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A REVIEW ON ENHANCED OIL RECOVERY

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Abstract— **It has been observed during the last decades there is decline in oil discoveries. It is believed that EOR technology plays an important role to meet the energy demands in future. This paper presents a review of EOR & further opportunities to increase final recovery factor in reservoirs. This paper discusses the offshore onshore fields risk and rewards of EOR methods in recent years like co_2 injection high pressure injection and chemical flooding.**

Keywords—Enhanced oil recovery (EOR); co_2: steam injection ; air injection ;chemical flooding

I. Introduction

According to the report of "oil and gas journal" there were 652 projects on enhanced oil recovery . however, only small fraction of hydrocarbon resource is produced during EOR methods. The following diagram shows the classification of global EOR projects. Worldwide EOR production is below 4% of total production. In a mature area like USA 48 LS EOR production is above 10% of total production. Majority is onshore EOR.

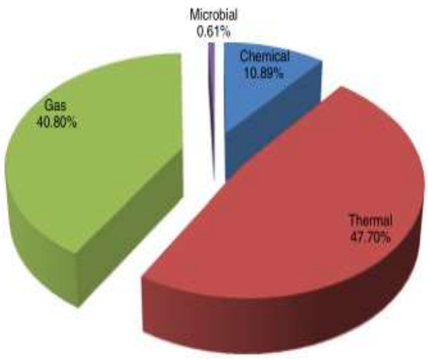


Fig.1.world EOR project classification.

The term " enhance " means "to advance, or elevate; to make or become larger." Thus the term enhanced oil recovery can be applied to any situation where some action has been taken to increase the recovery of oil or gas from a reservoir. Earlier, the term secondary recovery was applied to water flooding and gas flooding although some engineers included pressure maintenance through water and gas injection in secondary recovery. Later, when there was an effort to increase the recovery from reservoir that had previously been subjected to water or gas injection, the term *tertiary* recovery was used. (D.B. Guralink, ed., *Webster's* New world Dictionary) (Matheny, "EOR methods help ultimate recovery")

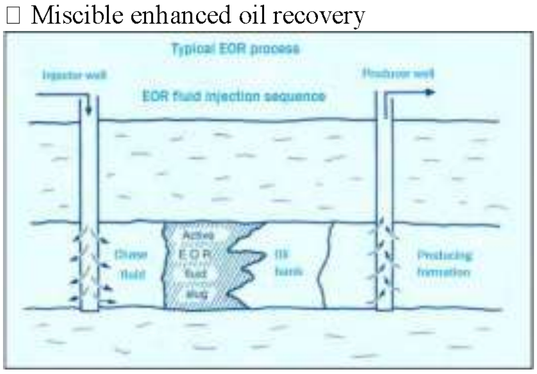
II. Enhanced Oil Recovery

The goal of any enhanced oil recovery process is to mobilize" remaining"oil.
This is achieved by enhancing oil displacement and volumetric sweep efficiencies.

- Oil displacement efficiency is improved by reducing oil viscosity (e.g., thermal floods) or by reducing capillary forces or interfacial tension (e.g., miscible floods).

Volumetric sweep efficiency is improved by developing a more favorable mobility ratio between the injectant and the remaining oil-in-place (e.g., polymer floods, water alternating-gas processes)
Enhanced oil recovery divided into four groups, see figure 1.2:

- Chemical enhanced oil recovery
- Thermal enhanced oil recovery
- Miscible enhanced oil recovery



III. Literature Review

[K. BROWN, W. JAZRAWI, R. MOBERG, M. WILSON, 2010]
In this paper author has concentrated on the Enhanced Oil Recovery Project, the progress of the CO2 flood, and the goals of the Monitoring Project. Particular emphasis is placed on

