Indian Journal of Science and Technology, *Vol 8(14), 70682, July 2015*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Analysis on Capillary Pressure Curves by Wettability Modification through Surfactants

Prince Julius[1*], P. N. Ananthanarayanan[1] and G. Anbazhagan[2]

[1]Department of Petroleum Engineering, Amet University, Chennai - 603112, Tamil Nadu, India; prince466@gmail.com

[2]Bharath University, Chennai - 600073, Tamil Nadu, India

Abstract

Wettability of a reservoir rock is closely related to capillary pressure curves. The status of wettability is an important factor for oil recovery, can be clearly seen through the variations in capillary pressure curves. The aim is to analyze the changes in capillary pressure curves and saturations by altering wettability. An oil wet core sample was tested to alter wettability. During alteration process it is difficult to analyze the status of wettability. Surfactants were applied to modify wettability. Additionally, parameters like connate water saturation, spontaneous oil and water saturations, residual oil saturation and type of wettability can be analyzed. The concentration of surfactants was selected by conductivity test. The changes in saturations with variations in capillary pressure curves were stated.

Keywords: Adsorption Anionic Surfactant, Capillary Pressure Curves, CMC, Wettability

1. Introduction

Wettability is a property of rock which will have tendency to adsorb its related phase. It is connected with capillary pressure, relative permeability and resistivity. Wettability of a reservoir rock can be altered by application of EOR surfactants. Normally surfactants will be applied on oil wet to make water wet or intermediate. The changes in wettability can be easily modeled in capillary pressure curves. By observing these curve we can easily analyze changes in wettability[1].

Capillary pressure is the in difference between nonwetting pressure and wetting pressures. The result of this difference analyzing with fluid saturations makes capillary pressure curves. These curves are in three stages. In first stage flowing of nonwetting phase as oil into capillary tubes with positive capillary pressure until wetting phase reaches its critical limit as connate water saturation S_{cw}. In second stage wetting phase pressure as water rises to displace oil reaching capillary pressure zero at spontaneous water saturation as S_{pw}. Beyond this artificial injection of water is required to displace oil by making capillary pressure negative reaching residual saturation of oil as S_{or}. In third stage pressure dominance will be seen by nonwetting phase oil on water reaching spontaneous oil saturation as S_{PO} at zero capillary pressure[2] Beyond this saturation artificial injection of oil will displace water and reaches to S_{cw} as shown in the Figure 1. Objective is to observe the changes in capillary pressure curves by altering wettabilty of an oil wet core through surfactants[3].

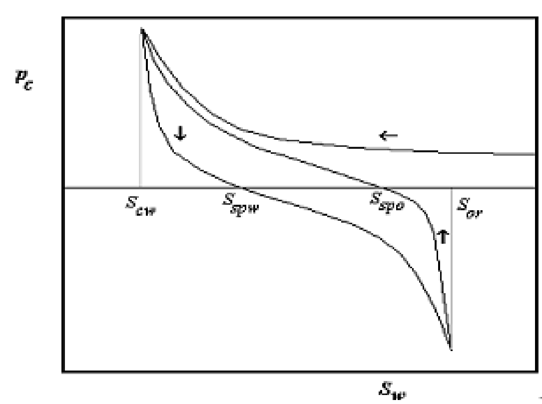

Figure 1. Capillary Pressure Curves.

* Author for correspondence

2. Methodology

2.1 Amott Wettability Index

The wetting property of core sample whether it is water wet or oil wet can be analyzed by formula:

$$I_w = \frac{S_{spw} - S_{cw}}{1 - S_{cw} - S_{or}}, \quad I_o = \frac{S_{spo} - S_{or}}{1 - S_{cw} - S_{or}}$$

and I_w- I_o = Negative (Oil wet), Zero (Intermediate), Positive (Water wet)
Based on Figure 2,

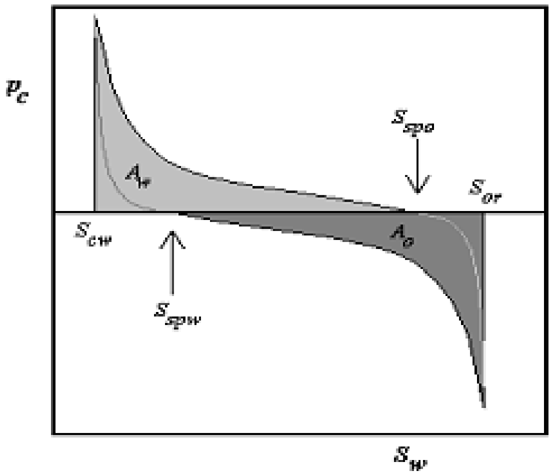

Figure 2. Capillary pressures showing area of wetting phase.

