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# Polymer and its Role in EOR and Water shut-off Process

**Pulkit Chaudhary[1], Saket Kumar[2] and Srinivasa Reddy D.[3]**

[1,2,3]*DIT UNIVERSITY*

*E-mail: [1]pulkit.chaudhary03@gmail.com, [2]itssaket@gmail.com, [3]devarapusrinu@gmail.com*

**Abstract—***Enhanced oil recovery (EOR) discoveries have created newer ways and advance technologies which aid in producing more hydrocarbons from reservoirs. The latest advancements in this domain are better modelling of reservoir, advanced bottom-hole technologies, and efficient chemicals for improved hydrocarbon recoveries. It is the most important need of petroleum industry and has got priority because in today's scenario, 50 to 60% of hydrocarbon production from reservoirs is through EOR. Thus the urge to get better unit recovery and recovery factor is the main driving force for such advancements. Before 1985, India used to export hydrocarbons to all over the world but today, due to the ever growing energy needs, India is a net hydrocarbons importing country. The capacity of hydrocarbon production of the country is decreasing vigorously. According to experts, when a new well is drilled, a total of just 30 to 40% of reservoir fluid is recovered initially. Application of EOR technology gives an additional chance to get out more oil from the reservoir, possibly about another 20%. Polymer is the material that plays an important role in the application of EOR technology. The most widely used polymers are surfactants and hydro-gels. In the technology, surfactant polymer is injected to the reservoir to reduce an interfacial tension between oil and water and is able to wipe out the trapped oil from the reservoir rock and hence increase the oil production. While an injection of hydro-gel polymer to the reservoir is to increase a viscosity of fluid containing water so that the fluid is more difficult to flow than the oil, and as a result, the oil production increases. Thus, in order to understand role of polymers in enhanced oil recovery and water shut off process, an attempt has been made to review different polymers and their significance in these processes.The abstract is to be in fully-justified italicized text, at the top of the left-hand column as it is here, below the author information.*

## 1. INTRODUCTION

Polymer is an important material that emphasis its major role in EOR technology. These polymers are water soluble polymers which are insoluble in oil and alcohol. They have molecular weight in millions and are used in aqueous solutions at concentration of .1 to 1 ppm. Polymer solutions are very viscous when the dilution is increased. The usual obtained viscosity is in range of 10 to100 cp. There is always a reduction in mobility if there is an increase in viscosity of a fluid but the mobility of solutions in porous media is usually less than predicted value. For polymers, the reduction effect is displayed using the concept of mobility reduction. It is defined as the ratio of mobility of water to the mobility of water containing polymer. A typical polymer flood project involves mining and injecting polymer over an extended period of time until about 1/3-1/2 of the reservoir pore volume has been injected. There is an interaction between the macro molecular chains and the solid matrix in porous media. It causes a loss of polymer both by adsorption and the physical trapping within the course. It is the nature of porous medium and concentration of polymer solution that determines the amount of polymer retained by a matrix. After the injection of polymer slug, it is then followed by continued long term water flooding to drive the polymer slug and oil bank in front of it toward the production well. Polymer is continuously injected to reach the desired pore volume since long time. Addition of polymer into reservoir increases the viscosity of water and reduces relative permeability of water in the reservoir then increases oil recovery due to increase of flow. By the application of mobility ratio, water soluble polymer can be used to increase viscosity of water phase. On reducing the permeability of water to the porous rock and thereby creating a more efficient and uniform front to displace oil from the reservoir. The injection of polymers in porous media causes a permanent reduction to mobility to water. The mobility of oil practically remains same. Polymer gel treatment is one the most effective gel treatment application in reservoir. Polymer gels have the capability to flow through fracture and also strong enough to withstand high pressure difference near well bore. Polymer solutions make large chains which could be broken from the process of violent agitation. There are a number of methods for this process such as ultrasonic homogenizing which reduces small particles in a liquid to improve uniformity and stability. Polymer water flooding is normally applied when the heterogeneity of the reservoir is high. Fig. 1 illustrates the flow sequence of polymer water flooding process.

