Effective role of XC-Polymer in the Non Damaging Drilling Fluid (NDDF) for Tipam Sand of Geleki Oilfield of Upper Assam Basin

Prasenjit Talukdar

Assistant Professor,

Department of Petroleum Engineering, DUIET,

Dibrugarh University, Dibrugarh-786004, Assam, India

Subrata Borgohain Gogoi

Associate Professor,

Department of Petroleum Technology,

Dibrugarh University, Dibrugarh-786004, Assam, India

ABSTRACT

One of the most important elements of oil and gas well drilling process is drilling fluid or drilling mud. To remove cuttings from well, to suspend the cuttings and weighting material when circulation ceases and release them, to transmit hydraulic energy to clean the bit and the bottom of the borehole, to maintain wellbore stability, to minimize damage to the pay-zone, to minimize environmental impact, etc. are the most important functions of drilling fluids. All these functions are connecting to the rheological properties, filtrate & particle invasion and mud-cake quality of drilling fluids and all are more or less controlled by the clay component in conventional Water Base Mud (WBM). Non Damaging Drilling Fluid (NDDF) is an environmental friendly polymer mud system mostly used in pay zone sections of development wells and specifically in horizontal drilling to avoid formation damage. Non degradable compositional fine solid like clay, barite, etc. are not used in NDDF to counter the formation damage as well as environmental pollution. So, to provide the above mentioned properties in drilling fluid to perform the above mentioned functions, the XC-Polymer (with some assistant constituents) is used in NDDF instead of the non degradable clays. XC-Polymer (XCP)/Xanthan gum is a polysaccharide secreted by the Xanthomonas Campestrisbacterium which can be used in drilling fluid where formation protection, solids suspension and improved borehole cleaning are the primary concerns. It provides non-Newtonian rheology in WBM which is extremely necessary due to the flat velocity profile it creates in annular flow required for effective cuttings lifting in lower density muds. It is susceptible to bacterial attack and has great tolerance for salinity, fair tolerance for hardness ions and high pH and starts to degrade around 200 to 250°F [93 to 121°C] temperature. In this work, an attempt has been made to study the effect of varying composition of XCPon the different properties of laboratory formulated NDDF and choose its optimum composition based on the required mud parameters of the study area. This paper reports the effect and optimum composition of XCPas a rheology as well as fluid loss control component in the NDDF.

Keywords:NDDF; XC-Polymer; Mud Rheology;Filtration Loss; Formation Damage; Geleki Oilfield;

Introduction:

Drilling fluid is one of the most critical components required for drilling a well. It is the backbone of drilling a well successfully. Aninadequate control of the drilling-fluid properties of conventional WBM may cause wellbore instability, formation damage, excessive torque and drag, differential pressure sticking, logging and primary cementation failures, borehole washouts etc. in problematic formations. These problems may more severe in directional or horizontal wells. The alternate option of oil-based mud (OBM) is also economically & environmentally not feasible (R. K. et al., 2010). So, in the current stringent environmental regulations, the oil industries are interested to environmental friendly bio-degradable drilling muds.

Drilling fluids are thixotropic fluid whose viscosity is time-dependent. These fluids have an internal structure that builds up strength while at rest. As they are sheared at constant shear rate, there gel structure break down in a short time period and allowed to approximate their flow behavior. The plastic viscosity, indicative of the number , type and size of colloidal particles present in the mud, increases with increasing solids content since it resulting from the interaction of solids in the mud.

Table 01: Reservoir Properties of Geleki Oilfield (ONGC, unpublished report)

SAND	Average Depth in MSL (m)	Average Porosity (%)	Permeability (md)	Temp. (^{o}C)
Gurujan Clay	2100-2270	22		
TS-1A	2401-2340	22	30	70-75
TS-2A	2470-2530	22	25	70-75
TS-3A	2350-2700	22	30-50	70-75
TS-3B	2420-2750	22		
TS-3C	2550-2950	18-22		
TS-4B	2700-3000	18-20	10-20	70-75
TS-5A1	2770-3000	18-20	10-30	70-75
TS-5A2	2800-3075	17-20		

TS-5B	2820-3200	18-22		70-78
TS-5C	2860-3200	20-23		
TS-6	3000-3400	15-18	18-30	78-80
BCS-VI	3420	15		
BCS-V	3400-3500	15-20		
BCS-IV	3500-3670	12-18		
BCS-III	3600-3670	15-18		90-92
BCS-II	3700-3800	15		
BCS-I	3740-3760	15		
BMS UP	3820-3920	15-20	5-45	98-105
BMS-LO	3855-3965	10	5-45	
BMS-I	3940-4010	10-14		
BMS-II	3900-3960	10		
BMS-III	3900-4070	10-13	5-45	
KSU-I	390-4080	13		
KSU-II	4060-4100	10-15		
KSU-III	4080-4160	10-11		
KSU-IV	4100	10		
KSU-V	4100-4230	10	5-45	100-108
KSU-VI	4130-4190	12-15		
KSU-VII	4265	10		
KSU-VIII	4270	12		
KSU-IX	4310	12		
KSU-X	4330-4380	12		
KSU-XII	4400-4535	10-14		

The Viscosity of the drilling fluid is of prime importance since it results the cuttings removal and annular pressure losses, which in turn, affects the actual and equivalent hydrostatic pressure of the mud. Viscosity at the bit is also very important since it determines the bit nozzle jet velocity and pressure loss which directly effects the bottom hole cleaning, a controlling factor in the penetration rate. At the surface, the viscosity of the mud determines the effectiveness of the solid separation equipments.

Yield Point is a measure of the internal resistance of a fluid to the initial flow. It directly determines the surface pressure required to start circulation and the initial pressure losses in the circulating system. High Yield Point causes high initial pressure losses which will increase the equivalent circulating density to a high value with possible fracture of the formation. If the Yield Point is too low, cuttings will settle in the bottom of the well during trips and result in drilling complications.

