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Effect of Alkalinity and the Nature of the Basic Solution [$Ca(OH)_2$ and $Ba(OH)_2$] on the Zeta Potential and Rheological Properties of the Drilling Mud

M. MAALLEM[1], B. SAFI[2,*], M. SAIDI[2], A. BENMOUNAH[2] and D. ABOUTALEB[2]

[1]Department of Process Engineering, Faculty of Engineering Science, University of Boumerdes, Boumerdes, Algeria
[2]Research Unit: Materials, Processes and Environment (UR/MPE), University of Boumerdes, Boumerdes, Algeria

*Corresponding author: E-mail: safi_b73@yahoo.fr; safi_b73@umbb.dz

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The drilling phase of 8"$^{1/2}$ wells of Hassi Messaoud in Algeria is a most difficult step, namely the nature of the geological and the choice of parameters governing drilling operations. The fall recurrently in alkalinity and pH of the mud was observed during the use of local barites towards higher salt saturated mud, resulting in a deterioration of rheological properties (plastic viscosity, yield value). For this purpose, the objective of this work is to study the physical-chemical problem of deterioration of rheological parameters caused by the effect of alkalinity and the nature of the basic solution [$Ca(OH)_2$ and $Ba(OH)_2$] on the electrokinetic stability and rheology of the drilling mud. The results show that the alkalinity of the mud can be ensured by the presence of a basic solution [$Ca(OH)_2$ and $Ba(OH)_2$] and has clearly improved rheological properties of the mud's. Also the nature of the basic solution has a positive effect on the rheological behaviour of saturated salt muds.

Key Words: Salt saturated mud, Barite, Alkalinity, Rheology, Plastic viscosity, Yield point.

INTRODUCTION

Drilling muds are dispersed colloidal systems. The dimensions and particle properties are important factors that determine the properties of systems dispersed. In all cases, the mud must keep certain physical-chemical and rheological properties[1,2].

The drilling fluids, especially in unconsolidated coal seams, are typically comprised of polymers such as starch, cellulose, guar or xanthan. The starch, cellulose and guar provide viscosity for borehole maintaining, friction reduction and lubrication while xanthan polymer enhances cutting transport capabilities. Although drill-in fluids are inherently less damaging than the conventional drilling muds, relatively impermeable filter cakes are nonetheless still deposited on the borehole wall. Insufficient degradation of the filter-cakes resulting from even these "clean" drill-in fluids can significantly impede flow capacity at the wellbore wall[3,4]. Different types of chemicals are used to modify starch used for preparing drilling mud to meet functional requirements such as appropriate mud rheology, density, fluid loss control property and thermal stability. Recently, numerous modified starches have been produced for oil field applications and this is carried out by gelatinization in the presence of a solvent. However, it is difficult to graft two groups using this process, especially, when one is hydrophilic and the other is hydrophobic in one reaction because they need different solvents. Amanullah and Long[5] reported on superior corn -based starch for oil field application[5]. Furthermore, a number of research works on polymers and their use in water-based drilling fluids have been carried out[6-8]. The use of polymers like guar gum, carboxymethyl cellulose (CMC) and hydroxy propyl starch as filtration control agents or as drilling fluids and the effects of temperature on the behaviour of these polymers have been discussed[7].

This reduced flow capacity can result in significant reduction of the well productivity or injectivity. Formation damage from drilling fluids leaking off into the formation, especially in unconsolidated and high permeability coal seams, as well as filter-cake impairment, must be eliminated to realize the full potential of horizontal completions. The primary problem is thought to be inadequate contact of the reactive solution with the drill-in fluid damage[9,10].

The phase 8"$^{1/2}$ has a many problems during the drilling operation. In the field of HMD, the phase 8"$^{1/2}$ is the most difficult phase to achieve, given the complexity of the problems, many difficulties inherent in the nature of the formations penetrated is indeed concentrated at this phase, namely: The presence of salt-bearing beds of massive TS1, TS2 and TS3; water inflows of chlorinated lime LD2 and the presence of clay fluent TS2.

To drill Phase 8''1/2, with a minimum of problems it is necessary to use a saturated salt slurry having:

- A viscosity low enough to flow through the annular space without excessive pressure drop.
- A high density.
- Properties of the suspension for the transport of cuttings to the surface.
- A thixotropic in order to develop rapidly a gel when stopping drilling.

