NIPES Journal of Science and Technology Research 4(2) 2022 pp.182 - 191 pISSN-2682-5821, eISSN-2682-5821

Journal of Science and Technology Research

Journal homepage: www.nipesjournals.org.ng

Investigation of the Effect of Some Salts on the Rheological Properties of Xanthan Gum and Gum Arabic Present in a Drilling Fluid

Paul Okaome, Sarah Akintola
University of Ibadan, Ibadan, 200284, Nigeria

Article Info

Received 25 Oct. 2021
Revised 08 Nov. 2021
Accepted 10 Nov. 2021
Available online 10 June 2022

***Keywords*:**
Drilling Fluid, Rheological Properties, Xanthan Gum, Gum Arabic, Potassium Chloride, Sodium Chloride, Calcium Chloride.

https://doi.org/10.37933/nipes.e/4.2.2022.18

https://nipesjournals.org.ng

Abstract

The rheological properties of a drilling fluid are important because they allow for extensive examination of the viscosity, fluid flow profile, pressure loss, equivalent circulation density, and hole cleaning capability making it the foundation for all wellbore hydraulics. The viscosity, gel strength, and yield point of Gum Arabic and Xanthan Gum contained in a fresh water-based drilling fluid were investigated in the presence of three distinct salts: calcium chloride ($CaCl_2$), potassium chloride (KCl), and sodium chloride (NaCl). The salts were introduced separately to three distinct fresh water-based drilling fluid samples in increasing weights. The Fann V-G viscometer was used for the required rheology properties measuring the RPM and gel strength. The plastic viscosity, apparent viscosity, and yield point were calculated from the experimental data. With increasing the salt concentration, the plastic viscosity, apparent viscosity, yield point, and gel strength all decreased, which was observed for all three salts used. This research aimed to investigate the effect of three different salts; Calcium chloride ($CaCl_2$), Potassium Chloride (KCl), and Sodium Chloride (NaCl) on the rheological properties of Gum Arabic and Xanthan Gum viscosified water-based drilling fluid.

1. Introduction

The term drilling fluid refers to a liquid, gas, or gasified liquid circulating continuous substance used in the rotary drilling process to perform any or all of the various functions required to drill a viable wellbore at the least overall well cost [1].

The key functions that a drilling fluid must accomplish differ depending on the fluid type. These functions include [1]; Drilled-cuttings removal—below the drill bit and from the annular area around the drill string, containment of subsurface formation fluid pressures, and hole stabilization—chemical and/or mechanical—before casing/cementing. Drilling fluids perform a wide range of minor functions, including: Cooling and lubrication of the drill string and drill bit, suspension of desired solids and ease of removal of undesirable solids, weight reduction of the casing string and drill string while suspended in the wellbore, and aids in formation evaluation and drill bit cleaning.

There are significant advantages to be achieved in addition to the functions listed. It is feasible to achieve minimal formation damage, minimal corrosion impacts on drilling equipment, increased rate of penetration (ROP), reduced environmental impact, improved safety, and reduced friction pressure losses if these fluids are properly selected [1]. Failure of a drilling fluid to accomplish any or all of its tasks might result in very expensive drilling issues [1].

Most drilling issues are caused by the drilling fluid utilized, either directly or indirectly [1]. As a result, the effectiveness of a drilling program, as well as the potential to lower overall drilling costs, are dependent on the right selection and maintenance of a drilling fluid, as well as an understanding of and application of its functions [1].

The petroleum industry uses many types of polymers and chemicals to design drilling fluids that meet certain functional requirements, such as suitable drilling fluid rheology, density, fluid loss control properties, and so on [2]. Because of its relatively stable viscosity properties as a function of salt content, pH, temperature, and shear degradation, xanthan gum, an extracellular polysaccharide produced by Xanthomonas Campestris [3], has spurred interest in both of these areas. Because of its distinctive rheological qualities, xanthan gum has been widely employed as a viscosifier in the oil industry [4].

