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Advanced Waterflooding in Chalk Reservoirs: Crude Oil/Brine Interaction Study

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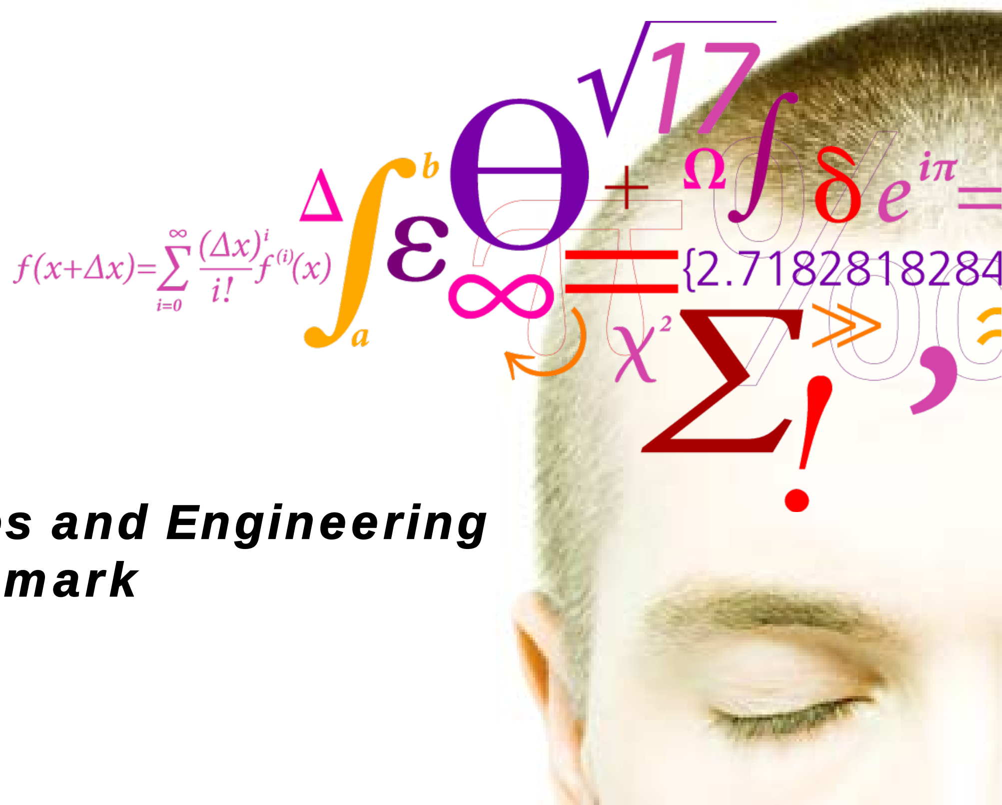
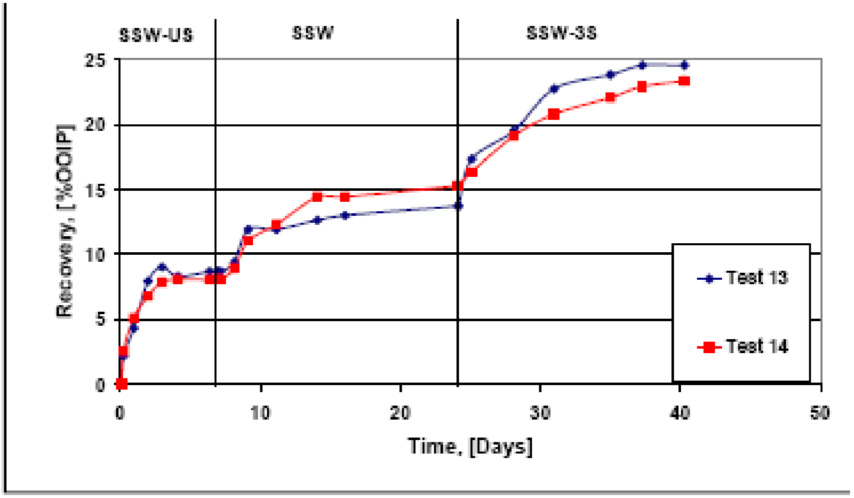
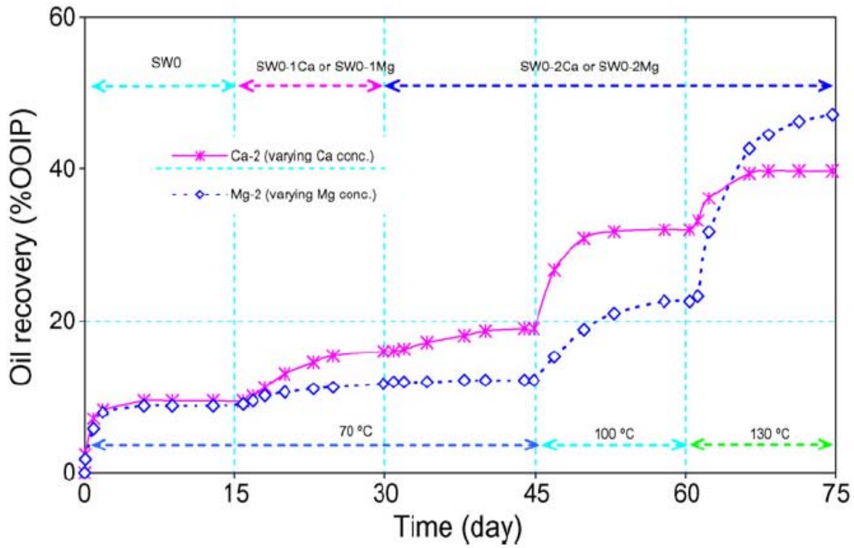


