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Research Paper

Zeolite-Nanofluids Performance Evaluation on Mechanism of Interfacial Tension for the Enhancement of Oil Recovery

Kayode S. Ekun[1*], L.S Kuburi[2], Y. Ibrahim[3]

[1,2,3]Mechanical Engineering Ahmadu BELLO University, Zaria, Kaduna State

**Corresponding Author: kayode.se@gmail.com*

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Abstract—The mechanism of interfacial tension (IFT) between crude oil, base fluids, and Zeolite nanofluids was studied by the pendant dropped method with Dropped Shape Analysis System (DSA-2 software), after core flooding experiments for the enhancement of oil recovery from different nine core plugs with three base fluids(Brine, Ethanol, and Distilled water) of 3.0wt% concentration, and developed Zeolite nanofluids (ZNPB, ZNPD, ZNPE) from base brine, distilled water, and ethanol at a concentration of 0.005wt.%, 0.001wt.%, and 0.015wt.%. two sets of experiments were conducted for all the fluids obtained from nine cores after the flooding process to determine the effect of zeolite nanofluids on IFT, IFT Data before and after the application of zeolite nanofluids was obtained. The result demonstrates that IFT can be decreased by boosting nanofluid concentrations in core samples by the range of 0.005 weight percent, 0.010 weight percent, and 0.015 weight percent. IFT between oil and brine was 20.82 mN/m when only brine was injected; as zeolite nanofluids were applied, IFT between oil and Zeolite nanofluid (ZNPB) decreased to 16.50 mN/m, 10.89 mN/m, and 7.59 mN/m from DSA data obtained; the result of the second fluid tested (distilled water only) before nanofluid application shows that IFT between oil and distilled when ethanol is used the IFT Between oil & Ethanol only Before Application of ZNPE, tested to be 25.38mN/m, 27.50mN/m, 38.82mN/m from core CC1 to CC3, and with nanofluids application, **IFT between ZNPE &Oil** drastically Dropped to 2.7 mN/m, 2.55mN/m, and 1.85mN/m, the report has shown from this study that base fluids concentration and nanofluid's concentration are the main parameters that impact IFT reduction under the confining pressure of 400psi and constant temperature of 65°C.

Keywords— Zeolite nanoparticles, Zeolite Nanofluids, enhancement of oil recovery, Interfacial tension mechanism, base fluids, cores samples, core flooding, dropped shape analysis.

1. Introduction

Zeolites are still utilized in a variety of applications to address problems pertaining to the environment, science, business, and daily life. The importance and uses of these materials in chemistry (and daily life) cannot be overstated; one important sector that is impacted in this regard is the oil and gas sector, particularly in EOR. Zeolite nanofluids will increase oil recovery because they reduce the interfacial tension (IFT) between crude oil and displacement fluids. Traditional surfactants, however, are ineffective in high temperature and salinity conditions in reservoirs [14], [29], [38]. Because of this, interfacial or surface tension (IFT) is the force that keeps a fluid's surface from separating when it is in contact with another fluid. In the oilfield, interfacial tension is frequently expressed in dynes/cm or mN/m and depends on pressure, temperature, and the makeup of each fluid. According to reports, the interfacial tension between crude oil and brine is between 25 and 35 mN/m [7]. Interfacial tension (IFT) is the force required to increase the surface area between two immiscible fluids per unit area. IFT [16], [22] is a representation of the strength of the imbalanced molecular cohesive forces at the contact. Understanding the interactions and forces at interfaces can be accomplished, for instance, by studying IFT as a macroscopic quantity [16], [22], and [30]. Surface tension (SFT) is typically associated with this characteristic. regarding the gas or air phase. There is a particular need for accurate interfacial tension estimation due to capillary forces' significant influence on reservoir fluid movement. Changes in interfacial tension with temperature, pressure, and composition have a substantial impact on the movement of the media in a reservoir. [1]. Currently, the global economy is growing steadily. Energy use is consequently rapidly increasing as well. Oil production must be increased to meet this rising demand. Enhanced oil recovery (EOR) technology is becoming more popular as a third recovery method due to the inefficiency of primary and secondary recoveries [33]. Nanofluids are regarded as one of the most effective chemical flooding agent improvements because of their capacity to significantly reduce the interfacial tension (IFT) between the water and oil interfaces, increase values for sweep efficiency and crude oil displacement efficiency, as well as decrease residual oil saturation [27]. However, several obstacles prevent precise nanofluid predictions [37]. The effectiveness of the on-site IFT on nano flooding depends on several factors: Reservoir development conditions, the partitioning of nanofluids between confined oil and dispersing fluid phases, the level of dilution, and adsorption onto the rock surface. Even though it can be challenging to predict how IFT will change in a reservoir setting precisely, research [13]. has discovered some concerning chemical elements that could affect IFT. This research looks into how the hydrocarbon phase and zeolite nanofluid solution are affected by pressure, temperature, salinity, and nanofluid concentration. It is possible to explain the mechanism for IFT reduction in aqueous solutions using colloidal surfactant aggregates. When nanoparticles are combined with dispersing liquids like ethanol, distilled water, and brine solution, the surface free energy is decreased because the dissolved nanoparticle molecules are dispersed on the interface as monomers. When the critical micelle concentration (CMC), a predetermined surfactant concentration, is reached by adding more nanofluids, the surfactant starts to aggregate into micelles [33]. IFT has a significant impact on the hydrodynamics and phase interaction, which affect processes like extraction, emulsification, and enhanced oil recovery (EOR) [14],[18]. Drop dispersion and velocity in liquid-liquid extraction are significantly impacted by this characteristic [9], [19], [21]. Low IFT promotes oil solubilization in water during EOR and increases oil output [14], [21], [31]. As a result, the goal is to reduce the IFT in a variety of situations, and numerous studies focus on ways to gradually reduce this feature. As a result, this work focused on measuring the IFT at all three of the dispersing fluids used—ethanol, distilled water, and brine—and evaluating the effectiveness of zeolite nanofluids on the interfacial tension mechanism for improving oil recovery. via the core flooding procedure and dropped shape analysis of fluids, the impact on IFT both before and after the application of zeolite nanofluids.