Gum Arabic is mainly obtained from Acacia Senegal [5]. Because gum Arabic dissolves easily in water and produces low viscosity solutions, it is rarely used as a thickening agent [6]. In the presence of electrolytes and at high and low pH values, the viscosity of Gum Arabic solutions reduces. Due to denaturation at pH and precipitation of the high molecular, mass protein, and rich components, the viscosity of Gum Arabic solutions decreases irreversibly after heating. Long before bottling, it is utilized as an emulsifier in the encapsulation of oils. At the oil-water contact, Gum Arabic can also create thick visco-elastic films [6].

Different kinds of salt have been added to water-based polymer drilling fluids in some well trajectories to impact the necessary weight needed to control the prevailing formation pressure, where the polymer is required to meet the viscosity needed to improve the fluids' solid transporting capability [7]. Salts have been added to drilling fluids used in deepwater wells in particular to suppress hydrate and clay formation, however this has resulted in fluid properties that are sometimes unstable and not desirable [8].

This research investigates the effect of three different salts; Calcium Chloride ($CaCl_2$), Potassium Chloride (KCl) and Sodium Chloride (NaCl) on the rheological properties of Gum Arabic and Xanthan Gum viscosified water-based drilling fluid. Rheological properties include; viscosity which is the internal resistance to the flow of fluid, which is a measurement of the attractive forces of the drilling fluid while at rest or under static conditions [1]. It is measured in lbs/100 ft^2 (10 sec/10min) and the yield point which is a measure of the electro-chemical attractive forces within the drilling fluid under flowing conditions [1]. It is the initial resistance to flow caused by electrochemical forces between the particles [1].

A non-Newtonian fluid is one whose viscous property cannot be described by a single term. Rather, the viscous property is approximated to behave in accordance with one of the following assumed models [1]:

- Bingham plastic: $\tau = \tau_y + \mu_p\gamma$ (1)
- Power law: $\tau = K\gamma^n$ (2)
- Power law yield: $\tau = \tau_y + K\gamma^n$ (3)

• $viscosity, \mu = \frac{shear\ stress, \tau}{shear\ rate, \gamma} \frac{Dyne.sec}{cm^2}\ (defined\ as\ poise)$ (4)

In the oil field, the Bingham Plastic Model is the most extensively used mathematical rheological model [1]. The 600 and 300 readings on the Fann VG Meter were used to obtain all of the data. The model assumes that the fluid under consideration behaves linearly on the shear rate-shear stress curve, but has a positive yield stress. Although most drilling fluids do not exactly follow the Bingham plastic model or any universal model, their behavior may typically be predicted with reasonable accuracy [1].

The Bingham Plastic model's equation is:

$$\tau = \mu_p \left(\frac{\gamma}{300}\right) + y_b \quad (5)$$

Plastic Viscosity, μ_p(PV) = $\Phi_{600} - \Phi_{300}$ (cP) (6)

Apparent Viscosity, (AV) = Φ_{600} / 2 (cP) (7)

Yield Point, y_b (YP) = Φ_{300} - μ_p (Ib/100ft^2) (8)

τ = shear stress (Ib/100ft^2)

τ_y = yield value or yield stress

μ_p = Bingham Plastic Viscosity (PV)

K = consistency index

n = the power law index

γ = shear rate (sec^{-1})

Φ600 = Dial Reading at 600rpm speed

Φ300 = Dial Reading at 300rpm speed

2. Methodology

Bentonite clay, freshwater, Gum Arabic, Xanthan Gum, Potassium Chloride (KCl) salt, Calcium Chloride ($CaCl_2$) salt, and Sodium Chloride (NaCl) salt were the materials utilized for this study. The Fann V-G Viscometer, Glass Beaker, Spatula, measuring cylinder, Hamilton Beach Mud mixer, Digital Weighing Machine, and pH Meter were among the tools used.

