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Intermittent and short duration ultrasound in a simulated porous medium

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ABSTRACT

Ultrasound is an unconventional method used to recovery oil, despite the report on the use of this technique, the focus has always been on the continuous application of ultrasound. But the continuous ultrasound has its own limitation of high cost of production and maintenance of equipment because of high energy generated. In this study, the use of short duration, intermittent ultrasound was investigated, and the result compared with the continuous ultrasound. The effect of viscosity and intensity on both intermittent and continuous ultrasound was also investigated. A 2D micro-model placed inside an ultrasonic bath under an ultrasound radiation was used, a stereo microscope with the camera mounted at the top of the micro-model recorded the displacement process. The snapshot of each time interval was used to give the estimate in percentage (%) of the residual oil left in the micro-model. The results show that, short duration and intermittent ultrasound can recover more oil compared with the application using continuous ultrasound and longer duration. Therefore, the use of intermittent ultrasound as a green and cost-effective technique is herein proposed.

1. Introduction

Even with the increased interest in alternative source of energy, the world population continue to rely on fossil fuel for their daily activities. The need to increase production to meet this global demand is paramount to the oil industries as they continue to search for new oil fields, expand existing ones and develop new enhanced oil recovery (EOR) technique to mobilize residual oil. EOR chemical methods have been used in the past to recover by-passed oil, but with the uncertainty in crude oil price, the rise in the cost of EOR chemical, environmental concern arising from the use of these chemicals and other technical limitations, has led to the search for unconventional method such as ultrasound stimulation as an additional method for additional oil recovery.

A kick in oil production prompted by cultural noise and an earthquake [1] has led to the use of artificial seismic wave to increase recovery which began with series of laboratory investigations from Duhon and Campbell [2] to Hamidi et al. [3], field pilot test [4] and field application has been reported [1,5]. But most field application has been limited to damage removal near wellbore areas. This was reported by Mirzaei-Paiaman and Nourani [1], when a 5.7 magnitude earthquake hit three gas condensate wells along the Persian Gulf. One well responded to the earthquake generated seismic wave and increased production but the other two did not. The responding well was reported to have a condensate dropout near the wellbore porous media while the other two wells had no condensate accumulation. This natural seismic wave is believed to be responsible for this change in reservoir.

The experimental work of Mohammadian et al. [6] proved that reduction in pressure is caused by the reduction in viscosity of water as a result of ultrasonic stimulation. They identified cavitation, viscosity reduction and emulsification as the main mechanisms in the application of ultrasonic wave. Hamidi et al. [7] included heat generation to the list of the mechanisms causing increase in oil recovery under ultrasound. A mathematical model

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developed from Poiseuille's equation for controlled and uncontrolled environment proved viscosity reduction using ultrasound, but the viscosity was higher for lighter liquids compared to heavier ones. Higher ultrasound shows higher viscosity reduction and therefore, viscosity reduction was inversely proportional to the increasing frequency in temperature-controlled experiment [8]. Alhomadhi et al. [9] believed that gravitational separation as a result of wave stimulation due to the interaction of waves in fluids in the pores cause changes in the relative permeabilities of the rock to oil and water is one of the mechanisms resulting in increased oil production. This was demonstrated by Abramov et al. [5] when they reported a 30–50% increase in production from a well. Ultrasound was used to increase the permeability of the bottom holes zone and alleviated the blockage as a result of mineral particles. They demonstrated that ultrasound is effective with reservoirs containing low permeability and porosity.

Naderi and Babadagli [10] using sandstone cores placed in an inhibiting cell, studied the influence of intensity and frequency of ultrasonic waves on capillary interaction and the oil recovery from different rocks. They noticed a relationship between the inhibition recovery and the intensity, frequency and distance from the ultrasonic wave. Hamida and Babadagli [11] found out that ultrasonic irradiation enhances capillary inhibition recovery for various fluid and that the process is dependent on the interfacial tension and density of the fluid. While, water-air inhibition tests isolated the effect of ultrasound on wettability, capillarity and density, oil-brine inhibition on the other hand, outlined ultrasonic effect on viscosity and interfacial interaction between oil, rock and aqueous phase. Hamida and Babadagli [12] speculated that ultrasound breaks droplet from the capillary tip which slows down the formation of consecutive drops and the improved adherence of water films onto the inner walls of the capillary, thereby increasing the capillary pressure. This led to a change in the interfacial forces between the oil and water which they suggested could be responsible for the increased recovery when ultrasonic wave is applied. Hamidi et al. [13] accepted that reduction of interfacial tension by ultrasound assisted surfactant flooding is also a contributing factor, but towing the line of emulsification, suggested that, the application of ultrasound causes emulsification of oil and water in the reservoir which can be achieved through a short duration stimulation of ultrasound. Short duration stimulation leads to more volume of mini-emulsion, compared to a long duration stimulation, thereby keeping the interfacial tension low and reducing surfactant consumption. In another development, Hamidi et al. [3] used ultrasonic-assisted CO_2 flooding to enhance oil recovery. They reported that ultrasonic wave creates a more stable interface between the displacing fluid and the displaced fluid which could be due to the reduction in viscosity, change in capillary pressure and change in interfacial tension.

Behrend and Schubert [14] advocated for a detailed investigation of continuous phase viscosity on the droplet disruption due to ultrasound which has led to the investigations using the continuous ultrasound. However, the continuous process has its own limitations, the main limits because of the energy generated are the high cost production and maintenance of equipment. Going back to the event of 1950s, where the earthquake altered the state of a producing well that prompted series of investigations was not a continuous wave form that vibrated the reservoirs. The longest time duration for an earthquake ever recorded is between 8.3 and 10 min and the previous studies this not take this into consideration. Therefore, the objectives of this study are to (I) evaluate the recovery of oil under intermittent ultrasound wave and compare it with the continuous ultrasound; (II) investigate the effect of short duration and long duration ultrasound on both intermittent and continuous ultrasound; (III) determine the effect of viscosity and intensity on both intermittent and continuous ultrasound.

