

Polyvinyl Alcohol with Superior Flooding Properties to Enhance Oil Recovery Process

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Abstract: Polymer flooding is one of most important Enhance Oil Recovery (EOR) processes. This study concerns two key parameters influencing polymer flooding efficiency. As it is expected, some of key parameters such as: salinity and reservoir temperature and pressure, play important roles in improving oil recovery through polymer flooding. Regarding the fact that Hydrolyzed Poly Acryl Amid (HPAM) decomposes in high temperature and pressure conditions, only reservoirs with medium temperature and pressure are suitable for polymer flooding technique. On the other hand, viscosity of polymer solution decreases in high reservoir salinity, therefore HPAM is not effective for reservoirs with high salinity and temperature. We strongly believe that Poly vinyl Alcohol (PVA), as a viscous surfactant and IFT reducer, would be stable in extreme conditions of high salinity and high temperature (above 480° F) and therefore, it can be used for reservoirs with high salinity and temperature.

Keywords: Polymer flooding, PVA, Salinity, Temperature

INTRODUCTION

Polymer flooding is one of the chemical flooding techniques that improve water flooding oil recovery by controlling the mobility of aqueous phase in reservoirs. In fact, polymer solution can increase both volumetric and displacement efficiencies (Silva *et al.*, 2010). Partially Hydrolyzed Polyacrylamide (HPAM) is widely used in water treatment as well as in EOR processes to displace more oil and increase the recovery efficiency of water flooding process by modifying the water/oil mobility ratio and hence improving sweep efficiency, as an anionic coagulant (Zeynali *et al.*, 2004). During the standard water flood operation, the sweep efficiency is not as good as desired, because the mobility of water stream is higher than oil which leads to the bypass of the oil zone in a finger shape and break into the well bore at the early stage of the process (Perry *et al.*, 1982; Du, 2004; Alban and Gubitta, 1999). Water mobility enhancement through the viscous behavior of PHPA solutions has an important role in improving oil recovery efficiency when soluble polymers are added to water, solution viscosity will be increased owing to the high molecular weight of polymer. Hence, during the flooding tests, the mobility ratio of

water to oil reduces and as a result, more sweep efficiency will be obtained. Polymer solutions injection as an EOR technique has been studied by many researchers. Polymer solution which has less mobility compared to fresh water can increase the sweep efficiency around 10% OOIP. In 1964, Perry and Sandiford expressed that partially Hydrolyzed Poly acryl amide (HPAM) could reduce the mobility of displacing water by increasing its viscosity (Wang *et al.*, 2006; Alban and Gubitta, 1999). In 2007, Zhang and Seright considered the suitable conditions for polymer flooding in oil reservoirs and expressed that polymer flooding stability was subjected to mechanical degradation as well as salinity and temperature. High temperature causes polymers degradation by radical scission and decomposition. Furthermore, the high salt concentration might decrease efficiency of a polymer solution (Zhang and Seright, 2007). Kotler and Helle (2007) investigated the influence of combination of polymer (mobility control agent), surfactant (IFT reducing agent) and a small bi-functional molecule (increasing solubility agent and reducing salinity effect) during flooding to enhance oil recovery factor and deduced that oil recovery can be increased by 20% of OOIP (Original oil in Place) (Kotler and Helle, 2007). This work will

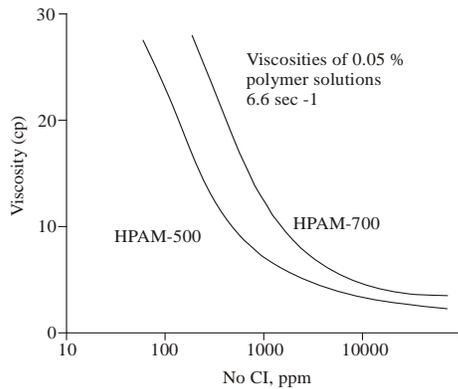


Fig. 1: Effect of brine salinity on viscosity of 0.05 polymer solution (Alban and Gubitta, 1999)

investigate a new polymer having some advantages which enable it to overcome the obstacles encountered by polymer flooding at high temperatures and high salinity compare to HPAM.

Extreme salinity and temperature: The high salt concentration decreases efficiency of a polymer solution, especially by decreasing its viscosity. Figure 1 illustrates the effect of salinity on the viscosity of Dow Pusher 500 and 700 Polyacryl Amide solutions (Du, 2004). At some salinity level, the relative viscosity of PHPA becomes constant (Perry *et al.*, 1982). It is concluded that HPAM is not a good candidate for the reservoirs with high salinity. On the other hand, Polymers are very sensitive to the thermal effect. At high temperature, the rate of hydrolysis of polyacrylamide polymers is significant over reservoir time scales. Thus, the hydrolysis and the corresponding change in viscosity as the polymer flows through the reservoir, should be taken into account. It is believed that most of the polymers decompose at high temperatures and their applications will be hindered. Previous works in this area showed that the reservoirs with temperature higher than 300°F should usually be avoided for using HPAM (Mohammad *et al.*, 2008). In addition, temperature rise leads to a delay in achievement of full adsorption on the rock surface. Therefore, more pore volume of polymer solution is necessary (Sharma and Huh, 2010). Also, water viscosity slightly decreases with increasing temperature (Wonham, 1967).

