TECHNICAL NOTE

EFFECTS OF SALINITY, pH AND TEMPERATURE ON CMC POLYMER AND XC POLYMER PERFORMANCE

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Abstract The rheological and filtration properties of drilling mud under down-hole conditions may be very different from those measured at ambient pressures and temperatures at the surface. This paper presents the results of an experimental investigation into the temperature and salinity and pH effects on drilling mud rheological and filtration properties. Results are given from tests on water base mud containing CMC polymer and XC polymer. Drilling fluid was investigated at three different temperatures (21.1°C, 48.9°C, 80°C) containing 8.165Kg/bbl bentonite. The drilling mud salinities in this study were fresh water (Ahwaz water: ppm: 400, Hardness: 120), 2000 ppm, 4000 ppm, 8000 ppm and 40000 ppm. It was found that pH of drilling mud should be kept at range of 8-10, because increasing pH of drilling mud will increase its rheological properties. The salinity and temperature effects show that as the salinity and temperature of drilling mud are increased the effectiveness of polymers in drilling mud will decreased. Moreover, they have a negative effect on filtration properties of drilling mud. In suspensions of sodium montmorillonite that are well dispersed and have low gel strength, both plastic viscosity and yield point decrease with increasing temperature.

Keywords Salinity, pH, Temperature, CMC, XC, Polymers, Drilling Fluid

چکیده تاثیر خصوصیات رئولوژیکی سیال حفاری با خصوصیات آن در شرایط آزمایشگاهی گاهی کاملا" متفاوت است. در این مقاله به بررسی روند تغییر رفتاری ترکیب سیال حفاری تحت تاثیر حرارت، شوری، pH و خصوصیات رئولوژیکی پرداخته ایم. نتایج بدست آمده از یک سری آزمایش ها روی گل پایه آبی ساخته شده در این مقاله تحلیل شده است. مایع حفاری بر اساس دوسری آزمایش در دماهای ۲۱/۱ و ۸۰ درجه سانتی گراد دارای ۸/۱۶۵ Kg/bbl کیلوگرم بنتونایت در هر بشکه بوده است. آب استفاده شده برای سیال حفاری بترتیب آب اهواز با شوری ۴۰۰ پی پی ام و سختی ۱۲۰، ۲۰۰۰، ۴۰۰۰، ۸۰۰۰، ۴۰۰۰۰ بوده است. نتایج بررسی و آزمایش ها مشخص نمود که pH سیال حفاری باید بین ۸ تا ۱۰ باشد زیرا افزایش pH باعث افزایش تغییر رفتار رئولوژیکی گل می شود. بعلاوه آزمایش‌ها نشان داد که با افزایش شوری و درجه حرارت تاثیر پلیمرهای CMC و XC کاهش می یابد. بخصوص مشخص گردید که تاثیر منفی روی خصوصیات روان روی سیال حفاری نیز دارد از طرفی با افزایش حرارت و وجود کانی مونت موریونیت سدیم دار در سیال حفاری همراه با مقاومت ژلی کم گران روی را کاهش می‌دهد.

1. INTRODUCTION

The control of the flow properties and the filtration rate of drilling fluids in deep drilling operations are important aspects of drilling fluid technology. Low viscosities are desirable in the interest of efficient hydraulic horsepower utilization; low filtration rates imply thin filter cakes, which are desirable in order that annular clearances be restricted to a minimal extent.

It is perhaps not sufficiently well recognized that room temperature measurements do not necessarily give an indication of mud properties at elevated temperatures. Not only can degradation processes alter the performance of additives, but also the colloidal stability of the system may be upset by temperature-induced effects such as changes in adsorption phenomena and solubility.

This study compares viscometric and filtration properties of a water base mud treated with sodium carboxymethyl cellulose (CMC) and XC polymer at room temperature and 80°C.