Gel Strength is the measurement of electrical attractive forces within the drilling mud under static condition and gives an indication of the ability of mud to develop and retain a gel structure and hold the solids in suspension. If the Gel Strength is too low, the drilling fluid will not effectively suspend the cuttings and weighting materials during connections and trips. If the Gel Strength is too high, the pressure required to start flow may fracture a weak formation and the resulting high swab and surge pressures by the pipe movement can cause temporary over or under balance of hydrostatic pressure.

Due to the overbalance pressure, the mud invades the formation and can cause formation damage. Invading particles which were initially suspended in the drilling fluids can plug the pores and hence reduce rock permeability. Mud filtrate can interact with formation minerals to cause mobilization and subsequent re-deposition of in-situ fines, to swell the pay-zone clay, to alteration of reservoir rock wettability, to development of emulsions leading to reduction of permeability.

Thus, all the above mentioned properties must be optimum for drilling a well without any complications and formation damage. Without the right mud, right mud properties and right mud management, a well cannot be drilled right and successfully. To diminish the formation damage, the most important points to keep in mind for the designing a NDDF are (N. G. et al., 2006):

- Should not usedispersant and non-degradable fine solids like- Clay, barite, etc. in the mud,
- Diminish fluid loss
- Should minimise drilled fine solids in the mud
- Produce inhibitive filtrate which would not swell the clay envelop in the formation particles and should not react with the formation fluid to generate insoluble precipitate
- Should retain all relevant drilling fluid characteristics
- Contain specialized sized materials to bridge all exposed pore openings.
- Deposit a non - damaging filter cake that is easily and effectively removed by initial production and / or by treatment of mild reactant / oxidizing agents.
- Lower overall well costs and optimize production without neglecting HSE regulations.

NDDF incorporate long-chain, high molecular weight polymers in the systems either to encapsulate drill solids to prevent dispersion or to coat the shales for inhibition as well as to increase Viscosity, Yield Point and Gel Strength and to reduce Filtrate and Particle invasion and Mud Cake thickness. An extensive range of particle sizes is used which, on de-hydration, fit together into a strongly compacted very low permeable high quality Mud Cake on the surface of the rocks to quickly seals off the permeable paths of the pay-zone. The drilling fluids are essentially designed to build a filter cake, which is basically intended to decrease filtrate loss to the formation, be thin and hold the drilling fluid in the wellbore. Moreover, the nature and thickness of the filter cake deposited on the borehole wall will influence the potential for differential pressure sticking to occur (Shafeeg and Fattah, 2013).

XCP/Xanthan gum (a biopolymer), a high molecular weight polysaccharide produced by fermentation of carbohydrate with Xanthomonas Campestris, is a premium grade viscosifier and display exceptional shear thinning properties and good suspension characteristics even in the absence of inorganic colloids. This allows for high penetration rates, borehole cleaning and pays zone protection. It is highly bio-degradable. There is an increase in the rheological properties of drilling fluid as XCP increased. The thickness, porosity and permeability of the filter cake of the drilling fluid also slight decreases as XCP concentration increases (Shafeeg and Fattah, 2013).Therefore, the XCP is used in NDDF as a substitute of the non degradable clays (e.g. Bentonite).

Geleki field was discovered in 1968 and was put to trial production in August, 1970. The commercial production started in August, 1974. The Geleki structure is located towards the southern fringe of Upper Assam near Naga Hills. The field has been divided into twenty-three blocks by faults. All the twenty-three blocks are oil/gas producers.

In the Upper Assam basin, following producing horizons have been identified (top to bottom): a) Tipam Sand, b) Barail Sand, c) Kopili, d) Sylhet, e) Basal Sandstone, and f) Basement. In Geleki-field, the main horizons are Tipam and Barail main sand. In addition, few wells are producing within Barail coal-shale unit. The geological age of the Barail main sand and Barail coal-shale is Oligocene and that of Tipam is Miocene.

As discussed earlier, the formation damage basically depends upon the type and properties of the mud and formation properties.Table 01 shows that the average Porosity and Permeability of the Tipam Sands of Geleki field are about 21% and 26 md which are very much susceptible for spurt as well as filtration loss. With the conventional WBM, the spurts loss during drilling is tremendously high and continuous in this formation. So, the loss cannot be arrested without using the NDDF.

Particles less than 2 micron is known to bridge rock permeability less than 100 md, 10 micron to bridge consolidated rocks permeability between 100-1000 md and 74 micron (200 mesh) up to 10 Darcies. Particles up to 74 micron size will bridge and forms filter cake on all formations except macro openings or open fractures (Shyam and Jnan, 2010).

Materials and Methods:

Materials:

The general components used for formulation of NDDF are:

1. Base fluid - fresh water
2. Viscosifier- XCP
3. Fluid loss control / coating agent - Starch e.g. PGS (Pre Gelatinized Starch), PAC (LVG) & PAC (RG)

4. Lubricity- Linseed oil

5. Formation clay/shale inhibitor-Potassium Chloride

6. Weighing and bridging materials: Limestone, MCC (Micronized Calcium Carbonate)

7. Other additives- Caustic soda, Bactericide

To study the effect of XCP, the NDDF is prepared by properly mixing of Fresh Water: 1.5 Litre, PGS: 3%, PAC (LVG): 0.5%, PAC (RG): 0.3%, Biocide: 0.1%, NaOH: 0.025%, KCl: 5%, Limestone powder: 3.5%, MCC: 6%, and varying composition of XCPin gm /100ml basis (Appa and A.K. 2010) and (S.K. et al., 2010).

As discussed earlier, the drilling fluids are designed based upon the formation characteristics. So, to study the detail characteristics of the study area, some data of reservoir rock properties as well as some mud policy & well cards for NDDF of drilled wells, mud chemicals, etc. are collected from Assam Asset, ONGCL, Sivasagar.

Methods:

According to proper measuring manual instructions different muds samples are formulated by varying the concentration of XCP, keeping the other components as constant using the following equipments:

a) Mettler Electronic Precision balance to measure the mass of different chemicals for proper composition.

b) 1000 ml measurable stainless steel cup for measuring the water volume.

c) Hamilton Beach Mixer for proper stirring/mixing water and the mud component for generation of proper mud properties.

d) 15 ml pipette to measure small liquid volume.