2. Experimental set-up and procedure

2.1. Equipment

An ultrasonic generator provided the energy which was emitted to a water bath through an immiscible transducer. A Crest Genesis™ XG-500-6 ultrasonic generator with a frequency of 40 kHz and power output of 500W was used for the experiment. A single syringe pump model NE-1000 was employed for injecting brine water and oil into the micro-model for the displacement test. The bath (W: 21 cm × L: 50 cm × H: 30 cm) and a micro-model holder was designed to make a suitable surrounding for the application of the ultrasound. The micro-model holder was placed at the center of the ultrasonic bath to ensure maximum exposure to the ultrasonic radiation. A stereo microscope with the camera (Cannon Powershot A-2200) mounted at the top of the micro-model to record (video) the displacement process. The schematic diagram of the micro-model experiment is shown in Fig. 1.

2.2. Fluid properties

Two different types of brine were used for the experiment, sodium chloride (NaCl) and calcium chloride ($CaCl_2$) as displacement fluids. Two types of oil; paraffin and kerosene were used as the non-wetting phase in the experiment, paraffin was used as the heavier (medium viscosity) oil and kerosene as the lighter oil (low viscosity). The viscosity of the fluids was measured using a viscometer at 40 °C. Red dye was used to give colour to the oil. Table 1 summarizes the properties of the fluid used in the experiment.

2.3. Porous media

The porous media is a 2D micro-model, the micro-model was attached with the injection needle at the inlet and outlet of the glass. A silicon tube was glued to the inlet of the injection needle and connected to control the valve of the model. The flow of fluid was controlled by the valve. Another silicon tube was glued to the outlet of the micro-model as a path for the collection of the recovered fluid. A syringe pump was used to inject brine and oil into the micro-model at a fixed rate of 1.0 ml/h for all experiments. Figs. 2 and 3 show the 2D glass micro-model used for the experiment. The specification of the micro-model is shown in Table 2.

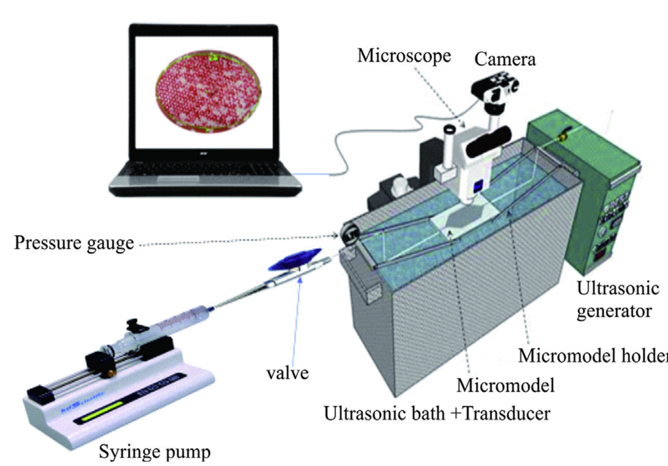

Fig. 1. Caption schematic diagram of the micro-model experiment.

Table 1
Caption fluid properties in the displacement experiment.

Fluid	Viscosity@ 40 °C (cp)	Density @ 27 °C (g/litre)
Kerosene	1.4	860
Paraffin	12.6	800
NaCl + $CaCl_2$ + Brine	–	1004.5

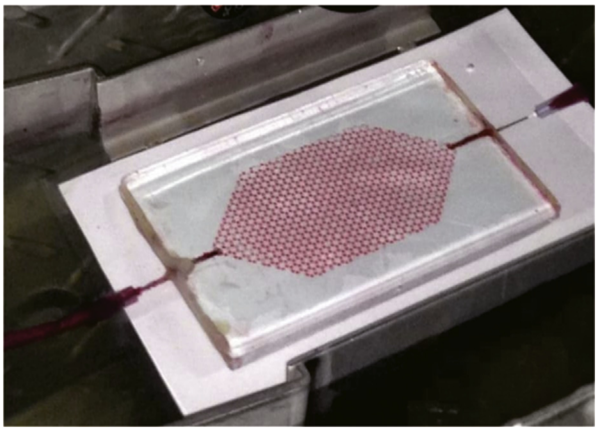

Fig. 2. Caption 2D Glass Micro-Model used in the Study.

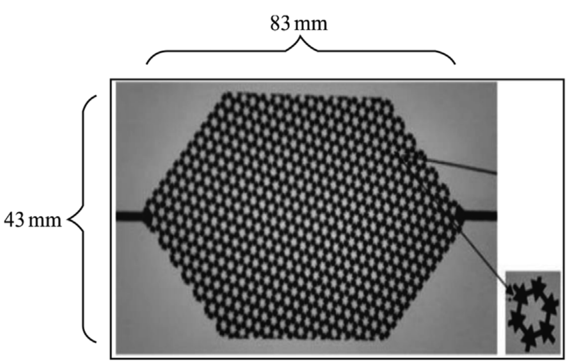

Fig. 3. Caption 2D glass micro-model with triangular pore pattern.

Table 2
Caption specification of the micro-model.

Parameters	Values
Length × width of porous Area	83 mm × 43 mm
Porosity	41%
Permeability	1.94 Darcy (Homogenous)
Pore Volume	37.688 mm^3 (0.037688 ml)
Throat Diameter	0.15 mm
Wettability	Water wet

2.4. Experimental procedures

NaCl and $CaCl_2$ with concentration of 0.35 wt% and 0.1 wt% were injected continuously into the micro-model at 0.5 ml/min to saturate the micro-model and then left for 60 min. The oil was injected continuously into the micro-model until only oil was produced at the outlet. Brine was then injected into the micro-model at a constant injection rate of 1.0 ml/h. Ultrasound wave was then applied to the system. Intermittent ultrasound was achieved by manually turning the ultrasonic generator on and off. The ultrasonic generator was on for the first 5 min and then off for the next 5 min. The whole off and off process was conducted for 60 min. In the continuous stimulation experiment, the ultrasound generator was left on for the whole 60 min duration. The camera was set to record the whole displacement process. The recorded video was played, and a snapshot of a certain times was analysed. Five different snapshots representing 0, 5, 10, 15 and 60 min were taken for each run. An Adobe Photoshop CS5 image software was used to analyse the snapshots and calculate (in %) the area of pore space that was occupied by the oil for a certain time frame (Table 3).

