

## Utilizing A Dual Use Local Materials Instead of Imported Foreign Materials for Drilling Mud Conditioning

تحسين مواصفات سائل الحفر بأستخدام مواد محلية (ثنائية العمل) بدلا عن المواد الاجنبية  
المستوردة

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### Abstract

The most important constituents of drilling operation success is keeping the drilling fluid rheological properties within a certain limit to maintain continuity of their functions in a good manner. To achieve that, the drilling mud system needs continuous and direct supervision such as measuring its rheological properties and treating any deviation in their values. Viscosity is the most important property in hydraulic program success due to its direct relation with a bottom hole cleaning during well drilling, thus related with the drilling rate, so this property should be kept essentially to ensure bottom hole cleaning and high drilling rate at the same time.

Some chemicals should be added to the mud system to keep both viscosity and other properties within certain standards and the required limit, the high cost of such chemicals increase both the metric cost and the final cost of such wells.

The aim of this research is to test the physical and chemical properties of a local material, as a thinner and a filtration rate reducer, which tends to decrease the rheological properties of drilling mud. Twenty six samples of different types of drilling mud are tested with both the local and imported foreign materials.

The results for both additive materials are compared and it is found that the local thinner has the same trend as the foreign material to a certain extent. Also, in this work, the ideal rheological model is detected among six rheological models by preparing an excel system program to determine the Average Absolute Percentage Error (AAPE). This program compares the calculated shear stress values and the measured values obtained from high pressure high temperature viscometer.

The selected models are Bingham plastic model, Power law model, Modified power law model, Robertson stiff model, and Modified Robertson stiff model and Casson model.

The results show that the Power law and Casson models coincide with the tested samples.

### الخلاصة

إن من أهم مقومات نجاح عملية الحفر هو الحفاظ على الخواص التيارية لسائل الحفر ضمن حد معين لدوام نجاحه في أداء وظائفه بشكل جيد، ولتحقيق ذلك تحتاج منظومة سائل الحفر الى الاشراف المباشر و المستمر و المتمثل بقياس خواصه التيارية ومعالجة اي تغير في مواصفاته اذ تعتبر لزوجة سائل الحفر احد أهم اسباب نجاح البرنامج الهيدروليكي وذلك لارتباطها المباشر بعملية تنظيف قعر البئر اثناء عملية الحفر و بالتالي ارتباطها مع سرعة عملية الحفر و لذلك يجب الحفاظ على لزوجة سائل الحفر بالدرجة الاساس لغرض ديمومة نظافة قعر البئر وزيادة سرعة الحفر في آن واحد .

هناك مواد كيميائية يتم اضافتها الى منظومة سائل الحفر للحفاظ على لزوجة سائل الحفر و الخواص الاخرى ضمن الحدود القياسية المطلوبة ، ان تلك المواد الكيميائية المضافة تكون ذات كلفة عالية الامر الذي يزيد من كلفة حفر المتر الواحد و زيادة الكلفة النهائية لحفر البئر.

إن الهدف من هذا البحث هو اجراء بعض الفحوصات الكيمياوية والفيزياوية لمادة محلية وطنية تعمل على تقليل كل من اللزوجة والراشح وبالتالي التقليل من الخواص التيارية لسائل الحفر حيث تم اجراء فحوصات مختبرية لـ 26 نموذج من سائل الحفر باستخدام المادة الوطنية والمادة الاجنبية ومقارنة النتائج حيث اثبتت تلك الفحوصات ولحد ما نجاح المادة الوطنية في تحقيق المطلوب اسوة بالمادة الاجنبية المضافة لتحقيق نفس الغرض. كما تم في هذا البحث تحديد النمط الامثل من بين ستة انظمة تم اختبارها من خلال اعداد برنامج بنظام الاكسل يقوم بحساب معدل الخطأ النسبي المطلق (Average Absolute Percentage Error) والمعروف بالـ (AAPE) حيث يقوم هذا البرنامج بمقارنة نتائج اجهاد القص المحسوب باستخدام تلك الانظمة مع النتائج العملية المقروءة من جهاز قياس اللزوجة بظروف الحرارة والضغط العالين اما الأنظمة المختارة فهي:-

- 1- نظام بنكهام بلاستيك (Bingham plastic model)
- 2- نظام القانون الأسّي (Power law model)
- 3- نظام القانون الأسّي المّطور (Modified power law model)
- 4- نظام روبرتسون سنف (Robertson stiff model)
- 5- نظام روبرتسون سنف المّطور (Modified Robertson stiff model)
- 6- نظام كاسون (Casson model)

ولقد ثبت تطابق كل من انظمة القانون الأسّي وكاسون مع النماذج المفحوصة.

## **1- Introduction**

When recommending a drilling fluid system it must keep in mind that the mud properties must be capable of maintaining the essential functions and at the same time of minimizing both the cost and the expected problems in the well. However, choosing a drilling fluid system must be based on general experience and on the experience gained on site to achieve all the best available technology.

Usually, when functions drop, the mud engineer always requires a change in the conditions and handling to maintain the optimum drilling conditions .A high viscosity mud will undoubtedly improve cleaning of the well, but it will also increase pressure losses and the retention of cuttings. An expert mud engineer knows how to handle these changes and hence how to improve a given function and minimize the resulting impact of other functions on the mud properties.[1]

Drilling fluids technology has developed as a significant economic contribution to the production of oil and gas in most countries .Both the introduction of new product for drilling fluids and the development of better practices in their application have come about because there were problems to be solved. Such problems as how to reduce waste of natural resources, how to improve safety in drilling and how to lower costs through time and materials savings have led to the recognition of the drilling fluid as a vital factor in the success of many drilling operations.[2]

Well drilling in Iraq is expensive due to the high cost of the imported chemicals used in the drilling fluid system to control the rheological properties. The aim of this study is to find out such local material which can be used safely as a thinner and as filtration rate reducer at the same time instead of the costly foreign material.

