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# Investigating the Effect of Polythin and Polydrill on the Properties of Drilling Fluids

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## Abstract
In this study, synthetic sulfonated polymers were used in order to enhance the rheological properties of drilling fluids. The capability of these polymers in reducing the effects of environmentally friendly, but harmful, pollutants such as cement, calcium chloride, gypsum as well as pH changes were investigated. In the present work, two sulfonated synthetic polymers, namely Polythin and Polydrill, which are considered to be environmentally friendly polymers, were used. Polydrill controls the fluid loss and is resistant to high temperatures and also pollutants. The injection of this polymer into drilling fluid slightly increases the viscosity levels. Polythin prevents the precipitation of bentonite at high temperatures and facilitates fluid pumping by reducing its rheological and static shear strength. Polythin polymer also prevents the formation of bentonite gelation (precipitation of bentonite) at higher temperatures and is stable up to 260 °C. This polymer is also capable of completing the effects of fluid loss additives and reduction of filtration in HTHP drilling fluids. Furthermore, this polymer reduces rheology, strength, and static shearing values and facilitates pumping of the drilling fluid. The combination of aforementioned polymers improves the thermal resistance of drilling muds while maintaining the rheology and reducing the amount of filtrate for HTHP drilling fluids. In these experiments, the rheological properties of the fluid including apparent viscosity (AV), plastic viscosity (PV), yielding point (YP), gelation resistance or gel strength (GEL), fluid loss (FL), and the pH of the fluid were studied before and after the addition of the pollutants. The results indicate that certain proportions of these two polymers increase the rheological properties of drilling fluids and can significantly change the weight percentages of pollutants. It is also notable that the rheological properties were normally constant. However, in some cases, smaller values of rheological parameters enhanced the efficiency in the presence of pollutants. In the case of calcium chloride, rheological parameters (AV, PV, YP, and gel strength) are almost constant, while fluid loss greatly increases.

**Key words:** Drilling Fluid, Rheology, Filter Loss, Sulfonated Polymer, Contamination Tolerant Additives, Environmentally Friendly

## Introduction
The injection of drilling fluids into a well serves different purposes. One of the most important ones is to transfer drilling debris from the bottom of the well to the surface. Drilling fluids undergo significant changes by the passage of time and therefore their chemical compositions have successively been modified [1]. They are normally composed of a liquid and a solid phase. The liquid phase is usually water (salt, fresh, or sea water). The solid phase may include weighting materials, viscosifiers, and fluid loss controllers. Nowadays, various polymers, which can be in the form of natural (e.g. starch), synthetic, and/or modified (e.g. carboxymethyl cellulose or CMC) polymers, are used in order to control the fluid loss and viscosity. Drilling fluids should be environmentally friendly and contain the lowest possible amount of pollutants. Therefore, care should be taken in the selection and formulation of raw materials [2].
The main and most effective parameters regarding the efficiency of such polymers are temperature, bacteria, pH changes, and the concentrations of salt present at the drilling site. It is obvious that higher temperatures result in the decomposition of polymers. Thermal decomposition is one of the limiting factors in the application of polymers as drilling fluids. This can be compensated by the injection of new polymers. However, decomposition rates significantly increase at elevated temperatures [3]. Organic polymers constitute by far the largest group of

filtration control additives. Important members within this group are starch and cellulose gums like carboxymethyl cellulose and PAC. Recently developed synthetic organic polymers provide superior HT stability and electrolyte tolerance compared with the semi-synthetic starch and cellulose products [4].

The thermal limit of cellulose type polymers necessitated the use of the temperature stable vinyl sulfonate/vinyl amide (VS/VA) copolymers during the rather early stage of making the hole. In many cases, these copolymers provided sufficient $Ca^{2+}$ and temperature stability, but their major disadvantage was excessive cost [5].

