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COMPARATIVE ANALYSIS OF BARITE AND HEMATITE USED IN WATER-BASED DRILLING FLUID

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ABSTRACT

To meet the future demands and tackling the challenges, the O&G industry needs more than just going for discovering the unproven hydrocarbon reserves. Technologies way beyond the available ones requires tremendous development, to achieve the objective of recovering oil. To overcome such shortcomings, there should be scope and facilitation of development and application of those researched and developed technologies. Ample of understandings has to be considered about the rheology of the drilling fluids that are being put to operation in reaching deep targets of oil. Selective designing of the drilling fluids holds a strong place of concern in achieving economic project results in the oilfields and shall be strongly emphasized upon, so as to achieve shortening of the non-productive time during operations. Mud additives contribute to the specific functions and properties to the drilling fluid, especially in case of rheological properties, which in turn attains multiple roles in the wellbore. The project work emphasizes only on three of the many available fluid additives – bentonite, barite and hematite; whose rheological characteristics were determined in varying operating conditions and compared among the other two. The base drilling fluid was 'water + bentonite'. Fresh / Tap water was used, which had a density of 8.5 ppg (1.0185 g/cc). Drilling fluid samples having varying concentrations of mud weighing agents (5%, 10%, 15% and 20% of the total weight of the drilling fluid) were simulated and operated in the Fann viscometer to obtain the plastic viscosity, yield point and gel strength. Results attained from the experiments revealed that out of the two weighing agents, hematite had the highest degree of rheological parameters when kept in same concentrations.

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INTRODUCTION

Drilling fluids (mud) are an essential element to the drilling processes of the O&G industry. Both the rotary as well as the directional drilling operations rely greatly on the effectiveness of the drilling fluid to cut through the formations and reach the target depths (payzones). Without drilling muds and their additives, corporations would find it difficult if not impossible to drill for oil and gas and we would hardly have any of the fuels and lubricants considered essential for modern industrial civilization (Davies *et al*., 1992). Fundamentally drilling fluid is used in the drilling operations are a heterogeneous mixture of water, clay, additives and chemicals. It is an influential component in the drilling process, which brings about varied functions into play. Due to their nature of occurrence and specific rheological properties, drilling fluids are considered as a complex fluid. They are shear thinning, thixotropic and thermal dependent fluids. Depending on the subsurface flow conditions and shear conditions, the complex internal structure of a drilling fluid is liable to change that might cause a non-homogenous phenomenon. Hence a proper characterization of the drilling fluid in terms of rheological measurements is very important. A successful drilling operation requires enhanced quality of drilling mud with well formulated properties that will enable them to perform creditably during drilling operations (Darley & Grey, 1988). Primarily the job of any drilling fluid is to remove the rock cuttings from the borehole during drilling of the well. Other functions of a drilling fluid include

- Transportation of the removed rock cuttings from the well bore to the surface through the annulus;

- Suspending the rock cuttings in it when fluid circulation is stopped;
- Cooling and cleaning the drill bit;
- Lubrication of the drill bit;
- Managing formation pressure so as to maintain well bore stability;
- Assisting in cementing and completion of the drilled well;
- Preventing influx of formation fluids into the well bore by forming a low permeable filter / mud cake;
- Providing Weight-on-Bit (WOB);
- Aiding in the interpretation of formation data through the collected rock cuttings and cores;
- Minimizing any possible damage on the sub-surface equipment.

To meet these design factors, drilling fluid offer a complex array of interrelated properties. Five basic properties are usually defined by the well program and are closely monitored during drilling. They are

- Rheology
- Density
- Fluid loss
- Solid content; and
- Chemical properties.

For any type of drilling fluid, all five properties may to some extent, be manipulated using additive, however, the resulting chemical properties of a fluid depends largely on the types of mud chosen, and this choice rest on the types of well, the nature of the formation to be drill and the environmental circumstances of the well. (Baker Hughes, 2011). To ensure proper functionality, an appropriate drilling fluid is to be designed and selected. Understanding the factors effecting the working of the drilling fluid is very much critical. The drilling fluid is related with most of the drilling problems. If the drilling fluid does not perform the above mentioned functions and according to the expectations of the bore hole conditions, then situations might arise leading to abandoning of the well. Also, the additives and chemicals used are expensive. So, it is to be kept in mind that the drilling fluid is maintained in a good condition and at a lowest possible expenditure.

Research methodology and experimental procedure

The objective of this research work was to study about the effects of the additives – barite, hematite and bentonite; on the rheological properties of the drilling fluid. The experiment mainly emphasizes on the changes in the rheological properties of the drilling due to the addition of these additives under varying concentrations. The water-based mud samples were formulated by M/s Geologging Industries Limited, which is providing mud-logging operations and services to the oil Duliajan – Naharkatiya fields of Oil India Limited, Duliajan. The samples were prepared by mixing up of deionized water and bentonite, followed by addition of the respective additives. The components were thoroughly mixed with the help of a variable speed mixer` (Single Spindle Hamilton Beach Commercial Mixer).

Mud program

The mud program for the drilling fluid in the operating field was as follows

Table 1. Mud program for oil well NHK 549, Dikom (Courtesy – M/s Geologging Industries, Mumbai)

Operating company	:	M/s Geologging Industries Limited, Mumbai
Operating area	:	Duliajan – Naharkatiya, Dibrugarh
Well Number	:	NHK 549
Location	:	Dikom, Dibrugarh
Target Depth (TD)	:	3085 m (3100 m)
Mud weight	:	9.35 – 9.48 lbs/gal (69.94 – 70.92 lbs/ft^3)
pH	:	9.5
Plastic viscosity	:	14 – 16 cP
Yield point	:	24 – 26 cP

Fig. 1. Mud preparation laboratory of M/s Geologging Industries at Naharkatiya (Assam)

Rheology Methodology

The base mud sample for the experiment was prepared by adding 32 g of bentonite to 400 g of tap water. The bentonite-to-water ratio of 8% was maintained throughout the experiment work. Other mud samples were prepared by adding additives of varying concentrations, in the order of – 5%, 10%, 15% and 20%. The rheological properties were measured at an ambient temperature of 23.9 ^{o}C.