3. Results and discussion

3.1. Image processing with and without ultrasound

3.1.1. 0-15 minutes

Fig. 4 shows a series of snapshot from the experiment utilizing paraffin with both intermittent and continuous waves. Point A (Fig. 4) is the inlet and point B is the outlet. The white portion in the snapshot is the water and the red are the residual oil left in the micro-model after a certain time frame. To compare both with and without ultrasound, paraffin behaves, a series of snapshot are shown together.

From the snapshot observation (Fig. 4), it shows that paraffin with intermittent radiation (Fig. 4a) has less residual oil left inside the micro-model than the continuous radiation (Fig. 4b). Meanwhile, without ultrasound (Fig. 4c) shows more residual oil left in the micro-model. This is because for medium viscous oil such as paraffin, intermittent radiation with high intensity is needed to produce more oil.

From the observation (Fig. 5), it also shows that intermittent radiation with kerosene can increase oil recovery. Less residual oil remained in the micro-model (Fig. 5a) than in the continuous (Fig. 5b). On the other hand, less oil was trapped in the micro-model without ultrasound (Fig. 5c) compared to the continuous radiation (Fig. 5b). This is because for light oil such as kerosene, intermittent radiation with low intensity is good enough to produce more residual oil. And by using intermittent ultrasound wave more emulsion could be generated which is dominant over demulsification [13].

3.1.2. 0-60 minutes

The rate of oil recovery was very high for the first 15 min of the experiment. Brine easily displaced the oil within this period. The rate of recovery decreased significantly for the rest 45 min of the experiment. Ultrasonic stimulation of 500 W/cm^2 intensity created a more visible wave pattern on the surface of the water as compared to 150 W/cm^2. The volume of oil displaced during intermittent ultrasound was higher. Fig. 6 shows series of snapshot

Table 3
Caption experimental runs performed in the study.

S/N	Viscosity of Oil (cP)	Intensity of Ultrasound (W)	Ultrsasonic Stimulation Mode
1	1.4	500	Intermittent
2	1.4	500	Continuous
3	1.4	150	Intermittent
4	1.4	150	Continuous
5	12.6	500	Intermittent
6	12.6	500	Continuous
7	12.6	150	Intermittent
8	12.6	150	Continuous
9[a]	1.4	–	–
10[a]	12.6	–	–

[a] Non-Ultrasonic Stimulation Experiments.

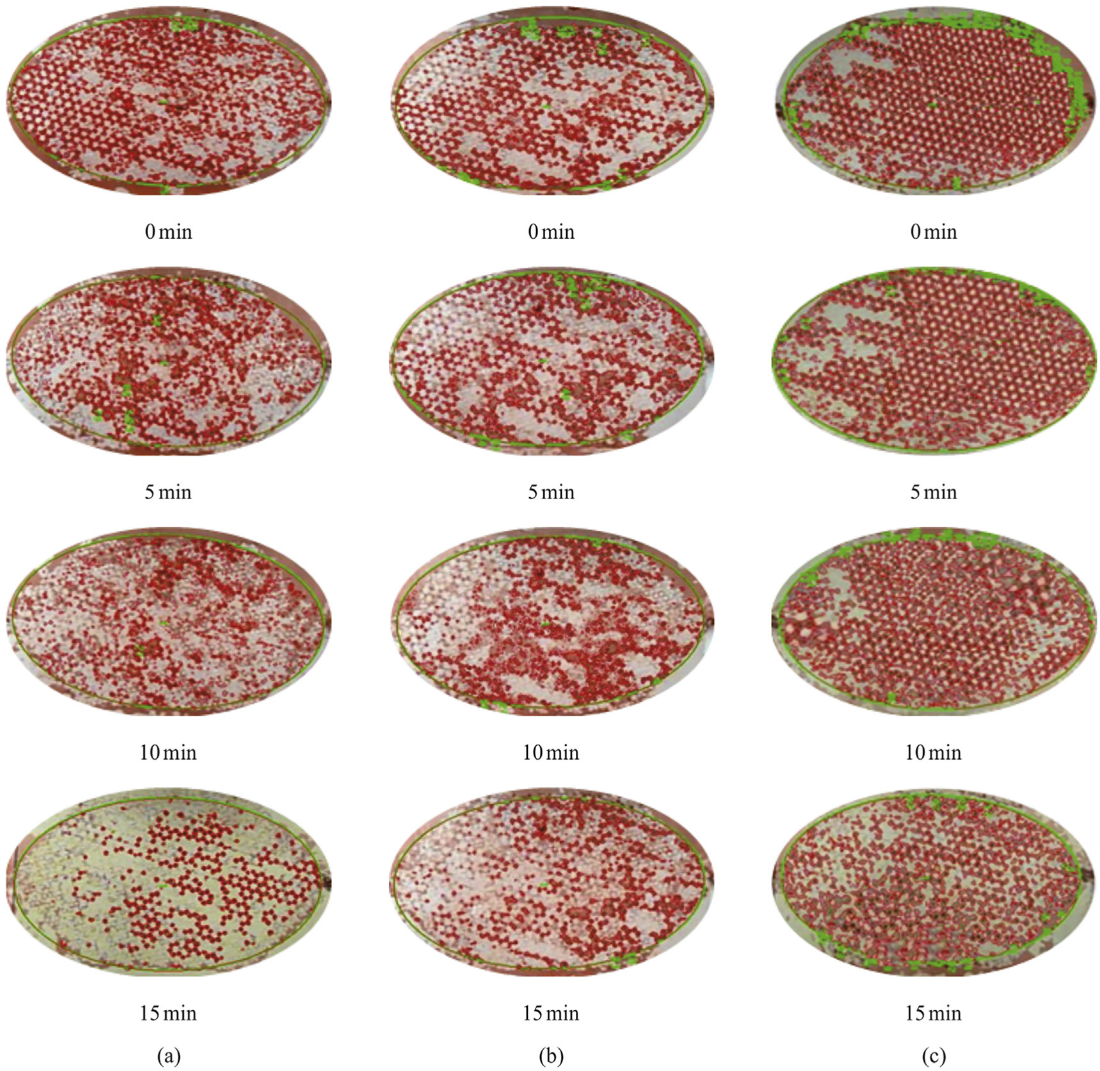

Fig. 4. Caption Comparison of Water Wet Experiment for Paraffin with Frequency, Intensity and Distance from the Ultrasound Source of 40 kHz, 500W and 15 cm respectively. Obtained with (a) intermittent (b) continuous, and (c) without the Application of Ultrasound Radiation.

of the displacement experiment with kerosene. Intermittent ultrasound radiation (Fig. 6d and e) has less residual oil left inside the micro-model compared to the continuous radiation (Fig. 6b and c), but the difference is not very pronounced as compared to the 0–15 min of the experiment (Figs. 4 and 5), as the intermittent 150 W/cm^2 and continuous radiation 500 W/cm^2 both recovered 81% of the OOIP.