2. CLAY PARTICLE LINKING PROCESSES

Clay is largely responsible for a mud's thixotropic and gel-forming characters. To understand and control rheological changes in drilling fluids, the clay particle linking processes must be understood, According to van Olphen, plate-like particles have two different surfaces: the flat-face surface that normally is negatively charged and the edge surface that may be charged positively. These particles can associate in three different ways: face-to-face, edge-to-face or edge-to-edge. The linking of particles in these different fashions may proceed simultaneously, or one type or another may predominate [1].

Face-to-face association (aggregation) merely leads to the formation of thicker plates. This decreases the number of particles and causes a decrease in viscosity, Dispersion, the reverse of aggregation, leads to a greater number of particles and to higher viscosities.

Edge-to-edge or edge-to-face association is a flocculation process that leads to the formation of a "house-of-cards" structure. This also causes an increase in viscosity. Certain chemicals added to mud neutralize the edge charge, with the result that particles no longer associate edge-to-edge or edge-to-face so the mud deflocculates.

2.1. Description of Equipment and Materials Hamilton Beach was used for mixing the drilling mud materials. It has three rates for mixing; the medium rate for the drilling mud mixing was used here.

For high temperature tests, the mud sample was poured into some special cells and then the cells were put into the rolling oven (from Magcobar Company) for about 120 minutes. After that stage, the samples were tested.

Rheological properties were measured by using Fan Viscometer (Model 35 SA). For high temperature testing the Heating Cup Viscometer was used. Pumping water from Water Bath equipment (from NESLAB Company, See Figure 4) into the heating cup viscometer kept the drilling fluid temperature constant during the rheological testing. HTHP Filter Press was used to obtain the API water loss volume.

The clay type in the experiments was Sodium Montmorillonite. Salt water-based mud was prepared through a pre-hydrate method. The first step for constructing salt-water base mud was mixing bentonite, water and some times soda ash and caustic soda. After preparing brine water, it is mixed with the initial mud.

High-viscous CMC and Low-viscous CMC and XC-polymer were tested at different salinities, Concentrations and temperatures.

At ambient temperature, two types of starch polymers were also tested (Green starch and corn starch) to obtain a comparative diagram for these polymers.

2.2. Sample Preparation 8.165 Kg/bbl bentonite was mixed by Hamilton beach for about 10 minutes. Since the base mud is constructed from Ahwaz water (Hardness: 120 mg/l), therefore Soda ash was added to all suspensions for controlling the Ca^{2+} cations. Its concentration was constant and was measured according to the following formula: [2]

$$\text{mg/l } (Ca^{2+} \text{concentration}) \times F_w \times 0.000928 \qquad (1)$$

After 10 minutes, the polymer was added into the suspension to mix for about 15 minutes.

For high-salinity tests, the prepared brine was added into the suspension just after the first period. The following formula is applied in the laboratory to reach such value of salt concentration:

$$V_{brine} = (ppm_1 \times V_{mud} \times \rho_{mud})/((ppm_2 - ppm_1) \times \rho_{brine}) \qquad (2)$$

For ambient temperature tests, the mud sample was tested immediately after the mixing. But for high temperature tests, the mud sample was put into the Rolling Oven for about 1.5-2 hours after the mixing period. Eventually, the mud was tested with the fan viscometer and heating cup of viscometer and HTHP filter press.

3. RESULTS AND DISCUSSION

3.1. Effects of Polymer Concentration on Drilling Mud Properties The viscosity of drilling mud largely depends on the number of solid particles in the mud and the shape of them. Hence, adding polymers with any concentrations and complex structures will increase the amount of the viscosity of drilling mud. Moreover, they will form long molecule chains that will cause an increase in drilling mud viscosity.

At high salinity that Montmorillonite platelets tend to flocculate, addition of polymer has also another effect. Polymers can form a sealing layer around the clay platelets that will inhibit cations to substitute between clay platelets.

CMC Lv. and CMC Hv. have the same chemical structure. Both have a carboxymethyl group on their structure, but CMC Hv. has a higher D.P. (Degree of polymerization) rather than CMC Lv. It causes CMC Hv. to exert higher viscosity than CMC Lv. It is true for plastic viscosity, yield point and gel strength [4].

