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Research Article

Investigation of Flowing Properties of Novel Drilling Fluid

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Abstract: The objective of designing drilling slurry for extreme and deep environment (HPHT wells) is to develop high performance drilling fluid system in well bore to achieve zonal isolation. The primary objective of drilling slurry is to improve rheological properties and displacement efficiency of drilling fluid system. Oil well slurries depend on its homogeneity of additive concentrations, quality and quantity to contribute the placement and success of a well drilling cementing operation. This experimental research investigated the High Performance Drilling Fluid System (HPDFS). This watery drilling slurry is prepared with adding ferric oxidenano particles into 21% silica foam to observe the rheological properties at different concentrations of nano particle. Results indicate the prevention effect of Nano particles in the amount of yield stress with temperatures in range of 20 C to 80 C. The decrease of 10% and 6% in the amount of plastic viscosity and apparent viscosity is observed, respectively.
Keywords: drilling fluid additives; high performance drilling fluid system; rheology; Ferric oxidenano particle.

INTRODUCTION

During a well cementing operation purpose should be achieve zonal isolation [1]. That belongs to the slurry design, to ensure the best quality of cementing especially at high temperature environment such a HPDFS Silica Fume (SF) use as a cement slurry additive to reduce the density of cement[18]. SF increase slurry performance and control hydrostatic pressure during drilling cementing. This mixture used as primary source for a hydraulic seal in the well bore as secondary application is used for remedial operations including depleted zone closing, splits and leaks repair [1]. The function of SF is allows a well to reach full production potential besides producing a blocking effect in the oil well. It is also responsible to prevent gas migration and highly effective for proper placement and decrease permeability for better control of weak zones[18]. Compressive strength of concrete containing SF is proved higher strength; as increase the concentration of silica fume it improves stress resistance in the early development and reduces the free water [2]. The mixing of silica fume into cement several optimum conditions are noticed [3]:

- It is nature to consume more water to prove as s function of extender and substitute for lightweight cements.
- High water adsorption to increased pozzolanic reactivity promotes enhanced compressive strengths.
- The purity and solubility of the material makes it suitable for combating strength retrogression in cements at temperatures above 230°F (110 °C).

HISTORY AND LITERATURE REVIEW

Rheological properties of cement slurry play important role to determine the workability of slurry, fineness [4]. The mixing process is very important parameters for rheological behavior of cement slurry, the criteria of designing slurry depends on formulation, density, plastic viscosity, shears tress, yield point and gel strength for enhance durability and toughness for cement slurry [5] Cement grout is used for sealing geothermal wells for is olatezones during drilling cementing operation. Rheological behavior of cement slurry is important for the drilling process; it will be optimum to predict correctly about slurry placement [6]. Cement slurry is concentrated suspensions of small and heavy particles so rheological measurements are suffering to the disruption of cement operation [12]. Rheology of Oil Well Cement (OWC) should be considered when it applied on the originally and primarily casing cementing. Therefore, fundamental knowledge of OWC slurry rheology is necessary to evaluate the ability to mix and pump grout, remove mud and slurry placement optimization and to predict the effect of temperature on the slurry pit [5]. Incomplete mud removal can result in poor cement bonding, zone communication and ineffective stimulation treatment

