Investigation of Propagation and Permeability Modification of Grafted Bentonite Particles in Porous Media

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***Abstract*— In oil and gas industry, excess water production is a major problem that leads to early well abandonment and unrecoverable hydrocarbon. Gel treatments at the injection wells to plug the thief zones are cost-effective methods to improve sweep efficiency and reduce excess water production. Yet, the stability of gel particle when subjected to high temperature still remain questionable. A new waterflood experiment with the introduction of grafted bentonite particles as the plugging agent is proposed to provide a solution to this uncertainties. Propagation and permeability modification process by grafted bentonite particles involved in the treatment and conditioning of high permeability porous media is investigated. The permeability modification and resistance factor are inferred by measurements of pressure differentials with time across the sandstone core by using core flood experiment. Propagation of grafted bentonite particles are observed by using Scanning Electron Microscope (SEM) and present of particles in effluent. The effective mechanism of the consecutive plugging process during the flow of grafted bentonite particles through the sandstone core are identified and the best-estimate values of their rate coefficient are determined. This study reveals valuable information about the functional trend of porous media plugging by grafted bentonite particles which is essential for successful mitigation of formation plugging in the field.**

Keywords*— *propagation, permeability, bentonite, core flood

I. INTRODUCTION

Water production is one of the main obstacles that always creates crisis to oil producing companies. For each barrel of water produced, the process uses the same amount of energy or even more compared to the energy required to produce 1 barrel of oil. Environmental regulation imposed has become the factor on why water production reduction is very important in oil and gas industry[4]. In order to ensure effectiveness of water flooding treatment, the thief zone need to be plugged to guarantee the aim of the treatment achieved by the end of the operation. In this study, grafted bentonite has been identified to be used as permeability reducing agent in high water producing zone. Thus, parameters such as propagation and adsorption of grafted bentonite particle, residual and resistance factor and effect of grafted bentonite on injection pressure will be studied upon the injection process to identify its effectiveness in permeability plugging. Many reservoirs have extremely hostile environments that are well outside the limits of many water soluble polymer applications. Therefore, polymer gels and preformed polymeric gel placement, thermal degradation and strength are important factors in determining the efficiency of permeability reduction and hence improving hydrocarbon recovery [1]. The stability limits of most water-soluble polymers used in EOR remain questionable and unresolved[4]..

This study is focused on transportation of grafted bentonite in porous media and post injection permeability reduction factors. In the first section of this paper, methodology of preparing and injecting the grafted bentonite are described. Then the main results of coreflooding and permeability reduction factors are presented and discussed.

II. METHODOLOGY

First, Grafted bentonite particles has been chosen as permeability plugging agent in this experiment. All particles investigated here were prepared by free radical polymerization according to Ahmed, A. A. (2015). The particle size of the grafted bentonite was determined by Dynamic Light Scattering (DLS). The colloidal core of the particles consists of bentonite (Figure 1) from which long chains of poly (N-isopropyl-co-Acrylic Acid) are covalently grafted. The grafted bentonite

particles are characterized with regard to their size (average 2 µm at pH 7 and 1 µm at pH 9) and viscosity almost water-like viscosity (1 cp).

Sandstone core were cut into short for the core flooding experiment. The dimension of the core was 7.7 cm in length and 3.8 cm in diameter. Caliper was used to ensure every core has the same dimension throughout the experiment. The core was put in the oven for at least 6 hours and at 120 °C before they were vacuumed and saturated with desired brine. Potassium chloride was used in this experiment to prepare all brines. Potassium chloride brine with 3.5wt% was used. Core flood system (Figure 2) was used to determine the permeability reduction from injecting grafted bentonite particles.