Then the effect of varying concentration of XCPon mud properties with change in time are investigated to see the role of XCPin NDDF and to select optimum concentration of XCP which gives proper / suitable parameters (i.e. the parameters which will not create any mud related drilling complications and will not damage the pay-zone accomplishing the other mud functions properly) of NDDF for the study area of Upper Assam Basin. The suitable parameters of NDDF for the study area have been selected from the well cards collected from ONGC and optimum concentration of XCP was selected by interpreting the parameters with the generated graphs.

To investigate the effect of varying concentrationon the various mud properties and change in mud parameters with increasing time in days, the following equipments have used:

a) OFITE 4 scale plastic model Mud Balance to measure the density of formulated mud.

b) OFITE plastic Marsh Funnel Viscometer to measure the Funnel Viscosity of formulated mud.

c) OFITE model 800 Viscometer to measure/determine Gel_0, Gel_{10}, Apparent Viscosity, Plastic Viscosity, Yield Point of formulated mud.

d) Filter Press for measuring the Fluid Loss and Mud Cake Thickness of formulated mud.

e) pH Meter for measuring the pH of water used for formulating mud and the formulated mud.

f) Conductivity Meter to measure Salinity of water used for formulating mud and the formulated mud.

Results and Discussion:

As discussed earlier, reservoir minerals have a great role in the formation damage mechanism when they come in contact with the filtrate from WBM. The minerals of the study area have studied and identified with the help of X-ray diffraction analysis. The major minerals in most of the rock samples found to present are Smectite,Chlorite, Illite, Kaolinite, Quartz, Orthoclase and Feldspar as shown in Figure 01-02. The study reveals that in all the portion of Tipam sand of Geleki field contains both the swelling (Smectite) and non-swelling (Kaolinite, Chlorite, Illite, etc.) clay and the swelling is always more than the non-swelling clay.Of the clay minerals, Smectite is the least stable and the most susceptible to hydration and diagenetic alteration.Smectites can swell with changing ionic conditions and eventually disperse and migrate with the flowing fluid. Swelling reduces the effective area for flow and causes reduction in permeability. Kaolinite is non-swelling clay that tends to detach from the rock surface and migrate when the colloidal conditions are conducive for release. The migrating particles can get trapped in pore throats, thus causing a reduction in permeability. High pH (e.g. 10.5) causes the kaolinites to develop sufficiently high potentials to cause them to detach from the surface, migrate and be in the pore constrictions (K. K. et al., 1993).SEM study reveals that some of the clay minerals occurring as coating over the detrital grains which may reduce the intergranular pore volumes (Nayan and Minati, 2014). Therefore, the Tipam Sand of Geleki field is a very good candidate for the implementation of NDDF.

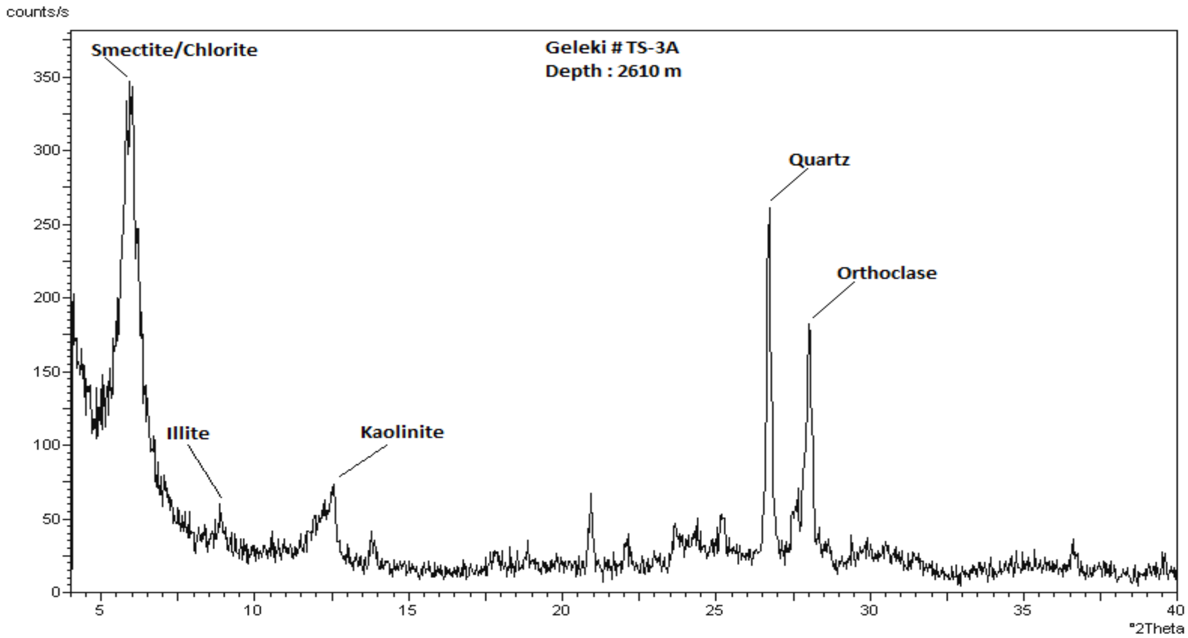

Figure 01: X-Ray Diffractogram (XRD) of Core Sample (Depth: 2610 m) of Geleki oilfield showing Smectite/Chlorite, Illite, Kaolinite, Quartz, and Orthoclase