## **2- The Rheological Properties Of The Drilling Fluids**

They are related to the flowing of the drilling fluid in the mud circulation system.

The rheological properties include the following:-

**2-1 Viscosity:** It can be defined as a fluid resistance to flow. It is measured by Marsh funnel or rotational viscometer. The measuring unit is centipoises (C.P).

Viscosity depends on two components:

**a-Plastic viscosity:** it results from mechanical friction force which happens

among:-

- The solids in the drilling fluid.
- The solids and surrounding liquid phase.
- The liquid phase surfaces. [3]

The plastic viscosity depends on the concentration, shapes, and volume of the solids. Mathematically, the plastic viscosity can be calculated by the following formula:-

$$\mu_p = \theta_{600} - \theta_{300}$$

Where:

$\mu_p$  = plastic viscosity (C.P)

$\theta_{600}$  = Dial reading at 600 RPM ( $\text{lb}/100 \text{ ft}^2$ )

$\theta_{300}$  = Dial reading at 300 RPM ( $\text{lb}/100 \text{ ft}^2$ )

**b- Yield point:** The second component of the flow resistance of drilling fluid is a measure of the electrochemical and attractive forces inside a fluid. These forces result from the positive or negative charges on or near the surface of the particles. Yield point is a measure of the overall effect of these forces and it depends on:

- The surface properties of the clayey solids dispersed in the mud.
- The volumetric concentration of the solids.
- The electrical environment of the solids which are depending on the concentration and types of ions in the fluid phase.

The value of yield point can be calculated by the following formula:

$$Y_p = \theta_{300} - \mu_p$$

Where:

$Y_p$  = yield point ( $\text{lb}/100 \text{ ft}^2$ )

$\theta_{300}$  = Dial reading at 300 RPM ( $\text{lb}/100 \text{ ft}^2$ )

$\mu_p$  = plastic viscosity (C.P)

There are other types of viscosity:-

**a- Apparent viscosity:** It results from the combined effect for both plastic viscosity and yield point, it can be calculated by the following formula:

$$\mu_a = \theta_{600} \sqrt{2}$$

Where:

$\mu_a$ =Apparent viscosity (C.P)

$\theta_{600}$ = Dial reading at 600 RPM ( $\text{lb}/100 \text{ ft}^2$ )

**b- Effective viscosity:** It is defined as an equivalent viscosity, it takes into consideration hole diameter, drill string diameter in addition to plastic viscosity and yield point. It can be calculated by the following formula [4]:

$\mu_e = \mu_p + (6.65 Y_p (d_H - d_P)^v)$  where:-

$\mu_e$ =effective viscosity (C.P)

$\mu_p$ =plastic viscosity (C.P)

$Y_p$ =Yield point ( $\text{lb}/100 \text{ ft}^2$ )

$d_H$ =Hole diameter (inch)

$d_P$ =Drill string diameter(inch)

**2-2 Gel strength:** A measure of attractive forces between particles in the static state. It also represents the shear stress necessary to start the fluid flowing.

The units of gel strength are ( $\text{lb}/100 \text{ ft}^2$ ) and measured by rotational viscometer at 3 RPM. [5]

**2-3 Alkalinity:** It is defined as a negative logarithm of positive hydrogen ion concentration.

$\text{PH} = \log (\text{H}^+)$

Where:-

$\text{PH}$ =Alkalinity

$(\text{H}^+)$ =Hydrogen ion.

It can be measured by digital PH meter, or special test papers. [5]

**2-4 Filtration:** Percolation of drilling fluid filtrate into the permeable zone due to the pressure difference that results in settling part of solid phase on the wall, thus a film of mud cake can be formed. The filtration is measured by API filter press and the measuring unit is  $\text{cm}^3/30 \text{ min}$ . [3]

### **3- The Local Material**

#### **3-1 Description**

It is a mixture of some plant shells which are found in nuts and fruits such as gall oak ,pomegranate, sumac and pistachio .These plants are widely spread in different countries over the world especially in Iraq, Syria, Iran, south Africa, Argentina and India.[6]

The local material contains organic matters as Tannins and Lignin with 28% and 25.25% respectively. [6, 7], These two matters are used mainly as a thinner in most of the drilling fluid systems, Also they contain Cellulose with 53.98% which is used in filtration rate reducer [8], Thus ,this material is of dual use.

#### **3-2 Chemical Tests:**

##### **3-2- 1 Detection of tannin proportion**

It has been found that the tannin ratio is 28% by the following process:

1 gm of local thinner is dissolved in 40 ml of boiling water, 0.1gm of cupric acetate is added and the mixture is reboiled and then filtrated by a filter paper.

The paper is dried with 0.1 gm of nitric acid. The precipitation is burned and the weight of CuO is measured. The tannin proportion is calculated by the following formula: [2]

$$\text{CuO} \times 1.45 = \text{tannin}\%$$

$$0.194 \times 1.45 = 28\%.[6] [9]$$

##### **3-2-2 Detection of real density**

It has been found that the real density of the local material is 1.4262 gm\cc.

##### **3-2-3 Fourier transform infrared test.**

It has been found that the local thinner contains hydroxyl, ester, and benzene groups in addition to aromatic compounds.

**Note:-**The first test was conducted at the analysis laboratory in Baghdad oil training institute, while the other tests were done at the laboratories of the petroleum research and development center.

#### **3-3 Physical Tests:**

In order to detect the effect of local material on the rheological properties of the mud, two types of drilling fluid are tested with local and foreign thinners.

The test results are compared and discussed, the foreign thinner used in these tests is (FCl) which is used in Iraqi fields.

