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RESEARCH ARTICLE

THE EFFECT OF TEMPERATURE ON NANO (ZINC OXIDE PARTICLE) WATER BASED MUD RHEOLOGICAL PROPERTIES.

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Abstract

For a successful drilling of oil and gas wells, the mud rheological properties should be examined and additives included where necessary. Designing a proper drilling fluid that can withstand different sub-surface(temperature) conditions is a challenging task. In this work, the effect of temperature on nano water based mud rheological properties was examined at different temperature ranges (25^{o}C, 30^{o}C, 35^{o}C, 40^{o}C, and 45^{o}C) using chandler rheometer,oven , marsh funnel and mud balance. For accuracy the equipment used were all calibrated and the rheological properties of water based mud where determined for different mass fractions(0g, 5g ,10g , 15g ,20g) at temperatures of 25^{o}C, 30^{o}C, 35^{o}C, 40^{o}C, and 45^{o}C . The result shows that the plastic viscosity, yield point and gel strength decreases with increases in temperature. At any temperature, increase in the mass fractions (grams) of the Zinc oxide nano particle increases the mud density, plastic viscosity, Gel strength, mud pH and the electrical conductivity of the mud. The yield point was not linear with increase in grams of the Zinc oxide nano particle as increase in grams of the particles decreases the yield at higher temperature and increases the yield at lower temperature. Generally, the rheological properties of the water based mud improved with addition of zinc oxide nano particle.

Introduction:-

Proper examination of the constituents of drilling mud is necessary to avert drilling problems. Since increase in temperature affects the rheological properties of mud and drilling performance,the search for additives that can offset this tendency remain prominent. As exploration activities increases offshore, oil and gas reservoirs are found at high depth with high temperature and pressure conditions(Ibeh,2007). Advancement of drilling operations into high temperature formations requires the use of drilling fluid with additives that can withstand such condition and improve the rheological properties of the fluid(Shushant *et al*,2011; Makinde *et al*.,2011). Accurate knowledge of the behavior of drilling fluid at a certain temperature and pressure condition is necessary for efficient and safe drilling operation in deep reservoirs (Bland *et al*.,2006). Whether water based or oil based fluid, at a certain temperature and pressure conditions, the rheological properties of the drilling fluid will be altered and the effect significant without sufficient or adequate additives. Increase in temperature of an oil based fluid with different properties at ultra-HP/HT conditions has negative effect on the rheological behavior(decreases the viscosity, yield

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point and gel strength of the fluid). The behavior been attributed to the thermal degradation of the solid, polymers and other constituents of the fluid(Amani, 2012). For water based fluid with different properties at extremely high temperature and pressure conditions(600^{o}F and 40000psig) with state of the art viscometer, the rheological properties(viscosity, yield point and gel strength) decreases exponentially with increasing temperature until the mud fail(Amani and Al-Jubouri,2012). So many chemicals and polymers have been used in designing drilling mud to suit different sub-surface conditions and improving the rheology, density, and fluid loss control. Recently, addition of nano particles have improved fluid thermal conductivity, electrical conductivity and fluid loss property (Jung *et al*., 2011; Youngsoo *et al*.,2011). Nano particles were found to be valuable agents and improved the properties of fluids in several oil field applications in the oil and gas industry (Amanullah and Yu, 2005). Its adsorption and transportation behavior in porous medium makes it useful as stabilizers, fluid loss additives and rheology modifiers in water based mud (Hoelscher *et al*. 2013). Aluminium oxide nanoparticles as additives in water based fluid provide thermal stabilization and maintained the shear stresses of the fluid as temperature increases at defined level of shear rate(Amarfio *et al*.,2016). Similarly, iron nano particles maintained the desired rheological properties and shear stresses of drilling fluid as temperature increases at defined levels of shear rate(Amarfio *et al*.,2015).Addition of iron oxide nano particle does not only improved the rheological properties of the mud but slightly increased the filter cake thickness (Vryzas *et al*.2014).Multi-walled carbon nanotube(MWCNT) and metal oxides (titanium oxide, aluminium oxide) records a significant improvement in the rheological properties(yield point, plastic viscosity, and gel strength) of water based drilling fluid(Ismail *et al*.,2014). Since mud formulation and its additive is expensive and drilling safely at the lowest cost is paramount to the drilling engineer, it is therefore necessary to examine the effect of temperature on different nano particle water based mud rheological properties.

Materials and Methods:-

Apparatus and Materials:-

The following apparatus and materials were used for the experiment; Baroid mud balance , Marsh funnel, Speed Rheometer, PH Meter, Heater, Electric Mixer, Stirrer, Thermometer, Conical Flask, Retort Stand, water based mud, Zinc oxide(powder).

Procedures:-

The water based mud used for the experiments has the following component; fresh water, barite, bentonite, Potasium Chloride, Caustic soda, Barax, Carboxymethylcellullose, PolyAnionic Cellulose. It was divided into five samples of equal volume (three (3) liters each) in different plastic containers. Zinc Oxide nano particles were then added to the samples in the following mass fractions, 0 gram, 5 grams, 10 grams, 15 grams, and 20 grams and labeled A to E. Sample A (0gram of Zinc Oxide(ZnO)), Sample B (5 grams of ZnO), Sample C(10grams of ZnO), Sample D(15grams of ZnO), and Sample E (20 grams of ZnO) as shown in Figure 1.0 .The samples were then stirred vigorously and homogenized with an electric mixer for three minutes for stability and proper dispersion of the Zinc Oxide nano particle. They were then subjected to a range of temperature (25^{o}C, 30^{o}C, 35^{o}C, 40^{o}C, 45^{o}C) as presented in Appendix A.

