Feasibility Study on Offshore Polymer Flooding, Forecasting Production Through Integrated Asset Modelling, A Technical and Economic Approach

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Introduction

Substantial percentage of current world oil production derives from mature fields and the rate of replacement of the produced reserves by new discoveries has been declining in the previous years. In order to sustain such upsurge in the demand for economical energy throughout the world, the recoverable oil resources in known reservoirs can be produced economically by applying EOR techniques.

The following work is a comprehensive review of offshore polymer flooding through Integrated Asset Modelling (IAM). Polymer flooding has been one of the emerging EOR techniques in offshore environement in the recent decades. The pilot implementation of polymer flooding has proved to be challenging due to the difficulties associated with the operational facilities and the high Capital Expenditure (CAPEX) required to initiate the project. Coupling the IAM technique to such project would provide valuable insight to the current and future field production levels and expected operating conditions. IAM can add essential values in areas of field and well optimization, production forecasting, operational decision making and effect of extending field life on surface and subsurface facilities.

Objectives

The objective of this work was to determine the performance and feasibility of polymer flooding in an offshore environment. Areas under scope were those such as ideal polymers for such environments, typical range of polymer concentration and slug size, injection rates, rock integrity and fracture pressure, polymer adsorption, along with the perspective need for required surface facilities such as polymer mixing unit, storage tanks, dispersion units, desalinization unit etc. The surface facilities required for such projects, which require incremental investment on platform, have proved to be an obstacle faced by the field operators in the process of polymer flooding implementation.

The execution of such projects would normally require significant initial investments which would go towards refurbishing or building the surface facilities required. Once the facilities are in place and the flooding is implemented, it would then take an average of 10 to 15 years before any significant incremental oil is recovered. To this end, it was essential to determine whether this project would be identified as rewarding considering the current oil price and the waiting time before any major lucrative incremental oil recovery.

Finally, the role that UK government has played in the recent times through the sanctioning of legislations such as Brown Field Allowance (BFA) and its corresponding effect on company's desire to tackle such projects was analysed.

Polymer Flooding

Polymer flooding is one of the chemical enhanced oil recovery mechanisms which has been used in the oil and gas industry since the late 1960s. It involves addition of water soluble polymers to injection water in order to increase injected fluid viscosity and enhance the oil displacement in the reservoir. The resulting increase in injected fluid along with the decrease in aqueous phase permeability would cause a reduction in mobility ratio, therefore increasing the volumetric sweep efficiency and lowering the swept zone oil saturation (Russell T, et al. 2014).

A typical polymer flooding consists of mixing and injecting polymer solution over an extended period of time until certain amount of reservoir pore volume has been injected. Subsequently, through long term waterflooding, the polymer slug and the oil bank will be driven towards the production wells.

Polymer Flooding Screening

In order to have an effective polymer flooding, the field under investigation needs to have the desired characteristics such as moderate reservoir temperature, permeability etc. Figure below is an illustration of screening criteria for polymer flooding.

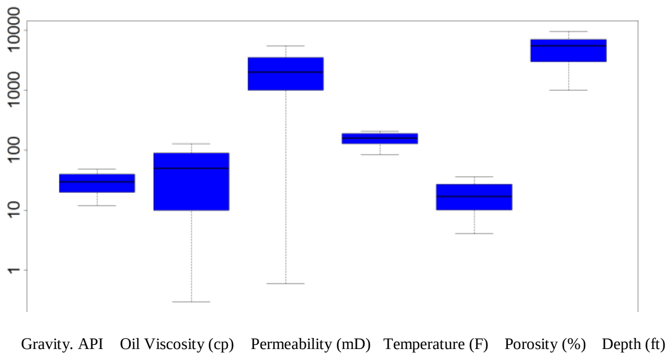


Figure 1: Illustration of the polymer flooding criteria

Polymer types and selectivity criteria

There are numerous types of polymers available in the market, however, choosing the right type of polymer out of those available is of paramount importance. In this work, Hydrolyzed polyacrylamide (HPAM) and Xanthan polymers were chosen as ideal polymers. The reason behind this decision was based on numerous factors such as their performance as a viscosifier, thermal stability, prices etc.

HPAM

More than 90% of polymer floodings around the world have been performed by HPAM. HPAM which is a synthetic type of polymer is relatively cheap compared to other types of polymers. It has high molecular weight ranging between 2 – 20 million Dalton. HPAM solution can reach high viscosity levels at low concentration. It is however known to be sensitive to temperature, salinity and hardness (Russell T, et al. 2014).

Xanthan

Xanthan is from the category of biopolymers which has an even higher molecular weight ranging between 2 – 50 Million Dalton. Compared to HPAM it comes at a higher price, however, due to its molecular structure, it has higher tolerance to temperature, hardness and salinity conditions. It is however known to be sensitive to bacterial degradation (Russell T, et al. 2014).

