A study on the effect of PVA (poly vinyl acetate) on the rheology of water and crude oil in EOR processes

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Abstract

As consequence of pressure drop in oil reservoir, production of oil will be difficult and EOR methods are used to improve recovery. In many countries Polyacrylamide is used for polymer flooding in EOR processes, but the problem is that Polyacrylamide is expensive also Acrylamide needs to be handled using best laboratory practices (such as having safe systems of work and wearing appropriate gloves, lab coat etc.) to avoid poisonous exposure since it is a neurotoxin.

In this paper, it is intended to investigate the effect of PVA (Poly Vinyl Acetate) on rheological properties (such as viscosity) of crude oil, water, and their mixture and to see if it is possible to use this polymer in order to enhance oil recovery. Our objective is to determine the minimum amount of polymer to increase the viscosity of water and decrease the viscosity of crude oil simultaneously.

Since this polymer is shear thickener for water, is not exorbitant in comparison to Polyacrylamide, and not biologically degraded, it could positively affect oil recovery under slow shear stresses.

Key Words: EOR (enhance oil recovery), Recovery, GOR (gas oil ratio), OOIP (original oil in place), Saturation, Displacement, Mobility, Viscosity, Fingering, Degradation, RPM.

Introduction

In order to evaluate the effect of polymer flooding on oil recovery PVA was used to determine if it is suitable as a polymer to increase the viscosity of water or not. Also viscosity of crude oil experimentally measured in order to compare the results to the results obtained when this polymer was mixed with crude oil. The apparatuses are a VG meter (FANN, model 355A), mixer and PVA (which is not pure), crude oil, and water. We extended to measure the viscosity of crude oil mixture with water and polymer at different ratio. We measure the Dial Reading, "theta" (θ) of "RPM"s 600, 300, 200, 100, 6, 3 and then the plastic viscosity is reported as: [1]

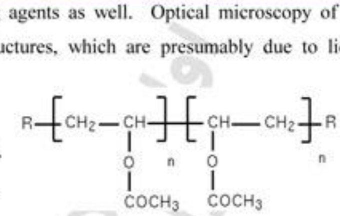
$$\text{Plastic Viscosity } (\mu_p) = \theta_{600} - \theta_{300}$$

One can observe that the theta (θ) in the low RPM for various percent of the crude oil which is mixed by polymer is approximately equal. [2]

PVA is a common copolymer with more expensive acrylics, used extensively in paper, paint and industrial coatings, referred to as vinyl acrylics. This polymer is also used in various aspects such as a main material in producing building color. This polymer is water soluble, so if it considerably increases the viscosity of water it can be used in petroleum industry as a polymer in EOR.

Vinyl acetate VA helps recovering trapped crude oil, an important mineral resource. The proposed approach is to use the polymer as a foaming surfactant (in water or brine), which will be driven by a gas, such as carbon dioxide or nitrogen. Neutralized forms of the polymer results in an anionic surfactant, which has been found to have minimal adsorption onto the rock matrix. The neutralized VA polymers synthesized found to outperform other anionic surfactants and even more adsorbing nonionic surfactants. Due to the long chain nature of the hydrophilic groups of nonionic surfactants, they are found to produce better foams than anionic ones. Since VA polymers have long chain hydrophilic groups, it is not surprising that they are good foaming agents as well. Optical microscopy of VA emulsions reveals that they form microscopic network surface structures, which are presumably due to liquid crystalline formation in macromolecular scale.

The general formula for PVA (poly vinyl acetate) is:



It is good to remind that this polymer costs about 200$ per bbl, whereas Polyacrylamide costs approximately 1000$/Lit in pure form.

Vinyl acetate based polymers have been shown to be attractive foaming surfactants for the recovery of crude oil that is trapped within rock matrices. Results were obtained, based on static foaming tests, and optical microscopy of emulsions. These new copolymer materials could put micellar foam flooding in the forefront of enhanced oil recovery. [7,8]

As it has been reported crude oil is a non Newtonian fluid. Similar result has been found as it is shown in Fig.1, 9. As it was mentioned viscosity of PVA mixed with crude oil was evaluated. The results of our findings are shown in figures 2-7 and 10-15.As one can notice addition of PVA to crude oil resulted in viscosity reduction.