Fig.1:- Mud samples with different mass fractions of Zinc oxide nano particle

The density of the nano water based mud was determined using baroid mud balance after calibration with fresh water for each samples of mud (with different mass fractions of Zinc Oxide nano particles) at different temperature conditions (25°C, 30°C, 35°C, 40°C, 45°C). Plastic viscosity, Yield Point and gel strength were determined from the dial reading (300rpm and 600 rpm) of direct indicating viscometer(variable speed rheometer) using eqn (1) and (2). The electrical conductivity and pH of the mud samples were determined using a conductivity meter and a pH meter.

Plastic Viscosity (PV) = $\boldsymbol{\theta}_{600} - \boldsymbol{\theta}_{300}$ (1)

Yield Point (YP) = $\boldsymbol{\theta}_{300} - PV$ (2)

Results and Discussion:-

The results of the Rheological Properties of the Zinc oxide nano particle water based mud at different temperature conditions is presented in Apendix B.

Effect of Temperature on Mud Density:-

Result of the density test shows that mud density increases as the mass fraction of the nano particles increases at a constant temperature. Increase in temperature of the mud decreases the mud density at any given mass fraction of the nano particles as shown in Fig. 2. Alternatively, the density of the mud increases at a constant mass fraction of the nano partilces as the temperature decreases as represented in Fig. 3

