A BREAKTHROUGH CONCEPT: ALL-IN-ONE RESERVOIR NANO CONTROLLER TO IMPROVE OIL RECOVERY

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Abstract

Most fields in Indonesia have reached their mature phase; thus, conventional technologies have challenged further production. The decrease in oil production of the mature field is a natural phenomenon, and many methods have been conducted to solve this issue especially using Enhanced Oil Recovery (EOR). The current popular method for EOR is a thermal method which usually includes flooding the reservoir with steam, gasses, or chemical polymer. This study aims to bring to light a breakthrough concept that contains new nanoparticles application to improve oil recovery. Firstly, as the methodology, a literature study and benchmarking were conducted to identify current EOR technology gaps. Then conceptual technology is designed considering three variables: economic, practicality, and feasibility, mainly because in a mature field, when the oil is trapped in the reservoir, it needs heat to diffuse. The current technologies have proposed various methods that have seen success even in the most challenging field. Unfortunately, such technologies still have a limited range of effects as the problem often happens upon the scale-up of a project. The chemical flooding EOR is reviewed, including the current development and challenges, and finally, nanotechnology is found to be promising to boost reservoir production. A breakthrough new technology in the form of nanoparticle EOR is proposed. The proposed set of nanoparticles can dissipate heat to the reservoir combined with molecular communication to control the reservoir temperature and better mobility (flow) of the oil within the reservoir. The set of nanoparticles consists of nanoparticles A and B (all in one), which are responsible for altering the surface wettability and heating respectively with ultrasonic and electromagnetic sources to activate them.

Keywords: EOR, electromagnetic, graphene oxide, nanoparticles A & B, ultrasonic.

Introduction

In recent years, the oil production in Indonesia has kept on decreasing as more oil fields matured and dried. This matured field cannot be exploited in traditional methods, and the technology to continue the production on this field is commonly called EOR (Enhanced Oil Recovery). There are various methods in doing EOR, but unfortunately, these EOR methods tend to cost significantly higher or have a high degree of difficulty in their field application than the conventional oil production method. This problem is further amplified by the recent pandemic that still hits the nation, making economic leeway for investing in these risky EOR methods more undesirable for Indonesia.

To improve the situation, Indonesia will need EOR technology that is both practical and affordable, and in recent years, the technology that has been growing in popularity is nanoparticle technology. Nanoparticle technology has seen many uses in almost every industry, medical use, automotive, and the petroleum industry. The nanoparticle is a technology for designing tiny materials. In practical use has been seen to have a high surface-to-volume ratio, tiny size for increased penetration, and practically low cost and more ecologically friendly than using common chemicals (Sun, Zhang, Chen, & Gai, 2017). These factors made nanoparticles an exciting field and a potential solution to EOR problems.

In recent years, the application of nanoparticles have been rapidly develop to help EOR processes, such as in chemical flooding, thermal flooding, miscible flooding and microbial flooding tecnologies (Sircar, 2021). One of them is the smart-and nano-hybrid chemical EOR flooding using Fe_3O_4/eggshell nanocomposites that able to improve oil recovery by 8.16% during tertiary recovery. The nanoparticle was synthesized from *Commersomia bartramia* plant through a hybrid chemical solution. It could effectively reduce interfacial tension and change the wettability to water to water when dispersed in CTAB surfactant (Omidi, et al., 2020). However, there are still many challenges in implementation of nano-EOR technique into practice, such as cost-effective, disperse nanoparticles into reservoirs, etc.

In this study, a concept of EOR that will mainly use nanoparticles is given. The concept is given by using nanoparticle combinations that can alter the surface wettability and excitable properties that control the underground oil flow by heating; thus, the oil can be extracted easily. These excitable properties will be controlled by magnetic influence. Moreover, the combination of ultrasonic and magnetic waves can propagate a longer distance. The concept of this paper will be supported by various related findings from journals and books to prove its possibility for future realization theoretically.