Starch polymers are non-ionic or slightly anionic; due to this property, the polymer chain of starch will be shorter than anionic polymers such as CMC Hv. or CMC Lv. In addition, the hydration of starch at fresh water is less than anionic polymers. Because of these reasons starch has a lower viscosity (Apparent and Plastic viscosity) and thixotropic property (Yield Point and Gel Strength) than CMC. [4].

As Figures 1 through 4 shows at low concentration of polymers, there is little difference between rheological properties of different polymers. But at high concentration this difference will be clearer. It is due to the polymers structures, meaning the long chain polymers will make more viscous fluid than the short types at the same concentration. So the difference between them will become more obvious at high concentrations.

As Figure 5 shows, API Water Loss graph of XC-Polymer is approximately the same as that of Green starch. In spit of the weakness of XC-Polymer on filtration properties, this polymer is very effective for improving the rheological properties of mud. CMC Polymers are more effective for controlling fluid loss of drilling mud in comparison with others.

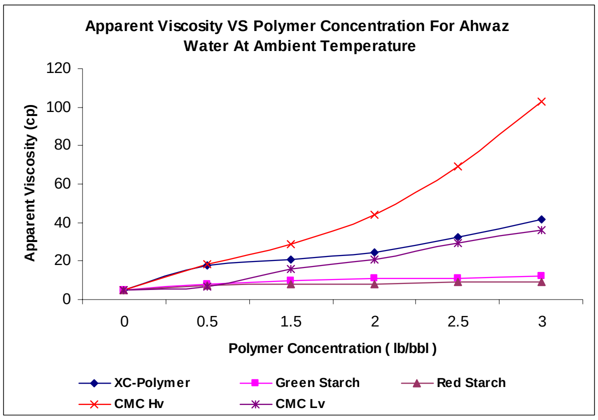

Figure 1. Apparent viscosity versus various polymers concentrations.

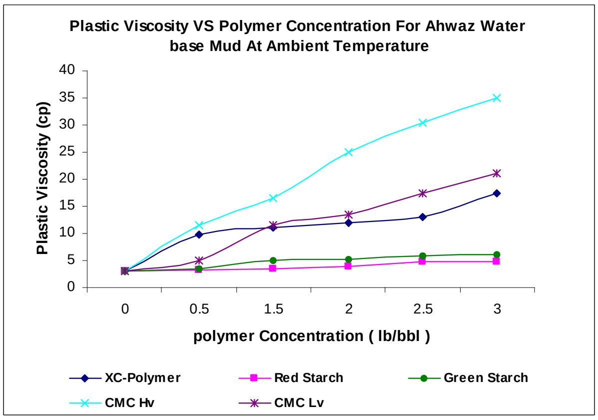

Figure 2. Plastic viscosity versus various polymers concentrations.

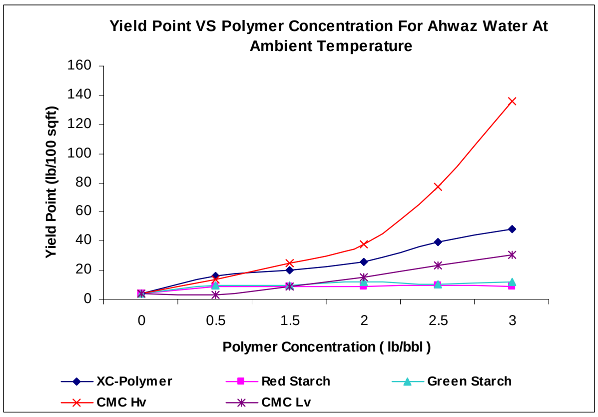

Figure 3. Yield point versus various polymers concentrations.

3.2. The effect of Salinity on Drilling Mud Properties With the addition of NaCl, the double layer of the clay particles is compressed enhancing flocculation of the suspension. In other words, the separation between the clay platelets was reduced with increasing concentration of salt. It will decrease the viscosity of drilling fluid.