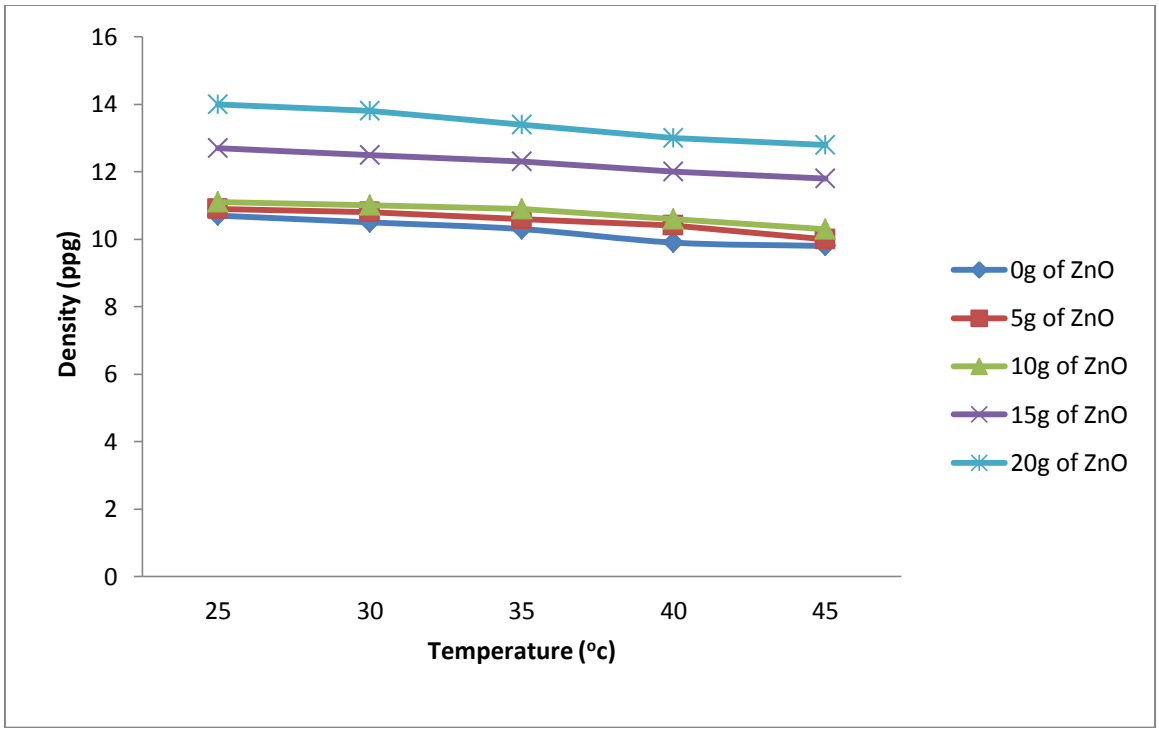

Fig. 2:-Effect of Temperature on Mud Density

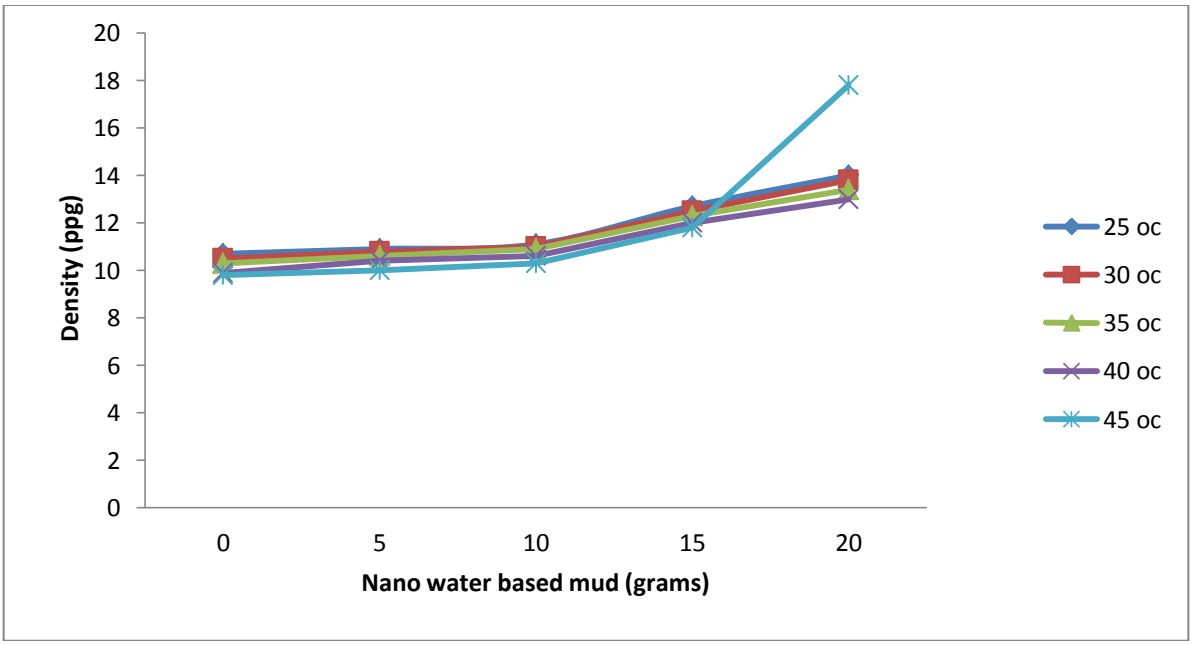

Fig. 3:-Effect of Zinc Oxide nano particle on mud density

Effect of Temperature on Plastic Viscosity:-

Increase in temperature of the nano water based mud decreases the plastic viscosity as the mass fraction of the zinc oxide nano particle increases as shown in Fig.4. At a constant temperature, the plastic viscosity of the nano water based mud increases and decreases slightly with the temperature as the mass fraction of the zinc oxide nano particle increases. Also, at a constant mass fraction of the zinc oxide nano particle, the plastic viscosity decreases as the temperature range increases as shown in Fig. 5.