Data and Method

The concept of this study is developed by doing literature studies, which concentrates on classic EOR technologies and the latest development in nanoparticle technologies, and by mentoring professionals and academics in the field. The research is done to create a concept that can improve existing EOR technology. It is conducted theoretically by combining the nanoparticles technologies application with commonly used EOR technology. The advantages and disadvantages of each technology are listed and compared, then applications of nanoparticles technology are applied to improve their advantages or mitigate some of the weaknesses theoretically. The presented result on this paper discussion is based on the strongest candidate where nanoparticles are deemed most crucial and significantly impact current EOR technology. The research is done online with the help of *Remote UI* to obtain the most reliable sources of data. There is no laboratory experiment as the research is done during self–isolation due to the pandemic in Indonesia.

Results and Discussion

Enhanced oil recovery (EOR) is a technique used to increase oil production. One of the techniques to increase the oil production is ultrasonic-based EOR. This technique is used to improve oil extraction and help minimize damage to wellbore formations by supplying mechanical vibrations in an elastic medium. Ultrasonic is energy generated by longitudinal mechanical waves with frequencies above 20 kHz and categorized into low frequencies (20kHz-1MHz)(Shafiai & Gohari, 2020).

Ultrasonic waves are transmitters in an elastic medium. In wave propagation, the amplitude and velocity of the elastic particles change significantly, resulting in stirring, loosening of boundary friction, dispersion, micro-cracking, impact fragmentation, thermal action, and others. The advantages of this mechanical vibration are:

1. Mechanical vibration can damage the cohesion between the embedded particles and the reservoir rock.
2. Mechanical vibration changes the size of the capillary pores, reducing the surface tension of the pores, resulting in capillary expansion and contraction.
3. The impact stress generated by mechanical vibrations causes micro-cracks in the rock formations. When the vibration reaches a certain intensity, the affinity between the crude oil and the rock weakens. Thus, the crude oil is separated from the rock mass.
4. Boundary friction exerts a local heating effect on the fluid. The local heating effect of this boundary friction is the source of the ultrasonic thermal effect. This friction occurs locally and is intense, resulting in enormous localized high temperatures.
5. Reducing the viscosity of crude oil and increasing the seepage rate.

Crude oil is a liquid that contains wax, colloids, asphaltene, and other macromolecular compounds. The action of high-frequency and high-intensity ultrasonic waves causes mechanical vibrations of large molecules, thereby accelerating the formation of relative motion between large molecules. Due to the inertia of the molecule, the molecular chain is broken, and the macromolecule is destroyed, especially in the cavity state, and the depolymerization is more pronounced. For compound polymers in crude oil, depolymerization is sufficiently verified to reduce crude oil viscosity. Of course, this can only happen at a high sound intensity and over a long period. The high temperature generated by the vibration can also reduce the viscosity (Shafiai & Gohari, 2020; Wang et al., 2020).

Based on this explanation, the application of this technology dramatically improves the recovery of oil wells. The construction is simple and does not pollute the oil layer, so it has broad prospects. Ultrasonic-based oil recovery technology has a considerable cost advantage. The cost between the ultrasonic and polymer injection was compared by Meribout, where polymer injection devices can reach 230,000 US$, while ultrasonic devices are much cheaper (90,000 US$) (Meribout, 2018). Thus, applying this technique leads to actual savings in the cost of the oil recovery operation. However, due to the limited range of ultrasonic wave propagation in the reservoir, ultrasonic waves cannot play a role far from the oil well (Shafiai & Gohari, 2020; Wang et al., 2020).

On the other hand, Kundu has researched the use of ultrasonic and electromagnetic waves for medical purposes. The research has proven that, when combined, both ultrasonic and electromagnetic waves could propagate a longer distance (Kundu, 2014). Thus, the idea of this concept is to combine the energy from both ultrasonic and electromagnetic waves in nanoparticle.

The proposed idea is to use electromagnetic waves to activate the nanoparticles. A set of nanoparticles consist of nanoparticle A, and nanoparticle B. Nanoparticle A can alter the surface wettability. In contrast, nanoparticle B has the function of storing energy from electromagnetic waves. The transducer will transmit an electromagnetic induction which will cause electron excitation so that the nanoparticle can release heat to oil and reservoir. After the heat is released, the oil's viscosity will be lowered; thus, the oil flow will increase. Besides, the ultrasonic waves could enlarge the reservoir rock porous, resulting in a higher yield of oil and easier of its transportation.