The presence of salt and bacteria also reduces the efficiency of polymers. The transformed polymers are stable up to certain concentrations of salt, but decomposition begins at higher concentrations. Another factor to be considered is acidity or basicity levels of drilling site. At high pH values and in the presence of calcium ions, polymers begin to hydrolyze and consequently lose their properties. Also, polymer chains may get trapped in cavities and lower the efficiency. Under these conditions, certain amounts of acid should be applied in order to minimize the harmful effects [3].

In this study, two sulfonated synthetic polymers, namely Polythin (Pt) and Polydrill (Pd) were used; these polymers are considered to be environmentally friendly polymers. Polythin is a highly active solution of synthetic polymer thinner, which is soluble in fresh water and salt muds. The product is a brown liquid with a density of approximately 1.3 kg/l and a pH of 7.0-7.5. It contains no heavy metals and is environmentally safe [6]. Polythin controls the high temperature gelation of bentonite and other clays in all water based drilling fluids and prevents their flocculation at high temperatures up to 205 °C (400 °F). Polythin stabilizes a mud against most contamination by salt, calcium, magnesium, and $CO_2$. This is due to its unique chemistry, which tolerates all common drilling fluid contaminants [7].

Polydrill is a sulfonated polymer fluid loss control additive (Figure 1), which stabilizes rheology in a wide range of drilling and completion fluid systems.

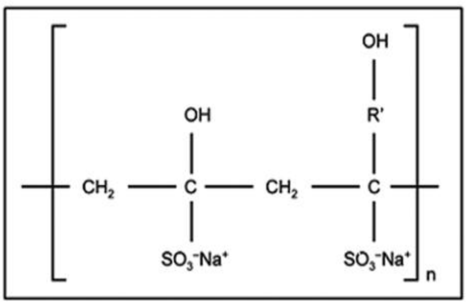


**Figure 1-** Polydrill polymer structure

Polydrill is resistant to most forms of contamination to which drilling fluids may be exposed. Polydrill is resistant to sodium and KCl to the point of saturation. Polydrill also tolerates high levels of calcium and $CO_2$. Polydrill performs effectively where contamination, high temperature, and elevated densities occur. Polydrill is non-damaging to the formation and environmentally safe [8]. The polymer has a molecular weight of 200,000, which gives it the advantage of slightly increasing rheology. Polydrill achieves fluid loss control by reducing the pore size of the filter cake and plugging these pores. The polymer has an enormous water binding capability, which ties up much of the free water. Polydrill controls the fluid loss amounts and is resistant to high temperatures and pollutants. An injection of this polymer into drilling fluid slightly increases the viscosity levels and is therefore usually added to high density solid phase (2.4S.G-20 lb/gal) in the temperature range of 65-230 °C (150-450 °F) [9]. One of the outstanding features of Pd polymer is its stability in seawater based mud systems in the presence of calcium or salt, which makes it the best option for the reduction of fluid loss in high temperature and high pressure (HTHP) muds. Another characteristic of this polymer is the reduction of friction rates, which results in lower torque, drag values, and the adhesion of pipes to the surface of well. Pt polymer also prevents bentonite gelation at higher temperatures and is stable up to 260 °C (500 °F) [5]. This polymer is also capable of completing the effects of fluid loss additives and reduction of filtration in HTHP drilling fluids. Furthermore, this polymer reduces rheology, strength, and static shearing values and facilitates pumping of the drilling fluid. Therefore, using low amounts of this polymer makes it possible to transform a gelated mud into its initial condition. The combination of Pd and Pt enhances the thermal resistance of the drilling fluids and reduces the filtration amounts of HTHP fluids while having the lowest effect on rheology [10].

## Experimental

While drilling, different pollutants might penetrate through the mud system and therefore change its properties. Among these are calcium chloride, gypsum, and/or unhardened cement present in the well. Also, the presence of harmful corrosive or acidic gasses such as $H_2S$ might change pH and other properties of the drilling fluid. Therefore, these pollutants should be taken into account while designing the drilling fluids. This can be achieved by the addition of suitable additives in order to avoid any change in the chemical composition of the drilling fluid.

