Proceedings World Geothermal Congress 2015
Melbourne, Australia, 19-25 April 2015

Preparing Drilling Fluid Compositions for Geothermal Reservoirs

B. Toka and N. Toka

The General Directorate of Mineral Research and Exploration

tokabulent@yahoo.com, nurayceyhan2001@yahoo.com

Keywords: Drilling Fluid, Polymer, Rheology, Filtrate Volume, Temperature

ABSTRACT

The success or failure of a geothermal drilling depends on the selection of drilling fluid. Drilling fluids should provide carrying and suspending drilling cuttings, high rates of penetration, maximizing bit life, minimizing fluid loss into the formation and stability of the formation. Drilling fluids which are used to reach these objectives must not damage the reservoir and can be removed during the completion phase but the filtrate and solid invasion cause irreversible formation damage, permeability reduction and detrimental effect to well productivity. Some studies show that the reservoir must be drilled to mitigate formation damage with specific drilling fluid that contains high molecular weight polymers for viscosity, bridging agents like fine calcium carbonate (CaCO3) and low molecular weight polymers for fluid loss control.

In this study, the rheological and filtration properties of drilling fluids were designed with different types of polymers and the effect of components such as calcium carbonate and nontreated bentonite on filtration and rheological properties of mud were determined. Although designed different types of polymer compositions did not meet the required rheological and filtrate properties; the addition of calcium carbonate to PAC L+modified starch+ XCD composition and to XCD+ modified starch composition gave better rheological and filtrate properties. While the addition of bentonite decreased the amount of polymer to reach the required properties , bentonite + CMC composition and bentonit+PAC L+XCD composition showed more favourable rheological and filtrate properties than the other compositions with bentonite.

1. INTRODUCTION

Two critical aspects of the design of drilling fluids are the control of flow properties and the filtration rate of drilling fluids in deep drilling operations. Over the years various chemicals have been used to control the rheological properties and filtration characteristics of water based drilling fluids. A class of water soluble polymers is added to a drilling fluid for different functions. Among the various functions of soluble polymers, two are important: the control of the rheology of the liquid phase and the reduction of fluid loss (Simon et al 2002). Water soluble polymers, such as starch, carboxylmethylcellulose (CMC), polyanioniccellulose (PAC) and xanthan gum also known as XCD, the most suitable polymers in classical drilling operations, are frequently used as viscosifiers and fluid-loss reducers (Asselman and Garnier, 2000).

The desired properties of drilling fluid, once established, should be stable under normal drilling conditions and temperatures. However, high temperatures affect many of clays and additives used to tailor the fluid properties and cause a reduction in range of stable options and alter the rheological and filtration behaviour of a drilling fluid. To achieve this goal, it is desirable to drill with clay-free drilling fluids which are stable under geothermal drilling conditions, especially in production zones where conventional clay-based muds create a risk of formation damage.

Geothermal reservoir sections are drilled with specialized reservoir drilling fluid that contains polymers for viscosity, bridging agents such as fine calcium carbonate (CaCO3) or sodiumchloride (NaCl) salt and additives (usually starch or another polymer) tailored to control fluid loss.

The goal of this work is to determine water based drilling fluid compositions containing polymer and additives which do not have detrimental effect to geothermal reservoir, and also to carry out a comparative study between polymers in order to decide which product gives better rheological and filtrate properties. For this reason many polymers used widely in drilling sector, such as carboxymethylcellulose (HV CMC and LV CMC), polyanionic cellulose polymer (PAC R and PAC L), xanthan gum (XCD) and modified starch, were tested in different compositions with calcite and bentonite, separately.

2. MATERIALS AND METHODS

In this study different types and amounts of polymers, bentonite and calcium carbonate were used to find the best drilling fluid composition for geothermal wells. HV CMC, PAC R and XCD were used to increase viscosity of drilling fluid and LV CMC, PAC L and modified starch were used to control fluid loss in drilling fluids. According to literature, while CMC and PAC are thermally stable material up to 149 °C (300 °F), XCD and starch are stable to 121 °C (250 °F). Commercially available nontreated bentonite (Reşadiye Na-bentonite) and fine calcium carbonate were used in these experiments.

The rheological properties of drilling fluid were measured by Fann Model 35SA type viscometers and the filtrate losses were determined using API filter press at the conditions of temperatures of 25 °C±1 °C. Water based drilling fluids behave according to the Bingham model and rheological and filtrate properties of drilling muds were determined according to API Specification 13A-ISO 13500 (2010). The plastic viscosity (PV), yield-point (YP) and apparent viscosity (AV) are calculated from 300 and 600 rpm readings using following formulas from API Specification for Drilling Fluid Materials.

