AN EXPERIMENTAL INVESTIGATION ON THE EFFECT OF WATER HARDNESS ON THE RHEOLOGICAL AND FILTRATION LOSS PROPERTIES OF AQUEOUS BASED DRILLING MUD

Abstract

From many years Water Based Mud is being used as drilling mud in oil and gas industry. The base that is the water can be collected from different areas so there could be a difference in the amount of mineral content in it. The concentration of these salts or minerals could referred as water hardness. The water hardness will vary from location to location because of the difference in the change in salts present. Usually the carbonates and sulphates of magnesium and calcium will be the reason if this hardness. This project is focusing on how the water hardness will affect the properties of the drilling fluids. In this we will be determining the effect on Low Pressure and Low Temperature (LPLT) wells by using LPLT filter press as a model to find the filtration as well as the mud loss properties. Extensive research work has been conducted on the effect of water hardness on the rheological properties of the drilling fluids such as plastic viscosity, apparent viscosity and gel strength as well as the filtration properties. Graphs has been plotted on all these properties and results has been obtained. The comparative studies of the results shows that the properties are changing by a huge margin with the change in concentration of the water hardness or the salt content.

Keywords: Hardness, Aqueous, Rheological, Filtration, Mud

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I. INTRODUCTION

Drilling mud is one of the most vital component for a successful drilling operation. It serves many function like. Counter balancing formation pressure, cleaning the hole, lifting the drilling cuttings, cooling the bit, lubrication of the drill string etc. [1]. If drilling fluid failed to perform any of these functions then it will jeopardize the entire drilling operation [2]. So we should be very careful while selecting the components of drilling fluid. There are mainly two type of drilling fluid-aqueous and non-aqueous. Non aqueous has many environmental concerns associated with it so the industry mainly prefer Aqueous drilling fluid mainly comprise of-continuous phase which is water, reactive phase which is clay particles mostly, inert phase which are mostly weighting agents like Barite and additives [2] [3]. These additives are mostly used to manipulate the rheological properties of the drilling fluid [4]. Water becomes arduous by being connected with soluble, divalent, auriferous cations. The two main cations that cause water hardness are atomic number 20 (Ca^{2+}) and metal (Mg^{2+}). Atomic number 20 is dissolved in water because it passes over and thru sedimentary rock deposits. There are 2 varieties of hardness – temporary hardness and permanent hardness. Temporary hardness – conjointly referred to as 'Carbonate hardness'. Temporary hardness could be a style of water hardness caused by the presence of dissolved hydrogen carbonate minerals (calcium hydrogen carbonate and metal bicarbonate) [5]. Each atomic number 20 hydro carbonate and metal hydro carbonate decompose once heated. The first insoluble carbonate is reformed. This happens once water is stewed. Permanent hardness conjointly cited as 'non-carbonate hardness. Permanent hardness in water is hardness because of the presence of the chlorides, nitrates, and salt of atomic number 20 and metal, which can't be precipitated by boiling [6]. Once this is often the case, it's typically caused by the presence of the atomic number 20 sulfates or metal sulfates within the water, Several classification schemes exist for denoting the degree of hardness General tips for classification of waters are: 0 to 60 mg/L as carbonate is assessed as soft; 60 mg to a 120 mg/L as moderately arduous. a 120 to a 180 mg/L as arduous; and quite a 180 mg/L as terribly hard. The hardness of water is set by titrating with organic solution Ethyl Diamine carboxylic acid (EDTA) that could be a complexing agent. Since EDTA is insoluble in water, the disodium salt of EDTA was added EDTA reacts with metal ions having four to six coordination bonds. The salt content or the hardness is removed by many strategies if there's a presence of carbonate salts, it can cause temporary hardness which might be removed simply by boiling and in alternative hand if there's the presence of salts which can cause permanent hardness will have different strategies for the removal like reverse diffusion, precipitation strategies, natural action strategies, etc. Hard water is sometimes outlined because the water, contains a high concentration of atomic number 20 and metal ions. However, hardness is shaped by many alternative dissolved metal salts; those kinds of power or multivalent cations together with Al, barium, zinc, etc. [Diggs et.al. 2009]. An increase within the concentration of the salts resulted in an exceedingly decrease within the physical science properties of the mud samples. This means that with the monovalent and power salt contamination, there's a big decline within the performance of lubricant since the salts affect the dispersion, association, and activity behavior of the particles. The result was a lot of profound with $CaCl_2$ and $MgCl_2$ salts than the KCl salt. Salinity encompasses a bigger result on the physical science properties also because the physical science properties of drilling fluids because the salinity will increase the resistance is additionally increasing and also the physical science properties