An attempt was made to study the effects of pollutants such as $CaCl_2$, $CaSO_4$, and cement and pH changes caused as a result of NaOH and HCl addition. Also, various properties of the drilling mud such as rheological behavior, fluid loss values, and pH were measured at ambient temperature, before and after the addition of pollutants.

As stated earlier, experiments were carried out to study the effects of pollutants on the behavior of Polydrill and Polythin polymers. The polymers were prepared by BASF Company. Generally, the following experiments were done:

Note: These concentrations of Pd (Polydrill) and Pt (Polythin) are the optimum concentrations obtained from previous tests.
- Investigating the effects of the addition of 6 lb Pd and 2 lb Pt on the properties of the drilling fluid containing 20 g of $CaCl_2$.
- Investigating the effect of $CaSO_4$ addition on the properties of polymeric mud containing 6 lb of Pd and 2 lb of Pt.
- Investigating the effect of cement addition on the properties of polymeric mud containing 6 lb of Pd and 2 lb of Pt.
- Investigating the effect of pH on the properties of polymeric mud containing 6 lb of Pd and 2 lb of Pt.

In these experiments, the rheological properties of fluid including apparent viscosity (AV), plastic viscosity (PV), yielding point (YP), gel strength (GEL), fluid loss (FL), and pH of the base mud before and after the addition of the pollutants were studied. The base mud composition and properties are given in Table 1.

**Table 1-** Base mud composition and properties before contamination

| Base Mud Composition | | |
|---|---|---|
| Fresh Water | ml | 350 |
| Sodium Chloride | g | 70 |
| Polydrill | g | 6 |
| Polythin | g | 2 |
| Salt Water Clay | g | 24.5 |
| Base Mud Properties | | |
| Apparent viscosity | cps | 3.75 |
| Plastic viscosity | cps | 3 |
| Yield point | lb/100ft$^2$ | 1.5 |
| Gel strength $10_{sec}/10_{min}$ | lb/100ft$^2$ | 0/0.5 |
| pH | - | 7.45 |
| API filter loss | ml | 10 |

## The Effects of $CaCl_2$ Added on Drilling Fluid Properties Containing 6 lb Pd and 2 lb Pt

In this test, the mud properties of contaminated base mud (without Polydrill and Polythin) with 20 g of calcium chloride were measured before and after the addition of 6 lb of Polydrill and 2 lb of Polythin. The results of these experiments are presented in Figure 2. It can be observed that the rheological properties of mud are almost constant, but fluid loss values have drastically decreased. This means that the addition of Pt and Pd to the fluid has greatly reduced the fluid loss values.

## The Effect of $CaSO_4$ Added on Polymeric Mud Properties Containing 6 lb Pd and 2 lb Pt

In this experiment, 1, 3, and 5 lb of gypsum were added to the base fluid (Table 1). The rheological properties, fluid loss, and pH values were measured before and after the addition of gypsum. The results are shown in Figures 3-4. It can be concluded that:
- Higher values of $CaSO_4$ have no effect on the apparent viscosity (AV). This means that the pollution of the drilling mud does not change AV.
- Higher gypsum additions reduce the plastic viscosity (PV), while the yield point (YP) of the fluid slightly increases at 5 lb.
- Gel strength is nearly a constant value. Although the addition of gypsum is expected to significantly increase the fluid loss, the presence of Pd and Pt has caused a slight increase in this value. Also, pH remains constant in the system.

It can be concluded that these polymers do not allow $CaSO_4$ pollutants to change the rheological properties of the drilling fluid and even in some cases these properties are enhanced. Also, a slight increase in fluid loss in the presence of gypsum is one of the unique effects of these polymers.

## The Effect of Cement Added on Polymeric Mud Properties Containing 6 lb Pd and 2 lb Pt

Similar to previous test, the properties of the base mud were studied before and after the addition of 1, 3, and 5 g of cement (Table 1).