Effects of brine components on oil recovery

- (Austad et al., 2005,2006)



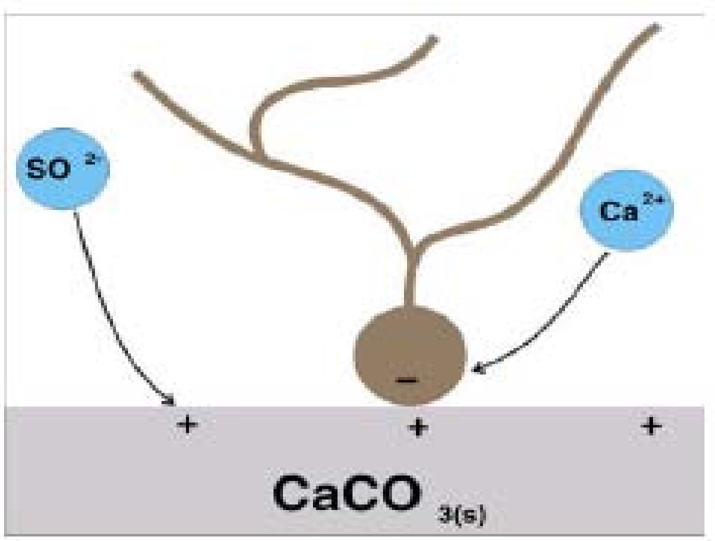


Higher sulfate ion concentration → Higher oil recovery

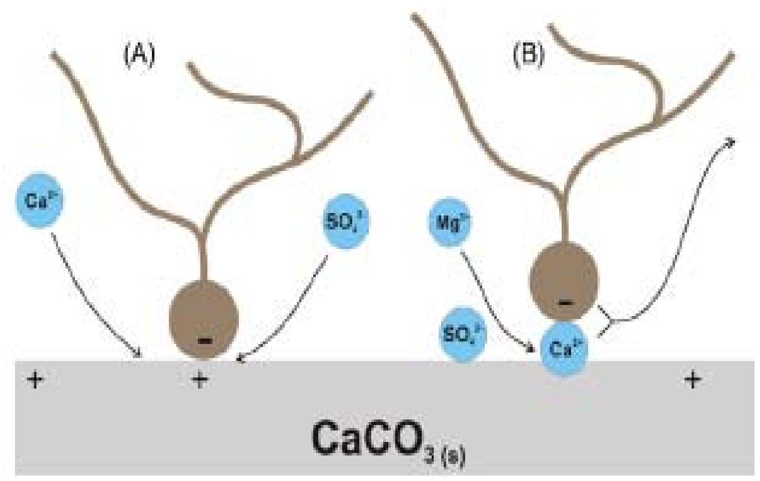
Wettability alteration is believed to be the oil recovery mechanism

