Improving the Performance of Drilling Fluid Using MgO Nano Particles

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Abstract

One of the most important factors that cause formation damage is drilling fluid invasion caused by mud filtration. Hence, it is essential to minimize the mud filtration in order to reduce its damage to the formation using drilling fluid additives that control and minimize the filtration rate. Magnesium Oxide (MgO) nanoparticles at different masses (0.01, 0.05, 0.07, 0.1, and 0.2) gm with water base mud have been investigated in this research to measure its effect on the filtration rate. Four types of drilling fluid are used in this research; API water base mud WBM, Saturated salt water mud, DURA THERM mud and polymer mud. Filtration rate was tested under high temperature high pressure (HTHP) conditions; at (75 and 100) C and (500 psi), and at room temperature and pressure at (100 psi). The viscosity of all drilling fluid types is measured using a rotational viscometer at room temperature and atmospheric pressure. In general, the results showed that adding MgO nano particle helped in reducing the filtration rate of drilling fluid, the best results were gained in DURA THERM mud and Saturated Salt Water Mud at MgO concentrationof 0.07gm and 0.2gm, respectively; where the filtrate reduction 60% at 100 C. Also, MgO addition improves rheological properties and drilling fluid stability

Key words: Nanoparticales, drilling fluid, fluid loss control, HTHP conditions

تحسين اداء سائل الحفر باستخدام دقائق اوكسيد المغنيسيوم النانوية

الخلاصة

ان من اهم العوامل المسببه ضرر للطبقات المكمنية هو اختراق سائل الحفر لها وذلك ناجم عن ترشيح الطين. لذلك كان من الضروري التقليل من كمية الراشح للحد من الضرر للطبقات وذلك باستخدام اضافات لسائل الحفر للسيطره على معدل ترشيحه. استخدم دقائق نانوية من مادة اوكسيد المغنيسيوم (MgO NP) وبأوزان (0.01 - 0.05 - 0.07 – 0.1 – 0.2) غرام مع الطين ذو الاساس المائي لغرض دراسة تاثيره على معدل الترشيح. واستخدمت في الدراسة الحالية اربع انواع من سوائل الحفر هي:

- API water base mud WBM
- Saturated salt water mud
- DURA THERM mud
- Polymer mud

حيث تم قياس معدل الترشيح تحت درجات الحرارة العالية 75)°C– 100) وضغط (500 psi) باستخدام (HTHP filter press)، وبدرجة حرارة الغرفة وضغط (100 psi) باستخدام (Filter press) بينما تم قياس الخواص الريولوجية لسائل الحفر باستخدام (Rotationalviscometer). وقد اظهرت نتائج الدراسة ان اضافة (MgO NP) لسائل الحفر ساعد في اختزال معدل الترشيح، ولاسيما عند اضافته (0.07) و (0.2) غم الى (DURA THERM mud) و (Saturated salt water mud) على التوالي بمعدل 60% وبدرجة حرارة 100 C، فضلا عن تحسين الخواص الريولوجية لسائل الحفر وزيادة استقراريته.

1. Introduction

Mud and filtration loss within the formation during drilling and completion operations, have direct effect on bore hole stability, the formation damage.Filtrate loss occurs in the high permeability formation where the drilling fluid filters through the wellbore and invades the formation. As a result of the mud filtration, the solid residue of the drilling fluid will form a layer of mud deposition which called cake on borehole wall. In high permeability formation, high pressure difference between the wellbore and the formation, and thick mud cake caused by high filtration rate can cause the drill pipe sticking.

Drilling operation considered as HTHP if bore hole static temperature and the pressure exceeds (350^{o}F, 25.000 psi). However, as the depth of the drilling wells keeps increasing, more severe drilling conditions can be expected, which may exceed 600^{o}F temperature and 40,000 psi pressure [1]. Most organic filtration control additives degradation begins when temperatures exceed 100C, so it is very important to find other alternatives that can be used in HTHP conditions. Formation damage is related more to the type of filtrate than to theamount of filtrate lost to a formation. If the filtrate reacts with the formation solids or formation fluids, that cause a reduction in permeability [2].

The nanoparticle additives are explored as an alternative to the polymer based additives. Inorganic characteristics of the nanoparticles additives are expected to stabilize the drilling fluids even at high temperature and high pressure conditions. [1] Used three types of nanoparticales (Nickle, copper and Cobalt) to replace polymer additives in drilling fluids. They found that these additives lose their effectiveness at high temperatures and when small amount of these materials had been used, the mud exhibited not only excellent shear-thinning behavior but also stable rheological properties at high temperature.Jimet al.used two types of mud (water base mud and salt mud) with two types of nano additives (Graphene oxide and carbon nano tube), they gained a good result on rheological properties but the fluid loss control still an issue with these fluids [3]. Abdul Razak et al.used Multi Walled Carbon Nano Tubes (MWCNT) to improve the rheological properties of two mud types (water base mud and ester base mud), they showed good results on rheological and filtration properties with increasing MWCVT particle mass in ester base mud, they also concluded that increasing temperature affected on rheological, filteration and stability properties of both mud types [4].

