Investigation of Nanoparticles Dispersion in Sodium Hydroxide (NaOH) Solvent

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Abstract. Recently, the study on nanoparticles application in enhanced oil recovery (EOR) starts to growth. Nanoparticles have given better indication for EOR development such as in foam stability as its nano size particles can be feasibly dispersed in aqueous solution and easily flow through porous media. Aggregation of nanoparticles are said to be a major contributor for paralyzing nanoparticles dispersion deep into the formation. Hence, in this research sodium hydroxide (NaOH) is used as stabilizing solvents or carrier fluids in enhancing nanoparticles properties to prevent coagulation of nanoparticles when mixed to create a nanofluid. The dispersion of various concentration of silica oxide (SiO_2) and aluminium oxide (Al_2O_3) are examined by using turbidity test. Results from this research show that the silicon dioxide nanoparticles are at best to be mixed in NaOH solvent to retain longer retention time.

1 Introduction

Nanoparticles are being used in industries in a considerable amount of time. It has been proven to give significant results that could be projected into the oil and gas industry specifically in tertiary recovery or enhanced oil recovery (EOR). With its nano-sized, these particles are theoretically able to disperse further into the formation covering a substantial amount of drainage area. It could also act as a stability agent for some EOR applications such as in foam flooding.

Nanotechnology was first popularized in the 1980's by a physicist named K. Eric Drexler, it was then talking about building machines on a molecular scale and even whole computers in cell sizes. Over the years, as nanotechnology became an accepted concept, the meaning of the word shifted to incorporate the simpler kinds of nanometer-scale technology for example nanoparticles. In the subject of nano-particles stream in permeable media has turned into another go for the headway in petroleum study. The development of nanotechnology application is truly sudden as of late. The disclosures of the nano-innovation potential to wind up arrangements towards a few issues in petroleum industry has ended up empowering according late research. EOR is the most theorized region for the potential improvement by this nanoparticle application. The ascent of vitality request in worldwide scale which anticipated that would happen in the oil and gas industry has made EOR the most essential technique as to meet this desire and demand from the market. The salient point of nanoparticles in EOR is its capacity to adjust certain component in the arrangement and liquid properties.

However, the dispersion of nanoparticles in porous media are still in questions. This is due to the aggregation of nanoparticles after a certain amount of time. Hence, the aim of this research is to evaluate the dispersion of various concentrations of hydrophilic and metal oxide nanoparticles for different concentrations of stabilizing fluids in brine. The scope of study with regards to this project would comprise the factors contributing to the dispersion of nanoparticles into the reservoir formation by using various concentrations of stabilizing fluids/agents.

2 Literature Review

2.1 Nanofluids

The nano-fluids are shaped by the addition of nanoparticles to fluids for amplification and development of some properties at low volume concentrations of the dispersing medium [1]. Nanofluids can be delegated as a strong nanofluid and weak nanofluid as to the quantity of nanoparticles added into the liquid. Advanced nanofluids are the liquids with more than one nano-sized added substance in the interim of basic nanofluid (the liquid with one nano-sized added substances). Nanoparticles can remain with multifunctional or single use of sort. Developing applications of nanotechnology in the industry involve new types of these nanofluids for various applications, particularly for EOR purposes [2].

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The test was conducted on Newtonian oil displacement showed a significant recovery utilizing nanofluids in oil recovery in a high pressure column filled with quartz sand of permeability 1 Darcy and porosity of 26% [1]. Concentration of nanofluids derive an essential key factor in optimizing EOR of low permeability water wet Berea sandstone by reducing contact angle as nanofluid concentration increases resulting in a desired nanofluid concentration of 0.01, 0.03 and 0.05 wt. % [3].