[6]. A rheology is study related to the flow of fluids and deformation of solids under stress and strain. In shear flows, fictitious parallel layers of liquid past each other in response to a shear stress to produce a velocity gradient, in term of two shear rate, which is equivalent to the rate of increase of shear strain [7]. Rheology of cement slurry is complex which has the appearance and interactions between the additives [8]. The chemical composition of cement, particle distribution, test in g methods, size shape, W/C ratio, mixing time and temperature [9]. Cement slurry is viscous plastic materials that exhibit yield stress and tension below the yield stress ultimately slurry behaves as a rigid and solid [10]. Bingham plastic and power-law model is widely used to describe the rheological properties of cement slurry measurements[9].That can be determined the properties of cement flow i.e., plastic is cosity, yield point, friction characteristics and gel strength [11]. Concentration and form of so lid particles has a significant impact on the rheological properties of the OWC slurry to yield stress and plastic viscosity of cement paste usually increase as the cement becomes finer and increases the stability of slurry [13]. Equivalent Circulating Density (ECD) is important factor to understand the flow behavior, flow rate, annular velocity and differential pressure; for that purpose number of computer simulation software is available to predict the ECD. The displacement efficiency is achieving the maximum mud displacement. A standoff value of the percentage of casing centralization in the wellbore, job operation time for proper thickening and Reynolds numbers base on laboratory methods is measuring rheological properties to understand flow behaviors [14]. These parameters will be evaluating the cement pump-ability and cement grout with strength correspond to behind the casing to increase efficiency and displacement. High flow rate may cause fracture the formation there should be investigated the current effective equivalent cement density [15].

Maximum drilling fluid or colloids or emulsions as a non-Newtonian liquids in plastic or behave in such circumstances is that the gel analysis function of the intermolecular forces. The initial 10-sec and 10-min gelstrength measurements gelation indications of the gel that will occur after the flow is stopped and the drilling fluid remain static[19]. When circulating drilling mud and fluids during cementing operations abnormal results in bottom hole, which may cause challenge to the integrity and safety. To maintain hydrostatic pressure of the fluid column below the fracture gradient but above the pore pressure and designing drilling slurry to improve efficiency and displacement without causing any form of collapse to the formation for this condition to focusing on ECD and rheological properties[21].

Design of cement slurry

Oil well cement compositions are typically used for sealing subterranean zone at High Temperature and High Pressure (HTHP) such as the annular space in oil well between the surrounding formation and casing [4]. Slurry blend consist of cement class G with additives and water. The productivity of an oil well is significantly affected by the quality of cementing between the well casing and the surrounding strata[19]. Cement slurry flow ability and stability are major requirements for successful oil well cementing [16] because the cement is the most active component of the slurry and usually has the greatest unit cost. Its selection and proper use are important in obtaining an effective, for long term integrity of the well[20]. Portland cements can be used for cementing around the casing of oil and gas wells having deeper depth wells usually require special oil well cements[19]. There are currently eight classes of API Portland cement designated A through H that are arranged according to the depths to which they are placed at pressure and temperature to which they are exposed [11]. In oil well drilling industry class G and H type well cement are well known for deep wells; because enoaddition other than calcium sulfate and water both shall be inter-ground or blended to the clinker during manufacturing of these oil well cement. Therefore with addition of ample quantity of additives such as retarders and dispersants can change their setting time to the cover wide range of well depths, pressure and temperature [16]. In this study silica fume used as extender, as it is function to reducing slurry density also light slurry is used to control hydrostatic pressure during cementing operation. This slurry has greater strength to use in weak and unconsolidated formation.

Mixing energy

The cement slurry is a mixture of cement, water and additives[21]. The mixing process is exothermic and the energy required to this called is mixing energy.

The mixing energy equation is given as Williams *et al.* [20]:

$$E/M = k\omega^2 t/V \qquad (1)$$

where,

E	Mixing energy (KJ)
M	Mass of slurry (kg)
K	$6.1*10^{-8}\ m^5/s$ (constant found experimentally)
ω	Rotational speed (radians/s) t
t	Mixing time (sec)
V	Slurry volume (m^3)

The prepared cement slurry is dispatch to Viscometer for measuring rheological properties.

SOURCE OF MATERIALS

Silica fume is obtained from WR Grace Malaysia which a global specialty in chemicals and drilling fluid materials.

Standard of well drilling fluid test

American Petroleum Institute (API) has presented "Recommended practice for testing well drilling fluid s [17]. The standard has been followed which is used worldwide. These tests areadvise and very helpful to drilling personnel for determine a given drilling fluid composition will be feasible for well conditions according to API-10B [17].

