International Journal For Technological Research In Engineering
Volume 3, Issue 10, June-2016 ISSN (Online): 2347 - 4718

EMERGING APPLICATIONS OF NANOTECHNOLOGY IN OIL AND GAS INDUSTRY

Rakesh Kumar Pandey[1], Shwetank Krishna[2], Jyoti Rana[3], Natra Kamal Hazarika[4]
[1,2,3,4]Assistant Professor, Department of Petroleum Engineering, Chandigarh University, Gharuan,

Abstract: Nanotechnologies have already contributed significantly to technological developments in many industries including biomedical, pharmaceutical, aerospace, metallurgy, electronics and more recently the energy industry. Advances in nanotechnology have revolutionized many aspects of the oil and gas industry. The range of applications is enormous and has the potential of enhancing well integrity and productivity along with improving recovery. Nano-sized catalysts have been used in refining and petrochemical processes for many years, but the use of nanomaterial and techniques have only recently entered the upstream domain. Better analytical techniques for the characterization of oil interactions with in subsurface, agents for advanced exploration and surveillance, novel fluids for enhanced oil recovery and subsurface modification applications in the upstream business have been largely influenced with advances in the nanotechnologies. This paper will showcase some of the applications of nanotechnology on theE & P business, particularly emphasizing on the emerging applications of nanotechnology in the petroleum industry for drilling and enhanced oil recovery such as use of "smart fluids", nanosensors, nanoparticles to improve wellbore stability and sweep efficiency with efficient, economical and environmentally sound technologies. This paper also briefly reviews the developments in research areas in petroleum sector with the opportunities and challenges on the applications of nanotechnology in near future of oil and gas industry.

I. INTRODUCTION

The Oil and Gas exploration and production industry faces difficult challenges due to rising energy demands of an increasing and more affluent population. Although the supply from alternative sources of energy, such as nuclear and renewable, is increasing yet for at least two decades, it is estimated to complement and supplement, rather than replacing the hydrocarbon usage. Therefore, most of the increase in the energy demands has to be met by traditional hydrocarbon sources, which will continue to dominate the energy market. Breakthroughs in nanotechnology have the potential to move the industry beyond the conventional alternatives of energy supply by introducing technologies that are more efficient and environmentally sound. Basically, Nanotechnology refers to a field of applied science and technology whose unifying theme is the control of matter on the atomic and molecular scale, generally 100 nanometers or smaller, and the fabrication of devices with critical dimensions that lie within that size range. The advancements in nanotechnology have led to development of significantly enhanced materials and devices with features and characteristics that remain unmatched by conventional technologies. Research and development in nanotechnology has exploited the unique combinations of mechanical, thermal, electronic, optical, magnetic, and chemical properties observed at the nano-length scale (Krishnamoori, 2006). Due to their size, efficiently engineerired nanoparticles would be able to flow though a typical reservoir pore space with sizes at or below one micron. By altering the nanoparticle properties it is possible not only to enhance their mobility but also to improve the properties of injected fluids and/or collect information about the environment the particles are exposed to in their flow path.

II. A BRIEF OF NANOTECHNOLOGY APPLICATIONS

Nanoparticles

Nanoparticles have properties potentially useful for oil recovery processes, formation evaluation and scale formation control. Nanoparticles, with diameter ranging between 1 and 100 nm, may possess special physical properties and are of high interest as they effectively bridge bulk materials and atomic or molecular structures. When the size of nanoparticles approximates or is less than the wavelength of conduction electrons, the periodic boundary conditions become damaged, and magnetism, internal pressure, optical absorption, thermal resistance, chemical activity, catalysis and melting point undergo great changes that are unlike those of normal particles. The enhanced retention of Ca-Diethylenetriaminepentatakis nanoparticles and slow dissolution of these nanoparticles are highly advantageous in slowing the phosphonate release from porous media and ensuring successful inhibitor treatments in oil fields (Shen and Zhang, 2008). The lipophobic and hydrophilic polysilicon nanoparticles that could change the wettability of reservoir rock through their adsorption on porous walls (Binshan et al., 2002).

Nanofluids

One of the most promising applications of nanotechnology to the oil industry, in particular for drilling and enhanced oil recovery, is the new generation fluids based on nanofluids and nanoparticles. Nanofluids are a class of fluids engineered by dispersing nanoparticles (nanofibers, nanotubes, nanodrops, nanowires) in base fluids. With the addition of the nanoparticles, the base fluid properties such as viscosity, density, specific heat and thermal conductivity can be modified to optimum levels. The nanoparticles used in the design of such fluids are preferably inorganic with properties of no dissolution or aggregation in the liquid environment. The most commonly used nanoparticles for enhanced oil recovery study are the spherical silica nanoparticles with a diameter in the range of several to tens of nanometers. Recent experiments have revealed certain capable nanofluids with amazing properties such as fluids with advanced drag reduction, binders for sand consolidation, gels, products for wettability alteration, and anticorrosive coatings (Chaaudhury, 2003; Wasan and Nikolov, 2003; Zhang, 2001). Emerging applications of nanotechnology in the oil industry involve new types of smart fluids for various applications, particularly for EOR purposes.