From the observation (Fig. 7), it also shows that intermittent radiation with paraffin had the highest recovery of 74%. Less residual oil was left in the micro-model (Fig. 7e) than in the continuous (Fig. 7c) without ultrasound had the least recovery of 59% OOIP. The experimental runs are presented in Table 3.

3.2. Effect of intermittent and continuous ultrasound on total oil recovery

This displacement test was performed to determine the effect of intermittent and continuous ultrasound on oil recovery. From the results, the rate of oil recovery was very high for the first 15 min. Fig. 8 shows the recovery for kerosene under intermittent and continuous ultrasound. Intermittent stimulation had the highest recovery of 82% compared to 81% recovered through continuous vibration. Meanwhile, the continuous ultrasound with intensity of 150 W/cm^2 recovered the least amount of 78%.

Fig. 9 shows the recovery for paraffin. Intermittent ultrasound also had the highest recovery of 74% while, the continuous vibration was 73%. The continuous vibration with intensity of 150 W/cm^2 had the least recovery of 67%.

For the first 15 min of the experiment for both kerosene and paraffin, there was a significant difference in the recovery achieved, but as the displacement progressed further the difference begins to diminish. This is because the microemulsion (o/w) formed by the agitation of ultrasound during the 15 min period are found to be more stable. This was visible by the wave pattern created and the movement of the oil in the micro-model which led to higher recovery at this interval. As the ultrasound continues, the volume of micro-emulsion increases which is higher for a short duration of ultrasound stimulation compared to a long duration of ultrasound [13]. The results of the ultimate recovery are summarized in Fig. 10.

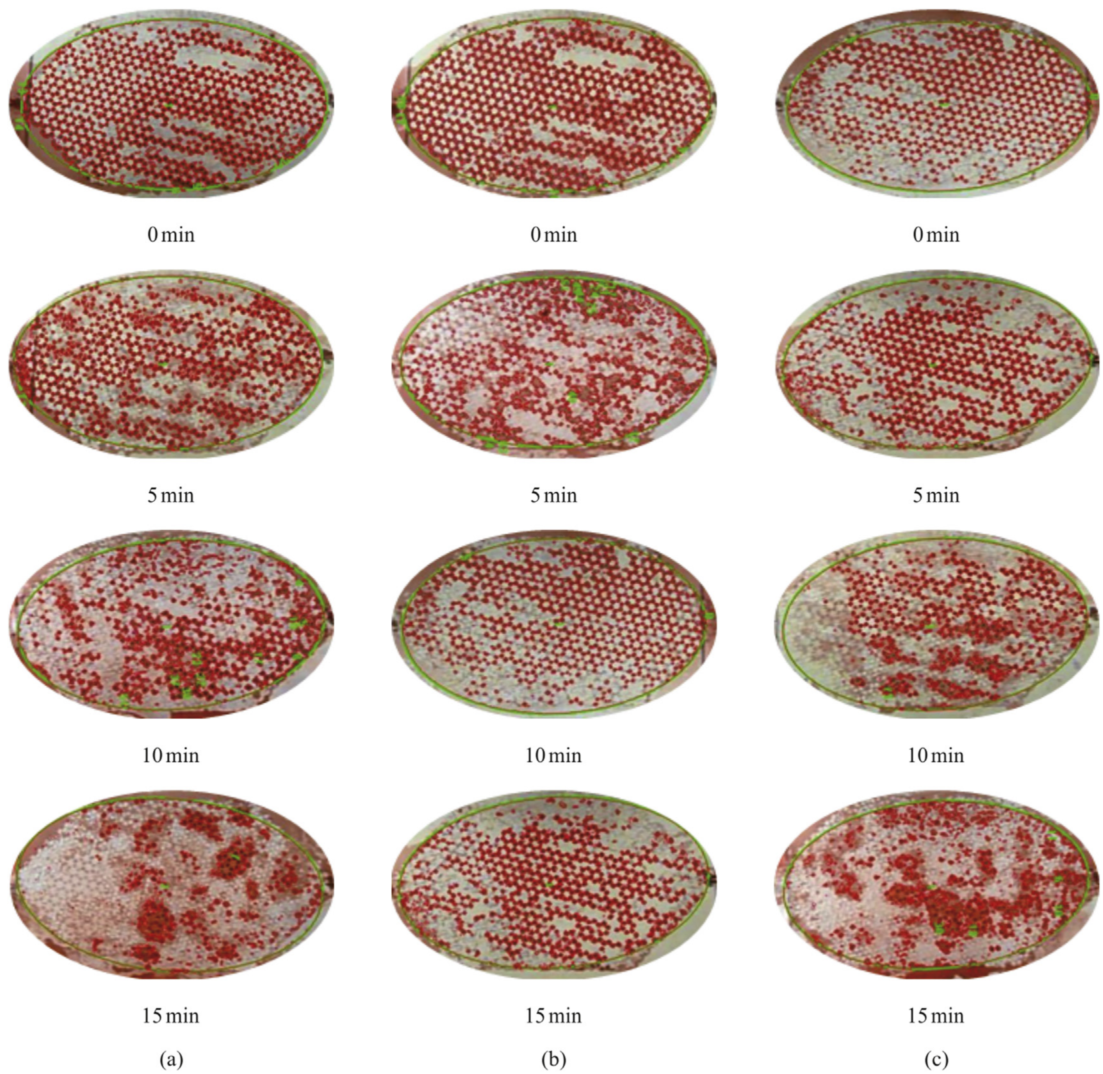

Fig. 5. Caption Comparison of Water Wet Experiment for Kerosene with Frequency, Intensity and Distance from the Ultrasound Source of 40 kHz, 500w and 15 cm respectively. Obtained with (a) intermittent (b) continuous and (c) without the application of ultrasound.

