Experimental Investigation of Rheological Properties of Drilling Fluid with Size Variation of Clay Particles

Aashish Tyagi[1], Arun T J[2], Midhun Krishna[3], Romith Vijay[4], Bhairab Jyoti Gogoi[5]

[1]Student & Dept. of Petroleum Engineering, Presidency University, Bangalore, India
[2]Student & Dept. of Petroleum Engineering, Presidency University, Bangalore, India
[3]Student & Dept. of Petroleum Engineering, Presidency University, Bangalore, India
[4]Student & Dept. of Petroleum Engineering, Presidency University, Bangalore, India
[5] Assistant Professor, Dept. of Petroleum Engineering, Presidency University, Bangalore, India

---***---

Abstract - *Drilling fluid is one of the major component for any drilling operation. Clays act as a reactive phase in any aqueous based fluid. In the recent times the rheological and filtration loss properties has been improved by addition of nano particles in drilling fluid system. In this study different sizes of Bentonite clay particles were used to prepare drilling fluid samples. Rheological and filtration loss properties were studied and it was found that the size of clay particles has lot to do with these properties. Significant change in drilling fluid properties has been observed and it was concluded that lesser the size of the clay particles better will be the properties.*

Keywords: *Drilling mud, Gel strength, Rheological properties.*

1. INTRODUCTION

Drilling mud, or drilling fluid, represents any fluid which used during any drilling operation. Drilling fluid is the most important component for any successful drilling operations. The main properties of drilling fluids are Plastic Viscosity (PV), Apparent Viscosity (AV), Yield Point (YP) and Gel strength. These are also called as rheological properties. Along with these filtration loss properties are also plays a vital role during any drilling operation [1]. The main function of drilling fluid is to counter balance the formation pressure, carry the drilling cutting to the surface, to provide stability to the wellbore etc. [2]. If the PV is low then the drill bit will be capable of drilling rapidly because of the low viscosity of mud whereas high PV will lead to a viscous mud. The reactive phase of any aqueous based drilling fluid is the clay particle. These clay particles are the main reason for the development of the rheological properties [3]. Bentonite is the most common and widely used clay particles in oil industry. The roles that a drilling fluid has to play during drilling are like removal of the drill cuttings from subsurface to the surface, cooling and lubrication of the drill bits, maintain the hydrostatic pressure and increases the stability of the well bore [4]. The effectiveness of these functions are depending on rheological properties of the fluids as mentioned above. Most encountered problems while drilling the wells are, lost circulation and differential sticking [5]. Changing or enhancing the rheological properties without affecting the chemical composition is the best way to overcome these kind of drilling problems [6]. Currently we see a lot of application of Nano technology in oil industry [7]. Not only in drilling technology but also it has applications in enhanced oil recovery. It can also be used to stabilize water in oil emulsions in place of polymeric surfactants [8]. But getting a nano size is a complicated, costly and time consuming task. So if the size of the clay is very less like nano bentonite clay which has the size ranges from 1nm-1000nm, the use of such clay can give better quality mud cakes and the problems also could be reduced. In our work we did sieve analysis on Bentonite clay particles using readily available sieve with different mesh size. Using those different sizes of clay, we prepared drilling fluid samples and then their properties were studied.

2. MATERIALS AND METHODOLOGY

2.1 Material used
The material used for this work are Bentonite clay (API Grade), weighting Barite (Industry grade), Carboxy Methyl Cellulose (CMC, Sigma Aldrich), Xanthan Gum (XC, Sigma Aldrich), Calcium Carbonate-Fine ($CaCO_3$, Karnataka Fine Chem.), Sodium Hydroxide (NaOH, Karnataka Fine Chem.), Potassium Chloride (KCl, Karnataka Fine Chem.), Nut Plug and Mica

2.2 Equipment used
The instrument used for this work are Hamilton Brach mixer, Fann VG meter (Model 35, Fann Instrument Company, Houston, Texas), Methylene Blue Test Kit (Fann Instrument Company, Houston, Texas), Fann API filter press (Model 300, Fann Instrument Company, Houston, Texas), Fourier-transform infrared spectroscopy (Shimadzu), Scanning Electron Microscope (Zeiss Sigma).

