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Preparation and Optimalization Nano Silica Base Nanofluid Effect in Wettability For Enhanced Oil Recovery

Sumadi Paryoto *[1], Khasan Rowi[2], Agus Subagio[3], Michael Arya Yutaka[4], Tino Diharja[5]
[1,4,5] PERTAMINA, [2,3] UNDIP
* Email: sumadi.paryoto@pertamina.com

Abstract. This study focused on observing the effect of nano silica base nanofluid to change contact angle value on preparation to use for enhanced oil recovery (EOR). Nano Silica is known for its effectiveness on surfactant and easily synthesized and have lower cost production. The biggest problem in using nano silica for application on EOR process is figuring out how much is the proper amount that can be applied to give the best result. In this study, we use three concentration variation of nano silica base nano fluid and then compare them with salt water as base fluid to observe the impact reaction to EOR effectiveness by first testing its wettability measurement. For size measurement using PSA, the result shown for 0.01; 0.05; and 0.1 % variation in sequence is giving 330.8 nm, 326.1 nm and 341.4 nm respectively. For the wettability test, measurements that were completed within three days was giving contact angles of 56.31˚; 60.49˚; 62.01˚ sequence for base fluid, 20.39˚; 24.67˚; 27.21˚ sequence for concentration 0,1% nano fluid, 22.47˚; 28.35˚; 28.88˚ sequence for concentration 0.05% nano fluid, and 50.67˚; 54.66˚; 56.31˚ sequence for concentration 0.01% nano fluid. The result is shown, when higher concentration of nano fluid applied, it produces lower wettability and giving good potential to use for EOR.

Keyword(s): Nano Silica, Nanofluid, Wettability

1 Introduction

Increasing population means increasing demand for energy, but in this time shortage of the resource of gas and oil mining and the production rate is nearing the decline period. So, it is very important to maximize recovery of abandoned existing old oil and gas wells using various different technology of enhanced oil recovery (EOR) (Liu et al., 2020; Zhao et al., 2022). Based on Figure 1, many technologies were applied in fields to get an optimized recovery factor such as thermal technology, chemical flooding using chemical agent such us polymer and surfactant, miscible and immiscible gas. With the rapid growth of science and technology, nano technology also experienced maturity in its application for wide and various fields. In recent pass, nano material have been given more attentions in petroleum industry, especially in the field of EOR, which targets low permeability reservoir with water brine for assist injectivity (Liu et al., 2020; Chaturvedi & Sharma, 2021).

Nano material has shown some potentials for EOR application. By adding nano material and nano particle into the reservoir will critically change some properties of fluid like viscosity, density, and thermal conductivity (Kumar et al., 2022). Nano material also has ability to improve some factor in oil recovery properties like wettability alteration and interfacial tension (IFT) reduction. Some type of nanomaterial (e.g., SiO_2, TiO_2, Al_2O_3) have been tried for EOR application (Liu et al., 2017). Among all that have been tried, SiO_2 nanoparticle got more highlight in this field (Liu et al., 2020). In 2015, Moghaddam et al., has been study eight types of nano particles for wettability alteration from oil to water wet in carbonate rocks. The result has showed that $CaCO_3$ and SiO_2 nanoparticles were able to increase the oil recovery about 8 to 9 %. Nano fluid are nano particle in colloidal suspension dispersed in base fluid and have strong rheological, big transfer properties, better structuring, and high surface area to volume ratio (Moghaddam et al., 2015; Panchal et al., 2021).

One of the main marking factors of EOR was contact angle value that showing wettability (Kumar et al., 2022). Wettability alteration from oil wet reservoir to water wet was important to EOR. Some research groups claim that wettability alteration is the primary mechanism for EOR (Chaturvedi & Sharma, 2021; Kamal et al., 2017). They studied the alteration of the contact angle with varying concentrations of silica nanoparticles and observed that silica nano particles assist in changing the wettability of the reservoir from oil-wet to water wet (Hendraningrat & Torsaeter, 2014). Nano silica also showing effect on disjoining pressure and IFT reduction (Panchal et al., 2021). Nano fluids wetting and spreading on a solid surface, is believed to be enhanced by structural disjoining pressure (Figure 2) (Wasan et al., 2011). Nanoparticle affected to lowering IFT between oil and water by increasing the viscosity of water. In 2013, Hendraningrat has demonstrated using nanofluid with 0.05 wt% silica nanoparticle and showed that can changed wettability by reducing the contact angle from 53 to 21˚ (Hendraningrat et al., 2013). Surfactant and polymer ordinary combined with silica nanoparticle to make stable of nano fluid. Polymer uses to improve the stability of nanoparticle also addition amount of polymer can help to reducing IFT by increase the viscosity of water at macroscopic which has decrease by addition of surfactant. Absorption of polymer also change the wettability of surface of rock (Pratiwi et al., 2019; Saha et al., 2019).