understanding how the monitoring project will help determine the capacity of oil reservoirs to retain CO2 for the long-term. Injection of CO2 into a carbonate oil reservoir in south eastern Saskatchewan, Canada, began on September 22, 2000. Prior to the start of injection, substantial baseline data were obtained from the field. This baseline data include extensive seismic work (3D-seismic, VSP, cross-well and single-well seismic) and geochemical sampling. The monitoring project will evaluate the distribution of CO2 in a carbonate reservoir and will determine the chemical reactions that are occurring within the reservoir between the CO2 and the reservoir rock and fluids. The ultimate goal of the monitoring project is to verify the long-term storage capacity of an oil reservoir, with particular emphasis on reservoir integrity. Understanding how CO2 moves within and interacts with the reservoir fluids and minerals will allow a determination of total reservoir capacity should CO2 storage become the ultimate goal. On a short-term basis, the monitoring will identify new, cost-effective ways to track the path of CO2 in any oil reservoir. The monitoring study will also identify the most effective ways of assessing the motion of CO2 in the reservoir and understanding the optimization of CO2 storage as opposed to necessarily optimizing oil recovery alone. Understanding CO2 movement will help to provide the information necessary to develop strategies to improve sweep efficiency within the reservoir. While not discussed in the text of this paper, one of the goals of this study is to study mobility control in the reservoir. Effective injection strategies, including the possible use of mobility control techniques, will improve sweep efficiency and potentially increase the volume of reservoir holding CO2. While injection has only just begun, initial indications are that there are no immediate injectivity issues. Prior to injection number of geophysical surveys using a variety of techniques. The data quality appear to be good from these programs. It should be possible to determine with some confidence the longer-term consequences of greenhouse gas injection into the subsurface and the integrity of storage. The risk analysis will evaluate the potential for leakage, migration paths this leakage may take and future land-use changes that may impact on reservoir integrity

[The California energy commission, Enhanced oil recovery scoping study, 1999 www.energy.ca.gov]

The author has compared several EOR techniques in this paper, By applying the enhanced oil recovery techniques millions of barrels of oil can be extracted from existing fields, as it increases the recovery up to 60 % of the oil in the reservoir, billions of dollars are invested in enhanced oil recovery researches to get the maximum amount of recovery with the lowest possiblecost from the existing fields before moving to the remote areas. Thermal EOR (mostly steam, hot water drive and huff-and-puff operations) accounts for about 393,000 BOPD which is about 7% of the states production. Oil recovered using carbon dioxide (CO2) EOR is about 196,000 BOPD is about 3% of U.S. production. Amount of oil recovered by hydrocarbon miscible EOR (mostly natural gas injection) accounts for about 86,000 BOPD or about 1.5 % of U.S. production and nitrogen miscible/immiscible EOR accounts for about 32,000 BOPD or about 0.5% of U.S. production. These methods account for well over 99% of all U.S. EOR production with considerably less than 1% coming from chemical EOR and microbial EOR which is still in the research stage." Nowadays, enhanced oil recovery techniques account for about one-third of Alberta's conventional recoverable oil reserves. As in the fullness of time exploration prospects suffer from depletion, the ability to obtain more from what has already been found gained greater importance as a source of additional oil supply.

"EOR is gaining attention as it is considered to provide us with the future fuel. The wide survey available every couple of years by the Oil & Gas Journal (Moriti) shows that the production using EOR techniques in Canada and U.S.A. is about 25% and 10% respectively of the total oil production and is growing"

[J. Roger Hite, SPE, Business Fundamentals Group; S.M. (Sam) Avasthi, SPE, Avasthi& Associates, Inc.; and Paul L. Bondor, SPE, BonTech, Planning of EOR projects, SPE 92006, 2004].

This paper includes the methods of EOR by which the recovery is maximum. Among the other techniques used for enhanced oil recovery is "the solvent and improved gas drive method" this method can be divided into three methods, such as; i) Solvent flooding. ii) Enriched gas drive. iii) High pressure gas drive. Some of the aspects responsible for increasing the recovery factor using carbon dioxide are: a) Promotes swelling. b) Reduces viscosity. c) Decreases oil density. d) Vaporizes and thus extracts portions of oil. Following are the properties that enhance the recovery: a) Carbon dioxide is highly soluble in water. b) It exerts an acidic effect on the oil. c) Carbon dioxide is transported. In addition to the above mentioned: i) Eliminates swabbing. ii) Provides rapid cleanup of silt. iii) Prevents and removes emulsion blocks. iv) Increases the permeability of the carbonate formations. v) Prevents the swelling of clay and the precipitation of iron and aluminum hydroxides. Carbon dioxide is used in EOR techniques due to the combination of solution gas drive, swelling of the oil, reduction of its viscosity and the miscible effects resulting from the extraction of hydrocarbon from the oil. Carbon dioxide is highly soluble in hydrocarbons and this solubility causes the oil to swell, but for reservoirs containing methane a smaller amount of the carbon dioxide dissolves in the crude oil causing a less oil swelling.When reservoir oil is saturated with carbon dioxide at elevated pressures that will result in a substantial decrease in oil viscosity in the reservoir, the water in the formation is also affected by carbon dioxide, some expansion occurs for the water as well causing the density to decrease, so it means after injecting carbon dioxide both the densities of oil and water decreases moving their values near to each other which reduces the effect of gravity segregation.