2.3 Plan of work

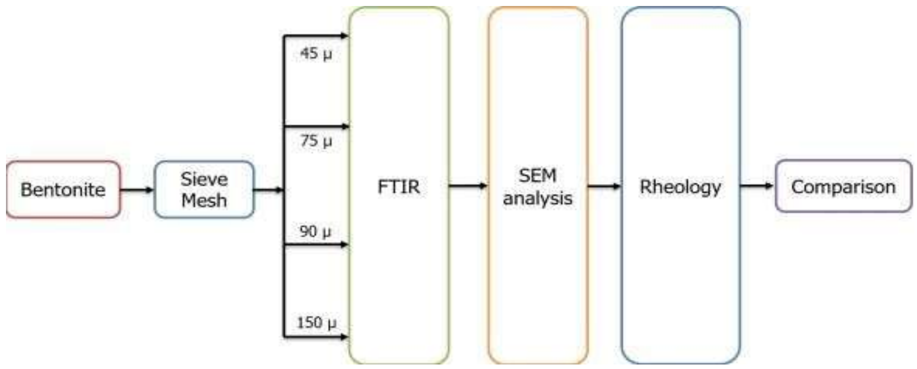

Fig. 1: Flow chat of Plan of work

First sieved the Bentonite powder through the meshes having sizes 45, 75, 90 & 150 microns. To check the chemical composition of all four samples perform FTIR (Fourier Transform Infrared spectroscopy) analysis followed by SEM (Scanning Electron Microscope) analysis, to identify size variation. After that to prepare the Drilling fluid with different additives as required. Perform the rheological analysis on different samples and obtain the results and then compare the rheological properties for samples having different sized clay particles.

2.4 Sieve Analysis

The Bentonite clay particles were allowed to go through the four different type of sieves having mesh size 45, 75, 90 & 150 microns. The larger size particles on the top of the sieve were remove and the fractions of Bentonite particles passing through sieve were collected for further process

2.5 Preparation of Samples

Twenty different experimental samples were prepared and tested following the American Petroleum Institute (API) standards to investigate the effects of size variation on the rheological and filtration properties of bentonite based drilling fluids. Different additives were added with varying composition given in the Table No 1. All samples were mixed with Hamilton Beach mixer.

Table 1: Composition of various samples

Sample No	Water (mL)	Bentonite (gm)				Barite (gm)	CaCO3 (Fine)	Xanthan Gum (gm)	CMC (gm)	KCl (gm)	NaOH (gm)	Nut Plug (gm)	Mica (gm)
		45 micron	75 micron	90 micron	150 micron								
1	1000	25	-	-	-	15	10	6	-	8	10	-	-
2	1000	-	25	-	-	15	10	6	-	8	10	-	-
3	1000	-	-	25	-	15	10	6	-	8	10	-	-
4	1000	-	-	-	25	15	10	6	-	8	10	-	-
5	1000	25	-	-	-	15	10	-	6	8	10	-	-
6	1000	-	25	-	-	15	10	-	6	8	10	-	-
7	1000	-	-	25	-	15	10	-	6	8	10	-	-
8	1000	-	-	-	25	15	10	-	6	8	10	-	-
9	100	6	-	-	-	2	-	-	-	-	-	-	-

10	100	-	6	-	-	2	-	-	-	-	-	-	-
11	100	-	-	6	-	2	-	-	-	-	-	-	-
12	100	-	-	-	6	2	-	-	-	-	-	-	-
13	1000	25	-	-	-	15	10	6	-	8	10	10	10
14	1000	-	25	-	-	15	10	6	-	8	10	10	10
15	1000	-	-	25	-	15	10	6	-	8	10	10	10
16	1000	-	-	-	25	15	10	6	-	8	10	10	10
17	1000	25	-	-	-	15	10	-	6	8	10	10	10
18	1000	-	25	-	-	15	10	-	6	8	10	10	10
19	1000	-	-	25	-	15	10	-	6	8	10	10	10
20	1000	-	-	-	25	15	10	-	6	8	10	10	10

2.5 FTIR and SEM
Fourier transform infrared (FTIR) spectrometer and Scanning Electron Microscopy was carried out to characterize all four sieved samples and to get the internal structure of the clay particles.