3.3. Effect of ultrasound and viscosity on oil recovery

3.3.1. 0-15 minutes

Two different viscosities were used to determine the effect on intermittent and continuous vibration. Kerosene with viscosity of 1.4cp and paraffin with a viscosity of 12.7cp were used. By using the same frequency of 40 kHz, the intensity of 500 W/cm^2 and distance of 15 cm from the source, results from the experiment (Fig. 11) reveals that, paraffin (viscous oil) with intermittent vibration recovered 70% of OOIP and with continuous vibration, the recovery was 55% of OOIP. On the other hand, kerosene (light oil) with intermittent vibration recovered 42% of OOIP, while the continuous vibration recovered 32% of OOIP. During ultrasound vibration boundary friction leads to increase in fluid temperature at the interface. The difference between vibration velocity of fluid and solid leads to sound energy been converted to heat energy which result in the reduction in viscosity [4]. The heat generated can reduce viscosity up to 30% [15]. The increase in recovery for paraffin agrees with the study by Xianghong and Zhang [16] when they inferred that ultrasonic wave could effectively decrease the viscosity of heavy oil and increase mobility which was reported in Gudao oil field located in Bohai Bay Basin in China. The heat generated could also be because of cavitation at the point when bubble collapses.

3.3.2. 0-60 minutes

The experiment was repeated for 60 min period to determine the effect of viscosity on the intermittent and continuous ultrasound for a long duration of ultrasound. For kerosene, the percentage of oil recovery was higher for the ultrasound stimulation than the non-ultrasound. The intermittent ultrasound had the highest recovery of 82% OOIP. The 500 W/cm^2 intensity of continuous ultrasound and 150 W/cm^2 of intermittent ultrasound both have 81%. The lowest recovery for kerosene was from the continuous ultrasound at 150 W/cm^2 with 78% OOIP (2% increment). Fig. 12 shows the oil recovery with intermittent and continuous ultrasound and without ultrasound for kerosene.

For more viscous paraffin (Fig. 13), the recovery without ultrasound is 59% and with the application of ultrasound wave stimulation, 74% was recovered (15% increment) with intermittent at

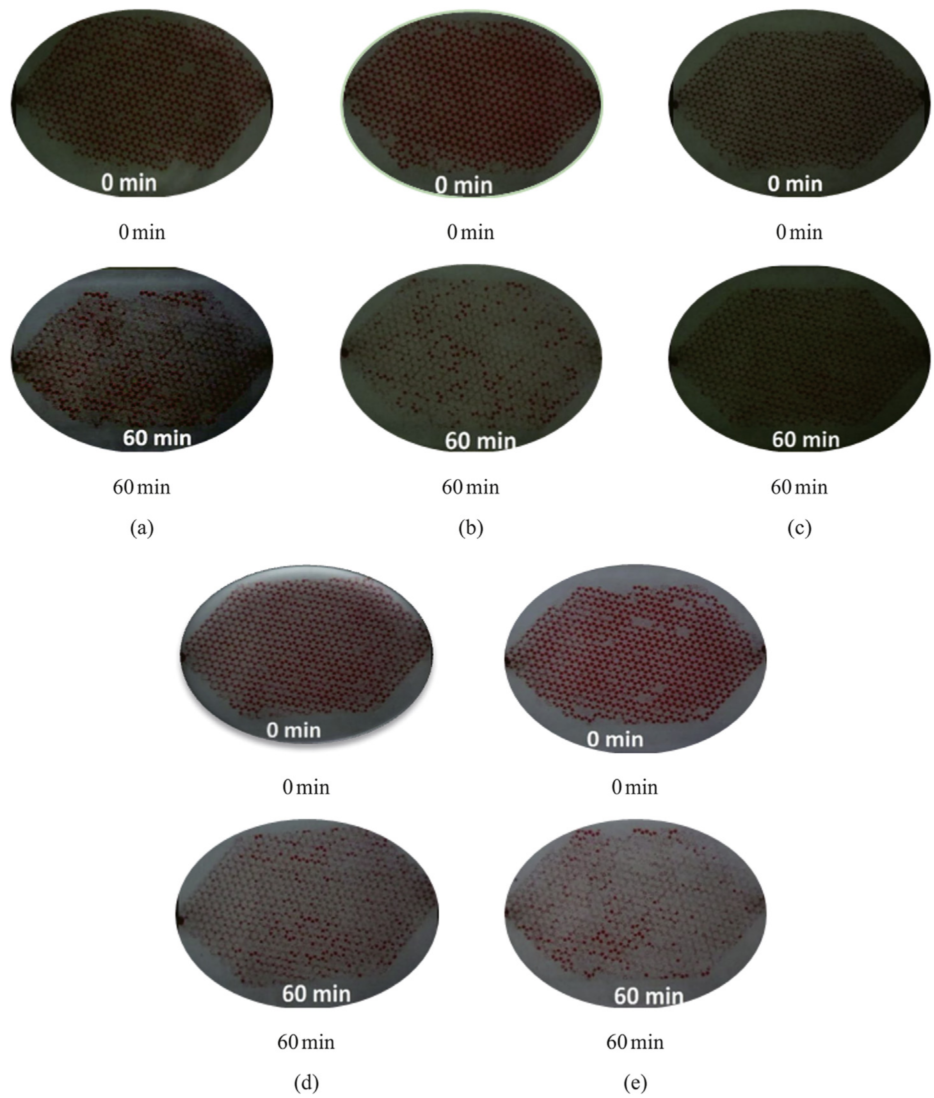

Fig. 6. Caption Snapshot of Displacement Test for Kerosene obtained with (a) Without Ultrasound, (b) With Continuous Ultrasound at 150W, (c) With Continuous Ultrasound at 500W, (d) With Intermittent Ultrasound at 150W, (e) With Intermittent Ultrasound at 500W intensity.