We know that PVA can increase the viscosity of water and the result of our experiment also shows it (Figures 8 and 9).It is good to mention that a non uniformity pattern noticed in figures 7 and 15 may be due to effect of diffusion of air (N_2 & O_2) in the mixture prepared. Even though it was tried to prepare a mixture free of air bobbles, due to foaming action of PVA, this phenomena is inevitable. In all the figures the first two dial readings (for RPM 3& 6) usually are not reliable and it is better to see the trend of line in the four point remained. Viscosity of the mixture of crude oil With PVA at different ratios has been measured and the results are presented in Fig.2 to 6 and 10 to 14. As one can notice addition of PVA to crude oil results in decrease of viscosity of crude oil, the extent of decrease in viscosity depends on the percent of PVA (5%, 10%, 15%, 20%, 50%, 300%), which varies from 41cp to37cp. Addition of PVA to water has result in increase of viscosity as it is shown in Fig.8 and 16. For instance addition of 53% PVA by weight to water has increased the viscosity from 1cp (water) to 28cp.

Conclusion

The PVA must have a good resistance against increasing pressure and temperature, (i.e. the expansion and construction due to changing the condition in the reservoir) because of condition of mixing polymer and water with the crude oil in the front of the water, the gases such as O_2 or N_2 may diffuse into the mixture and it causes decreasing the viscosity. Also the temperature may increases due to mixing process and it causes the decreasing the viscosity. Due to phase separation (water and oil) the mixture should not allowed to cool down to room temperature. It should be noticed here due to lake of pure PVA, we were forced to use PVA available in the marketplaces in the form of painting colours. These mixtures are not pure and to some extent have pigments in the paint. The result showed that addition of PVA increases water viscosity, therefore due to Darcy's law "Q" has decreased, for this reason one can conclude that water mobility decreases and resistance due to mobility of water can effect enhancement of movement of crude oil. The shear thickening polymers are not used in EOR processes unless in low injection rate, because they have glutinous state in high shear rates. [8, 9]

$$Q = \frac{kA(p_1 - p_2)}{\mu Ln\frac{r_1}{r_2}}$$ [3]

When we use (polymer + water) to recover the oil in reservoir it may mix with oil, if viscosity of mixture decreases, it causes viscose fingering. [4]

This polymer is shear thickening for water and in very low amount shear thinning for crude oil. So we can use it for polymer flooding. But since large amount of polymer is requested it seems that economically it is not profitable. If we use 15percent of polymer we need 7.5 bbl from our polymer to recover 100bbl oil. You should bear in mind that this polymer was not pure. If we could use pure polymer may decrease the amount of polymer. This amount is used for reaching the maximum amount of decreasing the viscosity of crude oil, which is unnecessary for polymer flooding.

Acknowledgment

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Results and Diagrams

RPM	Dial Readings…………							
	Crude oil	*5%	*10%	*15%	*20%	*50%	*300%	PVA
600	86	89	85	81	95	144	100	68
300	44	48	47	44	58	107	63	40
200	32	34	32	31	38	75	44	30
100	17	19	17	17	20	46	27	20
6	3	3	3	3	3	6	10	5
3	2	2	2	2	2	3	4	3
	*PVA%							

Table 1. RPM of VG Meter vs. Dial Readings of Different Ratio of Crude Oil + Water + PVA Mixture