When a polymer is added to water, the cations (usually Na^+) release from the polymer chain and leave behind a negatively charged site. The polymer is now anionic and free in hydrate water. As the polymer hydrates the water, the envelope surrounding the polymer increases in size and along with it viscosity increases. With the presence of salt the availability of water is limited and polymer cannot hydrate and expand easily. It means that hydrogen bonding is not formed between the polymer chains and water molecules; therefore the gel strength of this fluid will become negligible [4].

Figures 6 through 8 show the Plastic Viscosity Versus Polymers Concentrations (CMC Polymers and XC-Polymer) in various drilling muds with different salinities. As these figures show plastic viscosity of drilling mud at 400 ppm (Ahwaz water salinity) and 8000 ppm are close to each other. But at high salinities the plastic viscosity values decreased sharply. It is also true for the yield point and Gel Strength. (See Figures 8 through 13).

Another effect of salinity is increasing filtrate volume of drilling mud. It is probably due to the sticking of clay platelets together, in other words the hydration of freshwater clays decreases rapidly with increasing concentrations of the salts.

Figures 6 and 10 show apparent viscosity as a function of polymer concentration at different drilling mud salinities.

3.3. Effect of Temperature on Drilling Mud Properties The effect of high temperatures on montmorillonite suspensions can be attributed to the complicated interplay of several causes, among which the following are prominent: [5]

- Reduction of the degree of hydration of the counter ions,
- Changes in the electrical double-layer thickness,
- Increased thermal energy of the clay micelles,

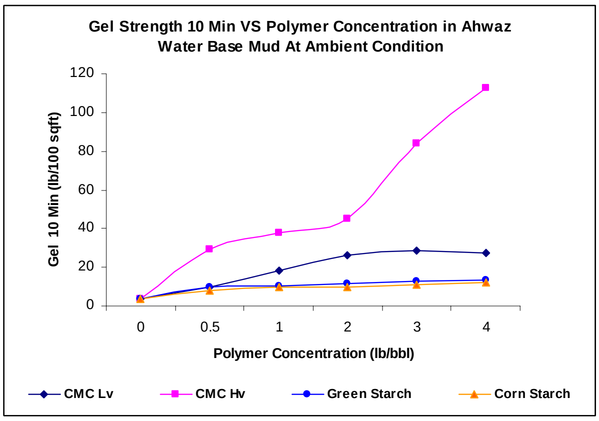

Figure 4. Gel strength 10 min versus various polymers concentrations.

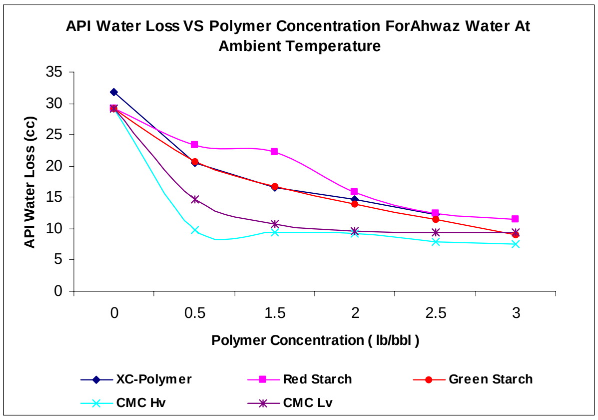

Figure 5. Api water loss versus various polymers concentrations.

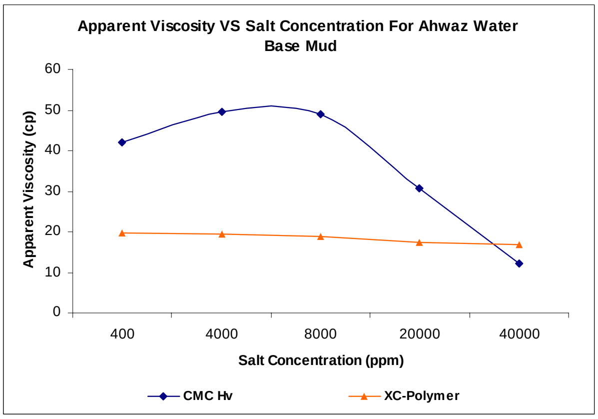

Figure 6. Apparent viscosity versus salinity for two muds containing CMC Hv and XC-polymer.