2.6 Rheological Test
AV, PV, YP and Gel strength of the all samples were carried out using Fann VG meter (Model 35, Fann Instrument Company, Houston, Texas) at dial readings at 300 and 600 rpm. All experiment were performed as per the API recommended procedures. Similarly, to determine API filtration loss and API filter-cake thickness, Fann API filter press (Model 300, Fann Instrument Company, Houston, Texas) was used as per the API recommended practice of standard procedure for field testing of drilling fluids. To determine the amount of reactive clay content Methylene Blue Kit (Fann Instrument Company, Houston, Texas) was used.

3 RESULTS AND DISCUSSION

3.1 FTIR results
The FTIR results for all four sizes of the clay particles are shown in the Fig. 2 It is clearly evident from the figure that with the size variation the composition of clay particles are not changing. For all four samples we get considerable peaks at the wavenumber 1633, 1396, 1033. The corresponding band represent these wave numbers are analyzed in the Table 2.

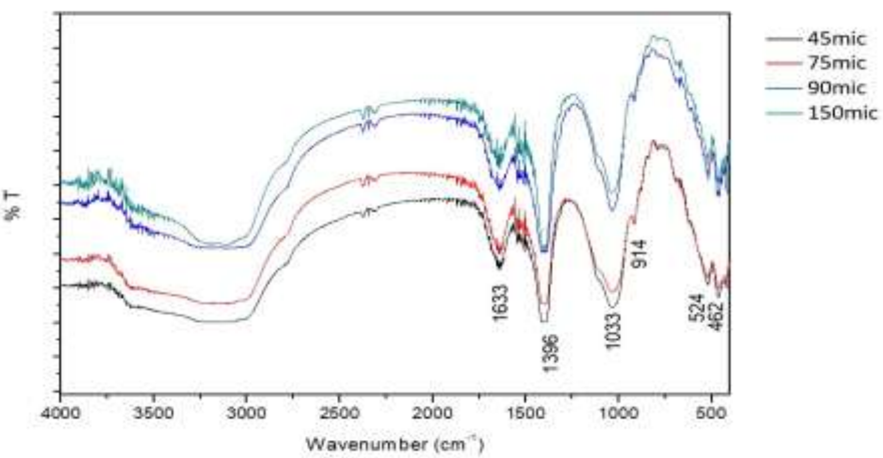

Fig. 2: FTIR results

Table 2: FTIR spectrum analysis

Absorption (cm-1)	Appearance	Group	Compound Class
1650-1600	medium	C=C stretching	conjugated alkene
1410-1380	strong	S=O stretching	sulfonyl chloride
1070-1030	strong	S=O stretching	sulfoxide

3.2 SEM Analysis

For finding the internal image of all four sample Scanning Electron Spectroscopy was performed and the images obtained are given in the Fig. 3, 4, 5 & 6. It is evident from the images that with the decreasing mesh size the clay particle size also decreasing.