[ALIREZA SOUDMAND-ASLI, S. SHAHAB AYATOLLAHI, HASSAN MOHABATKAR, MARYAM ZAREIE, 2007]

In the present study the authors have analyzed the microbial enhanced oil recovery (MEOR) technique in fractured porous media using etched-glass micromodels. Three identically patterned micromodels with different fracture angle orientation of inclined, vertical and horizontal with respect to the flow direction were utilized. A nonfractured model was also used to compare the efficiency of MEOR in fractured and non-fractured porous media. Two types of bacteria were employed: Bacillus subtilis (a biosurfactant producing bacterium) and Leuconostoc mesenteroides (an exopolymerproducing bacterium). The results show that higher oil recovery efficiency can be achieved by using biosurfactant-producing bacterium in fractured porous media. Considerable permeability reduction was observed when the biopolymer-producing bacteria were incubated in sand-packed column. The microbial oil recovery efficiency by using biosurfactant producing bacteria (i.e. B. subtilis) in the fractured

porous media is higher than that of the non-fractured media. High oil recovery efficiency was achieved in the fractured porous media when the biosurfactant producing bacteria were used as the microbial treating agent mostly due to the interfacial tension and viscosity reduction. No sign of wettability alteration was observed during the MEOR process using both biosurfactant and biopolymer-producing bacteria.

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In this paper the author estimate of the amount to be recovered through EORapplication is based on actual reservoir parameters of oil saturation, pore volume and previous primary and secondary recovery, and the actual recovery calculation differs among techniques. This estimate is displayed as total incremental EOR production and incremental production per year from the time the project was initiated. The oil recoveries obtained by using compositional reservoir simulation model. The estimate of price is based on the projection of cash flows and a set rate of return. Cash inflows are generated by the production of oil. Cash outflow are comprised the following investment and operating costs: field development expenditures, equipment expenditures, operating and maintenance costs, injection material costs and other costs.

The cash flows are expressed as dollars per year from the time of project initiation. They are based on development characteristics, numerous technique specific and general costs parameters, and several assumptions, all of which are discussed later. The production estimate is matched with investment and operating costs and various rates of return to calculate the required price for the oil. Conversely, the models compute the rate of return yielded at series of fixed prices. The quantities of oil are aggregated by price to construct the price-supply curves. Individual price-supply curves for each technique and an overall price-supply curve for EOR recovery are generated. Based on selected prices and development assumption, these price-supply curves are converted to the timing at which reserves become proved and are produced. These curves are then extrapolated based on remaining oil in place and then the aggregated quantities of oil are aggregated by price to construct the price-supply curves.

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This paper discuss the methods to improve the recovery from mature oilfields have been applied already since the 1960s. Until the late 1980s, these techniques have been a permanent topic of research to broaden the scope of applicability. With drastically dropping oil prices these efforts have practically come to a stop. After recovery of the oil prices, the oil industry has restarted R&D on Enhanced Oil Recovery in the last ten years with an increasing level of activity since then. The research topics deal a lot with methods already applied in the 1980s such as thermal processes and methods using chemicals with proven applicability, e.g., synthetic polymers and surfactants.

However, also now processes using biobased thickeners, low-salinity flooding, nanoparticles or using chemicals with a complete new mode of action are increasingly coming into the focus of research.