EXPERIMENTAL

Composition of drilling mud: For the water-based drilling mud (salt saturated heavier), usually in 1 m^3 of water, the composition is given in Table-1. The density and particle size analysis of different barite are, respectively shown in Table-2 and Fig. 1. For drilling phase 8"1/2, d_b = 2.02 g/cm^3.

TABLE-1
COMPOSITION OF WATER-BASED DRILLING MUD IN 1 m^3

Salt	Starch	$Ca(OH)_2$ or $Ba(OH)_2$	Barite
360 kg	35 kg	2 kg	Depending on density of mud

TABLE-2
MEASURED DENSITY OF DIFFERENT BARITE

	D1	D2	D3	Average density
Barite I	4.33	4.35	4.29	4.32
Barite II	4.34	4.52	4.44	4.43
Barite III	4.36	4.27	4.46	4.36
Barite IV	4.27	4.26	4.26	4.26

Tests and method: All rheological tests were carried using a FANN viscometer (Fann Instrument Company) with a Couette rotational geometry. This viscometer type is used to evaluate rheological properties of drilling fluids (well cement and mud's). The test fluid (mud) contained in the annular space or shear gap between two cylinders. In the six-speed models, test speeds of 600, 300, 200, 100, 6 and 3 rpm are available *via* synchronous motor driving through precision gearing. Any test speed can be selected without stopping rotation. In our case, the 115-volt instrument used for the rheological experiment is powered by a two-speed synchronous motor to determine the shear stress at 300 and 600 rpm from which plastic viscosities and yield points were calculated using eqns. 1-3, respectively.

For the plastic viscosity (V_P) is calculated by the following formula:

$$V_p = \theta_{600} - \theta_{300} \quad \text{(in cp)} \qquad (1)$$

The apparent viscosity (V_A) is calculated by:

$$V_A = \frac{\theta_{600}}{2} \quad \text{(in cp)} \qquad (2)$$

and the yield point (Y_P) is calculated by:

$$Y_P = \theta_{300} - Y_P \quad \text{(in l b/100 ft}^2\text{)} \qquad (3)$$

with; θ_{600}: is the reading at 600 rpm, θ_{300} : is the reading at 300 rpm.

To highlight the problem of deterioration of rheological properties, we have prepared saturated salt mud's heavier (BSSA) with different barium origins [local (Barite I), Tunisian (Barite II), Turkish (Barite III), Intec (Barite IV)]. Next, we controlled the main physical-chemical and rheological properties before and after the aging of the mud and after the Hot-Rolling (*i.e.*, that the mud was put into rotation at 120 ºC for 16 h). Barite I and II were chosen for the preparation of mud: A different size (< 32, 45.60, 80, 100 microns). At various concentrations of NaCl (0, 50, 100, 150, 250, 350) g/L.

RESULTS AND DISCUSSION

From the chemical control of the drilling mud salt saturated, we see a significant decrease in pH mud barite in local *versus* time; more mud gets older, its alkalinity decreases. This drop is considerable alkalinity after the test at Hot-Rolling, whose mud becomes neutral with a pH close to 7 (Fig. 2) reflecting the deterioration of rheological parameters (V_p, Y_p) of the mud (Fig. 3). This drop of alkalinity can also be explained by a solubility of the fine fraction presented in the barite I (30 % fraction < 6 µm), which is due on the one hand; to the increase of the state of grain surface promoting their chemical activity[3].