2.2 Nanoparticles Selection

In this study, silica nanoparticles for hydrophilic nanoparticles and aluminum oxide as metal oxide nanoparticles are chosen to be utilized as it has shown a great potential to be used in EOR (Table 1). Silicon dioxide, otherwise called silica, is an oxide compound that of silicon with the chemical formulae SiO_2. Silica nanoparticles possess a noticeable position in systematic research, in view of their simple readiness and their wide range of uses in different applications, for example, catalysis, electrics and electronics, pharmaceutical and various sensors [9]. Silica nanoparticles are also ventured for in enhanced oil recovery applications. These are due to the main component of sandstone comprises primarily of silica which directly makes silica nanoparticles an environmental friendly substance. Silica nanoparticle dispersion is said to have good stability due to its properties in the ability to counterbalance the gravity force effect [10].

Table 1. Nanoparticles Selection

Nanoparticles	Findings
Silicon Oxide	Dispersed in ethanol improved recovery through change in rock wettability [4].
	Homogeneous and heterogeneous water free-oil recovery increased better with surfactant dispersing agent [1].
	Reduction of interfacial tension and wettability alteration using polymer coated SiO_2 [5].
	Adjusting the surface charge density of the nanoparticles, stable fluids can be employed to more effectively displace oil from flow impaired locations [6].
	Lower interfacial tension (IFT) was observed with increasing nanofluid concentration from 0.01 to 0.05 wt. % and reduces oil saturation by 13% [3].
Aluminum Oxide	Reduce viscosity of the oil [7].
	Results demonstrate that the wettability alteration plays a more dominant role in the oil displacement mechanism using nano-EOR using Polyvinylpyrrolidone (PVP) as stabilizing agent [8].
	Produced oil lighter than injected oil in terms of viscosity reduction [4].

In a research conducted in 2013, the trend showed that an increased in hydrophilic silica nanofluid concentration will increase water-wetness in a low-permeability Berea sandstone core plug due to the electrostatic repulsion force between particles will be higher with an increased amount of nanoparticles [3]. The nanofluids will spread along the solid surface and adsorption may be occurred, decreases contact angle and displace most of the trapped oil that remains after secondary flooding with brine [11]. Torsaeter also concluded that the concentration of the nanoparticles comprised in the nanofluid affects the effectiveness in displacing oil as a tertiary recovery method. Although nanoparticles have a tendency to block pore network at higher concentration (e.g. > 0.06 wt%) in low-permeability Berea cores.

2.3 Retention and Aggregation

The major retention mechanism is the irreversible attraction to the rock grain surfaces [12]. The paper predicted a rock grain surface retention with the colloids, a constant first order rate coefficient is preferably used. On the other hand, it was also specified that when the colloids and rock grain have repulsive force, the coefficient has been found to be underestimated.

Retention and aggregation of nanoparticles are the major factors governing the dispersion of nanoparticles through the reservoir formation, hence, affecting drastically the recuperation of oil. Retention time indicates the time taken for any suspended particles to settle down or sediment in the bottom of the container. Theoretically, as the retention time is longer, more particles are left suspended within a certain fluid which indicates a more stable nanofluid. Transport in reservoir rock has two major components which comprises 1) the nanoparticle retention which quantifies the fraction of injected nanoparticles that reach the target zone and 2) the mobility of the nanoparticle dispersion through the porous media under operating conditions to bring the injected nanoparticles through the desired path and time to the target location [13].

2.4 Nanoparticles in Enhanced Oil Recovery (EOR)

Although the use of nanoparticles in EOR is very recently ventured, there are extensive researches done on the ability of nanoparticles to aid in EOR applications. Foam flooding is an advancement in EOR. Foams have been proposed for utilization as mobility control and to enhance oil recovery in several secondary recovery and EOR, for example, steam, CO_2 and nitrogen flooding. Distinctive surfactants are obliged to create foams that are tolerant to oil, electrolyte and steady at downhole demanding conditions. Sodium dodecyl sulfate (SDS) foam was used in a specific experiment where the foam stability was increased with the aid of SiO_2 nanoparticles. It also shows a better tolerance to downhole temperature whereby the foam bubbles are able to maintain a spherical shape with time through the permeable media [14]. Findings indicated how dispersed nanoparticles in a fluid mixture can alter the interfacial properties of the fluid/fluid frameworks [3, 15]. The study indicated that the surface of the whole formation can be altered in a sense of ionic changeability or nanofluid coating.