Nanosensors

Nanomaterials are excellent tools for the development of sensors and imaging-contrast agents because of the substantial alterations in their optical, magnetic and electrical properties along with their ability to form percolated structures at low volume fractions (Krishnamoorti, 2006). Such nanomaterials, combined with smart fluids, may be used as an extremely sensitive downhole sensor for temperature, pressure and stress even under extreme conditions. These new sensors are smaller in size, work safely in the presence of electromagnetic fields, are able sustain high temperature and pressure environments, and can be replaced at a viable cost without hindering the oil exploration. Additionally, using the anisotropic nature of many nanoparticles, the percolation is a strong function of orientation, and, thus, for appropriately processed materials, highly anisotropic electrical and mechanical properties are observed in different directions.

Nano-coatings

Intelligent or smart coatings may combine the shielding aspect with sensor or actuator functions, depending on their responding capability to physical, chemical or mechanical stimuli by developing readable signals. Nanomaterials are expected to be used not only as advanced functional materials, but also as an integral part of complete smart structures composed of various elements including sensors, actuators, and control devices. The coating using carbon nanotubes adds to an innovative application to conduct current for evenly heating surface, which could be used on pipelines to reduce gas hydrate formation or to de-ice the blades on wind turbines. The corrosion-resistant material solution could also be represented by nano-metric thin films and composites with nanostructured fillers. The Nano-coated, wear-resistant probes, made of tungsten carbide enhance the lifespan and efficiency of the drilling systems, thus inducing remarkable cost savings. The same applies to the Nano-layered corrosion inhibitors in pipes or tanks, which creates a permanent molecular layer on the surface of metals, thereby; eliminating or hindering the HCl or H2S induced corrosion.

III. OIL AND GAS INDUSTRY CHALLENGES AND NAONOTECHNOLOGY SOLUTIONS

The oil and gas industry is facing major future challenges (summarized in Table 1) in terms of materials, techniques and environment friendly operations. Recently nanotechnologies have received substantial attention as potential candidates to offer efficient solutions to some of these problems. The recent progress in relevant research and development in significant areas of the oil and gas have briefly been reviewed and followed by a summary of possible solutions the nanotechnology can offer in a number of areas of critical importance to the industry.

Exploration and Production

The oil and gas exploration and production industry faces increasing technical challenges due to changes in the operational conditions, the nature of subsurface geological hazards with increasing depth, the complexity of wellbore profiles to maximize reservoir contact. The current state-of-the-art technologies still lack the needed resolution and/or the ability to deeply penetrate reservoir lithologies. Moreover, in hostile conditions, such as high temperature and high pressure, conventional electrical sensors and other measuring tools are often not reliable. Despite the use of advanced 3-D and 4-D seismic surveys, the industry still needs advanced downhole electrical methods, sensitive electromagnetic imaging methods, and sophisticated modeling and simulation techniques to improve in-depth understanding of the reservoirs.Due to changes in operating conditions such as operational depth or a shift from vertical to horizontal, the conventional drilling and stimulation fluids perform poorly. In addition, the drilling industry needs improved, lightweight, rugged structural materials for several applications, such as weight reduction of offshore platforms, energy-efficient transportation vessels, and better-performing drilling parts. Other unsolved problems confronting oil production are scale formation and the untimely deposition of heavy organic compounds present in the oil. These issues lead to increased costs and limit the operating envelope of exploration and production technologies.

Nanosensors deployed in the pore space can provide data on reservoir characterization, fluid-flow monitoring, and fluid-type recognition. Nanoscale metals have already been used to delineate ore deposits for geochemical exploration.Drilling equipment and platforms can be made or coated with nanomaterials for improved corrosion-resistance, wear-resistance, shock-resistance, and enhanced thermal conductivity. Due to the special properties and interaction potential of nanomaterials compared to their parent materials, the nanomaterials are considered the most promising future materials for “smart fluid” design for oil and gas field applications. Such smart fluids will further enhance drilling by adding benefits such as wettability alteration, advanced drag reduction, and binders for sand consolidation.