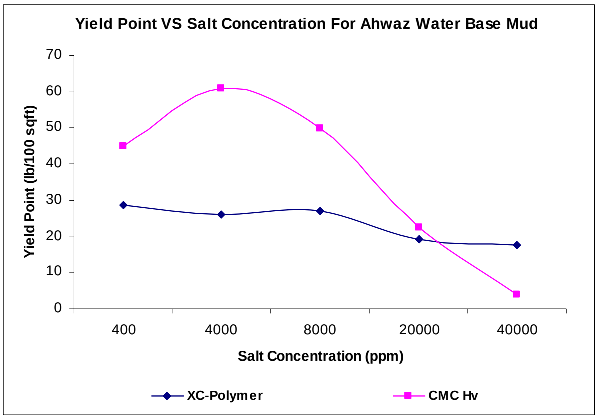

Figure 7. Yield point versus salinity for two muds containing CMC Hv and XC-polymer.

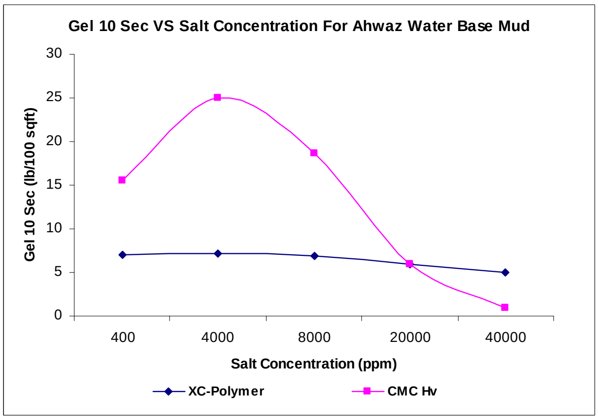

Figure 8. Gel strength 10 Sec versus salinity for two muds containing CMS Hv and XC-polymer.

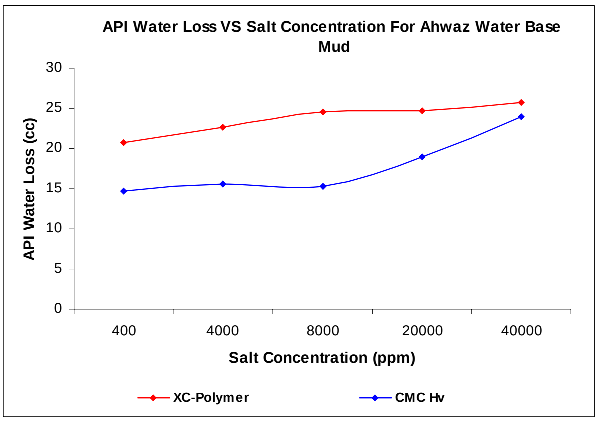

Figure 9. API water loss versus salinity for two muds containing CMC Hv and XC-polymer at 80˚C.

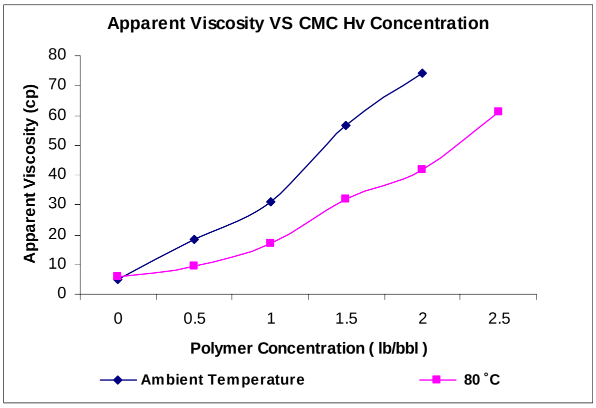

Figure 10. Apparent viscosity versus CMC Hv concentration at different temperatures.