Plastic Viscosity $= \Theta_{600} - \Theta_{300}$

Yield Point = Θ_{300}- [PV]
Apparent Viscosity = $\Theta_{600}/2$

In addition the mud compositions were aged at different temperatures (50. 75, 100 °C) for 24 hours in a roller oven. The aged samples were cooled to room temperature, removed from the aging cell, and stirred on a mixer for 5 minutes to break down any gels formed in the aging process. Then, the rheological properties such as apparent and plastic viscosities, gel strengths (initial/10 minutes), yield points were measured.

All of the tests based on to reach the minimum required value for apparent viscosity (≥15 cP) and maximum required value for filtrate volume (≤15 ml/30 min.).

3. RESULTS AND DISCUSSION

3.1 The Evaluation of Rheological and Filtrate Properties of Polymer Based Drilling Fluid Compositions

In these tests, the rheological and filtrate properties of different types of polymer based drilling fluid compositions were determined. Table 1 shows the four types of drilling fluid compositions prepared with different concentrations.

Table 1 Compositions of Polymer Based Drilling Fluid

1st Composition	5 ppb LV CMC + 1 ppb HV CMC
2nd Composition	2,5 ppb PAC L+ 0,5 ppb PAC R
3rd Composition	1 ppb PAC L+ 2 ppb M. Starch + 1 ppb XCD
4th Composition	5 ppb M. Starch+ 1 ppb XCD

In the first composition prepared by LV CMC and HV CMC; low values of yield point (4 lb/100 ft^2) and gel strengths (1,5-2 lb/100 ft^2) of drilling fluid (Figure 1) show difficulty of carrying and suspending capacity of drill cuttings and weighting materials, such as barite and hematite. As well, high filtrate loss (18 cm^3/30') of drilling fluid limits to use this type composition in active shales and clays.

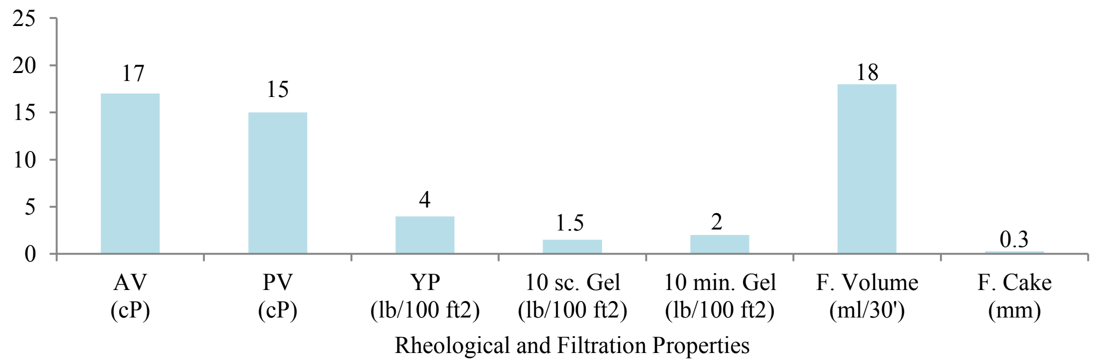

Figure 1- Rheological and Filtration Properties of 1st Composition

In the second composition prepared by PAC L ve PAC R; as can be seen from Figure 2, YP value (11 lb/100 ft^2) was higher than first composition but gel strengths were as low as the first one's. As well, the filtrate volume (25 cm^3/30') of the second composition was higher than first one's.

