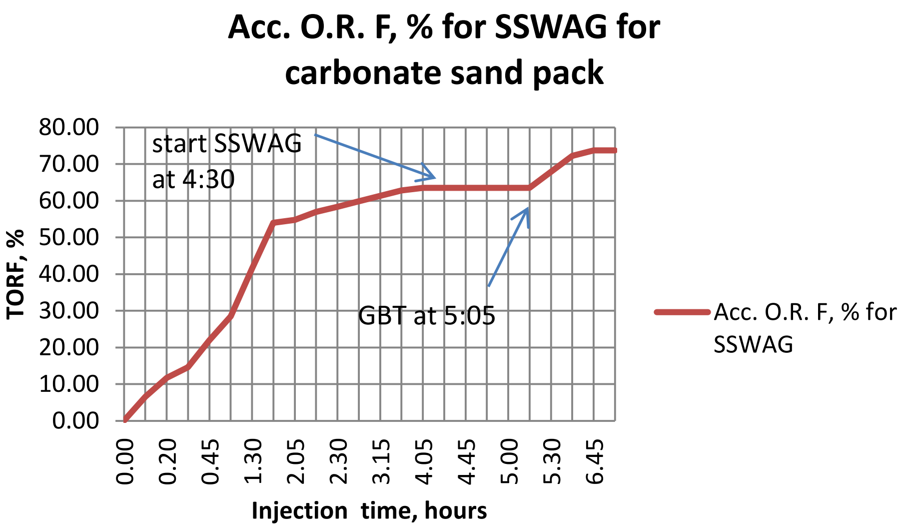


Figure 5: SSWAG (nitrogen) process (Carbonate) ; Injection Time V.S. Acc. TRF%

6. CONCLUSION

SSWAG (N_2) process has proved improvement in oil recovery after WF. Gas breakthrough was earlier when applying SSWAG in carbonate than in sandstone. Applying SSWAG in carbonate sand pack has slightly given better in total recovery compared with sandstone's. Comparing the results of recovery factor according to, OIP, RF in sandstone sand pack was better than the one in carbonate sand pack.

7. RECOMMENDATIONS

In this paper, the operation pressure was only 2000 psi. Different values of injection pressure and temperature are recommended to test the effect of the injection pressure and temperature on the recovery factor.

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