NaNoEOR

Zero-emissions oil recovery

WHITE PAPER

Renewable and non-renewable energy sources remain the two fronts for meeting global emergent energy demand. Renewable energy sources such as crude oil, in meeting energy needs, is a function of new hydrocarbon discoveries and improving the recovery of existing oil fields. However, new crude oil discoveries are made at a decreasing rate; likewise, existing fields are at a declining phase with conventional recovery techniques not being able to produce as much as two-thirds of the oil in place. In complementing existing oil recovery techniques, research into the use of nanotechnology has emerged as a potential alternative for tertiary oil recovery scheme.

Despite the increasing investments in renewable energy, none of such resources proved to be able to stand alone against the increasing demand of energy. Consequently, oil remains as the main energy resource for the time being. Hence, it is very crucial to produce the utmost oil recovery before abandoning existing wells to newly explored fields. It is widely known that tertiary recovery methods constitute around two-thirds of the oil produced of the total oil initially in place (OIP). However, because of the increasing prices of chemicals and the decreasing prices of oil after the recent oil recession, nanotechnology is being utilized enormously on the lab scale to enhance the performance of EOR and make it more cost effective.

The need for new technologies is required for the exploitation of new hydrocarbon discoveries and improving oil recovery from existing oil fields. Consequently, new technologies are required across the petroleum value chain, i.e., exploration (frontier exploration and basin exploitation), appraisal, field development, production, reserves growth, and field reactivation or abandonment. Recent research trend has shifted in various disciplines from the “Macro-domain” to the “Microdomain” and “Nano-domain”. Furthermore, areas such as microfuidics, nanofuidics, nanoscience, and nanotechnology have witnessed increased research due to the advancing trend of scaling down in technological innovations.

While the adoption of new technologies has its associated risks, the prospects of NaNoEOR™ remains extremely high. Nanoparticles have recently gained great attention as effective agents for enhanced oil recovery (EOR) applications.

The use of nanomaterials in thermal and chemical enhanced oil recovery is becoming the cutting-edge technology. The main governing equation for the interaction of fluids in porous media is the mobility ratio (Mr) equation for oil/ water system. The equation controls either the fluid’s (displacing or displaced) mobility or the rock’s wettability. The mobility ratio can be favorable when it is less than or equal to one to promote better oil mobility in comparison with water’s mobility, hence better oil displacement.

Nanotechnology is an emerging technology that has profoundly changed the course of different applications in various fields. In petroleum engineering, this modification can be attributed to the nanomaterials’ unique properties including high surface to-volume ratio, wettability control, and interfacial tension reduction. To this end, the use of nanomaterials to enhance oil recovery is an extremely attractive, yet challenging task.

NaNoEOR™ is a novel and game changing alternative strategy to other proposed nanoparticles for enhanced oil recovery. Researchers globally have been studying various nanoparticles to assess their potential in EOR. Efforts in the last several years have resulted in the discovery of several novel EOR mechanisms such as: disjoining pressure log jamming, wettability alteration, reduction of interfacial tension (IFT), but have failed to achieve crude oil viscosity reduction. NaNoEOR™ has achieved all the required mechanisms.

A nanoparticle has size typically less than 100 nm. It is composed of two entities: the core and a thin shell. The core and shell may have underlying structures and may be composed of more than one entity. The molecular shell has three separate regions: tail group, hydrocarbon chain and active head group. The chemical nature of shell will determine solubility of nanoparticles. However, the oil displacement mechanism using nanoparticles is not clearly understood yet. Oil recovery mechanism using nanoparticle could be interfacial tension (IFT) reduction, wettability alteration during NaNoEOR™ process.

The uniqueness of nanoparticles is tied to its size-dependent properties, which are a consequence of its large surface-to-volume ratio thereby enabling surface atoms/molecules to have a significant impact on its properties. Furthermore, due to the small size of nanoparticles, the amount of surface atoms is large compared to the bulk atoms. This enables the properties of nanoparticles to be governed by the surface atoms and described by the physics of quantum mechanical consideration. In addition, the high surface-to-volume ratio of nanoparticles ensures that considerable amount of free surface energy exists within them. This explains the strong force of attraction that exists between nanoparticles when in suspension.

The attraction between nanoparticles or to other molecules ensures that the free energy is minimized. Nanoparticles can be tailor-made to meet specific application depending on the property of interest. The desired properties can include thermal, mechanical, chemical, electrical, optical, magnetic, etc. The discovery of oil reserves in challenging offshore location has made research into the thermal and mechanical properties of nanoparticles paramount. The application of nanoparticles, for example, in the formulation of water-based drilling muds has improved their performance in reducing fluid loss when applied in shale formations because of their size-dependent properties.

