THE MECHANISMS OF POLYMER INJECTION IN OIL RECOVERY PROCESSING

LORINA MALOLLARI[1], DRILONA SAULI[1], LUMTURI HOXHA[2], LUSIVJANO LLUPI[3]

[1]Department of Energy Resources, Polytechnic University of Tirana, Albania

[2]Kolegji Universitar REALD, Vlore, Albania

[3]Bankers Petroleum Albania Ltd

e-mail: lorina.lici@fgjm.edu.al

Abstract

The purpose of this research was to study the polymer injection process and modelling of injection schemes in oil wells, thus exploring the possibility of increasing oil production from existing wells. In laboratory studies and field experiences, it has been demonstrated that this method is highly effective. The use of polymers started in the 1970s of the last century and continues, and they are still used in many locations with different characteristics. Polymer injection aims to use the ability of the polymer to reduce the water-oil mobility rate. Increasing the viscosity of the water reduces the fingering effect and causes the oil to be pushed toward the well conductor. It was considered the injection of polymer in the Patos Marinez wells in Albania. The lithology of the soil, the types of polymers, the changes in the flow rates of the wells, the rheology of the fluids, and the influence of the temperature and salinity were analysed. Petroleum is the primary source of energy worldwide. The increasing demand for fuels and energy has led to the search for new sources and the development of methods to intensify the use of existing reserves. One of the intensifying methods of oil production certainly is the methodology and technique of polymer injection into the oil-containing layers and/or existing reservoirs.

Key words: *Oil recovery, formation damage, polymer injection, water-oil mobility.*

Përmbledhje

Qëllimi i këtij hulumtimi ishte të studiohej procesi i injektimit të polimerit dhe modelimi i skemave të injektimit në puse nafte, duke eksploruar kështu mundësinë e rritjes së prodhimit të naftës nga puset ekzistuese. Në studimet laboratorike dhe përvojat në terren është dëshmuar se kjo metodë është shumë efektive. Përdorimi i polimereve filloi në vitet 1970 të shekullit të kaluar dhe vazhdon ende, dhe ku përdoren në shumë vende me karakteristika të ndryshme. Injeksioni i polimerit synon të përdorë aftësinë e polimerit për të ulur shkallën e mobilitetit të ujit dhe naftës. Rritja e viskozitetit të ujit redukton efektin e "fingering"-ut dhe shkakton shtytjen e naftës drejt tubacionit të pusit. U konsiderua injektimi i polimerit në puset Patos-Marinëz në Shqipëri. U analizuan litologjia e tokës, llojet e polimereve, ndryshimet në shpejtësitë e rrjedhjes së puseve, reologjia e lëngjeve, si dhe ndikimi i temperaturës dhe salinitetit. Nafta është burimi kryesor i energjisë në mbarë botën. Kërkesa në rritje për karburante dhe energji ka çuar në kërkimin e burimeve të reja dhe zhvillimin e metodave për intensifikimin e përdorimit të rezervave ekzistuese. Një nga metodat për intensifikimin e prodhimit të naftës padyshim është metodologjia dhe teknika e injektimit të polimerit në shtresat që përmbajnë naftë dhe/ose rezervuarët ekzistues.

Fjalë kyçe: *Rimarrja e naftës, dëmtimi i formacionit (ose dëmtimi i rezervuarit), injeksioni i polimerit, mobiliteti ujë-naftë.*

Introduction

The polymer injection process and modelling of injection schemes in oil wells have the primary aim of examining the potential for increasing oil production from existing wells, as this method is highly effective and exploits the ability of the polymer to reduce the water-oil mobility rate.

By increasing the viscosity of the water, it reduces the special division effect and pushes the oil towards the well conductor. As a case study, the polymer has been used in the Patos Marinez wells in Albania. The lithology of the soil, the types of polymers, the changes in the flow rates of the wells, the rheology of the fluids, and the influence of the temperature and salinity were crucial factors to be analysed (Peretomode, et al. 2022). One of the intensifying methods of oil production certainly is the methodology and technique of polymer injection into the oil-containing layers and/or existing reservoirs.

The most critical issues are: the types of polymers suitable for injection into oil deposits, the preparation of solutions for injection, the rheological model of the oil and the layer where the polymer will be injected, and the organisation of the geological data for the deposits where the polymer is injected in Albania, among others (Li, J. et al., 2022; Gbadamosi. at al. 2022)..