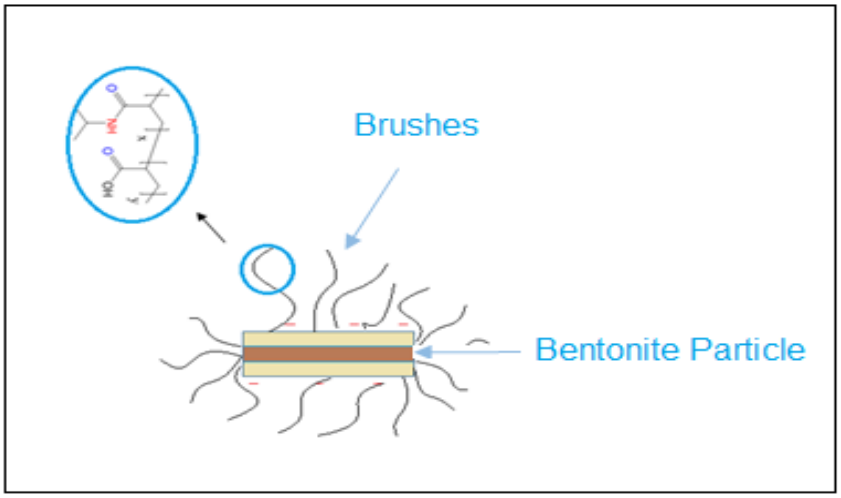

Fig. 1. Schematic representation of the grafted bentonite investigated in this study. poly(N-isopropyl-co-Acrylic Acid) chains are grafted from colloidal particles made from bentonite clay. (Ahmad A. A., 2015)

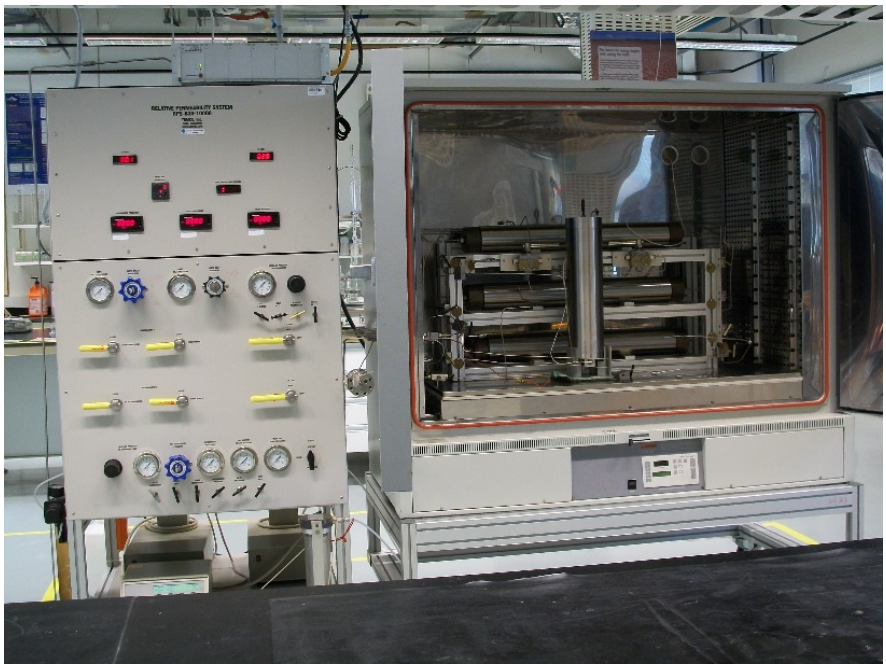

Fig. 2. Schematic representation of core flood system

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III. RESULTS AND DISCUSSION

A. Coreflooding experiment

Figure 3 and 4 show the experimental results of pH 7 grafted bentonite particle size. From the above figure, higher flow rate have higher resistance factor and residual resistance factor. This implies that higher permeability reduction is observed with higher flow rate. From the residual resistance factor, the thickness of grafted bentonite deposited on the surface of porous media is estimated. With high residual resistance factor, more plugging has been resulted. The nature of the grafted bentonite particle that deforms enable it to plug permeability efficiently when high velocity is applied. With low flow rate the big particle is not having sufficient energy to deform plug permeability.

