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The Thermal Encroachment of Microwave Heating with Nano Ferro Fluids Injection on Heavy Oil Deposits

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Abstract

Heavy oil demands more energy for its lifting to the surface facilities. A critical parameter that can be altered to enhance the production from the reservoir is the viscosity. Lowering oil viscosity predominantly achieved by thermal methods. This study investigated thermal encroachment in the sand pack layers as simulated heavy oil reservoir was generated by the microwave stack heated mixtures of 22 ^{0}API of Indonesian heavy crude, nano-ferro fluid Fe_2O_3 and saturated brines. The wave guide was used to focus microwave radiation into the sand bed. The experimental results showed that microwave heating with maximum output power of 900 Watt and Fe_2O_3 as the nano particles, works at the frequency of 2.45 GHz reduces oil viscosity from 4,412.11 cP on its pour point at 51 ^{0}C to 134.24 cP at 90 ^{0}C. Thermal heating with nano ferro fluids decreased the viscosity of heavy oil and make it easier to be flowed. The increases of temperature are directly proportional with power output and nano-ferro concentration.

Keywords: heavy oil, viscosity, thermal recovery method, nano-ferro fluid, microwave heating

1. Introduction

Abundant amount of heavy oil resources can be one of the alternative solutions to fulfill the world's energy demand. Commonly, heavy and extra-heavy oils are difficult to flow naturally to the wellbore, therefore, they demand more energy for their production. A critical parameter that can be altered to enhance the production from these reservoirs is viscosity. Lowering oil viscosity predominantly achieved by thermal methods (Bera & Babadagli, 2015). Nowadays, many conventional methods have been applied to decrease heavy oil viscosity, such as steam injection, hot water injection, or gas injection. However, some of those methods have limitation. As instances, steam injection can only be used in shallow reservoir and not permitted to be implementing in offshore. It should have abundant brine supply and hot water system. Others become ineffective due to corrosion problem, significant heat loss and economic criteria. Therefore, developing of heating concept as an alternative to drain additional reserves of heavy crudes is needed. A thermal method that recently attracts many researchers to investigate is electromagnetic heating.

Previous research on heating concept was conducted by Chakma & Jha, (1992) to understand that electromagnetic (EM) heating is an effective way to introduce energy to the reservoir in control manner and that this energy can be directed into a specific region. Carrizales, et al., (2008) introduced EM heating refers to Radio Frequency (RF) or Microwave (MW) heating, where heating is produced by absorption of electromagnetic energy by the polar molecules in the formation. Pramana, et al., (2012) defined that combination of resistive heating and injection nano ferro fluid are directly related to increase the temperature distribution.

In this research of advanced technology to decrease viscosity of heavy fluid is electromagnetic microwave method with nano-ferro fluid Fe_2O_3 as stimulant injection to achieve low viscosity of heavy oil. Microwaves thermal heating was explored as an alternative solution for heavy oil drainage and sand packs and artificial cores have been made to simulate oil deposit sediments. Multiphase fluids (nano-ferro, saturated brines, and heavy crude) then saturated into those simulated reservoir samples. The thermal heating of microwave was controlled at 90 ^{0}C and heating exposures recorded in every 20-sec.

2. Method

2.1 Materials

Heavy oil origin is from Jatibarang formation, Indonesia. The samples originally were in solid condition and has been liquified at the laboratory at 100 ^{0}C of boiling water in a beaker glass. The oil viscosity, gravity and pour point were measured using water bath viscometer, pycnometer, and a pour point tube, respectively.

The powder nano particles (Fe_2O_3) supplied by Aldrich Chemistry has size ≤ 50 nm. Sand pack container was made from a modified cylindrical tube Pyrex glass which has 9 cm in high and 8.56 cm of inside diameter and equipped with a coned-shape lid. This sand pack mimics the oil reservoir to simulate the reservoir layers. The sandstones grains size was 45-50 meshes supplied by the geology laboratory of Institut Teknologi Bandung. Table 1 presents physical properties of sand pack and the fluids been used in this study.

Table 1. Physical properties of sand pack and the fluids been used in this study

Properties	Unit	Experimental results
Oil Density	^{0}API	22
Crude Viscosity	cP	273974.7
Fe_2O_3 particles	nm	50
Brine	mg/ml	1,024
Sand particles	mesh	45 - 50
Sand volume	ml	250
Brine volume	ml	61.6
Nano-ferro volume	ml	16
Emulsifier volume	ml	2.4

2.2 Experimental Procedures

Nano-ferro-fluid was made by mixing hematite powder and brine solution in the sonicator for 20 minutes. In this research, nano-ferro fluids concentration were 10 and 14 ppm to minimize aggregation (Santoso, et al., 2016). This experiment used alternating current to generate voltages. The current voltages then were step up by a transformer before it passed through into the capacitor. The magnetron and microwave antenna transformed the electrical energy into microwaves heating. The maximum income voltage of this concatenation was 1300 watts with maximum outcome voltage was 900 watts. The magnetron has frequency of 2.45 GHz and various power which were 900, 792, 657, and 468 watts. The thermometers have recorded temperature encroachment in the sand pack for every 20 sec. Four thermometers were inserted into the Pyrex wall for every 2 cm distance apart measuring temperature changes which occurred inside the sand pack. The lowest thermometer was tagged as Point-1 and continued up with Point-2, Point-3, and Point-4. However, the observing temperature was limited up to 90 ^{0}C due to water evaporation that might be occurred above 90 ^{0}C (Fig. 1).