Experimental procedure: Drilling fluid slurry is prepared according to API-10B [17]. The mixing method strongly influences on slurry and set cement properties. Cement additives can be wet blended in cement slurry. When additives are mixed in water prior into cement, it is called wet blending.

Electronic balance

This is used for weighting dry cement, distilled water and additives, to use for preparation of drilling fluid slurry.

Electronic standard 7000 constant speed mixer

Measure cement and additive prepared in lab using the standard 7000 Constant Speed Mixers provide all the necessary functions to mix drilling slurries according to API and ISO specifications and recommended practices. Normally 600 mL of slurry are prepared. Slurry is mixes for 70 sec the mixer is operated at 4000 RPM during first 15 sec which the dry cement is added to water this is followed by 35 sec at that condition set mixer at 12000 RPM followed at 70 sec.

Rheology measurement

The prepared drilling slurry is placed into sample cup i.e., Bob1 having capacity of drilling fluid is 42 mL slurry different Bob having different capacity for drilling slurry's high performance advance pressurized viscometer model 1100 with ORCADA software is used for measuring rheological properties of drilling slurry's. According to API recommended practice 10B viscometer is used for oil well drilling fluid testing materials having wide range of temperatures. Where the viscosity is determined, the dial readings at various rotational speeds are giving the slurry behavior at different condition. In this study the temperature is set at above 120°C the viscometer heat bath help to simulate down whole condition. After heat conditioning, the viscometer starts to take the dial reading at different RPMs to measure rheological parameter at down whole condition.

MATERIALS AND METHOD

Properties of ferric oxide

Ferric oxide nanoparticles, a common ingredient has a huge variety of applications. This topic is proven that, the application of Fe2O3nano particles in low dosage is not toxic. So, this type of metal oxide is chosen as additive.

Method of preparation of Ferric oxide nanoparticle

Nano fluids that are used in this experimental work are prepared in two steps. At the first, the amount of 1.16 g of Ferric oxide in powder form is dissolved in de-ionized water contains 0.38 g of citric acid crystals. Then Ammonium hydroxide is added gradually (till obtaining pH=7) into the mixture and is homogenized effectively in magnetic stirrer simultaneously. To produce the powder form of ferric oxide, the mixture is heated for 1h at 250 °C and then to 500 °C for 90 min to change the colour of powder into bright yellow.

Nano particles diameter is in the range of 40-60 nm and morphology of particles are characterized with SEM and TEM images. Table 1 shows the specifications of the used nanoferric oxide. Then 0.01 wt.% nano particles are added in the drilling fluid, alkyl-aryl sulfonate as a surfactant in the fraction of 0.3:1 to the amount of nano particles is used to improve the interaction between nano particles and the molecule of drilling fluid. Stabilization step is done with ultrasonic technique through 2 hours. The individual effect of surfactant on the properties of drilling fluid could be neglected, considering the less amount of surfactant comparing with the amount of drilling fluid. Produced spherical particles with the average diameter of 40 -60 nm in size areobserved approximately. Figure 1 shows TEM and SEM photos of produced nano particles a and b) in the scale of 5 micrometer and c) in the scale of 500 nm.

Table 1: Physical properties of aluminum nano-catalyst

Ferric oxide nano-catalyst properties	
Assay	≥95% Trace metal basis
Form	Nano powder
Resistivity	>10'4 μΩ-Cm at 20C
Average Particle Size	75 - 89nm
Thermal conductivity	20W/m.K
Density	3.7 gr/ml at25C