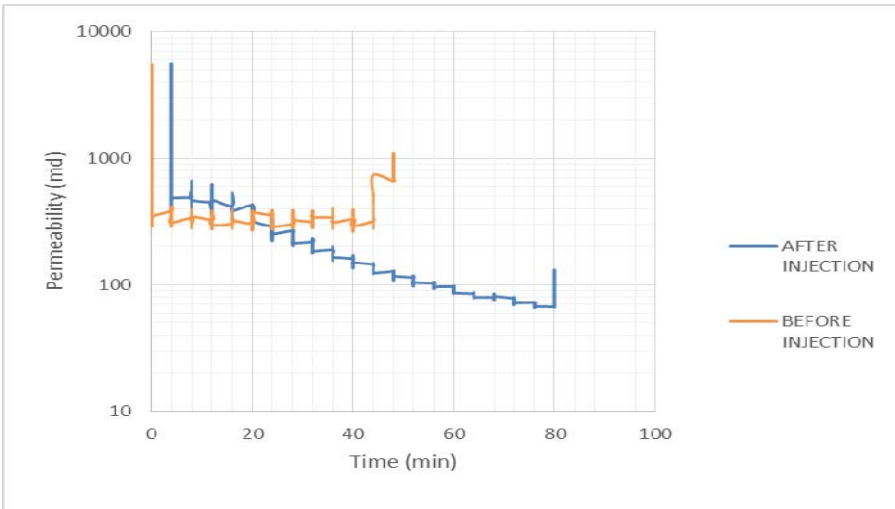

Fig. 3. Permeability reduction at 1.0 cm^3 per min for pH 7 particle size

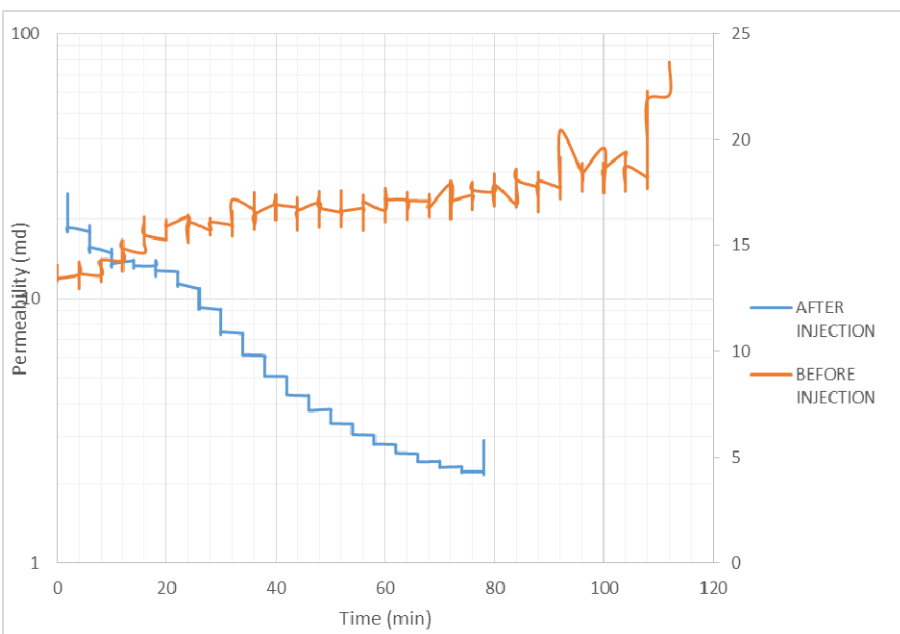

Fig. 4. Permeability reduction at 0.5 cm^3 per min for pH 7 particle size

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For smaller particle size which is pH 9, less permeability reduction is observed. From figure 5, the effect of high velocity influence the reduction in permeability. However at a lower flow rate, the permeability reduction increases significantly. From the results in figure 6, the smaller particle size need low flow rate in order for it to function well.