Preparation of mud samples for rheological purpose

Samples of varying concentrations of barite and hematite were prepared for the rheological purposes. The base mud was 'bentonite + water'.

Table 2. Composition of barite mud samples

Sample code	% of Barite	Mass of Water (g)	Mass of Bentonite (g)	Mass of Barite (g)
B^1	5.0	400	32	21.6
B^2	10.0	400	32	43.2
B^3	15.0	400	32	64.8
B^4	20.0	400	32	86.4

Table 3. Composition of hematite mud samples

Sample code	% of Hematite	Mass of Water (g)	Mass of Bentonite (g)	Mass of Hematite (g)
H^1	5.0	400	32	21.6
H^2	10.0	400	32	43.2
H^3	15.0	400	32	64.8
H^4	20.0	400	32	86.4

Experimental procedure

To study the effects of the mud additives on water-based drilling fluid, an experimental procedure was developed.

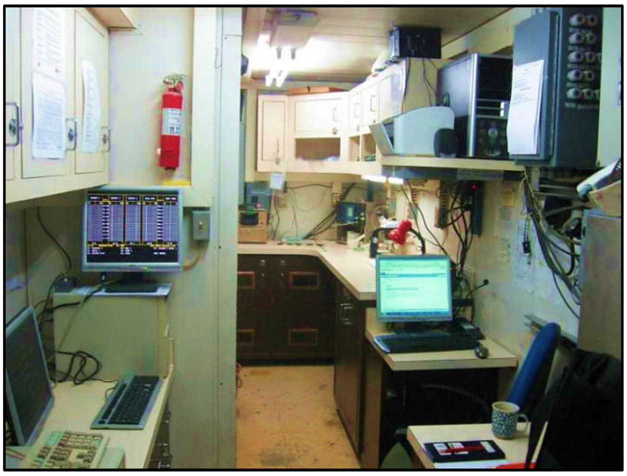


Fig. 2. Mud testing lab of M/s Geologging Industries, Naharkatiya

This procedure aimed to give an insight of the real-life problems faced during drilling operations, where a lot can occur and change the fate of oil production.

- 10 beakers of 500ml capacity were used for confining the mud samples of different additive concentrations. The beakers were labelled accordingly to the mud samples they were to be put in. For the control mud sample, which had neither of the two weighing agents mixed was marked as C*. For the corresponding mud samples having barite and hematite in varying concentrations, the beakers were labelled as B^1 to B^4 and $H^1$to H^4 respectively.
- Prior to employing the beakers with the mud samples, they were treated with ethanol and then by acetone to degrease them. Later the beakers were washed with deionized water and were put in the oven to dry.
- To release any entrained gases, the mud samples were thoroughly mixed in the mixer.
- One by one, all the beakers having mud samples were engaged with the Fann viscometer for obtaining the plastic viscosity and yield point results. The control mud sample – C*, was the first sample to be tested. The Fann Viscometer was operated at the speeds of 600 and 300 RPM for determining the plastic viscosity and yield point of the samples.
- For determining the gel strength of the drilling fluid samples, the Fann viscometer was operated at a low speed of 3RPM. For the 10 – second gel strength test, the samples were left undisturbed for 10 seconds, after which the readings were noted.

Fig. 3. Mud sample preparation

Equipment used

For performing the rheological experiments, certain equipment were used. All these instruments were readily available at the mud-logging laboratory of M/s Geologging Industries. With the help of the below specified equipment, activities like – preparation of drilling fluid, mixing of additives with mud, performing rheological tests on the samples, etc. were carried out. The equipment along with their brief descriptions are specified below –

Fann viscometer – Model 35A

To measure the viscosity of the mud samples Fann viscometer was used. Before using it for the experiments, the viscometer was calibrated according to the operating manual.

Fig. 4. Fann Viscometer – Model 35A

Fann mud balance – Model 140

Fann - Model 140 mud balance was used to calculate the mud weight of the prepared samples. The mud weight had an operating range from 7 – 24 lbs / gal. To ensure the accuracy and precision of data recording, all the obtained mud weight readings were rounded off to one decimal places.

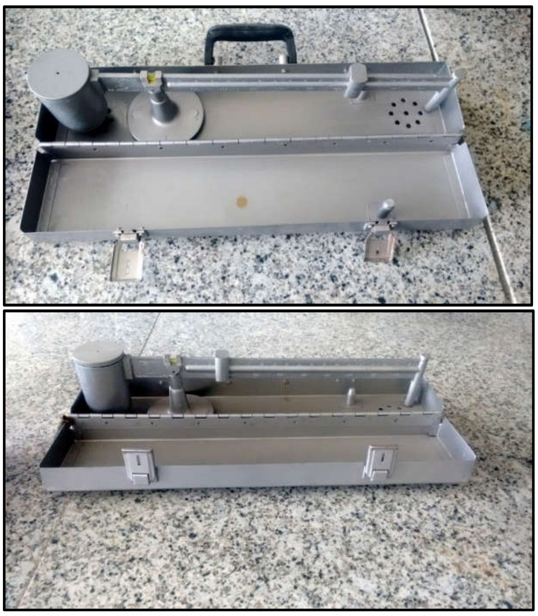


Fig. 5. Fann Mud Balance – Model 140

Single spindle Hamilton beach commercial mixer

To mix the additives well and to prepare the mud sample, a variable speed mixer – single spindle Hamilton beach commercial mixer was used. The mixer is configured with 3-speed settings and has an additional pulsating switch.