One of many challenges in oil production is enhanced oil recovery (EOR) from oil-wet carbonate reservoirs. Many oil reserves in the world are found in oil-wet carbonate reservoirs (Jarrahian, Seiedi, Sheykhan, Sefti, & Ayatollahi, 2012). In oil-wet rock, oil tends to stick to the rock due to the hydrophobicity of the walls of porous media. On the other hand, water tends to stick to the rock in a water-wet rock (Hosseini, Sadeghi, & Khazaei, 2017). However, the water-wet reservoir is more efficient because water flooding is far cheaper than organic solvent. Therefore, the chemical injection is conducted to alter the wettability of reservoir rocks.

Nanoparticles can alter the superhydrophobic to super hydrophilicity rock in the reservoir because of their ability to pass through some reservoir rock pores. Hosseini et al. studied an effective method in wettability alteration of carbonate rocks from superhydrophobic to hydrophilic state using TiO_2/SiO_2 nanoparticles with relatively high stability in contact with the salt solution, thermal stability at 150°C, and high durability of the coated surfaces in environmental conditions. Besides, another nanoparticle such as fluorochemical-modified graphene oxide can alter the original liquid-wetting to strong gas-wetting in the gas reservoir (Wang, et al., 2021).

Ultrasonic waves with the fluids in the pores lead to improved oil production rate because they change the permeability of the rock to oil and water. The capillary mechanism is used for this method because peristaltic transport makes mechanical deformation of the pore walls (Salem *et.al.*, 2015). Nanoparticles can deeply penetrate a very long distance through a rock pore. The situation of the reservoir from oil-wet to water-wet will significantly improve oil recovery (Hassan *et.al.*,2020). With the help of nanoparticles, the mobility of oil in the water-wet reservoir is increased with water injection.

The development of magnetic nanoparticles (MNPs) has become one of the main issues, especially in biology, medicine, and engineering. In medical purposes, the use of MNPs can range from MR imaging (Sun, 2008) (Kim, Zeng, Ng, & Brazel, 2009) to localization (Darton, et al., 2008) (Martina, Wilhelm, & Lesieur, 2008), or improving the delivery of drugs to a specific location. This concept can also be used in the EOR method in the oil reservoir. Studies show that MNPs are usually composed of a stabilized metallic core and functionalized by the addition of an outer shell with conjugated functional groups.

In most cases, the metallic core is composed of iron or iron-oxide-based compounds, such as maghemite (γ-Fe2O3) or magnetite (Fe3O4). A magnetic core enables the MNPs to be manipulated using a magnetic field gradient (Williams, 2017). The size of MNPs usually is smaller than 100 nm. MNPs can be synthesized from any material with magnetism (Gupta, Li, & Xiao, 2000). Study found that magnetic field can be used to induce heating around superparamagnetic or ferromagnetic nanoparticles, such as Fe_3O_4 or γ–Fe_2O_3 (Dennis, et al., 2008). In either method, metal (or metal oxide) nanoparticles can be easily combined with several different polymer systems (Glover, et al., 2013).

From the explanation above, we can conclude that graphene oxide-based of super hydrophilic and super paramagnetic nanoparticles can be applied to this concept. Nanoparticle A could be a nano surfactant modified graphene oxide, and nanoparticle B could be an iron oxide/graphene oxide nanocomposite. Both graphene oxide layers could be connected with a crosslinking process (Li, et al., 2018). Thus, we propose an idea of a set of nanoparticles such as illustrated in Figure 1 and the design process as shown in Figure 2.

Conclusions

A set of nanoparticles that consists of nanoparticle A and nanoparticle B with graphene oxide base is predicted to improve the oil recovery. In this concept, the combination of ultrasonic and electromagnetic waves is utilized to activate the nanoparticles.