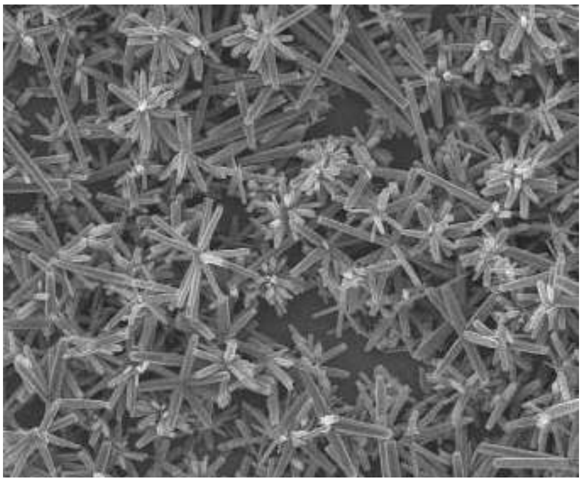

Fig. 1-a).The TEM picture.

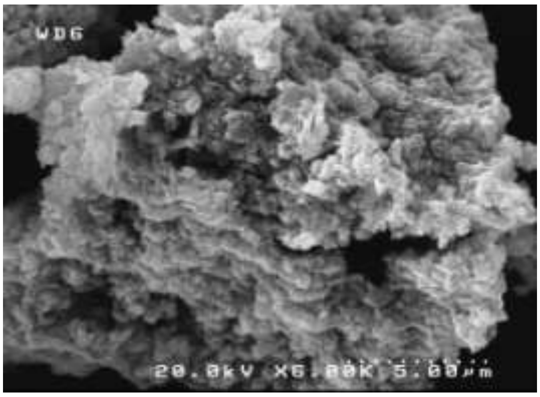

Fig. 1-b).The SEM picture.

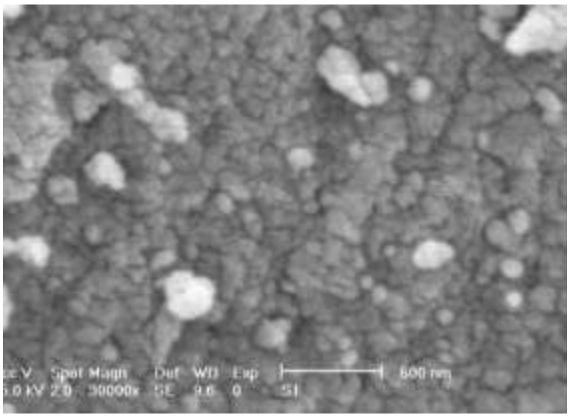

Fig. 1-c).The SEM picture.

RESULTS AND DISCUSSION

Experimental results are shown in this section of article. Important rheological properties of slurry mud as a non-Newtonian fluid such as yield stress, apparent viscosity and plastic viscosity are studied. The effect of amounts of nano particle, temperature and amounts of shear rate on the above parameters are reported in the following Figures.

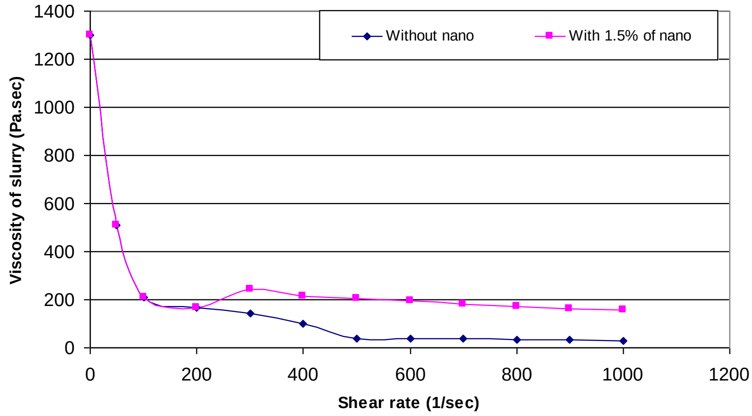

Fig.2: Relation between shear rate and viscosity with and without nanoparticles.

According to Figure 2, higher amounts of shear rates result lower amounts of slurry viscosity. Adding 1.5% nanoferric oxide results higher amounts of viscosity for shear rates higher than 200 1/sec comparing with amounts which are obtained without nanoferric oxide.