#### **3-4 Cost Of The Local Material:**

The estimated cost for the local material preparation (with 10 kg package) is about 7000 Iraqi dinars in comparison with \$25 (32500 ID) for foreign material of the same weight <sup>\*1</sup>

#### **3-5 Characteristics Of The Local Material:**

- 1-Eco-friendly.
- 2- Low cost and available.
- 3-Safe to use.
- 4-Accessiable.
- 5-Does not need modern technique to prepare.
- 6-Does not affect the other properties.
- 7-Easily to use and it can be added directly without any other additives or solvents.
- 8-Soulble in both fresh and salt waters.
- 9-Effective, especially at high temperatures condition.

### **4- The Apparatus Specifications And Operating Steps:**

#### **4-1 The apparatus**

The apparatus used in this research is high pressure high temperature viscometer type M5600 (Fig. 1) which is run by a computer. This apparatus is very sensitive for any change in shear stress or in any drilling mud ingredients.

The apparatus is characterized by the following:-

- 1-Speed range (0.00001-1100)RPM.
- 2-Temperature range (Ambient to 500) F<sup>0</sup>
- 3-Pressure range (ATM-1000)psi
- 4-Viscosity range (0.5-5000000)c.p

The results are listed with excel mode as tables or as diagrammatic plot [10].

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<sup>\*1</sup>The cost for the foreign material are obtained from formal documents followed by Iraqi drilling company

#### 4-2 The operating steps

1. Create a test program by feeding the computer with the test sequence which it includes the required speeds and the number of test sequence.
2. Put the drilling fluid sample in the cap tester and secure tightly.
3. Apply the required temperature and pressure.
4. When the temperature reaches the set value, the test program (which created in step 1) will be restored automatically.
5. Press zero buttons and then the start button. The program will show the shear stress according to the pointed shear rates in the program.

At the end of the test, the results can be read directly from the data screen [10].



**Fig. (1) HPHT Viscometer type M5600 [10].**

## 5 - Results And Discussions:

### 5- 1 For Fresh Water Mud:

A number of samples for this type of mud are prepared. They contain 22.5 gm of Bentonite with 350 ml distilled water, then the mixtures are left for 24 hours for hydration, the FCI thinner is added with weights (0.5, 1, 1.5, 2, 2.5, 3) gm respectively, then the samples are mixed for 20 minutes before conducting test process at room temperature, 100, 150, 200 and 250 F<sup>0</sup>. The tested properties are apparent viscosity, plastic viscosity, yield point, filtration, and the alkalinity of the



filtrate. The same procedures are repeated again with the local material. The results are compared and discussed.

#### 5-1-1 For FCI thinner as Foreign Material:

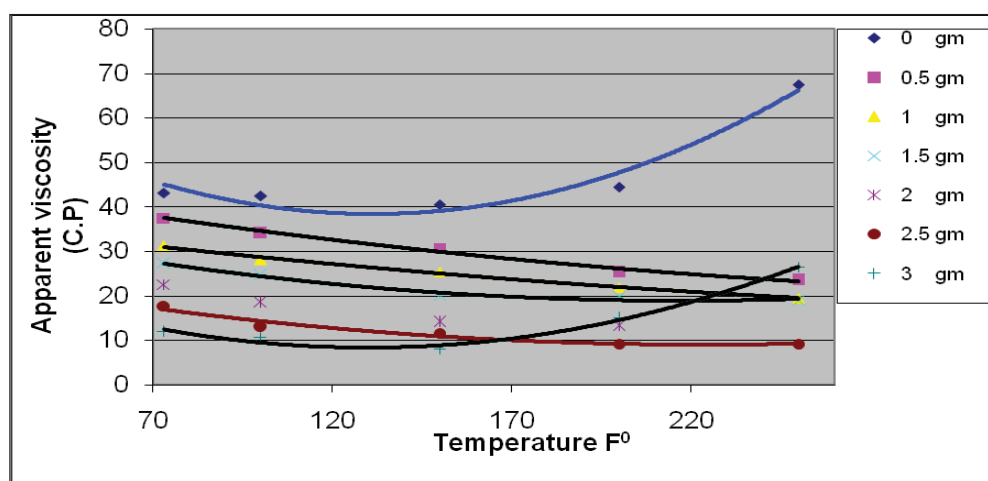
The results showed that the (FCI) has a great effect on the rheological properties for this type of mud at addition range (0.5-2.5) gm at 250 F<sup>0</sup> and 150 psi in which at these condition, the apparent viscosity decreases from 43.2 c.p to 9.1 c.p, and the plastic viscosity decreases also from 13.2 c.p to 3.4 c.p while the yield point decreases from 60 lb/100 ft<sup>2</sup> to 11.4 lb/100 ft<sup>2</sup>.

The gel strength decreases from 25 lb/100 ft<sup>2</sup> to 6.4 lb/100ft<sup>2</sup>.

At 3 gm of this additive, the effect is still active to about 150 F<sup>0</sup> and 100 psi before losing its effects due to the solids flocculation which it leads to increase all the mentioned rheological properties, it is found at 250 F<sup>0</sup> and 100 psi the apparent viscosity, plastic viscosity, yield point and gel strength are 26.5 c.p, 12 c.p, 29c.p and 12 lb/100 ft<sup>2</sup> respectively.

The filtration rate is clearly decreased to 10 ml/30 min. after it was 15.2 ml/30 min. before addition, while the filtrate alkalinity ranged (8.5-9.8).

Figs (2, 3, 4 and 5) show the effect FCI thinner as foreign material on the rheological behavior for this type of mud.