2.1. Preparation of Water-Based Mud

With the digital weighing meter, 21.5 grams of Bentonite were weighed, and 350ml of fresh distilled water was poured into the multi-mixer cup, followed by the slow introduction of the bentonite to achieve adequate mixing and homogeneity of the bentonite and freshwater prepared based on American Petroleum Institute (API) standard [9]. The viscosifier (Gum Arabic or Xanthan Gum) was then added and mixed until it the mixture was homogeneous.

2.2. Procedure for Measuring Rheological Properties

Salt in the amounts of 2, 4, 6, 8, and 10 grams was added to the already prepared drilling fluid samples in a volume per volume measurement and carefully mixed until homogeneity was obtained. The Fann V-G viscometer was used for all rheology measurements. The cup RPM and gel strength were the key output variables. The plastic viscosity, apparent viscosity, and yield point were calculated using Equations 6, 7, and 8, utilizing the 600rpm and 300rpm dial reading determined based on the API Specification 13B recommended practice for field testing water-based drilling fluids [10]. The gel strength was determined by setting the Fann V-G viscometer to "GEL" and measuring it in 10 minutes and 10 seconds.

3. Results and Discussion

Tables 1 to 8 shows the test results, which are displayed in Figures 1 to 6, with relevant discussions noted in the discussion section.

Table 1. Fresh water drilling mud + Xanthan Gum

Xanthan Gum							
Wt. of Xanthan Gum in WBM (g)	Fan Speed (RPM)	Dial Reading	Apparent Viscosity (cP)	Plastic Viscosity (cP)	Yield Point (lb/100 sq ft)	Gel Strength (lb/100 sq ft)	
1	600	226	113	42	142	10 SECS	77
	300	184				10 MINS	98

Table 2. Fresh water drilling mud + Xanthan Gum + $CaCl_2$ salt

Xanthan Gum + $CaCl_2$								
Wt. of Viscosifier in WBM (g)	Weight of Salt (g)	Fan Speed (RPM)	Dial Reading	Apparent Viscosity (cP)	Plastic Viscosity (cP)	Yield Point (lb/100 sq ft)	Gel Strength (lb/100 sq ft)	
1	2	600	198	99	38	122	10 SECS	107
		300	160				10 MINS	139
1	4	600	156	78	25	106	10 SECS	78
		300	131				10 MINS	99
1	6	600	125	62.5	23	79	10 SECS	53
		300	102				10 MINS	68
1	8	600	88.5	44.25	15.5	57.5	10 SECS	40
		300	73				10 MINS	45
1	10	600	52	26	8	36	10 SECS	29
		300	44				10 MINS	38

Table 3. Fresh water drilling mud + Xanthan Gum + KCl salt

Xanthan Gum + KCl								
Wt. of Viscosifier in WBM (g)	Weight of Salt (g)	Fan Speed (RPM)	Dial Reading	Apparent Viscosity (cP)	Plastic Viscosity (cP)	Yield Point (lb/100 sq ft)	Gel Strength (lb/100 sq ft)	
1	2	600	298	149	33	232	10 SECS	195
		300	265				10 MINS	232
1	4	600	253	126.5	30	193	10 SECS	161

		300	223				10 MINS	193
1	6	600	226	113	24	178	10 SECS	142
		300	202				10 MINS	164
1	8	600	210	105	25	160	10 SECS	115
		300	185				10 MINS	125
1	10	600	190	95	22	146	10 SECS	75
		300	168				10 MINS	86

Table 4. Fresh water drilling mud + Xanthan Gum + NaCl salt

Xanthan Gum + NaCl								
Wt. of Viscosifier in WBM (g)	Weight of Salt (g)	Fan Speed (RPM)	Dial Reading	Apparent Viscosity (cP)	Plastic Viscosity (cP)	Yield Point (lb/100 sq ft)	Gel Strength (lb/100 sq ft)	
1	2	600	274	137	34	206	10 SECS	170
		300	240				10 MINS	205
1	4	600	261	130.5	37	187	10 SECS	161
		300	224				10 MINS	191
1	6	600	252	126	40	172	10 SECS	151
		300	212				10 MINS	170
1	8	600	232	116	32	168	10 SECS	140
		300	200				10 MINS	155
1	10	600	212	106	24	164	10 SECS	132
		300	188				10 MINS	145