The essay is structured as follows: Section 1 of the paper contains a general introduction to the study, Section 2 the review of the literature and related research, Section 3 the methodology, equipment, and materials, Section 4 the results and discussion of the impact of zeolite nanofluids on interfacial tension IFT after DSA data and as well as % of oil recovery before and after application of zeolite nanofluids, with graphical analysis relations and comparison Section 5 contain the conclusion and future scope of the study.

2. Related Work

2.1 Mechanism of interfacial Tension (IFT).

Numerous studies have examined the possibility of IFT reduction by nanoparticles and nanofluids [11], [28], [34], and [39] and have concluded that IFT reduction is the primary mechanism for EOR by nanofluids. For instance, [34] described a reduction of 70-90% in the interfacial tension of oil/water systems when surface-dynamic methods with aqueous solution and the use of nanofluids were used in the investigation. [39], who used nanofluid and observed a 91% decrease in IFT (16-1.4 dynes/cm). To determine the conditions anticipated to dispense with residual oil, typically after a water flooding process, various trials have been conducted on reservoir rock. most of the time, the oil appeared to be a part of the proportion $\Delta P/L\sigma$, where ΔP is the strain drop across the distance L and σ is the interfacial tension among oil and water. No residual oil has been given the option to be removed before exceeding this proportion, which seemed to be a crucial feature from all accounts. Additionally, by applying more strain or lowering interfacial tension, both of which can be accomplished using surface dynamic [35], this fraction can be increased. Additionally calculated IFT using a tensiometer and the Swinging Drop technique (Drop Shape Analysis System (DSA-2)). A specific liquid drop is suspended in a large volume phase using a needle. Interfacial tension and gravity determine the drop's state. Furthermore, the strain inside the drop phase increased along with the interfacial tension between the outer and inner stages. The drop then deforms as it falls due to gravity. The following equation can be used to calculate the interfacial tension when the drop's thickness and that of the surrounding liquids are known.

$$\sigma ow \cos \theta w = \sigma os - \sigma ws \quad (2.5)$$

where d_e is the most extreme width of the drop as displayed in Figure 2.6, ρd is the thickness of the drop stage, ρa is the encompassing liquid stage, H is steady that is a component of de/ds, and g is the acceleration of gravitational speed. High temperatures and tensions can both be handled by this method [40]. Mention how IFT is used to determine nanofluid development in permeable media and how important the IFT between the oil and liquid is during the EOR process. To determine IFT, pendant drop techniques are frequently employed.

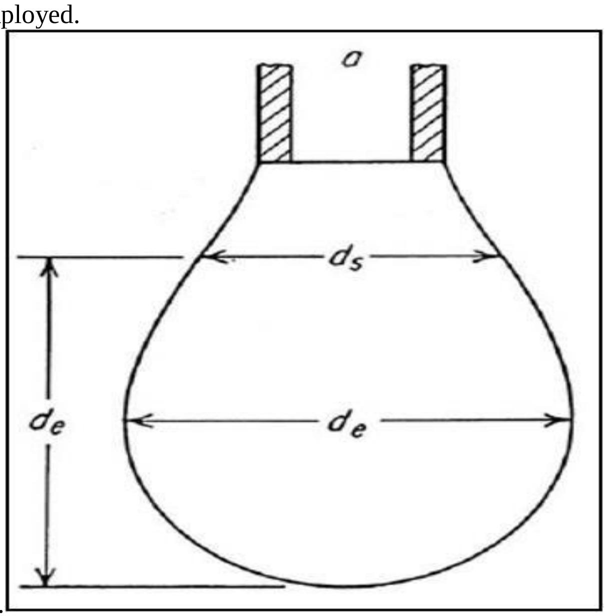

Figure: 1 Pendant drop method schematic

Scientists are being urged to select materials that are effective even under the most difficult conditions as the need to reduce IFT has grown. Considering these, numerous applications for nanofluids are currently being researched. [12][20],[24],[25]. Eleven ionized liquids (ILs) from three different chemical groups—ammonium, lactam, and hydroxylammonium—were used in a typical examination, according to [31], which reviewed the findings. The employed ionic liquids (ILs) significantly reduced the IFT when compared to common non-ionic surfactants, according to an analysis of the IFT values given for the composition of crude oil and water systems [3],[31]. There are numerous factors that influence how the ILs adsorb at the interface, including the structure of the ILs and the phases, the presence of electrolytes and contaminants, and many others. Even though many works have been devoted to the use of the ILs, the analysis of the structure-property correlations of ILs has not progressed as much as it should have [8].

2.2 Reduction of interfacial tension (IFT)

The main mechanism entails the movement and structuring of the oil-water interface, which is influenced by the hydrophobic and hydrophilic properties of the nanoparticles. Nano flooding aims to increase the capillary number [1],[4] by decreasing the IFT between the oil and the water. When compared to using only surfactants, using nanofluids of 70–150 nm dissolved in an aqueous surfactant solution can effectively displace oil by 35% in a homogeneous reservoir and 17% in a heterogeneous reservoir at a temperature of 25 °C. When the fluid's properties shift from Newtonian to non-Newtonian, recovery increases because of decreased IFT [34].