Fig. 6. Single Spindle Hamilton Beach Commercial Mixer

Fann aging cell assembly – Part 76001

To initiate the aging process of the water-based drilling fluid, Fann aging cell assembly was used. The aging cell had a capacity of holding 260 ml of fluid within it. The maximum operating conditions of this aging cell was – 175 °C and 1250 psi.

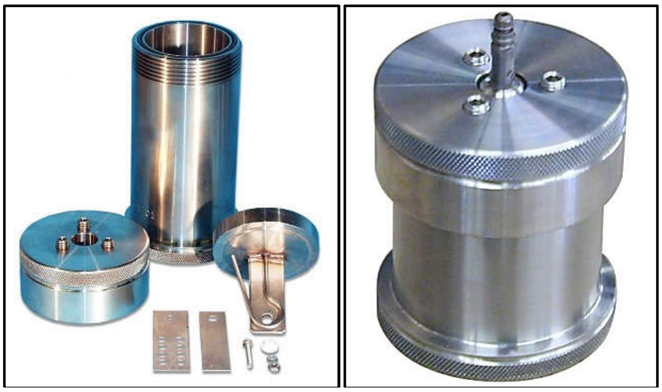


Fig. 7. Fann Aging Cell Assembly – Part 76001

Fann roller oven – Model 704ES

In order to simulate the downhole conditions of the drilling fluid, Fann roller oven was utilized. This was done especially to work on the slow flow rate of the drilling fluid in the annulus. For the experiment, the operational settings were – 50 RPM and 80 °C.

Fig. 8. Fann Roller Oven – Model 704ES

TEST RESULTS AND DISCUSSIONS

The test results are being grouped into: - mud density, plastic viscosity, yield point and 10 second gel strength test results. The data obtained from the respective experimentation of the mud samples along with their graphical representation is being shown.

Mud density test results

Table 3. Mud density result for barite mud sample

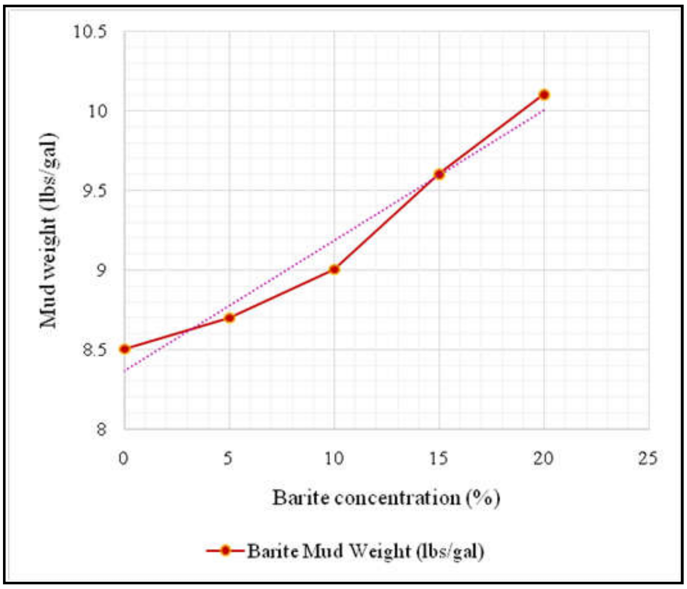
Additive Conc. (%)	0	5	10	15	20
Additive Weight (g)	--	21.6	43.2	64.8	86.4
Mud Weight (lbs/gal)	8.5	8.7	9	9.6	10.1

Table 4. Mud density result for hematite mud sample

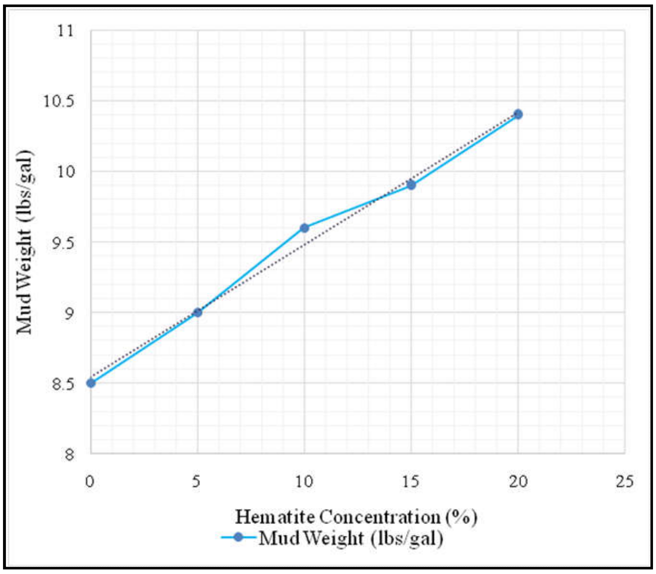
Additive Conc. (%)	0	5	10	15	20
Additive Weight (g)	--	21.6	43.2	64.8	86.4
Mud Weight (lbs/gal)	8.5	9	9.6	9.9	10.4

The initial density of the drilling fluid sample was 8.5 lbs/gal. This value of the mud weight (MW) is only of the base drilling fluid, which has no additives added into it. On adding 21.6 grams of barite, i.e., 5% of the total weight of the mud sample, the density of the drilling fluid slightly increases to 8.7 lbs/gal. Further, on adding 43.2, 64.8, and 86.4 grams of barite respectively, i.e., 10, 15, and 20% of barite to the base drilling fluid, the mud weight values of 9.0, 9.6 and 10.1 lbs/gal are obtained.