are being reduced. [7] [8]. In this work we are trying relate the water hardness with the rheological and filtration loss properties of drilling fluid.

II. EXPERIMENTAL WORK

1. **Chemical** used the chemical used in this experiment are as follows Bentonite (API Grade), Carboxymethyl cellulose (CMC) (Karnataka Fine Chem.), Barite (Industry grade) (Gumpro Drilling Fluids Pvt. Ltd, Mumbai) Hydrochloric acid, Hydrochloric acid (Karnataka Fine Chem.) and calcium oxide (Karnataka Fine Chem.)

2. **Equipment used**: Hamilton Beach Mixer, Fann VG meter (FANN), Water Hardness Test Kit (NICE Chemicals), API Filter press (FANN), FANN VG meter (FANN)

3. **Methodology used:** Our aim of the project is to determine the effect of water hardness on the rheological properties as well as the filtration properties of drilling fluids. To check the effect of different concentration of salts we have collected sample with a specific concentration of salt present. To alter the salt concentration we have used magnesium sulphate salt. To determining the concentration of salt or the water hardness we have performed a test called water hardness test by which we could find the total hardness of the water sample. After that to get to know about the rheological properties we did rheological properties test by using hand crank viscometer followed by filtration loss test by the help of LPLT filter press. All samples are tested using different equipment present in Drilling fluid lab and results obtain from these test were compared and a conclusion is drawn.

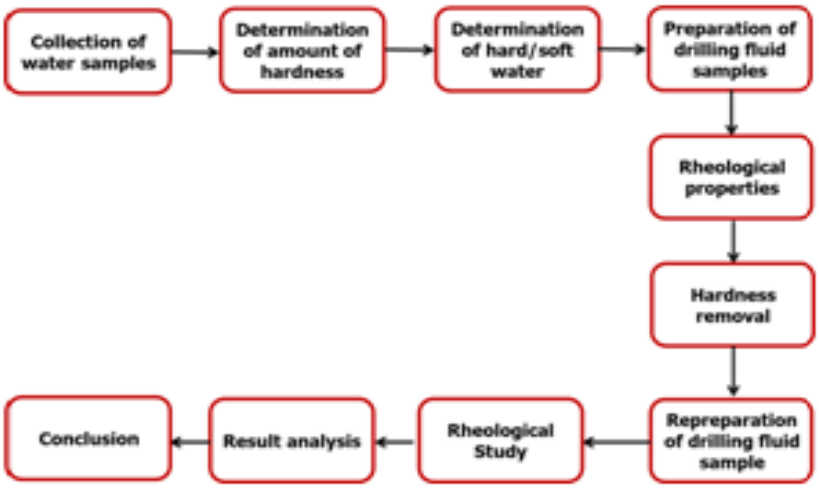

Figure 1: Methodology flow chart

4. **Measurement of Hardness of water samples:** Eleven different water samples are collected from different sources and their hardness is measured. The equipment which has been used to determine the total hardness of the water sample is that, Water Hardness Kit (NICE Chemicals). The kit had contained different reagents for various range of hardness as well as the buffer ammonium chloride solution for the determination of the concentration of calcium carbonate salts or the hardness. To measure the hardness we

took 25ml of water sample in the test bottle and add 10 drops of total hardness reagent- 2 (TH-2) and mix. Then few drops of total hardness Reagent- 1 (TH-1) and mix until a distinct pink color develops.

- For hard water add total hardness reagent- 3 (TH-3) shake well after each drop until the color changes to pink to blue, count the number of drops of reagent added.