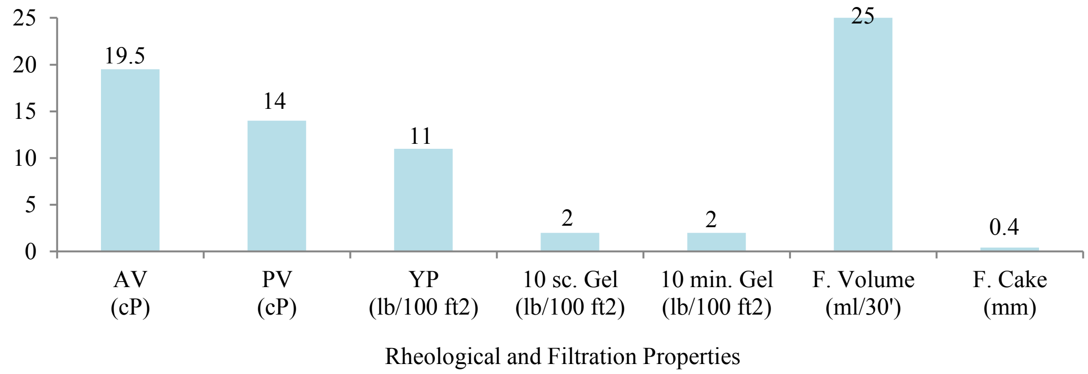

Figure 2- Rheological and Filtration Properties of 2nd Composition

For the third composition prepared by PAC L, modified starch and XCD; Figures 3 indicates that the yield point value (14 lb/100 ft^2) was higher than plastic viscosity (10 cP) and gave better 10 second and 10 minute gel strengths (6-9 lb/100 ft^2) values. Although this composition gave much better reological properties than the first and the second compositions, high filtrate volume was the disadvantage of the third one for active clays.

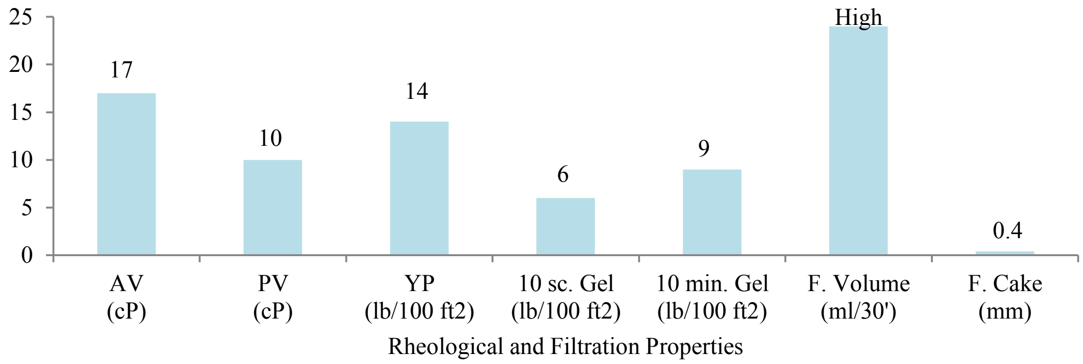

Figure 3- Rheological and Filtration Properties of 3rd Composition

Figure 4 shows that XCD and modified starch composition (the forth one) had higher yield point and gel strengths compared to CMC and PAC including compositions. As can be seen from Figure 4, xanthan gum and modified starch gave better rheological properties but filtrate volume was too high.

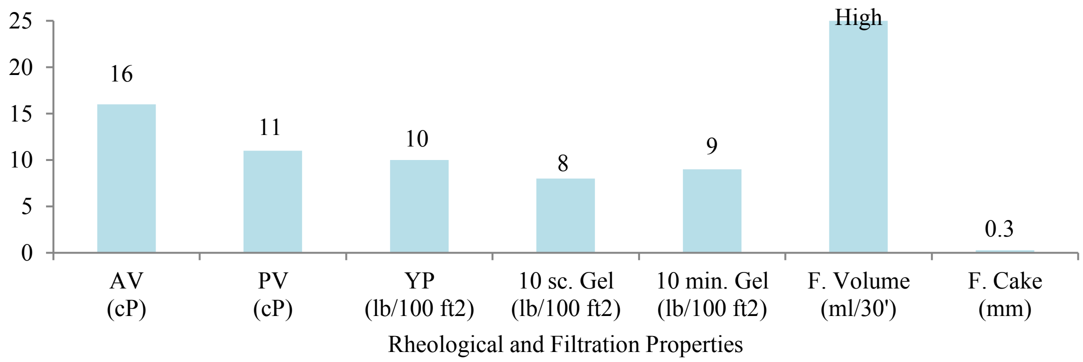

Figure 4- Rheological and Filtration Properties of 4th Composition

As a result, the rheological and filtrate properties of drilling fluid were dependent on polymer types and quantities and all of the compositions tested did not meet the desired requirements.

3.2 The Effect of Calcium Carbonate on the Rheological and Filtrate Properties of Polymer Based Drilling Fluids

Due to the high filtrate volume of polymers muds, the compositions were treated with 10 ppb calcium carbonate which was used as bridging agent. The concentrations of polymers and calcium carbonate used were given in Table 2.