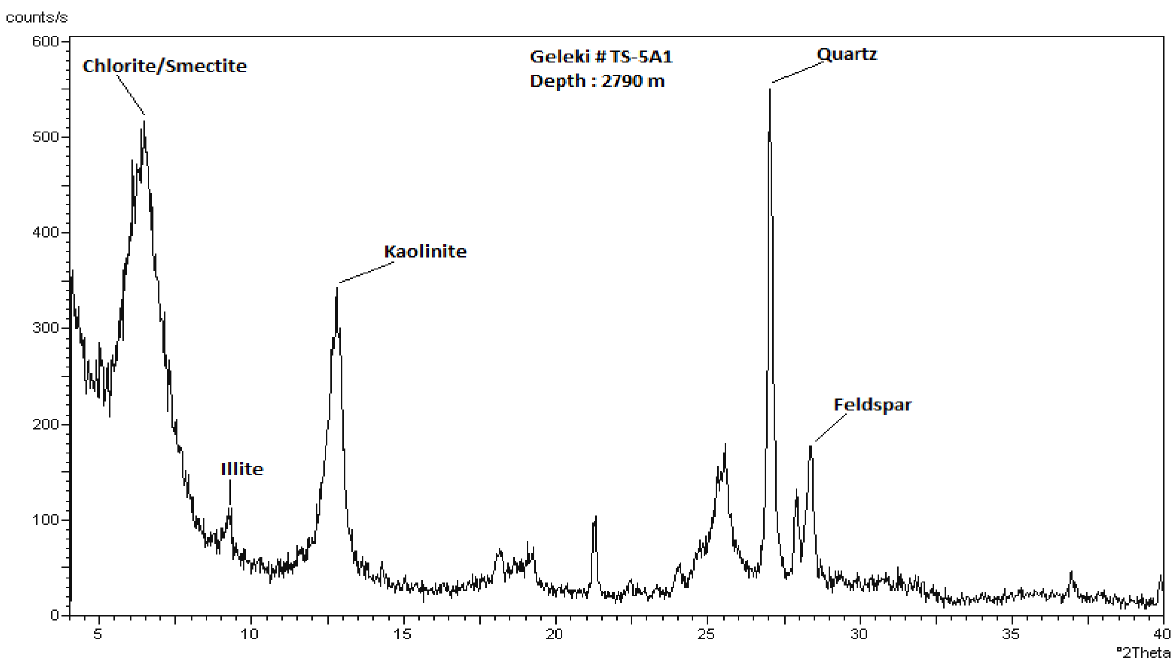

Figure 02: X-Ray Diffractogram (XRD) of Core Sample (Depth: 2790 m) of Geleki oilfield showing Chlorite/Smectite, Illite, Kaolinite, Quartz, and Feldspar

The mud properties were start to measure at the day of formulation (Zero-day) after 2-3 hours of proper mixing in the Hamilton Beach mud mixer. Then the measured / determined values of mud properties are tabulated and the effects on these properties of varying composition of XC-Polymer are investigated as follows:

Table-02: Properties of the NDDF at the 0-Day with increasing concentration of XCP

0(Zero)-Day														
Composition of XC-Polymer, gm/100ml	Mud Properties													
	Funnel Viscosity, Seconds	θ600	θ300	Apparent Viscosity, CP	Plastic Viscosity, CP	Gel Strength, lb/100ft^2		Yield Point, lb/100ft^2	Density of mud, kg/m^3	pH (Hydrogen Ion Concentration)	Salinity, psu	Fluid Loss, ml	Mud Cake Thickness, mm	Temperature, ^{o}C
						Gel_o	Gel_{10}							
0	35	26	15	13	11	1	1.1	4	1079	9.8	0.01	6.5	3.5	24
0.05	37	33.7	20.5	16.9	13.2	1.5	1.7	7.3	1075	9.8	0.01	7	0.35	25
0.1	40	43.1	27.8	21.6	15.3	2.3	2.4	12.5	1071	9.7	0.01	6.7	0.25	25
0.15	43	52	35.5	26	16.5	4.6	5.5	19	1068	9.7	0.01	6.4	0.26	24
0.2	47	61	42.5	30.5	18.5	8.2	8.6	24	1064	9.8	0.01	6.4	0.27	26
0.25	50	66.7	46.5	33.4	20.2	9.1	11	26.3	1061	9.5	0.01	6.3	0.27	24
0.3	56	75.2	54.8	37.6	20.4	11.5	13	34.4	1060	9.4	0.01	6.2	0.27	24
0.35	61	80.5	59.2	40.3	21.3	14	15.5	37.9	1058	9.4	0.01	6.2	0.26	25
0.4	68	88.2	66	44.1	22.2	15	18.5	43.8	1053	9.7	0.01	6.2	0.26	26
0.45	73	91.5	69	45.8	22.5	16.5	21	46.5	1052	9.6	0.01	5.8	0.26	23