Knowing characteristics of underground fluids (water and oil), together with the other lithology indicators, it allows you to select and manipulate the method of injecting the polymer at specific concentrations and certain pressures, to make it possible to increase production from the current oil wells, increasing the oil extraction coefficient and achieving better economic results.

Polymer flooding is a chemical enhanced oil recovery (EOR) technique in which a polymer is added to the injection water, increasing its viscosity and decreasing the water-oil mobility ratio, thereby improving sweep efficiency.

This recovery method creates unique conditions that are absent in traditional water flooding, making an adequate production strategy essential to the project's success (Hassan, et al. 2022; Turgay., et al., 2023).

This work is part of a complete decision analysis process with polymer flooding. The results demonstrate the feasibility of applying polymer flooding in early heavy oil field development, yielding a better economic return than water flooding. Moreover, this work highlights the importance of using the process separately for water and polymer flooding, as incorrect decisions can be made if simple comparisons are performed (Saboorian-Jooybari. et al 2016; Guo K. et al., 2016). Polymer flooding is a chemical enhanced oil recovery (EOR) method that involves adding polymer to the injection water, thereby increasing its viscosity. These factors cause a decrease in the water-oil mobility ratio, resulting in improved sweep efficiency, which is the primary objective of any polymer injection project.

Besides the higher water viscosity, other phenomena related to polymer flooding exist, such as the non-Newtonian behaviour of the polymer solution and adsorption. Some works suggests polymer flooding to be applicable in reservoirs with oil up to 150 cP Despite that, in recent years polymer injection has been studied as a possible alternative to recovery heavy oil fields (Fang, et al.,2022), since it can reduce water cut and can improve displacement efficiency of heavy oil by lowering the mobility ratio and reducing viscous fingers.

Materials and methods

For the laboratory studies, a list of tasks needs to be performed to achieve the primary goal of the study. Essential screening and qualification processes in the following areas:

Polymer Selection: rheology analysis, filterability, thermal, mechanical, and chemical stability, porous media evaluation: adsorption, retention, injectivity, in-situ rheology, and produced water.

Water analysis: polymer detection and quantification, de-oiling, and environmental fate of polymer (Fang Q, et al., 2022).

Compatibility: Testing to determine maximum suitability with various other production chemical additives contained in specific fluids, including fluid loss control agent selection, rheology, and performance product selection for mud and cementing fluids.

Quality Assurance / Quality Control: methodologies and premium analytical expertise, wellsite measurements and related training.

Key polymer types which can be used: a) Synthetic polymers, b) *Biopolymers*: Scleroglucan and xanthan gum offer superior salinity tolerance but face biodegradation challenges (Olabode O, et al., 2024), c) *Novel polymers*: Terpolymers, d) *Hybrid methods*: Low-salinity water preflushes reduce adsorption before polymer injection.

For environmental considerations, biodegradable polymer systems need to be selected that are suitable for reducing the ecological footprint (Rellegadla, et al., 2017).

This framework integrates physicochemical damage mechanisms with polymer engineering solutions, providing a foundation for experimental or simulation-based research.

Now, let’s see what the leading causes of formation damage in oil fields are

The leading causes of formation damage in oil fields can be categorised into mechanical, chemical, biological, and thermal mechanisms. Here is a detailed breakdown:

1) Mechanical Causes: *Solid invasion, fines migration, and phase trapping. Water or gas invasion during drilling or production can result in trapped phases near the wellbore, impeding hydrocarbon flow. Compaction* *and stress effects: Mechanical* stress from production or injection can alter rock properties, leading to reduced porosity and permeability.

2) *C***hemical Causes:** *clay swelling and dispersion, alteration of wettability, precipitation of solids, emulsion formation, biological causes, microbial activity, and souring.*

3) **Thermal Causes:** *mineral transformations* and *thermal stress*.

Additional Factors

- *Water Blocking*: In carbonate reservoirs with micro-pores and fractures, capillary effects can trap water, reducing hydrocarbon flow (Mahajan, et al., 2021).

- *Operational Practices*: High flow rates, improper well completions, and poor fluid design exacerbate formation damage risks.