500 W/cm^2 intensity. The continous ultrasound of 500 W/cm^2 recovered 73% OOIP (14% increment). For the intermittent ultraound at 150 W/cm^2 intensity and continous ultraound at 150 W/cm^2, the oil recovery was 69% (10% increment) and 67% (8% increment) respectively. Fig. 13 shows the oil recovery for paraffin with and without ultrasound.

The results for the 60 min duration of ultrasound reveals that, viscosity reduction under ultrasound is higher for lighter crude compared to the heavier ones, this was also noticed in the 15 min duration even though it did not transform to higher recovery in the later. Ultrasonic cavitation has been reported as one of the possible mechanisms for the reduction. Cavitation is easily formed in lighter fluid and very difficult to form in viscous fluid because the wave function must overcome the cohesive forces acting within the liquid and this force is very pronounced in heavier fluid [8,11]. The results is therefore, in agreement with previous studies of Mohammadian et al. [8]; Hamidi et al. [8,17]; Chong [18]; Syamsul [19]; Agi et al. [20] when they reported that less viscosity will lead to lower mobility ratio and better sweep efficiency. The results for the 60 min duration of ultrasound, although it shows that internittent ultrasound can recover more oil than the continous, the difference is not much as compared to the 15 min interval and are quit similar like in the case of the continous ultrasound at 500 W/cm^2 and intermittent at 150 W/cm^2 intensity, both recovered 81% OOIP. The possible reason can be as a result of the uniformity in rock and fluid properties that became very pronounced as the experiment prolonged, which could not be noticed at the initial stage of the experiment that resulted in the wide difference in the results. Another possible reason is the peristaltic movement of water that might have resulted in more oil production for the viscous paraffin oil. As the ultrasound is exposed, the water energy suddenly comes under peristalsis which propel it jump and get closer to the equivalent cases [21].

3.4. Effect of Ultrasound Intensity on oil recovery

3.4.1. 0-15 minutes

Two different intensities were considered in the experiment, a

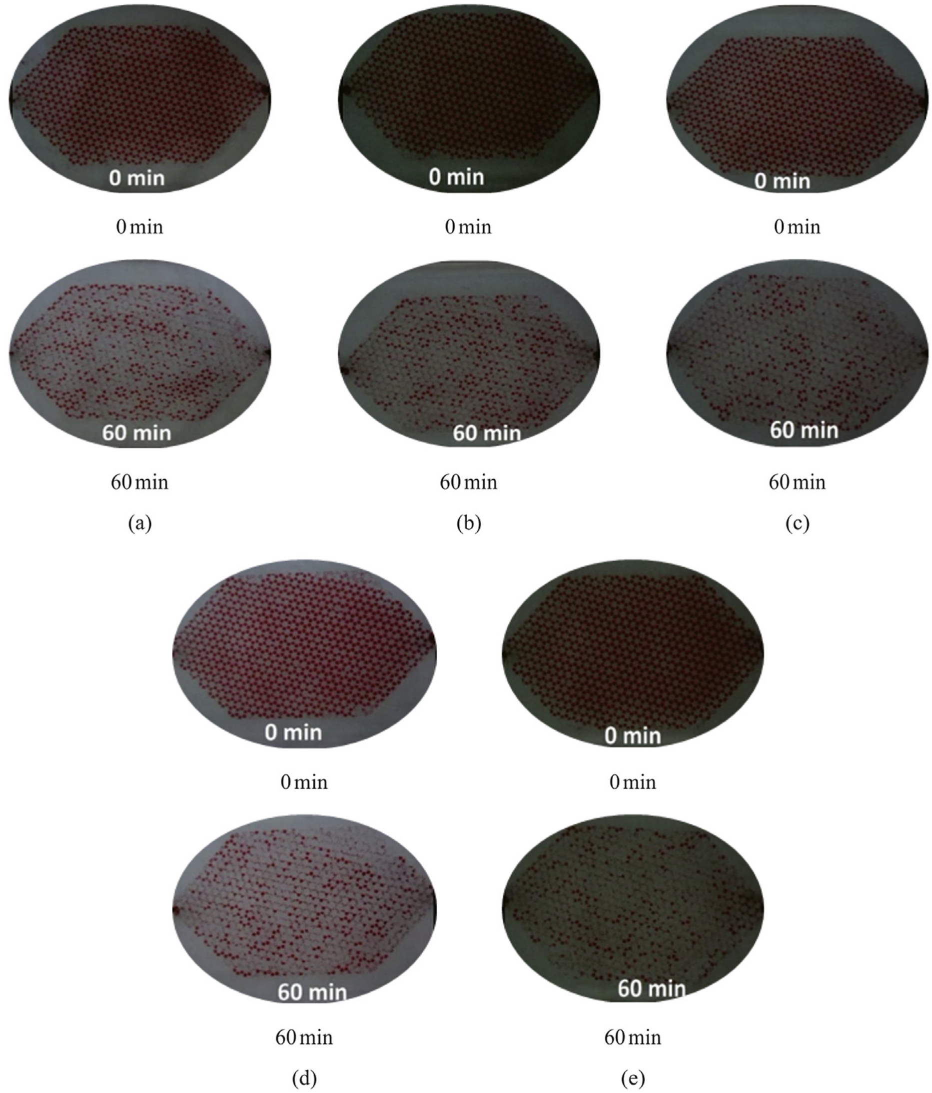

Fig. 7. Caption Snapshot of Displacement Test for Paraffin obtained with (a) Without Ultrasound, (b) With Continuous Ultrasound at 150W, (c) With Continuous Ultrasound at 500W, (d) With Intermittent Ultrasound at 150W, (e) With Intermittent Ultrasound at 500W intensity.

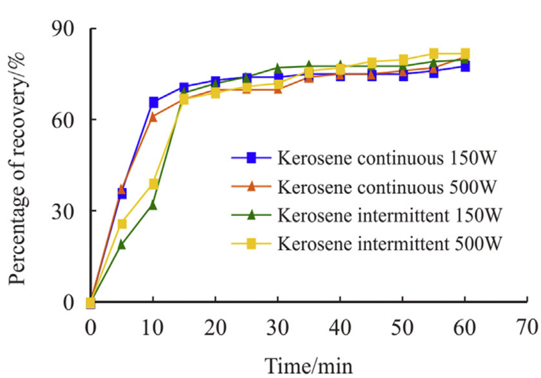

Fig. 8. Caption effect of intermittent and continuous ultrasound on recovery of kerosene.