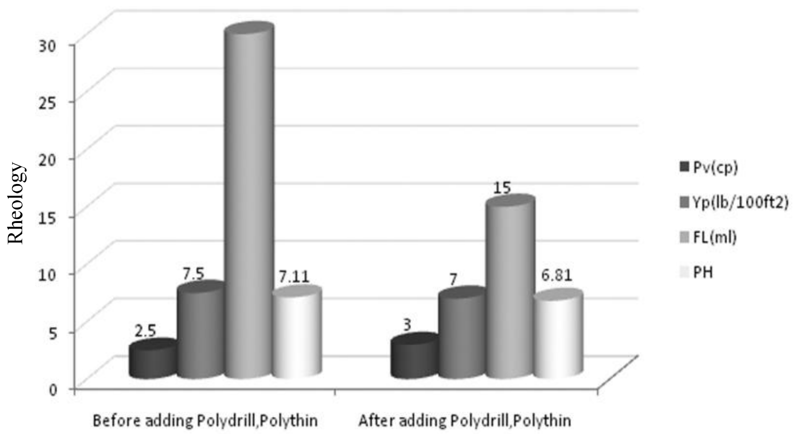


**Figure 2-** Effect of the addition of 6 lb of Pd and 2 lb of Pt to the drilling mud in the presence of $CaCl_2$

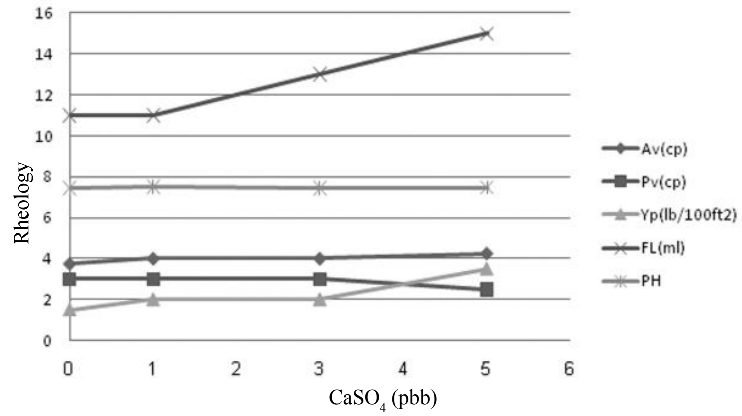


**Figure 3-** Effect of $CaSO_4$ on the properties of the polymeric mud containing 6 lb of Pd and 2 lb of Pt

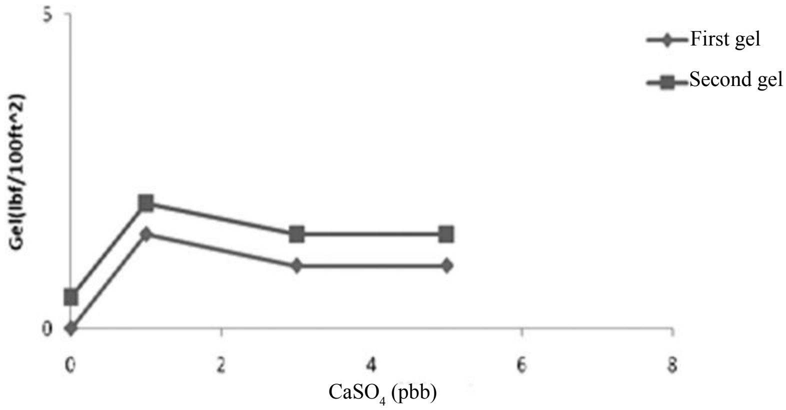


**Figure 4-** Effect of $CaSO_4$ on the gelation properties of the polymeric mud containing 6 lb of Pd and 2 lb of Pt

Figures 5-9 have been drawn based on these results and one may summarize the results obtained as follows:

- According to these diagrams, the rheological properties of the drilling fluid have been enhanced in the presence of cement. Therefore, Pd and Pt polymers are very efficient in the presence of cement.
- FL values slightly increase at higher contents of cement. This means that these polymers have neutralized the harmful effects of cement on drilling fluids.
- The basicity index of the system is constant even after the addition of cement.