In this work, we decided to create nano silica base nano fluid combine Silica nanomaterial with polymer and brine (salt 3%) with ultrasound treatment and focusing on alteration of wettability on surface of berrea sandstone substrate.

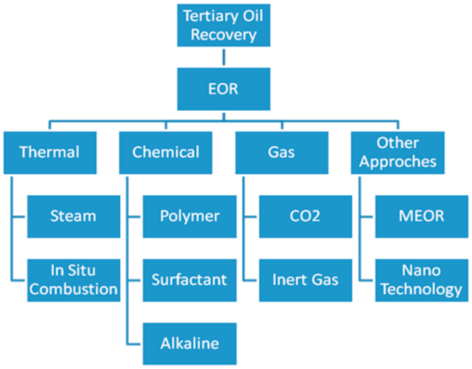

Figure 1. Applied technology in EOR (Panchal et al., 2021)

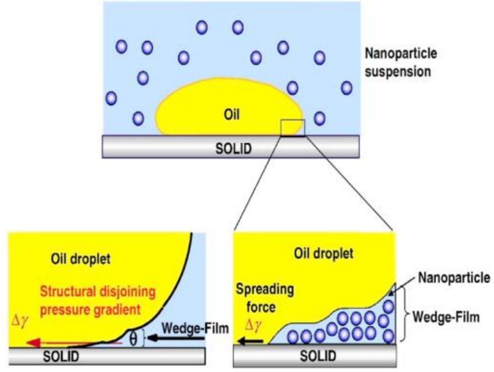

Figure 2. Ilustration Nano Silica affected to disjoining pressure (Wasan et al., 2011)

2 Experimental Method

2.1 Material

Silica Nanoparticle was supplied from Nano Technology Laboratory UNDIP. The salt used was a pharma grade from Roomdave Prima Indonesia, Polyvinyl Pyrrolidone (PVP 90) as the polymer used was on analytical grade from Merck Germany. The crude oil used for wettability test in this research was n-hexadecane acquired from Sigma-Alderich. Sandstone core from Berea USA was used using for wettability measurement and core flooding test.

2.2 Synthesis

All material in preparing Nanofluid was mixed by stirring in medium speed using magnetic stirrer. First, a good amount of silica Nanoparticle was stirred until it reached homogenous in distilled water. After the first stage was completed, some amount of PVP 90 was then added slowly into that mixture while maintaining a continuous stir for about 1 hour in room temperature. Next, ml of water with dissolved salt was added until the fluid has reached concentration of brine of 3% and became a saltwater base fluid. The next process to strengthen the bind of the Nanofluid, ultrasonic homogenizer was used to re-homogenization within 20 minutes.

2.3 Analysis

Analysis particle of nano silica was done using transmission electron microscopy (TEM) method. Size analysis on nanofluids was using the Particle Size Analyzer (PSA) method with the use of Malvern penalytical Mastersizer 3000. Contact Angle measurement was performed to know the wettability level of core sampling with Nanofluid using sessile drop technique. Oil was injected from the bottom of the tank and then swim up (due to density separation) to the top slice of the core (rinsed in fluid). Core type that use Berea sandstone 30 X 25 mm width 1 mm. Oil that used for droplet was n-hexadecane synthetic oil

3 Result

TEM analysis is used to identify particle size and also morphology of nano silica in the solution. The TEM method was chosen because it allows to see particle images below 10 nanometers. Based on the Figure 3, it can be known that the nano silica material used on synthesis of nanofluid is at a vulnerable size below 10 nm. It is also seen that the tendency of nano silica to gather resulting easy agglomeration process happened.