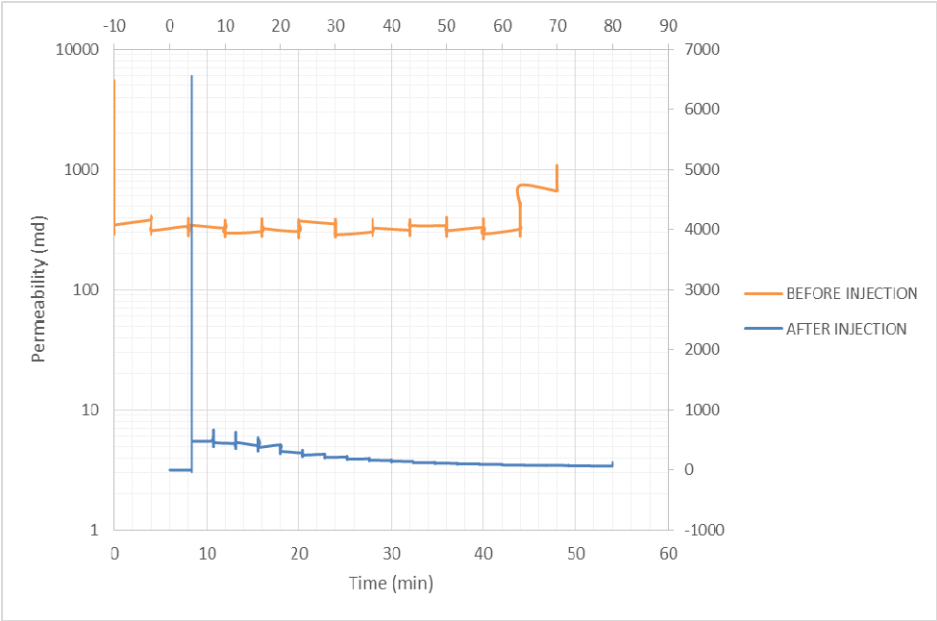

Fig. 5. Permeability reduction at 1.0 cm^3 per min for pH 9 particle size

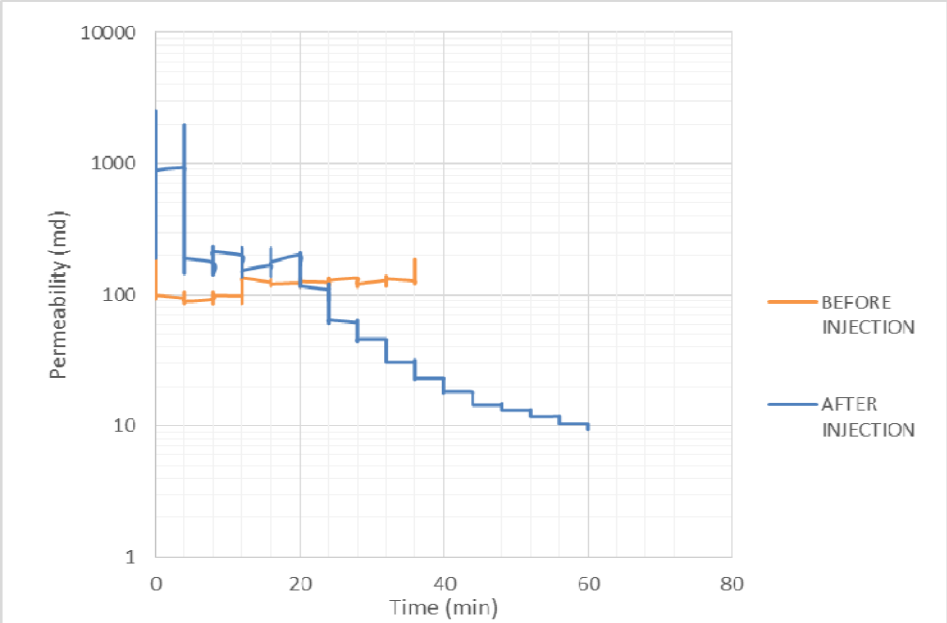

Fig. 6. Permeability reduction at 0.5 cm^3 per min for pH 9 particle size

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TABLE I. RESISTANCE FACTOR AND RESIDUAL RESISTANCE FACTOR

Flow Rate	Particle Size	Resistance Factor	Residual Resistance Factor
0.5 cm3 per minute	pH 7	8.44	6.22
1.0 cm3 per minute	pH 7	16.25	23.00
0.5 cm3 per minute	pH 9	10.17	12.86
1.0 cm3 per minute	pH 9	5.00	6.00

B. SEM Results

The results from SEM analysis are as attached in figure 7 to 10. For pH 7 particle size, the differences from the SEM results is not varying significantly. The grafted bentonite particles deposits on the core surface and reduces permeability.The grafted bentonite particle is well distributed. For pH 9 particle size, the grafted bentonite particle is observed to be more distributed at 0.5 cm^3 per min flow rate. This supports the results from the resistance factor and residual resistance factor calculation that shows more permeability reduction compared to 1.0 cm^3 per minute flow rate. In each experiment, the effluents collected is observed to confirm the propagation of the bentonite particles in the sandstone core.