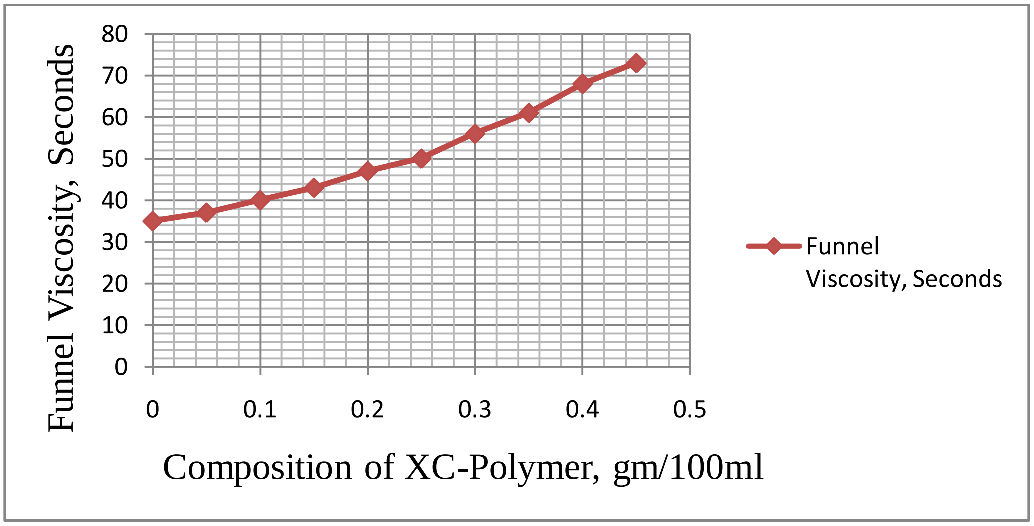

Figure-03: Funnel Viscosity vs. Composition of XC-Polymer

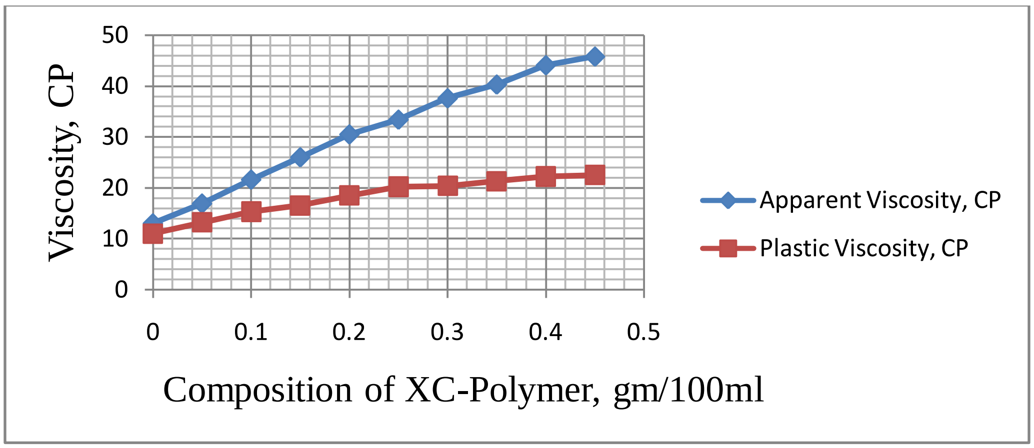

Figure-04: Apparent and Plastic Viscosity vs. Composition of XC-Polymer

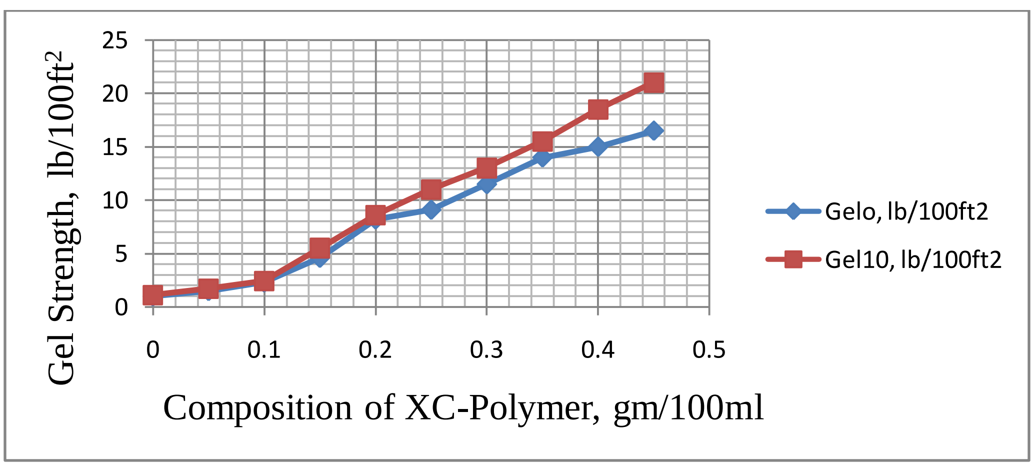

Figure-05: Gel Strength vs. Composition of XC-Polymer

Table 03: NDDF parameters of ten(10) successfully drilled wells in Tipam Sand of Geleki field of Upper Assam Basin

(Prepared from Well-Cards of mud services, , Assam Asset, ONGCL)

Well Name	Well's Brief Description	NDDF Parameters									
		Specific Gravity		Funnel Vis.,Sec		Fluid Loss, ml		Plastic Vis., CP	YP, $lb/100ft^2$	GS, $lb/100ft^2$	
		Proposed	Actual	Proposed	Actual	Proposed	Actual			Gel_0	Gel_{10}
Geleki # A	Development well, Inclined (L) profile, TS-2A Pay-zone, 2617m TVD	1.08-1.10	1.07-1.08	50-55	55-59	6-8	5-8	11-16	30-36	8-10	16-18
Geleki # B	Development well, Inclined (L) profile, TS-3A Pay-zone, 2880m TVD	1.05-1.08	1.06-1.07	45-55	42-55	6-8	7-8.5	11-14	16-24	6-8	11-16
Geleki # C	Development well, Inclined (L) profile, TS-3 Pay-zone, 2900m TVD	1.05-1.08	1.08-1.11	55-60	53-60	5-6	5.5-6.2	14-19	25-35	6-7	10-13
Geleki # D	Development well, Inclined (L) profile, TS-3A Pay-zone, 2900m TVD	1.05-1.10	1.08-1.12	50-60	47-57	5-6	4.2-7	10-17	35-38	8-12	15-18
Geleki # E	Development well, Inclined (L) profile, TS-5A1 Pay-zone, 3051m MD	1.07-1.10	1.08-1.12	50-55	43-50	6-8	3.4-7.6	9-18	22-37	8-12	10-17