In a research done, it was observed that the interfacial tension (IFT) between the crude oil and nanofluids decreases as the nanofluid concentration increases [16]. On top of that, aluminum nanoparticles have a tendency to displace oil through their capability in reducing oil viscosity when used with fresh water and brine as dispersing fluids [4, 16]. In a research conducted using a spinning drop to observe a decrease in the interfacial tension between synthetic oil and a brine/nanofluid, a 0.01 wt % silica nanoparticle solution in brine will decrease the interfacial tension from 14.7 mN/m to 9.3 mN/m. Furthermore, when increasing the weight percent to 0.05% resulted further reduction of the interfacial tension to 5.2 mN/m. A reduction in IFT is one of the potential applications by which nanoparticles may aid in enhanced oil recovery due to less energy required to mobilize and remove oil trapped in the formation [15, 17].

3 Methodology

3.1. Nanofluid preparation

The nanoparticles used are silica oxide (SiO_2) and aluminium oxide (Al_2O_3). These nanoparticles are prepared by mixing them in carrier fluids or 3 wt% brine (NaCl) to investigate the effect of dispersion due to different concentrations of nanoparticles and stabilizing agent (NaOH). Silica and aluminium nanoparticles are prepared by mixing different concentrations of each nanoparticles in various concentrations of stabilizing agents (NaOH). These arrangements are then blended with a magnetic stirrer bar at various velocities for 4 hours [18]. Preparations for the nanofluid are shown in Table 2.

Table 2. Nanofluid preparation.

Nanoparticles	Nanoparticles (wt. %)	NaOH (wt. %)
SiO2 + 3 wt.% Brine (NaCl)	0.01	1.00
		5.00
	0.05	1.00
		5.00
Al_2O_3 + 3 wt.% Brine (NaCl)	0.01	1.00
		5.00
	0.05	1.00
		5.00

3.2. Nanofluid stability

A turbidity meter is used to confirm the aggregation effects for each samples. Prior to inserting the nanofluids into the turbidity meter, the nanofluids are stirred with a magnetic stirrer for another 4 hours in total of 8 hours. The turbidity meter reading was recorded every 10 minutes for one hour period in order to analyse the stability for each nanofluid mixtures.

Once prepared, the nanofluids stability were then tested via Nephelometric Turbidity Unit (NTU) readings on a turbidity meter. Theoretically, a higher NTU reading shows more particles suspended within a liquid hence showing a more stable nanofluid. Although, the high readings must retain its value throughout a certain time period, in this case one hour, to show that the suspended particles stay suspended instead of just settling down.

4 Results and Discussion

As shown in Figure 1 to Figure 4, a much stable nanofluid will represent a small or no deflection on the graph of NTU against time. Although aluminum oxide nanoparticles at 0.05 wt% have a much higher initial value of NTU, the nanoparticles was not able to retain that value within the one hour period instead most of the particles settled down.

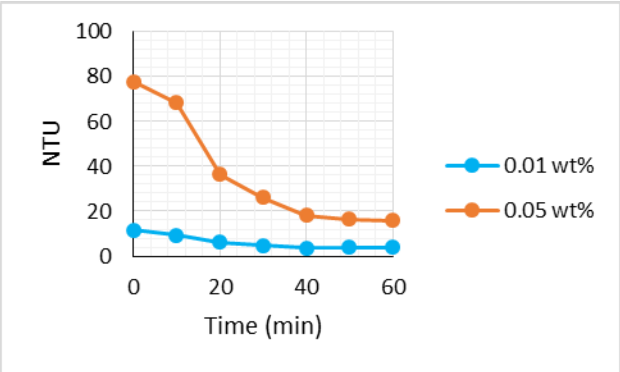

Figure 1. Aluminum oxide nanoparticles stability in 1 wt% sodium hydroxide (NaOH).