3. Experimental Method/Procedure

3.1 Materials and equipment.

The materials and equipment used are; **(i)** Zeolites Nano particles **(ii)**Dispersing fluids (Distilled water, brine, and ethanol) (iii)Crude oil, (iii) Core samples, (iv) Fourier Transform Infrared (FTIR) spectroscopy, (v) Scanning electron microscopy (SEM), (vi) Digital weighing balance (OHAUS),(vii) Magnetic stirrer, hot plate, and beaker, (viii) pycnometer and Brook field viscometer or Ostwald's viscometer, (ix), Water-wet sandstone core plugs (Core Samples), (xi) porosimeter and liquid Hassler permeameter,(xii) Capillary Tubes and Beakers,(xiii) tensiometer and model 700 vinci technology, (xiv)Oven, (xv) Pressure gauge (barometer)

3.2 Fluids Facts information used.

crude oil was obtained from an offshore oil field in the South/South region of Bonny Island Rivers State (Niger Delta). Distilled water and ethanol were bought from a chemical shop in Port Harcourt, Nigeria while the inland sea water of Bonny Island was obtained as brine because of its salinity. Moreover, an alternative synthetic reservoir brine was developed using deionized water as the base fluid and sodium chloride (NaCl) 3.0 wt.% as the salt. By using a pycnometer and an Oswald viscometer, the density and viscosity of the crude oil and the three dispersing fluids were measured. to formulate and develop the nanofluids, different wt. % (0.005, 0.01, and 0.015 adopted from [15]. of nano Zeolite particles were added to the base fluids with surfactants like Sodium dodecyl sulphate (SDS), added for stability and vigorously mixed with the help of the sonication method(ultrasonicate) for a more homogenized suspension and uniform dispersion.

Table 1 Fluids Properties

Oil/Base Fluids	Density @ 27ºC	Viscosity (cp)	API Gravity(^{0}C)
Crude oil	0.9114g/cc	52.27cp	23.36
Brine	1.008g/cm3	1.00	-
Distil Water	1.00g/cm3	1.00	-
Ethanol	0.7908g/cm3	1.12cp	-

3.3 Formulation of Zeolite nanofluids procedure with three base fluids of (Distilled Water, Brine and Ethanol)

Y-Zeolite Nanoparticles of the same nano size(80nm) with a high surface area of small size were measured in different wt. % of (0.005, 0.01 and 0.015), and dispersed in different base fluids of (Distilled water, Brine and Ethanol) to form three respective concentrated fluids namely as (**ZNPB,** ZNPD and ZNPE) i.e., zeolite nanofluid with base brine, zeolite nanofluid formation with distilled water, and zeolite nanofluid with ethanol. The respective formulated fluids (ZNPB, ZNPD and ZNPE) was repeatedly mixed and stirred using the below figure 2 two-step method of mixture with addition of 0.02wt% of Sodium.

dodecyl sulphate (SDS), as surfactant to each solution and sonicate for 120 minutes respectively to attain a more homogenized suspension and uniform dispersion of zeolite nanofluids (**ZNPB, ZNPD and ZNPE)** formation. viscosity of the respective formulated fluids was measured by an Oswald viscometer.

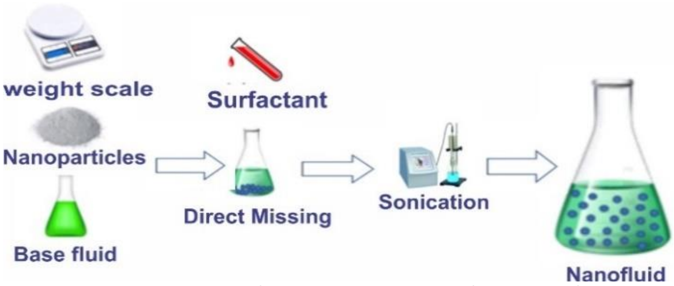

Figure 2 two-step method of mixture with addition of 0.02wt% of Sodium dodecyl sulphate (SDS)

Figure 3 core samples used for core flooding experiment.

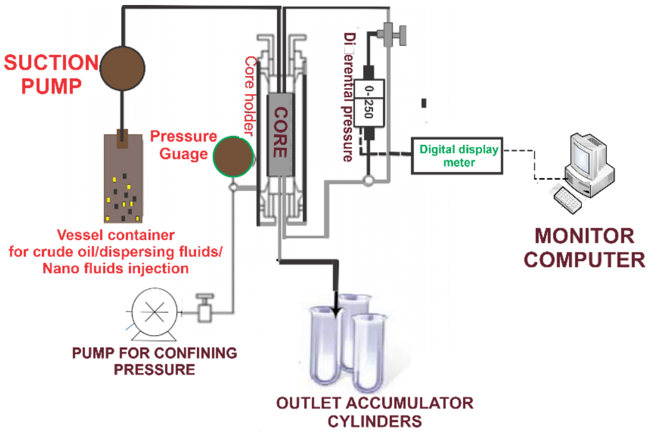

Fig. 4 Core flooding experimental set up.