Table 5. Fresh water drilling mud + Gum Arabic

Gum Arabic							
Wt. of Xanthan Gum in WBM (g)	Viscocity Dial (RPM)	Viscocity Dial Reading	Apparent Viscosity (cP)	Plastic Viscosity (cP)	Yield Point (lb/100 sq ft)	Gel Strength (lb/100 sq ft)	
1	600	328	164	45	238	10 SECS	196
	300	283				10 MINS	243

Table 6. Fresh water drilling mud + Gum Arabic + $CaCl_2$ salt

Gum Arabic + $CaCl_2$								
Wt. of Viscosifier in WBM (g)	Weight of Salt (g)	Fan Speed (RPM)	Dial Reading	Apparent Viscosity (cP)	Plastic Viscosity (cP)	Yield Point (lb/100 sq ft)	Gel Strength (lb/100 sq ft)	
1	2	600	215	107.5	7	201	10 SECS	103
		300	208				10 MINS	157
1	4	600	190	95	9	172	10 SECS	80
		300	181				10 MINS	103
1	6	600	175	87.5	12	151	10 SECS	63
		300	163				10 MINS	79
1	8	600	160	80	17	126	10 SECS	46
		300	143				10 MINS	67
1	10	600	130	65	10	110	10 SECS	30

		300	120				10 MINS	50

Table 7. Fresh water drilling mud + Gum Arabic + KCl salt

Gum Arabic + KCl								
Wt. of Viscosifier in WBM (g)	Weight of Salt (g)	Fan Speed (RPM)	Dial Reading	Apparent Viscosity (cP)	Plastic Viscosity (cP)	Yield Point (lb/100 sq ft)	Gel Strength (lb/100 sq ft)	
1	2	600	237	118.95	19	199	10 SECS	103
		300	218				10 MINS	121
1	4	600	192	96	12	168	10 SECS	95
		300	180				10 MINS	112
1	6	600	179	89.5	12	155	10 SECS	103
		300	167				10 MINS	118
1	8	600	159	79.5	39	81	10 SECS	90
		300	120				10 MINS	105
1	10	600	129	64.5	32	65	10 SECS	80
		300	97				10 MINS	95

Table 8. Fresh water drilling mud + Gum Arabic + NaCl salt

Gum Arabic + NaCl								
Wt. of Viscosifier in WBM (g)	Weight of Salt (g)	Fan Speed (RPM)	Dial Reading	Apparent Viscosity (cP)	Plastic Viscosity (cP)	Yield Point (lb/100 sq ft)	Gel Strength (lb/100 sq ft)	
1	2	600	180	90	11	158	10 SECS	110
		300	169				10 MINS	133
1	4	600	171	85.5	12	147	10 SECS	102
		300	159				10 MINS	119
1	6	600	155	77.5	12	131	10 SECS	85
		300	143				10 MINS	107
1	8	600	136	68	7	122	10 SECS	65
		300	129				10 MINS	95
1	10	600	110	55	20	70	10 SECS	50
		300	90				10 MINS	80