According to Figure 9, pH increases to 10 and then remains constant. This is due to the presence of Pd and Pt polymers.

**Investigating the Effect of pH Values on Polymeric Mud Properties**

In these series of tests, the pH values of base muds were controlled by the addition of NaOH and HCl and rheological properties and FL were studied. The results are presented in Figures 10-11. As it can be seen, AV and PV are constant at higher pH values. These two parameters begin to decrease at the pH values equal to or greater than 10. YP was constant throughout the test and FL changes were inconsiderable. It can be concluded that pH values do not have any effect on the efficiency of the system.

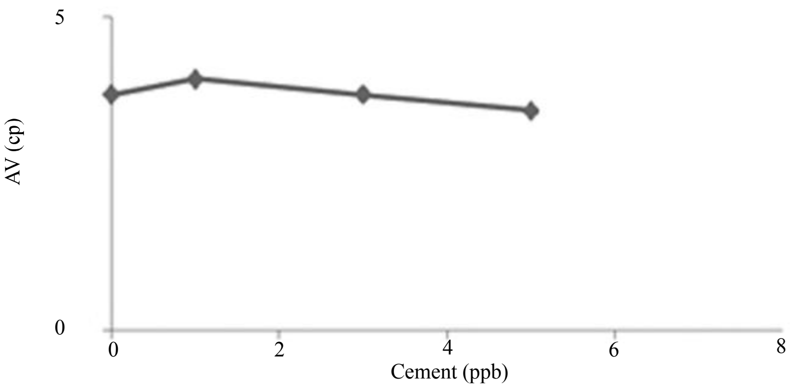


**Figure 5-** Effect of cement on the apparent viscosity of the polymeric mud containing 6 lb of Pd and 2 lb of Pt

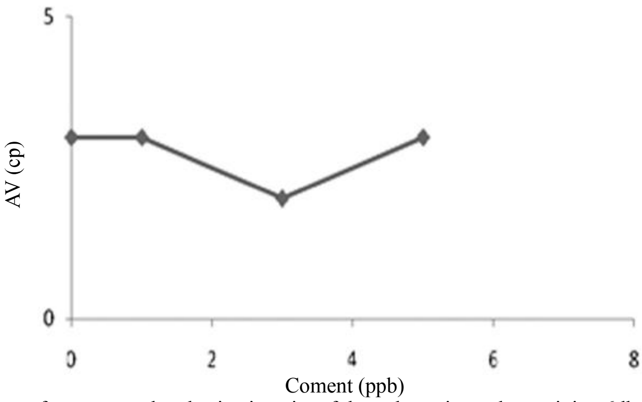


**Figure 6-** Effect of cement on the plastic viscosity of the polymeric mud containing 6 lb of Pd and 2 lb of Pt

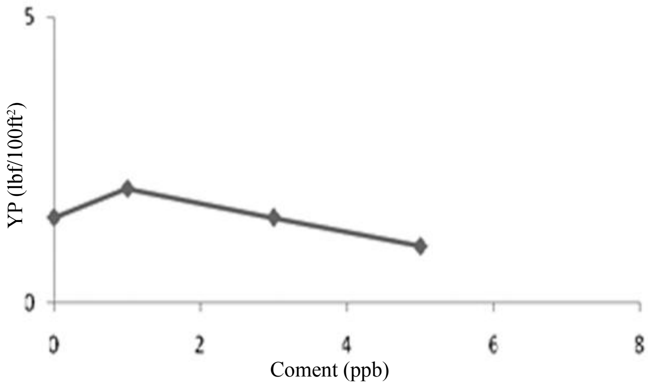


**Figure 7-** Effect of cement on the yield point of the polymeric mud containing 6 lb of Pd and 2 lb of Pt

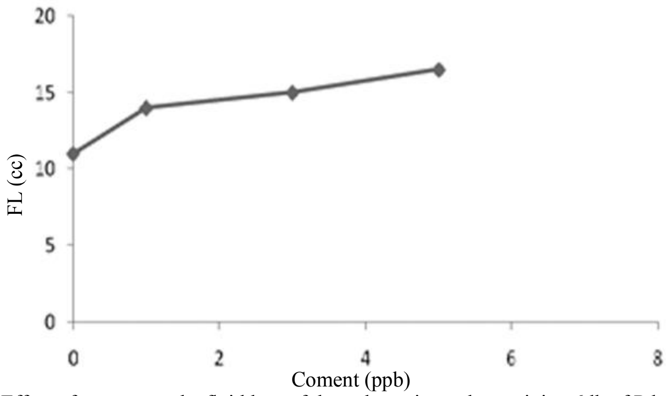