When we consider an ideal condition in this case (represented by the pink dotted line), the mud weight of the drilling fluid tends to increase linearly due to the addition of barite on every stage. On correlating the points of intersection between the actual behavior (red line) and the ideal behavior (pink dotted line) of the drilling fluid due to the addition of barite, it can be seen that mud weight of the drilling fluid when 5% and 10% of barite is used, the actual results comes comparatively a way down below the ideal results. But as the barite concentration is increased (in cases of 15% and 20%), actual mud densities are higher than the ideal mud density values.

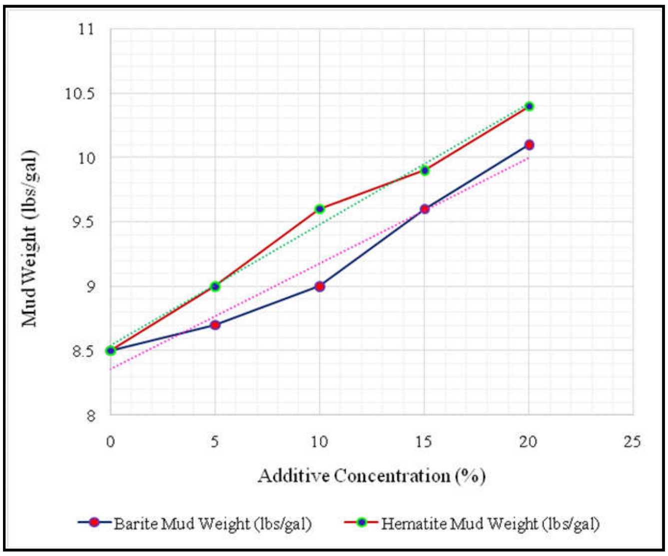


Plot 1. Effect of barite on mud density of the mud sample



Plot 2. Effect of hematite on mud density of the mud sample

Mud weight of the drilling fluid due to the addition of hematite, gradually increases from the initial condition itself, roughly acquiring a linear trend (linearly increasing). In correlation to the ideal conditions, which was theoretically assumed, the actual readings of the mud weight almost match the ideal trend line (dotted line). However, during the addition of 10% of hematite to the base drilling mud, there is slightly an abrupt rise in the overall density of the mud sample (from 9 lbs/gal to 9.6 lbs/gal), as it can be seen that actual mud weight results (blue line) aremoving away far from the trend line. But when 15% of hematite is added to the base fluid sample, the hike in the mud weight is comparatively low in comparison (which is 9.9 lbs/gal) to the mud weight that was attained during the addition of 10% of hematite to the drilling fluid. As the trend line intersects the actual result halfway across, the obtained mud weight reading falls below the assumed value of the ideal mud weight. When 20% of hematite is added to the base fluid, a mud weight value of 10.4 lbs/gal is obtained and the actual graph almost equals the ideal behavior (trend line) of the fluid, which was presumed to be.



Plot 3. Comparison of addition of additives on mud density of the mud sample

On comparing the behavior of addition of varied concentrations of both barite and hematite to the base drilling fluid, it can be concluded that addition of hematite to the base sample of water-based drilling fluid (comprising of only water and bentonite), helps in achieving a higher mud weight for the drilling fluid in contrast to barite. The addition of barite leads to obtaining of a lower value of the drilling fluid density at every stage of additive addition. While using the same concentrations of hematite and adding to the base mud can help us in achieving a higher mud weight. On an ideal consideration, a low mud weight (as low as the weight of water) is a beneficial choice to achieve the most favorable rates of penetration (R.O.P.) in the formation. But in industrial practice and real-life scenarios, a mud weight of much higher values is needed to perform the primary job of suppressing the subsurface pressure. The control of drilling fluid weight is critical, because an unnecessarily heavy drilling mud can cause breakdown of formations leading to loss of circulation or even a complete loss of a well, and reduction in drilling rate. On the other hand, if the mud weight becomes too small to suppress subsurface pressures, well kick and /or blowout may occur (Walter, 1963 & Kruse, 1975).

Viscometer readings

To obtain the plastic viscosity and yield point of the prepared mud samples, Fann viscometer was employed for the purpose. The viscometer having variable rotor speeds was operated at 600 and 300 RPM for determining the plastic viscosity and yield point. Plastic viscosity, after having the viscometer readings, was calculated out using equation 2.4 or equation 2.5. Similarly, the yield point was calculated out using equation 2.6.

The plastic viscosity for any drilling fluid can be calculated as,

$$\mu p = 300\frac{\theta N}{N} - \frac{300\ \tau y}{N} \quad \text{.................(2.4)}$$

And when N = 300 and 600 RPM,

$$\mu_p = \theta_{600} - \theta_{300} \quad \text{.................(2.5)}$$

Where,

μ_p = plastic viscosity of the drilling fluid (cP);
τ_y = yield point of drilling fluid (lbs / 100 ft^2);
θ_{300} = viscometer dial reading at 300 RPM;
θ_{600} = viscometer dial reading at 600 RPM.

$$\tau_y = \theta_{300} - \mu_p \quad \text{.................(2.6)}$$

Table 5. Viscometer readings for barite mud sample

Additive Conc. (%)	0	5	10	15	20
Θ_{600}	55	74	82	91	117
Θ_{300}	37	50	56	62	80

Table 6. Viscometer readings for hematite mud sample

Additive Conc. (%)	0	5	10	15	20
Θ_{600}	54	94	131	145.5	205
Θ_{300}	36.5	71	100	112.5	161