Where 'I_w' and 'I_o' are imbibition levels of water and oil respectively. If the reservoir is extremely water wet 'I_o' will become zero and 'U' will become positive and for extremely oil wet 'I_w' will become zero and 'U' will become negative[4].

2.2 Conductivity Test

This test is conducted to determine exact surfactant concentration which can be soluble in brine and oil. That concentration is known as Critical Micelle Concentration (CMC) where micelles start to form[5]. Conductivity rises up to the level of CMC with concentration. After CMC micelles will start to aggregate with concentration makes conductivity to be in constant position. This concentration was selected for flooding[6].

3. Results and Observations

For conductivity test five concentrations of surfactants were chosen to determine CMC in Figure 3. The deviation in graph has observed at 200 ppm concentration as per the Table 1.

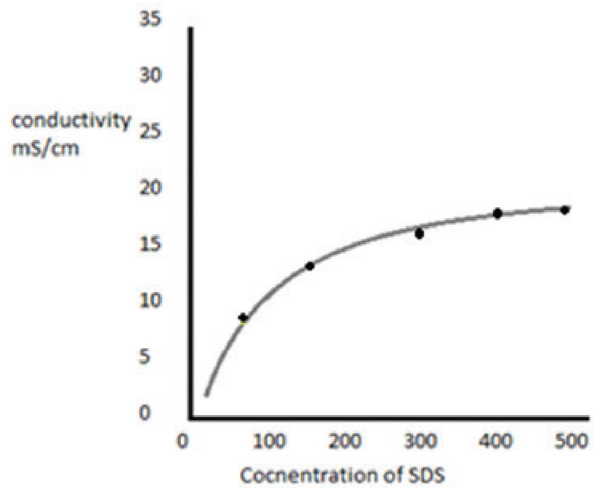

Figure 3. Conductivity of SDS in ppm.

3.1 Bottle Test

Berea core of 3 inch×3 inch has been aged with oil for seven days and considered as oil wet. Water has been continuously injected into the core sample displacing oil. Again oil has been injected into oil wet core and capillary pressures have been recorded until connate saturation of water reached. Then water has been injected displacing oil and pressures were recorded until it reaches negative capillary pressure up to residual Oil Saturation as shown in Table 2.

Table 1. Surfactant concentration vs Conductivity

Conductivity mS/cm	Surfactant Concentration ppm
7	100
14	200
15	300
16	400
18	500

Table 2. Capillary pressure for oil wet reservoir

Sl. No.	Capillary Pressures	S_o	S_w
		Curve 1	
1	+1.5	0	1
2	+2.0	0.2	0.8
3	+3.5	0.6	0.4
4	+4.0	0.8	0.2(S_{cw})
		Curve 2	
1	+4.0	0.8	0.2
2	+3.5	0.75	0.2
3	+2.0	0.65	0.3
4	+1.5	0.6	0.3
5	0	0.6	0.35(S_{pw})
6	-1.5	0.5	0.45
7	-2.0	0.4	0.55
8	-3.5	0.35	0.65
9	-4.0	0.35(S_{or})	0.65
		Curve 3	
1	-4.0	0.35	0.65
2	-3.5	0.45	0.55
3	-2.0	0.40	0.60
4	-1.5	0.40	0.60
5	0	0.55(S_{po})	0.45

After reaching residual oil saturation S_{or} oil have been injected by displacing water until capillary pressure reaches zero. The oil saturation at that level is spontaneous oil saturation S_{po}.

$I_w = (0.35\text{-}0.2)/(1\text{-}0.2\text{-}0.35) = 0.33$
$I_o = (0.55\text{-}0.35)/(1\text{-}0.2\text{-}0.35) = 0.44$
$I_w - I_o = -0.11$

Shows the core is oil wet and the capillary pressure curves are shown in Figure 3.

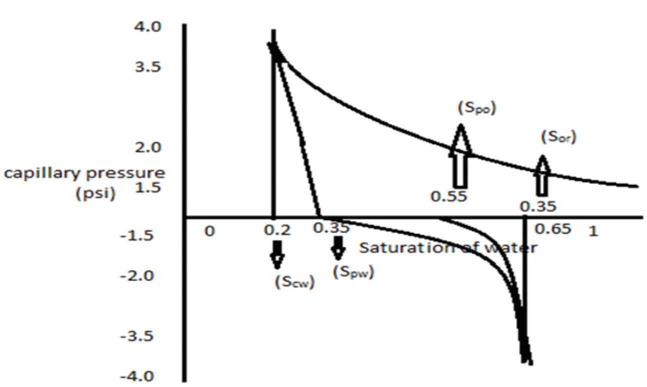

Figure 4. Oil wet capillary pressure curve.