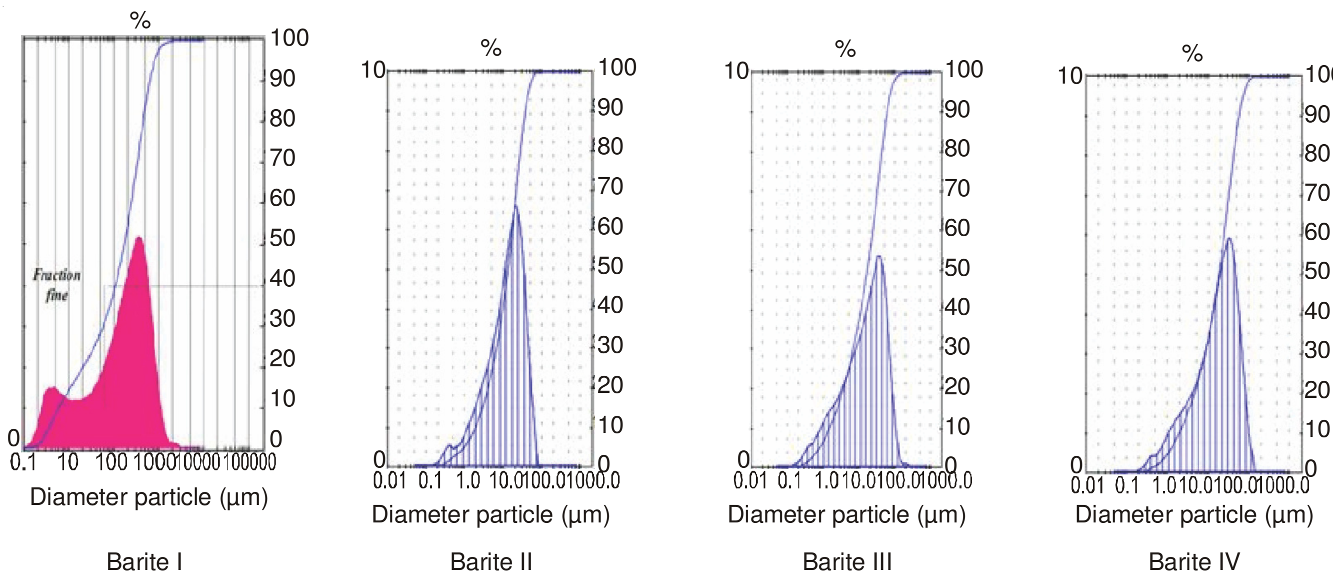

Fig. 1. Particle size analysis of different barite

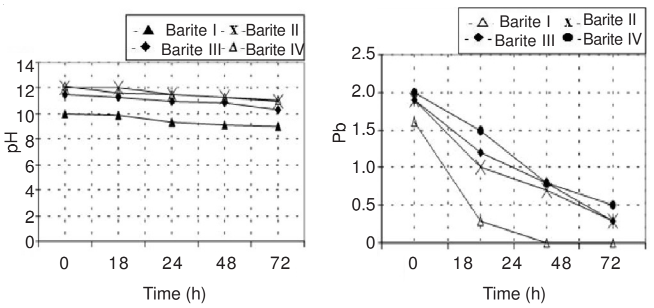

Fig. 2. Evolution of the physical-chemical properties (pH and Pb) of drilling mud as function time

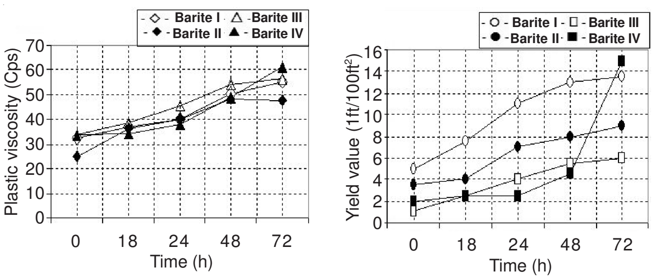

Fig. 3. Evolution of the rheological properties (plastic viscosity and yield value) of drilling mud as function time

Fig. 3 shows that the pace of the increase in apparent viscosity is similar for all the four drilling mud. After 24 h, the yield value increases by 50 % compared to baseline, then a relatively small increase during the 24 h that follows. The ionic strength of the solution increases by the phenomenon of solubility of the fine fraction of the barite I, this which tends to decreased distance between the grains[11].

Effect of particle size and salinity on the parameters of the mud: To better clarify the problem, we proceeded to study the effect of factors (grain size and salinity) on the main physico-chemical parameters and rheological properties of the drilling mud salt saturated.

Effect of particle size: Mean particle size of a product, whether solid or powdered or more less coarse, the whole of all the factors that characterize granular texture, that is to the shape and size of the grains and their distribution[4].

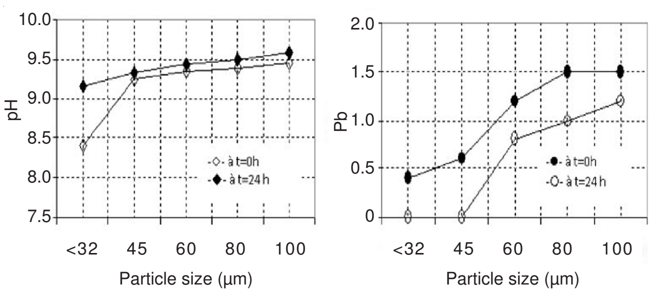

Fig. 4. Evolution of the physical-chemical properties (pH and Pb) of drilling mud as function particle size

The study of particle size and dispersed systems of particular interest to ceramics, glass, cement and explosives industries. The drilling mud technologists interested in the effect of particle size of the barium and on the rheological parameters of physical-chemical drilling fluids. They have applied to the problem deterioration of the rheology of the drilling mud for $8^{1/2}$ phase by influence of the colloidal particles on the latter.

