Significance of Nanotechnology in Oil and Gas Offshore Engineering

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Abstract—Nanotechnology is a science concerned with the design, construction and utilization of functional structures with at least one characteristic dimension measured in nanometers. Presently, nanotechnology are used in a number of industries, including electronic, materials and manufacturing, aerospace, photography, construction and more recently the energy industries. Nanotechnology has the potential to introduce revolutionary changes in several areas of the oil and gas industries from upstream to midstream to downstream. This paper present a broad overview of the application of nanotechnology in the offshore engineering.

Keywords—Nanomaterials, offshore, structure

I. INTRODUCTION

The global demand for energy is anticipated to continue over the next few decades with the expectation that the world’s energy consumption will increase by as much 50% in the next 20 years [1] as shown in figure [1]. This unabated global demand for energy will translate into growing demand for traditional hydrocarbon resources since the rate of alternative energy sources, at least for the next 2 decades, will be compliment and supplement, rather than replace the hydrocarbons [2].

Moreover, since as readily accessible hydrocarbon basins are diminishing quickly and the easily recoverable oil and gas reserves are declining rapidly, the oil and gas industry are looking for new reserves of oil and gas every corner of the earth. According to Shihab-Eldin [3] the average field size of new discoveries in traditional onshore and offshore areas has declined from 220 MM BOE per discovery in 1960s to less than 50 MM BOE in 1990s. As ocean occupies three quarters of the earth and has high prospect of hydrocarbon resources in addition to other valuable marine resources [4], there are increasing activities in the offshore areas with a major focus on deep water drilling. The decreasing reserve of onshore and shallow water hydrocarbon basins and high prospect of deep water basin are the major driving forces in shifting the industry focus to deep water drilling for oil and gas. According to Matthew [5] the potential of discovering future giant oil and gas fields in deep water environments are much higher than in onshore and shallow water environments. Leisman [6] also pointed that reserves at depths approaching a mile or more now represent the biggest single new oil resources for the world communities. Published information indicates the presence of more than 20% of world’s proven reserve in offshore geological structures. As per future production forecast of hydrocarbon resources, about 40 to 50% of future hydrocarbon recovery will be from offshore reserves [7].

Nanotechnology represents the development and application of materials, methods and devices, in which critical length scale is on the order of 1-10 μm. Proven a game changer for exploiting fossil-based fuels and, over the next 30 years nanotechnology will be critical component in developing fossil-base energy technologies. [8].

The most obvious application of nanotechnology for offshore operations is developments of better-materials. By building up such substances on a nanoscale, it could produce equipment that is lighter, more resistant, and stronger. This paper examines the potential areas where nanotechnology can benefit petroleum engineering. The data and information collected is from current literature. The purpose is to point out clear cut direction among the nanotechnology development areas where the petroleum process would immediately harness nanotechnology, by specifying clear recommendations. The information would be beneficial to both petroleum engineering education and research.

II. APPLICATION OF NANOTECHNOLOGY IN OFFSHORE OIL AND GAS INDUSTRY

Compared to other industries, application of nanotechnology is very limited in oil and gas industry and the...
built environment. However, within the next few decades, significant improvements are expected in intelligent, cost effective, durable and environmental friendly materials and structures since nanotechnology generated products have many unique characteristics [8,9]. These include product that are for: lighter structure, stronger structural composites, low maintenance coating, better properties of cementitious materials, improving pipe joining materials and techniques, and reducing the thermal transfer rate of fire retardancement and insulation.

There are large number of applications of nanotechnology in offshore oil and gas industry. Some of these applications are examined in detail below.

III. STRUCTURAL COMPOSITES

Steel with various grades, from mild steel to high-strength steel, is a major construction materials in offshore oil and gas platforms (in which steel and concrete are the materials for choice for offshore, with steel dominant in the topside applications). The properties of steel, such as strength, corrosion resistance and weld ability are very important for design and construction.