MATERIALS AND METHODS

Poly Vinyl Alcohol (PVA): PVA is a water soluble hydrophilic polymer and is the largest volume synthetic resin produced in the world (Briscoe *et al.*, 2000). Excellent chemical resistance, physical properties and biodegradability lead to the development of so much produced based on this polymer. PVA is used as an emulsifier and as a stabilizer for colloidal

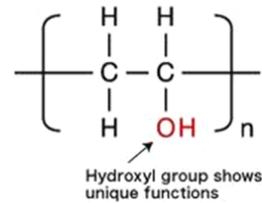


Fig. 2: Molecular structure of polyvinyl alcohol

suspensions as a sizing coating in the textile and paper industries and as an adhesive too. The degree of hydrolysis influences the polymer behavior in the solution. The viscosity of solution, surface tension and other properties can be related to the degree of hydrolysis. The molecular structure of this polymer confirms the unique functions of this polymer (Fig. 2).

Laboratory measurement procedure: To investigate the effect of salinity and temperature on this polymer solution, a number of experiments in different conditions were conducted. First, Polyvinyl Alcohol with the degree of hydrolysis of 87% and degree of polymerization 1700 was prepared in Sina Company (Located in Arak, Iran). Then, solution was made in different concentrations and the viscosity of each solution was measured accurately in the same condition. In next step, NaCl with different concentrations was added to solution in order to make a solution with required salinity. This study was carried out in Polymer and Petrochemical Institute (IPPI) located in Tehran, Iran between August and September 2011.

RESULTS AND DISCUSSION

Effect of salinity on PVA solution: As expected, experimental results confirmed that with adding NaCl to PVA solution, its viscosity not only decreases with increasing salinity, but increases and therefore, this polymer will be stable at high salinity. Adding PVA to water lowers the surface tension effectively and surface tension of aqueous PVA solution decreases significantly with increasing NaCl concentration. It is significantly important that PVA is not decomposed at high concentrations of NaCl. Maximum viscosity has been observed at 1.2 wt% NaCl. Therefore, in oil reservoirs with high salinity, this polymer could act as a viscous surfactant and it can be used. Figure 3 illustrates the viscosity of PVA NaCl solution in different concentrations.

Effect of temperature on PVA solution: To evaluate the effect of temperature on PVA polymer solution, some other experiments were done. In this case, PVA solution in various concentrations was prepared and the solution was heated up to 482°F, and it was observed that PVA solution could sustain temperature up to 482°F without

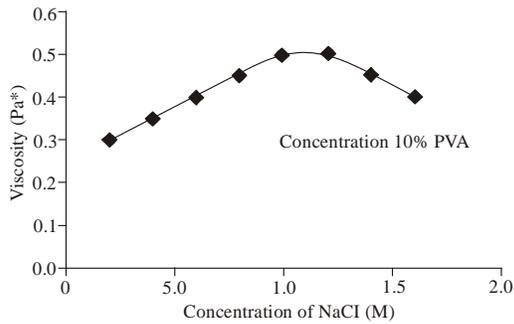


Fig. 3: Effect of NaCl additions on viscosity of PVA solution

missing its property and our experiments indicated that this polymer is stable at high temperatures, confirming previous study showing thermal decomposition of PVA takes place at temperature above 480°F. The same was done for HPAM solution and it was observed that thermal decomposition of HPAM takes place above 250°F.

CONCLUSION

Although the HPAM solution is commonly used for polymer flooding, but we strongly recommend PVA because of its Thermal and electrolyte stability and IFT reduction compare to HPAM. Since concentration of cationic components such as Na^+ , Ca^+ and Mg^{2+} have negative effect on HPAM solution and viscosity of the HPAM solution decreases in high salinity condition, HPAM will not be a good candidate for highly saline reservoirs. Because viscosity of PVA solution increases in high salinity and also can act as gel polymer in very high salinity, it could be used for polymer flooding in oil reservoirs with such an extreme conditions. Accordingly, HPAM is decomposed at high temperatures and reservoirs with temperature higher than 300°F should usually be avoided for using HPAM, while PVA, due to its thermal stability can be utilized in reservoirs with high temperature above 480°F.

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