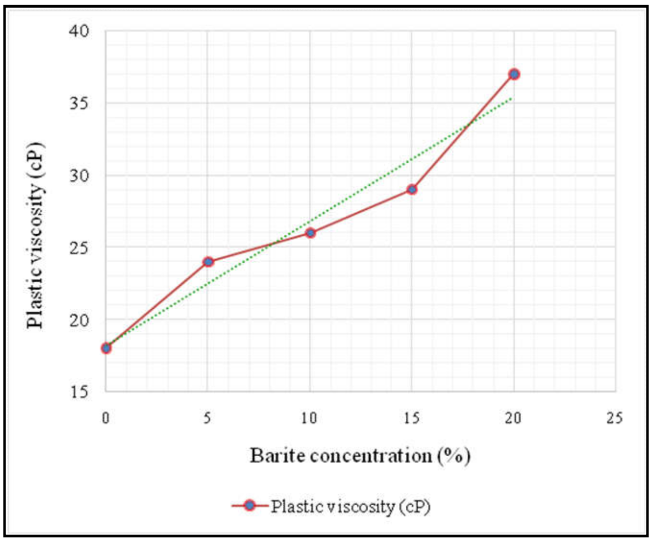
Plastic viscosity test Results

Table 7. Plastic viscosity result for barite mud sample

Additive Conc. (%)	0	5	10	15	20
Additive Weight (g)	--	21.6	43.2	64.8	86.4
Plastic Viscosity (cP)	18	24	26	29	37

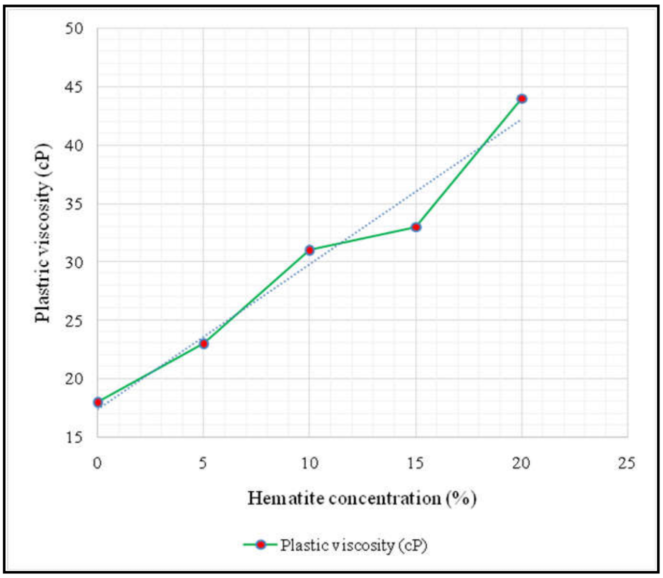
Table 8. Plastic viscosity result for hematite mud sample

Additive Conc. (%)	0	5	10	15	20
Additive Weight (g)	--	21.6	43.2	64.8	86.4
Plastic Viscosity (cP)	18	23	31	33	44



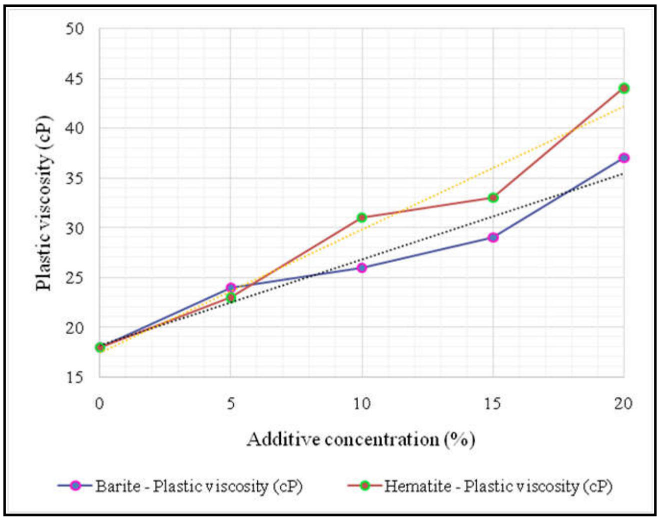
Plot 4. Effect of barite on plastic viscosity of the mud sample

The base drilling fluid without any addition of barite and hematite had a plastic viscosity (PV) of 18 cP. As different concentrations of barite were added to the base mud, the plastic viscosity started increasing. However, the trend of the increase (orange line) in the plastic viscosity was not consistent. In correspondence to the ideal behavior expected in this case, the actual plastic viscosity of the mud during the addition of 10% and 15% of barite fell below the ideal trend line (green dotted line), which indicate a linear increase in the plastic viscosity of the mud. But, after the addition of 20% of barite to the drilling fluid, the plastic viscosity obtained was way above the ideal conditions.



Plot 5. Effect of hematite on plastic viscosity of the mud sample

The plastic viscosity of the drilling fluid on the addition of hematite increases rapidly. After the addition of various concentrations of hematite, the correlation of the actual results (green line) with the ideal conditions (blue dotted line) shows fluctuating behavior. Though the plastic viscosity increases after the addition of every 5% increase in hematite concentration, initially after obtaining the PV value for the first mud sample (having 5% hematite in it), there is a minor decrease in the plastic viscosity in comparison to the expected value (or ideal value). But when 10% of hematite is added to the drilling fluid, the plastic viscosity (31 cP) of the mud is better than the ideal case, being higher than the expected results.