  Total hardness = no. of drops * 5……Eq. 1
- For soft water add total hardness reagent – 4 (TH-4). Shake well after each drop until the color changes to pink to blue, count the number of drops of reagent added.

  Total hardness = no. of drops * 2……Eq. 2
- For very hard water add total hardness reagent – 5 (TH-5). Shake well after each drop until the color changes to pink to blue, count the number of drops of reagent added.

  Total hardness = no. of drops * 50……..Eq. 3

Hardness obtained from all eleven samples are listed in the Table 1.

Table 1: Total hardness of samples

Sample	% Concentration of salts	Total Hardness of water
1	Distilled water	36
2	Tap water	360
3	0.25	1296
4	0.5	2560
5	0.75	3840
6	1	5120
7	1.25	6400
8	1.5	7680
9	1.75	8960
10	2	10240

5. **Preparation of drilling fluid samples:** Take all the chemicals in the required composition by using the weighing machine. Measure the required amount of water in a measuring jar (1000ml). Pour the water into the cup of Hamilton Beach Mixer then add all the chemicals very slowly for better mixing. Turn on the mixer and keep the mixer at a required 400 RPM. Once the fluid got mixed well continue with the further experiments.

   Composition: Water: 750ml; Bentonite: 3% (22.5gm), Carboxymethyl cellulose: 0.5% (3.75gm)

6. **Measurement of rheological properties:** The viscometer which has used for the experiments is the one which has been manufactured by FANN Instrument Company. The Fann VG meter is a direct-indicating, manually operated, rotational viscometer. Gently agitated sample of fluid in placed in the cub and the device is set to measure the reading at 300 and 600 RPM. Once the reading are taken now the device is set at 2 RPM

to take Gel strength reading. Reading obtained are calculated Plastic viscosity (PV), Apparent Viscosity (AV), Yield Point (YP) and Gel strength reading are listed in Table 2.

7. **Measurement of Filtration loss properties:** To determine the filtration properties the mud sample we are using API filter press which has been made by FANN Instrument Company. This filter press is used in a static filtration test to measure fluid loss and filter cake characteristics of drilling fluids. The pressure sources for this filter press are carbon dioxide (cartridges or cylinder). The Filtrate loss of the samples are recorded at 15 min and 30 minute time interval. Mud cake thick obtained for the samples are reported in 32 seconds-inch. All values are listed in Table 3.

Table 2: Values of Rheological properties

Sample	PV (cP)	AV (cP)	YP (lb. /100sq. Ft.)	Initial Gel strength (10 sec)	Final Gel strength (10 min)
1	35	55.5	41	120	127
2	28	47.5	39	107	112
3	12	23.5	23	46	49
4	10	20	20	34	38
5	5	15.5	21	29	33
6	6	12.5	13	26	30
7	5	11	12	21	25
8	7	9	4	16	18
9	4	7	6	11	14
10	3	5.5	5	9	12

Table 3: Values of Filtrate loss and Mud cake thickness

Sample	Filtrate loss (mL) (7.5 min)	Filtrate Loss (mL) (30 min)	Mud Cake Thickness (1/32")
1	14.2	33	6
2	13.2	30	5.5
3	11.8	28	4.5
4	11.4	24	4.4
5	10.1	20	4
6	8.5	18	3.8
7	8	15	3.5
8	7.5	12.5	3
9	7.41	12	2.5
10	7	11	2.5

III. RESULTS AND DISCUSSION

Upon measuring the hardness of the water samples it was observed that hardness of the samples increase from Sample 1 to 10. Drilling fluid samples were prepared using the same water samples and its properties are evaluated. While comparing the Plastic Viscosity (PV) (Fig 2) and Apparent viscosity (AV) (Fig 2) it was observed that as the water hardness

increases both PV and AV value are decreasing. Similarly Yield Point values (Fig 3) same trend is observed. YP values decreases with the increase in hardness of water.

When considering the gel strength (Fig 4) we can clearly understand that the gel strength is decreasing with the increase in the water hardness. This can lead to a poor hole cleaning. In the filtration loss experiment it was observed that as the hardness of the samples increases, filtrate loss for the samples also increases (Fig 5). This is not at all desirable as this can lead to formation damage or even contamination of the nearby water bodies. However in decreasing trend of mud cake thickness is observed as the water hardness increases (Fig 6).