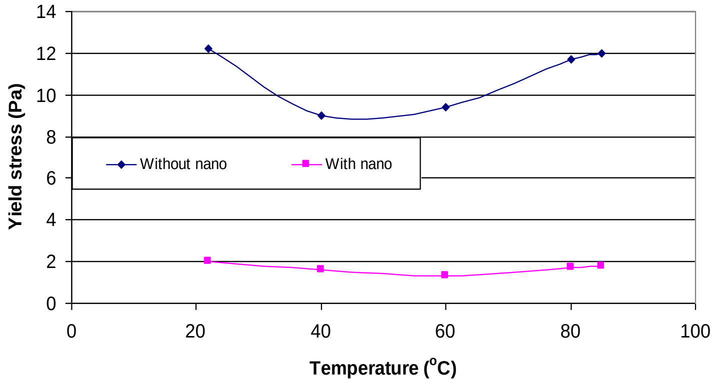

Fig.3: yield stress versus temperature.

The effect of temperature on the amount of yield stress for slurry mud which contains nanoferric oxide and without ferric oxide is shown in Figure 3.

The amounts of yield stress are between 1.8 to 2 Pa for drilling fluid contains nanoferric oxide. It seems adding nanoferric oxide eliminates the severe effect of changes in temperature (20 C to 85 C) on the amounts of yield stress. So, the values of yield stress are near together. However, the values of yield stress of drilling fluid changes between 9 Pa to 12.3 Pa white changes in temperature from 20C to 85C for drilling fluid without nanoferric oxide. So, the nanoferric oxides decrease the amounts of yield stress and somehow also eliminate the effect of changes in temperature.

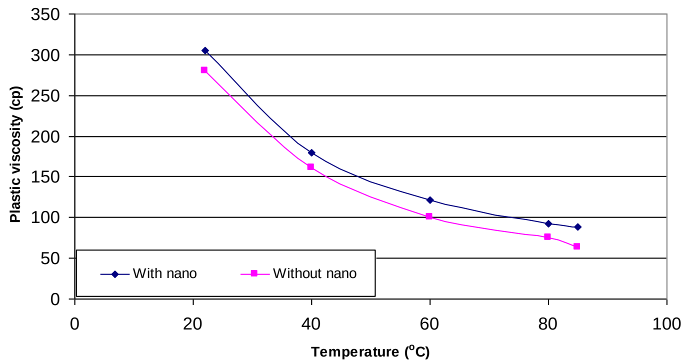

Fig.4: Plastic viscosity versus temperature.

Changes in the amount of plastic viscosity due to changes in temperature for drilling fluid which contains nanoferric oxide and without nanoferric oxide are shown in Figure 4. The increase in temperature shows the decrease in the amounts of plastic viscosity in both with and without nanoferric oxide.

Higher amounts of plastic viscosity are obtained when nanoferric oxide is used. Temperature changes from 20 C to 80 C results the amount of plastic viscosity between 280 cp to 60 cp for drilling fluid without nanoferric oxide and 300 cp to 90 cp for drilling fluid contains nanoferric oxide.

CONCLUSIONS

The effects of nano particles on the rheological properties of drilling fluid are investigated in this research. Plastic viscosity, apparent viscosity, shear rate and shear stress are considered as the important rheological parameters. So, the quantity of these parameters in various temperatures and also in presence of nano particle are measured and compared with what are measured without nano particles. Nano particles in drilling fluid, prevents variations in yield stress in various temperatures in range of 20 C to 80 C. Nano particle decreases the amount of plastic viscosity and apparent viscosity about 10% and 6%, respectively.