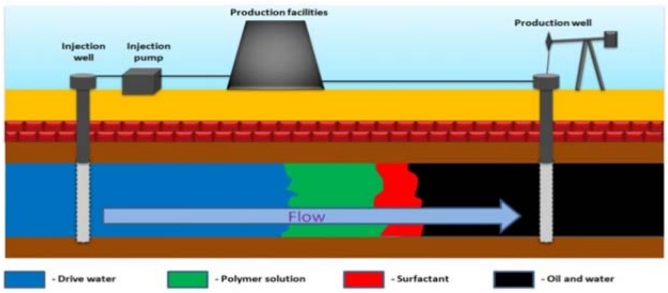


**Fig. 1: Illustration of polymer water flooding**

There are three types of basic polymers as illustrated in fig2 which are linear polymers, branched polymers and cross-linked polymers. For the production of excessive water or gas flow cross-linked polymers are generally put into application. Cross linking provides higher tensile strength, improves cut through, displays better crush resistance, better over load characteristics, improved fluid resistance etc. There are two types of cross linker in polymer:-**Organic polymer system and metal ion cross linker.** Organic polymer system is more predictable to change of reservoir temperature, component concentration, brine type, salinity and pH value. From the laboratory test data result, organic cross linker can penetrate into formation eight times as far as traditional chrome based polymer. Organic cross linker is an eco-friendly system it also took less job to mix and pump to the field. Chrome based cross linker is the most common use for metal ions cross linkers. Al (+3), cr (+3), cr (+6) are all the components of metal ions cross linkers. Polymer gel is also known as cc/AP gels can be applied in broad pH range and also has a wide range of gel strengths. Cc/AP gels can be both used as water shut off treatment and sweep improvement treatment.

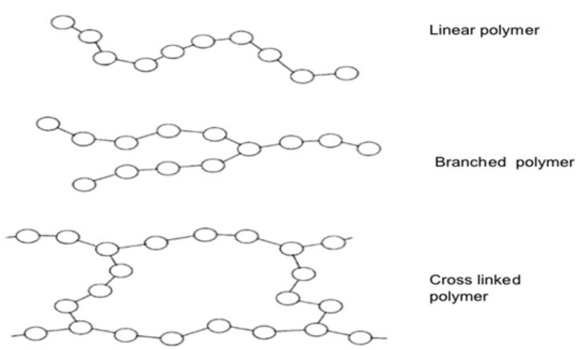


**Fig. 2: Types of polymers**

A. *Polymers used in enhanced oil recovery*

Polyacrylamide gels- It is basically a synthetic polymer. The performance of polyacrylamide is dependent on two factors molecular weights and its degree of hydrolysis. Polyacrylamide gels are used to reduce water cut in production wells and also used to control profiles in injectors. Formations up to 66 degrees have been treated rather routinely. These gels are used at high temperature containing relatively hard brines. A number of studies have been done with these gels cross-linked with trivalent chromium and aluminium with c-13 NHR. Now the cross linking ions formed will react with occasional carbohydrate group distributed. Dynamic rheological studies have been carried out with cross linked polyacrylamide gel by varying the gel strengths while keeping the temperature, salinity and cross linker concentration constant. The viscosity of polyarcyamidiles solution is greatly reduced by the presence of salts. Therefore the possibility of getting contaminated because of interstitial water of polymer solution prepared using this polymer is high and is therefore a disadvantage of using polyacrylamide as a polymer for EOR.