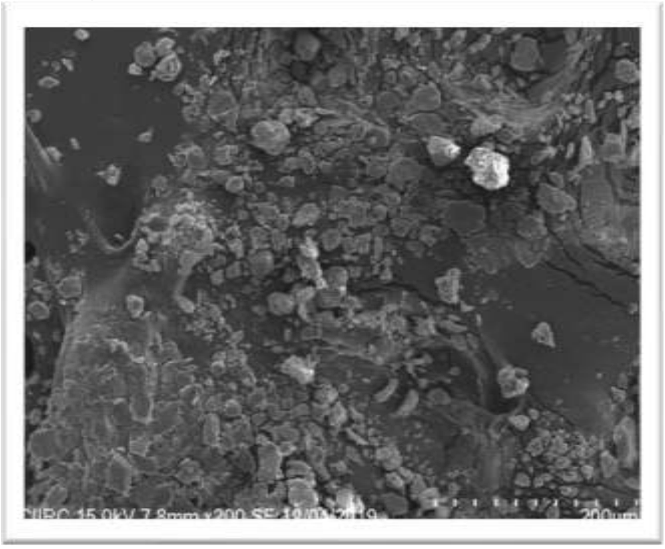

Fig. 3: SEM image for clay particle sieved through 45 micron mesh size

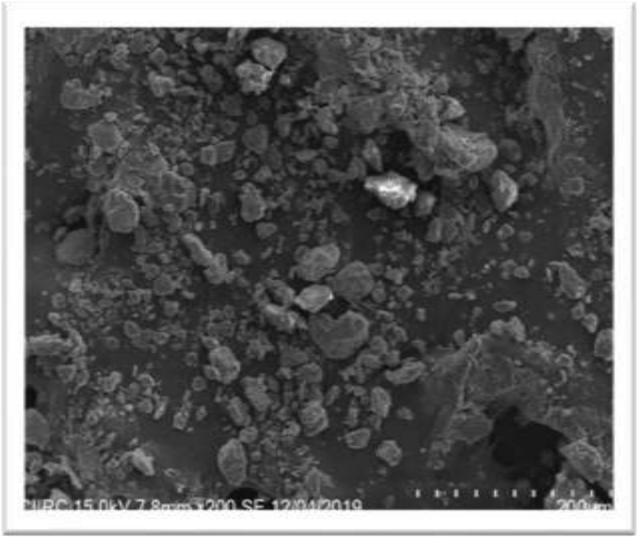

Fig. 4: SEM image for clay particle sieved through 75 micron mesh size

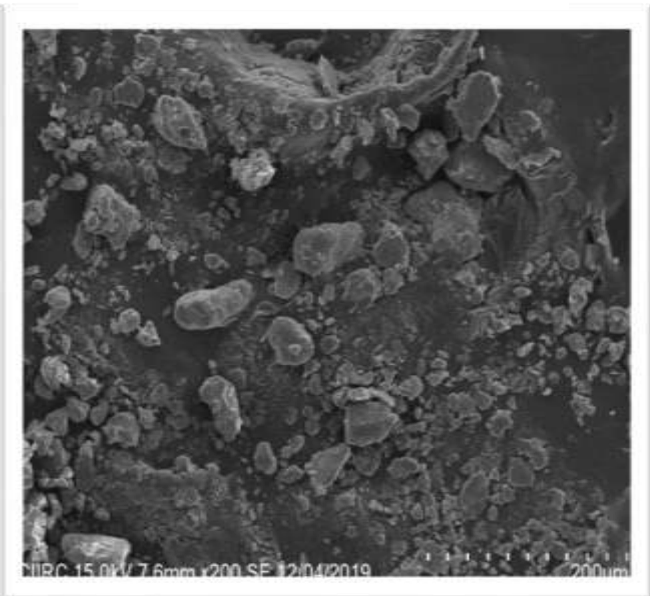

Fig. 5: SEM image for clay particle sieved through 90 micron mesh size

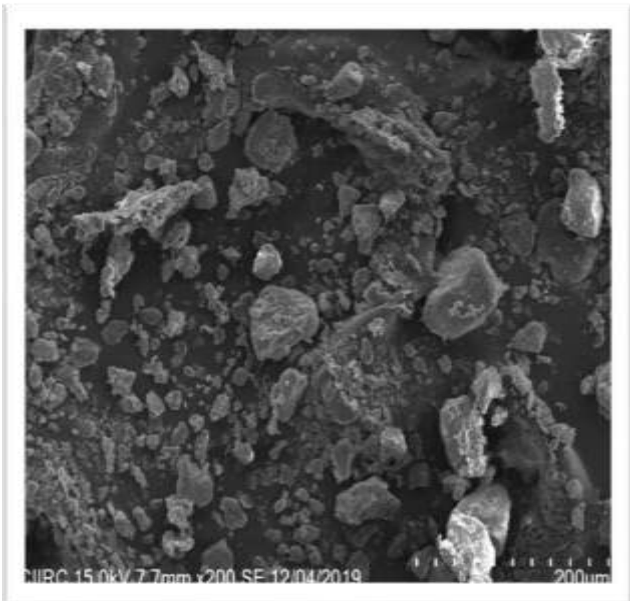

Fig. 6: SEM image for clay particle sieved through 150 micron mesh size

3.3 Rheological test data

3.3.1. Fann VG meter results

FANN VG meter was used to determine the rheological properties of the sample 1, 2, 3 & 4. Dial reading for each sample at 600 and 300 RPM were taken and using equation (I), (II) and (III) PV, YP and AV were determined.