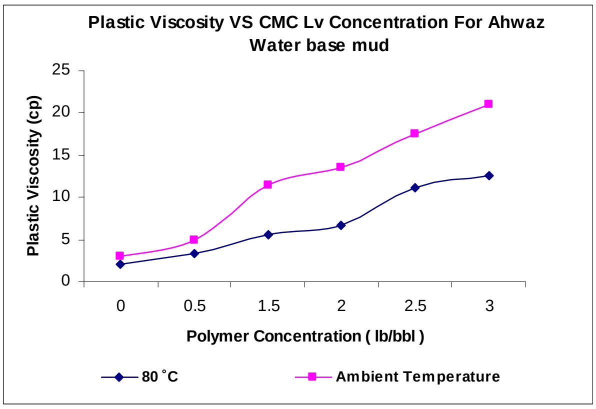

Figure 11. Plastic viscosity versus CMC Lv concentration at different temperatures.

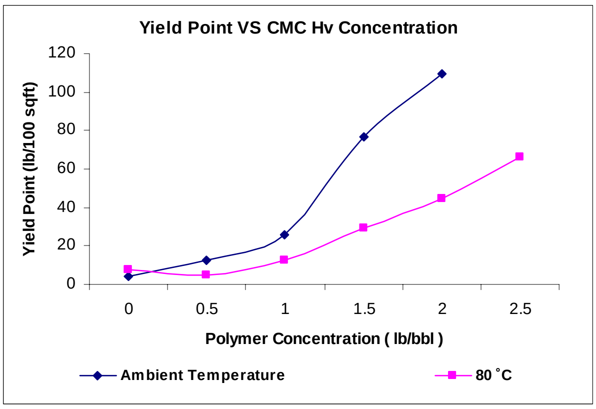

Figure 12. Yield point versus CMC Hv concentration at different temperatures.

- Reduction of the viscosity of the suspending medium and increasing dispersion of associated clay micelles.

All these processes take place simultaneously, and an interpretation of the observed results is possible only in those cases where some of the effects are predominant, so that they can be identified.

Figures 10 through 14 show the effects of temperature on Rheological and Filtration properties of drilling mud for CMC Hv and CMC Lv and XC-Polymer.

The effect of increasing temperatures on the dispersed suspensions of sodium montmorillonite can be explained by a simple weakening of the strength of the bonds between particles by thermal energy, this effect explains the decrease in Yield Point. The plastic viscosity also decreases at higher temperatures for all sodium montmorillonite suspensions. This is probably because of a partial destruction of the hydration shell [6]. This is another factor that should be considered is decreasing viscosity of the base mud with increasing temperature. In Figures 10 through 14 apparent viscosity of drilling mud at an ambient temperature and 80°C are compared. As can be seen increasing temperature caused a significant decrease in the apparent viscosity of drilling mud.

Figure 18 compare API water loss volume of drilling mud as a function of polymer concentration at two different temperatures (ambient temperature and 80°C).

Increasing temperature will lead to a decrease in the viscosity of the liquid phase of drilling mud that in turn will increase fluid loss volume if all other factors remain constant. Another reason of increasing fluid loss due to increasing temperatures are breaking bonds between polymer chains and also at very high temperatures thermal degradation of polymers.

3.4. Effect of pH on Drilling Mud Properties

Caustic soda and lime were used for increasing pH of drilling mud. Therefore, comparative diagrams were created for these two additives.

As Figures 15 through 17 show, Rheological Properties (Plastic viscosity, Apparent Viscosity, Yield Point and Gel strength) of drilling mud will increase gradually until pH = 10 but it has a sharp

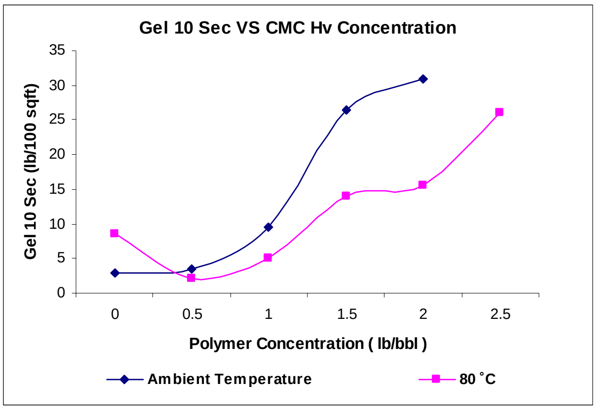

Figure 13. Gel strength 10 sec versus CMC Hv concentration at different temperatures.