In the heating process, two sand packs with different nano- ferro concentration of 10 ppm and 14 ppm were used. The sand pack without nano ferro (0 wt.%) was used as the reference sample. Further, the samples were heated by 6 different output powers: 900, 792, 657, 468, 378, and 180 watts. Temperature changes have been recorded for every 20 sec which started at 25 ^{0}C until a point of measurement reached 90 ^{0}C.

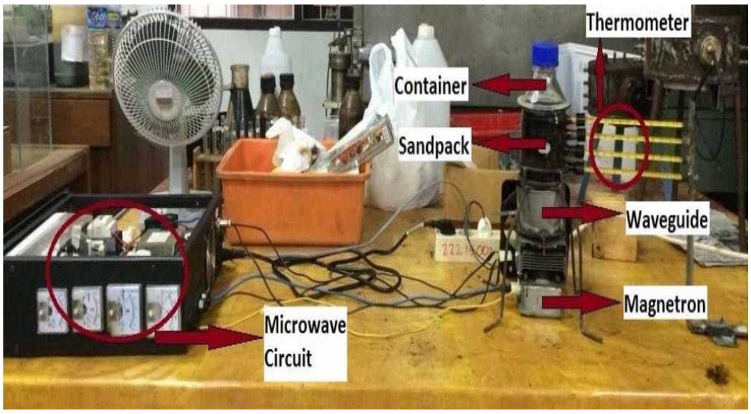

Figure 1. The microwave heating apparatus configuration of microwave heating that has been used in this study

The magnetron and microwave antenna transformed the electrical energy into microwaves heating. The maximum income voltage of this concatenation was 1300 watts with maximum outcome voltage was 900 watts.

3. Results and Discussion

The study used nano-ferro fluid with concentration 10 ppm and 14 ppm. However, 10 ppm nano-ferro fluid was slower to encroach the heats up to 90 ^{0}C than 10 ppm. During the heating, only thermometer at Point-1 that could reach 90 ^{O}C, therefore, all the analysis will use Point-1 as the reference point. Figure 2 and 3 show temperatures profiles of heats encroachment of microwave heating when the apparatus operated at low and high power, 180 and 900 watts, respectively. At low power 180 watts, the temperatures encroachment increased as the nano-ferro concentration was increased. Similar trends also appeared at high power 900 watts. Temperature changes affected heavy oil viscosity. With this heating process method, heavy oil viscosity has been decreased from 4412.11 cP on its pour point at 51 ^{0}C to 134.24 cP at 90 ^{0}C (Fig. 5).

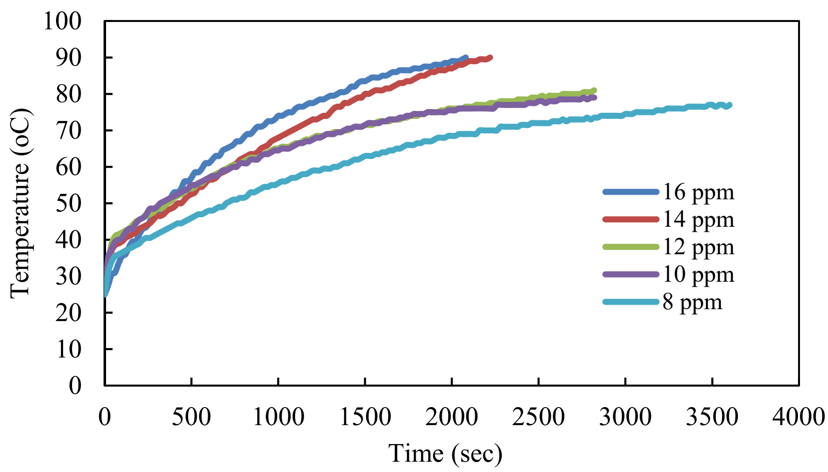

Figure 2. Temperature versus time profile of low power of microwave heating

The power of microwave tuned at 180 watts. However, temperature was limited up to 90 ^{0}C and the concentration of nano-ferro fluid are varied up to 16 ppm.