Geleki # F	Development well, Inclined (L) profile, TS-5A1 & TS-5B Pay-zone, 3010m TVD	1.08-1.2	1.10-1.12(TS-1,2,3,4) & 1.08-1.09(TS-5A,5B)	45-55	45-50(TS-1,2,3,4) & 45-47 (TS-5A,5B)	6-8	4.5-4.8(TS-1,2,3,4) & 5.5-6.5 (TS-5A,5B	15-20(TS-1,2,3,4) & 12-15 (TS-5A,5B	32-36(TS-1,2,3,4) & 23-25 (TS-5A,5B	7-12(TS-1,2,3,4) & 7-8 (TS-5A,5B	14-22(TS-1,2,3,4) & 16-17 (TS-5A,5B
Geleki # G	Development well, Inclined (S) profile, TS-4B Pay-zone, 3150m TVD	1.07-1.10	1.09-1.11	50-55	45-49	4-6	5.5-6.0	11-18	20-28	7-11	14-16
Geleki # H	Development well, Inclined (Horizontal) profile, TS-5A1 & TS-5B Pay-zone, 3258m TVD	1.05-1.08	1.04-1.06	55-60	54-60	6-8	9.0	7-14	26-40	10-15	17-20
Geleki # I	Development well, Inclined (L) profile, TS-3A & TS-6 Pay-zone, 3569 m TVD	1.10-1.12	1.12-1.18	45-55	42-47	6-8	5.7-6.5	10-17	19-25	5-7	11-17
Geleki # J	Development well, Inclined (L) profile, TS-5A1 & TS-6 Pay-zone, 3600m TVD	1.08-1.10	1.08-1.09	55-60	53-58	5-6	6-8	10-12	32-42	10-13	17-20
Actual Mean Average		**1.11**		**51**		**6.2**		**13.5**	**28**	**10.5**	**16**
Actual Range		**1.04-1.18**		**42-60**		**3.4-9**		**7-20**	**16-40**	**6-15**	**10-22**

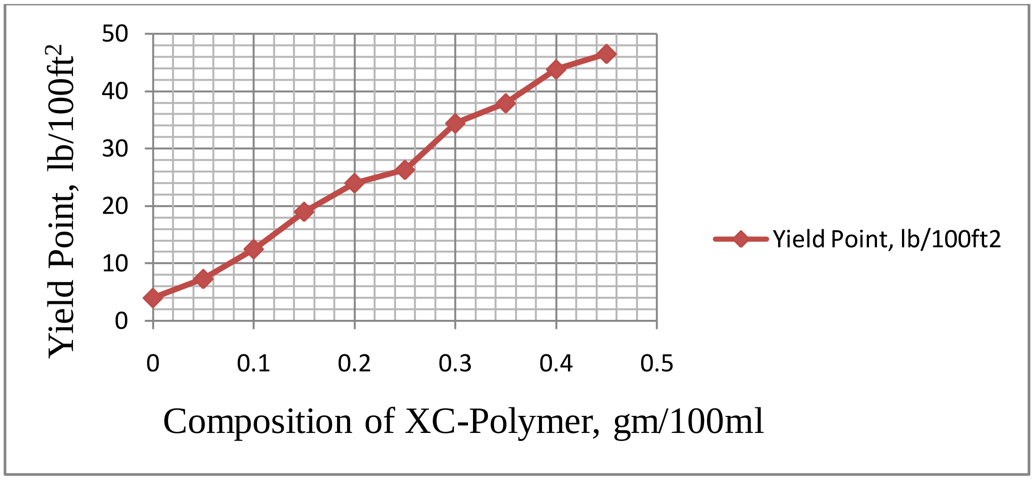

Figure-06: Yield point vs. Composition of XC-Polymer

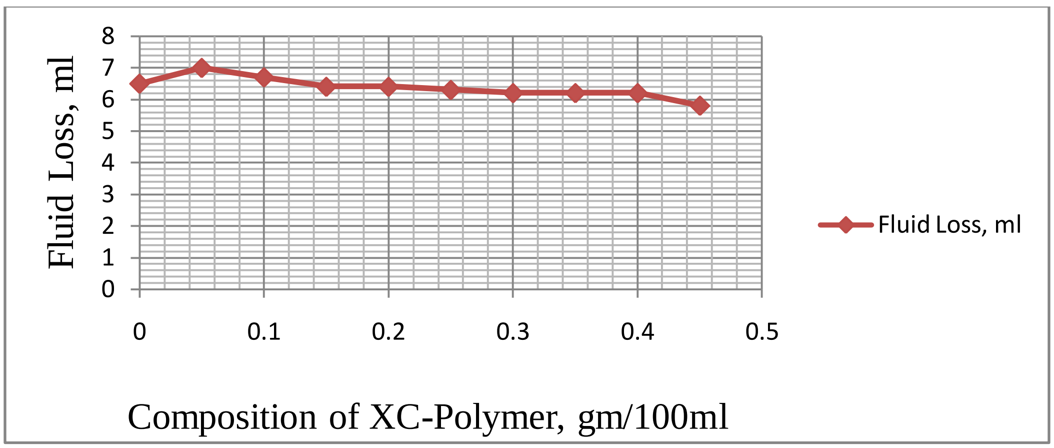

Figure-07: Fluid loss vs. Composition of XC-Polymer

All the mud parameters must be optimum for smooth successful drilling without any complications. A low value of Viscosity and Yield Point can results in low cuttingscarrying capacity of mud; high values can results in high pumping pressure which may results in formation fracture, lost circulation, may demands high capacity rig, etc. A low value of Gel strength and Yield Point may results in low capacity to suspend the solids of mud at rest; high values can results in high pumping pressure. Low density can results in well kick and blow out; high density can results in lost circulation and low drilling rate. Both the low and high value of pH is unfavourable for the mud and the equipments. Low pH results in corrosion and low crude oil recovery related problems; high pH causes the Kaolinite clays to develop sufficiently high potentials to cause them to detach from the surface, migrate and be captured in the pore constrictions, although it has positive role in oil recovery. Low salinity results in decrease in permeability due to clay swelling, increase in the value of pH although it has positive role in oil recovery; high salinity results in corrosion related problem due to decrease in the value of pH.

From the Figure 03-07 and Table 02, we can investigate that the XCP has negligible effect on Specific Gravity, pH and Salinity of mud, and has minor effect on the Mud Cake thickness and the Fluid Loss characteristics of mud, but it has great effect on the rheological properties of mud, e.g. Viscosity, Yield point and Gel Strength.