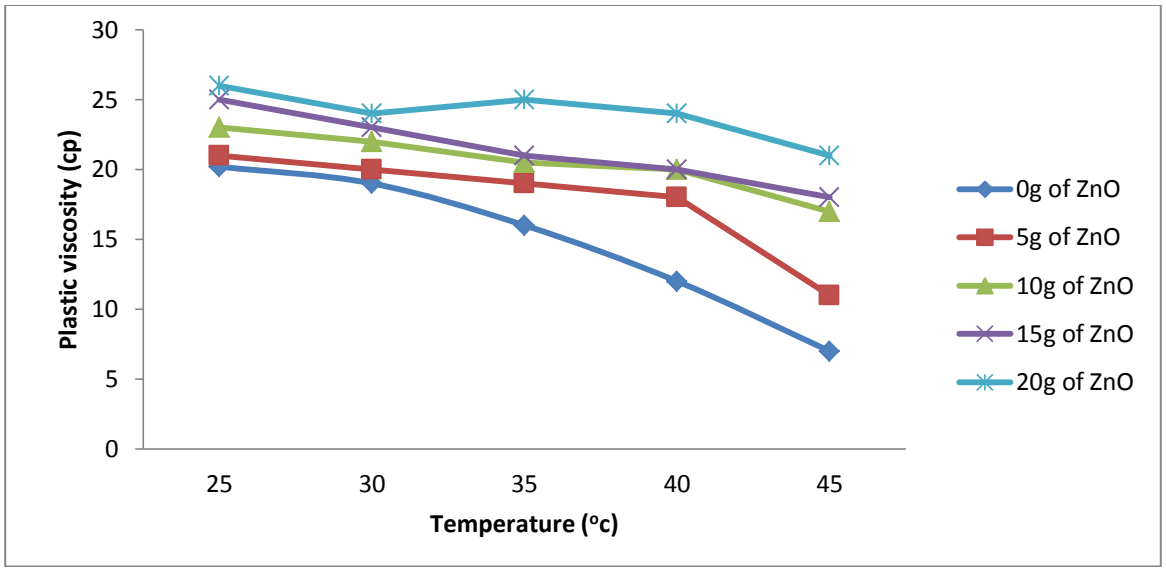

Fig 4:-Effect of Temperature on Plastic Viscosity

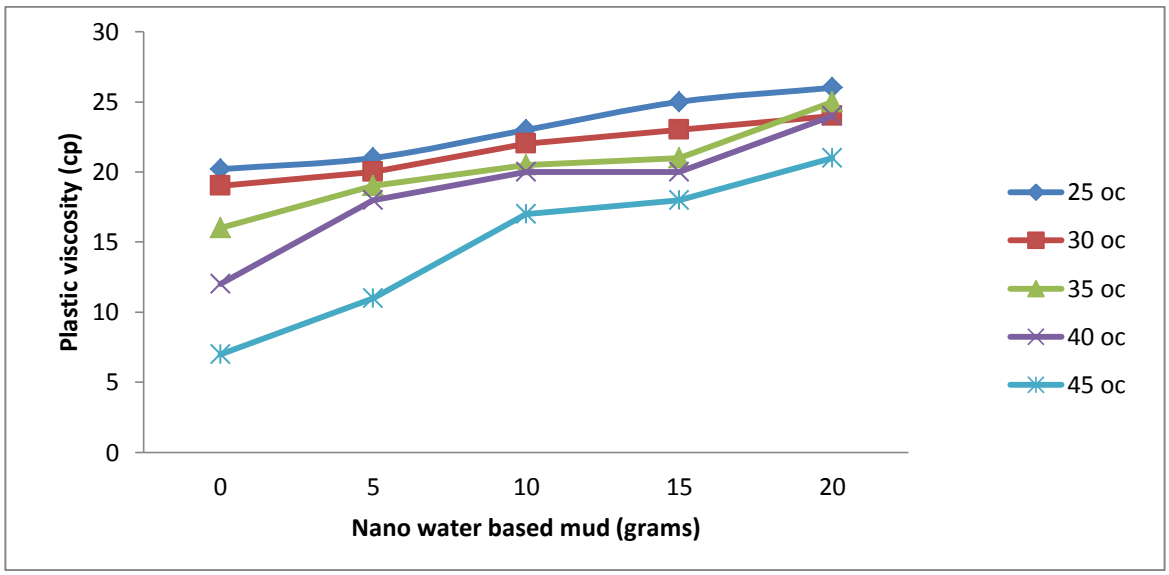

Fig.5:-Effect of Zinc Oxide nano particle on Plastic viscosity

Effect of Temperature on Yield Point:-

Yield point decreases with increase in temperature up to 40°C for 0gram, 5 grams and 10 grams of zinc oxide nano particle additive and later increases above 40°C while it decreases below 40°C for 15 and 20 grams of zinc oxide nano particle additives as shown in Fig 6. At a given mass fraction of the nano particles, increase in temperature was not uniform with the yield point as presented in Fig. 7