3.4 Core samples plugs preparation/Core flooding Experiment.

Nine natural core samples plug(sandstones) label accordingly in the order of (CA1, CA2, CA3, CB1, CB2, CB3, CC1, CC2, and CC3) respectively, each were used for different fluid's formulated in this work, and which are water wet sandstone rocks obtained from an offshore oil reservoir well in Niger Delta. These core plugs samples shown in the Figure 3 are unconsolidated sandstone core samples representing typical oil well reservoir rocks in Niger Delta, the core plugs were cleaned with toluene through Soxhlet extraction apparatus at 65^{o}C for 2hrs. afterward, the core plugs were heated in the oven at 70 ^{o}C for 2hrs, all the fluids that passes through the cores before and after application of nanofluids was tested with crude oil to get all the interfacial interaction with tensiometer

3.5 Core flooding process with Water flooding (secondary recovery with Brine only)

3.0 weight percent (30000 ppm) of a low-salinity brine was injected into the core sample until it was fully saturated. Oil was then added to reveal the brine that already existed. It is important to remember that not all the brine was replaced by oil at this point. The calculated amount of un-displaced brine now represents the connate water saturation because the amount of displaced brine in this case is equal to the initial oil in place (IOOP). This is accomplished by subtracting the total amount of brine that was initially injected to saturate the core sample from the amount of brine that has been displaced due to oil. This brine was injected into the base run to replace the oil, and this case illustrates the typical water flooding scenario. The amount of oil displaced by brine was determined to determine the oil recovery factor only by waterflooding. The dropped shape method was used to establish the wettability condition. To evaluate the effect of the recovery factor of the reference nanofluids used in this case, the results of the brine nanofluid case were compared to the case of conventional water flooding. This case of the trial was used as a reference case for brine nanofluid flooding that varied in weight percent concentration.

3.6 Core flooding process with Zeolite Nanofluid flooding (Tertiary recovery with ZNPB).

Following the completion of the conventional water flooding (secondary recovery), ZNPB was injected in three different concentrations (0.005, 0.01, and 0.015 wt.%) as a reference. The oil recovery for each sample was calculated in addition to keeping an eye on the change in wettability. As a result, the reason for each change in oil recovery (whether an increase or decrease due to a change in wettability) was established. The steps and procedures for the experiment are as follows. The Core samples (CA1, CA2 and CA3) were Cleaned, and oven dried for another 1hr after which its dry weight was measured and recorded.

1. The core sample were soaked for 72hrs in the base fluid after which was fixed backed to the piston cylindrical core holder and Brine was injected with pump until the core sample is fully saturated; absolute permeability was calculated from Darcy equation. Then, the core plug sample weight was measured at its saturated condition and recorded.
2. The dry weight was subtracted from the saturated weight and then divided the result by the brine density to calculate the pore volume (PV).
3. Thereafter, Crude oil was injected to displace the existing brine. (It is interesting to note that not all the brine was displaced by the oil. Accordingly, the amount of displaced brine was the same amount as the initial oil in place (OOIP) for this case, and by subtracting the amount of brine displaced by oil from the aggregate sum of brine that was initially. injected to saturate the sand pack, presently the calculated amount of un-displaced brine represents the connate water saturation.
4. Weight percent concetration (0.005, 0.01 and 0.015 wt.%) of ZNPB are injected in turns into the core sample to investigate the effect of different concentrations on oil recovery and to displace the oil. For each fraction of the pore volume of nanofluid injected, the amount of injected nanofluid was measured and the time is determined to calculate flow rate, then by substituting in Darcy equation, effective permeability was as well easily calculated.
5. The amount of oil extracted was measured to determine the oil recovery percentage.
6. Captive Drop method was used to measured and determine the wettability condition in reference to contact angle behavior.
7. The above procedure was repeated for core plug samples (CB1, CB2, CB3 of distilled water, and CC1, CC2 and CC3) of Ethanol at different concentration of (0.005, 0.01 and 0.015 wt.%) across all the cores samples.

3.7 *Experimental procedure in determined the* Interfacial Tension with Tensiometer *Drop shape Analysis between the oil and the several base fluids (Brine, Distil water and Ethanol), and between oil and the developed Zeolite nanofluids*

Figure 5 demonstrates the tensiometer used to measure interfacial tension. The tensiometer apparatus in Figure 5 was heated to a temperature of 65 °C. The experiment was conducted at a constant temperature. Additionally, the required test solutions were put in a tube, and the Drop Shape Analysis System (DSA-2 software was calibrated using a needle with a diameter of 0.6 mm. After the calibration, the tube was filled to prevent gas bubbles from getting stuck at the ends of the tube. A 2.5 ml drop of oil was injected into the tube using a pressure syringe, and the tube was rotated between 2200 and 3800 rpm. The IFT 700 device connected to a computer is used to record the values using the software, which requires the density of the oil and nanofluid solution. Both the oil sample and the nanofluids recovered from the core flooding experiment are fed to the sample cylinder and heated to a temperature of 65°C because the density of the oil and nanofluid solution is required to record the values using the IFT 700 device. The IFT Chamber received the nanofluid concentration at a constant confining pressure of about 400 psi. As shown in Fig. 5, the camera attached to the computer detects the generated drop produced by the calibrated capillary in the chamber. With various spinning rates, the reduced oil interfacial tension was continuously measured using drop shape analysis (DSA) software; in addition, the IFT measurements of each fluid concentration sample in the range of (0.005, 0.01, and 0.15wt%) with the crude oil used were methodically recorded. obtained; this experiment was repeated for all three base fluids (Brine, ethanol, and distilled water), and different concentration.

(0.005, 0.01 0.015 wt.%) of Zeolite Nanofluid after core flooding process.