Norazwan et al tended to improve the performance of SBM with silicon dioxide nano powder with two steps, first by measuring rheological and filtration properties for base fluid at different concentrations of nano silica and temperatures (275 &350)^{o}C,second,by leavingsamples in hot rolling for 16 hr. They found that nano silica proven to be a good fluid loss control with stablerheology [5]. Matthew M. et al. studied the effect of Fe_2O_3 nano particles, as fluid loss control additives, at different concentrations with two other additives; Iron oxide Clay Hybrid (ICH) and AluminoSilica Clay Hybrid (ASCH). The result showed a good reduction in filtration volume up to 37% and 47% at normal condition and at HTHP respectively [6]. Zisis. et al. tested two nano additives (Fe_2O_3 and SiO_2) in water base mud, they found that the reduction of filtration efficiency increased with increasing Fe_2O_3 concentration while silica nano powder was unstable under different temperatures [7].

The objective of this research is to investigate the influence of MgO nano particle at different concentrations on filtrate volume at HTHP conditions. Four types of drilling fluid have been used WBM, Dura THERM mud, saturated salt water mud and polymer mud.

2. Experimental work

2.1. Materials

MgO NP was equipped from Sky Spring Nano materials; it has size 20 nm with 99% purity. Bentonite clay and other mud materials were supplied from Iraqi drilling company. The copolymers (TS30LC AND TS705) were equipped from SNF FLOERGER.

2.2. Experiments

This study will focus on specific conditions, where at the large depths temperature degree and pressureincreases, certainly when drilling fluid passage through these conditions the mud properties would effect, especially filtration and rheological propertiesTherefore, this research include four types of water base drilling fluids (API WBM, DURA THERM mud, Saturated Salt Water mud and polymer mud), studying their behavior during three temperature degrees (room temperature, 75 °C and 100 °C) and then add MgO NP at different weights (0.01, 0.05, 0.07, 0.1 and 0.2)gm to study its effect on the improvement mud properties (Rheological and filtration properties).

API WBM (22.5 gm) Bentonite and (350 ml) water. *Polymer mud* (11.5 gm) Bentonite, (350 ml) water, (0.5 gm) KOH, (2 gm) KCL, (2 gm) PAC polymer and (0.07 gm) TS30LC copolymer, *DURA THERM mud*and *Saturated Salt Water mud* components are shown in Tables (1, 2).

Table (1) DURA THERM mud contents (MI manual)

Materials	Weights (gm)	Primary function
Bentonite	1 - 10	Viscosity/Gel Strength / Filter Cake and Fluid Loss Control
Barite	0 – 600	Increase Density
NaOH	0.5 – 1.5	Increase pH
$Ca(OH)_2$	0 - 2	Treat out CO_3 and pH
Lignite	15 - 20	Thinner and Fluid Loss Control
XG polymer	0.5 – 1.5	Viscosity / Gel Strength
Thermix	0 - 12	HTHP Fluid Loss Control
RESINEX	0 - 6	HTHP Fluid Loss Control

Table (2) Saturated Salt Water mud contents (MI manual)

Materials	Weight(gm)	Primary function
Bentonite	10 - 30	Viscosity/Gel Strength / Filter Cake and Fluid Loss Control
Barite	0 - 550	Increase Density
NaOH	0.2 – 2.5	Increase pH
NaCl	110 - 125	Increase Chloride
NaCO3	0.2 - 1	Control Calcium
ChromLignosolfonate	5 - 15	Thinner and Fluid Loss Control
PAC polymer	0.5 - 2	Stability and Fluid Loss Control
XG polymer	0.25 - 1	Low Shear Rate Viscosity

Bentonite used as a base for the preparation of the drilling fluid. In this study, a specific amount of bentonite, related to each type mud, was added into 350 ml of tap water. The drilling fluid was hydrated overnight, after nearly 16 hstirred by Hamilton beach mixer Figure 1(a) for 2 minutes, starts with adding mud components with continuous blending, the specific amount of nano add into the mud mixture and satire for 10 min with Hamilton beach mixer and 10 min with ultra sonic device Figure1 (b). Filtration properties at (100 psi pressure and room temperature) were obtained by using OFITE Filter Press Figure1 (d) and at [(75, 100) °Cand (500 psi)] were obtained by using OFITE HTHP filter press Figure1 (e). The rheological properties were analyzed withOFITE model 900 Viscometer Figure1(c). Mud properties measured at drilling fluid laboratory at (University of Technology/ Petroleum Technology department).

Fig. (1) Test devices (a) Hamilton Beach Mixer, (b) Ultra Sonic, (c) OFITE model 900 Viscometer, (d) OFITE Filter Press, (e) OFITE HTHP filter press

3. Results and Discussion

3-1 Filtration Properties

3-1-1 Filtrate volume

Figure (2) shows the effect of different temperature degrees with different MgO NP weights on API WBM filtration rate. In general, it can be noticed that the filter loss increases as temperature increases, this mean that this material is losing its activity at highertemperature. On the other hand, at 35°C and 75°C filtrate volume is nearly stable with MgO addition while at 100°C the filtrate volume increased with MgO addition. This result differs from that obtained by the work of [8] who concluded that MgO addition improves filtration properties at room temperature, this due to the difference in bentonite type that has been used.

