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New Frontiers In EOR Methodologies By Application Of Enzymes

Tarang Jain, SPE, University of Petroleum and Energy Studies, Dehradun
Akash Sharma, SPE, University of Petroleum and Energy Studies, Dehradun

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Abstract

Enhancement of the amount of oil recovered from existing reservoirs is slowly becoming a standard procedure during the operational life of an oil well. The need for a cost effective and efficient method led to EEOR or Enzyme Enhanced Oil Recovery, a process based on the application of enzymes. It is basically a subset of Microbial EOR in which co-injected micro organisms or nutrients are used for reduction of oil viscosity.
EEOR offers a wide array of applications due to efficient surfactant mechanism and utility in both oil-wet and water-wet systems. Moreover its cost effectiveness has led to applications in marginal oil fields, for example in the Mann Field in Myanmar this led to an increase in production from 10 bopd and 109 bwpd to 17 bopd and approximately 1636 barrels of incremental oil was produced from one of the wells within 9 months of enzymatic treatment.
Use of engineered enzymes not only counter the risk of using nutrients over a long period of time but also enhance the recovery process by accelerating desired biochemical reactions between a substrate, water medium and formation. Enzymes tend to reduce viscosity and inter facial tension to a remarkable extent. Moreover they are not consumed during the reaction and act even in low concentrations. Certain strands of enzymes like Acinetobacter sp.6A2 have the ability to degrade alkanes with a chain length ranging from C_{10} to C_{40} and reduce paraffin content.
The present paper effectively summarizes the utility of EEOR through its various advantages. Enzymes are the key to the future which eradicates the long term use of microbes. Moreover its utility in marginal fields and paraffin reduction abilities make it highly suitable for countries like India which greatly suffer from such issues.

INTRODUCTION:-

Discoveries of new reservoirs, is a high-risk business that companies undertake hoping to achieve a correspondingly high return. Sometimes they are successful but more often they are not. In many cases, increasing the recovery of oil from existing reservoirs can be less expensive than exploration and less risky as well. The reservoir will have already been partially developed therefore wells and surface production facilities are already in place. In 2008, total worldwide energy consumption was 474 exa joules (474×10^{18} J) with 80 to 90 percent derived from the combustion of fossil fuels. This is equivalent to an average annual power consumption rate of 15 terawatts. Not all of the world's economies track their energy consumption with the same rigor, and the exact energy content of a barrel of oil or a ton of coal will vary with quality.
Despite advances in efficiency and sustainability, of all the energy harnessed since the industrial revolution, more than half has been consumed in the last two decades.
In 2009, world energy consumption decreased for the first time in 30 years (-1.1%) or 130 Mtoe (Megaton oil equivalent), as a result of the financial and economic crisis (GDP drop by 0.6% in 2009). This evolution is the result of two contrasting trends. Energy consumption growth remained vigorous in several developing countries, specifically in Asia (+4%). Conversely, in OECD, consumption was severely cut by 4.7% in 2009 and was thus almost down to its 2000 levels. In North America, Europe and CIS, consumptions shrank by 4.5%, 5% and 8.5% respectively due to the slowdown in economic activity. China became the world's largest energy consumer (18% of the total) since its consumption surged by 8% during 2009 (from 4% in 2008). Oil remained the largest energy

source (33%) despite the fact that its share has been decreasing over time. Coal posted a growing role in the world's energy consumption: in 2009, it accounted for 27% of the total.
Hence it can be clearly seen that the world is in the dire need to improve and enhance its resource productivity. In such a case we need to expand our view to reach out to a broader scenario of technologies and advancements. Hence technologies like Enzyme Enhanced Oil Recovery put forward a strong viewpoint in the entire situation and can help reduce the demand and supply gap.