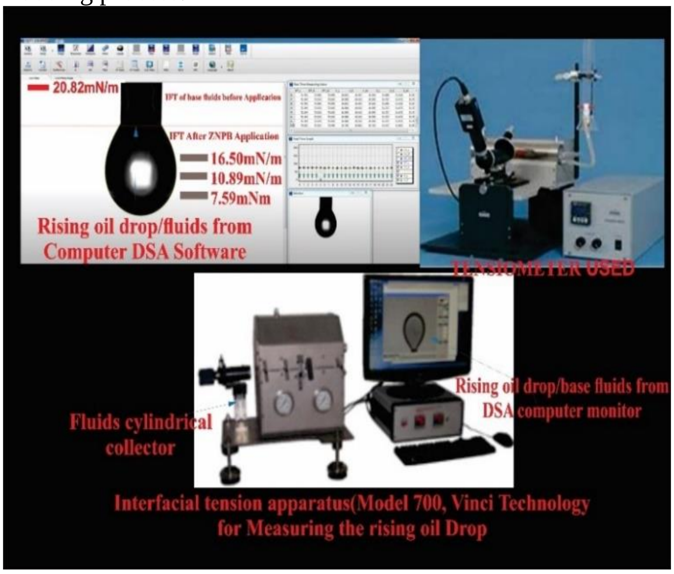

Figure 5 IFT Experimental Apparatus and DSA in determine IFT Before/After application of Nanofluids (ZNPB, ZNPD, ZNPE)

Table 2 Operating conditions for IFT measurement

Parameters	Operating conditions
Type of base fluids before application of nanoparticles	Nacl (Brine), distilled water, Ethanol.
Base fluids concentration wt.%	3.000 (30,000ppm)
The Developed fluids	Zeolite Nanofluids(ZNPB,ZNPD and ZNPE).
Nanofluids concentration (wt.%)	0.005, 0.01, 0.015
Temperature (°C)	65
Pressure (psi)	400
Salinity (ppm)	30,000ppm

4. Results and Discussion

3.8 Results effect analysis of IFT

The table 3 shows the result effect on IFT between brine and crude oil before application when core flooding with base brine only and with crude oil injection.

Table 3 Results effect analysis of IFT (Brine and Oil before application of zeolite nanofluid (ZNPB).

Core ID	Brine Concentration in wt.%	IFT Between oil & Brine Before Appl. of ZNPB (mN/m)	% Oil recovery without ZNPB (Brine only)
CA2	3.00	20.82	45.50
CA3	3.00	20.82	48.50
CA1	3.00	20.82	52.00

Table 4 Results effect analysis of IFT (ZNPB and Oil after application of zeolite nanofluid (ZNPB).

Core ID	Zeolite Nano fluid concentration in wt.%	IFT between (ZNPB &Oil) (mN/m)	Total oil recovery efficiency(%) after appl. of ZNPB
CA2	0.005	16.50	57.00
CA3	0.010	10.89	62.05
CA1	0.150	7.59	69.90

The table 4 shows the result effect on IFT between the displayed Crude oil and Zeolite Nanofluid from base brine after application.

3.9 Effect analysis on IFT between Brine/oil before application of zeolite nanofluid (ZNPB)

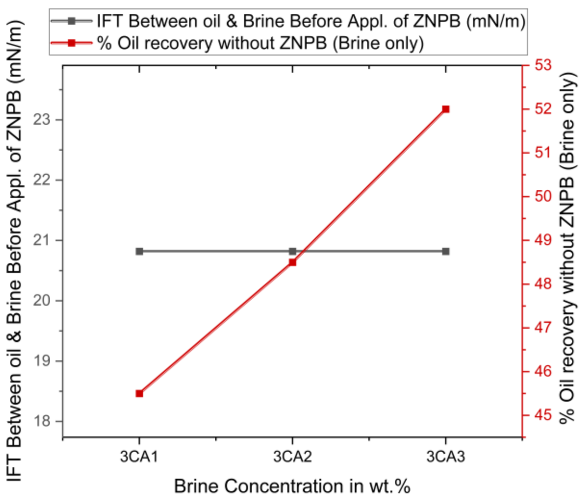

Figure 6 IFT between oil and brine before application of ZNPB

3.10Effect analysis on IFT between Zeolite nanofluid/oil after application of (ZNPB).