The research efforts largely benefit from the overall advances in chemistry and microbiology over the last decades and from, wherever established, improved cooperation within large integrated, multidisciplinary teams. One example is the usage of indigenous microbes to recover more oil called Microbial Enhanced Oil Recovery (MEOR). New research trends and the status of innovation are highlighted as well as challenges on the way to recover more of the „black gold“ from maturing and

increasingly challenging oil fields.

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The Enhanced Oil Recovery (EOR) technology covers the injection of specific type of a fluid or fluids into the reservoir by several methods (e.g.: chemical, thermal and microbial). The injected fluid promotes to dislocate of crude oil toward the producing well. Besides, the injected fluids interact with the reservoir rock/oil system and generate advantageous conditions for oil recovery. These interactions incorporate lowering the interfacial tension (IFT), improving the flow properties, modify wettability and help developing preferential phase behaviour.

As a consequence of the interactions, physical and chemical mechanisms can occur, as well as the formation of thermal energy. EOR is a challenging field for several scientific disciplines. The number of patents highlights the importance of this area. Most of the publications label that the target of the chemical processes is the reduction of IFT between the displacing liquid and oil phase. Based on the results in the last two decades the surfactants and flow modifier type polymers have shown more potential for a higher efficiency of the EOR than in any other methods. Chemical flooding of oil reservoirs could be the one of the most successful method to increase oil recovery rate of the depleted reservoirs. The research and developing projects of the EOR surfactants are very costly due to the expensive field tests. Numerous screening test methods have been elaborated to reduce the costs and to estimate the potential efficiency of the tested surfactant compositions .

However, the previous experiments showed that the surfactant composition has to be effective under different and often extreme conditions, which are complicated to be modelled in the laboratories. There is no generally accepted test method for the selection of surfactants. Therefore, the further development of screening methods remains important. The aim of this work was to develop different surfactant testing methods that are capable to characterize the most important surfactant properties separately and to evaluate their combined or complementary effects

[SCOTT C. JACKSON, DUPONT, ALBERT W. ALSOP, DUPONT, ROBERT FALLON, 2010] In this paper author observed the demonstrated two mechanisms that exceeded, in the lab, the targeted increase in the recovery factor. 1. Improved sweep efficiency by plugging of high permeable zones thereby forcing water to produce oil from previously unswept parts of the reservoir. 2. Reduced oil / rock surface tension resulting in a change in the wettabilty of the rock and lower residual oil saturation. This paper describes the field data used to demonstrate the effectiveness of the improved sweep efficiency by using a microbe to plug high permeable zones in a target reservoir – called bioplugging. The microbe and the nutrients are tailored to the conditions of each reservoir thus giving MEOR the greatest chance for success. We have tested the efficacy of the microbial treatment with a series of slim tube tests and interwell tests. Oil production has increased in the field by 15 to 20% with a corresponding reduction in water cut. Our ongoing research has provided many insights into the appropriate application of microbial EOR. The unique aspects of each production area, the nature of the oil, the water, the formation matrix, and the background microbial population and their complex interactions must all be assessed when considering the potential application of microbial EOR. The amount of work described for assessing potential MEOR mechanisms is extensive. However, this process has been streamlined and we have been able to assess new target reservoirs for potential MEOR treatments quickly

VI. CONCLUSION

MEOR is well-proven technology to enhance oil recovery from oil wells with high water cuts and also to improve it in mature oil wells, but still in order for MEOR processes to be well accepted and successful, extensive laboratory tests are required prior to field implementation to select the suitable microbes, to understand their growth requirements and production conditions. Also, optimization of nutrients and testing the microbes and their bioproducts compatible with reservoir conditions are required. During field tests, design of the microbial system and oil production response has to be well documented and results have to be monitored and followed up.

VII. FUTURE SCOPE

Improvements of the operational performance and the economical optimization of EOR projects in the future would require the application of a synergistic approach among EOR processes, improved reservoir characterization, formation evaluation, reservoir modelling and simulation, reservoir management, well technology, new and advanced surveillance methods, production methods, and surface facilities as stated by Pope. This synergistic approach is in line with the Smart Fields Concept, also known as Intelligent Field, Digital Field, i-Field or e-Field, developed by Shell International Exploration and Production that involves an integrated approach, which consists of data acquisition, modelling, integrated decision making, and operational field management, each with a high level of integration and automation.

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