Background of EEOR

Enzyme Enhanced oil recovery is a process which is aimed at mimicking the effect of MEOR or Microbial Enhanced Oil Recovery. A sub-category of MEOR involves the microbial product being Bio surfactants which serve the following purposes:-

- Reduce Interfacial tension between oil and rock/water surface
- Leading to emulsification
- Improving pore scale

EEOR also serves the following needs as have been discussed in the previous section.
Microbial enhanced oil recovery refers to the use of microorganisms to retrieve additional oil from existing wells, thereby enhancing the petroleum production of an oil reservoir. In this technique, microorganisms are introduced into oil wells to produce harmless by-products, such as slippery natural substances or gases, all of which help propel oil out of the well. Because these processes help to mobilize the oil and facilitate oil flow, they allow a greater amount to be recovered from the well

What Are Enzymes?????

Enzymes are biological catalysts made of proteins that catalyze (i.e. significantly accelerate) specifically desired biological chemical reactions between a substrate (oil), the water medium and formation. The enzymes lower the activation energy needed for the reaction without being consumed. Enzymes can catalyze up to several million reactions per second. Our enzymes are engineered with an active site having a strong affinity for the oil. Shown in figure 1.

EEOR -THE TECHNOLOGY AND THE PRINCIPLE

The enzymes involved are in the Hydrolase (water soluble) class of Enzymes. Hydrolases catalyze reactions between a substrate (oil), formation and water, and bind water to certain molecules. In this way, larger molecules are broken into smaller ones. These enzymes also break various bonds in the oil environment to release and mobilize the oil.
The EOR Solutions technology is based on a water soluble liquid enzyme with unique properties to interact catalytically with hydrocarbons. The product is made of oil loving microbes where the oil digesting property is neutralized, but where the ability to attach to and release hydrocarbons is kept.
The enzymatic function of the product is due to the fact that the enzymes seek and release the oil, but is not consumed in the releasing mechanism. After the release of hydrocarbons the enzymes will be attached to the solid surfaces and be dissolved in the water phase in the reservoir. Accordingly the enzymes are available to interact with new hydrocarbons and cause release of oil.
An oil wet system is characterized by the major part of the rock surface to be covered by oil. The oil releasing principle of the enzymes in such a system is shown in the figure 2 and 3
Due to the biological nature and catalytic action of the enzymes, it is very different from surfactants and microbes that are being used for EOR. The well stimulation process with the enzyme technology is very simple and since the enzymes are not consumed in the oil releasing process, they continue to act in low concentrations and as long hydrocarbons are present. The effect of the treatment with enzymes could last for years. Hence, oil well stimulation with this technology is economically extremely favorable to end users.

Working Principle

Similar to the oil wet system, a water wet system is characterized by the major part of the rock surface to be wetted by the water phase. In such an arrangement the water exists more or less as a continuous film through pores and open channels and the oil is resting on a film of water Such a system is also typical for a result of a process referred to as snap-off of oil. This is a system where water is pushing oil through pore throats and droplets of oil are released from the main oil globule by a snap-off. This process leaves trapped oil drops in pores.
When the enzyme – water solution floods and replaces the water or brine phase in such a system, the solid surfaces also become wetted by an enzyme – water phase. In addition the enzyme recognizes – attaches to and releases

hydrocarbons from the oil globule. This in turn drastically reduces the surface tension between the oil globule and aqueous phase. The reduction in Interfacial Tension (IFT) between the oil and hydrocarbon is documented by separate lab measurements. These effects in turn cause release of oil droplets from the parent oil globule and the now formable shape of the parent oil globule makes it subject to be pushed out of the pore in the direction of flow for the displacing fluid. This situation is schematically shown in Figure 4. Model sketch of oil releasing mechanism of enzymes in a typical water wet system. Red spots indicate a few enzyme molecules attached to oil globule surface. The enzyme wetted surfaces of the solids are not marked.

PARAFFIN REDUCTION

Paraffins, mainly composed of long chain alkanes (LCA), pose a problem in the recovery of oil from fields producing paraffinic oil. This is due to the build up of paraffinic deposits. Solidification and aggregation of LCA can cause serious problems in oil recovery due to clogging of oil production pipes, deposits in the process equipments and sealing off pores in the reservoirs. Partial degradation, i.e. reduction in chain length of LCA present in such oils is likely to greatly increase its quality as well as enhance the recovery.