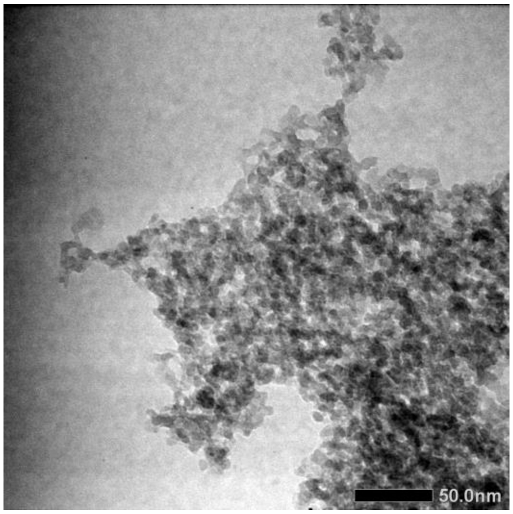

Figure 3. TEM analysis of nano silica

PSA analysis was conducted in means of measuring diameter of dissolved particles. Based on the results of data analysis in Figure 4, at 0.01 wt% concentration of nanofluid if silica nanoparticle to 0.05 wt%, the particle size decreases in diameter from 330.8 nm to 326.1 nm. When the concentration of nano silica was raised to 0.1%, the particle diameter also increased to 341.4 nm. Nano silica variations has a direct effect on the changes in nanofluid diameter. This indicates that at concentrations from 0.01 wt% to 0.05 wt% nano silica binds to PVP, while at concentrations 0.05 wt% to 0.1 wt% there is a decrease in diameter due to the hydroxyl group in PVP experiencing saturation in binding nano silica. So that many particles of nano silica are free in such solutions that cause a decrease in diameter. Nanoparticles tend to aggregate to reduce the large surface energy. This aggregation is governed by interparticle collisions, which occur as a result of Brownian motion that the nanoparticles are continuously subjected to. During the Brownian motion of nanoparticles in different fluids, their stabilities are determined by integration of the attraction and repulsion forces between the NP surfaces.

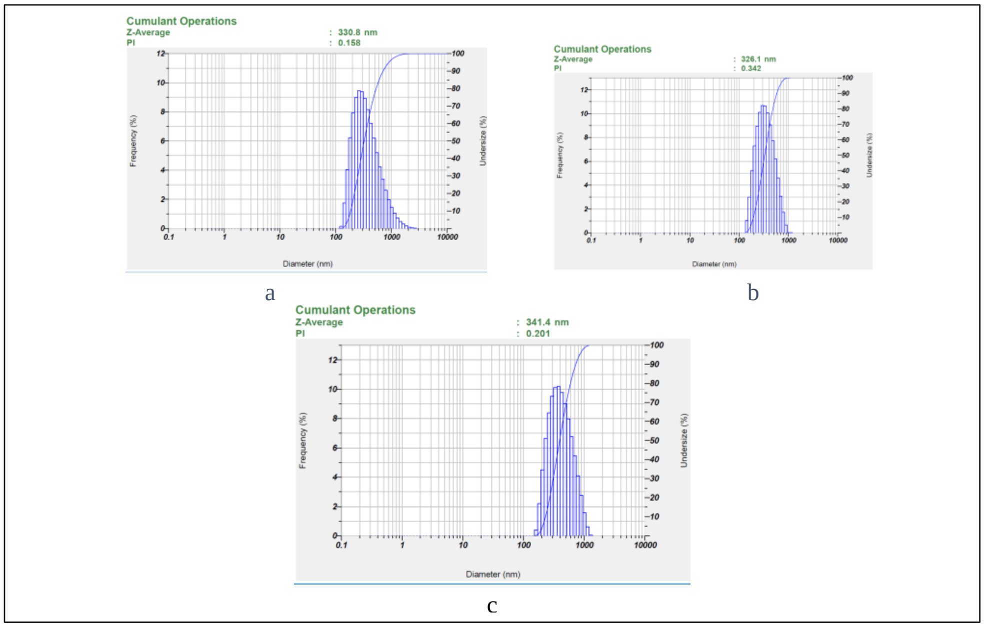

Figure 4. PSA Result for Each concentration Nanofluid contain nano silica:
a. 0.01 wt%; b. 0.05 wt%; c. 0.1 wt%

Wettability alteration of any solid surface can be determined using spontaneous imbibition, contact angle measurements, zeta potential measurements, and surface imaging tests. Atomic force microscopy, scanning electron microscopy, and nuclear magnetic resonance spectroscopy can provide changes in the rock properties because of wettability alteration. The aim of this test was to see the effect of nano silica on surface wettability alteration during nanofluid injection and hence its impact on improving the oil recovery factor. Wettability measurement showing different result in contact angle in different type of fluid in sessile drop technique.