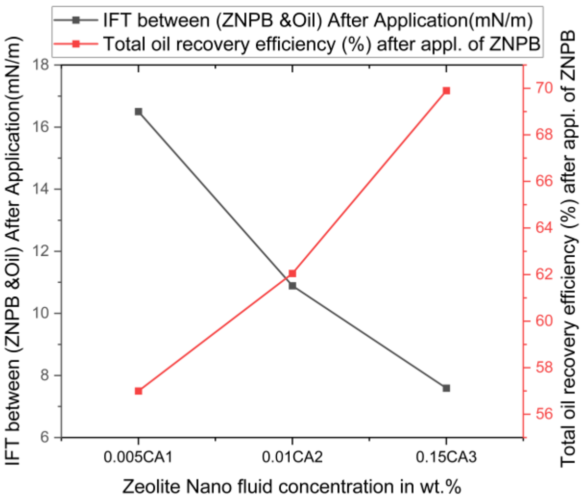

Figure 7. IFT between oil and brine after application of ZNPB

The above two graphs in figure 6 and 7 clearly showing interfacial tension IFT obtained from tensiometer Between brine and oil before application of ZNPB and IFT between oil and zeolite Nanofluid after application across core samples, when waterflooding with 3.0wt.% concentration of brine only across core CA1, CA2, and CA3 the IFT obtained is 20.82 (mN/m) across samples core, similarly in figure. The IFT obtained when Nano flooding with concentration of (0.005, 0.010, 0.015) wt.% across samples core is 16.50mN/m, 10.89mN/m, and 7.59mN/m across core samples. In the above graphs after Nano flooding with zeolite nanofluid, the IFT reduce to 16.50mN/m, 10.89mN/m, and 7.59mN/m across core sample because of the nanofluid reason be that as the concentration increases from 0.005 to 0.015wt.% the IFT dropped to 7.9mN/m attributed to [10]. as the mechanism that drive EOR, who reviewed the effect of increasing nanofluids concentration in core samples as it affects the IFT in reservoir formation and it can be deduced from the graph figure 7, that as concentration of fluids increases across cores the value of the IFT keep dropping see the which, agreed with [6], and the displacement crude increase as concentration values is raised across each core. The increase in recovery because of lowering of IFT occurs when the fluid changes characteristics from Newtonian to non-Newtonian state [34], the above results and finding detail when base brine was used, and the base fluids developed fluids nanoparticles.

Table 5 Results effect analysis of IFT (Distilled water and Oil before application of zeolite nanofluid (ZNPD).

Core ID	Distilled water Concentration in wt.%	IFT Between oil & Distilled water Before Appl. of ZNPD (mN/m)	% Oil recovery without ZNPD (Distilled water)
CB1	3.00	25.068	33.89
CB2	3.00	25.068	35.68
CB3	3.00	25.068	37.89

The above table 5 shows Distilled water Concentration in wt.%, the result effect of IFT between Distilled water and oil, and the percentage of oil recovered via core flooding analysis before application Zeolite nanofluid.

Table 6 Results effect analysis of IFT (between Zeolite Nanofluid and Oil after application of (ZNPD).

Core ID	Zeolite Nano fluid (ZNPD) concentration in wt.%	IFT between (ZNPD &Oil) (mN/m)	Total oil recovery efficiency(%) after appl. of ZNPD
CB1	0.005	20.81	42.90
CB2	0.010	20.66	48.05
CB3	0.150	20.41	51.00

The above table 6 shows **Z**eolite Nano fluid (ZNPD) concentration in wt.%, the result effect on IFT between Zeolite nanofluids (ZNPD) and oil after application and as well as the crude oil percentages displayed after application of nanofluid injection via core flooding process.

3.11 Effect analysis on IFT between DW/oil before application of zeolite nanofluid (ZNPD)

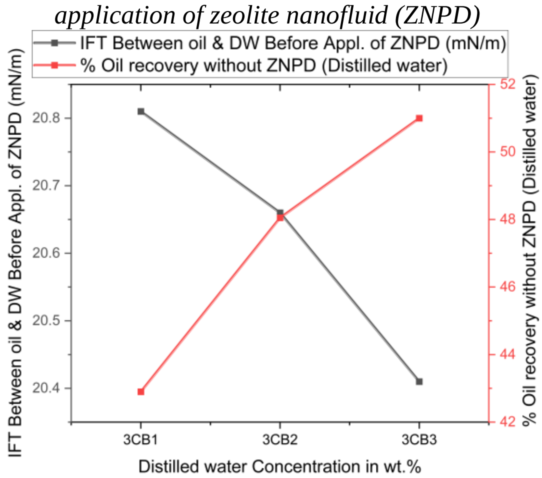

Figure 8 IFT between oil/ Distilled water and percentage of oil recovery before application

3.12 Effect analysis on IFT between Zeolite nanofluid/oil after application of (ZNPD).

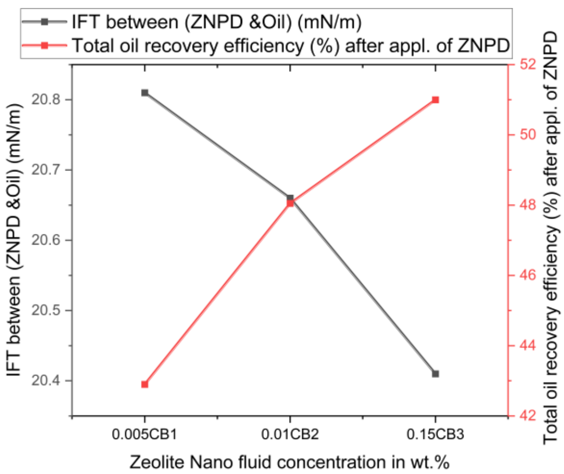

Figure 9 IFT between Zeolite nanofluid and oil and the percentage of oil recovery after application

The above two graphs in figure 8 and figure 9 clearly showing interfacial tension IFT obtained from tensiometer of pendant drop experiment Between Distilled water and oil before application of ZNPD and IFT between oil and zeolite Nanofluid after application across core samples, it can been seen that when waterflooding with 3.0wt.% concentration of Distilled water only across core CB1, CB2, and CB3 the IFT obtained is 25.06 (mN/m) across samples core, similarly in figure.2 The IFT obtained when Nanofluid flooding with concentration of (0.005, 0.010, 0.015)wt.% across samples cores is 20.81mN/m, 20.66mN/m, and 20.41.mN/m across cores. In the above graphs after Nanofluid flooding with zeolite nanofluid ZNPD, the IFT reduce to 20.81mN/m, 20.66mN/m, and 20.41. mN/m across core sample due to the effect of the nanofluid, reason be that as the concentration.
increases from 0.005 to 0.015wt.% the IFT dropped to 20.41mN/m attributed to [10], as the mechanism that drive EOR and [6], agreed to [10]. Who have studied the effect of varying nanofluid concentration on core samples.

Table 7 Results effect analysis of IFT (Ethanol only and Oil before application of zeolite nanofluid (ZNPE).