Table 2 Compositions of Polymer Based Drilling Fluid with Calcium Carbonate

5th Composition	10 ppb Calcium Carbonate+ 5 ppb LV CMC+1 ppb HV CMC
6th Composition	10 ppb Calcium Carbonate + 2,5 ppb PAC L+ 0,5 ppb PAC R
7th Composition	10 ppb Calcium Carbonate + 1 ppb PAC L+ 2 ppb M. Starch + 1 ppb XCD
8th Composition	10 ppb Calcium Carbonate + 5 ppb M. Starch+ 1 ppb XCD

It can be seen in the Figures 5, 6, 7, 8 addition of calcium carbonate on polymeric solutions formed impermeable cake by increasing the thickness, thereby decreasing the filtration loss, but no change in AV, PV, YP and 0/10 gel strengths values were observed.

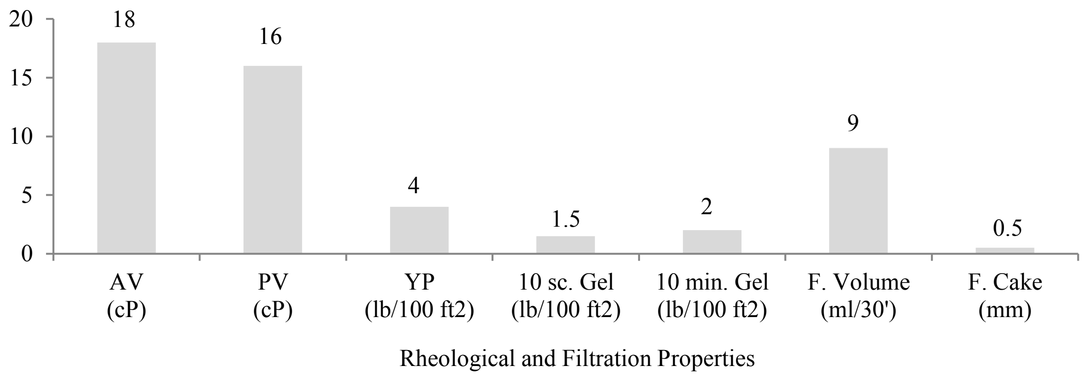

Figure 5- Rheological and Filtration Properties of 5th Composition

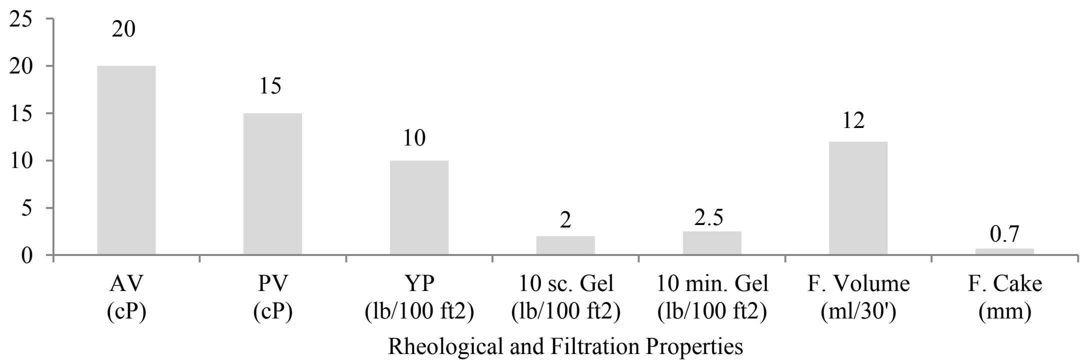

Figure 6- Rheological and Filtration Properties of 6th Composition

Addition of calcium carbonate on PAC L, modified starch and XCD solutions caused important decrease on filtrate volumes (12 cm^3/30') and increased yield points (15 lb/100 ft^2) and made 0/10 minute gel strengths more favorable (7-9 lb/100 ft^2) (Figure 7). High enough YP's and close and high gel strength values made them preferable compositions for geothermal wells. As well, nondamaging acid-soluble solid properties of this type drilling fluid decreases the risk of reservoir damage.