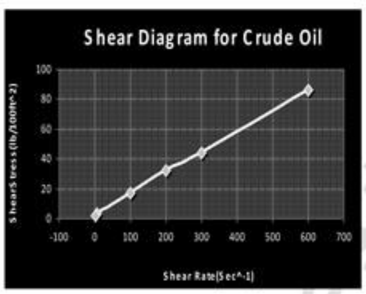

Figure1. μ_p =42cp

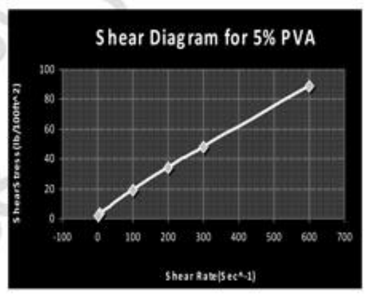

Figure2. μ_p =41cp

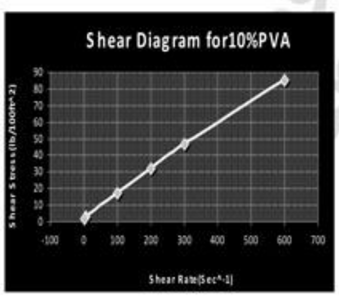

Figure3. μ_p =38cp

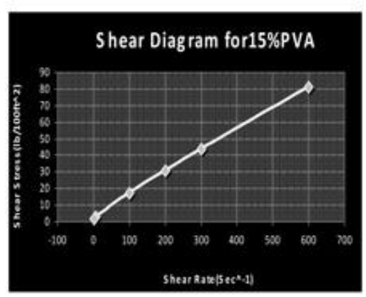

Figure4. μ_p =37cp

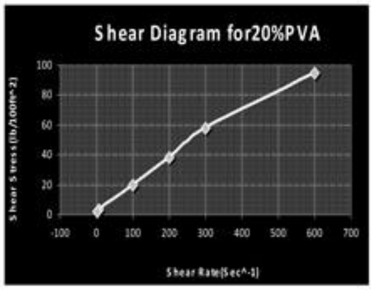

Figure5. μ_p =37cp

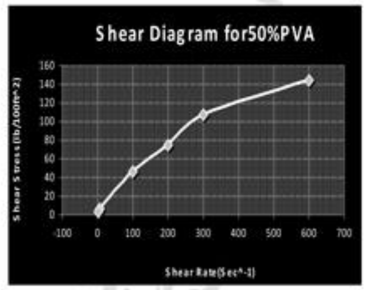

Figure6. μ_p =37cp

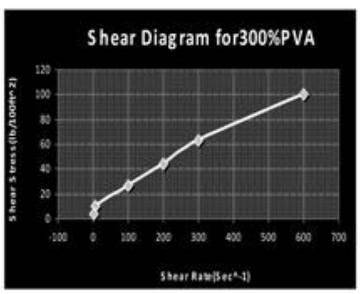

Figure7. μ_p =37cp

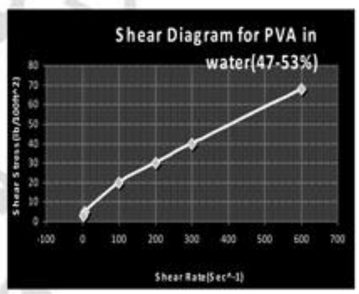

Figure8. μ_p =28cp

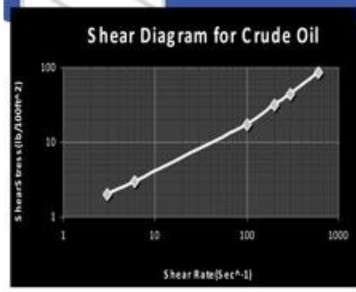

Figure9. μ_p =42cp

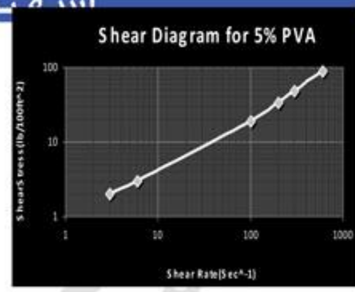

Figure10. μ_p =41cp

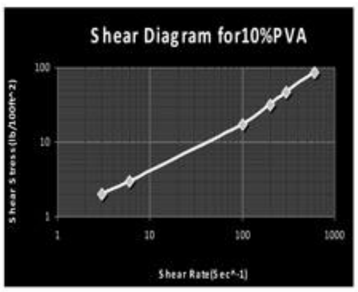

Figure11. μ_p =38cp

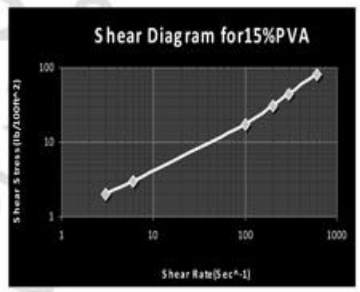

Figure12. μ_p =37cp

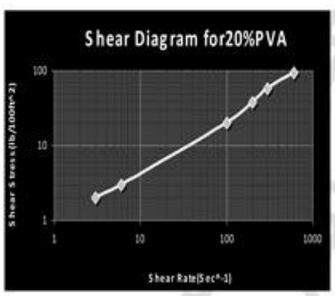

Figure13. μ_p =37cp

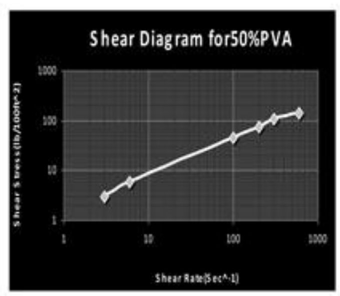

Figure14. μ_p =37cp

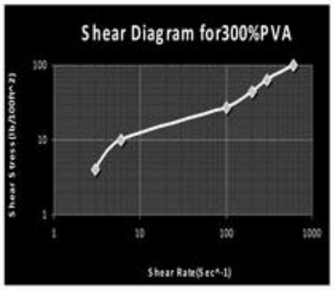

Figure15. μ_p =37cp

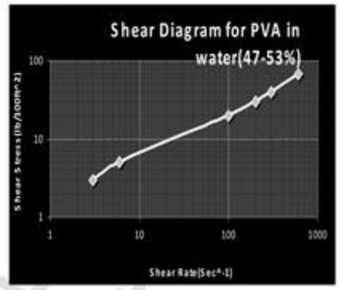

Figure16. μ_p =28cp

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