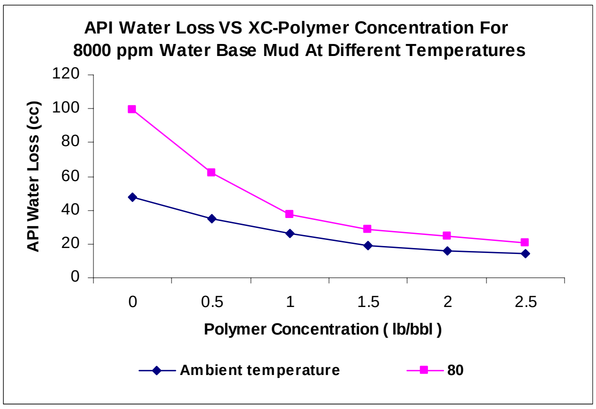

Figure 14. API water loss versus XC-polymer concentration at different temperatures.

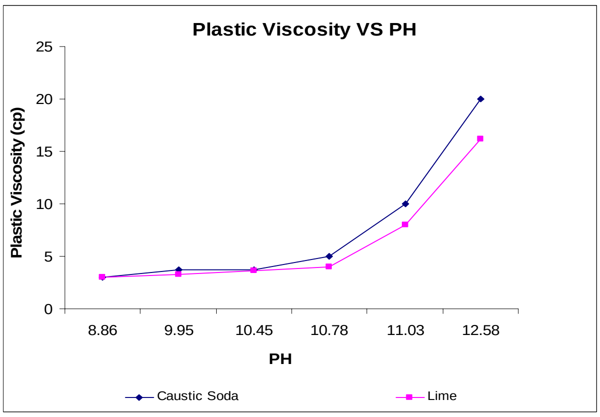

Figure 15. Plastic viscosity versus pH.

increase after this point. It will confirm dispersion of clay minerals at high pH values.

Therefore, adding Caustic soda is more effective than Lime for increasing the viscosity of drilling mud. It is due to the existence of Divalent cations such as Ca^{2+} in lime and Monovalent cations such as Na^{+} in Caustic Soda. Existence of cations will increase the attractive force between platelets. Monovalent cations give rise to a lesser attractive force and allow more water to penetrate between the platelets than divalent cations [2]. So platelets will be dispersed well, while adding Caustic Soda and consequently rheological properties of the mud is more efficient than the adding of lime.

Yield point is a measurement of the electro-chemical or attractive forces in a fluid at dynamic conditions, but Gel strength in this measurement are at static condition. Therefore increasing caustic soda and lime concentrations will lead to an increase in Yield Point and Gel Strength of drilling mud.

Figure 18, confirms that increasing pH will lead to a decrease in the API water loss volume. It is probably due to increasing viscosity of drilling mud.

4. CONCLUSIONS

The initial aim of this paper was the interpretation and analyzing of the Drilling mud behavior in different situations (Such as: Salinity, pH, Temperature and polymer concentration) and comparison of their effect on mud properties.

Some significant results that have been seen during this study are:

- CMC Hv had considerable effect on filtration control and a little increase in its concentration caused a considerable growth at mud viscosity.
- Increasing pH of drilling mud will increase rheological properties (Plastic viscosity, apparent viscosity, Yield Point and Gel Strength) of drilling mud. It is probably due to increasing flocculation of sodium Montmorillonit (clay) platelets as a result of increasing cation concentration in mud.
- Caustic soda (NaOH) is more effective than