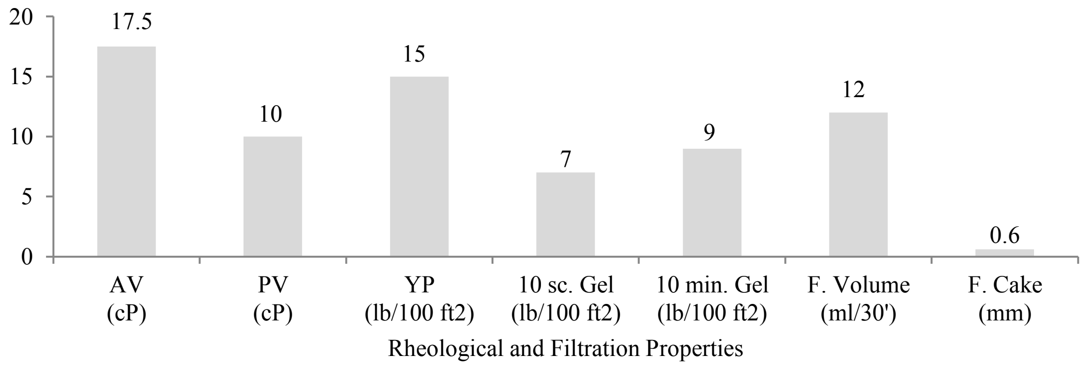

Figure 7- Rheological and Filtration Properties of 7th Composition

In the 8th composition including XCD and modified starch; as can be seen from Figure 8 low filtrate volume (as low as 8 cm^3/30'), high YP and good value of 0/10 minute gel strengths (6-8 lb/100 ft^2) showed better rheological and filtrate properties for drilling fluid to carry cuttings and potential of reservoir damage decreased.

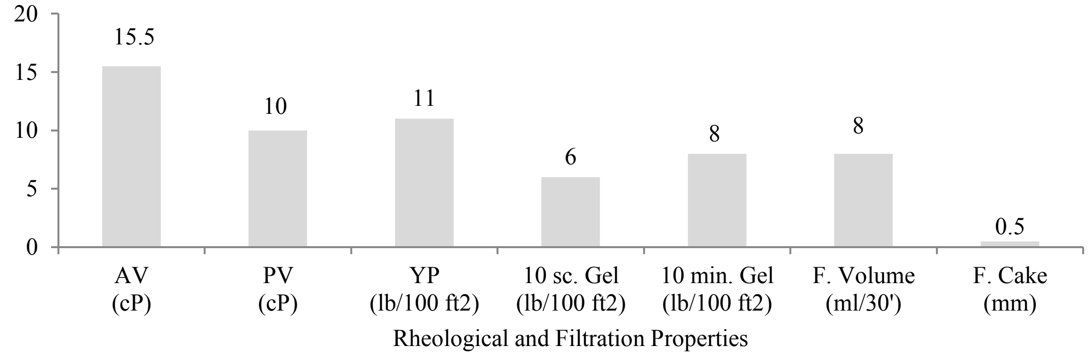

Figure 8- Rheological and Filtration Properties of 8th Composition

As a conclusion, the rheological properties did not depend on calcium carbonate quantities but filtrate volume value depended on calcium carbonate quantities. As well 7th and 8th compositions showed better rheological and filtrate properties for drilling fluid to carry cuttings and to minimize reservoir damage.

3.3 The Effect of Bentonite on the Rheological and Filtrate Properties of Polymer Based Drilling Fluids

In this step, we varied the polymer concentrations by maintaining the bentonite concentration fixed for studying the effect of clays on drilling fluids. We fixed clay value as10 ppb and varied polymer concentrations which were used for viscosifying and fluid loss control.

Table 3 Compositions of Polymer Based Drilling Fluid with Non-treated Bentonite.

9th Composition	10 ppb Non-treated Bentonite+ 0,7 ppb LV CMC + 0,6 ppb HV CMC
10th Composition	10 ppb Non-treated Bentonite + 0,7 ppb PAC L+ 0,1 ppb PAC R
11th Composition	10 ppb Non-treated Bentonite + 0,8 ppb PAC L + 0,4 ppb XCD
12th Composition	10 ppb Non-treated Bentonite + 0,9 ppb M. Starch + 0,7 ppb XCD

As can be seen from Table 3, with the addition of bentonite, amounts of polymers decreased. Because we reached desired values at lower concentrations.

Figure 9 shows that the addition of bentonite increased YP and gel strengths and decreased filtrate volume but in this composition 10 minute gel strength (17 lb/100 ft^2) was too high compared to 10 second gel strength (3 lb/100 ft^2).