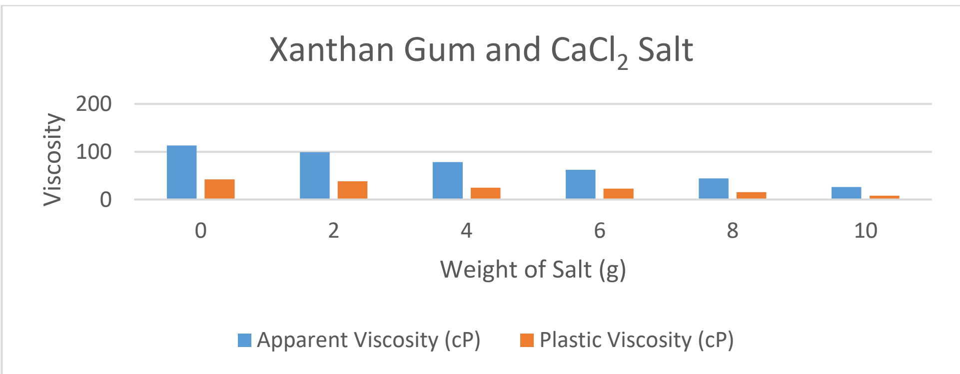

Figure 1. Effect of Xanthan Gum and $CaCl_2$ salt on the Viscosity of the Drilling Fluid

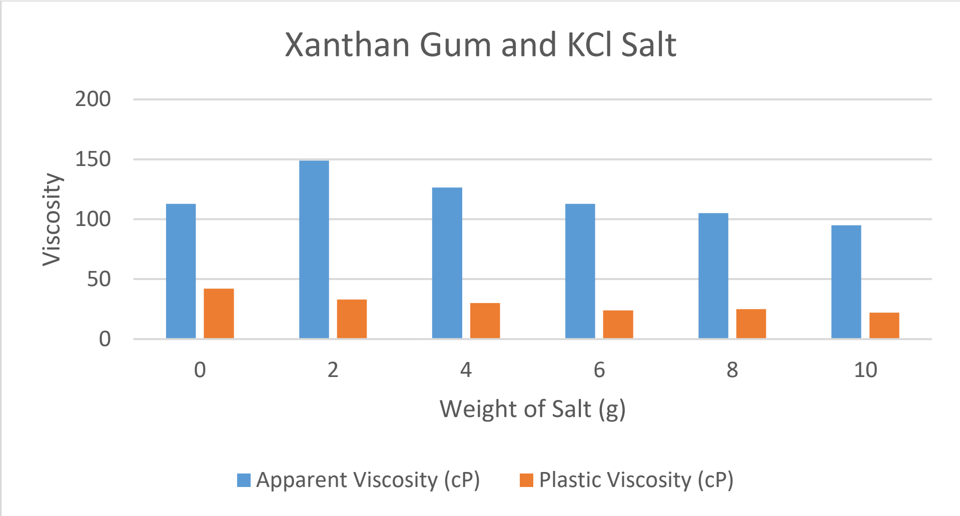

Figure 2 Effect of Xanthan Gum and KCl salt on the Viscosity of the Drilling fluid

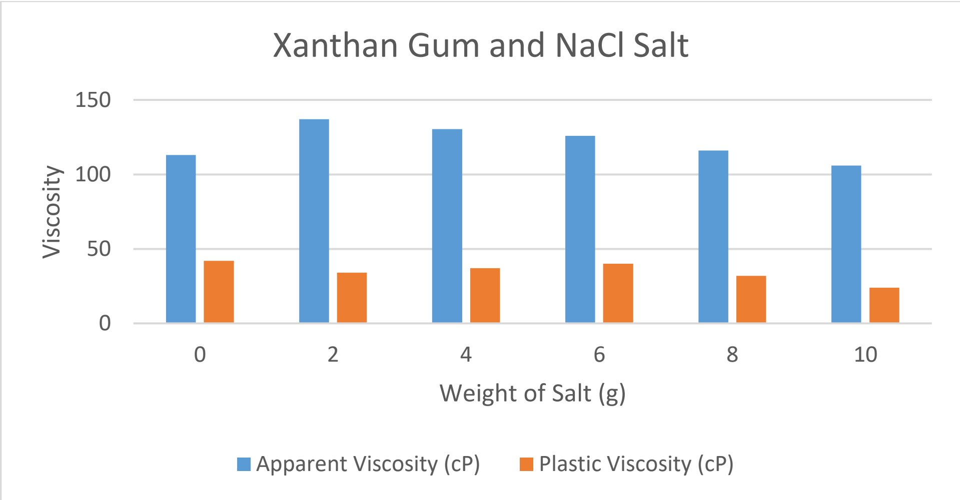

Figure 3 Effect of Xanthan Gum and NaCl salt on the Viscosity of the Drilling fluid