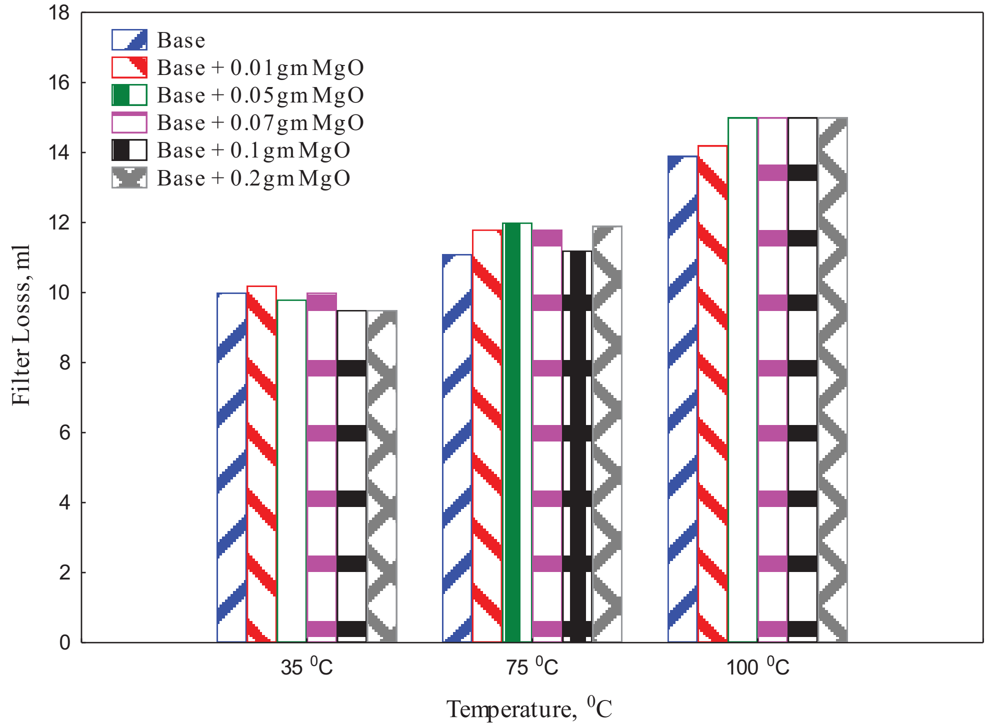

Fig. (2) Filter losses of API WBM with Mgo NP

Figure (3) shows the effect of different temperature degrees with different MgO weights on DURA THERM mud filtration rate, at 35°C the filtrate volume is slightly increased with MgO NP weight until reached 0.2gm MgO the filtration rate returns to the blank form. At higher temperature (75 and 100) °C, the filter losses have regular results with increasing nano particle weight. At 75°C the filtrate volume decreased about 30% after adding 0.01gm MgO NP but it increased with weight, while at 100°C the filtrate volume decreased with MgO NP concentration increasing and the best filtrate reduction ratio was 60% at 0.07gm MgO NP addition.

The effect of different MgO NP mass on Saturated Salt Water mud filtration rate at different temperatures is shown in Figure (4). The behavior of this mud type is un clear at small concentrations but after addition 0.07gm of MgO NP, the filter losses decreased and the filtrate reduction ratio was 42.8%, 46.4%, 60% at 35 °C,75 °C, and 100 °C respectively at 0.2 gm MgO NP addition.

Figure (5) shows the effect of different temperature degrees with different MgO NP concentrations on Polymer mud filtration rate. The results show a uniform reduction in filtrate volume with increasing nano particle weight at 35°C till it reaches 21.6% at 0.2gm MgO addition. The filtrate reduction decreased to 16% at 75°C with the addition of 0.1gm of MgO NP. At 100 °C the filtrate volume decreased with MgO NP concentrations increasing and the maximum reduction in the filtrate was about 22.5% with adding 0.05gm of MgO NP.

Comparing this result with WBM results, it can be noticed that MgO addition affected on filter losses in DURA THERM, Saturated salt mud, and Polymer mud, especially at higher temperature, this can be due to the presence of another oxide like sodium hydroxide and potassium hydroxide as well as the presence of Cl ions, these ions can be replaced with MgO causing a deflocculating of the solution yielding a low permeability filter cake and reducing filter loss.