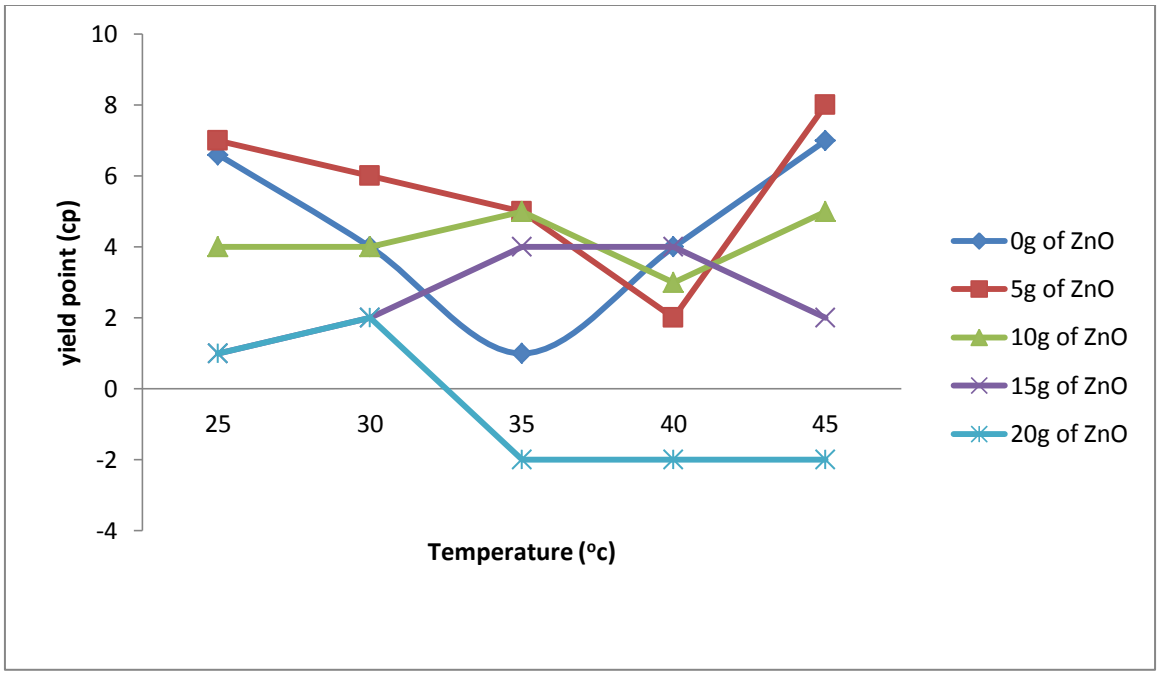

Fig. 6:- Effect of Temperature on Yield Point

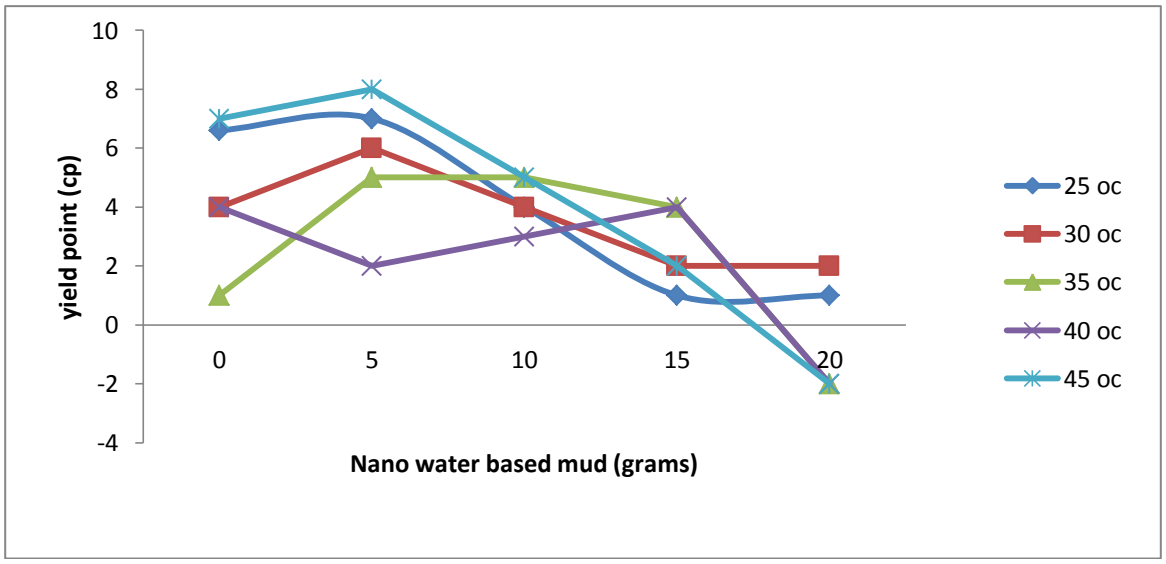

Fig. 7:- Effect of Zinc Oxide nano particle on Yield point

Effect of Temperature on Gel strength:-

The result shows that increase in temperature decreases the gel strength and at a given temperature, increase in the mass fraction of the zinc oxide nano particle increases the gel strength as shown in Fig. 8. An indication that it will take more time to initiate flow if circulation is stop when using mud with such additive. At a certain mass fraction of the nano water based mud, increase in temperature increases the gel strength as presented in Fig. 9