	HPAM	*XANTHAN*
Industrial Availability	550 Tons/year	32 tons/year
Performance as Viscosifier	Low salinity tolerance	High salinity tolerance
Thermal Stability	Threshold of 110 °F	Threshold of 150° F
Gel issues	May require filters	No experience
Prices	3 to 5 $/kg	8 to 10 $/kg
Industrial scheme	Successfully implemented	Successfully implemented
Timing	Available	Slightly less availability

Surface facilities on FPSO/Platform

The minimum required surface facilities in a typical polymer flood comprises of water treatment and mixing facilities, piping, valves, injection pumps and metering equipment. In most cases, the mixing process is operated at low pressure since there is no need of high pressure to be effective. Some of the aforementioned facilities could be the actual source of mechanical degradation of polymer. In some cases, special separation equipment is required at the surface due to the emulsion created by the produced polymer (Russell T, et al. 2014).

Figure 2 is an illustration of the surface facilities such as mixing unit, storage tanks, desalinization unit etc, on FPSO/Platform.

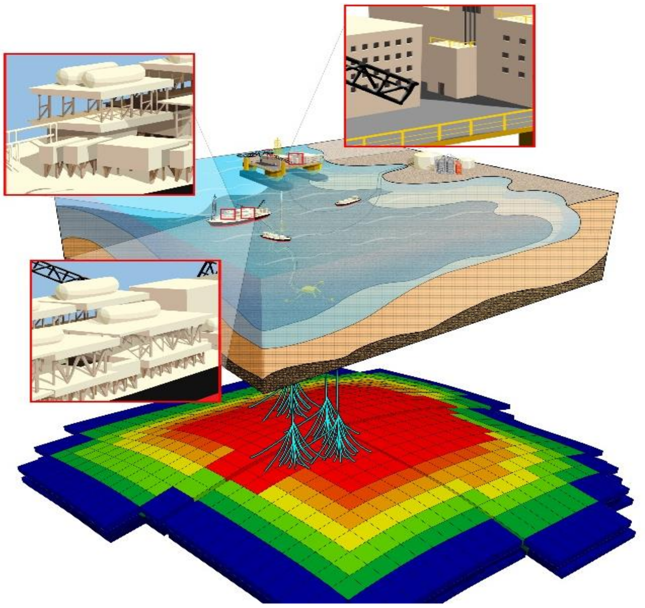


Figure 2: Surface facilities required on FPSO/Platform

Challenges associated with polymer flooding implementation and post-production surface facilities

The design, construction and operation of surface facilities for offshore polymer flooding has always been a challenging task for operators. In addition, considering the potential emulsion occurrence at production level as a result of produced polymer demands emulsion treatment facilities, oil/water separation and water disposal facilities (Binayak K, et al., 2011)

Considering the large quantity of polymer being injected on daily basis, the logistical challenges in terms of transportation, handling and storage of polymer throughout the entire supply chain, from manufactures site to floating facilities, cannot be ignored.

In some cases where the existing facilities have been in operation for years the integrity of the assets become a factor. Some facilities will be approaching their end of design life. The facilities would need to be upgraded considering the potential rejuvenation and the respective extension life of the field facilities (Binayak K, et al., 2011).

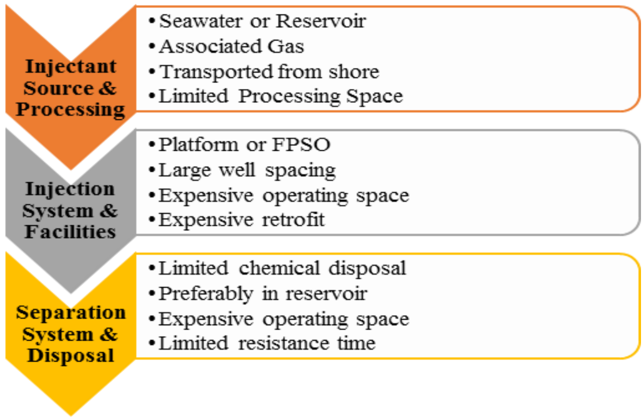


Figure 3: Challenges associated with implementation and post-production facilities required (Alvarado,V et al., 2013)

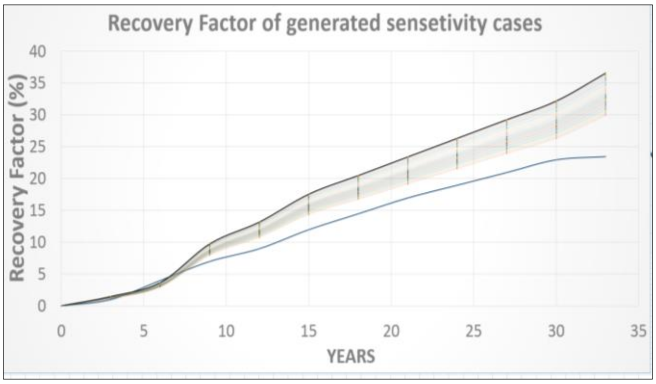
Sensitivity Analysis

Through experimental design, sensitivity cases were generated in order to envisage the factors driving the value of the project. The sensitivity parameters were categorized as technical and economic.