**Fig. (2) Effect of FCI thinner on the apparent viscosity for fresh water mud at high temperature and high pressure**

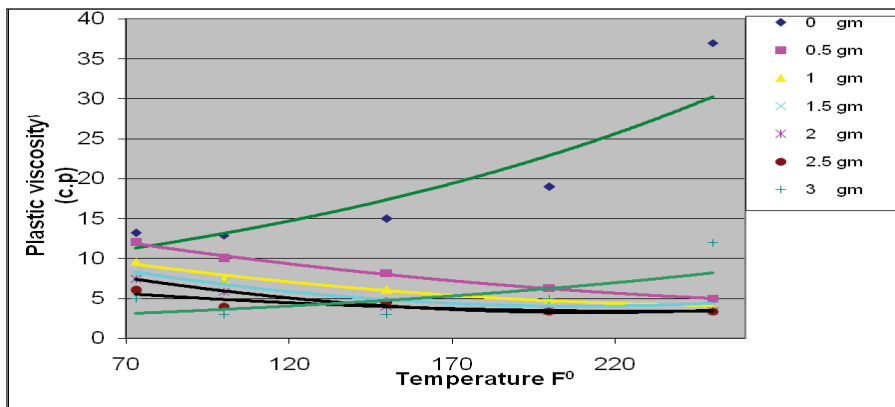


Fig. (3) Effect of FCI thinner on the plastic viscosity for fresh water mud at high temperature and high pressure

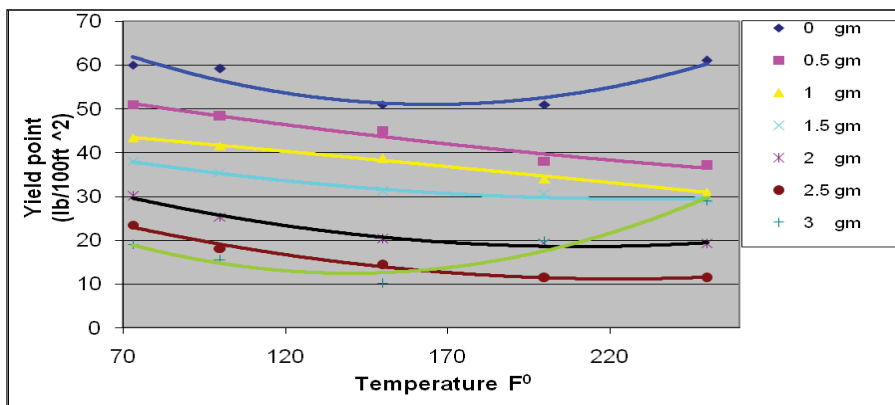


Fig. (4) Effect of FCI thinner on the yield point for fresh water mud at high temperature and high pressure

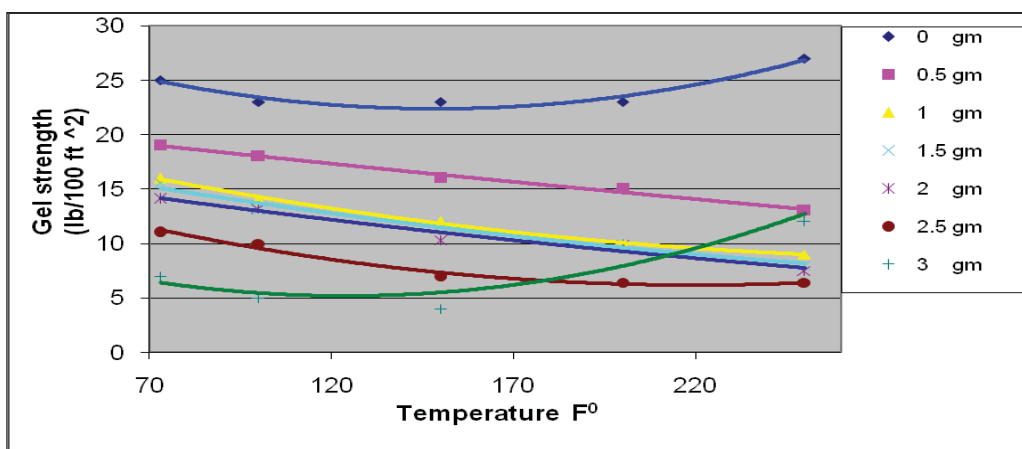


Fig. (5) Effect of FCI thinner on the gel strength for fresh water mud at high temperature and high pressure

**5-1-2 For Local Material:**

When adding (0.5-1.5) gm of the local material. It is noticed that all the rheological properties at 200 F<sup>0</sup> and 100 psi are decreased clearly in which the apparent viscosity decreases to 22 c.p (43.2 c.p before addition). The plastic viscosity decreases to 4.9 c.p (13.2 c.p before addition), while the yield point is 20 lb/100 ft<sup>2</sup> (60 lb/100 ft<sup>2</sup> before addition) and gel strength decreases from 25 (lb/100 ft<sup>2</sup>) to 12 (lb/100 ft<sup>2</sup>)

At 250 F<sup>0</sup> all the mentioned properties increased gradually due to the evaporated portion of the liquid phase and solid flocculating.

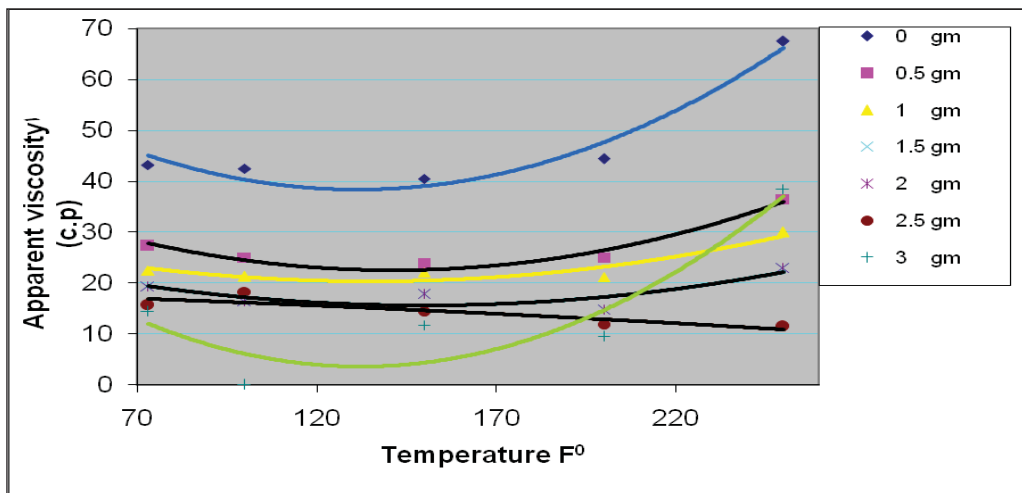
When adding (2-2.5) gm of local material, all the rheological properties are continued decreasing with a good thermal stability at 250 F<sup>0</sup> when the apparent viscosity, plastic viscosity, yield point and gel strength are 15 c.p, 3 c.p, 17 lb/100 ft<sup>2</sup> and 7 lb/100 ft<sup>2</sup> respectively.