Understanding these mechanisms is essential for designing effective mitigation strategies to preserve reservoir productivity, as described in Fig. 1.

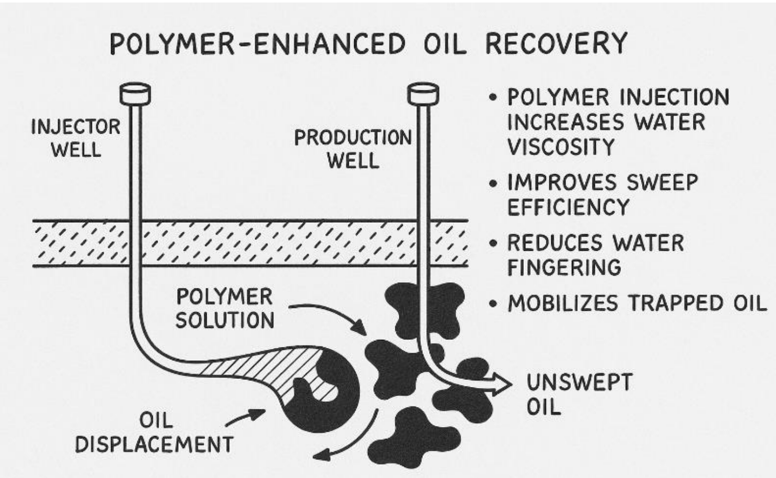

Figure 1. The mechanism of how polymers enhance oil recovery in EOR processes

Polymers enhance oil recovery (EOR) by modifying fluid dynamics and improving sweep efficiency through mechanisms rooted in their rheological and structural properties. Below is a detailed breakdown of their primary roles:

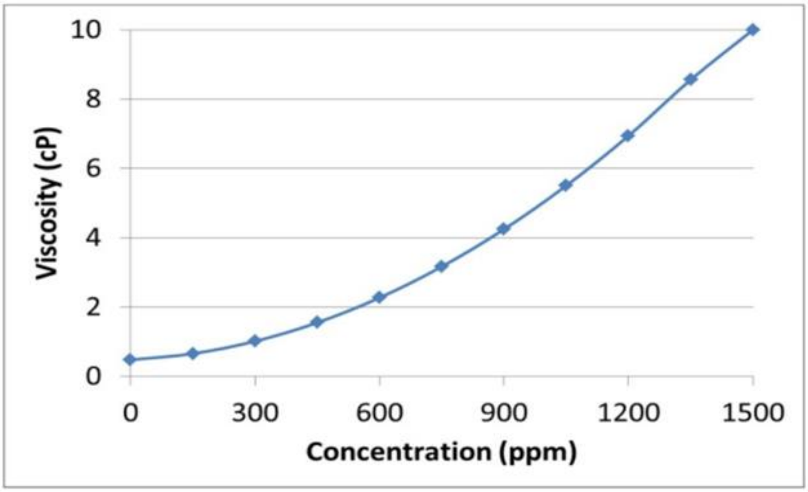

Figure 2. Polymer solution concentration vs viscosity

Additional Mechanisms

- *Disproportionate permeability reduction*: Polymers swell in water-saturated zones, thereby reducing the relative permeability of water and diverting flow to oil-rich regions.

- *Residual oil saturation reduction*: Viscoelastic flow destabilises trapped oil, lowering residual oil saturation by up to 15% in lab studies (Ahmed S, et al. 2017). Future advancements focus on smart polymers with pH and temperature responsiveness, as well as hybrid methods (e.g., low-salinity preflushes), to optimise performance in harsh reservoirs.

Results and discussion

Polymer Specificities: In this work, different concentrations can be applied to each well. The polymer solution aims to achieve a 10 cP viscosity at 1500 ppm (base value). Figure 2 shows the behaviour of the viscosity with concentration.

We presented a procedure for selecting a production strategy comparing polymer and water flooding for heavy oil field development. This process is part of a complete decision analysis, which will be performed in further work using a probabilistic approach. For the studied case, polymer flooding proved to be a feasible alternative.