**Figure 8-** Effect of cement on the fluid loss of the polymeric mud containing 6 lb of Pd and 2 lb of Pt

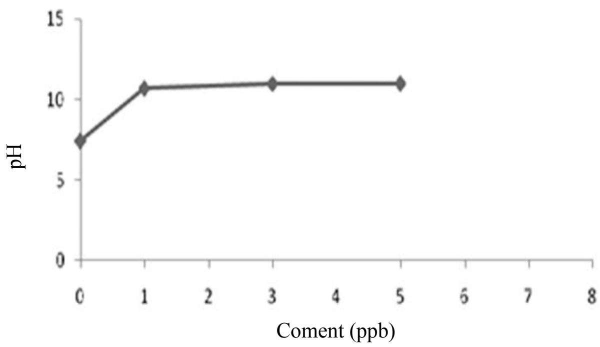


**Figure 9-** Effect of cement on the pH of the polymeric mud containing 6 lb of Pd and 2 lb of Pt

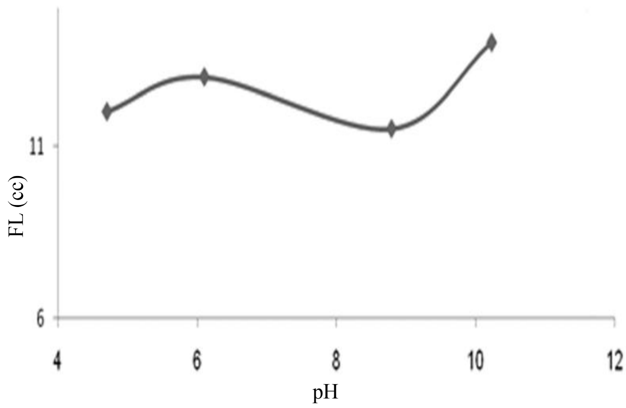


**Figure 10-** Effect of pH on the fluid loss of the polymeric mud containing 6 lb of Pd and 2 lb of Pt

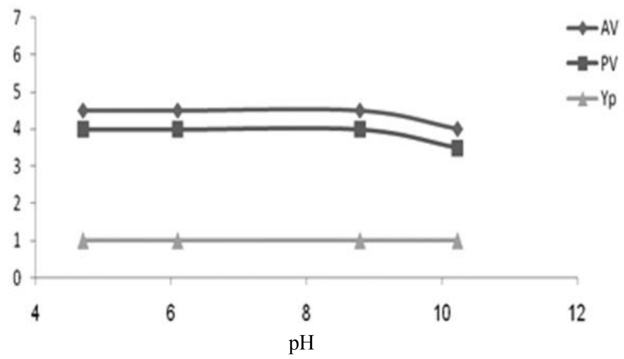


**Figure 11-** Effect of pH on the rheological properties of the polymeric mud containing 6 lb of Pd and 2 lb of Pt

## Conclusion

In this study, the effects of synthetic sulfonated polymers on the properties and efficiency of drilling fluids were investigated in the presence of pollutants such as cement, calcium chloride, and gypsum at different pH values. The results indicate better rheological properties due to the presence of such polymers. In the case of calcium chloride, rheological parameters are almost constant, while FL has greatly increased. The addition of cement and gypsum results in smaller values of rheological parameters, while it causes a slight increase in FL. Also, pH changes lead to smaller AV and PV values. However, YP and FL are nearly constant.

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