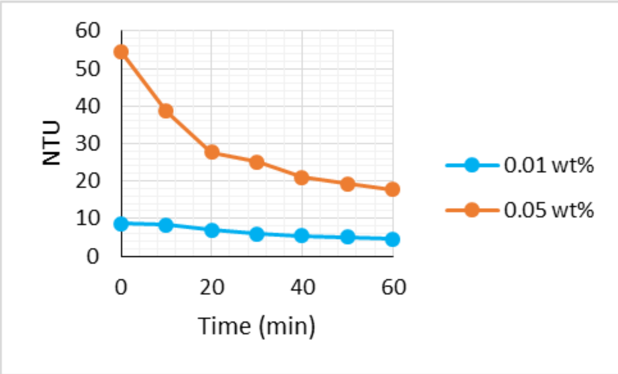

Figure 2. Aluminum oxide nanoparticles stability in 5 wt% sodium hydroxide (NaOH).

Figure 1 and 2 show the stability of aluminum oxide nanofluid in different concentrations of solvents and nanoparticles. As discussed, a higher NTU value results in more suspended particles within the fluid. Aluminum oxide nanofluid of 0.05 wt% mixed in 1 wt% NaOH resulted in the highest NTU value. The value was not stable and declined rapidly after 20 minutes and fluctuated 30 to 15 NTU. These values proves that the nanofluids prepared has more suspended aluminum oxide nanoparticles and stabilizes after 20 minutes.

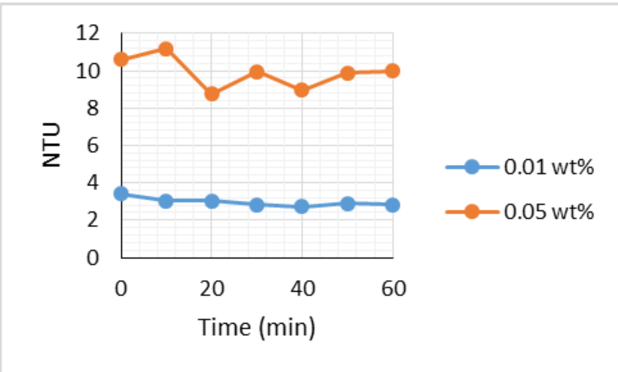

Figure 3. Silicon oxide nanoparticles stability in 1 wt% sodium hydroxide (NaOH).

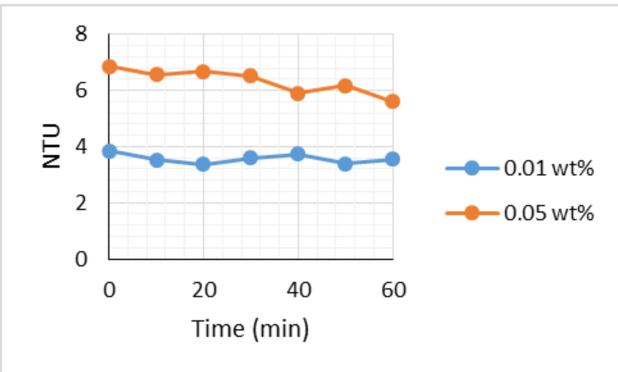

Figure 4. Silicon oxide nanoparticles stability in 5 wt% sodium hydroxide (NaOH).

Figure 3 and 4 illustrate silicon dioxide nanofluids in different concentrations of nanoparticles and NaOH solvent. The NTU values for silicon dioxide nanofluids are low resulting in a much lower amount of suspended particles within the fluid. Although displaying low values ranging at highest 13 NTU, these nanofluids are stable from the start until the end of one hour period. These results indicate that silicon dioxide nanoparticles are at best to be mixed in NaOH solvent to retain a longer retention time.

5 Conclusion

Fundamentally in concluding this project, majority of the literature reviews resulted in a positive reaction to the renowned properties of silica nanoparticles in aiding the effectiveness in EOR applications. Silica oxide nanoparticles was chosen as a representative for hydrophilic oxides. While aluminum oxide nanoparticles represents metal oxides. This way, the difference in effectiveness from both groups could be determined. Although aggregation is a major factor in the dispersion criteria, nanoparticles with the aid of different concentrations of stabilizing agents in this sense, sodium hydroxide (NaOH) will opt for a better result to overcome the retention effect.

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