The high water level produced by water flooding

(due to the presence of heavy oil) was significantly decreased when polymer was injected. Moreover, a higher level of oil production was achieved with polymer flooding, and all these factors contributed to the best economic efficiency for this recovery mechanism, despite the necessary higher investments. Due to the lower injectivity caused by the high viscosity of the polymer solution, the polymer flooding strategy required more injectors than the water flooding strategy.

Another difference in the strategies regards the position of the injectors, which were positioned closer to the producers than in the water flooding strategy. It was demonstrated that the importance of following separate processes for water and polymer flooding is to make an appropriate comparison between these two methods. Simple comparisons, such as injecting polymer in a strategy prepared for water injection, may lead to incorrect decisions, as polymer may seem inadequate if a straightforward procedure like that is employed.

The best option would be to consider the fluid that will be injected early in the field's development, thereby achieving the optimal efficiency for the project. However, it is possible to make some alterations, since the operational variables are also adjusted to be most suitable for the new injection fluid in the project.

However, it is possible to make some alterations, as the operational variables are also adjusted to be most suitable for the new injection fluid. The impact of temperature on the dissolution time of the polymer at a concentration of 10,000 ppm are given graphically in Fig. 3.

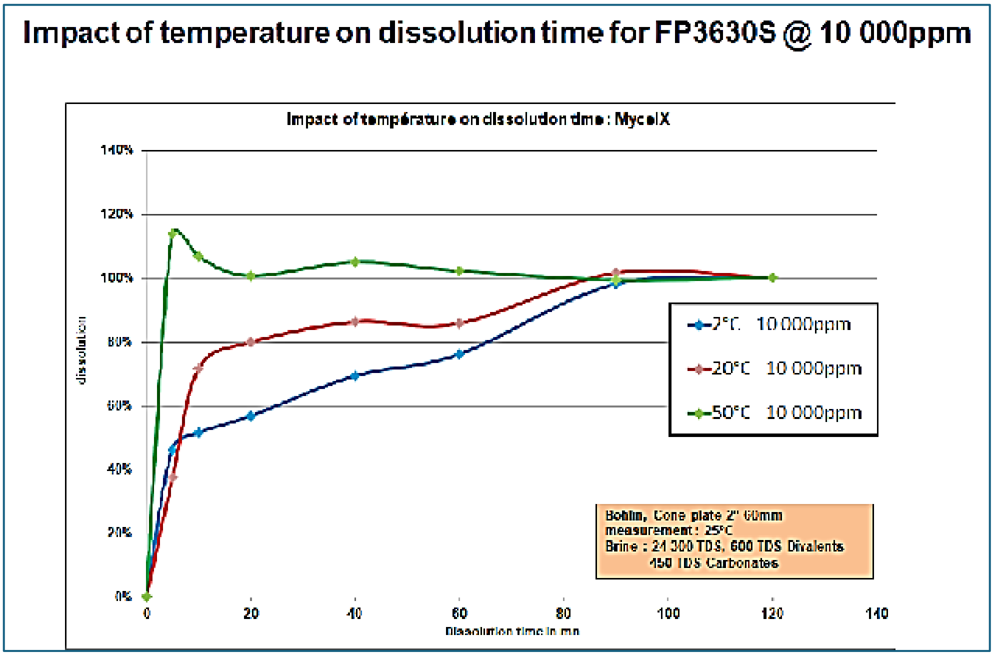

Figure 3.Impact of temperature on dissolution time of the polymer used in concentration 10000 ppm

Polymer solution preparation

After hydration and maturation of the polymer solution are complete, it is then diluted and injected without filtration into wells, according to injection rate and pressure guidelines. Nitrogen blanketing is used to preserve the polymer during the dissolution process, as shown in Fig. 4. There are different possible options for polymer flooding, depending on the preparation method used.

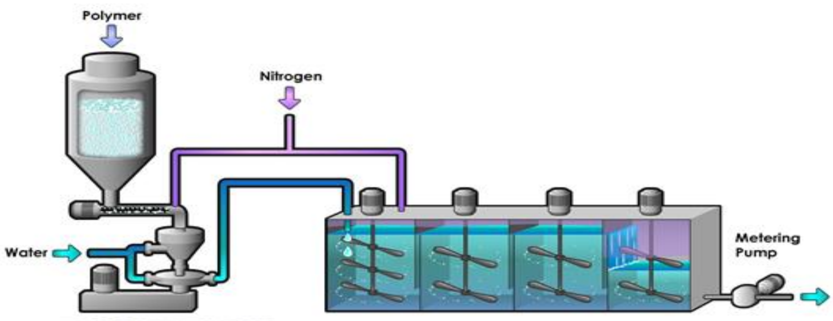

Figure 4. Equipment for polymer solution preparation

Modelling the Effects of Injection Rate

Polymer flooding

Backed by decades of successful field applications, polymer flooding represents a proven recovery technique that increases production efficiency and extends the economic life of conventional oil resources. Providing improved mobility control, the increased swept oil volume results in decreased water production and a sustained period of higher oil rate.