Plot 6. Comparison of addition of additives on plastic viscosity of the mud sample

Nevertheless, the plastic viscosity is increasing (33 cP), there is a substantial drop in the results if we compare it with the trend line, when 15% of hematite is added to the drilling fluid. As testing proceeded further, on adding 20% of hematite to the drilling fluid, a plastic viscosity of 44 cP is achieved and the value is significantly superior than the assumed PV value.

If the plastic viscosities of both the mud samples are evaluated between the addition of various concentrations of barite and hematite, it is learnt that addition of hematite will bring about a higher value of plastic viscosity and vice-versa in the case of barite. In general, a higher mud weight of the drilling fluid gives rise to a higher plastic viscosity. In operational practices, it is favorable to have plastic viscosities of lower values. A low plastic viscosity will suggest that the mud is able to facilitate in rapid drilling of the formations, due to a low viscosityprevailing nearby the bit. Low plastic viscosities are also obtained when drilling operations are carried in deeper depths. With the increase in drilling depths, the sub-surface temperature also increases, lowering the viscosity of the existing drilling mud. This will lead to a decrease in the plastic viscosity as well. While high plastic viscosities are warnings that the solid control equipment arefailing and acting inefficiently. High plastic viscosities are directconsequences of increments in solid contents in the drilling mud, drill solids or in lost circulation materials. To overcome problems arising from high plastic viscosities the solid content must be brought down. This can be carried out by using solid control equipment, by diluting the existing mud, or by going for both the preferences. Furthermore, if we face an increasing tendency of the plastic viscosity without any changes to the mud weight, this strongly points out that there is an upsurge in the ultra-fine drill content in the mud system.

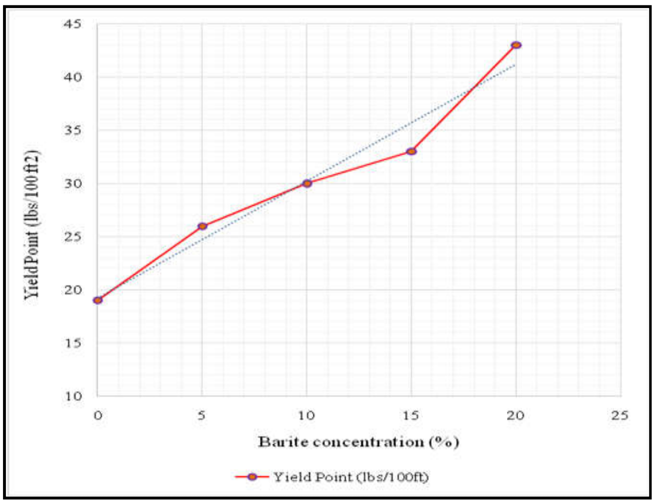
Yield point test results

Table 9. Yield point result for barite mud sample

Additive Conc. (%)	0	5	10	15	20
Additive Weight (g)	--	21.6	43.2	64.8	86.4
Yield Point (lbs/100 ft^2)	19	26	30	33	43

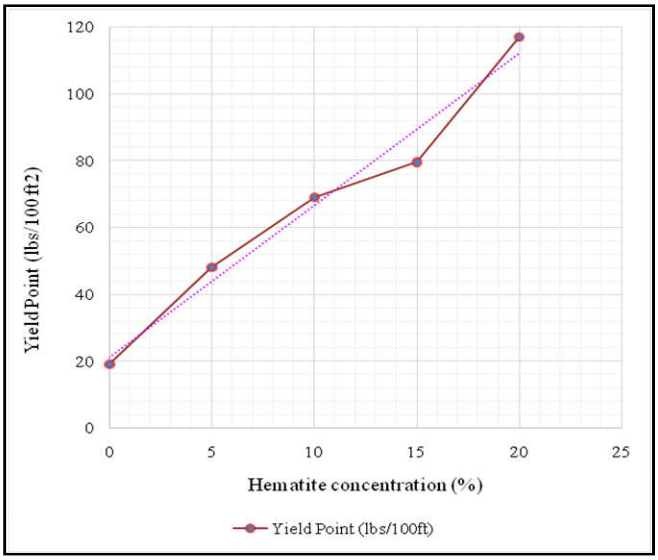
Table 10. Yield point result for hematite mud sample

Additive Conc. (%)	0	5	10	15	20
Additive Weight (g)	--	21.6	43.2	64.8	86.4
Yield Point (lbs/100 ft^2)	19	48	69	79.5	117