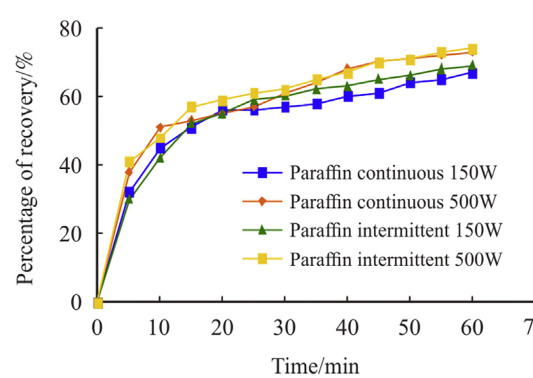

Fig. 9. Caption effect of intermittent and continuous ultrasound on recovery of paraffin.

low intensity of 150 W/cm^2 and a high intensity of 500 W/cm^2. The intensities were tested with different viscosities, intermittent and continuous vibration during the displacement process. For heavy oil at 15 cm (Fig. 14), intermittent vibration at an intensity of 500 W/cm^2 recovered 69% of OOIP while, that of 150 W/cm^2 recovered 65%. Continuous vibration with an intensity of 500 W/cm^2 recovered 58% while, 150 W/cm^2 recovered 55%. For light oil at 15 cm (Fig. 15), intermittent vibration with an intensity of 150 W/

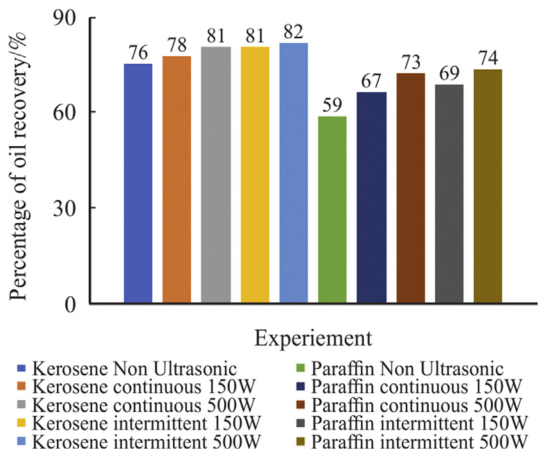

Fig. 10. Caption ultimate recovery of the displacement test.

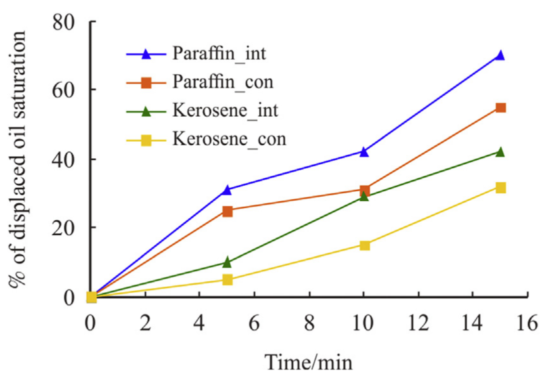

Fig. 11. Caption effect of viscosity on oil recovery for 15 minutes.

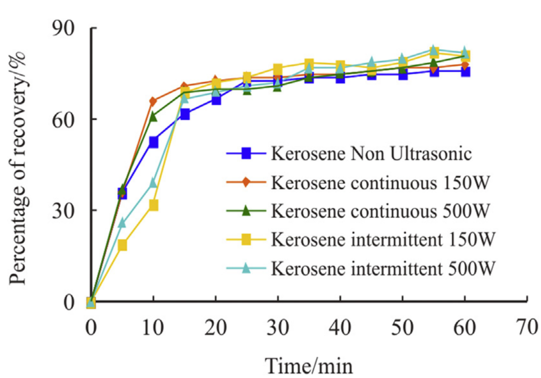

Fig. 12. Caption Effect of Viscosity on Oil recovery with Ultrasound and without Ultrasound for Kerosene (60 min).

cm^2 and 500 W/cm^2 both had 44% recovery, and continuous vibration of 150 W/cm^2 recovered 32% while, 500 W/cm^2 recovered 38%. Figs. 14 and 15 show the oil recovery for heavy oil and light oil under intermittent and continuous ultrasound at 150 W/cm^2 and 150 W/cm^2 respectively.

3.4.2. 0-60 minutes

The effect of different intensity on oil recovery for kerosene oil is shown in Fig. 16. From the result (Fig. 16) 500 W/cm^2 intensity for intermittent ultrasound recovered 82% OOIP while, the 500 W/cm^2 for continuous ultrasound and 150 W/cm^2 for intermittent ultrasound recovered 81% OOIP. The lowest recovery for kerosene was from 150 W/cm^2 with the continuous ultrasound. From the results, oil recovery has a direct relationship with the intensity of the ultrasound. It therefore, confirms earlier studies of Mohammadian et al. [22]; Hamidi et al. [8]; Mohammadian et al. [6]; Hamidi et al. [17,23]; Agi et al. [20] that ultrasound application can improve oil recovery. The oil recovery increased with increasing intensity of the ultrasound which agrees with previous studies by Naderi and Babadagli [10] when they observed that different recovery mechanisms governed the process in water-oil-wet cases. Favourable changes in the interfacial properties rather than temperature rise which did not have a massive effect on the viscosity or density was

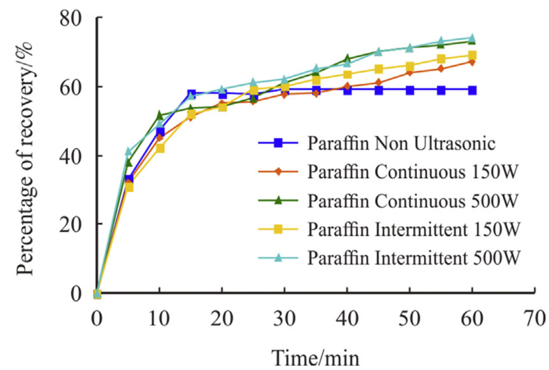

Fig. 13. Caption effect of ultrasound and viscosity on oil recovery for paraffin (60 minutes).