REFERENCES

1. Nediljka GM, Davorin M, GracijanK; Cement slurries for geothermal wells cementing. Rudarsko-Geološko-NaftniZbornik, 1994; 6(1): 127-134.
2. Mehta PK,GjorveOE; Properties of Portland cement concrete containg fly ash and condensed silica fume. Cem.Concr. Res., 1982; 12(5): 587-595.
3. Shadizadeh SR, KholghiM,KassaeiMHS; Experimental investigation of silica fume as a cement extender for liner cementing in iranian oil. Gas Wells, 2010; 7(1).
4. Shahriar A,NehdiML; Optimization of rheological properties of oil well cementslurriesusing experimental design. Mater. Struct., 2012; 45(9);1403-1423.
5. Shahriar A, Nehdi ML, ShahriarA; Investigation on Rheology of Oil Well Cement Slurries.2011.
6. Bannister, CE;. Rheological evaluation of cement slurries: Methods and models. Proceeding of the SPE Annual Technical Conference and Exhibition, 1980; 21-24,
7. Guillot D; Rheology of Well Cement Slurries. In: Nelson, E.B. and D. Guillot (Eds.), Well Cementing. Texas, Schlumberger, 2006;pp: 93-142.
8. Banfill D,KitchingPFG; The Yield Stress of Oilwell Cement Slurries. In: Rheology of Fresh Cement and Concrete.1991
9. Frittella BSF, Services BJ, Babbo M; Best practices and lessons learned from 15 years of experience of cementing hpht wells in italy. Proceeding of the SPE/IADC Middle East Drilling Technology Conference and Exhibition, 2009; 26-28.
10. Mirza J, MirzaM, RoyV,SalehK; Basic rheological and mechanical properties of high-volume fly ash grouts. Construct. Build. Mater., 2002; 16(6): 353-363.
11. HarrisKL, ServiceH; New lightweight technology for the primary cementing of oilfield casings in cold environments. Proceeding of the International Arctic Technology Conference, 1991; 29-31.
12. Miranda CR, Petrobras RD, Toledo F, Fairbairn EMR; New design of high-performance cement systems for zonal isolation: Influence on porosity, rheological parameters and chemical and mechanical resistance. Proceeding of the SPE Latin American and Caribbean Petroleum Engineering Conference, 2010; 1-3.
13. Boukhelifa L, MoroniN, SpaE, JamesSG, DelageSLR, ThiercelinMJ, LemaireG, NatlI,InsaA; Evaluation of cement systems for oil- and gas-well zonal isolation in a full-scale annular geometry.SPE Drill. Comp., 2005; 20(1): 44-53.
14. Labibzadeh M, Zahabizadeh B,KhajehdezfulyA; Early-age compressive strength assessment of oil well class G cement due to borehole pressure and temperature changes. Science,2010; 6(7): 38-47.
15. Hodne H; Rheological performance of cementitious materials used in well cementing. Ph.D. Thesis, 2007.
16. Kulakofsky D, Vargo R; New technology for the delivery of beaded lightweight cements.Proceeding of the SPE Annual Technical Conference and Exhibition, 2005; 9-12.
17. American Petroleum Institute, Recommended Practice for Testing Well Cements.API Publishing Services, Washington, D.C., 2005; pp: 171.
18. Siddique R, Khan MI; Supplementary Cementing Materials. Springer Berlin Heidelberg, Berlin, Heidelberg, 2011.
19. Teodoriu C, Schubert J, Ugwu I; Cement fatigue and HPHT well integrity with application to life of well prediction. Final Project Report Prepared for the Minerals Management Service Under the MMS / OTRC Cooperative Research Agreement Task Order M07AC12464 MMS Project Number 602 December," Stress: The International Journal on the Biology of Stress,. no. 602, 2008
20. Williams DA, Saak AW, Jennings HM; The influence of mixing on the rheology of fresh cementpaste. Cement Conc. Res., 1999; 29(9):1491-1496
21. Stephen OK, Samuel SM; The effect of mixing energy and shear rate on the thickening time of cement slurry.London J. Sci., 2005;13: 78-89