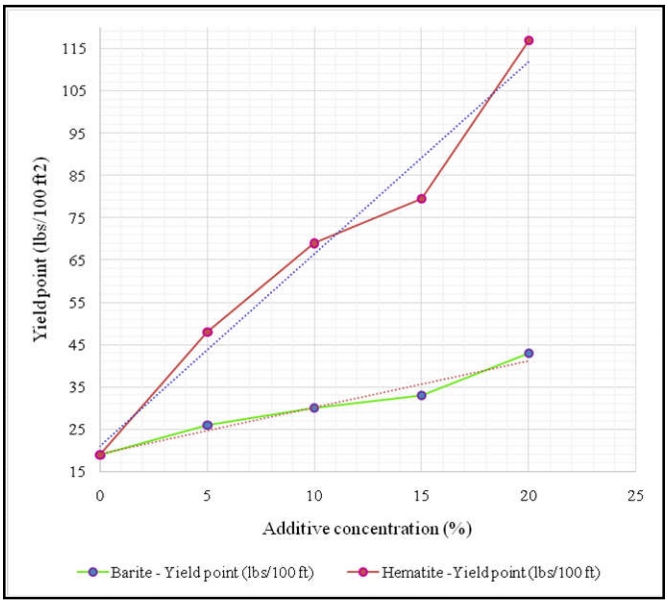


Plot 7. Effect of barite on yield point of the mud sample

Yield point (YP) of the base sample was 19 lbs/100 ft^2. As barite started pouring in to the drilling fluid, the yield point of the mud began to rise. Addition of 5% barite to the base drilling fluid attained a yield point of 26 lbs/100 ft^2. This yield point value is above what is usual in case of the ideal trend line (blue dotted line). When 10% of barite is added to the base drilling fluid, the yield point (30 lbs/100 ft^2) equals to the ideal value, as the trend line is seen intersecting at that point. Then again, the plastic viscosity even though increasing progressively after the addition of 15% of barite to the drilling fluid, it is seen that in comparison to the ideal trend of the behavior of the mud, the plastic viscosity has come down. The plastic viscosity thereon increases after the addition of 20% of barite and the obtained value (43 lbs/100 ft^2) being comfortably higher than the assumed values of the ideal condition.



Plot 8. Effect of hematite on yield point of the mud sample



Plot 9. Comparison of addition of additives on yield point of the mud sample

Yield point of the mud significantly increases when hematite is being added to the base drilling fluid. Right from the beginning of the addition of 5% of hematite till 20%, the yield point results are whopping. The base drilling fluid (0%

additive) had a yield point of 19 lbs/100 ft^2. But as soon as 5% of hematite is added to the drilling fluid, the yield point substantially builds up, reaching to 48 lbs/100 ft^2. Again, on adding 10% of hematite to the drilling fluid, a yield point of 69 lbs/100 ft^2 is attained. The values of both the yield, i.e., after addition of 5% and 10% of hematite respectively, is comparatively higher than the ideal values that can be assumed in the trend line (purple dotted line). But in comparison to the ideal conditions (trend line), the yield point (79.5 lbs/100 ft^2) is reasonably is lower when 15% of hematite is added to the base drilling fluid. Nevertheless, the yield point improves on a better note, being higher up than the trend line, when 20% of hematite is added. The graph shows yield point comparison in cases when both barite (green line) and hematite (orange line) of varying concentrations are added individually to the base drilling fluid. From the graph itself it can be inferred that addition of hematite will result in getting a higher value of yield point for the drilling mud. However, a higher yield point will indicate a possibility of high-pressure losses during mud circulation. Also, the value of yield point will determine the mud's ability to lift cuttings out of the annulus. Yield point of a mud can be decreased by the introduction of deflocculants into the drilling fluid, and the same can be increased by adding freshly dispersed clay or flocculants to the drilling fluid. So, it can related that an effective control of the mud's yield point will directly depend on the effective control of the drilled solids.

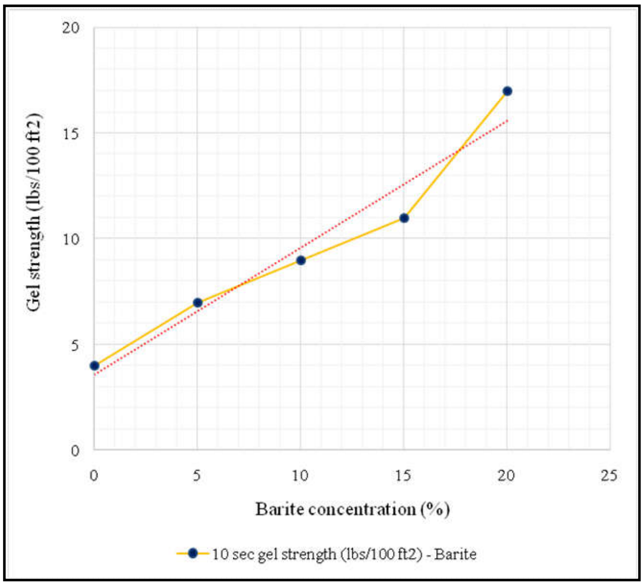
10 Second gel strength test results

Table 11. Gel strength result for barite mud sample

Additive Conc. (%)	0	5	10	15	20
Additive Weight (g)	--	21.6	43.2	64.8	86.4
Yield Point (lbs/100 ft^2)	4	7	9	11	17

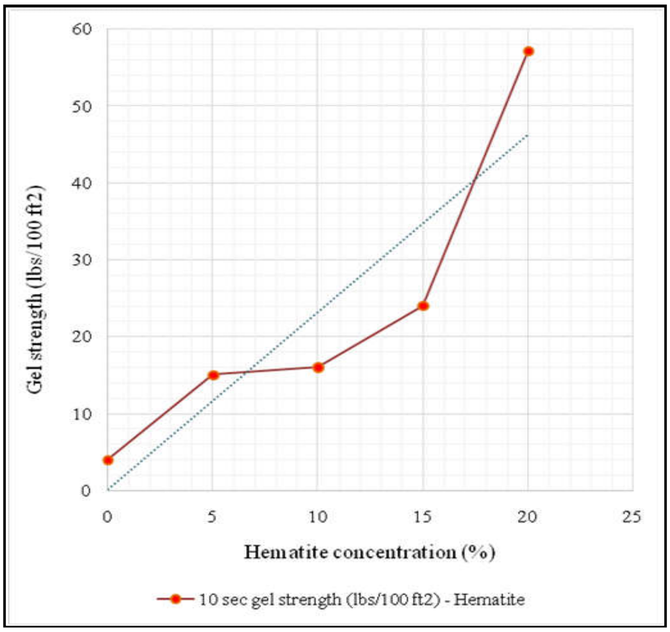
Table 12. Gel strength result for hematite mud sample