The change in pH causes a significant increase in alkalinity of the mud (Pb) (Fig. 5). This can be explained by the surface of grains of barite (low surface area) favouring especially the chemical activity of $BaSO_4$[4,12]. For mud whose grain size is less than or equal to 60 µ, the decrease in alkalinity is accompanied by an increase in the excessive rheological parameters. In this case, a specific adsorption of ions (ions indifferent) to mineral-solution interface has emerged as a result significant ionic strength of the aqueous medium, which are acting on the electric double layer of particles colloidal by compressing.

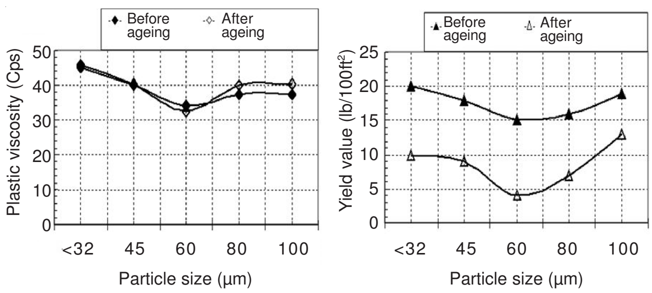

Fig. 5. Evolution of the rheological properties (plastic viscosity and yield value) of drilling mud as function particle size

The decrease in thickness of this layer causes the approximation of the particle[11,13-15]. There, from 60 µ, an increase in viscosity and yield value although the medium is basic. This is due not only to the causes described above, but also to the settling of large grains. This prevents the flow of mud. This problem becomes intensive with a long stay of the mud into the well (conditions: temperature and pressure).

Effect of salinity (NaCl salt effect): The drilling phase of 81/2 requires the use of saturated salt mud heavier, including the addition of NaCl take place until the complete saturation (350 g/L). If the mud is not saturated salts, at the time of release, it returned to reaction with salts of managed crossed layers which causes contamination of the mud and therefore the deterioration of rheological parameters. The study of the effect of NaCl on the rheological behaviour of the mud was carried out on of barium-based muds and local Tunisian by varying concentrations of NaCl (0, 50, 100, 150, 250 and 350) g/L. The results are shown in Fig. 6.

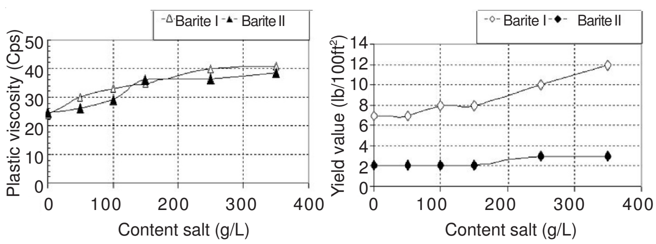

Fig. 6. Evolution of the rheological properties (plastic viscosity and yield value) of drilling mud as function salinity (salt content in mud)

The physical-chemical parameters (pH and b.pt.) of the mud are influenced by the addition of NaCl high concentration (> 250 g/L). Beyond this concentration the pH of the mud (based local barite) decreases to a value of 10 bp and decreases to a value of 0.6. The results of rheological tests carried out before aging mud, show a an increase the yield (Yp) and in plastic viscosity (Vp) increased as a function of increasing NaCl concentration; For concentrations from 250 to 360 g/L (high saturation) NaCl, increasing the yield (Yp) of the mud is important. Those carried out after aging show almost the same variations for the plastic viscosity (Vp), by the yield-cons (Yp). They are very important, especially for high concentrations of NaCl.

Effect of the alkalinity of mud: The concept of effect of common ions gives much more one approach of the resolution-from the chemical point of view-problem of the decrease of alkalinity of mud. The phenomenon of selective adsorption of the ions to the mineral interface-solution has also its share in the contribution of stability of salted mud saturated weighed down. On those, two products (extinct lime and barium hydroxide) were selected; same measurements of the physico-chemical and rheological properties were taken.