**Nano size micro gels -** Recently Wang et al. (2010) proposed the use of crosslinked polyacrylamide (PAM) Nano spheres for in depth profile control this is generally done to improve sweep efficiency. It is speculated that owing to Nano size, water absorbing selectivity brine tolerance, high water absorption, good dispersion in water, low aqueous solution viscosity, Nano spheres have the property that they can easily migrate into the high permeability zones (channels of low resistance to flow) where the nanospheres would swell due to their high water absorption capacity blocking off the thief zones. Micro gels nanospheres are the most recent used polymer gel in the EOR for several years (tang et al, 2003; James et al, 2003; Frampton et al, 2004; cozic et al, 2008), however its indeed a great pity for the considerable emulsifiers injected together without distinct decrease of IFT, so to discover new directions for the application of these emulsifiers and to probe into their roles in profile control and oil displacement it will be of great value. Diesel oil, sorbitan monoleate, polyethylene glycol sorbitan monostearate, acrylamide, n, n- methylene bisca acrylamide, and deionized water were employed separately as the oil phase, emulsifier, cross linker and aqueous phase to prepare the inverse micro emulsion. Diluted by cyclohexane, the once polymerized and twice polymerized micro gel nanospheres were separately pictured by transmission electron microscopy (TEM) made by JEOL, JAPAN.

**Hydrolyzed polyacrylamide(HPAM):-** HPAM is the most often used polymer in EOR applications especially because of its relatively low price with good viscosifying properties, and well known physicochemical characteristics. HPAM is more preferred because its implementation is easy and can improve significantly the oil recovery rate under the standard reservoir condition. Weight of the polymer weighs up to 30 million and can be used for temperature up to 99 c depending on brine hardness. More modified form such as HPAMAMPs copolymers and sulphonated polyacrylamide can be used up to 104 and 120 c. it is produced generally as free flowing powders or as self-inverting emulsions. Many reports revealed that it shows high sensitivity of salinity, presence of oil or surfactants and other chemicals.

**Xanthan gums:-** It is produced by microbial actions of xanthanonascampestris on a substrate of carbohydrate media, with a protein supplement and an inorganic source of nitrogen. The biopolymer is formed on the surface of cells and that's why we usually called extracellular slime. Xanthan gums show great performance in high salinity brine. It is relatively compatible with most surfactants and other injection fluid additives used in tertiary oil recovery formulations. Some recently report revealed that xanthan type polymer usually has cellular debris that can cause plugging. Beside it has significant hydrolytic degradation above 70 c. some companies tell that now by the help of special manufacturing techniques it can impart its thermal stability up to 105 c. this polymer is usually injected coincide with effective biocide to prevent microbial degradation.

Xanthan gums are now shortened to xanthan, and are widely used in an oil field. Xanthan is basically a microbial biopolymer, produced by the fermentation of glucose, sucrose or lactose by the xanthamonas compestris bacterium that are present in xanthan in d-glucose, d-mannose and d-glucuronic acid. Enhanced oil recovery will be an important use of xanthan gums in the next decades. The basic principle applied is to improve the separation of water and oil thereby would increase oil recovery. Xanthan gum is used in micellar polymer blooding as a tertiary oil recovery.

**Bright water (popping gel):-** The method is based on flow diversion by swelling and agglomeration of micro-gel particles in the injection water. Temperature plays an important role for the activation of injected particles. The chemical are regarded as 'red' with respect to HSE and thus it should not be used on field where produced water is not re-injected, as in the case on the veslefrikk field.

Following points should be taken in consideration when evaluating a potential candidate for bright water:-

- Available movable reserves
- Early water break through to high water cut
- Problem with high permeability contrast
- Porosity of highest permeability zone>17%
- Permeability of thief zone>100md
- Minimal reservoir fracturing
- Temperature from 50 to 150 c
- Expected injector producer transit time>30 days
- Injection water salinity under 7000ppm

The bright water method focusses on the reduction of permeability of thief zones deep within the oil reservoir to achieve more efficient displacement of the oil to the producing well. Bright water development was seen as having only one injected component with is considered its essential feature. Also the density should be close to that of an injection brine to minimize segregation. The bright water concept was based on that of a particle which could inject and propagate with the water flood through the pores of rock matrix, then after a temperature change in the thief zone or after a certain time, would increase in volume (popping) once popped, interactions with pore throat were intended to be the means of delivering water resistance factor.

