

Effects of Gum Arabic Addition on the Behaviour of Water Base Drilling Fluids

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ABSTRACT- This research paper discusses the use of Gum Arabic as additive materials to the fluids used in drilling and try to answer the following question, how Gum Arabic to a parched additive affects the drilling fluid properties? The researcher did a laboratory tests under different temperatures. The results showed high fluid stability when using Percentage of 0.76 and 21.44% as weight value of Gum Arabic.

Keywords: Gum Arabic, Drilling fluid, Flow behavior, Acacia segenal and additive material

المستخلص- تتناول هذه الدراسة استخدام الصمغ العربي مادة مضافة إلى السوائل المستخدمة في الحفر ، وتحاول الإجابة عن السؤال التالي : مامدى تأثير الصمغ علي خواص سائل الحفر وفاعليته ؟ أجرى الباحث تجارب معملية تحت درجات حرارة مختلفة لمعرفة تأثيرالصمغ العربي في تحسين أداء سائل الحفر ذي الأساس المائي . أظهرت النتائج التي تحصل اليها أن سائل الحفر تكون أكثر إستقرارا في خواصها عند إستخدام نسب 0.76 و 21.44 % قيمة وزنية للصمغ العربي.

INTRODUCTION

The major component in oil and gas for successful drilling and completion operations is the drilling fluid performance ^[1]. Drilling fluid is related either directly or indirectly to most drilling problems. Also, the additives required to maintain drilling fluid in good condition can be quite expensive ^[2]. The cost of searching for hydrocarbon reserves becomes more expensive when drilling occurs offshore, in deep water, and in hostile environments. These drilling environs require fluids that excel in performance. Measuring fluid performance requires the evaluation of all key drilling parameters and their associated cost ^[3]. The mud has a number of functions which must all be optimized to assure safety and minimize hole problems. This study is focusing on the Gum Arabic as an additive to water base mud's, optimizing the percentages of the added components and studying the flow behavior of the resulted mud.

Gum Arabic is the trade name for a natural forest product from the genus Acacia. It is manly obtained from Acacia senegal var. Senegal locally known as Hashab ^[4]. Gum Arabic tree is about 5 to 20 ft height and has a life span of 25 to 30 years. It grows in poor sandy, reddish soils and the colors of flowers are white or of cream. It has a deep-dark yellow to light brown on gray branches and the length of the leaf is 1 to 6 cm ^[5]. The name Acacia is derived from the Greek word (akis) meaning (sharp point) and relates to the thorny sharps and trees of tropical Africa and Western Asia that were the only known acacia at the time where the name was published^[6]. Synonym names include gum Arabic (Acacia senegal), Gum Hashab, Kordofanian Gum, Gum Arabic Acacia Gum, Arabic Gum INS. NO414 ^[7]. Acacia senegal is found in the Sudan throughout the states of Darfur, Kordafan, Blue Nile, part of White Nile, Upper Kassala and Gedaref. The main area of its occurrence is the part of Sudan where

the species is uniform and is found in pure stands, giving Sudan the advantage of being the major producer and exporter of the best quantity Gum Arabic supplying about 80% of the annual world requirements^[8].

GUM ARABIC PROPERTIES and CHARACTERISTICS

Gum Arabic readily dissolves in water to produce solutions of low viscosity and hence finds little application as a thickening agent. The Gum Arabic solutions viscosity decreases in the presence of electrolyte and at high and low pH levels. The viscosity of Gum Arabic solutions shows an irreversible decrease after heating due to denaturation at pH and precipitation of the high molecular, mass protein and rich components. It is used as an emulsifier in the encapsulation of oils for long prior to bottling. Gum Arabic also has the ability to form thick visco-elastic films at the oil-water interface

Size exclusion chromatography studies have shown that Gum Arabic from Acacia Senegal consists of two main components, proteins deficient major component and acetous which for on 30% of the total thus emphasizing the total dispersion of gum and confirming that gum Arabic is an arabinose galacton protein complex^[7] The gum has been fractionated using hydrophobic interaction chromatography to three fractions. A protein deficient arabinose galacton fraction forms 89.4% of the total and has a molecular mass of 2.79×10^3 g/mol and was low in protein 0.44% (Weight/Weight (w/w)), which is designated as an arabinogalacton fraction. The second major fraction forms 10.4% of the total (w/w) has a higher molecular mass of 1.45×10^6 g/mol and a greater proportion of protein 9.18% (w/w). The third fraction as the glycol protein, it is major fraction of about 1% of the total (w/w) and a molecular mass of 0.25%^[7].