Enhanced Oil Recovery (EOR)

The improvement in oil production efficiency by enhanced oil recovery techniques is of high consideration because it has been observed that in many of the world’s reservoirs only about one-third of the oil in place are recovered by conventional production methods. For conventional water and gas flooding, the driving fluids often quickly channel through the formation to the producing well, bypassing most of the oil and leaving it uncovered due to the unfavorable mobility ratio of the driving fluids and the driven fluids. Chemical recovery processes are also limited by the high cost of the injectants, potential corrosion of the formation, and injectant loss during the flow-through reservoir. The nano-agents can drastically increase oil recovery by improving the geo-mechanics of a reservoir through the improvement of surface tension as well as actual modification of the reserves themselves. The viscosity of a fluid injected to displace oil, such as water, surfactant solutionor CO2, is often lower than the viscosity of the oil. In this situation, adding nano particles can tune up the viscosity of the injected fluid to an optimum level, with net effect of improving the mobility, thus the oil recovery efficiency. Emulsification is another way to increase viscosity, but many current methods to stabilize emulsions are expensive or poorly suited to large-scale applications. The nanoemulsions, with droplets ranging from 1-200 nm, have good injectivity and penetration without filtration. In addition, these nanoemulsions are very stable over time and resistant to coalescence and the exchange of the dispersed phase between droplets. Thereby, a cost-effective process of enhanced oil recovery can be achieved.

IV. CONCLUSIONS AND OUTLOOK

- The paper presents an overview of the recent developments related to research in nanotechnology in areas of specific interest to the oil and gas industry. The oil and gas industry is facing many materialistic and technical difficulties with the increasing complexity of operations, which may successfully be addressed by nanotechnology.
- Nanotechnology offers real possibilities of changing the way in which we look at oil and gas exploration and production by contributing to efficient, cost effective, and environmentally sound technologies. It offers potential solutions to industry problems that cannot be handled using conventional approaches. The laboratory experiments and field tests suggest that nanotechnology has great potential for petroleum applications in the forms of structural nanomaterials, smart nanofluids, nanosensors and nanocoatings.
- Although most of the nanomaterial-based products are still in the stage of laboratory testing, they could be extensively applied in the oil industry. As the existing problems are solved, the innovations in nanotechnology will bring about a technological breakthrough and can extensively be applied in just about every area of oil and gas industry.

REFERENCES

[1] A. J. P Fletcher, J. P. Davis. 2010.How EOR Can beTransformed by Nanotechnology. Tulsa : s.n., 2010. SPE 129531.
[2] Abdelrahman Ibrahim El-Diasty, Adel M. Salem Ragab. 2013.Applications of Nanotechnology in the Oil & Gas industry: Latest Trends Worldwide & Future Challenges in Egypt. Cairo : s.n., 2013. SPE 164716.
[3] Decreasing Water Invasion Into Atoka Shale Using Nonmodified Silica. J. Cai, M.E. Chenevert, M.M. Sharma, Jim Friedheim. 2012. 01, 2012, SPE Drilling & Completion, Vol. 27, pp. 103-112.
[4] Effect of Nanoparticles on Oil-Water Flow in a Confined Nanochannel: A Molecular Dynamics Study. Jianyang Wu, Jianying He, Ole Torsæter, Zhiliang Zhang. 2012. NOORDWIJK, THE NETHERLANDS : s.n., 2012. SPE.
[5] Extracting the Benefits of Nanotechnology for the Oil Industry. Journal of Petroleum Technology. Krishnamoori, Ramanan. 2006. 2006, Journal of Petroleum Technology.
[6] Gongrang Li, Jinghui Zhang, Huaizhen Zhao, Yegui Hou. 2012.Nanotechnology to Improve Sealing Ability of Drilling Fluids for Shale with Micro-cracks During Drilling. Noordwjk : s.n., 2012. SPE 156997.
[7] Jianyang Wu, Jianying He, Ole Torsæter, Zhiliang Zhang. 2012.Effect of Nanoparticles on Oil-Water Flow in a Confined Nanochannel: A Molecular Dynamics Study. Noodwjk : s.n., 2012. SPE 156995.
[8] Kaoru Ohno, Masatoshi Tanaka, Jun Takeda, Yoshiyuki Kawazoe. 2008.Nano- and Micromaterials. s.l. : Springer, 2008.
[9] Nanotechnology Applications in Oil and Gas Exploration and Production. Sergio Kapusta, Leandro Balzano, Paul te Riele. 2012. BANGKOK, THAILAND : s.n., 2012. SPE.
[10] Nicolas Agenet, Navid Moradi-Tehrani, Olivier Tillement. 2012.Fluorescent Nanobeads: A New Generation of Easily Detectable Water Tracers. Bangkok : s.n., 2012. IPTC 15312.
[11] P Pourafshary, S S Azimipour, P Motamedi, M Samet, S A Taheri, H Bargozin, S S Hendi. 2009.Priority Assessment of Investment in Development of Nanotechnology in Upstream Petroleum Industry. Alkhobar : s.n., 2009. SPE 126101.
[12] Paul McElfresh, David Holcomb, Daniel Ector. 2012.Application of Nanofluid Technology to Improve Recovery in Oil and Gas Wells. Noordwjk : s.n., 2012. SPE 154827.
[13] recovery, 2012_Application of nanofluid technology in improving.
[14] Shahab Ayatollahi, Mohammad M. Zerafat. 2012.Nanotechnology- Assisted EOR Techniques: New Solutions to Old Challenges. Noordwjk : s.n., 2012. SPE 157094.
[15] Tianping Huang, James B. Crew. 2007.Nanotechnology Applications in Viscoelastic -Surfactant Stimulation Fluids. Scheveningen : s.n., 2007. SPE 107728.
[16] 2007.Nanotechnology Applications in Viscoelastic-