Enzymes used in the EEOR procedure have an essential and vital characteristic that they help in reduction of LCA in situ. [1] One strain, identified as *Acinetobacter sp. 6A2*, was isolated by screening for strains capable of utilizing paraffin with a melting of 52-54°C. The strain was shown to be able to degrade alkanes with a chain length from C10 to C40. Therefore by utilizing such enzymes in the EEOR procedure we can effectively control wax deposition and reduce paraffin content

Disadvantages of MEOR:

- Health, Safety and Environment (HSE)
- A better understanding of the mechanisms of MEOR is required
- The ability of bacteria to plug reservoirs
- Numerical simulations should be developed to guide the application of MEOR in fields
- Microbes may require a detailed pre-treatment of fermentable carbohydrate nutrient base.

Advantages EEOR:

- Reduce interfacial tension between oil and rock/water surface
- Leading to emulsification
- Improving pore scale
- The well stimulation process with the enzyme technology is very simple.
- Since the enzymes are not consumed in the oil releasing process, they continue to act in low concentrations and as long hydrocarbons are present.
- The effect of the treatment with enzymes could last for years.
- Hence , oil well stimulation with this technology is economically extremely favorable to end users.

Limitations of EEOR

- Enzyme enhanced oil recovery does not work on gas wells.
- In case of wells with water coning problem…they cannot be used until water cut problem is solved.
- In case of sand control problems enzymes cannot be used until the problem of sand production is rectified.
- Must be used within 2-3 years of manufacture.

EEOR in Waterflooding Processes

Since the enzymes used in EEOR are completely mixable with water, they can be diluted upto a level of below 750 ppm and can still be effective in releasing crude oil from the sand surfaces in the formation. These can therefore be used as a useful agent in all secondary oil – recovery drive process. This will not only increase the effectiveness of the waterflood process by increasing the amount of oil produced but also reduces the pumping pressure needed to a much greater extent thereby, reducing energy costs. As shown in figure 5.

CASE STUDY: Mann Oil Field, Myanmar:

Mann Field is a brownfield located in Salin sub-basin of Myanmar in Southeast Asia. The field began producing in 1970, predominately from Oligocene reservoirs that consist of 26 stacked sandstone payzones. More than 667 wells have been drilled and completed, and 118 million stock tank barrels of oil have been produced. Average porosity of the reservoir is 18% and average permeability is 10-250 md. Oil gravity is typically 36.5° API which is paraffinic in certain horizons, and the gas gravity is 0.65.

The Operation:-

A test well was treated with four drums of enzyme concentrate diluted up to 2% in formation compatible, filtered brine. Pretreatment production was 14 bopd and 2 bwpd. Current production is 18 bopd, and 530 incremental barrels were produced in 13 months following the 11,000 gal treatment. Pretreatment production from the second well was 10 bopd and 109 bwpd. The production increased to 16 – 17 bops and approximately 1636 barrels of incremental oil was produced during nine months since the treatment. Additional enzyme treatments are being designed for wells in Mann Field with higher current oil productivities.

Conclusion :-

Following are some of the facts related with Enzyme enhanced oil recovery:-

- Application of modified enzyme can improve oil production as proved in case of Mann oilfield.
- Production from other wells can also be enhanced by effective modification of the enzyme solution.
- Various tests indicate the possibility of using enzymes in wells with high water cut.
- Long chain alkane degradation has a potential as a new wax control technology in crude with high paraffinic content and this problem can be solved through use of Enzymes.
- Enzymatic action not only helps in reduction of pour point but also shows dramatic decrease in viscosity at low temperature.

With the ever increasing demand supply gap and the current energy hungry scenario it has become essential to enhance the efficiency of current energy resources. An optimization of the various processes that involve extraction of oil, i.e. the main energy resource. The current methods include Primary and secondary recovery techniques but they are still not completely efficient and optimum. Hence we look for out-of-the-box option for increasing the oil recovered from a reservoir. Proposed technique is Enzyme Enhanced oil recovery which is a leap of improvement from the current method used the MEOR. EEOR works efficiently and has various advantages which also serve the purpose of it serving as a revolutionizing process in the E&P process especially in the Indian scenario which suffers severely from various problem including high paraffin content and poor crude quality.