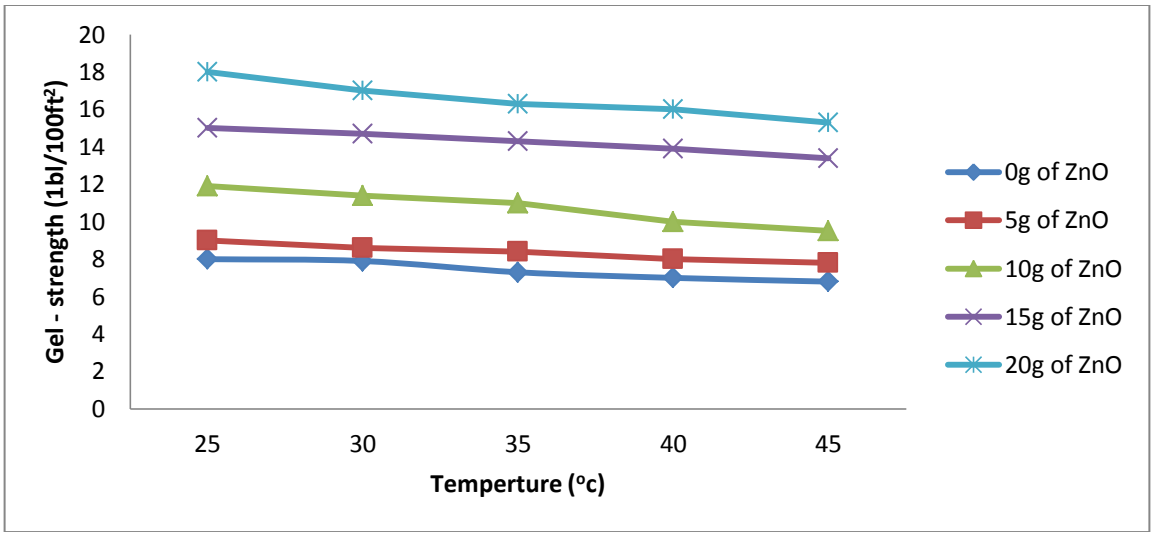

Fig. 8:-Effect of Temperature on Gel Strength

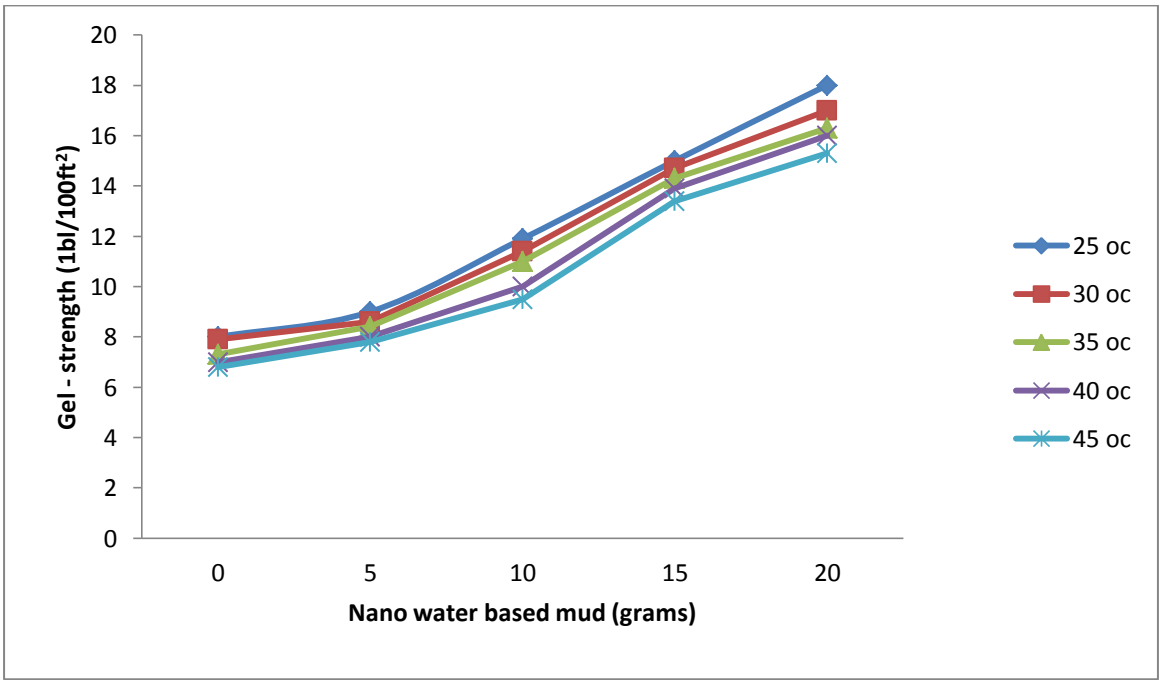

Fig. 9:-Effect of Zinc Oxide nano particle on Gel- strength

Effect of Temperature on Mud pH:-

The effect of temperature on mud pH is not significant as increase in temperature shows a slight decrease in the nano water based mud pH. Also, increase in the grams of the Zinc oxide nano particle at a given temperature increases the mud pH as shown in Fig.10 and Fig.11.