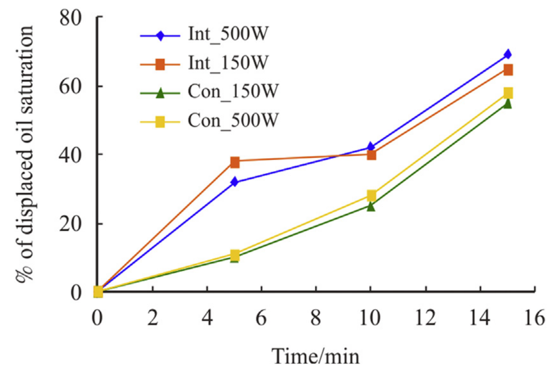

Fig. 14. Caption Effect of Ultrasound Intensity on Oil Recovery for Heavy oil (15 Minutes).

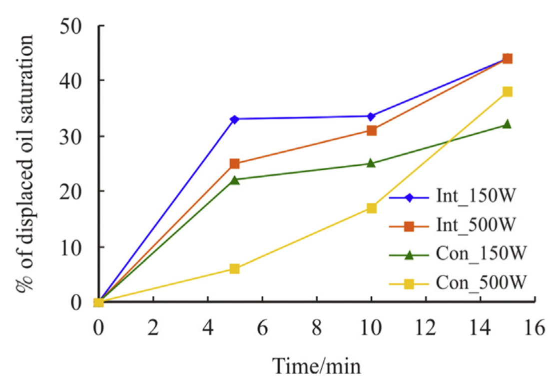

Fig. 15. Caption Effect of Ultrasound Intensity on oil Recovery for Light Oil (15 Minutes).

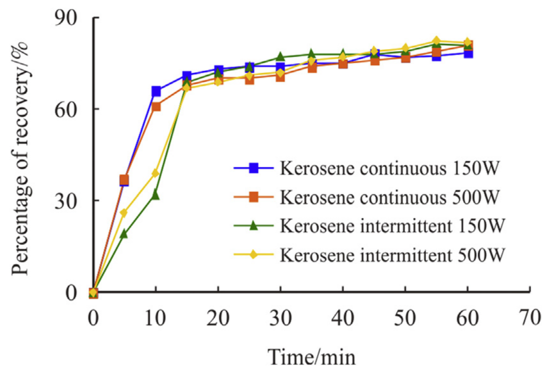

Fig. 16. Caption effect of different intensities on oil recovery for kerosene.

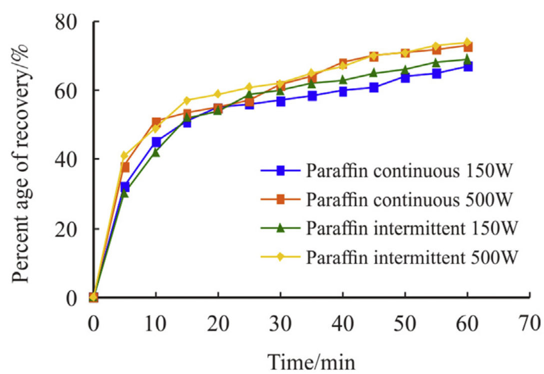

Fig. 17. Caption effect of different intensities on oil recovery of paraffin.

responsible for the increased recovery. Therefore, the possible mechanisms of Bjerknes forces and peristaltic movement of brine after ultrasound is applied are a major contributing factor. Where the aqueous phase has more tendency to flow rather than adhere to the surface of the pore [8,11,24].

Fig. 17 shows the recovery for different intensity for paraffin. 500 W/cm^2 intensity with intermittent ultrasound had the highest recovery of 74% and continuous at 500 W/cm^2 was 1% lower. Both, 150 W/cm^2 intensity for intermittent and continuous ultrasound recovered 69% and 67% respectively.

The results also indicate that oil recovery increases with intensity with intermittent ultrasound than with continuous ultrasound. The increase was less with paraffin (74%) as compared to that of kerosene (82%), which confirms previous studies by Naderi and Babadagli [10], and Hamida and Babadagli [25] that when oil viscosity increases, the effect of ultrasound wave decreases. Gulseren et al. [26] also reported that high intensity of ultrasound increases surface activity and hydrophobicity of the interface between the liquids. Another possible mechanism is the Brownian motion, as high intensity of ultrasound is propagated through porous media, the wave set molecules and particles in a zigzag and random motion which causes a periodic shock wave, which results in a great pressure gradient at the font of the wave which produces high temperature and pressure [20].

The results technically revealed that short duration and intermittent ultrasound can recover more oil compared to the longer duration and continuous ultrasound wave. The longer duration of 60 min did not transform to greater recovery, judging from the economics and technical point of view. The possible reason might be the continuous application of ultrasound could result to coalescence of liquid droplet and demulsification [17]. Hamidi et al. [23] also reported that by increasing the ultrasonic time can lead to increase temperature which might affect the performance by increasing the IFT and causing a change in the phase behaviour. In a study by Hamidi et al. [13] where the stability of emulsion was measured over a period of 60 min and 30 min. Emulsion was stable under the 30 min period compared the 60 min. Therefore, for increasing oil recovery under the influence of ultrasonic wave, it is recommended to use a shorter period compared to the long period of application. This is because more emulsion is generated at a shorter and intermittent period compared to a long and continuous period which might lead to demulsification and oil water separation.

4. Conclusions

Heavy oil had a higher recovery at a short duration of ultrasound compared to the light oil while the percentage of oil recovery was higher for the lighter oil at a longer duration of ultrasound. It implies that viscosity reduction is higher for light crude oil compared to heavy one. The oil recovery had a direct relationship with the intensity of the ultrasound as oil recovery increased with increasing intensity of the ultrasound and a possible mechanism of Brownian motion is responsible for the increased oil recovery with high intensity of ultrasound. Based on the experiments, it can be concluded that short duration and intermittent ultrasound radiation can recover more oil compared to long duration and continuous ultrasound radiation.

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