At 3 gm of local material, the rheological properties are continued decreasing till 200 F<sup>0</sup> before increasing once again at 250<sup>0</sup>, these high values are due to thermal degradation of solid content and solids flocculation.

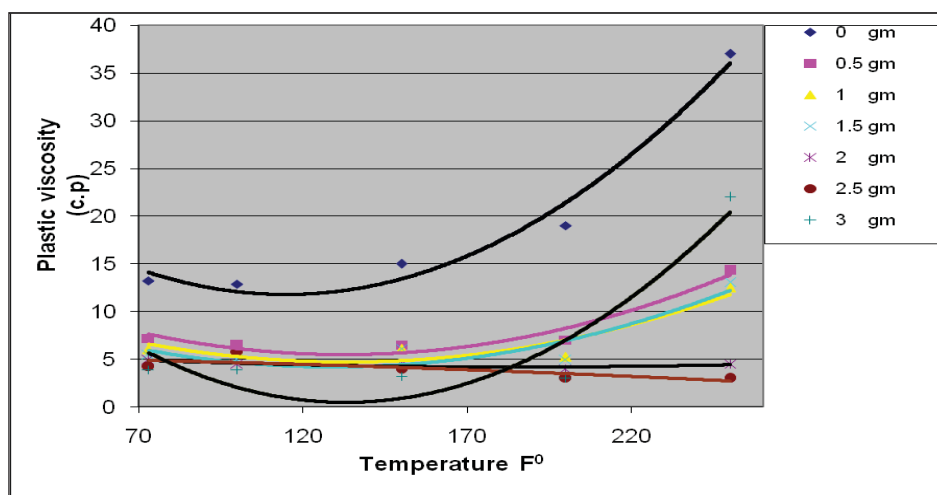
It is noticed that the filtration rate is decreased obviously to 8.5 ml/30 min. (15.2 ml/30min. before addition) this is due to the cellulose content present in the local material

There is no clear effect of local material on drilling fluid alkalinity in which its value ranges (9.55-9.7).

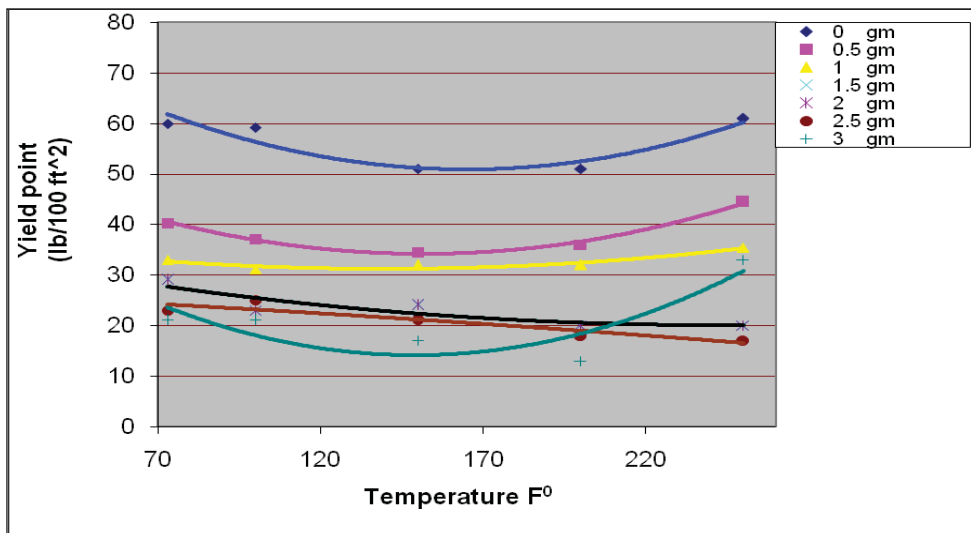
Figures (6, 7, 8 and 9) show the effect of local material on the rheological behavior for this type of mud.



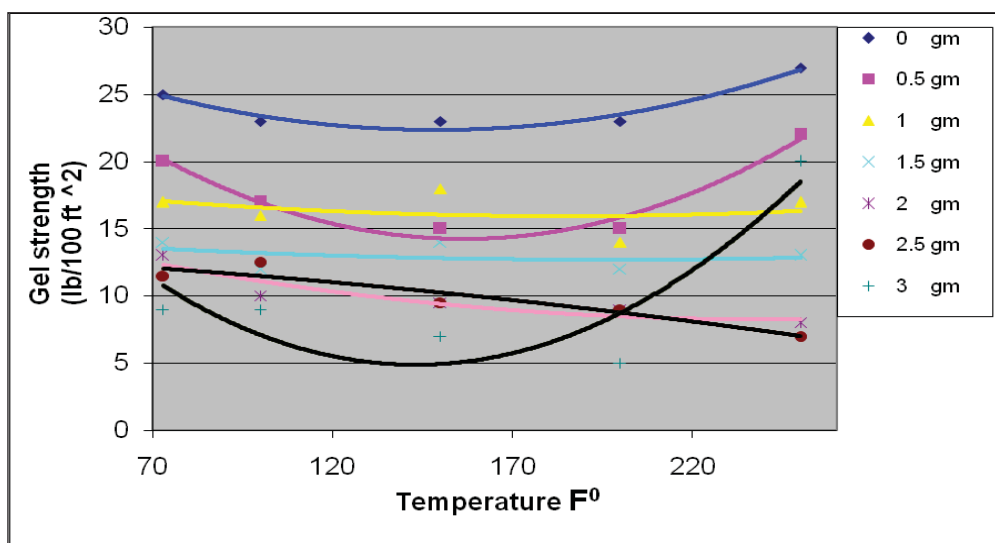
**Fig. (6) Effect of local material on the apparent viscosity for fresh water mud at high temperature and high pressure**