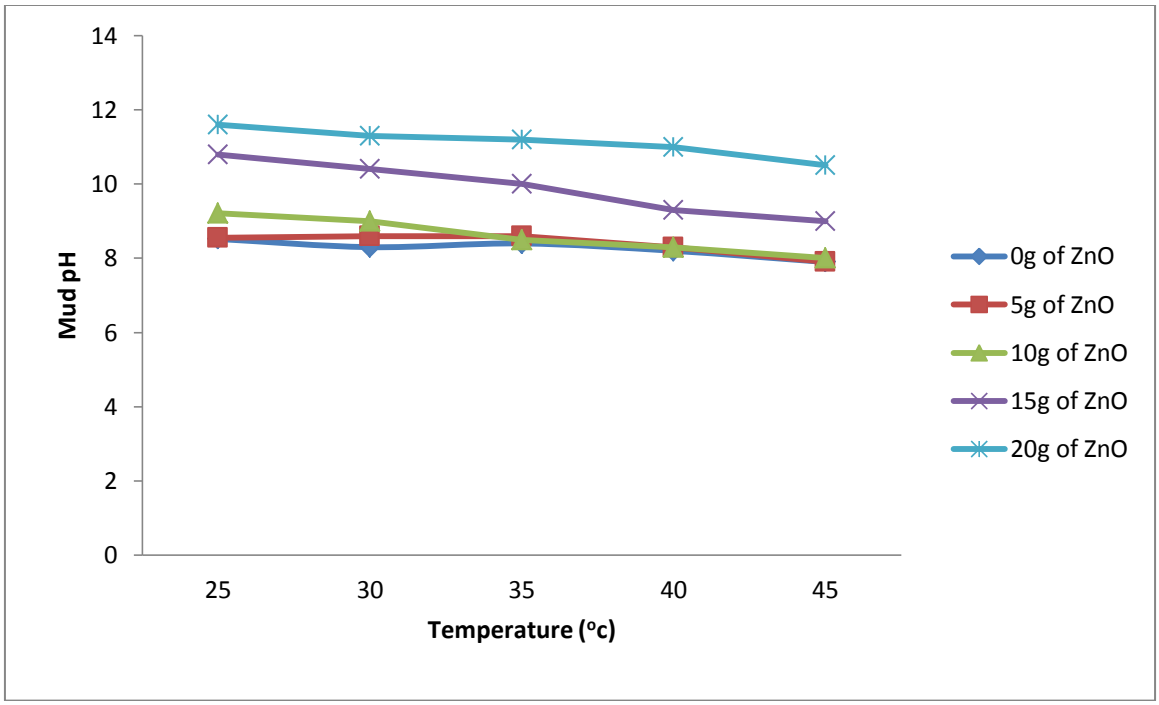

Fig. 10:-Effect of Temperature on mud pH

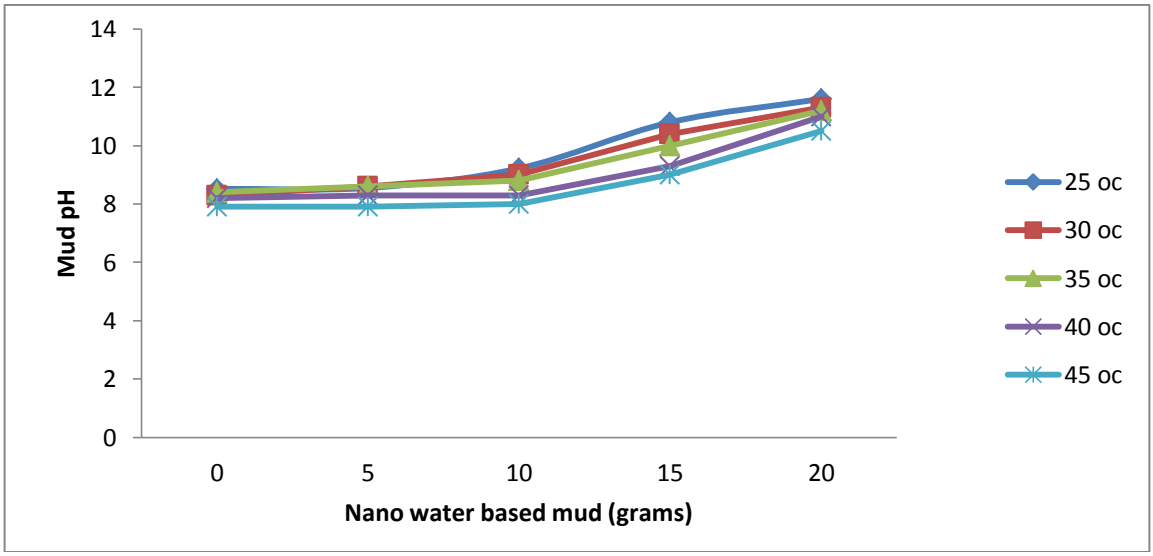

Fig. 10:-Effect of Zinc Oxide nano particle on mud pH

Effect of Temperature on Electrical Conductivity:-

Increase in temperature of the nano water based mud increases the electrical conductivity of the mud. At a given mass fraction of the Zinc oxide nano particle, increase in temperature increases the conductivity of the mud. Similarly, at a given temperature increase in the grams of the Zinc oxide powder increases the mud conductivity as presented in Fig. 11 and Fig. 12