At low concentrations of NaCl, ionic strength of the solution is not great influence, but for high concentrations, it becomes important which explains the variations. The compressive effect of ionic strength on the electrical double layer has creates agglomeration of the particles of the slurry thereby increasing its rheology (Figs. 7 and 8).

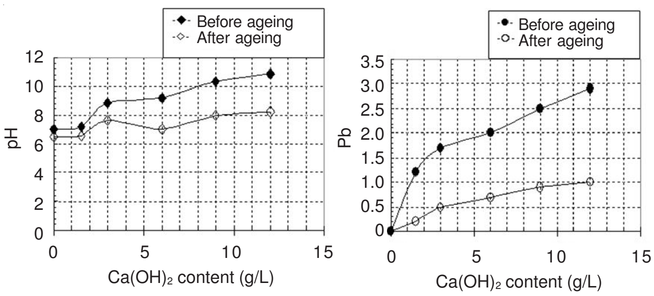

Fig. 7. Evolution of the physical-chemical properties (pH and Pb) of drilling mud as function alkalinity [$Ca(OH)_2$ content]

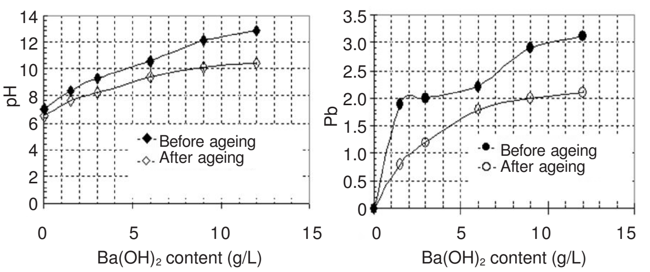

Fig. 8. Evolution of the physical-chemical properties (pH and Pb) of drilling mud as function alkalinity [$Ba(OH)_2$ content]

Electrokinetic study (zeta potential) of mud: With a concentration lower than 6 g/L in calcium hydroxide, an increase in the potential zéta is observed on L 'pace of the figure. Indeed, the behaviour of surfaces of the barite grains in the presence of lime, have an opposite affect that of NaCl. The ions OH^- and Ca^{2+} released by lime, present to surface grains better an affinity. The selective adsorption of these ions to the interface of the grain thus increases the thickness of the diffuse layer[16].

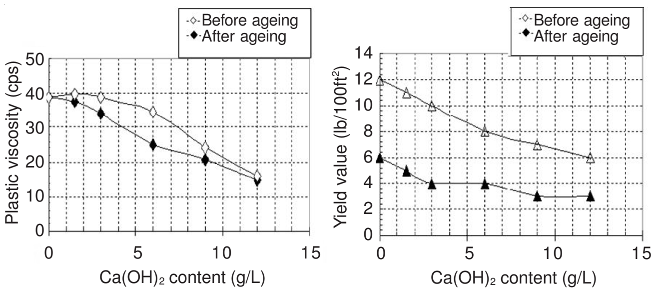

Fig. 9. Evolution of the rheological properties (plastic viscosity and yield value) of drilling mud as function alkalinity [$Ca(OH)_2$ content]

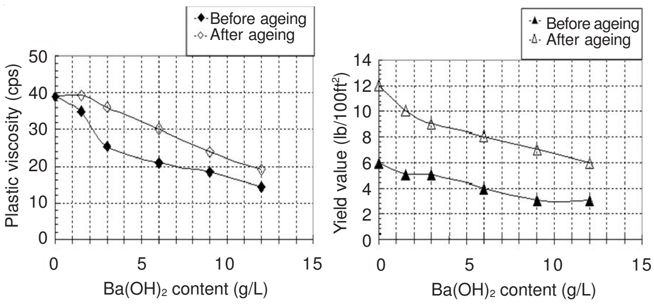

Fig. 10. Evolution of the rheological properties (plastic viscosity and yield value) of drilling mud as function alkalinity [$Ba(OH)_2$ content]

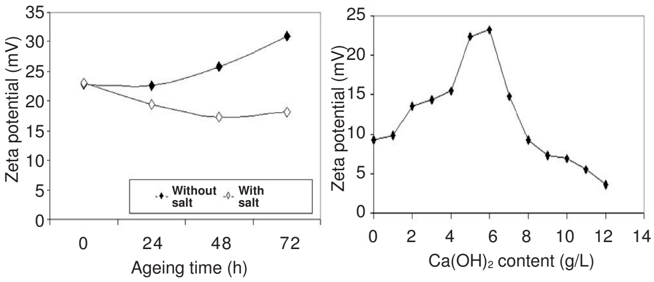

Fig. 11. Evolution of the zeta potential as function (a) Ageing time of drilling mud (b) alkalinity [$Ca(OH)_2$ content]

Beyond lime concentration (6 g/L), the value of the potential falls. This can be explained by the saturation of the diffuse layer, thus generating the bringing together of the grains and consequently the compression of this layer. It is noticed by people of the building site, that the lime excess causes an increase in viscosity and the yield[16-18].