Wettability alteration mechanisms

Calcium & Sulphate Ions Wettability Alteration Mechanism

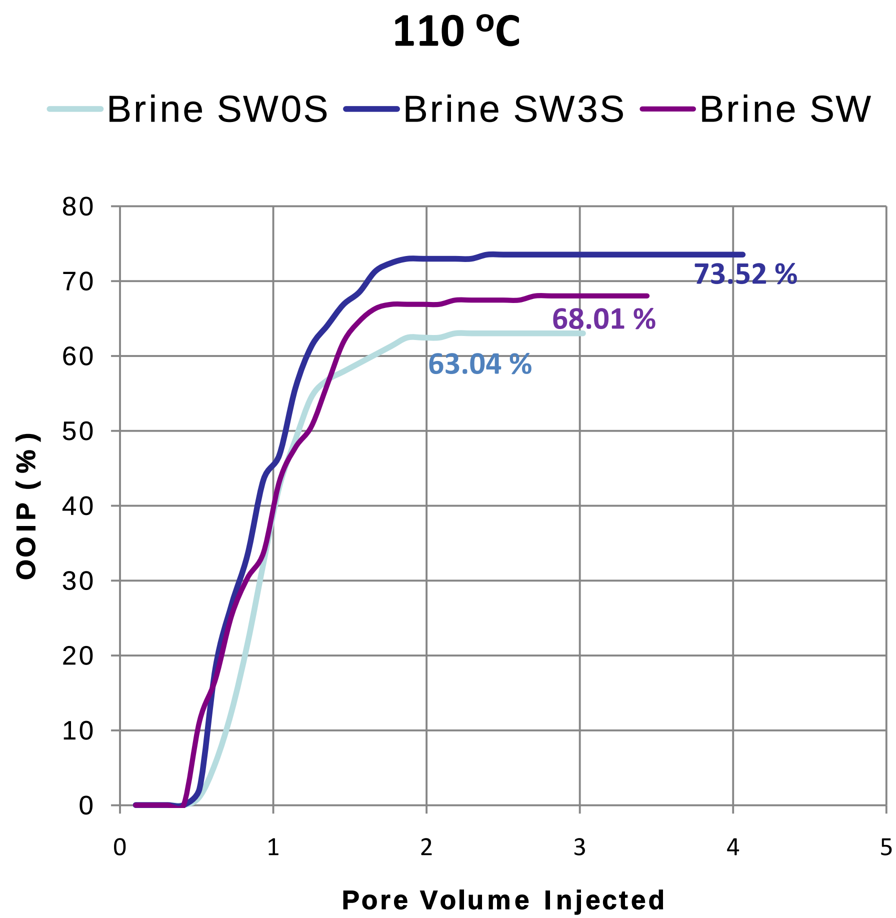


Calcium,Sulphate & Magnesium Ions Wettability Alteration Mechanism



Flooding in completely water-wetted cores

1. Waterflooding in completely water-wetted cores(Steven Klint)
2. 10% increase in oil recovery was observed (SPE EUROPEC 2010, Barcelona)
3. Wettability alteration seems not to be the oil recovery mechanims in such cases.



What could be the mechanims for oil recovery besides wettability alteration in such cases?

What are the effects of brine-oil interactions, besides the reported brine-rock and brine-oil-rock interactions?

EXPERIMENTAL STUDY OF BRINE-OIL INTERACTIONS

Crude oil samples

Crude Oils	Density @ 20 °C (g/cm³)	Acid Number (mg KOH/g oil)	Base Number (mg KOH/g oil)	Asphaltene (%)	Viscosity (cp)
Latin America	0.846	0.163	0.563	3.43	24.4
North Sea	0.847	0.095	2.442	0.302	8.837
Middle East	0.844	0.093	0.644	1.093	10.538

➢Crude Oil from three different parts of the world have been used for this study

Brine Solutions

Component	SW0S (mol/l)	SW0.5S (mol/l)	SW (mol/l)	SW1.5S (mol/l)	SW2S (mol/l)	SW2.5S (mol/l)	SW3S (mol/l)
Na^+	0.368	0.363	0.358	0.353	0.348	0.343	0.337
K^+	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Mg^{2+}	0.045	0.045	0.045	0.045	0.045	0.045	0.045
Ca^{2+}	0.013	0.013	0.013	0.013	0.013	0.013	0.013
Cl^-	0.492	0.463	0.434	0.405	0.376	0.347	0.317
HCO_3^-	0.002	0.002	0.002	0.002	0.002	0.002	0.002
SO_4^{2-}	**0.000**	**0.012**	**0.024**	**0.036**	**0.048**	**0.060**	**0.072**
TDS(g/L)	33.39	33.39	33.39	33.39	33.39	33.39	33.39

- Seven brine solutions with different sulfate concentrations were prepared for this study.