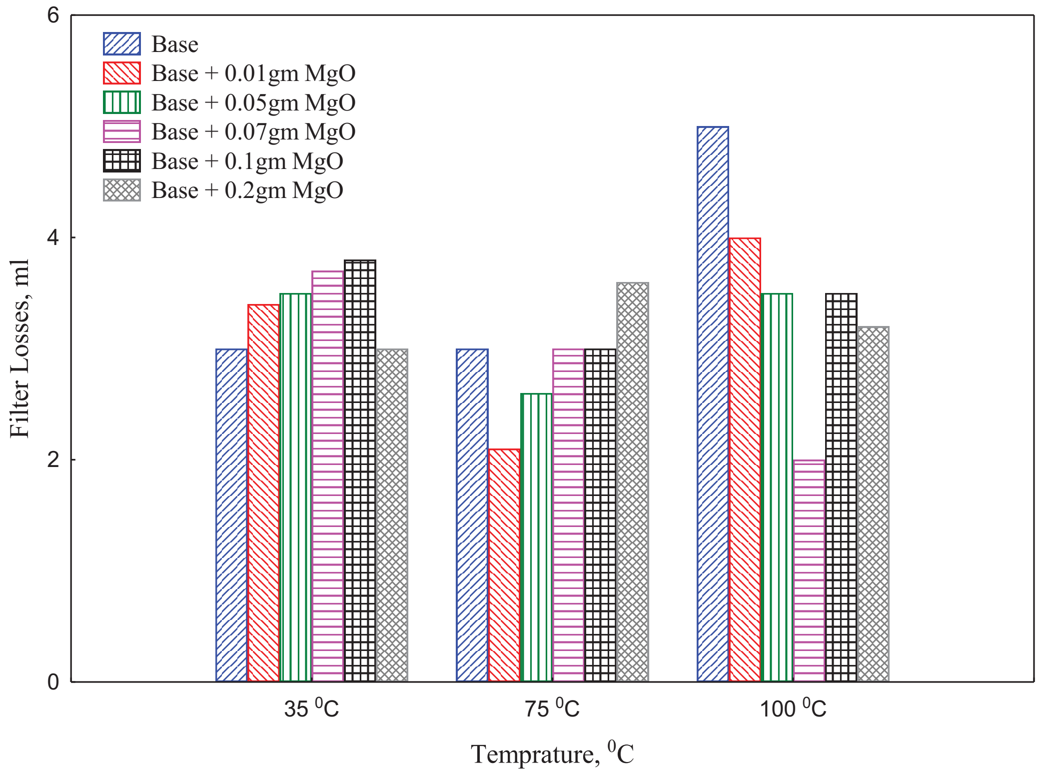

Fig. (3) Filter losses of DURA THERM mud with Mgo NP

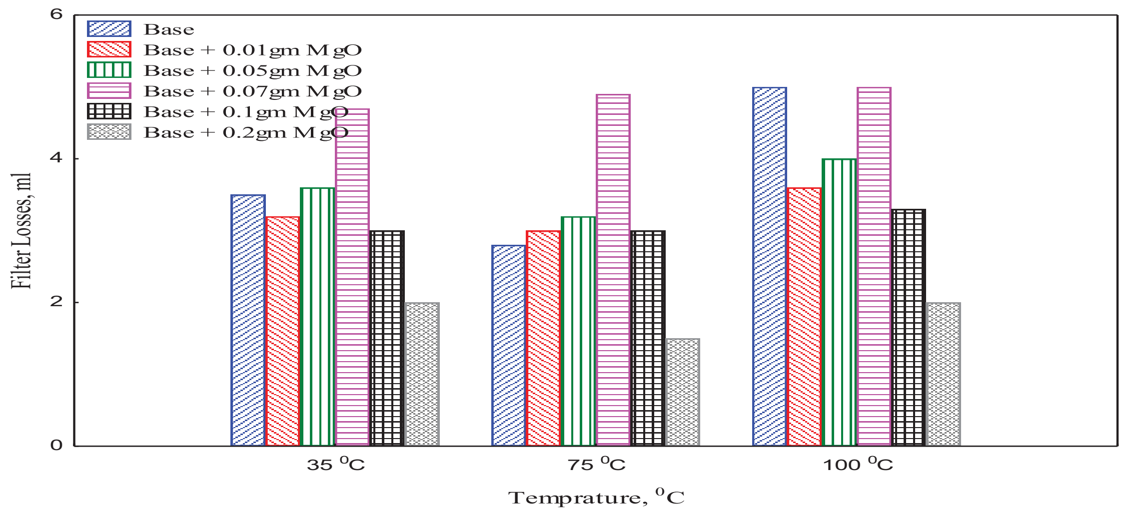

Fig. (4) Filter losses of Saturated Salt Water mud with Mgo NP

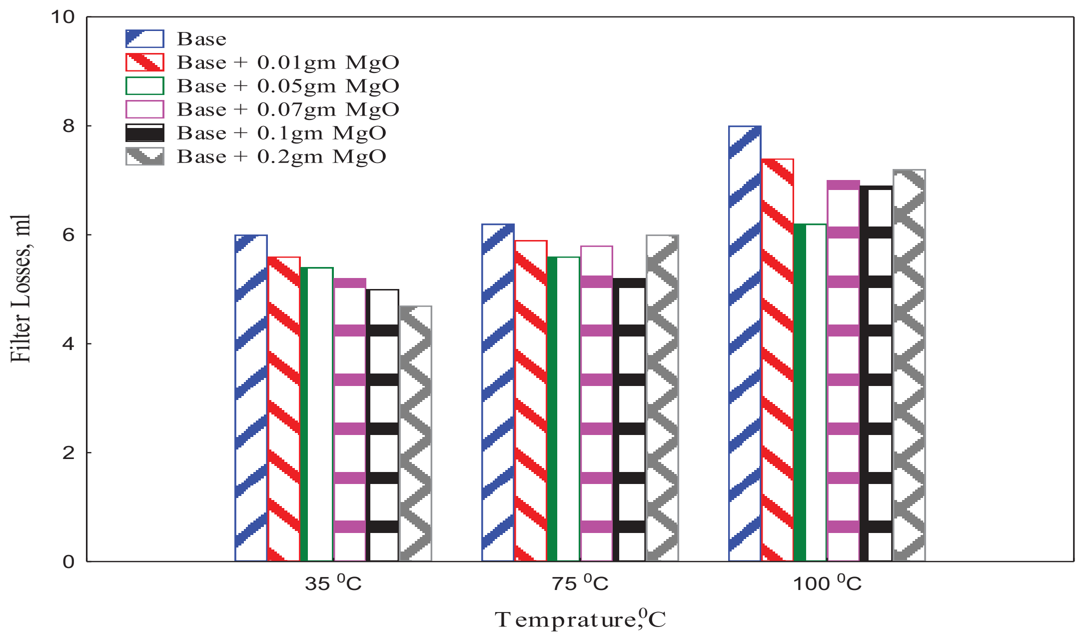

Figure (5) The filter losses of Polymer base mud

3-1-2 Mud Cake Thickness

The effect of MgO NP addition on Mud cake thickness of API WBM, DURA THERM mud, Saturated Salt Water mud and Polymer mud at different temperature degrees is shown in Figures (6-9) respectively.

In API WBM and at 35 °C and 75°C thickness of mud cake shows unstable behavior with MgO NP weights, while at 100°C mud thickness decreased about 13%. Figures (6 and 7) indicates that at 35 °Cthe mud thickness, of DURA THERM mud, decreased about 44% with the addition of 0.1gm MgO, while at 75 °C the mud thickness behaviors regular with MgO NP addition and the minimum thickness was gained at 0.05gm MgO. At 100 °C the mud thickness decrease with MgO NP addition, in spite of decreasing in the loss, this may attribute to that MgO NP block the small channels in filter cake rather than building a new layer on the cake. The reduction ratio about 55.5% by 0.07gm of MgO NP.The same trend of behavior can be seen in Figures (8 and 9).