**Fig. (7) Effect of local material on the plastic viscosity for fresh water mud at high temperature and high pressure**



**Fig. (8) Effect of local material on the yield point for fresh water mud at high temperature and high pressure.**



**Fig. (9) Effect of local material on the gel strength for fresh water mud at high temperature and high pressure.**

**5-2 For Salt Water Mud:**

A number of samples for this type of mud are prepared. They contain 22.5 gm of Bentonite with 250 ml of tap water with 4% NaCl dissolved in 100 ml of tap water. The mixtures are left 24 hours for hydration, the FCl thinner is added with weights (0.5, 1, 1.5, 2, 2.5, 3) gm respectively, then the samples are mixed for 20 minutes before the tests process are run at room temperature, 100, 150, 200 and 250 F<sup>0</sup>. The

tested properties are apparent viscosity, plastic viscosity, yield point, filtration, and the alkalinity of the filtrate. The same procedures are repeated again with the local thinner; their results are compared and discussed.

### 5-2-1 For FCI Thinner:

When adding (0.5-1.5)gm of FCI ,it is noticed that all the rheological properties are decreased gradually with increasing temperature to 150 F<sup>0</sup> and the pressure is held constant at 100 psi ,after this temperature value ,the values of properties increased slightly due to the thermal flocculation ,

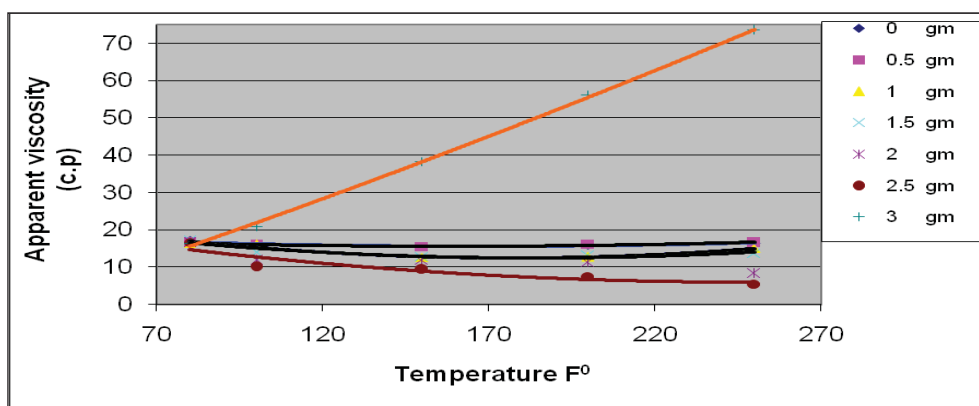
At weights of 2 and 2.5 gm of the added thinner ,the rheological properties are decreased clearly with increasing temperature to 250 F<sup>0</sup> and pressure to 150 psi and as follows:-

Apparent viscosity 5.5 c.p, plastic viscosity 4 c.p, yield point 3 lb/100 ft<sup>2</sup> and gel strength is 0.5 lb/100 ft<sup>2</sup>.

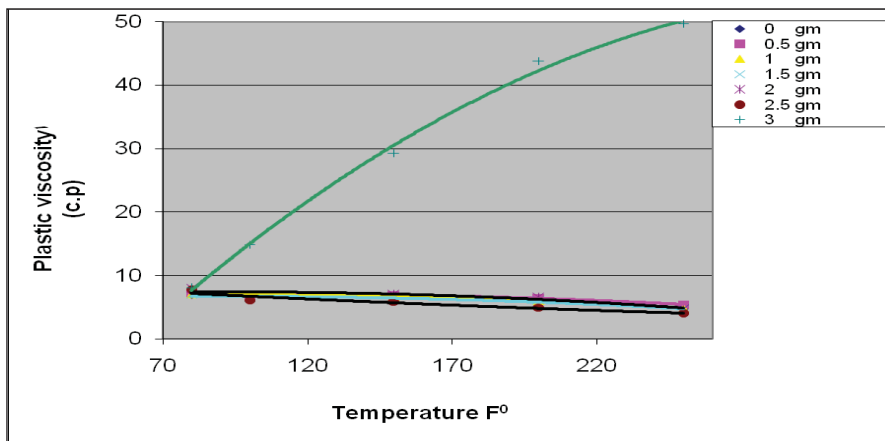
At 3 gm of addition, the rheological properties are continued decreasing under room temperature and ambient conditions, but with increasing temperature to 200 F<sup>0</sup> and more and due to the thinner over treatment and evaporation some of liquid phase, the apparent viscosity and yield point under condition of 250 F<sup>0</sup> temperature and 150 psi pressure are 73.5 c.p and 47 lb/100ft<sup>2</sup> respectively.

With addition of this material the filtration rate values ranged (42.8-54) Cm<sup>3</sup>/30 Min. and the alkalinity values rated (8.9-7.73).