Core ID	Ethanol Concentration in wt.%	IFT Between oil & Ethanol Before Appl. of ZNPE (mN/m)	% Oil recovery without ZNPE (Ethanol Only)
CC1	3.00	25.38	36.63
CC2	3.00	27.50	38.20
CC3	3.00	38.82	41.89

The above table 7 shows ethanol water Concentration in **wt.%,** the result effect of IFT between ethanol and oil, and the percentage of oil recovered via core flooding analysis before application Zeolite nanofluid (ZNPE).

Table 8 Results effect analysis of IFT (Zeolite nanofluid-ZNPE and Oil after application.

Core ID	Zeolite Nano fluid concentration in wt.%	IFT between (ZNPE &Oil) (mN/m)	Total oil recovery efficiency(%) after appl. of ZNPE
CC1	0.005	2.75	40.20
CC2	0.010	2.55	44.62
CC3	0.150	1.85	47.32

The above table 8 shows Zeolite Nano fluids concentration in wt.%, the result effect on IFT between Zeolite nanofluids (ZNPD) and oil after application and as well as the crude oil percentages displayed after application of nanofluid injection via core flooding process.

3.13 Effect analysis on IFT between Ethanol/oil before application of zeolite nanofluid (ZNPE)

increases from 0.005 to 0.015wt.% the IFT dropped to 20.41mN/m attributed to [10], as the mechanism that drive EOR and [6], agreed to [10]. Who have studied the effect of varying nanofluid concentration on core samples.

Table 7 Results effect analysis of IFT (Ethanol only and Oil before application of zeolite nanofluid (ZNPE).

Core ID	Ethanol Concentration in wt.%	IFT Between oil & Ethanol Before Appl. of ZNPE (mN/m)	% Oil recovery without ZNPE (Ethanol Only)
CC1	3.00	25.38	36.63
CC2	3.00	27.50	38.20
CC3	3.00	38.82	41.89

The above table 7 shows **ethanol water Concentration in wt.%,** the result effect of IFT between ethanol and oil, and the percentage of oil recovered via core flooding analysis before application Zeolite nanofluid (ZNPE).

Table 8 Results effect analysis of IFT (Zeolite nanofluid-ZNPE and Oil after application.

Core ID	Zeolite Nano fluid concentration in wt.%	IFT between (ZNPE &Oil) (mN/m)	Total oil recovery efficiency(%) after appl. of ZNPE
CC1	0.005	2.75	40.20
CC2	0.010	2.55	44.62
CC3	0.150	1.85	47.32

The above table 8 shows **Zeolite Nano fluids concentration in wt.%,** the result effect on IFT between Zeolite nanofluids (ZNPD) and oil after application and as well as the crude oil percentages displayed after application of nanofluid injection via core flooding process.

3.14*Effect analysis on IFT between Ethanol/oil before application of zeolite nanofluid (ZNPE)*

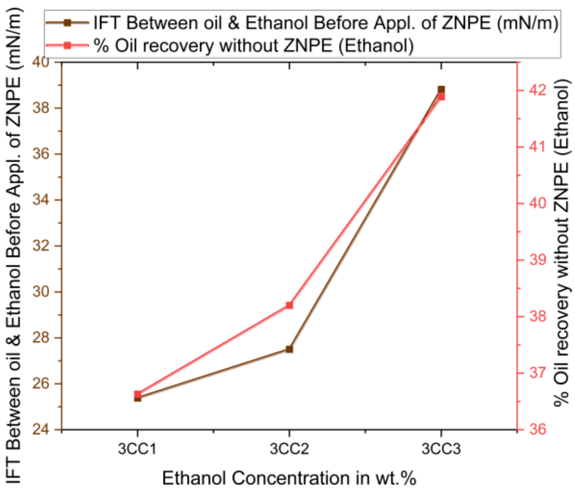

Figure 10 IFT between oil/water and percentage of oil recovery before application

3.15Effect analysis on IFT between Zeolite nanofluid/oil after application of (ZNPE)

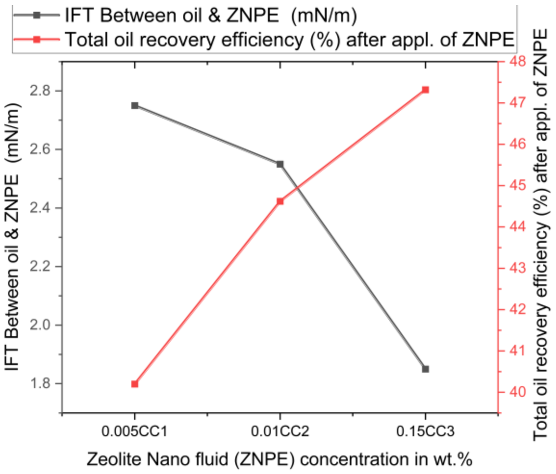

Figure 11 IFT between Zeolite nanofluid and oil and the percentage of oil recovery after application

The above two graphs in figure 10 and 11 clearly showing interfacial tension IFT obtained from tensiometer in pendant drop experiment Between Ethanol and oil before application of ZNPE and IFT between oil and zeolite Nanofluid after application across core samples, it can been seen that when waterflooding with 3.0wt.% concentration of Ethanol only across core CC1, CC2, and CC3 the IFT obtained is 25.38 (mN/m), 27.50(mN/m) and 38.82(mN/m) across core samples, similarly in figure.11 The IFT obtained when Nanofluid flooding with concentration of (0.005, 0.010, 0.015)wt.% across core samples is 2.75mN/m, 2.55mN/m, and 1.85mN/m across cores. In the above graphs after Nanofluid flooding with zeolite nanofluid ZNPE, the IFT reduce across core samples because of zeolite nanofluid, reason be that as the concentration increases from 0.005 to 0.015wt.% the IFT dropped to 2.75mN/m, 2.55mN/m, and 1.85mN/m across cores attributed to [10]. as the mechanism that drive EOR and [6], agreed to [10]. Who have studied the effect of varying nanofluid concentration on core samples.

