Retraction

Retraction: Laboratory Study of Residual Oil Mobilization by Induce Vibration in Porous Media (IOP Conf. Ser.: Mater. Sci. Eng. 1145 012052)

Published 23 February 2022

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IOP Publishing regrets that our usual quality checks did not identify these issues before publication, and have since put additional measures in place to try to prevent these issues from reoccurring. IOP Publishing wishes to credit anonymous whistleblowers and the Problematic Paper Screener [1] for bringing some of the above issues to our attention, prompting us to investigate further.

[1] Cabanac G, Labbé C and Magazinov A 2021 arXiv:2107.06751v1

Retraction published: 23 February 2022
Laboratory Study of Residual Oil Mobilization by Induce Vibration in Porous Media

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Abstract. The evolution of techniques required to mobilize reservoir fluids at critical saturation is important because of global petroleum needs because of the necessity to conserve the underground water that deteriorated because of the slowness of persistent organic pollutants’ dismantling. The acoustic waves of low-frequency are one of these methods, but the absence of understanding of the vibration effect to displace Oil prevents vibration application in the field until recently. This paper proves that oil permeability increased when the vibration induced in porous media; vibration makes resorting to the rock grains, which stimulates passage for liquid moving through the reservoir. The capillary pressure and reservoir pressure should be taken into consideration to make optimum validation for vibration stimulation.

Keywords: reservoir, vibration, core sample, permeability, porosity, grain, and elastic waves.

1. Introduction

Porous media are present in natural and artificial accumulations – such as aquifers, petroleum reservoirs, and infiltrations in buildings or implants in organisms for a continuous liberation of drugs. Capillary forces control imbibition, being permeability, one of the basic properties of the porous medium. Permeability is a measure of the medium's capacity to transmit fluids and is proportional to the porous medium's conductivity to the flow of a fluid. In the definition given analogous to Poiseuille's law, permeability relates to the pressure gradient, which causes a liquid with a certain viscosity to flow with a given velocity. Absolute permeability is determined when a single-phase fluid occupies the whole void volume of the porous medium, flows through it under conditions of viscous flow. Some references in the literature mention the dependence between the absolute permeability and the frequency of vibration of a porous medium. The importance of gaining a better understanding of such variation lies in the fact that this might contribute to developing yet other techniques for the additional recovery of fluids stored in porous media. Changes in the permeability itself or the flow rate through porous media under vibration range from water or oil wells’ behaviour after earthquakes to laboratory scale [1], [2].

There are also a wide variety of conditions under which the observations may have been made, such as under constant flow rate or constant pressure; under conditions of single-phase flow or under some proportion of multiphase flow; vibrating the sample supported over the vibration source or by the vibration source coupled to the sample's inlet face, such as the configurations used. The idea is that supporting the sample over the vibration source constitutes a way of simulating the transmission of
vibrations produced on the surface to the subsurface reservoir rock. Coupling the source to one of the sample faces would simulate bottom hole applications [3]. In the area of applications of the wide range's surface are usually used for the revitalization of the reservoirs of the moderately deep to 1500 of meters. The sonic wave to accumulate like vibration by mobilizing and strengthening a promising method to remove the besieged NAPLs (Non-Aqueous phase liquid) that happen in multiphase flows through the reservoir, especially the prevention of groundwater pollution and improve oil recovery from oil formation with great efficiency, environmental safety and low-cost compare with mobilization by conventional means [4].

A century ago, fluid flow through porous media studied both theoretically and experimentally. Most laboratory studies achieved by using the Darcy equation with some required modification. These two scientists studied elastic waves vibration both theoretically and experimentally. Their study concludes that the elastic wave can increase permeability, increasing petroleum recovery from the reservoir [5].

The evolution of the elastic wave theory- to study the sonic wave advance in the fully saturated reservoir formation- increase the research connected with the flow of fluid in the reservoir. described the movement of the elastic waves in the reservoir layer, which results in a widely known equation named the Biot equation, which became the principle for problem wave movement in the hydrocarbon formations. showed that the analysis of change in the water level because of tsunami land can be used to determine the storage capacity of aquifer. provide a method of un-steady state to calculate the core sample's permeability. [6] illustrated that the un-steady state permeability determination is sensitive to low-pressure compressibility. The litho-static pressure should be taken into consideration during permeability determination to get precise results. stated that oil recovery by vibration would be enhanced if the vibration accompanied by water or gas injection in the reservoir.