**Colloidal dispersion gels:-** According to the fielding et al. (1994), CDG is a solution containing low concentration of high molecular weight polymer and a cross linker that has a slow rate of formation and is considered semifluid. Injection well inject the CDGs micro gels for the purpose of improving vertical and real conformance deep in heterogeneous 'matrix rock' of sandstone reservoirs, while maintaining high temperature stability. CDG gels flow a high pressure differentials and resist flow at low pressure differentials.

Mack and smith reported a summary of 29 CDG projects in the rocky mountain area. CDG technology generated attention in china (zhidong et al. 2011) other regions in the U.S. (manrique and lante 2011) and more recently in Argentina (Diaz et al. 2008; huruga et al. 2008; menconi et al. 2013). However despite numerous successful fields results reported in the literature, laboratory scale experiments (al-assi et al. 2006; ranganathan et al.1998; seright 1994 and 2013) have generated controversy regarding the ability to inject CDGs in large volumes without reducing injectivity while also improving sweep efficiency.

Spilo et al. (2009and 2010) demonstrated that CDG aged a few days could propagate through Berea cores and increase oil recovery at irreducible oil saturation to water. Castro et al. (2013) recently validated that CDG (aluminium citrate) freshly made or aged for one.

**Application of polymers in water shutoff methods:**

Water production in oil producing reservoirs is the major problem facing by the oil industry in nowadays.

As most of the fluids in nature , reservoir fluids also tends to follows the path of less resistive from where it can migrate in reservoir, which are due to heterogeneous nature of the rock.

Heterogeneity of a rock mainly divided into two levels. The first is micro scale heterogeneity which is simple porous, feature distribution and the second one is macro scale heterogeneity. It includes layering, natural or induced fractures and high horizontal and vertical permeabilities. This can lead to poor results and hence need to be controlled, the conduits of water needs to be controlled if they are available in order for production well to continue operation. In order to compensate permanent losses, decrease production decline rates and activate recovery from a reservoir, a large number of workover operations are carried out to cut the watered intervals. The most important role in this domain is given to water shut-off works.

Water Shut-off treatments in production wells are a common routine operation and are a part of standard well service work. A number of methods are used extensively for water shut-off operation such as cement squeezing, mechanical isolation, gel-based treatment, and polymer gel treatment.

The most extensively used methods among the above mentioned techniques is polymer gel treatment. The treatment procedure is as follows. Firstly inaccessible drains are cleaned with a jetting tool, then a temporary chemical plug is set. After this a acid- soluble cement plug is set. After this pressure testing is done. The next step is to perforate the zone and perform injectivity test. In the next step, cross-linked gel polymers are pumped in. Then micro fine cement is pumped in. Pressures are again tested. Plugs are then cleaned out with a jetting tool. Usually after this, water is eliminated by high percentages and full oil production is restored.

Injection of polymers and gels in production wells is a well known technique for reducing water influx. The action of polymers help in reducing water production from high permeability layers in order to let oil and gas flow from low permeability layers. The result is achieved by reducing the relative permeability of water to the relative permeability of oil. The literature reports that a total of near 45% of near wellbore gel treatments are successful (Martin et al.. 1991). However, environmentally safe products are desirable because many products contain toxic components such as chromium, phenol etc. The polymer injection process consist of a simple injection of limited amount of chemicals, therefore the control and success of this operation requires the combination of several areas of expertise.

## 2. CONCLUSION

There is a big hope that polymer can play an important role in increasing production of oil well to bring out all of us from the current energy crisis since applications of polymer flooding in the enhanced oil recovery (EOR) field has shown some successes to recover more than 20% additional oil from OOIP. HPAM is one of the most common polymers used in the EOR so far, although its properties suffer sharply due to oil salinity and high temperature (more than 70 qC). Superabsorbent polymer composites (SAPc) give a light in overcoming this problem. SAPc has capability of swelling and retaining possibly huge volumes of water in swollen state and its stability in temperature and salinity can be improved such as by copolymerization and reinforcement.

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