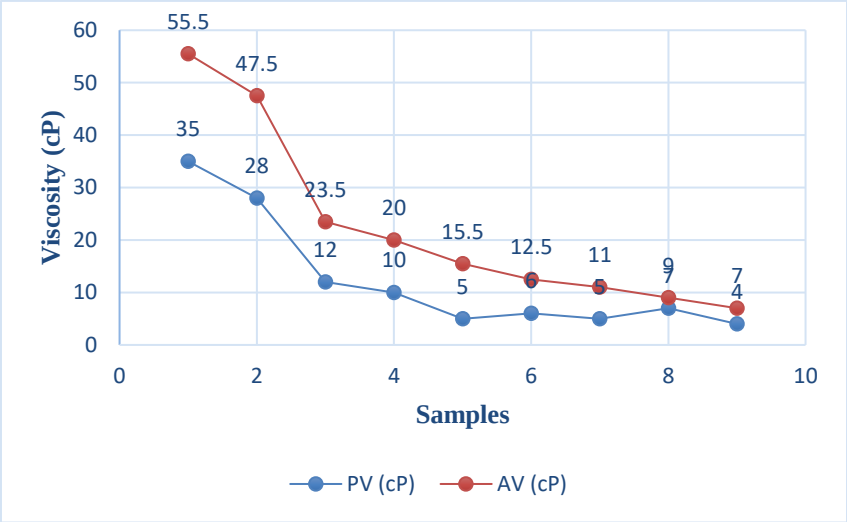

Fig 2: Comparison of Plastic Viscosity (PV) and Apparent Viscosity (AV)