5. Conclusion And Future Scope

By core flooding with Zeolite Nanofluids, enhanced oil recovery techniques are used to boost oil production. In this study, three base fluids (Brine, Ethanol, and Distilled water) were used to develop Zeolite nanofluids (ZNPB, ZNPD, and ZNPE), which were then applied and compared to determine IFT Values before and after application. The results show that nanofluids can reduce IFT between Zeolite nanofluids with base brine (ZNPB) and oil, Zeolite nanoparticles with base distilled water. The results of this study report the IFT data at various conditions with different base fluids and Developed Zeolite nanofluids, as well as the effects of each concentration parameter on IFT reduction at replica reservoir conditions at a confining pressure of 400 psi with constant temperature of 65^{o}c. Result shows that IFT can be reduced by increasing nanofluids concentration in the order of 0.005wt.%, 0.010wt.% and 0.015wt.%, within core samples. when only brine was used before application, IFT Between oil & Brine was constant across core sample to be 20.82mN/m, as zeolite nanofluids applied IFT between oil and ZNPB reduced to 16.50mN/m,10.89mN/m and 7.59mN/m from DSA data obtained, also similarly to the second fluid tested (Distilled water only) before nanofluid application result shows that IFT Between oil & Distilled water Before Application. of ZNPD was constant across the three core plugs samples to be 25.068mN/m and when zeolite nanofluids was applied, IFT Between oil and ZNPD Dropped to 20.81 mN/m, 20.66 mN/m, 20.41 mN/m across the fluids from data obtained from DSA analysis, when ethanol is used the IFT Between oil & Ethanol only Before Application of ZNPE, tested to be 25.38mN/m, 27.50mN/m, 38.82mN/m from core (CC1 to CC3), and with nanofluids application **IFT between (ZNPE &Oil)** drastically dropped to 2.7 mN/m, 2.55mN/m, and 1.85mN/m across core fluids, from the results thus far between all the fluids analysed in terms of their effects on the mechanism of IFT reduction in the reservoir formation for oil enhancement of oil recovery, Zeolite nanofluids from ethanol and zeolite nanofluids from brine shows more significant impact on IFT reduction, with Zeolite nanofluids from distilled water shows least reduction effect on IFT, These investigated effects of each parameter can be useful to understand and used as fundamental data to apply for oil recovery with reservoir conditions in EOR.

Furthermore, dynamic IFT is also helpful for comprehending changes in phase contact and conducting applied interface investigations. But not enough research has been done on the topic. Overall, it is thought that nanofluids and nanoparticles offer a chance to solve industry issues, but more research on various low-cost nanoparticles with various base fluid compositions is still needed for EOR processes to assess their suitability for the good formation and impact on the mechanism of reservoir formation.

Data Availability.

Any further data needed from the reader not stated in this study can be fully requested from the corresponding author via contact details, this data cannot be release due to organization private data policy that supported us.

Conflict of Interest

There is no conflict of interest encountered by the authors.

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None

Authors' Contributions

Author-1 researched literature and conceived the study. Author-2 is my major supervisor involved in reviewing of work, provide academy guidelines in terms of the work and approval, Author-3 is my minor supervisor supporting author 2 in screening and looking into the research and provide technical advice in supporting the work. All authors reviewed and edited the manuscript and approved the final version of the manuscript.

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AUTHORS PROFILE

Kayode Ekun earned a B.Eng. in Production and Materials Engineering in the department of Materials and Production Engineering now Industrial and Production Engineering Department in Ambrose Alli University, Ekpoma, Edo State, Nigeria, and also earned a Diploma in Chemical and petroleum studies (2008) in the department of Chemical Engineering in University of Benin City, Edo state, Nigeria currently a Master Degree student in Mechanical Engineering with specialization in "production" in Ahmadu Bello University, Zaria Kaduna State, Nigeria. My research area of interest is but are not limited to; Nanotechnology, Petroleum, and gas engineering, Energy system, Materials for Energy storage and generation, Behavior of materials at extreme pressures/temperature, process and production engineering, Corrosion and inspection technology, Static/rotating Engineering with 7years experience in both oil and gas upstream/downstream in oil industry, offshore and onshore.

L.S Kuburi earned B.Eng. and PhD all in mechanical Engineering, in Ahmadu bello university Zaria, Kaduna State, Nigeria. Currently an associate professor in the department of mechanical engineering Ahmadu Bello University Zaria, he has published so many journals to his name and he is an astute Industrialist, his research interest is in production engineering with much emphasis on materials and manufacturing process.

Y. Ibrahim Earned B.Eng. Msc. Ignacy Łukasiewicz University of Technology in Rzeszów, Faculty of Technical Engineering And Aeronautic, and PhD in Engineering Swinburne University of Technology: Melbourne, Victoria, AU, currently working in the department of mechanical Engineering, in Ahmadu Bello university Zaria, Kaduna and School of aviation, Mechanical Engineering department Zaria in Kaduna state. Nigeria. with research interest in Design engineering, industrial engineering research, he has also published many research journals to his name and contribution to knowledge, and with years of experience in Aeronautic and aviation industry home and abroad.