In the Figure 03-06, we can notice that the Viscosity, Yield point and Gel Strengthincreases with the increasing composition of XCP. And, from the Table 03, the Actual average range of Funnel Viscosity, Plastic Viscosity, Yield point and Gel_0 and $Gel_{10}$for the Tipam Sand of Geleki field are respectively 42-60 Seconds, 7-20 CP, 16-40 lb/100ft^2, 6-15 lb/100ft^2 and 10-22lb/100ft^2 with the mean values of **51** Seconds, **13.5** CP, **28**lb/100 ft^2, **10.5**lb/100ft^2 and **16**lb/100ft^2 respectively.

From the Figure 03-06 we can investigate that about 0.25 gm/100 ml XCP concentration is giving the Funnel viscosity of 51 seconds; about 0.15 gm/100 ml XCP concentration is giving the Plastic Viscosity of 13.5 CP; about 0.25 gm/100 ml XCP concentration is giving the Yield Point of 28 lb/100 ft^2; about 0.25 gm/100 ml XCP concentration is giving the Gel_0 of 10.5 lb/100ft^2; and about 0.35 gm/100 ml XCP concentration is giving the Gel_{10} of 16 lb/100ft^2.In the Figure 07 we can notice that the actual mean average Fluid Loss (6.2 ml) is giving by the concentration of XCP of about 0.25 gm/100 ml. But, as discussed earlier, the XCP is highly bio-degradable. The study from the figure 08-12 also reveals the same fact. And, from the field experience it has been noticed that, the average time period required for drilling of the pay-zone using NDDF in the Tipam Sand of Geleki field is about 15-20 days.

From Table 02, we can investigate that with the increasing composition of XCP, the mud cake thickness also decreases slightly. We know that for the smooth or problem free drilling operation, optimum mud cake thickness is necessary. Low mud thickness can results in high fluid loss and in turn high formation damage; high mud thickness results in sloughing or breaking and dropping of the cake which again results unstable borehole, high fluid loss and formation damage. Our objective is to forming high quality low permeable thin mud cake which can resist the further fluid and particle invasion into the formation without rupturing and dropping into the hole.

Thus, by considering the laboratory results and field experience we can conclude that we may start the formulation of NDDF at the Rig Site with the concentration of XCP of0.2 gm/100 ml and gradually increase the percentage upto 0.35 gm/100 ml for the compensation of bio-degradation of XCPfor the successful drilling in Tipam Sand of Geleki oilfield. Thenwe will start the drilling with this mud system and investigate the functions of the mud while drilling. We will investigate whether the cuttings are properly carrying out of the hole or not; drilling rate is satisfactory or not; mud solids are properly suspended or not at the rest of the mud, solid control equipments are properly working or not, etc. as well as continuous testing of the mud parameters e.g. density, rheological properties, fluid loss, mud cake, pH, salinity, etc. If we have the problem free drilling operations is going on, we will continue the drilling with the same composition and otherwise we may slightly increase the composition of XCP upto 0.35 gm/100 ml investigating the functions.

Then we have kept the same mud samples for two months in the laboratory in the ambient temperature & atmospheric pressure condition and the effect of mud properties with change in time periods are investigated. We have done the experiments for measuring the properties as an order of 0-day, 1-day, 2-days, 5-days, 10-days, 15-days, 20-days, 30-days, 45-days and 60-days and choose a fixed composition of XCP (0.25gm/100 ml) for making the graphs of various mud properties verses change in time for studying the properties as follows:

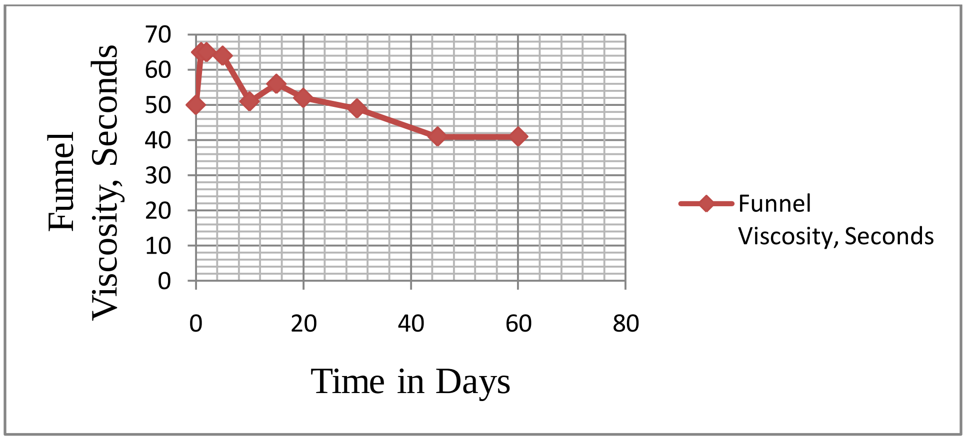

Figure 08: Funnel Viscosity vs. Time

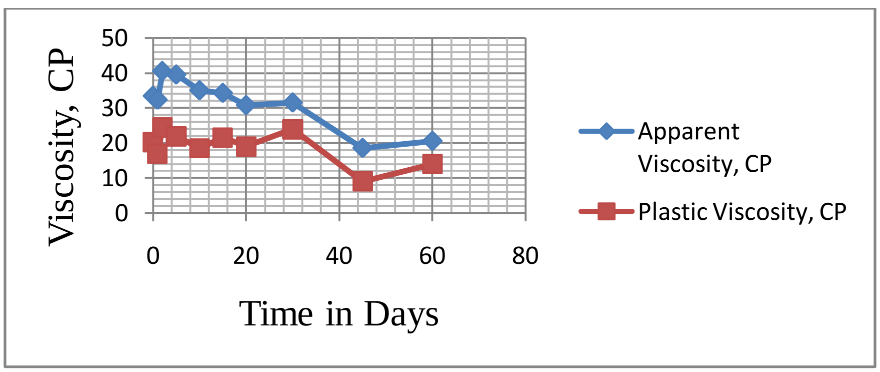

Figure 09: Apparent and Plastic Viscosity vs. Time

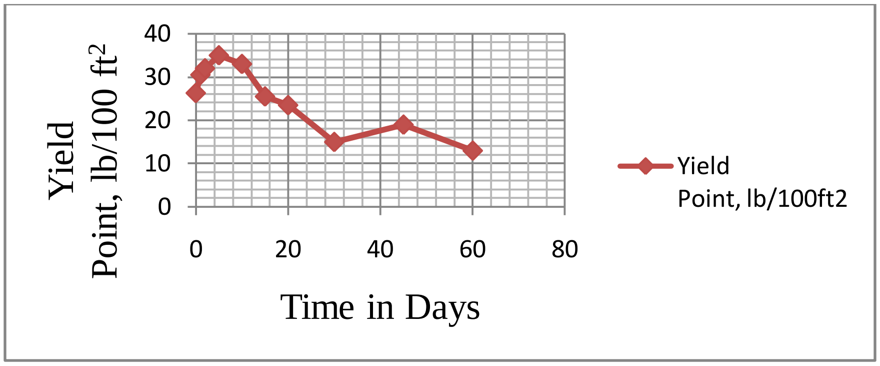

Figure 10: Yield Point vs. Time

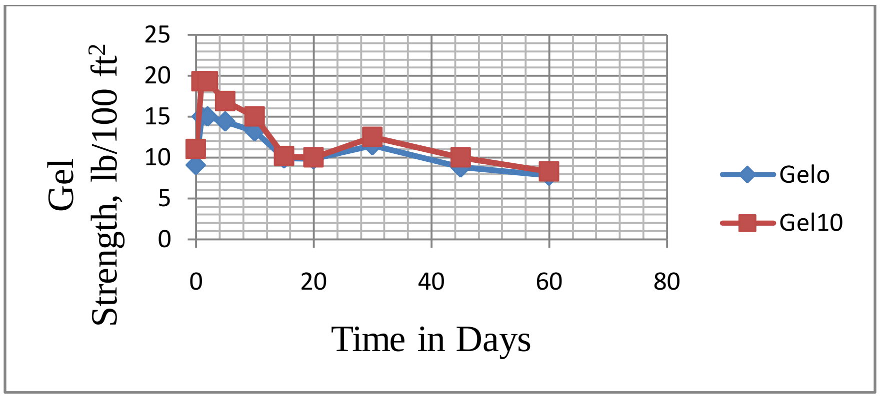

Figure 11: Gel Strength vs. Time

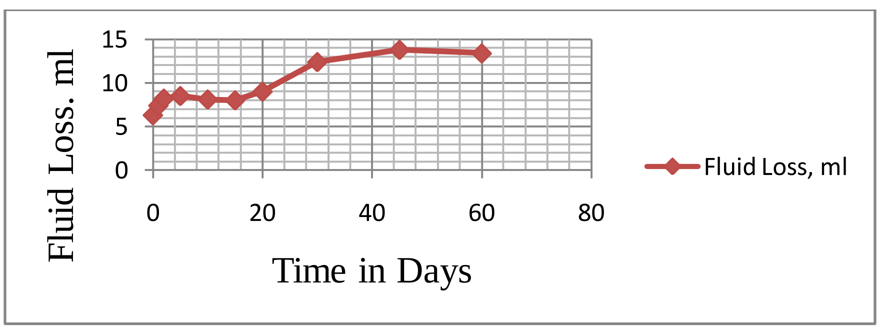

Figure 12: Fluid Loss vs. Time

It can be noticed from the Figure (08-12) that all the mud properties are degrading with increasing time span. The investigated trends are as follows:

- Funnel Viscosity: Decreases with increasing time.
- Apparent Viscosity: Decreases with increasing time.
- Plastic Viscosity: Decreases with increasing time.
- Gel Strength: Decreases with increasing time.
- Yield Point: Decreases with increasing time.
- Fluid Loss: Increases with increasing time.

All the rheological properties are decreases and the fluid loss increases with duration due to the bio-degradation of XCP. The pH, Salinity and Density are almost same due to the negligible effect of XCP on these properties. The Mud Cake Thickness slightly decreaseswith increasing time due to the less availability of XCP in mud. Therefore, the bactericide has significant role for reducing the degradation rate of XCP.

Conclusion:

From the above discussion, the following conclusions are drawn:

- The Tipan Sand of Geleki field of Upper Assam Basin is a good candidate for the application of NDDF. This formation having the average Porosity (21%) and Permeability (26 md) is very much susceptible for the formation damage. It contains both the swelling (Smectite) and non-swelling (Kaolinite, Chlorite, Illite, etc.) clay and the swelling is always more than the non-swelling clay. For the Smectites we must have to decrease the filtration loss and for the Kaolinite we must have to control the pH.

- XCP works excellently as the rheology control agent in NDDF (Figure 03-06) which also has a moderate role in controlling the fluid loss of the mud (Figure 07).So, it can be effectively used in drilling fluid where formation protection, solids suspension and improved borehole cleaning are the primary concerns. But, the drawback of XCP is that it is highly degradable. After few days of formulation it starts degrading and adversely affects almost all the mud properties (Figure 08-12). Therefore, the drilling time using NDDF should be as low as possible or the drilling rate in the pay zone should be as high as possible. The biocide must be used to decrease the degradation rate.

- All the reservoirs in the world are heterogeneous. The properties and characteristics are different in different location in the reservoir. Therefore, the composition of any component or the value of any properties of NDDF to serve any function will not be fixed. In this study, from the laboratory experiments and field experience regarding the composition of XCP as primarily as the rheology control agent and secondarily as fluid loss and mud cake thickness agent in NDDF used for drilling the pay-zone for eliminating the formation damage and drilling complicacy, we may start the formulation of NDDF with 0.25 gm/100 mlXCP and may increase upto 0.35 gm/100 ml with the requirements during the drilling.

- Intensive care of the mud and the circulation system is needed during drilling the pay zone section. All the solid control equipments e.g. Shale shaker, De-Sander, De-Silter, Mud Cleaner, etc. should be working properly during the drilling to control the solid particles in mud. Continuous investigation of the properties and functions of the mud, whether they are fulfilling the requirements or not, is necessary and if required we may have to change the composition of the mud during drilling.

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