PV= θ_{600} -θ_{300}……………………………………………………………….(I)

YP= θ_{300} –PV ………………………………………………………………(II)

AV= θ_{600}/2 ……………………………………………………………….(III)

It has been observed from the Chart-1, 2 & 3 that as the particle size decrease Plastic Viscosity (PV), Apparent viscosity (AV) and Yield point (YP) for the samples increases regardless of the polymer used with the samples. This increment give extra advantage to the cutting lifting capacity of the drilling fluid system. Plastic viscosity and Apparent viscosity also follows the same trend.

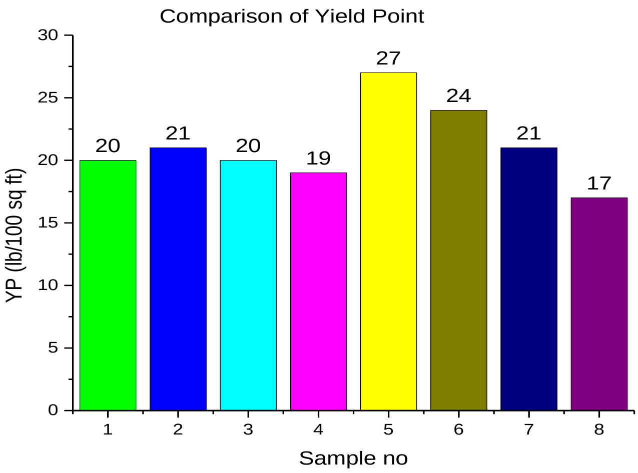

Chart-1: Comparison of Yield point for drilling fluid with different sizes of clay and polymer

Gel strength of the samples also measured using Fann VG meter and results were plot. From the Chart-4 it is evident that optimum gel strength is obtained for the sample prepared with the least particle size (i.e. 45 micron). It is also observed that Gel values are gradually decrease as the particle size decreases.

3.3.2. Methylene blue test

Methylene Blue test was performed on the sample 13, 14, 15 & 16. Upon performing the test it was observed that amount of reactive clay in those samples increases as the particle size is reducing. This may be due to the increment of surface area (Chart-5).

3.3.3. API Filter Press results

API filtration loss test was performed to measure the filtration loss and the mud cake thickness of the drilling fluid. From Chart-6 & 7 it observed that filtration loss is decreasing as the added clay particle size decreases regardless of the polymer used. Also it was found that mud cake thickness also considerable for the sample with least clay particle size (Chart-8). This variant may be due to the fact that as the clay particle size decreases the permeability of the mud cake also decreases. A thin mud cake is always desirable to prevent differential sticking.

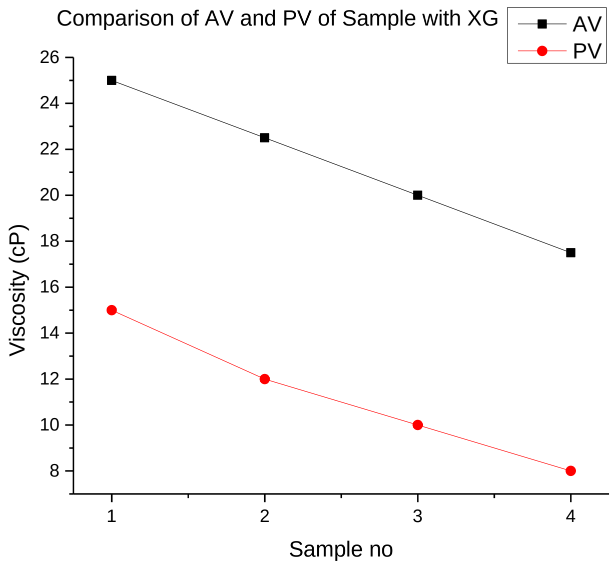

Chart-2: Comparison of Apparent viscosity (AV) and Plastic viscosity (PV) for drilling fluid with different sizes of clay added with Xanthan Gum (XG)