For modification of wettability core sample was saturated with oil initially. Dilute SDS of 200 ppm have been injected to displace oil in place of water, at the same time to alter wettability. Due to application of SDS core wettability have been altered to intermediate wet. Oil has been injected into core sample displacing aqueous SDS as saturation of water and S_{cw} has defined. The process has been continued for S_{pw}, S_{or} and S_{po} and capillary pressure curves were drawn as shown in figure on the basis of Table 3.

Table 3. Capillary pressure data for core of changed wettability

Sl. No.	Capillary Pressures	S_o	Dilute SDS in (S_w)
		Curve 1	
1	+1.5	0	1
2	+2.0	0.2	0.8
3	+3.5	0.4	0.6
4	+4.0	0.65	0.35(S_{cw})
		Curve 2	
1	+4.0	0.65	0.35
2	+3.5	0.55	0.45
3	+2.0	0.50	0.50
4	+1.5	0.55	0.45
5	0	0.45	0.55(S_{pw})
6	-1.5	0.35	0.65
7	-2.0	0.30	0.70
8	-3.5	0.20	0.80
9	-4.0	0.15(S_{or})	0.85
		Curve 3	
1	-4.0	0.18	0.82
2	-3.5	0.20	0.80
3	-2.0	0.25	0.75
4	-1.5	0.28	0.72
5	0	0.30(S_{po})	0.70

And
$I_w = (0.55\text{-}0.35)/(1\text{-}0.35\text{-}0.15) = 0.4$
$I_o = (0.30\text{-}0.15)/(1\text{-}0.35\text{-}0.15) = 0.3$
$I_w - I_o = +0.1$ (near to zero)

Shows the core has altered from oil wet to intermediate wet (slightly water wet) and the capillary pressure curves are shown in Figure 4.

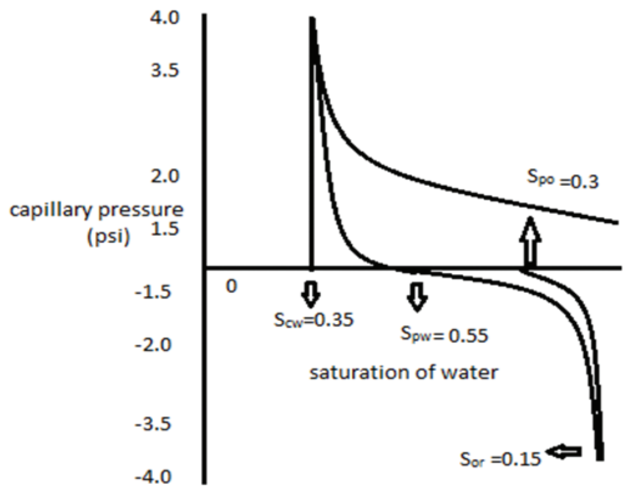

Figure 5. Water wet capillary pressure curves.

4. Summary

- Capillary pressure curves are good indicators for observing the changes in wettability[7].
- 200 ppm of anionic surfactants SDS from conductivity test has been successfully applied for wettability alteration on an oil wet sandstone core.
- Capillary pressure is closely related to relative permeability and resistivity of formation.
- When capillary pressures alter automatically other parameters also alters.
- Further investigation can be carried on observing changes in relative permeability and resistivity by application of surfactants. These observations can be seen in carbonate reservoir cores also.

5. References

1. Sheng JJ. Comparison of the effects of wettability alteration and IFT reduction on oil recovery in carbonate reservoirs. Asia-Pacific Journal of Chemical Engineering. 2013; 8(1):154–61.
2. Engler TW. Fluid flow in porous media - petroleum engineering. Fall. 2003; 524–9.
3. Sheng JJ. Modern chemical enhanced oil recovery - theory and practice. Burlington, MA: Elsevier; 2011.
4. Delshad M, Najafabadi NF, Anderson GA, Pope GA, Sepehrnoori K. Modeling wettability alteration by surfactants in naturally fractured reservoirs. SPE/DOE Symposium on Improved Oil Recovery; Tulsa, Oklahoma, USA. 2006 Apr 22–26.
5. Chen H-Y. Reservoir Engineering I. Properties of Reservoir Rocks and Rock-Fluid Systems. 2003 Sep.
6. Amyx JW, Bass DM, Whiting RL. Petroleum reservoir engineering. New York, NY: McGrawHill; 1960.
7. The University of Tulsa Petroleum Engineering Department: Laboratory Manual for PE 2101 (Rock and Fluid Property Lab). Tulsa, Oklahoma: Fall; 1998.