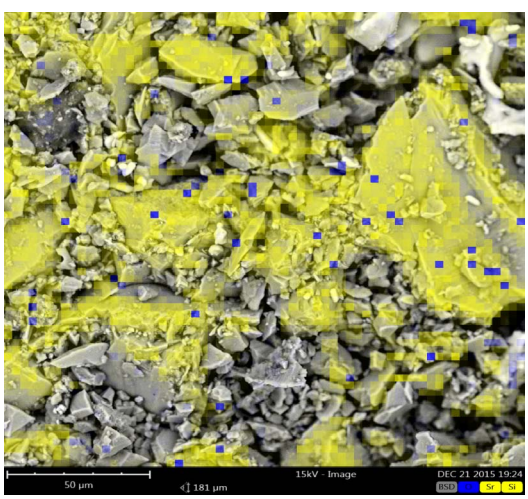

Fig. 7. SEM analysis for pH 7 at 0.5 cm3 per minute

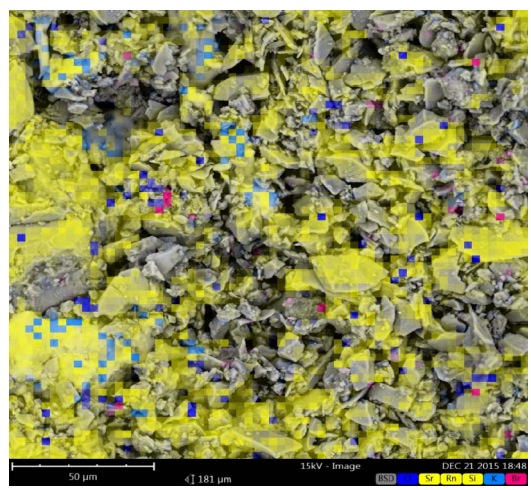

Fig. 8. SEM analysis for pH 7 at 1.0 cm3 per minute

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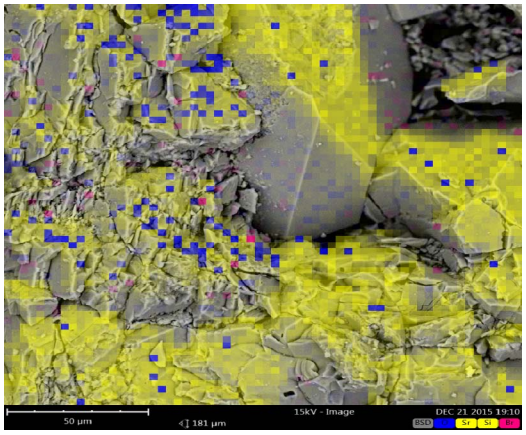

Fig. 9. SEM analysis for pH 9 at 0.5 cm3 per minute

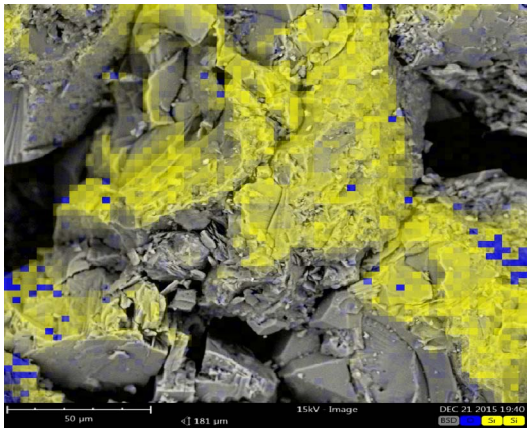

Fig. 10. SEM analysis for pH 9 at 1.0 cm^3 per minute

IV. CONCLUSION

The aim of this experiment is to identify the best working mechanism for grafted bentonite particle as permeability modification agent. 2 flow rates and 2 particle sizes has been identified to be used for this experiment. Different particle size has its own optimum working velocity and flow rate thus more studies need to be conducted to identify the working trend of grafted bentonite particles as permeability modification agent.

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BIOGRAPY

Nurul Hanisah is a petroleum engineering student of Universiti Teknologi Petronas currently majoring in production technology. She is working on her final year project regarding the potential of grafted bentonite particles as permeability modifier. .

Abdulazim Abass is a reservoir engineer and currently pursuing his doctorate in Universiti Teknologi Petronas. Has been working in the oil and gas industries especially in Sudan and working on studies to discover potential of grafted bentonite particles in enhancing water flooding

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