Achieved numbers of laboratory measurements on reservoir fluid movement in the capillary path. The permeability was determined at frequencies ranging from (0.1 Hz-1 Hz). proved that the acoustic waves could treated altered zone near well-bore that invaded by drilling mud and increases the layer's flow capacity around the well. stated that reservoir rock type, gas and liquid saturation, and type of layering are greatly altered frequency of vibration in the reservoir, affecting reservoir deliverability characteristics and would be able to improve oil and water production near-critical saturation. point out that the oil relative permeability and the interfacial tension (IFT) should be reduced to increase oil recovery. They also stated that oil production improved if a surface microseismic waved generator is used. illustrated some practical and laboratory experiments and explain that vibration waves can induce compressive and shear waves with magnitudes to improve recovery of reservoir fluids [7]. The obstacles that vibration techniques counter are the propagation of acoustic waves through the reservoir. It is also not obvious there are no verified modelling techniques to estimate stimulation in the porous media or to initiate valid field measurements. Several equations derived from practical and simulation research proved that the porous medium's vibration increases fluid recovery. The vibrations cause some re-sorting of the grains, which may lead to improve permeability. The vibration pulse may change the mechanical properties of solid material, which may reduce the adhesion force between the solid material and fluid. Support production and improve the performance coefficient of the reservoir [8]. Finally, the researchers find no literature about vibration on oil mobilization in porous media after 2002.

**Aim of the current study**

Study vibration effect induced by motor on porous media and evaluate the change in petrophysical properties of the clean Sand and Sand mixed with bentonite.

### 2. Apparatus Description:

The researchers do the design and manufacture of the device that used in the current experiment localities with the assistance of mechanics. The equipment's design is moderately simple, can be used easily, and can be used with all types of reservoir liquids of low viscosity figure (1). The device was designed on a mechanical scale and consisted of the following:-

1. A hollow steel tube length of (50 cm) and inside diameter of (10 cm).
2- A rectangular stand (80*50) cm.
3- The electric motor creates elastic wave vibration, 220 voltage and 50 Hz; it is an air-cooling motor shown in figure (1-B).
4- Springs to increase vibration.
5- Pressure gauges at inlet and outlet from (0 psi – 5 psi) degree of measurement.
6- Valves for opening and closing.
7- The fluid pump consists of (container& electric motor). The working fluids are water and Oil, while the core sample that simulates the reservoir consists of Sand and Sand polluted with bentonite.

Figure 1. a) Measurement System

Figure 1. b) Measurement System
Experimental preparation

- Take mesh number 8 of 2.36 mm, the pan in the bottom and start vibrating the sieve to get the sand particle of the required diameter for the core sample. Figures 2 and 3.
- Fill the tube with the core sample (the porous medium is Sand and Sand with bentonite).
- Start pumping the fluid until the samples get saturated.
- Maintain the pumping speed, then pumping again for maintaining the flow.
- Apply the vibration by generating the electric motor at the optimum speed required and the required number of nets on the motor shaft to produce the vibration effect. The vibration induced by a motor based on spring, the vibration controlled by the fan speed switch, has multiple speeds and multiple vibration magnitudes. The experiment achieved in the laboratory of college engineering at Misan University.
- Take out the fluid in a container for the flow rate calculation.
- Open and close the valve to control the flow
- Read the pressure gages during the flow and record the readings.
- Determine the time of the flow.

Porosity measurement
For porosity measurement, we need to calculate the bulk volume of the core sample by knowing the cross-sectional area and the length of the core holder (tube) and calculate the pore volume by knowing the total volume of the fluid in the container before and after pumping an amount of it (calculating the length, width and height of the fluid in the tank) were [9]:-

\[
\phi = \frac{V_p}{V_b} \quad (3-1)
\]

where:
- \( V_p \): pore volume
- \( V_b \): bulk volume

Permeability measurement
For permeability measurement, the Darcy equation used to determine the permeability of the core sample by pumping water (the viscosity of water should be known) at a constant rate and measuring the pressure difference between the inlet and outlet of the system by using gage readings were:

\[
k = \frac{Q \mu L}{1.127 \times 10^{-3} \times A \times \Delta P} \quad (3-2)
\]

\[
k = \frac{Q \mu L}{1.127 \times 10^{-3} \times A \times \Delta P}
\]

where:
- \( k \): permeability
- \( Q \): flow rate
- \( \mu \): viscosity
- \( A \): cross-sectional area
- \( \Delta P \): pressure drop
- \( L \): length of the porous media in the device.

Vibration wave generation
By determination of sample petrophysical properties (porosity and permeability), the vibration effect experiment was started, as in the following steps:

1. Running the function generator and tuning to multiple frequencies.
2. Turn on the power amplifier and gradually increasing the supplied current.
   This procedure is valid, except the accuracy of the wave signal is somewhat low.

3. Calculations

First experiment
"Sand + water without vibration."
The first experiment: This involves the calculation of the permeability and porosity of the reservoir. Default consists of Sand and water only.