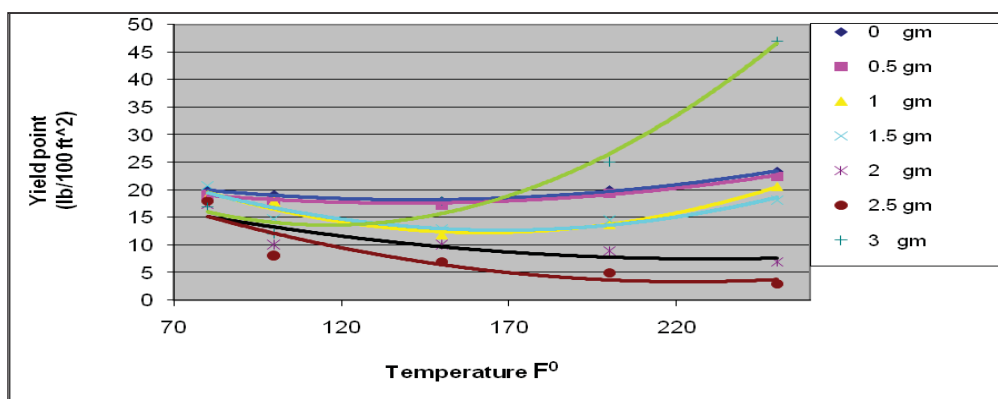
Figures (10, 11, 12 and13) show the effect of FCI thinner on the rheological behavior for this type of mud.



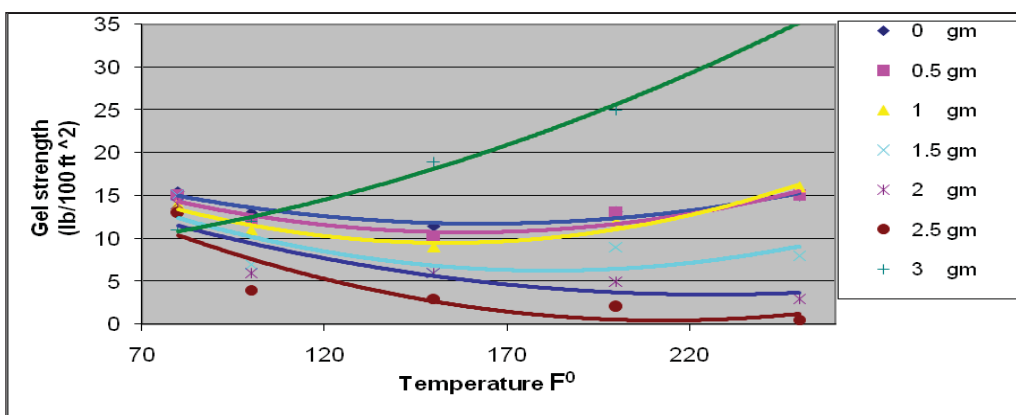
**Fig. (10) Effect of FCI thinner on the apparent viscosity for salt water mud at high temperature and high pressure.**



**Fig. (11) Effect of FCI thinner on the plastic viscosity for salt water mud at high temperature and high pressure.**



**Fig. (12) Effect of FCI thinner on the yield point for salt water mud at high temperature and high pressure.**



**Fig. (13) Effect of FCI thinner on the gel strength for salt water mud at high temperature and high pressure.**

**5-2-2 For Local material:**

When adding 0.5 gm of the local material it is noticed that all the rheological properties up to 100 F<sup>0</sup> and 100 psi are decreased clearly ,under these conditions the apparent viscosity, plastic viscosity, yield point and gel strength are 12 c.p,5 c.p,14 lb/100 ft<sup>2</sup> and 13 lb/100 ft<sup>2</sup> respectively but, when increasing temperature more than 150 F<sup>0</sup>,the rheological values start to increase gradually and this is due to insufficient weight of additive which leads to solids flocculation inside drilling fluid.

At weights of 1,1.5,2 and 2.5 gm of the additive and with increasing both temperature and pressure ,the effectiveness of the local material is increased clearly due to the full additive solution inside drilling fluids especially at weight of 2.5 gm in which, at this rate and under the condition of 200 F<sup>0</sup> and 100 psi, the rheological properties are decreased significantly ,for example the apparent viscosity is 5 c.p (it was 17 c.p before addition),the plastic viscosity is 3 c.p (it was 7 c.p before addition),the yield point is 4 lb/100 ft<sup>2</sup> (it was 20 lb/100ft<sup>2</sup>),and the gel strength is 5 lb/100ft<sup>2</sup>(it was 15.5 lb/100ft<sup>2</sup>).

The weight of 2.5 gm for the additive can be considered as an ideal treatment for this type of drilling fluids.

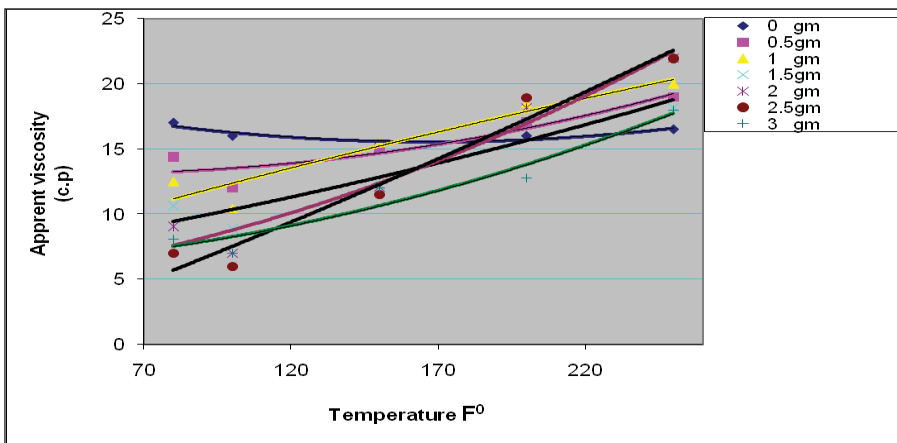
At 3 gm of this additive, the rheological properties continued to fall in values up to 150 F<sup>0</sup> and 100 psi before they are increase again with increasing both temperature and pressure. This is due to solids conglomerate and the increase in solids content.