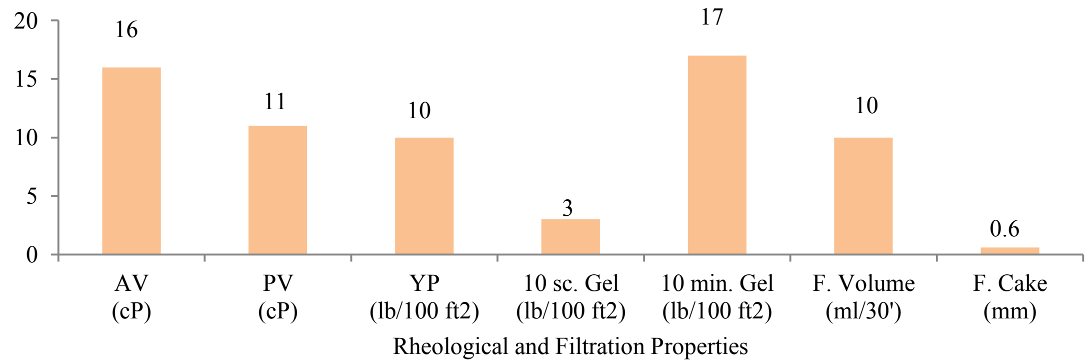

Figure 9- Rheological and Filtration Properties of 9th Composition

The 10th composition including bentonite and PAC caused low YP and gel strengths and high filtrate volume (Figure 10) when compared to CMC- bentonite composition.

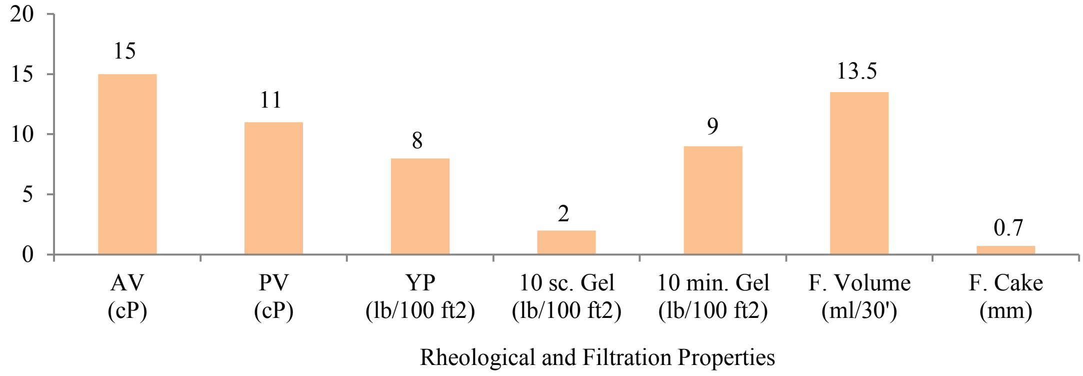

Figure 10- Rheological and Filtration Properties of 10th Composition

As can be seen Figure 11, PAC L, XCD and bentonite composition showed better YP (13 lb/100 ft^2) and gel strengths (4-8,5 lb/100 ft^2) and YP value was higher than PV value. These properties are favourable to select this type composition for geothermal wells.

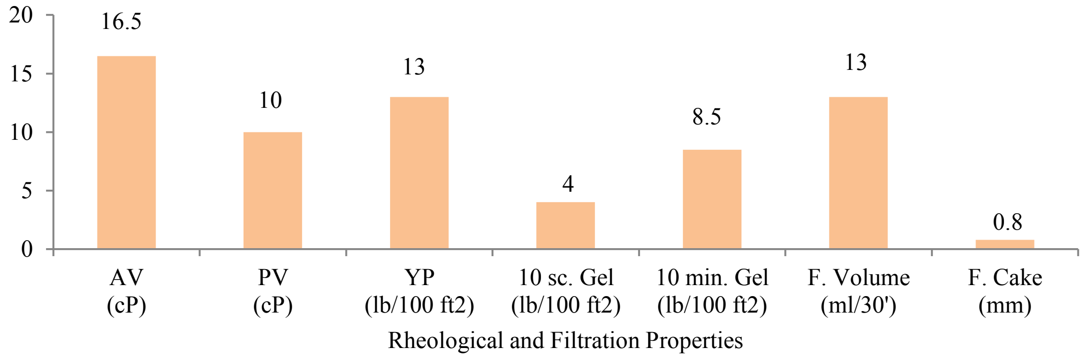

Figure 11- Rheological and Filtration Properties of 11th Composition

In the 12th composition 10 minutes gel strength was too high compared to 10 seconds gel strength. YP value was 12 lb/100 ft^2 and filtrate volume was 13 cm^3/30' (Figure 12).