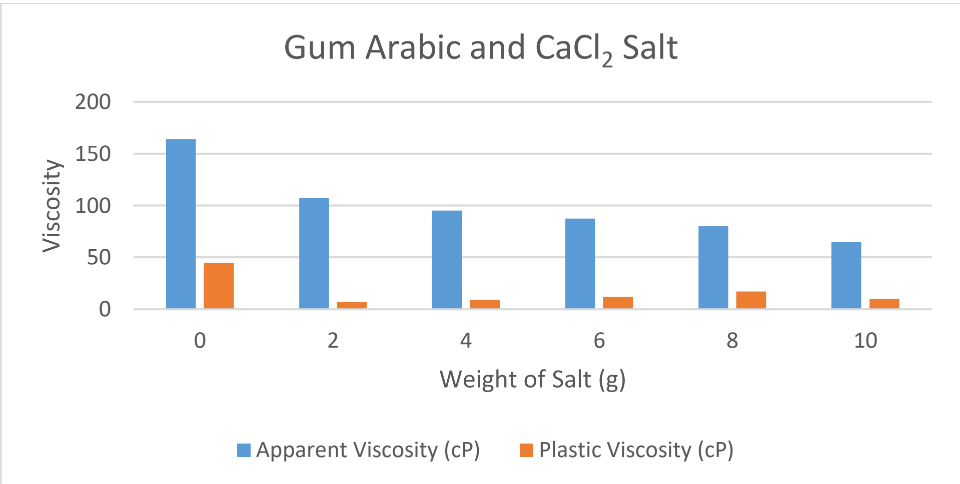

Figure 4 Effect of Gum Arabic and $CaCl_2$ salt on the Viscosity of the Drilling fluid

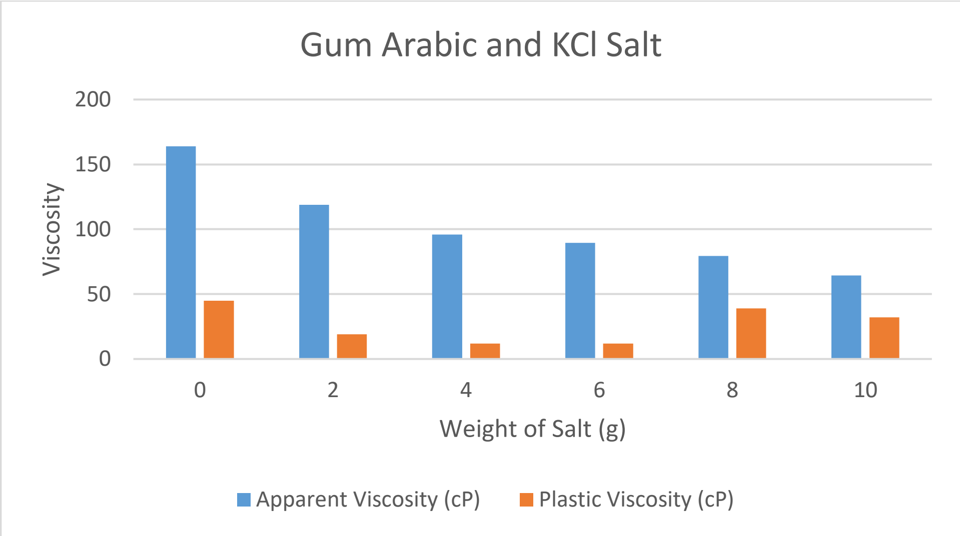

Figure 5 Effect of Gum Arabic and KCl salt on the Viscosity of the Drilling fluid