Conclusion

The extent, to which the mud performs functions demanded of it, can not simply be determined through dress and behaviour in the hole during drilling. Our study is to develop some properties of the mud and correlate those to good resistance hang drilling phase in question. It was found that the rheological parameters increase with time aging of the mud, however, this variation depends mainly on barite used. This deterioration of the parameters is undesirable for phase $8"^{1/2}$. This study allowed us to elucidate the problem of deterioration of the physical-chemical salt saturated mud is first a problem of chemical before it either electrical and rheological properties.

The extinct lime appreciably increased the pH and the alkalinity of mud, a concentration varying, respectively from

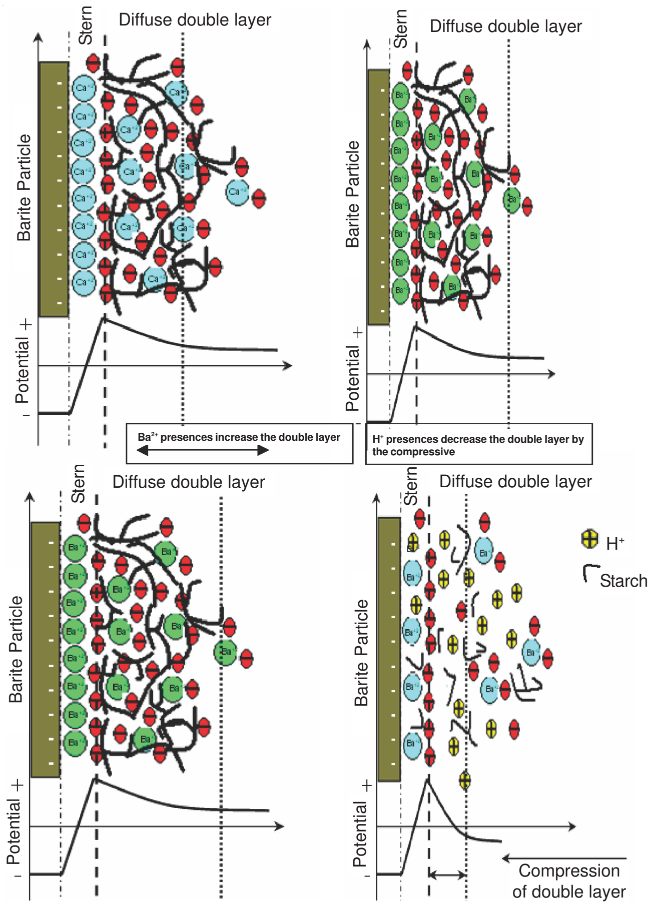

Fig. 12. Effect of the nature of ions (Ca^{2+} and Ba^{2+}) on the zeta potential values

0 to 12 g/L with enables us to reduce the rheological parameters (Vp, Yp).

• Barium hydroxide also influenced the pH and Pb, with the same contractions of that of extinct lime. But $Ba(OH)_2$ gave rheological parameters suitable to the phase $8''^{1/2}$, on the yield and the gel.

• The thinner lignin played the part of a deflocculated, because it is adsorbed with the interface of the grain, forming a layer which prevents the agglomeration of the grains and consequently a reduction in the rheological parameters (plastic viscosity and yield been worth) was also noticed.

Following determination of the potential zeta of different the mud system, one can noted that:

• The time of ageing influenced considerably the stability of mud. What was checked by the reduction in the potential, causing the bringing together of the particles. This confirms the increase in the rheological parameters according to time.

• In the same way, the results of measurements of the potential zeta of the muds treated with lignin, confirm the notable effect of surface-active on the aggregative stability of the mud system. This clearly improved in the presence of lignin and thus a better dispersion was observed and checked by measurements of the rheological properties.

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