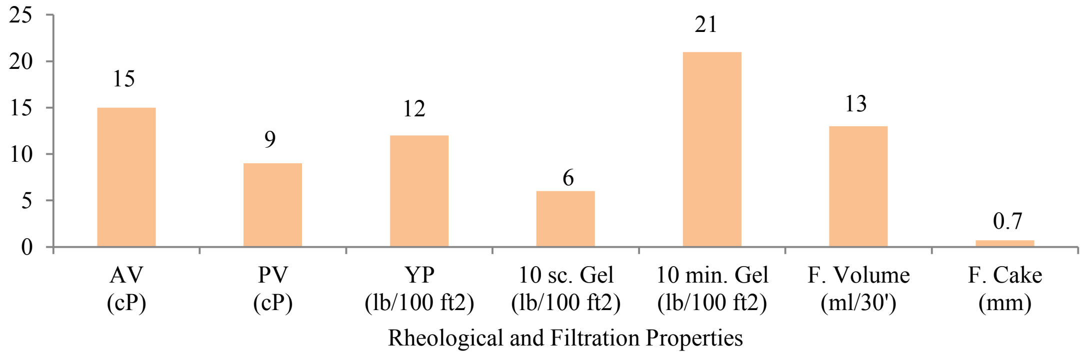

Figure 12- Rheological and Filtration Properties of 12th Composition

So we can say that addition of bentonite decreased the amount of polymer to reach the required values for drilling fluids. In this part of the study, bentonite + CMC and bentonit+PAC L+XCD compositions showed better rheological properties than the others.

3.4 The Effect of Temperature on the Rheological and Filtrate Properties of Polymer Based Drilling Fluids

In this study the rheological and filtrate properties of three type of drilling fluid sample (PAC + XCD + modified starch + calcium carbonate, HV CMC + LV CMC + bentonite and XCD + PAC L + bentonite) were examined after thermal aging. Samples were rolled for 24 hours at the temperatures of 50, 75, 100, 125 and 150 °C in a roller oven and were cooled to room temperature, then rheolocigal and filtration properties were measured. Figures 13, 14 and 15 show measured values. We can conclude from these figures that properties of given compositions changed with temperature. The rheological properties (apparent viscosity, plastic viscosity, yield point and gel strengths) of polymer suspensions stayed at stable condition during the process at 50 °C but after 50 °C the performance of polymers treated fluids was adversely affected by heat i.e., the fluids underwent serious thermal degradation. As can be seen from Figure 13 the rheological properties of PAC + XCD + modified starch + calcium carbonate decreased at the temperatures of 75 °C and above. This is not an expected result because it was assumed that the cellulosic materials can stand up to 149 °C for PAC and CMC and 121 °C for XCD and starch polymers.

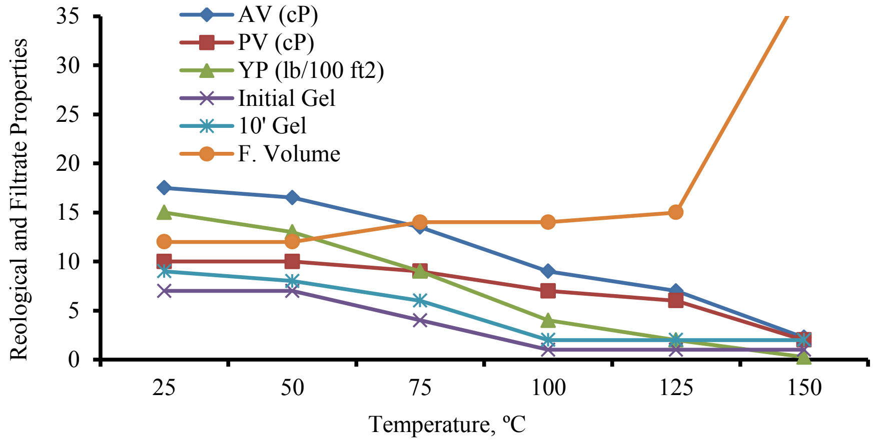

Figure 13- Effect of Temperature on PAC + XCD + Modified Starch + Calcium Carbonate Based Drilling Fluid

Figure 14 shows that the aging of bentonite + CMC fluids at high temperatures indicates a slight degradation up to 100 °C. When compared to calcium carbonate + PAC + XCD + modified starch fluid HV CMC +LV CMC + bentonite composition shows better rheological properties at elevated temperatures.