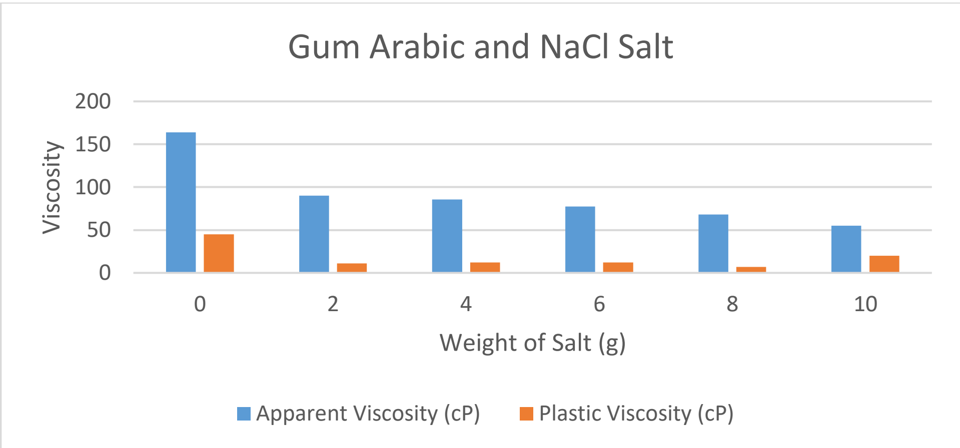

Figure 6 Effect of Gum Arabic and NaCl salt on the Viscosity of the Drilling fluid

The effects of $CaCl_2$, NaCl, and KCl salts on the rheological properties of fresh water-based drilling fluid with additives (viscosifiers in this case, Xanthan Gum or Gum Arabic) were investigated using five different salt sample weights for each of the three distinct salts used, with the viscosifier weight remaining constant (1 gram) for all samples analyzed.

$CaCl_2$ in Xanthan Gum Viscosified Water-based Drilling Mud

From the results in Figure 1, a downward trend of plastic viscosity and apparent viscosity is seen with a corresponding increase of $CaCl_2$ weight. This salt weight in solution is perceived in this instance as the concentration of salt and an increase in weight infers a corresponding increase in the concentration of salt. Also, from the tables of results, the ability of the drilling fluid to hold cutting and transport them to the surface (Gel Strength) was badly depleted upon the increase in the concentration of salts. This effectively means that $CaCl_2$ has a depleting effect on the rheological properties of Gum Arabic.

KCl in Xanthan Gum Viscosified Water-based Drilling Mud

From the results in Figure 2, a downward trend plastic viscosity and apparent viscosity is seen with corresponding increase of KCl weight. This salt weight in solution is perceived in this instance as concentration of salt and an increase in weight infers a corresponding increase in concentration of salt. Also, from the tables of results, the ability of the drilling fluid to hold cutting and transport them to the surface (Gel Strength) was badly depleted upon increase in concentration of salts. This effectively means that KCl has a depleting effect on the rheological properties of Xanthan Gum.

NaCl in Xanthan Gum Viscosified Water-based Drilling Mud

From the results in Figure 3, a downward trend of plastic viscosity and apparent viscosity is seen with a corresponding increase of NaCl weight. This salt weight in solution is perceived in this instance as the concentration of salt and an increase in weight infers a corresponding increase in the concentration of salt. Also, from the tables of results, the ability of the drilling fluid to hold cutting and transport them to the surface (Gel Strength) was badly depleted upon an increase in the concentration of salts. This effectively means that NaCl has a depleting effect on the rheological properties of Xanthan Gum.

$CaCl_2$ in Gum Arabic Viscosified Water-based Drilling Mud

From the results in Figure 4, a downward trend of plastic viscosity and apparent viscosity is seen with a corresponding increase of $CaCl_2$ weight. This salt weight in solution is perceived in this instance as the concentration of salt and an increase in weight infers a corresponding increase in the concentration of salt. Also, from the tables of results, the ability of the drilling fluid to hold cutting and transport them to the surface (Gel Strength) was badly depleted upon an increase in the concentration of salts. This effectively means that $CaCl_2$ has a depleting effect on the rheological properties of Gum Arabic.