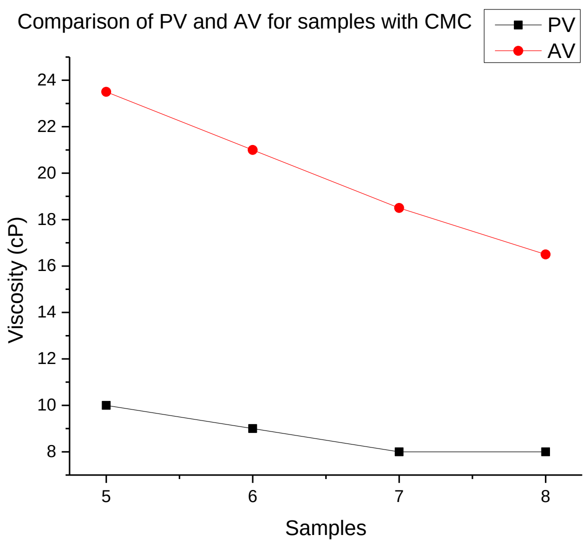

Chart-3: Comparison of Apparent viscosity (AV) and Plastic viscosity (PV) for drilling fluid with different sizes of clay added with Carboxy-Methyl Cellulose (CMC)

.

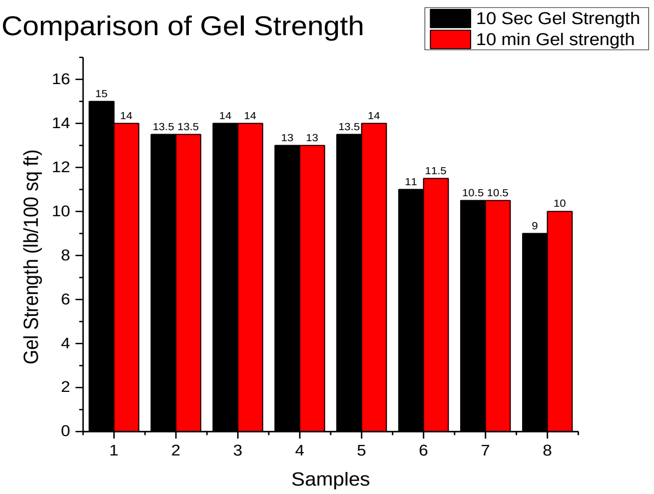

Chart-4: Comparison of Gel strength for drilling fluid with different sizes of clay and polymer

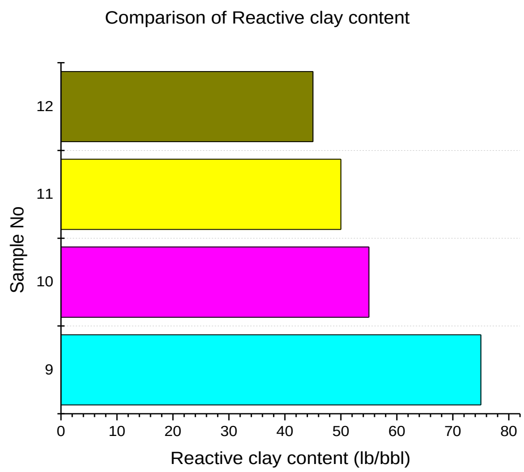

Chart-5: Comparison of Reactive clay content for drilling fluid with different sizes of clay