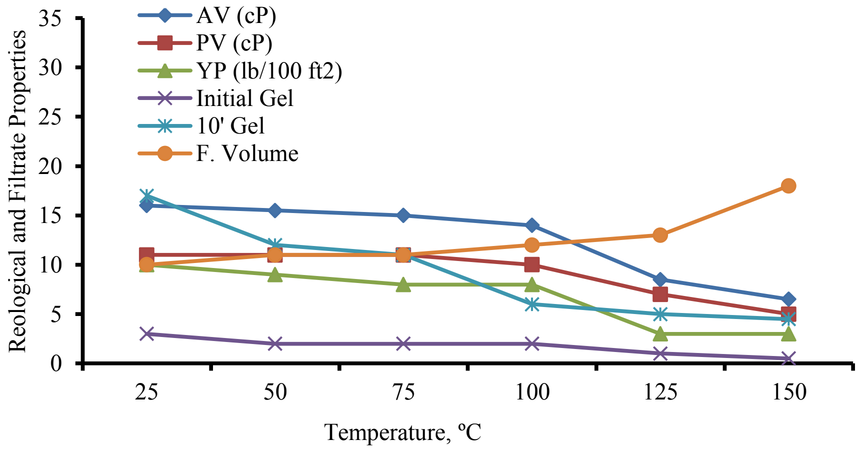

Figure 14- Effect of Temperature on HV CMC + LV CMC + Bentonite Based Drilling Fluid

XCD + PAC L + bentonite based drilling fluids began to degrade at 50 ºC and the reological and filtrate properties of this sample decreased very sharply after the mentioned temperature (Figure 15).

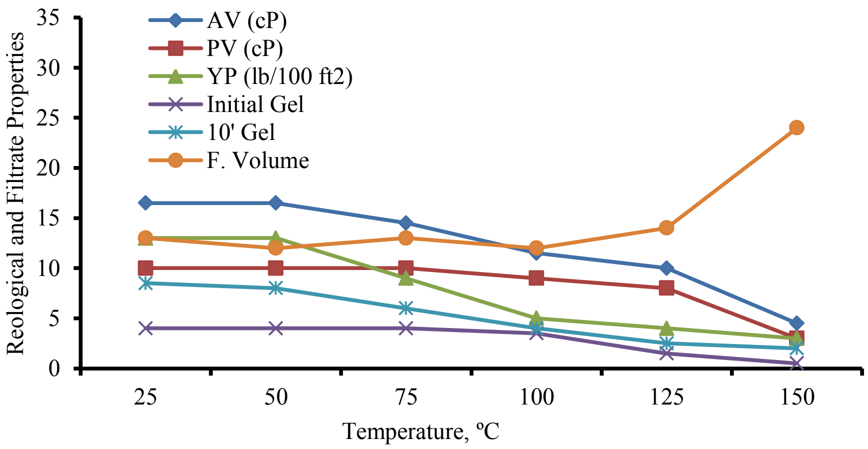

Figure 15- Effect of Temperature on XCD + PAC L + Bentonite Based Drilling Fluid

CONCLUSIONS AND RECOMMENDATIONS

- Drilling fluid compositions including only polymers have high filtration rates. Drilling fluids including CMC and PAC give low YP and 0/10 minute gel strength values while PAC + XCD + modified starch and XCD+modified starch drilling fluid show better rheological properties.
- Addition of calcium carbonate on polymer suspensions causes a decrease in filtration rate. The rheological and filtration properties of PAC + XCD + modified starch + calcium carbonate and XCD + modified starch + calcium carbonate compositions are more favorable when compared to other types of drilling fluid compositions mentioned.
- Bentonite addition on polymer compositions decreases the amount of polymer needed. Difference between the values of 10 seconds and 10 minutes gel strengths is too high for all compositions except PAC L + XCD + bentonite composition.
- The aging of bentonite+ CMC compositions at 100 °C showes better rheological properties than that of calcium carbonate + polymer fluids.
- For future studies to determine the effect of different types and amounts of additives on drilling fluids, additional tests should be performed at high temperature and pressure conditions.

REFERENCES

API Specification 13A (SPEC 13A), *Specification for Drilling Fluid Materials*, American Petroleum Institute, (July 2004).

Asselman, A. and Garnier, G., Adsorption of model wood polymers and colloids on bentonites, *Colloids and Surfaces A: Physicochemical and Engineering Aspects 168*, Elsevier, (2000), 175–182.

Simon, S., Cerf, D.L., Picton, L. and Muller, G., Adsorption of Cellulose Derivatives onto Montmorillonite: a SEC–MALLS Study of Molar Masses Influence, *Colloids and Surfaces A: Physicochemical and Engineering Aspects 203*, (2002), 77–86.