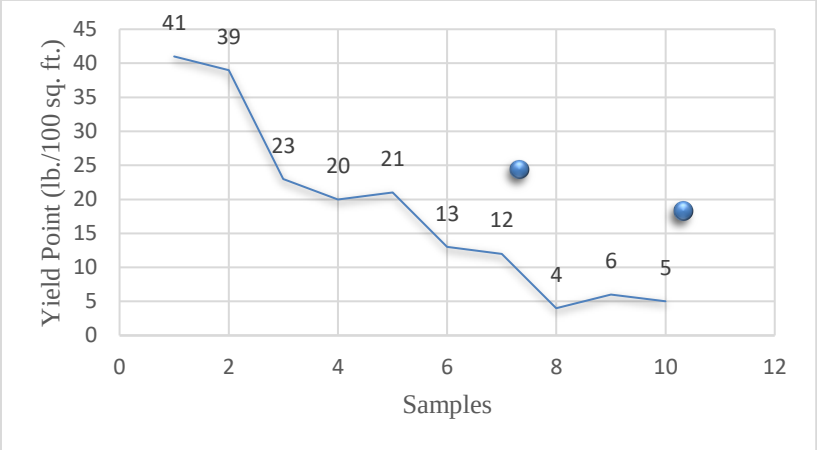

Fig 3: Comparison of Yield Point

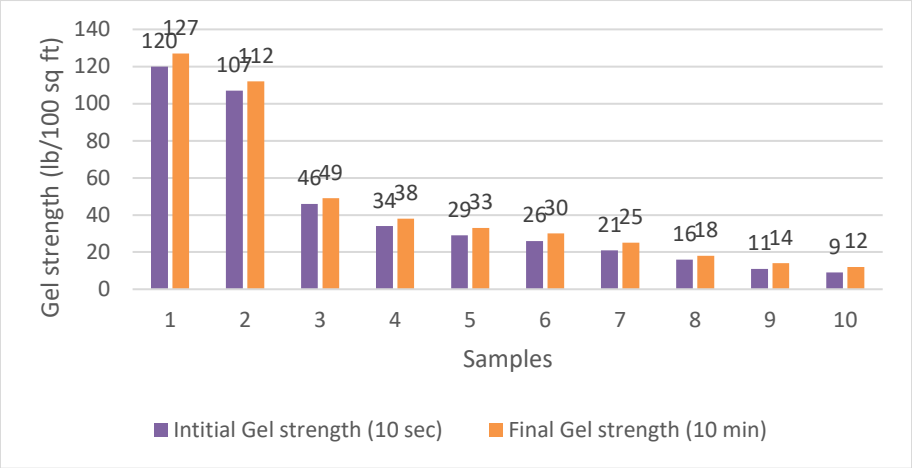

Fig 4: Comparison of Gel strength

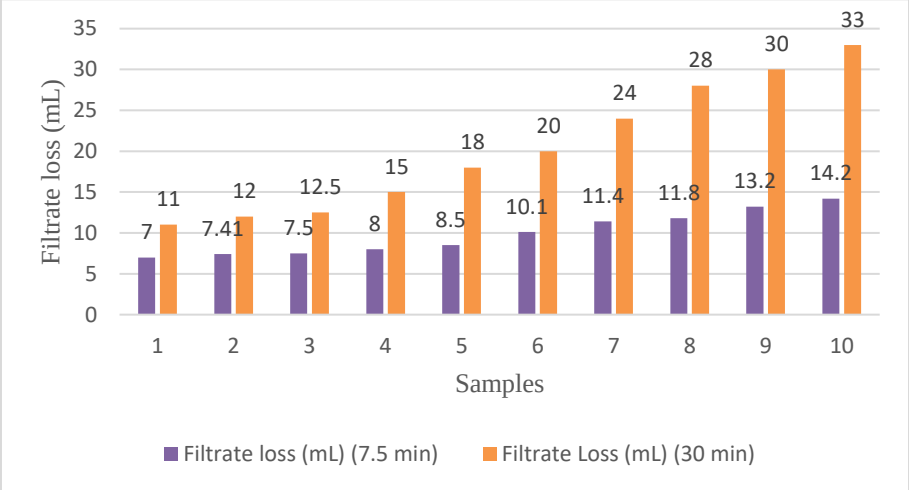

Fig 5: Comparison of Filtrate loss

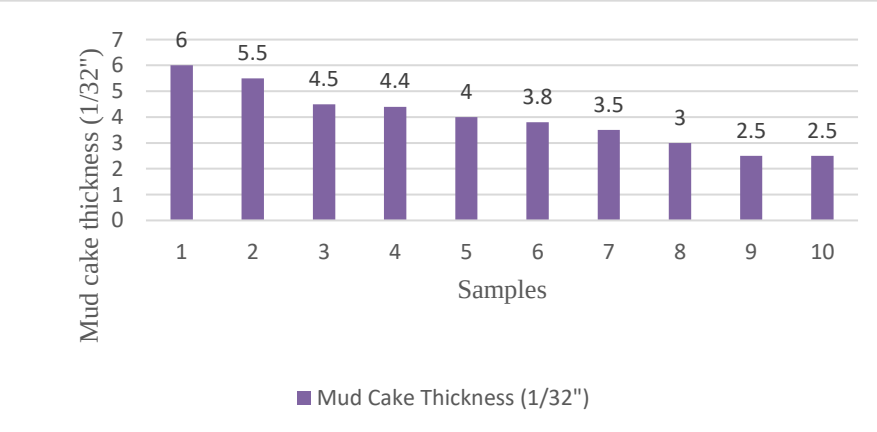

Fig 6: Comparison of Mud Cake thickness

IV. CONCLUSION

From the study we can conclude that Hardness of the water sample is important and it plays a role in the properties of the drilling mud. The samples used in this experiment (sample1-10) has an increase order of water hardness. The Plastic and Apparent viscosity of each water sample decreases with an increase of water hardness. It's evident from the experiments that, the increase in concentration of salts will lead to the decrease in the plastic viscosity of the drilling mud. Gel strength measurements denote the thixotropic properties of the mud. According to the increasing order of the water hardness, gel strength value declined gradually. This due to the presence of metal ions. Filtration loss is reduced with an increase of water hardness. The results from the LPLT Filter press experiments shows that the water hardness is inversely proportional to the mud cake thickness as well to the filtration loss properties.

Abbreviations and Acronyms

PV=Plastic Viscosity
AV=Apparent Viscosity
YP=Yield Point

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