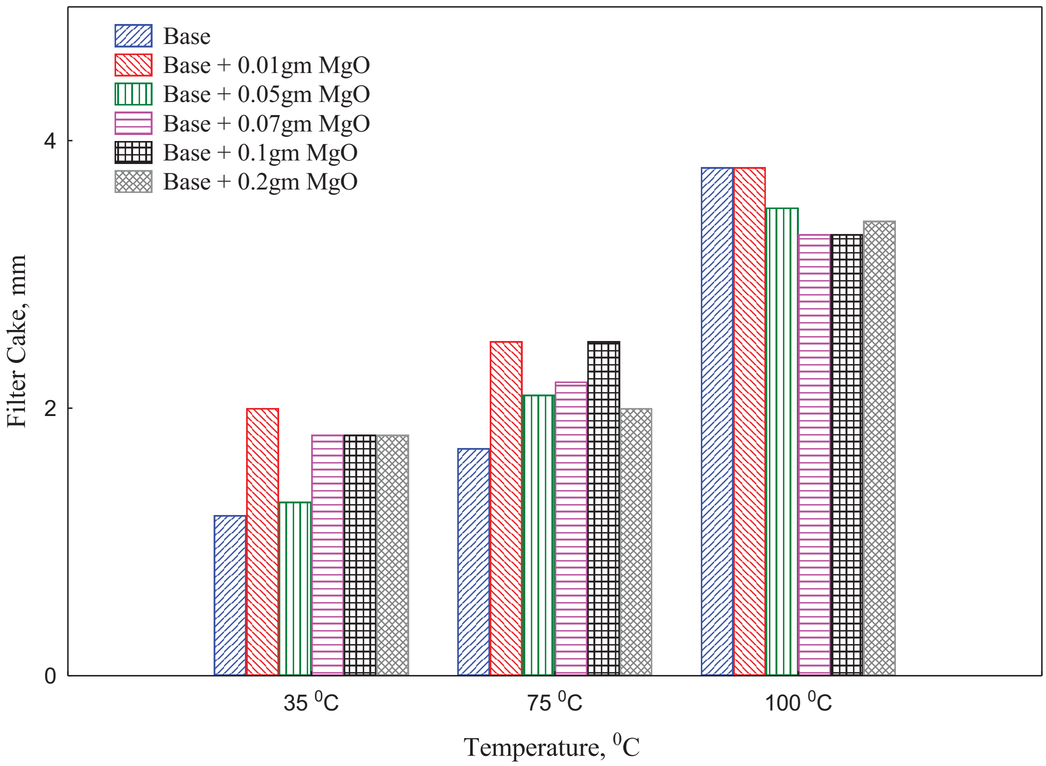

Fig. (6) Mud cake thickness of water base mud with MgO NP

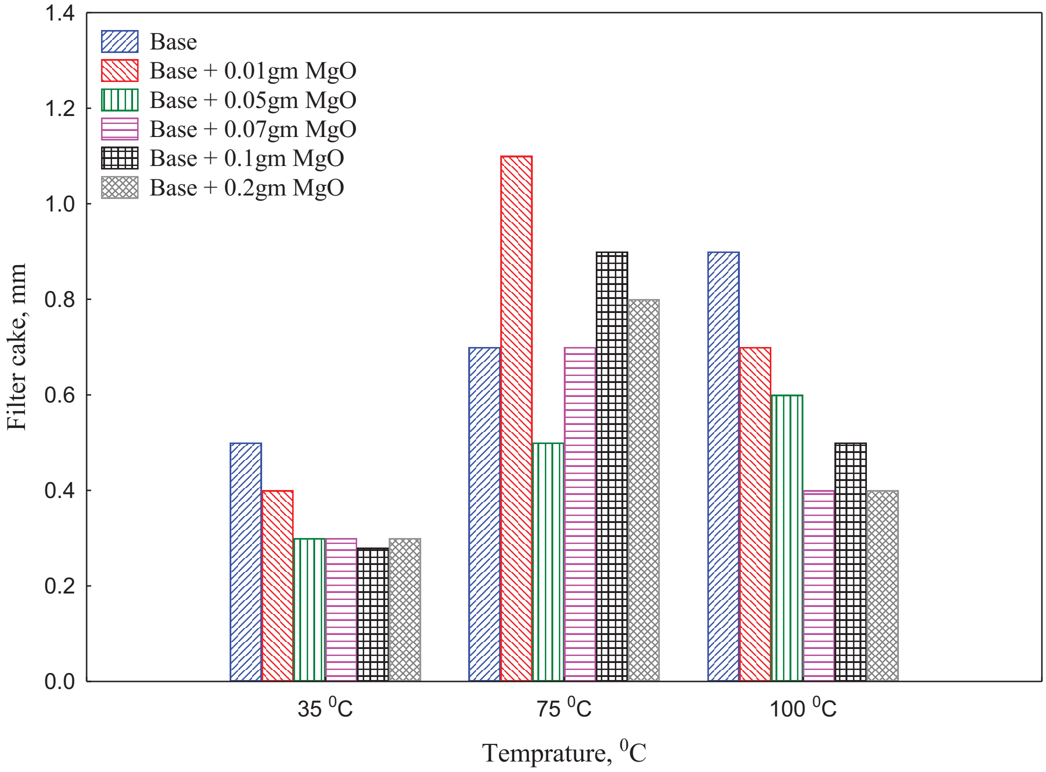

Fig. (7) Mud cake thickness of DURA THERM mud with MgO NP

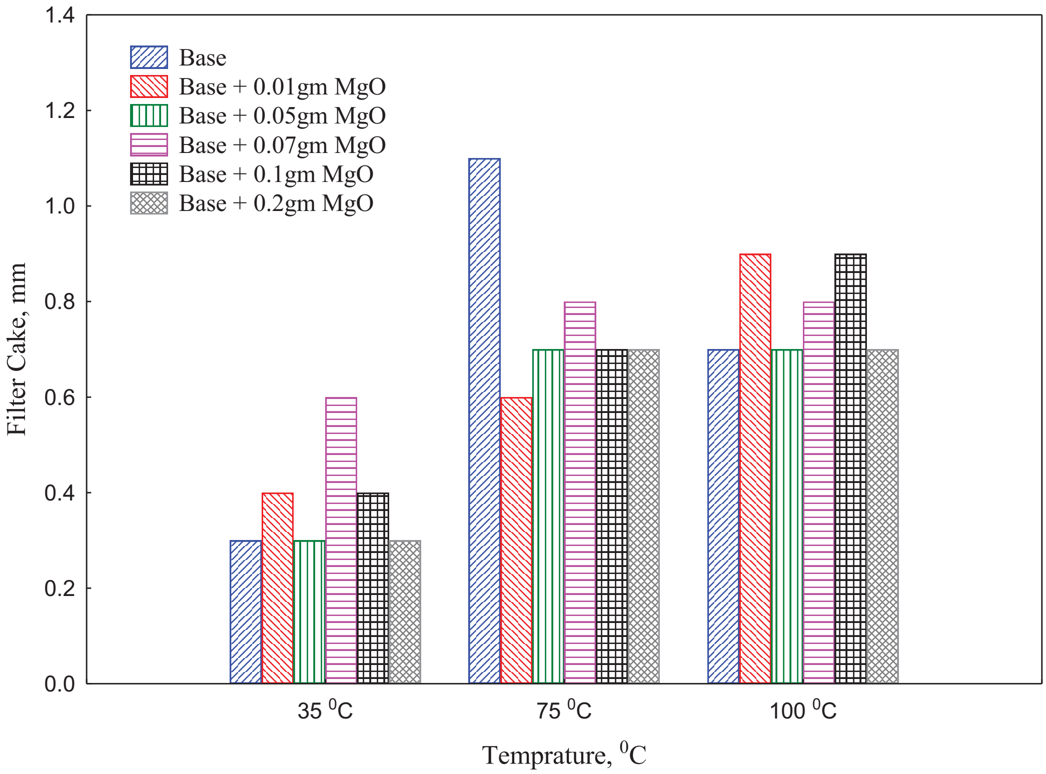

Fig. (8) Mud cake thicknessof Saturated Salt Water mud with MgO NP

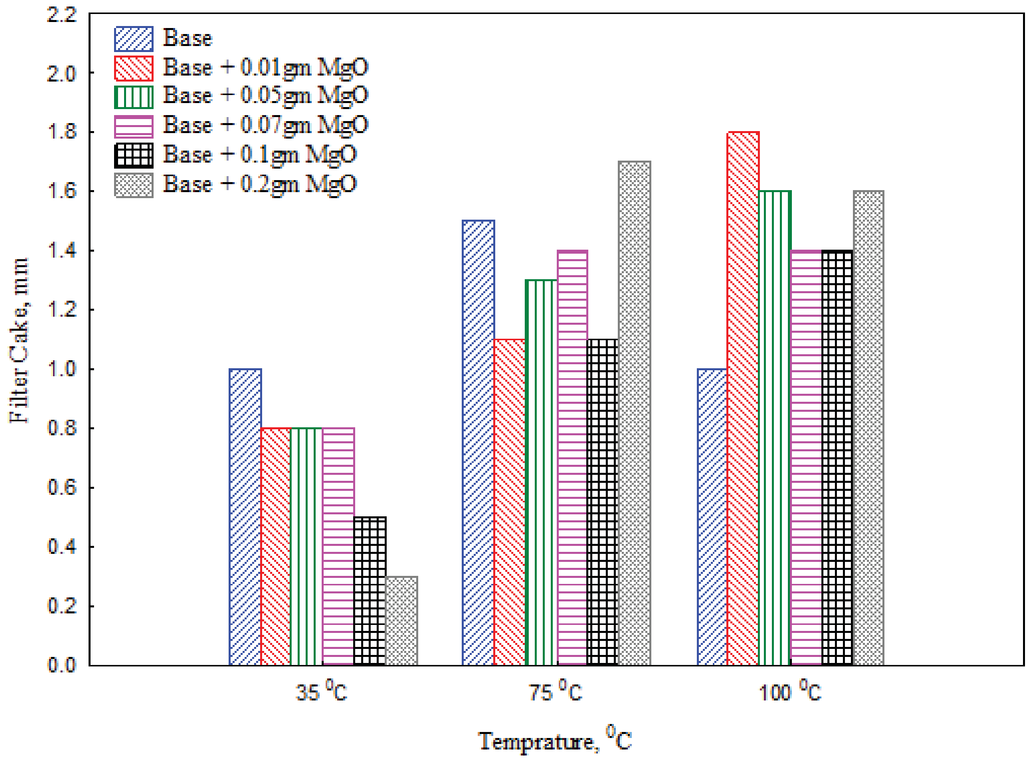

Fig. (9) Mud cake thicknessof Polymer mud with MgO NP

3-2 Rheological Properties

The effect of MgO NP on Rheological properties of four drilling fluid types is shown in Figures (10 and 11). Those figures show that adding MgO NP to water base mud led to increase in yield point value till it reaches (65.5 lbf/100 ft2) at 0.2 gm of MgO NP, while the plastic viscosity shows unstable behavior and it reaches 3.0 cP when 0.2 gm of MgO NP is added. In general, the high values of viscosity can be due to the higher attractive forces caused by adding MgO NP, where this causes moving the particles closer together so the attraction between particle is increased [9].

The effect of adding 0.01 gm of MgO NP to DURA THERM mud is very clear, where the yield point and plastic viscosity increases to 53.6 lbf/100 ft2 and 26.4 cP, respectively. Increasing the addition of MgO NP more than that value causes a decrease in yield point and plastic viscosity till it reach to 24.9 lbf/100 ft2 and 10.2 cP, respectively, at 0.2 gm MgO NP addition. This is due to the presence of NaOH in DURA THERM mud which is reduced the magnesium by precipitation magnesium as $Mg(OH)_2$.

Adding 0.1 gm of MgO NP to Saturated Salt Water mud causes an increase in plastic viscosity to 30.8 cP while there is no significant changes in yield point values has been observed. More additions of MgO NP show unstable changes in yield point and plastic viscosity.

The effect of MgO NP in polymer mud at low concentrations is clear, where adding 0.05 gm of MgO NP causes an increase in yield point to 103.6 lbf/100 ft2 and 10.1 cp plastic viscosity. As the concentration of MgO NP increases a decrease in yield point and plastic viscosity is observed.