KCl in Gum Arabic Viscosified Water-based Drilling Mud

From the results in Figure 5, a downward trend of plastic viscosity and apparent viscosity is seen with a corresponding increase of KCl weight. This salt weight in solution is perceived in this instance as the concentration of salt and an increase in weight infers a corresponding increase in the concentration of salt. Also, from the tables of results, the ability of the drilling fluid to hold cutting and transport them to the surface (Gel Strength) was badly depleted upon an increase in the concentration of salts. This effectively means that KCl has a depleting effect on the rheological properties of Gum Arabic.

4. Conclusion

Calcium Chloride ($CaCl_2$), Potassium Chloride (KCl), and Sodium Chloride (NaCl) Salts each had detrimental impacts on the desirable rheological properties of the Gum Arabic and Xanthan Gum viscosified water-based drilling fluid, according to this research.

A decreasing trend in plastic viscosity and apparent viscosity was seen across all samples, while the salt weight was increased as can be seen in the visualizations and tables of data. This salt weight in solution is interpreted as salt concentration in this case, and an increase in weight implies an increase in salt concentration.

Salts had a detrimental impact on the desirable rheological properties of the Gum Arabic and Xanthan Gum viscosified water-based drilling fluid, according to this research.

A decreasing trend in plastic viscosity and apparent viscosity was seen across all samples, while the salt weight was increased as can be seen in the visualizations and tables of data. This salt weight in solution is interpreted as salt concentration in this case, and an increase in weight implies an increase in salt concentration.

References

[1] Azar J. J. and Robello Samuel G., 2007. "Drilling Engineering". PennWell Publishing, Tulsa, Oklahoma, p. 37 – 83.

[2] Amanuallh M. D., Marsden J. R. and Shaw H. F., 1997. "An Experimental Study of the Swelling Behaviour of Mudrocks In the Presence of Drilling Mud System". Canadian Journal of Petroleum Tech. 36(3): p. 45-50.

[3] Salamone J. C., Clough S. B., 1982. "Xanthan Gum - A Lyotropic, Liquid Crystalline Polymer and Its Properties as A Suspending Agent". Baroid Industries, Inc., Houston, Texas, p. 1 - 4.

[4] Navarrete R. C., Himes R. E. and Seheult J. M..: 2000. "Applications of Xanthan Gum in Fluid-Loss Control and Related Formation Damage". Paper presented at the 2000 SPE Permian Basin Oil and Gas Recovery Conference, Midland, Texas, 21–23 March 2000.

[5] Parija, S., Misra, M. and Mohanti, A.K., 2001. "Studies of Natural Gum Adhesives: An Overview". J. Macromol. Sci., Polymer Rev. C41 3, p. 175–197.

[6] Lummus, J.C., and Azar, J.J., 1986. "Drilling Fluids Optimization—A Practical Field Approach" vol. 112, PennWell Publishing, Tulsa, Oklahoma, p. 160.

[7] Enilari M.G., Osisanya S.O., Ayeni K.: "Development and Evaluation of Various Drilling Fluids for Slim-Hole Wells" presented at the Petroleum Society's 7th Canadian International Petroleum Conference (57th Annual Technical Meeting), Calgary, Alberta, Canada, June 13 – 15, 2006.

[8] Elward-Berry J., Thomas E. W., 1994. "Rheologically Stable Deepwater Drilling Fluid Development and Application" presented at the 1994 IAOC/SPE Drilling Conference held in Dallas, Texas, 15-18 February 1994.

[9] API Recommended Practice 13B-1. "Recommended Practice for Field Testing Water-Based Drilling Fluid", 3rd Edition. API Publishing Services, Washington D.C., USA; 2003.