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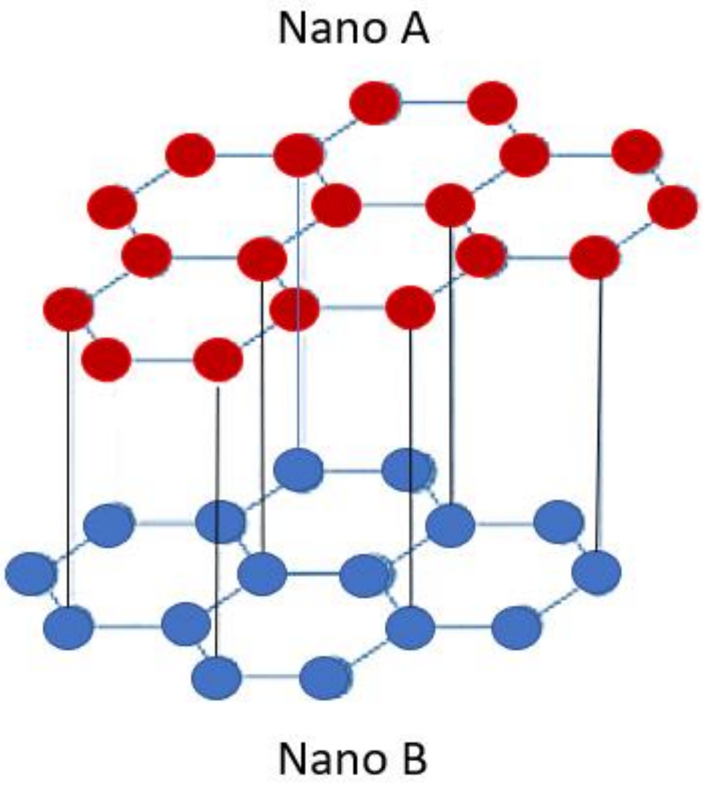

Figure 1: The proposed idea of nanoparticle A and nanoparticle B

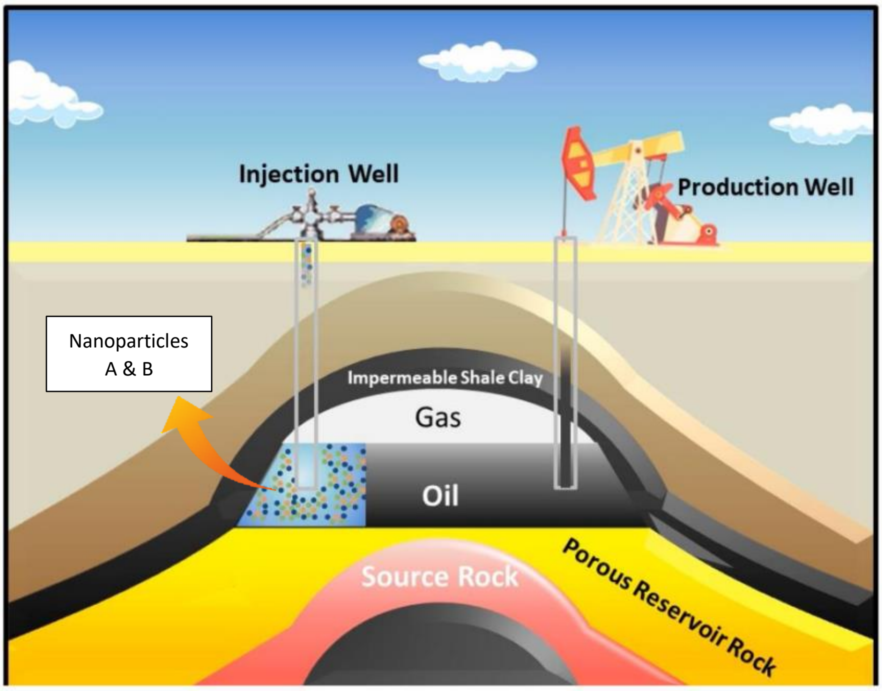

Figure 2: Design Process