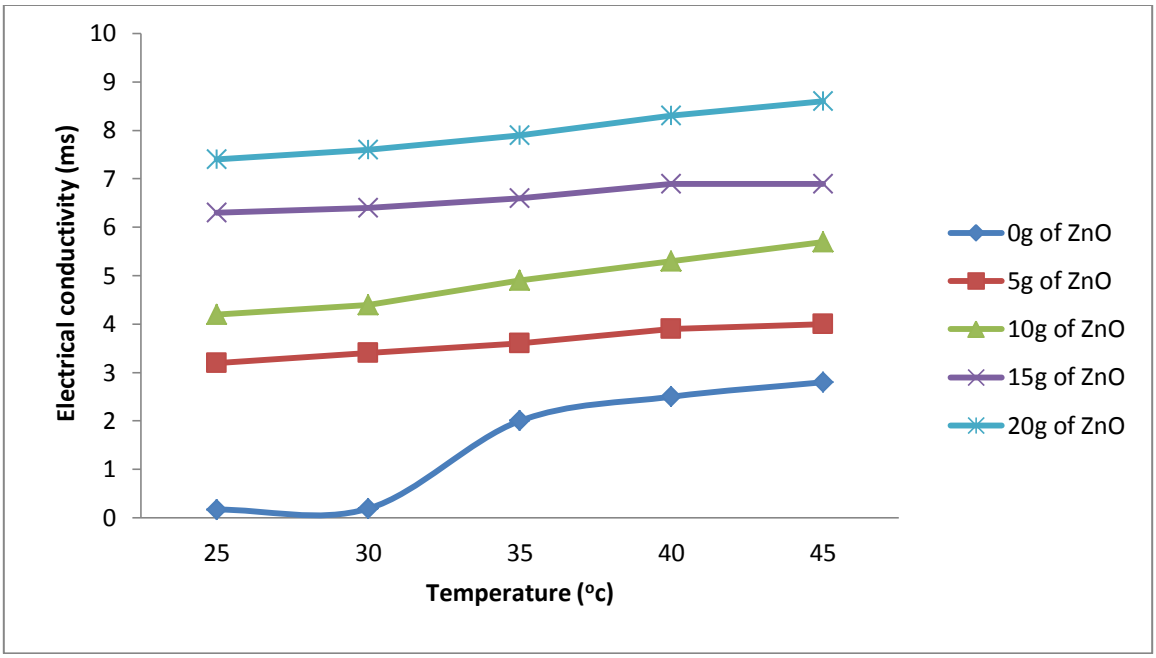

Fig. 11:-Effect of Temperature on mud conductivity

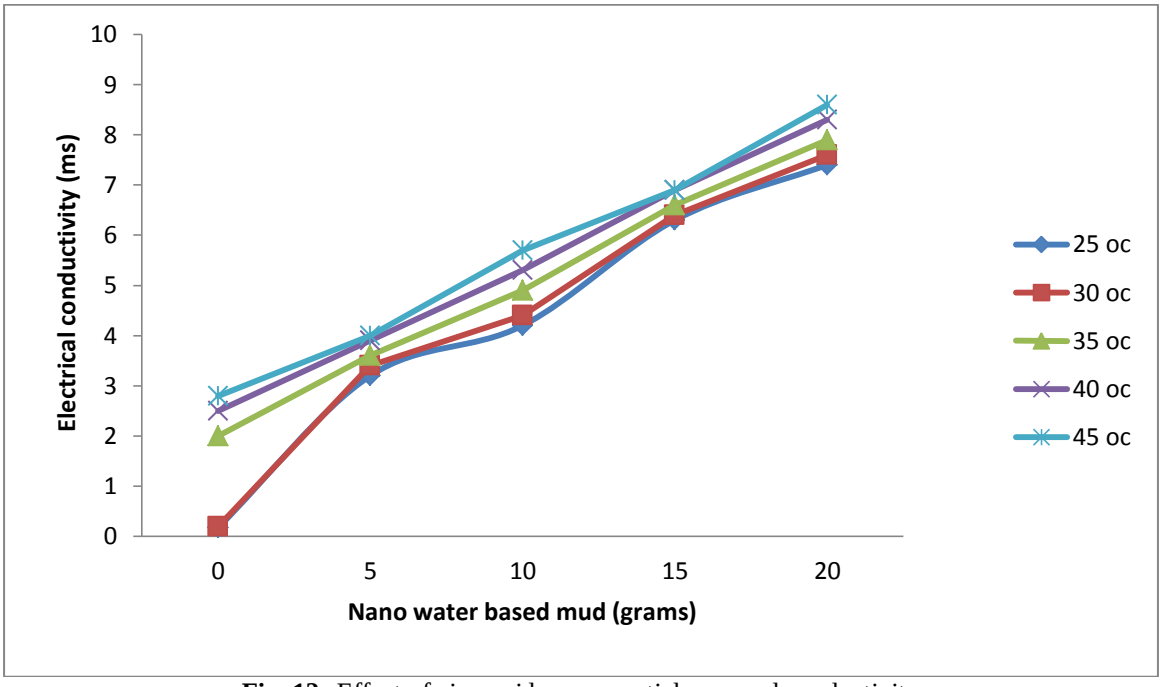

Fig. 12:-Effect of zinc oxide nano particle on mud conductivity

Conclusion:-

This study shows that addition of zinc oxide nano particle improved the rheological properties of the water based mud even when the temperature increases, independent of the pressure. It reveals the significant effect of temperature on mud. The following conclusions were drawn from the study;

1. Plastic viscosity decreases with increase in the temperature of the mud for any mass fraction of the Zinc oxide particle and also increase with increase in grams of zinc oxide nano particle
2. Yield point decrease with increase in the temperature to certain point and later increases with temperature increase and also with increase in grams of zinc oxide nano particle
3. Gel – strength decreases with increase in the temperature and also increases with increase in grams of zinc oxide nano particle.
4. Temperature has little effect on the mud pH, as the temperature increases the mud pH decrease by 2.6% but as the grams of nano particle increases, the mud pH increase.
5. Density decreases with increase in the temperature and also increase with increase in grams of the nano particle.
6. Electrical conductivity increases with increase in the temperature and also increase with increase in grams of zinc oxide nanoparticle .

Therefore, the effect of temperature on the rheological properties of water based mud can be reduced by addition of Nano particles which the study has shown.

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Appendix A:-Samples at different mass fractions and Temperature

Samples	**Zinc Oxide Particles(grams)**	**Temperature(^{o}C)**
A	0	25
		30
		35
		40
		45
B	5	25
		30
		35
		40
		45
C	10	25
		30
		35
		40
		45
D	15	25
		30
		35
		40
		45
E	20	25
		30
		35
		40
		45

Appendix B:- Rheological Properties of Zinc oxide nano particle water based mud at different temperature conditions.

Zinc Oxide Nano particle(grams)	**Temp. (^{o}c)**	**Density (ppg)**	**E.C (ms)**	**pH**	**Gel-strength (1b/100ft^{2})**	**Plastic viscosity (cp)**	**Yield point (1b/100ft^{2})**	**Apparent Viscosity (cp)**
0	25	10.7	0.17	8.52	8	20.1	6.6	23.5
	30	10.5	0.19	8.4	7.9	19	4	21
	35	10.3	2	8.3	7.3	16	1	16.5
	40	9.9	2.5	8.2	7	12	4	14
	45	9.8	2.8	7.9	6.8	7	7	6
5	25	10.9	3.2	8.55	9	21	7	24.5
	30	10.8	3.4	8.6	8.6	20	6	23
	35	10.6	3.6	8.6	8.4	19	5	21.5
	40	10.4	3.9	8.3	8	18	2	19
	45	10	4	7.9	7.8	11	8	15
10	25	11.1	4.2	9.22	11.9	23	4	25
	30	11	4.4	9	11.4	22	4	24
	35	10.9	4.9	8.8	11	20.5	5	23
	40	10.6	5.3	8.3	10	20	3	21.5
	45	10.3	5.7	8	9.5	17	5	19.5
15	25	12.7	6.3	10.8	15	25	1	26.5
	30	12.5	6.4	10.4	14.7	23	2	24
	35	12.3	6.6	10	14.3	21	4	23
	40	12	6.9	9.3	13.9	20	4	22
	45	11.8	6.9	9	13.4	18	2	19
20	25	14	7.4	11.6	18	26	1	26.5

	30	13.8	7.6	11.3	17	24	2	25
	35	13.4	7.9	11.2	16.3	25	-2	24.5
	40	13	8.3	11	16	24	-2	23
	45	12.8	8.6	11.5	15.3	21	-2	20