Oil/brine interaction experiments under room conditions

- 3 different oils and 5 different brines
- 20 % (2ml) of crude oil and 80% (8ml) of brine
- Glass was stirred at 1000 rpm for 15 mins
- All five systems were photographed. Formation of emulsions determined by naked eyes.
- Density, viscosity and pH are measured

This indicates that salinity affects the emulsion formation.

Latin American Crude Oil

North Sea Crude Oil

Middle East Crude Oil

oil

emulsion

brine

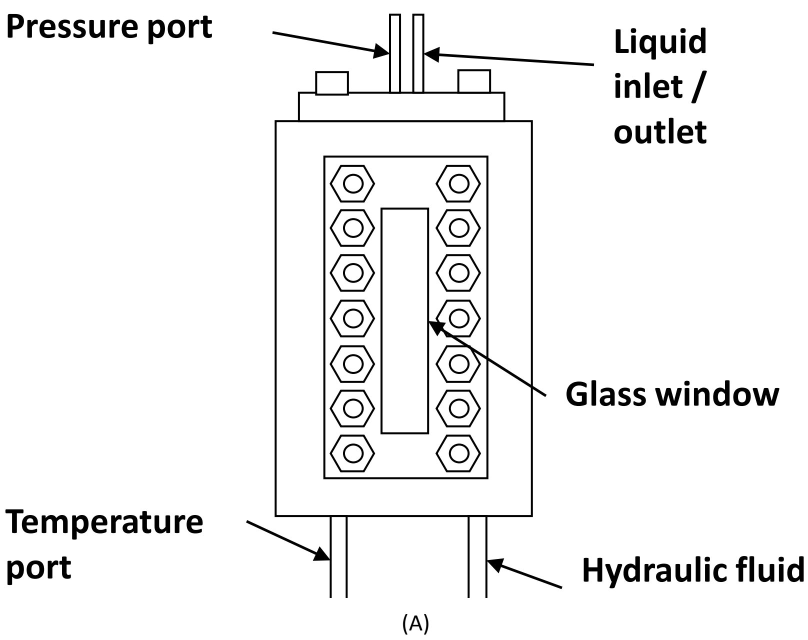
DW SW0S SW SW3S Mg^{2+}

Viscosity and density results

	Latin American		North Sea		Middle East	
	Viscosity (cP)	Density (g/cm³)	Viscosity (cP)	Density (g/cm3)	Viscosity **(cp)**	Density (g/cm3)
Only Oil	24.4	0.877	13.5	0.845	12.7	0.865
DW			13.5	0.846	13.3	0.865
SW0S	24.4	0.897	13.9	0.847	12.6	0.866
SW	22.2	0.901	14.0	0.848	12.9	0.866
SW3S	24.2	0.894	14.1	0.848	13.2	0.884
0.1 M $MgCl_2$	24.7	0.890	13.1	0.849	13.9	0.866

Brine solutions did not affect the viscosity and density of crude oils at room temperature.