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FIGURES

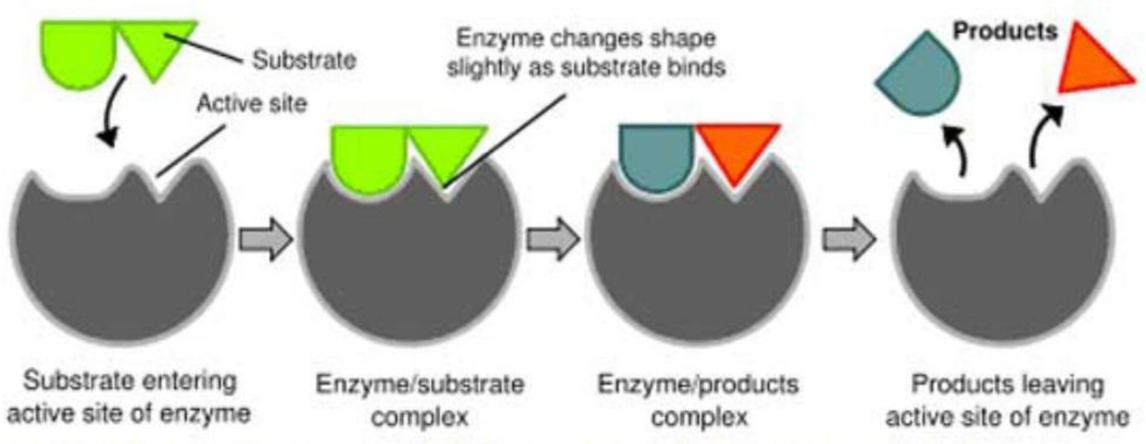


Figure 1 – *Working Principle of an enzyme*

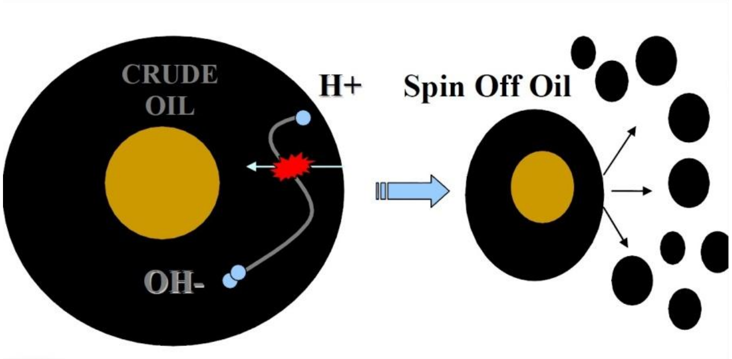