FHWA together with American Iron and Steel Institute and the U.S. Navy started to develop new, low carbon, high-performance steel (HPS) for bridges in 1992 [10]. The new steel was developed with higher corrosion-resistance and weld ability by incorporating copper nanoparticles from at the steel grain boundaries. Sandvik NanoflexTM is new stainless steel with ultra-high strength, good formability, and a good surface finish developed by sandvik nanoflex Materials Technology. Due to its high performance, Sandvik NanoflexTM is suitable for application which requires lightweight, and rigid designs. Its good corrosion and wear resistance can keep life-cycle costs low. Attractive or wear resistant surfaces can be achieved by various treatments (Sandvik Nanoflex Materials Technology). MMFX2 is nanostructure modified steel, produced by MMFX Steel Corp. Compared with the conventional steel, it has a fundamentally different microstructure a laminated lath structure resembling “plywood”. This unique structure provides MMFX2 steel with amazing strength (three times stronger), ductility, toughness, and corrosion resistance. Due to high cost, the stainless steel reinforcement in concrete structure is limited in high risk environments. The MMFX2 steel could be an alternative because it has the similar corrosion resistance to that of stainless steel, but at a much lower cost (MMFX Steel Corp.).

IV. CONCRETE

Concrete is a constructional material used in oil and gas production platforms with steel dominant in the topside application. Addition of nano scale materials into cement could improve its performance. In this regard, nanoparticles, especially nanosilica, nano-FeO2 [11-14] and nanoalumina [15] have been widely employed for increasing compressive and flexural strengths of Portland and Belite cement. Further, the self monitoring capability of cement mortar with nano FeO2 has been reported [13]. It is also been reported that adding small amount of carbon nanotube (1%) by weight could increases both the compressive and flexural strength [16].

V. DRILLING FLUIDS

Drilling fluids are used in drilling operations to cool and lubricate the drill bit, remove rock debris and drill cutting from the site and to counteract downhole formation fluids [9]. Current experience shows that, due to unique characteristic features of nanos compared to the parent materials and their easy manipulation to perform certain tasks, nanomaterials are consider to be the one of the best candidates for smart fluids formation to overcome the poor performance of the conventional drilling and simulation fluids [9,17,18].

Projects in the Adriatic sea and the gulf of Mexico [19] have demonstrated that the mixture of seawater and nano-based polymer fluids (which enables high quality fracturing [20], generate practical fracturing fluids in offshore operation to enhance production while simplifying the process, saving time and reducing cost.

Another area where nanomaterial can make impact is with shallow water flow problem which is frequently encountered in most of the deepwater drilling (and in some onshore) operations. It increases the drilling cost significantly [21-22], due to isolate the SWF zone. It is the most feared to geo-hazards associated with deepwater drilling and are frequently encountered in deep water drilling in the southern Caspian sea and Norwegian sea [22]. It is expected that the nanofluid can improve some of the challenges such as borehole and sea bed equipment stability used in offshore drilling and production, [18].

VI. COATING

The offshore environment is highly-corrosive and special stresses put additional pressure on the coating systems used for protection of the steel-structures. Nanotechnology presents a wide range of opportunities to improve performance of coatings, and incorporate new performance features. The coating incorporating certain particles or nanolayer have been developed to improve the corrosion-resistance, wear resistance, shock-resistance and enhanced thermal conductivity of offshore structures, vessels and drilling equipment [23-25].

These capabilities will greatly enhanced the ability of component to produce in more extreme conditions. Nancoating will lead to an increase of structural integrity of offshore structures as well as in service life.

VII. FUTURE CHALLENGES

As with most developing technologies, a major number of challenges exist during the initiation of the application of technology into reality. Although many achievements with nanomaterials have been made in laboratory conditions, serious challenges remain in field implementation for oil production in complex underground environment. Most nanomaterial-based products are still in the research and
development stage in the oil industry. However, very few nanomaterials-based products have yet to appear in the energy and petroleum (E&P) technology basket. This can be contributed to a number of factors [9].

(1) Lake of strong support for innovation in the E&P sector.
(2) Barriers to entry and adoption.
(3) Perceived cost and risk.
(4) Lake of awareness.

Once solutions to these problems are solved and the relevant technologies developed, nanotechnologies can be extensively applied in just about every area of the petroleum industry.

VIII. CONCLUSIONS

The exploration and exploitation of deep water hydrocarbon resources are associated with a suite of drilling hazards that are not normally encountered in onshore drilling operations. Construction of deep water wells, is difficult and expansive, and the narrowness of the operating pressure window poses many potential problems, including lost circulation, poor hole cleaning, stuck pipe, wellbore instability and tough environmental constraints. Thus deep water drilling requires the development of new technologies to reduce the drilling cost, improved safety and minimize environmental impact. However, from the reviewed literature, nanotechnology offers many potential solutions to the industry problems that can not be solved with conventional approaches. Innovations in nanotechnology as applied to the oil and gas industry will bring about a technological breakthrough to be industry with many win-win rewards for both sides.

REFERENCES