Oil/brine interaction in DBR PVT JEFRI Cell



Experimental procedures

1. Each system consists of 15 mL of crude oil and 35 mL of brine solution

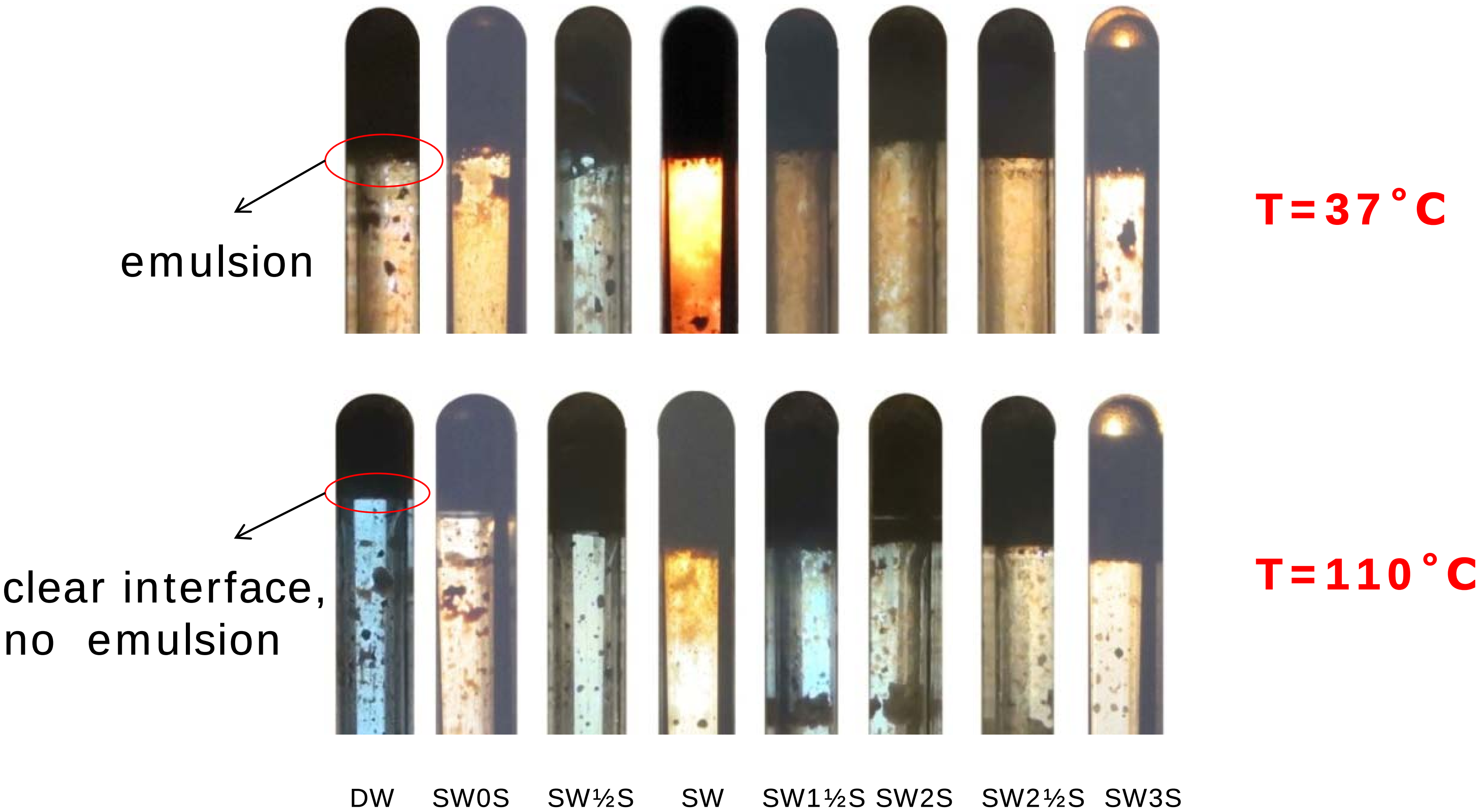
2. Samples were exposed at following conditions
   - **37 °C, 15 bar**
   - **37 °C, 300 bar**
   - **110 °C, 15 bar**
   - **110 °C, 300 bar**