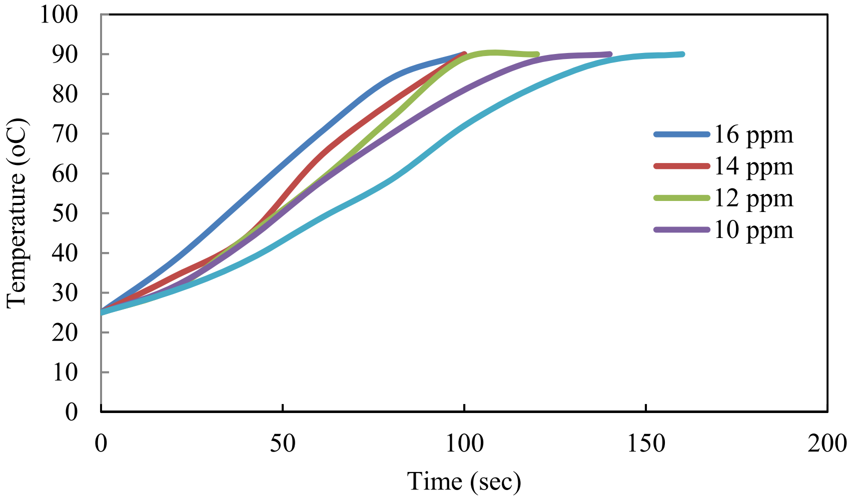

Figure 3. Temperature versus time profile of low power of microwave heating

The power of microwave tuned at 900 watts. However, temperature was limited up to 90 ^{0}C and the concentration of nano-ferro fluid are varied up to 16 ppm

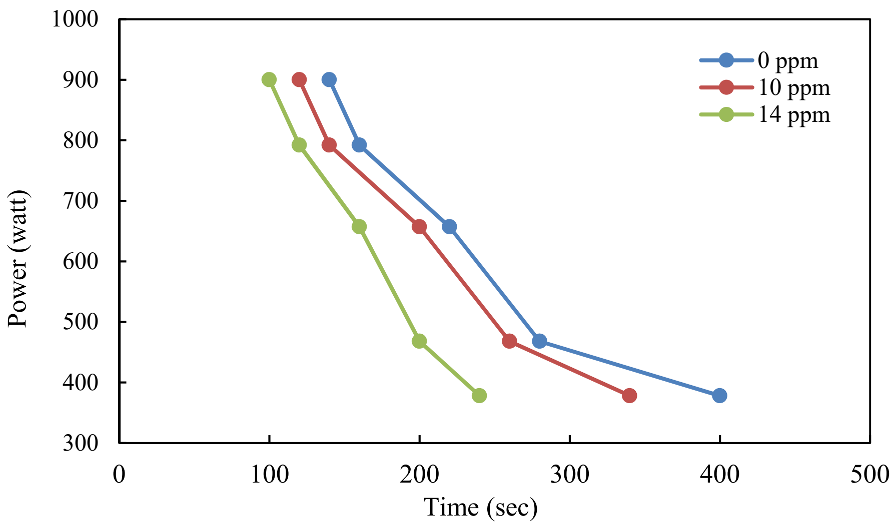

Figure 4. Power of microwave versus time profile of microwave heating

The time to reach a point of heating decreased as the concentration of nano ferro Fe2O3 was increased, at the certain power of microwave

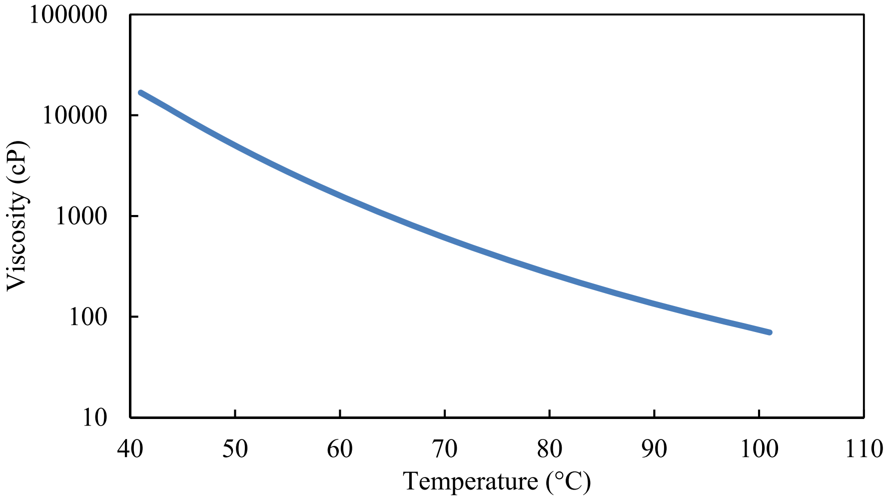

Figure 5. Viscosity (cP) versus Temperature of low power of microwave heating

The power of microwave tuned at 180 watts. The heavy oil viscosity has been decreased from 4412.11 cP at 51 0C to 134.24 cP at 90 0C

4. Conclusions

The study has been demonstrated the application of microwave heating to reduce the heavy oil viscosity. Further, experimental results show that the heating rate is directly proportional with the output power of microwave and nano-ferro concentration. The threshold concentration of nano-ferro Fe_2O_3 was 14 ppm, which determined when the microwave was tuned at low power, 180 watts. The experimental results also described that time to reach a point of heating decreased as the concentration of nano ferro Fe2O3 was increased, at the certain power of microwave. Further, an increase of temperature has also reduced the oil viscosity which could increase the oil production rate. In further, the increase of temperature could also affect the heavy oil recovery of a reservoir.

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