Polymer fluid systems are also part of Chemical Enhanced Oil Recovery (CEOR) schemes, such as Surfactant Polymer (SP) and Alkali Surfactant Polymer (ASP) floods, which are used to access bypassed capillary-trapped oil. Today, an extensive range of polymers is manufactured in both powder and liquid inverse emulsion form for application to oil reservoirs of varying conditions. The best polymer solutions can be selected based on fundamental criteria about key reservoir properties and fluids, including:

Reservoir permeability, reservoir temperature, brine salinity, oil viscosity
The following discussion outlines the findings and implications, including the benefits of polymer injection, improved recovery efficiency, and environmental considerations.

Conclusions

Use of polymers in the Albanian oil field

The application of polymers in Albania's Patos-Marinza oil field highlights both successes and challenges in managing mature reservoirs with heavy oil. Below is a key conclusions derived from field experiences regarding *effectiveness of polymer flooding.* Extended recovery in heavy oil: polymer flooding improved recovery rates in heavy oil (30–3,000 cP viscosity) by stabilising sweep efficiency and suppressing viscous fingering.

The Patos-Marinza case highlights the role of polymer flooding in extending the life of mature oil fields, provided that operational strategies evolve in response to changing reservoir conditions. Continuous innovation in polymer chemistry and hybrid enhanced oil recovery (EOR) methods remains critical to addressing Albania's heavy oil challenges. Polymer injection can impact the overall recovery rate at the Patos Marinza oil field.

Polymer injection at the Patos Marinza oil field has played a significant role in enhancing recovery rates, particularly when integrated with other enhanced oil recovery (EOR) techniques. Key impacts include: a) Initial success and peak production, b) challenges in mature reservoirs, c) synergy with thermal EOR, d) regional and operational insights, e) future potential.

Therefore, polymer injection has been a crucial component of Patos Marinza's EOR strategy, particularly when combined with thermal methods, although its efficacy is limited by reservoir maturity and energy depletion.

Some challenges have been encountered with polymer flooding in the Albanian oil fields. Polymer flooding in Albania's Patos-Marinza oil field, one of Europe's largest onshore heavy oil fields, has faced several challenges linked to reservoir maturity, operational constraints, and polymer-fluid interactions. Operational Limitations has characterized on water quality issues: high salinity (>25,000 mg/L TDS) and hardness (>450 mg/L Ca^{2+}/Mg^{2+}) in injection water degrade HPAM polymers, reducing viscosity and mobility control.

The Patos-Marinza experience highlights the importance of developing tailored polymer formulations, implementing them early, and employing hybrid strategies to address challenges in mature, heterogeneous heavy oil reservoirs. The characteristics of Albania's Patos-Marinza oil field significantly influence the effectiveness of polymer injection through several key factors: heavy oil viscosity, reservoir heterogeneity, formation water salinity, reservoir pressure decline, operational and geomechanical factors, and economic and logistical constraints.

Polymer injection in Patos-Marinza has yielded better-than-expected results in targeted zones (e.g., Lower Driza), characterised by rising reservoir pressure and a positive production response. However, its effectiveness is constrained by the field's maturity, heterogeneity, and harsh conditions. The field's unique characteristics demand adaptive polymer solutions and hybrid techniques to optimise recovery in Europe's largest heavy oil reservoir.

The Patos-Marinza field demonstrates that polymer flooding is a viable enhanced oil recovery (EOR) tool for heavy oil; however, its success hinges on adaptive strategies tailored to reservoir maturity, heterogeneity, and operational constraints. Continuous innovation in polymer chemistry and hybrid techniques will be critical for maximising recovery in this complex field.

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