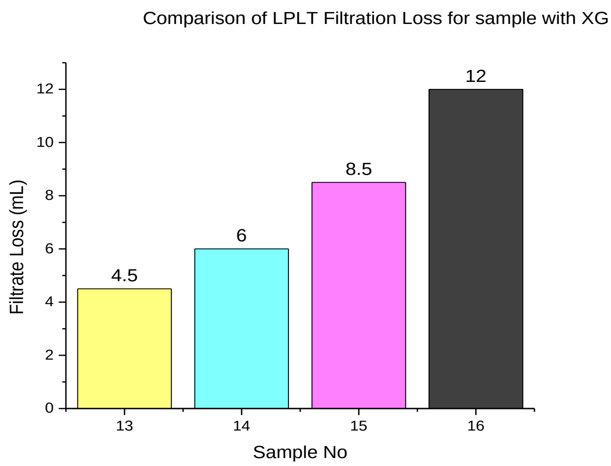

Chart-6: Comparison of Filtrate loss for drilling fluid with different sizes of clay added with Xanthan Gum (XG)

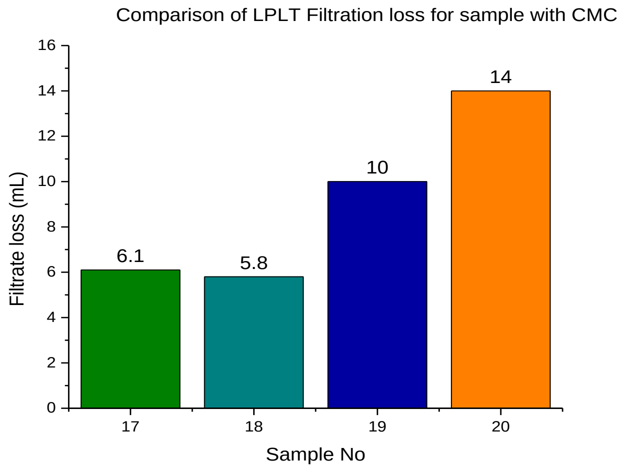

Chart-7: Comparison of Filtrate loss for drilling fluid with different sizes of clay added with Carboxy-Methyl Cellulose (CMC)

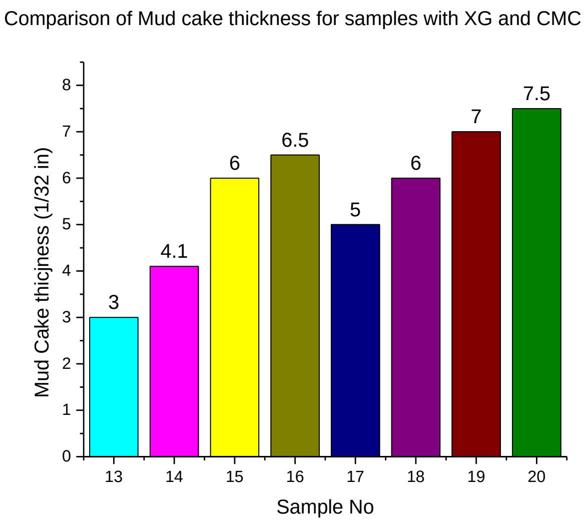

Chart-8: Comparison of Mud cake thickness for drilling fluid with different sizes of clay with added polymer

4. CONCLUSION

From the study we can conclude that with varying size of clay particles rheological properties also changing. The following conclusions can be drawn from the study

a) PV, AV, YP and Gel strength values are changing with the size variation of clay particles. As the particle size is reducing these properties are also increasing. The cutting transport properties of the drilling fluid also enhancing upon reducing the size of the clay particles in the drilling fluid
b) A significant reduction in the filtration loss is observed in the samples. The mud with least size clay particle has the lowest filtration loss. With that mud cakes size also less. This will be beneficial to prevent differential sticking problems
c) Methylene blue test prove that the particle with least surface area has more reactivity. This may be due to the increase in the surface area. As the reactivity of the clay is increasing the properties also enhancing
d) After careful observation of all the properties it can be concluded that size of clay particles added has significant effect on the Drilling fluid rheological properties. As the size reduces clay particles are becoming more reactive and it will enhanced other rheological and filtration loss properties.

ACKNOWLEDGEMENT:

We would like to thank Mr. Bhairab Jyoti Gogoi, Assistant Professor, Department of Petroleum Engineering, Presidency University, Bangalore, for his constant guidance and motivation, we also thank him for providing tremendous resource and references about the current Scenario in oil and gas field. We are also grateful to all the faculties and staffs of Petroleum Department.