3. System is vibrated for 30 minutes and then left for 1 to 2 hours to equilibrate

4. The interface between the oil and the brine phase was studied

5. Density, viscosity and pH is measured

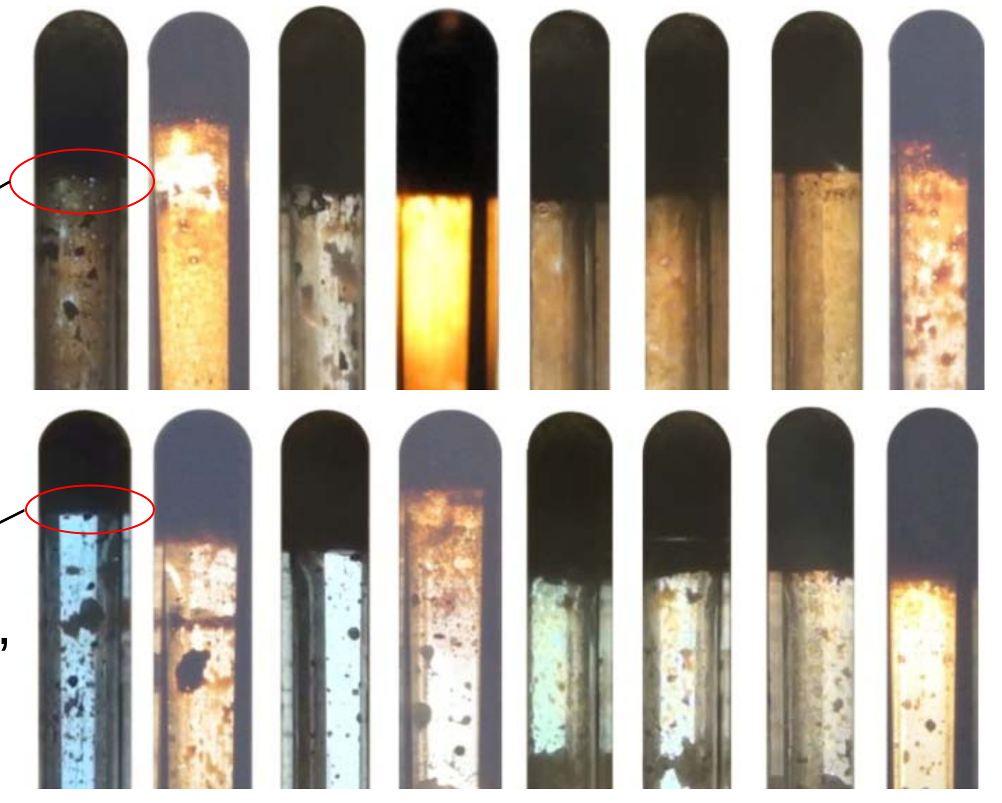
Latin American Crude Oil, 15 Bar



Latin American Crude Oil, 300 Bar

emulsion

clear interface,
no emulsion



T=37°C

T=110°C

DW SW0S SW½S SW SW1½S SW2S SW2½S SW3S

Viscosity

Crude Oil Viscosity Data after Interacting with Brine Solutions in JEFRI Cell

Latin American Crude Oil	
Samples	**Viscosity (cP)**
Crude oil	24.4
SW0S	21.5
SW	20.2
SW1.5S	18.7
SW2S	18.1
SW2.5S	18
SW3S	16.4

- The viscosity of oil is significantly reduced after interacting with sulfate ions at high temperature.
- A trend of decrease in viscosity with the increase in sulfate concentration.
- The mechanism of interaction of the sulfate ions with the crude oil which leads to viscosity decrease is not clear yet.

Water contents

Latin American Crude Oil	
Samples	**Water Content (%)**
Oil before interaction	0.017
DW	0.024
SW0S	0.645
SW0.5S	0.029
SW1.5S	0.473
SW2S	0.045

1. Water content in the crude oil is measured by the coulometric Karl Fisher (KF) titration method. (Metrohm 756 KF coulometer)

2. Observed decrease of viscosity cannot be explained by water present in the oil phase.

3. No significant change in viscosity of oil in contact with SW0S, (relatively high water content)

pH decrease

Brine Solutions from Latin American Crude Oil Samples		
Samples	**pH (before)**	**pH (after)**
DW	5.97	3.49
SW0S	6.29	4.30
SW0.5S	-	7.07
SW1.5S	8.02	7.50
SW2S	8.09	7.51

1. Decreases in pH are observed in all cases.
2. Some of the acidic components of the crude oil migrate into brine solutions.
3. The change in pH is not sufficient to explain the decrease in viscosity of the crude oil.

Discussion

- It has been shown that seawater is an excellent EOR fluid for chalk reservoirs at high temperature (Puntervold et al., 2007).

- Decrease in viscosity of the Latin American crude oil is also observed at high temperature.

- This clearly shows that this could be possible explanation for the observed increase in oil recovery.

- Further experiments will be carried out with the other crude oils in DBR Jefri Cell to check this viscosity decrease effect and for understanding of complex interaction of crude oil components with brine solutions.

Discussion

- Room Temperature Crude Oil/brine Study

- Room temperature crude oil/brine studies indicate that the salinity of the brine affects the emulsion formation.

- But no trend was observed with regard to amounts of the potential determining ions and especially with sulfate ions.

- Brine solutions did not affect the viscosity and density of crude oils at room temperature.

Conclusion

- The DBR JEFRI PVT cell high-pressure studies show that an increase in temperature de-emulsifies crude oils in all the cases.
- The viscosity of the Latin American crude oil was significantly reduced after interacting with sulfate ions at high temperature and high pressure conditions in the DBR JEFRI PVT cell.
- A trend of decrease in viscosity with the increase in sulfate concentration was observed.
- The viscosity decrease of the crude oil is a possible reason for the incremental oil recovery with sulfate ions.

Thank you!

Further questions may be redirected to:

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