Figure 2 &3 – *Crude oil release by enzymes in Oil wet systems*

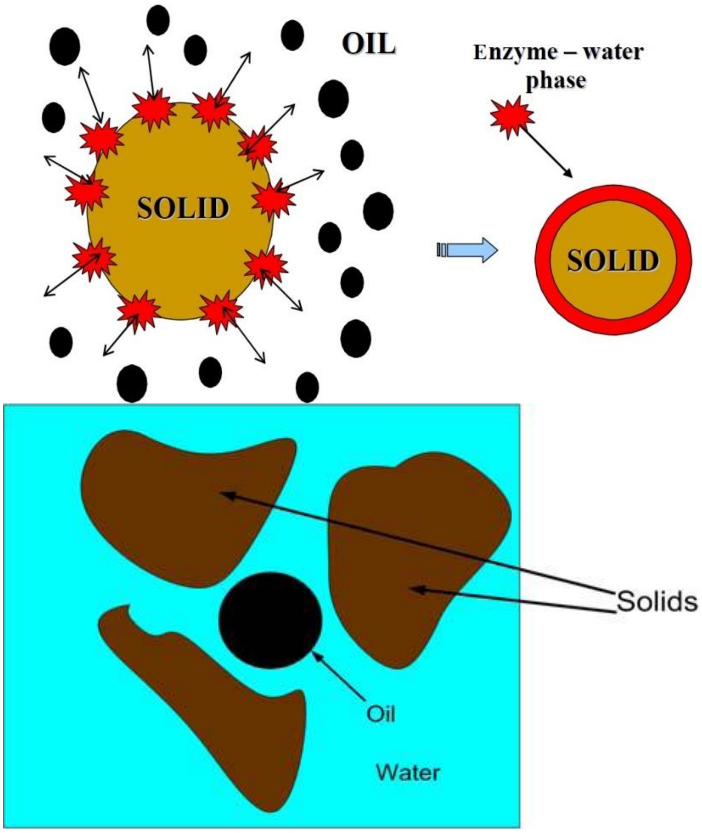
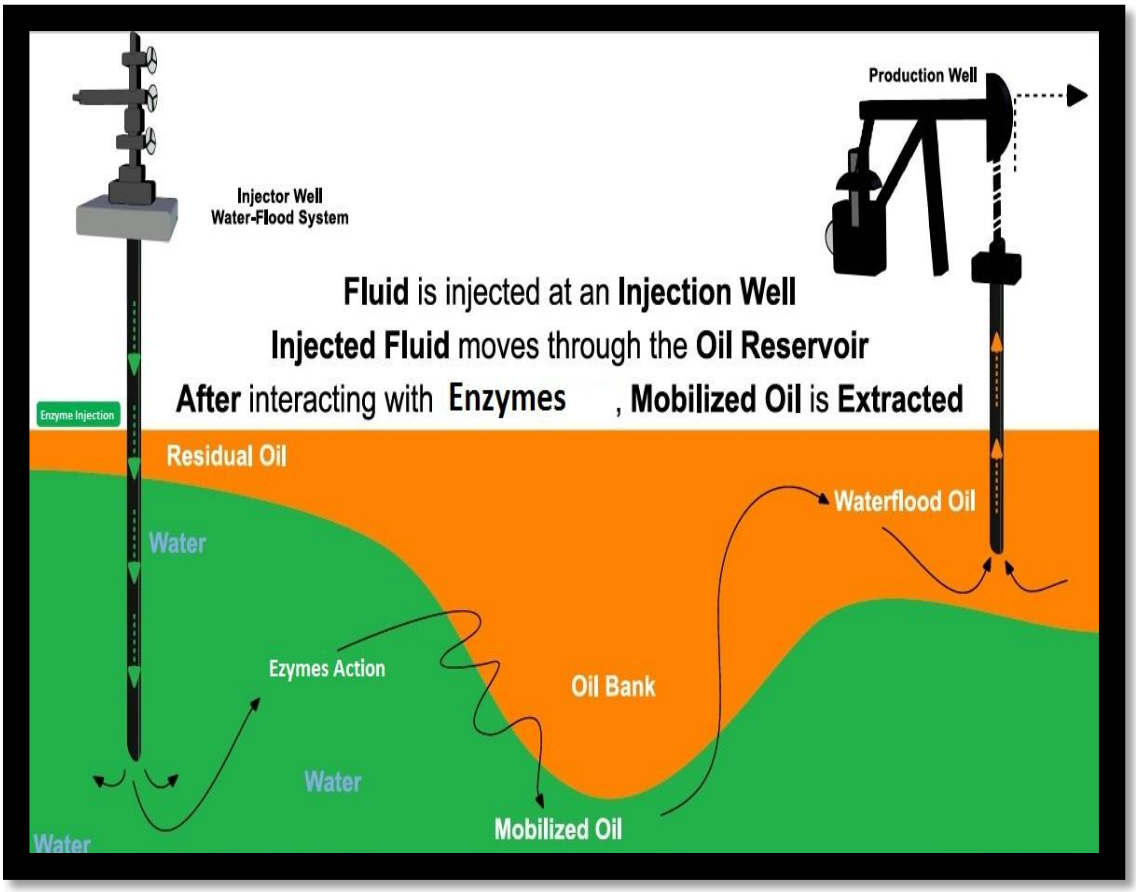


Figure 4 – *EEOR in water wet systems*



<u>Figure 5 –</u> *Enzymes in Waterflooding process*