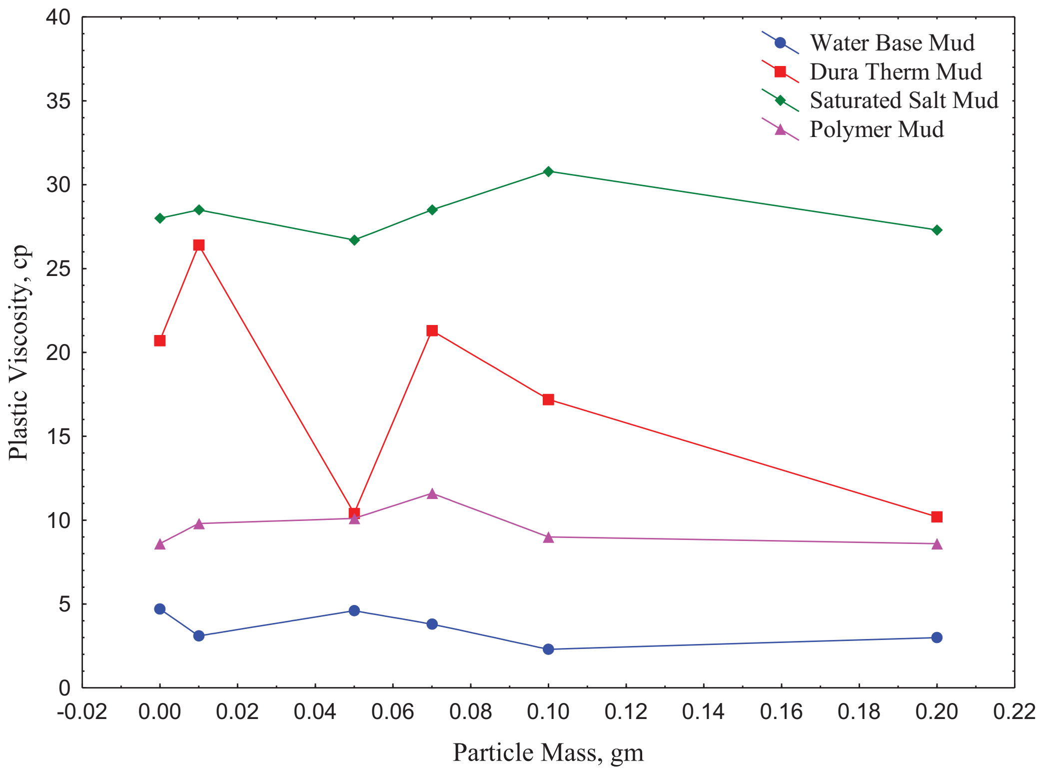

Fig. (10) The effect of MgO nanoparticle mass on plastic viscosity of different drilling fluid at 35^{0}C and normal pressure

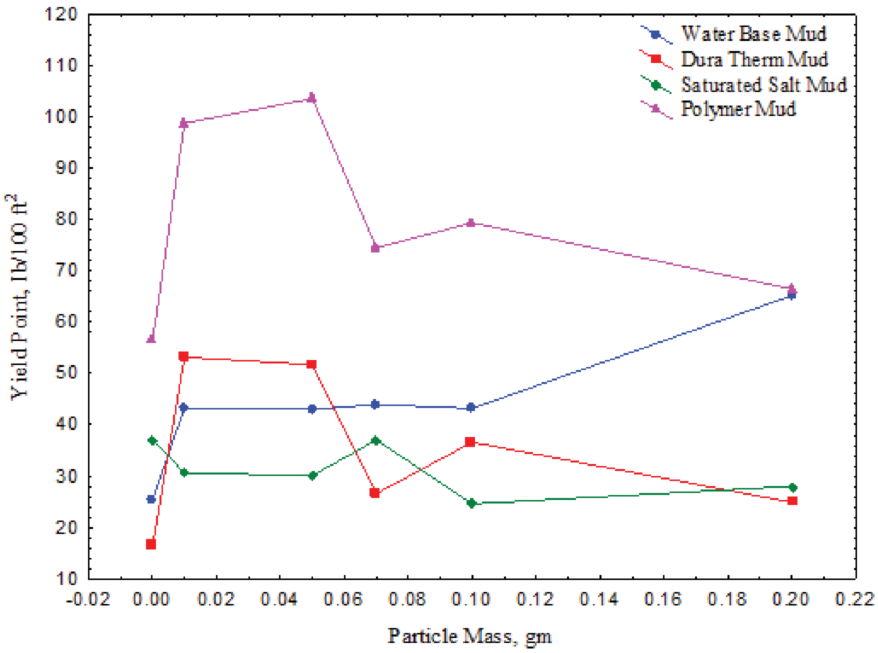

Fig. (11) The effect of MgO nanoparticle mass on yield point of different drilling fluidat 35^{0}C and normal pressure

4. Conclusion

1. MgO NP at HPHT improves the results of filtration loss for DURA THERM mud (best at 0.07gm), Salt Saturated Water mud (best at 0.2gm) and slight improvement for polymer mud (best at 0.05gm), while API WBM is not really affected by MgO nanoparticles.
2. The yield point as well as plastic viscosity can be improved with the addition of a specific value of MgO NP.

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