Second experiment
"Sand + bentonite + water without vibration"
In the second experiment was the reservoir (core sample) tainted with bentonite by Sand:1 bentonite. Bentonite clay is composed of ash made from volcanos.
Sand - Bentonite Percent = 1:3

Third experiment
Crude Oil + Sand
We have to ease the Oil's specific gravity from (0.43-0.83) by breaking blocs asphalt using polar solvents oxygenic using methanol for being the most practical sink, where specific gravity decreased significantly in table 1 and 2. Unfortunately, the experiment was not fully, and this is due to technical errors dating back to the pump’s inability to withstand high pressures and the lack of special accessories of the pump.

| Rock       | D (ft) | L (ft) | Vb (ft³) | Vp (ft³) | Ø (%) | K (md)   | Q (bpd) |
|------------|--------|--------|----------|----------|-------|----------|---------|
| Sand       | 0.3280 | 1.006  | 0.0845   | 0.002600749 | 30.7  | 4196.75  | 2.7971166 |
| Sand+Bentonite | 0.3280 | 1.006  | 0.0845 | 1.300374*10⁻³ | 15.3 | 2742.20  | 0.52219 |

Table 1. Physical properties of the samples without vibration effect

| Rock       | D (ft) | L (ft) | Vb (ft³) | Vp (ft³) | Ø (%) | K (md)   | Q (bpd) |
|------------|--------|--------|----------|----------|-------|----------|---------|
| Sand       | 0.3280 | 1.00 6 | 0.0845   | 0.002600749 | 61.4  | 6527.25  | 2.4859  |
| Sand+Bentonite | 0.3280 | 1.00 6 | 0.0845 | 2.600749*10⁻³ | 31.4 | 1592.12  | 0.6063  |

Table 2. Physical properties of the samples under vibration effect

4. Discussion:
- The Sand in the tube as a porous medium has a porosity of 30.7% that means it's a wide-packed system.
- The performance of sand system increase in the presence of the vibration effect, the reason behind that is the core sample consist mainly of Sand the grains of Sand have different shape and different size due to the so-called sorting, so vibration leads to resorting of these particles which lead to increase porosity by 53% and permeability by 63%.
- The Sand and bentonite system have a porosity of 15.3% that means it's a wide-packed system.
• The performance of the Sand and bentonite system decrease in the presence of vibration effect and that belongs to the water absorption and swelling property of bentonite; which can be expressed as follows; bentonite is absorbed water and expands, which lead to increase the porosity by 100% and reduction in permeability by 44%.

• Coefficient of permeability with void ratio exhibited a similar trend by slurry and compacted specimens. Preparation methods did not affect permeability. Permeability sharply decreased when values of void ratio were less than 2. Permeability noticeably decreased by the increasing rate of bentonite in the bentonite-sand mixture. The same mixture ratio due to types of bentonite permeability varied distinctly under loading or without loading conditions.

5. Results

Sand mixed with bentonite

The increase of vibration magnitude resulted in increasing porosity and porosity, and permeability, as seen in figures 4 - 7 for sand core sample.

Figure 4. flow rate versus porosity with and without vibration for Sand

Figure 5. flow rate versus permeability with and without vibration for Sand.
When a core sample of Sand and bentonite used, the porosity increase with the vibration effect application, the permeability shows a different trend that the permeability reduced when vibration induced during fluid flow through the holder's core. The porosity increased in the four experiments while the permeability decreases in the sand-bentonite porous medium.

6. Conclusions

- The vibration causes some re-sorting of the grains, which lead to improving the permeability. The vibration pulses change the mechanical properties of solid material, reducing the adhesion force between solid material and fluid (crude Oil).
- The effect of vibration waves increases flow rate at certain frequencies; that means vibration increases oil recovery to efficient levels.
- Phase behaviour of porous media fluids and pressure drop are not similar in bentonite and Sand that stated: flow characterizations are changed from reservoir rock to another.
- For Sand, increasing the frequencies leads to an increase in the flow, which leads to increased permeability and porosity.
- The shape and size of reservoir rock particles are an influential factor in explaining the vibration effect on the mobilization of single liquid phase flow in the reservoir. If the reservoir rock consists mainly of coarse grains, a change in dynamic viscosity can explain vibration impact. If
rock lithology consists of fine particles, the vibration effect can be understood by both changes in acoustic waves and dynamic viscosity.

- Further laboratory testing must provide a crude oil pumping system capable of withstanding high pressures.
- Application of vibration in the open holes to ensure the concentration of vibration waves in the selected zone.
- Practical application in the field is made by dropping off ultrasound device by wireline, and frequencies are controlled from the surface.
- Increase the current vibration effect test range by turning on multiple frequencies with greater values that increase vibration influence.

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