Additive Conc. (%)	0	5	10	15	20
Additive Weight (g)	--	21.6	43.2	64.8	86.4
Yield Point (lbs/100 ft^2)	4	15	16	24	57



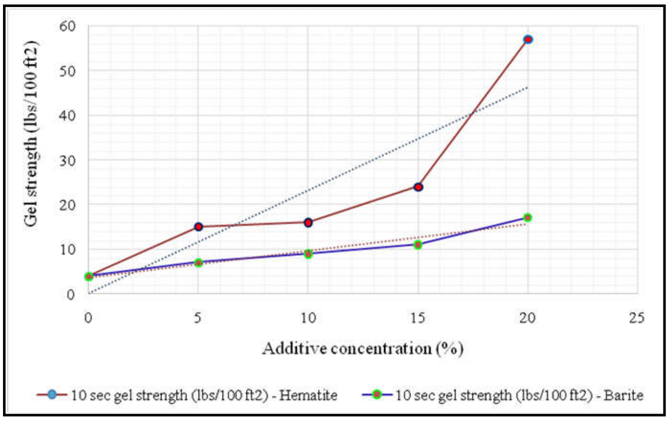
Plot 10. Effect of barite on gel strength of the mud sample

For the base drilling fluid, having only water and bentonite, the gel strength is 4 lbs / 100 ft^2. As the concentration of barite increases, the gel strength of the mud (yellow line) also increases in a roughly linear manner. At 5% addition of barite, a gel strength of 7 lbs / 100 ft^2 is obtained. As barite concentration is increased to 10%, the gel strength increases to 9 lbs / 100 ft^2. But this is relatively running down if the trend line (red dotted line) is taken as a base for ideal and assumed values for the condition. The same condition arises when 15% of barite is added to the drilling fluid and a gel strength of 11 lbs / 100 ft^2 is achieved. But after we add 20% of barite, the gel strength of the mud shows far better result (17 lbs / 100 ft^2), when comparing it with the ideal conditions.



Plot 11. Effect of hematite on gel strength of the mud sample

As 5% of hematite is added to the base drilling fluid (gel strength = 4 lbs/ 100 ft^2), the gel strength of the mud quickly increases, achieving a value of 16 lbs / 100 ft^2. In comparison to the effect hematite addition in case of 5% concentration, the increase in the gel strength value of the mud is not quite high, when 10% of hematite is added to the drilling fluid. The obtained results fall far below than the trend line (dark blue dotted line). Same is the case when 15% of hematite is being added to drilling mud, and a gel strength of 24 lbs / 100 ft^2 is obtained. But when 20% of hematite is added to the base drilling fluid, the gel strength escalates greatly, helping in attaining a value of 57 lbs / 100 ft^2. This value is way above the expected value from the ideal trend.



Plot 12. Comparison of addition of additives on gel strength of the mud sample

The evaluation between the gel strength results of barite and hematite clearly shows that addition of hematite leads to attaining a higher gel strength of the mud. The changes in the gel strengths in accordance to the individual addition of each additive (barite and hematite) are quite contrasting. In the case of barite, when varying concentrations are added to the base drilling fluid, the changes are gradual, depicting almost a linearly increasing trend. But for hematite, every 5% increase in the concentration very much alters (increases) the gel strength of the mud. Ideally, the two values of gel strength should be close rather than progressively far apart (Rabia H., 2002). The gel strength must be maintained throughout the operation, depending upon the solids control. The maintaining of the gel strength neither ensures a mud engineer that he / she shallkeep up a higher gel strength nor a lower gel strength value. A higher value of gel strength can cause mud to hold the rock cuttings strong, which will be challenging to separate out the solids at the surface facilities. Also, it can cause a high pump initiation pressure, which will break the mud circulation. This will lead to formation fracture and lost circulation. On the other hand, a low gel strength will causefailure of the mud to suspend cuttings when circulation is put off. This will result in pipe sticking and hole pack-off. Low gel strength can also cause the problem of barite sag, where the mud is unable to suspend the barite and there will be large fluctuations in the overall mud density.

Conclusion and recommendation

Conclusions

The experimental work examined the effects of bentonite, barite, and hematite on the rheology of water-based drilling fluids. Analysis was done between the rheological properties of barite and hematite (weighing agents), when these mud additives were treated with the base drilling fluid (water + bentonite). From all the results obtained and properties assessed, the purpose of the project work can come down to the following conclusion

- To control and achieve certain rheological properties of the drilling fluid, the concentration of mud additives is very much a central element. Due to changes in the concentration of barite and hematite, significant changes were observed in the mud weight, plastic viscosity, yield point and gel strength of the water-based drilling fluid.
- Hematite in comparison to barite, gave notably higher mud weight, plastic viscosity, yield point and gel strength, when same concentrations were being added to the drilling fluid.
- Hematite giving a higher mud weight than barite is a result of higher specific gravity of hematite than that of barite.
- Hematite contributing better values to the other rheological properties, is attributed to the presence of iron oxides in hematite, which also have lower rates od sedimentation, as compared to barite.

Recommendations

Based on the studies of rheological effects of the mud additives and the conclusion of the project work provided, the following can be recommended for any future work on this field –

- It is advised to study on the effects of drilling fluid aging on its rheological properties.
- It is advised to determine the effects of temperature and pH of the drilling fluid.
- It is advised to determine the effects of dissolved gases on the mud weight of the drilling fluid.
- It is advised to determine the effects of logging interpretation in flushed zones and how to improve it.
- It is advised to determine the effects of differential sticking caused by the water-based drilling fluids.
- To find out environment-friendly additives that can be used instead of the conventional additives and to protect the environmental norms.

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