Surfactant Stimulation Fluids. Scheveningen : s.n., 2007. SPE 107728.

[17] Xiangling Kong, Michael M. Ohadi. 2010.Applications of Micro and Nano Technologies in the Oil and Gas Industry An Overview of the Recent Progress. ABU DHABI, UAE : Society of Petroleum Engineers, 2010. SPE 138241.

TABLES & FIGURES:

AREA	INDUSTRY NEEDS	NANOTECH SOLUTIONS
EXPLORATION	• Less invasive methods of exploration, remote sensing • Methods to "sniff" for new pockets of oil • Enhanced resolution for subsurface imaging and computational techniques • Improved temperature and pressure ratings in deep wells and hostile environments • Improved instrumentation for gas adsorption • Improved 1, 2, 3 and 4-D seismic resolution	Nanosensors and Imaging
RESERVOIR MANAGEMENT	• Enhanced remote imaging, real-time continuous monitoring • Accurate early warning detection and location of leaks • Improved reservoir illumination and characterization	Nanosensors
	• Improved sand exclusion and mobility of injectant • Controlled agglomeration of particles • Ability to capture and store CO2	Nanomembranes
	• Improved stability and pressure integrity and heat transfer efficiency • Ability to minimize damage to formation of offshore platforms, reduce their weight requirements, and increase their sturdiness	Nanomaterials, Fluids and Coatings
DRILLING	• Increased effectiveness and longevity of drilling components, making cheaper, lighter and stronger pipes and drill bits • Extended lifetime of equipment with corrosion resistance, adhesion enhancement and wear resistance • Improved strength-to-weight ratio for an expanding range of geological settings • Expandable tubulars for deeper wells without needing to telescope the well, or casing-less wells • Improved cement integrity – light density and high strength, hole quality and well placement, hermetic seals • Innovative drill engines that can be sent deep into the shaft	Nanomaterials and Coatings
	• Improved drilling fluids and thermal conductivity • Removal of toxic metals (mercury, cadmium, lead • Ability to prevent drilling mud invasion, separating mud filtrate and formation water	Nanofluids, and Nano-membranes
PRODUCTION	• In situ sensing and control, monitoring of stresses in real-time • Ability to direct fracturing and withstand high temperatures to go deep into challenging resources of wellbore deep reading of oil-water interface • Chemical detection with no active components downhole • Enhanced measurements in the borehole (pressure, temprature, composition, conductivity) • Accurate detection and location of leaks (pipeline, downhole) • Improved understanding of matrix, fracture, fluid properties and production related changes	Nanosensors
	• Increased wear resistance • Self-healing materials • Pressure integrity, improved robustness • Enhanced hydro-phobic or hydrophilic behavior for waterflood applications	Nano-materials and Coatings
	• Improved water filtration (for industrial, agricultural and potable use) • Filtration of impurities from heavy oil and tight gas • Desulfurization, inhibiting H2S producing bacteria • Cost-effective CO2 sequestration • Sand exclusion • Effective water-shutoff • Scale/wax removal • Easy separation of oil/water emulsion on the surface	Nano-membranes
	• High-strength/lightweight proppants • Environmentally friendly fluids • Enhanced oil recovery: enhanced fluid viscosity and molecular modification • Improved production rates and water disposition • Reversible/reusable swellables • Ability to manipulate the interfacial characteristics of rock-fluids relationship • Reversible and controllable making and breaking of emulsion or foam • Improved combustion and enhanced prevention of fouling and corrosion	Nanofluids

Table 1: Recent Oil & Gas Industry Needs and Nanotech Solutions