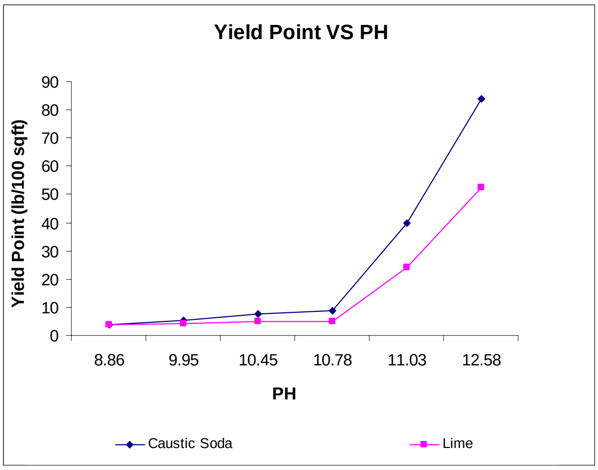

Figure 16. Yield point versus pH.

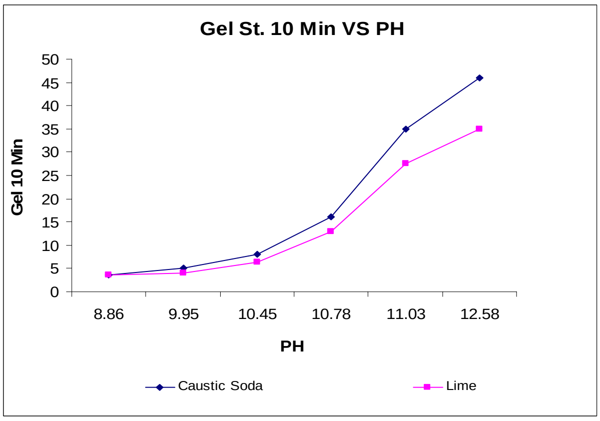

Figure 17. Gel strength 10 min versus pH.

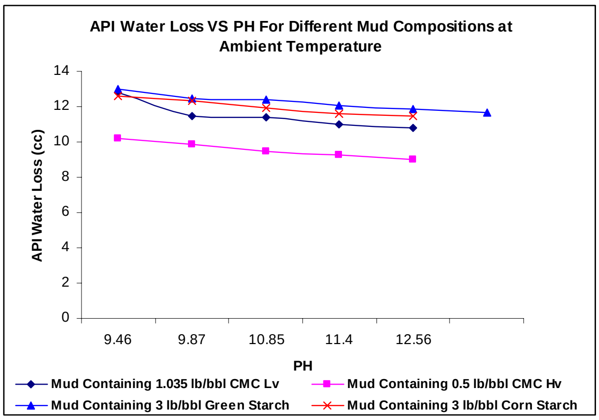

Figure 18. API water loss versus pH for drilling mud with different polymers.

lime (CaOH) for increasing viscosity of drilling mud.

- XC-polymer is not a strong fluid loss controller like CMC polymers, but it has significant effect on viscosity of drilling mud.
- Salinity has a considerable effect on rheological and filtration properties of drilling mud, especially when ppm of mud is above 10000.
- Effect of salinity on XC-polymer is negligible in comparison with the other polymers (CMC Hv, CMC Lv, Green starch and Corn starch).
- Under the same conditions (In the case of salinity and temperature) as the polymer concentration increased, the difference between their performances also gets more striking. For example at low concentrations of polymer, the difference between curves is negligible but with increasing polymer concentration, the difference will get more striking.
- Salinity and temperature have negative effects on filtration properties of drilling mud. Meaning that as the salinity and temperature of drilling mud increase, the filtrate volume of drilling mud that will penetrate into the formation will increase.
- As the salinity and temperature of drilling mud are increased the effectiveness of polymers in the drilling mud will decreased.

In suspensions of sodium montmorillonite that are well dispersed and have low gel strength, both Plastic viscosity and Yield Point decrease with increasing temperature.

5. NOMENCLATURE

Fw	The fractional % of water from retort.
V_{brine}	Volume of required brine, cc.
V_{mud}	Volume of mud, cc.
ρ_{mud}	Mud density, Gr/Cm^3.
ρ_{brine}	Brine density, Gr/Cm^3.
ppm_1	Target salt concentration of mud, ppm.
ppm_2	Initial salt concentration of brine, ppm.

6. ACKNOWLEDGMENTS

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