Nomenclature:

AV: Apparent viscosity (cP)

PV: Plastic viscosity (cP)

YP: Yield point (lb./100 ft2)

θ: Bob dial reading

XG: Xanthan Gum

CMC: Carboxy Methyl Cellulose

cP: centipoise

REFERENCES

[1] Ryen Caenn, H.C.H. Darley and George R. Gray, "Composition and Properties of Drilling and Completion Fluids" Book • 6th Edition • 2011

[2] Balho , M.T.; Lake, L.W.; Bommer, P.W.; Lewis, W.E.; Weber, M.J.; Calderin, J.M. Rheological and yield stress measurements of non-Newtonian fluids using a Marsh Funnel. J. Pet. Sci. Eng. 2011, 77, 393–402.

[3] Darley, H.C.; Gray, G.R. Composition and Properties of Drilling and Completion Fluids; Gulf Professional Publishing: Houston, TX, USA, 1988.

[4] Hall, H.; Thompson, H.; Nuss, F. Ability of drilling mud to lift bit cuttings. J. Pet. Technol. 1950, 2, 35–46.

[5] Bayu Wedaj, (main technical issues regarding problems when drilling geothermal wells Habtemariam Ethiopian Geological Survey wedaj.bayu2@gmail.com), 2012

[6] Abo Taleb T. Al-Hameedi, Shari Dunn-Norman, Husam H. Alkinani, Ralph E. Flori, Evgeniy V. Torgashov, and Steven A. Hilgedick, Missouri University of Science and Technology; Maitham M. Almohammedawi, Missan Oil Company, Preventing, Mitigating, or Stopping Lost Circulation in Dammam Formation, South Rumaila Field, Iraq; Requires Engineering Solutions, the Best Treatments Strategies, and Economic Evaluation Analysis, 2017

[7] J. Abdo, M.D. Haneef, "Clay nanoparticles modified drilling fluids for drilling of deep hydrocarbon wells" Mechanical and Industrial Engineering Department, Sultan Qaboos University, P.O. Box 33, Muscat, Oman

[8] Agarwal Sushant, Phuoc, Tham, Soong Yee, Martello Donald, "Nanoparticle-stabilized invert emulsion drilling fluid fr deep hole drilling oil and gas, The Canadiam Journal of Chemical Engineering Vol 91

[9] Mortatha Saadoon Al-Yasiri, Waleed Tareq Al-Sallami How the Drilling Fluids Can be Made More Efficient by Using Nanomaterials, American Journal of Nano Research and Applications,2015 (http://www.sciencepublishinggroup.com/j/nano)

[10] ASME Shale Shaker Committee. Drilling Fluids Processing Handbook; Elsevier: Amsterdam, The Netherlands, 2011.

[11] Bourgoyne, A.T.; Millheim, K.K.; Chenevert, M.E.; Young, F.S., Jr. Applied Drilling Engineering; Society of Petroleum Engineers: Richardson, TX, USA, 1986.

[12] Hussaini, S.M.; Azar, J.J. Experimental study of drilled cuttings transport using common drilling muds. Soc. Pet. Eng. J. 1983, 23, 11–20.

[13] Boyou, N.V.; Ismail, I.; Sulaiman,W.R.W.; Haddad, A.S.; Husein, N.; Hui, H.T.; Nadaraja, K. Experimental investigation of hole cleaning in directional drilling by using nano-enhanced water-based drilling fluids. J. Pet. Sci. Eng. 2019, 176, 220–231. [CrossRef]

[14] Rafati, R.; Smith, S.R.; Haddad, A.S.; Novara, R.; Hamidi, H. E effect of nanoparticles on the modifications of Drilling fluids properties: A review of recent advances. J. Pet. Sci. Eng. 2018, 161, 61–76.

[15] Smith, S.R.; Rafati, R.; Haddad, A.S.; Cooper, A.; Hamidi, H. Application of aluminium oxide nanoparticles to enhance rheological and filtration properties of water based muds at HPHT conditions. Colloids Surf. A Physicochem. Eng. Asp. 2018, 537, 361–371.