Filtration rate is gradually decreased to 40 cm<sup>3</sup>/30 min. after it was 50.4 cm<sup>3</sup>/30 min. before addition, while the filtration alkalinity ranged (8.7-8).

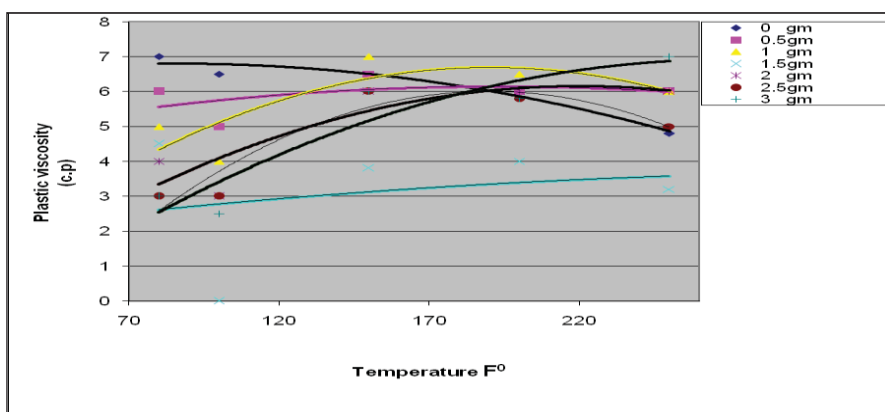
The results of the best model selection show that the power law and Casson models are the best for the two added thinners.

Figures (14, 15, 16, and17) show the effect of local material on the rheological behavior for this type of mud.

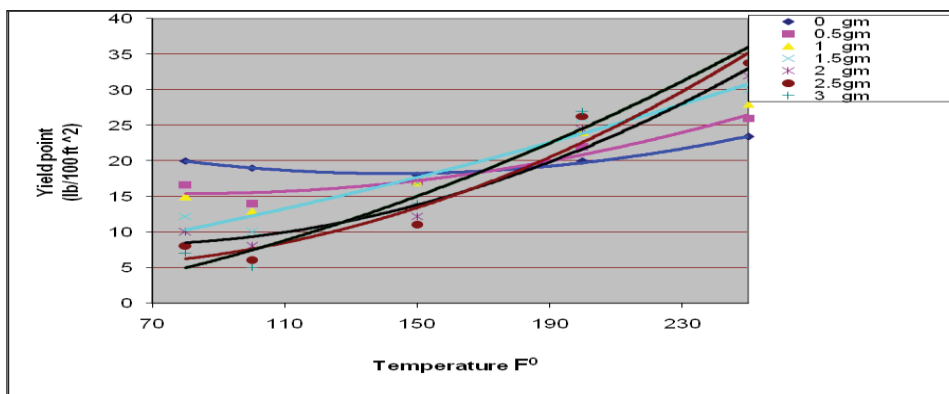




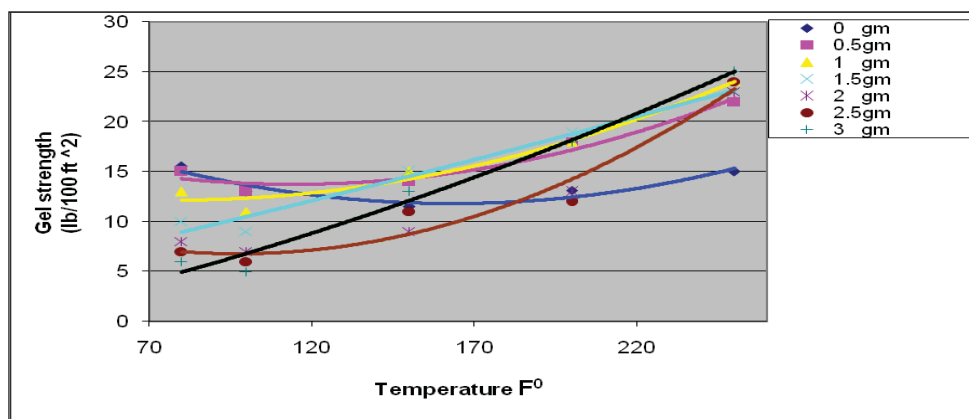
**Fig. (14) Effect of local material on the apparent viscosity for salt water mud at high temperature and high pressure.**



**Fig. (15) Effect of local material on the plastic viscosity for salt water mud at high temperature and high pressure.**



**Fig. (16) Effect of local material on the yield point for salt water mud at high temperature and high pressure.**



**Fig. (17) Effect of local material on the gel strength for salt water mud at high temperature and high pressure.**

## **6- Conclusions:**

Depending on the results obtained in this study we can conclude the following:-

### **1-For fresh water mud:**

There is a similarity in the behavior of the FCI and local material where the effect of the FCI was very effective especially at the weights (0.5-2.5) gm and has good thermal stability (till to 250 F<sup>0</sup>). The local was ideally efficient at weights (2-2.5)gm in terms of effectiveness and its tolerance to high temperatures

The alkalinity of this mud with local material ranged (9.7-9.55) while with the foreign material was (8.5-9.44), thus the local material is better than the other material to some extent and that why this material is more stable and effective with increasing both temperature and pressure.

### **2- For salt mud:**

There is somehow an obvious similarity in the behavior of the FCI and the local thinners to some extent, the local thinner works properly with increasing temperature and pressure at range (1- 2.5) gm of the added thinner, while the FCI works properly at weights of 2 and 2.5 gm. In this type of mud the local thinner is better than the FCI to certain extent in relation to its low effect on alkalinity.

**3-** The model selection results show that both Power law and Casson models represent the laboratory test results accurately.

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