Waterflooding techniques have been improved and optimized to have better oil recovery performance. The latest worldwide innovation trends are nanotechnology materials such as nanoparticles. Hence, one of the ideas is using nanoparticles to assist waterflood performance. However, it is crucial to have a clear depiction of some parameters that may influence displacement process for enhanced oil recovery (EOR) process due to nanoparticles such as particle size, rock permeability, initial rock wettability, injection rate and temperature in developing nanofluids for an alternative enhanced oil recovery based on the NaNoEOR™ method.

The effect of initial rock wettability on oil recovery due to NaNoEOR™, original core wettability has been changed with aging process from water-wet to intermediate and oil-wet, respectively. Temperature is also important to fulfill the possibility of applying NaNoEOR™ at reservoir temperature.

Unlike surfactants and polymers, it is evident that there is no single, universally accepted mechanism for nanoparticles enabled EOR. Although many mechanisms of nanotechnology for enhanced oil recovery have been proposed, but a lack of direct connections between the pore-scale mechanisms and the macro-scale oil recovery performance makes it hard to determine which mechanisms are dominant. Nanoparticles are also increasingly studied for addressing key challenges to supplement conventional EOR methods by reducing surfactants adsorption, increasing polymer viscosity and reduce shear degradation. Therefore, it is important that a mechanism for nanoparticle-enabled recovery be identified, and pore-scale physics be validated and expanded on a micro-model, then performance-validated in the reservoir core.

Nanoparticle-stabilized emulsions have attracted much recent research interest as emulsifiers for enhanced oil recovery (EOR) applications with advantages over conventional emulsions stabilized by surfactants or by colloidal particles. For example, solid nanoparticles can be attached to the oil/water interface and form a rigid nanoparticle monolayer on the surface of the droplet, which induces a highly stable emulsion that can withstand harsh environmental conditions. Emulsions stabilized using nanoparticles can travel greater distances than emulsions stabilized using colloidal particles. Recently, detailed characterizations of the properties of emulsions stabilized by nanoparticles have been reported. The influence of the nanoparticle wettability, particle concentration, initial location (i.e., whether dispersed in water or in oil), and the properties of the oil on the emulsion system have been studied. In addition, flooding experiments have been carried out using silica beads, sand packs, and sandstone to evaluate how effective nanoparticle-stabilized emulsions are as a displacing fluid for EOR. These studies report the possibility of substantial additional recovery over conventional water flooding. However, an accurate assessment of the potential for nanoparticle-stabilized emulsion flooding requires a detailed analysis of aspects such as the pressure difference under various flow phase conditions.

The major challenges facing oil production during/after secondary recovery include oil entrapment by water and high-water mobility. Hence, currently, Enhanced Oil Recovery (EOR) is considered a key solution for increasing oil production upon reaching the tertiary production phase. Unfortunately, EOR still has its drawbacks including the degradation of the chemicals (polymers and surfactants) used under reservoir conditions, large volumes of chemicals, and their high cost.

Generally, thermal methods reduce the viscosity/density of the displaced phase (oil) to increase the oil mobility and are mostly utilized in heavy oil reservoirs. Different thermal techniques include cyclic steam stimulation (CSS), steam flooding, and steam gravity drainage (SAGD). On the other hand, the mobility ratio also can be reduced chemically either by using polymer flooding to decrease the water's mobility, or surfactant flooding to reduce interfacial tension (IFT), which increases the relative permeability to oil, or a mixture of both polymer and surfactant. Unlike bulk materials, nanoparticles (NPs) have high surface-to-volume ratio and dangling bonds, making them more reactive than the bulk counterparts.

In addition, most NPs utilized in the EOR field are environmentally friendly and compatible with the reservoir formation. Moreover, the small size of the nanoparticles facilitates their ability to flow in tight pore throats without getting trapped and causing permeability reduction. Owing to their unique properties, nanomaterials have been researched in many aspects to solve current problems in the oil and gas industry. Nanomaterials have attracted major interest in the fields of thermal and chemical EOR because of their ability to enhance conventional techniques as additives or through nanofluid flooding. Stability of nanoparticles is one of the most important parameters affecting the success of NPs propagation in porous media and the different uses of NPs in thermal and chemical EOR and the most common types of NPs employed in each mechanism.

NaNoEOR™ Product Overview

NaNoEOR's proprietary product overview can be found in the Patent page. Please contact us for a confidentiality agreement.