Technical sensitivity parameters	Economic sensitivity parameters
Shut down time	HPAM at low, mid and high cost per kilogram
Injection rate	Xanthan at Low, mid and high cost per kilogram
Polymer concentration	
Polymer flooding period	

Results

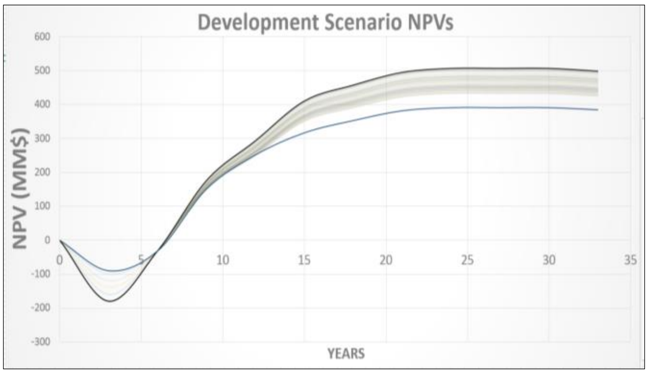
The sensitivity cases generated were then applied in simulation. The results generated indicated significant incremental recovery through Xanthan flooding. However it was not yet clear as to yet which case would be the most economically viable.



Graph 1: Summary of recovery factors obtained for polymer cases

Economic Analysis

Subsequently polymer and Waterflooding NPV cases were generated and compared



Graph 2: Summary of NPVs obtained for polymer flooding and waterflooding cases

- From the sensitivity analysis it was determined that the most sensitive parameter was the incremental CAPEX associated with the surface facilities required for polymer flooding. Small swings in CAPEX could make or destroy the value of project.

- IAM is a robust approach to incorporating the physics of facilities and fluids in the wellbore.

- During the simulation runs, it was noted that the polymer concentration, adsorption and slug size have significant effects in the effectiveness and the productivity of the flooding. The lower the polymer adsorption, the more effective sweep of residual oil in the swept zones were noted. As the polymer concentration and therefore the slug size were increased, the adsorption levels also increased. However, yet higher incremental oil was recovered with the increasing slug size. This did not indicate a linear relationship between concentration level and the incremental recovery, along with higher the polymer concentration levels, high injection rates are required. In this case the rock integrity and the corresponding fraction pressure needs to be taken into account. A reasonable polymer concentration should be used along with a sufficient rate of injection.

Conclusion

- Considering the current decline in the oil production rates in offshore field in the North Sea, in order to preserve the present production levels, incremental investments in the polymer EOR infrastructure, facilities and technologies are mandatory.

- The move of Polymer EOR to offshore environment to meet world's growing requirements for crude oil is becoming more appealing to operators, however considering the current volatility oil prices, more in-depth study needs to be carried out around the area.

- Such projects are expensive and require significant incremental CAPEX. Considering the late recovery in incremental oil and the subsequent impact on company bottom line, some operators may be more cautious to invest in such projects at this stage. To this end, companies should consider the ultimate recovery over immediate recovery when evaluating such projects.

- Governments can play significant roles when it comes to such investments on brown fields. Tax incentives for brown fields are appealing methods of promotion for the implementation of offshore polymer flooding. To this end, in September 2012 the UK government introduced a tax relief known as Brown Field Allowance (BFA) for producing fields in the North Sea with the intention of encouraging investments in mature assets therefore delaying the decommissioning. However, the sanctioning of the BFA in the recent budget proposal in the UK parliament could prove to be a step in the wrong direction in terms of encouraging companies to invest in offshore CEOR projects.

- Challenges associated with implementation of such projects in offshore environments are:
  - Platform space and weight limitations.
  - In case of remote locations it may be difficult to transport the polymers through pipeline from shore. The high shear degradation of polymers are the limiting factors.
  - Sea water can influence the performance of the polymer due to its high salinity levels. To avoid this, there would be a need for water treatment facilities on the platform (Alvarado,V et al., 2013).

- High injection rates may result in an acceleration in production, however, other limiting factors such as the rock integrity in terms of formation pressure need to be taken into account. Also, along with higher injection rates there will be higher degradation rate of polymers.

References

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