From Figure 5, we can see wettability alteration from rock substrate in different liquid. Brine fluid given higher contact angle at 56.31˚. For wettability of nanofluid, as shown at lowest nano silica concentration at 0.01 wt% got result at 50.67˚, next for concentration 0.05 wt% got result at 22.47˚ and for highest nanofluid concentration at 0.1 wt% got contact angle result at 20.39˚. From that result we can conclude the alteration of wettability are from oil wet to water wet correspondingly within increasing concentration of nano silica on nanofluid. The wettability test was done for three days measuring. Figure 6 showing alteration of wettability of each fluid type. For brine fluid given contact angle at 56.31˚; 60.49˚; 62.01˚. For nanofluid 0.01 wt% given given contact angle at 50.67˚; 54.66˚; 56.31˚. For nanofluid 0.05 wt% given contact angle at 22.47˚; 28.35˚; 28.88˚. And for nanofluid 0.05 wt% given contact angle at 20.39˚; 24.67˚; 27.21˚.

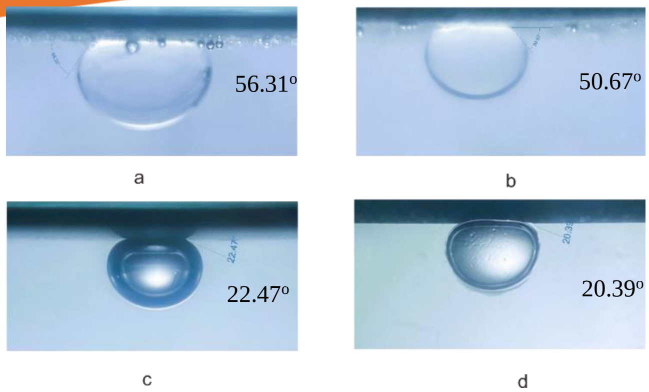

Figure 5. Contact angle of wettability measurement in different fluid type in sessile drop technique: (a). Brine fluid; (b). Nanofluid 0.01 wt% of nano silica; (c) Nanofluid 0.05 wt% of nano silica; (d) Nanofluid 0.1 wt% of nano silica

The wettability change happens due to absorption of nanoparticles on the solid-rock interface. In general, the sandstone reservoirs are negatively charged, and hence, the positively charged silica nanoparticles are expected to get adsorbed on the negatively charged sandstone reservoir because of electrostatic attraction. In other words, when silica nanoparticles were adsorbed on the solid surface, they formed a nanotexture coating on the oil wet surface. This phenomenon alters the wettability state of the surface from oil-wet to intermediate-wet, and this leads to higher oil recovery. This may help shift the wettability of the reservoir rock from oil-wet to water-wet, which is one of the significant factors in improving the oil recovery water (wetting phase) can imbibe into the rock matrix and displace the oil from the rock pores only when reservoir wettability changes from oil-wet to water-wet. In many research that uses nanofluid base nano silica, the alteration of wettability also impacting the increase of disjoining pressure.

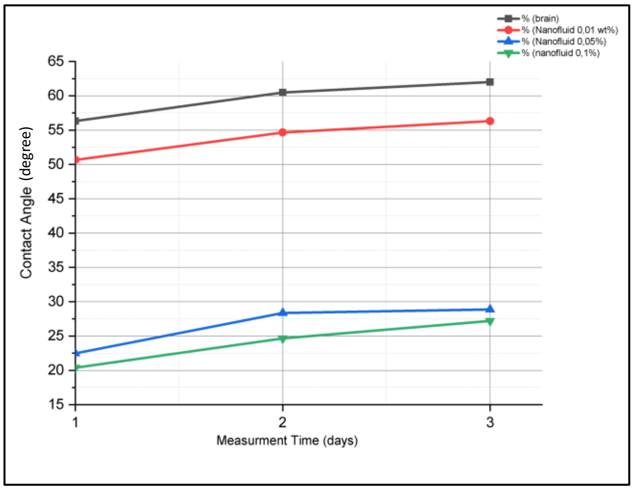

Figure 6. Measurement of wettability of each type fluid

4 Conclusion

Wettability is an important parameter in nanoparticle applications for EOR processes. Wettability can be reflected by the value of the angle of contact between the oil and the rock substrate. From the results of this study, it can be noticed that the higher the concentration of nanoparticles then the contact angle value will be smaller. The best results in the study is obtained at nano fluid within concentration of nano silica 0.1 wt% with a contact angle of 20.39˚.

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