ENHANCING DRILLING FLUIDS PROPERTIES

The Gum Arabic was used to maintain the required properties of water base drilling fluid. Certain tests were conducted and measurements were carried out under constant pressure (0.69 MPa) and different temperature conditions (30° to 100°C). The apparatus used in the study were tabulated as Table I.

PROCEDURES

Preparation: Five samples of Drilling Fluids were prepared for each Gum sample. Each Drilling fluid sample consists of water, Bentonite, Pac LV and Gum (A sample for each of Al-Taleh, AL-Damazeen Hashab and Abu Jibaihe Hashab). The diameter of the Gum samples range between (0.15 – 0.425mm). The percentage of Gum Arabic for each of the Gum sample for the five drilling fluid samples is as follows: (0.76, 9.4, 13.44, 17.15, 21.44%), while other constituents i.e. water, Bentonite, Pac LV have constant mass and volume composition. These percentages for Gum Arabic were chosen because 0.76% was the minimum percentage where the effect of the gum becomes apparent. Other percentages were then chosen as multiple weight proportions of this minimum percentage the percentages are regarded as a weight percentage of the whole sample weight. The rest of the sample is also stable and equals 8.8 lb/gal. The experiments were carried out on three samples of Gum Arabic. Those samples are Taleh Gum, Damazeen Hashab and Abu Jibaihe Hashab Gum. From each of the five drilling fluid samples, additional eight samples will be taken to measure the effect of temperature variation, thus making a total of forty test samples for each Gum.

Mixing: The first sample (Al-Taleh, 0.76%) was put in a mixer and mixed well for twenty minutes. After that, a quantity (250 ml) from the well mixed sample was taken to determine its density by using the density measurement device (Mud balance). This is to ensure that the density is fixed at a value of 8.8 lb/gal because all of the samples that will be studied in this research must have constant density.

TESTING

HP-HT Testing: Then, the sample was put in a high pressure-high temperature apparatus (Dynamic HP-HT) at a temperature beginning at 40° Centigrade and a pressure of 0.69 MPa and a rotation speed of about 137 rpm for thirty minutes, so as to put the sample under conditions similar to the conditions of the well during drilling operations, i.e. under constant pressure, constant rotation speed and one of the possible variable temperatures. This is done in order to calculate changes in the properties of the drilling fluid as the well temperature changes.

Speed measurements: After that, the speed was measured (Ø300, Ø600, Ø3, Ø6, Ø100, Ø200,

$\Theta_{3_{10sec}}$ and $\Theta_{3_{10min}}$) by using the Six speed Viscometer. These velocities were used to calculate the apparent viscosity, the plastic viscosity, the yield point and the gel strength using equations (1) to (4).

$$AV = \Theta_{600}/2 \quad (1)$$

$$PV = \Theta_{600} - \Theta_{300} \quad (2)$$

$$Yp = \Theta_{300} - PV \quad (3)$$

$$\text{Gel Strength} = \Theta_{3_{10sec}} / \Theta_{3_{10min}} \quad (4)$$

Where: AV is the apparent viscosity, PV is the plastic viscosity, Yp is the yield point and (Θ_{300} , Θ_{600} , $\Theta_{3_{10sec}}$, $\Theta_{3_{10min}}$) are the different speeds of Viscometer.

PH measurement: Next, the degree of basicity and acidity for the sample was measured by measuring the PH using the PH Meter and paper PH. This is because drilling fluids must be kept at a specific PH level (8-10). Taking the PH level of the sample will determine if treatment is required with chemical additives to maintain a constant ratio of hydrogen ion (H^+) and hydroxyl group (OH) for that PH level. The relationship between the concentration of hydroxyl and hydrogen ions is found to be constant for most of the solutions. These values, which should not be less, represent an important indicator used to control corrosion.

Filtration: The sample was then put on the filtration device (Four-cups mud water loss instrument) for thirty minutes at the pressure of 0.69Mpa so as to measure the filtration loss volume. After that a filtration paper was taken to measure the angle of friction using the device, Viscosity factor meter, and from this the friction co-efficient was found from the device guide.

The procedures above (mixing, HP-HT, density, speed, PH determination, filtration and angle of friction) were repeated for other quantities of the same sample but at different temperatures (30

,50°,60°,70°,80°, 90°and100°). After the test with the first sample (Al-Taleh, 0.76%) was concluded, similar test with the same procedures was carried out for the four remaining samples (Al-Taleh; 9.4, 13.44, 17.15 and 21.44%). A new test for each of the remaining drilling fluid samples (with gum sample; Damazeen Hashab and Abu Jibaihe Hashab Gum) using all the procedures mentioned above was then carried out.

DRILLING FLUID PROPERTIES at DIFFERENT TEMPERATURE (30° TO 100°C)

The results for all the tests were carefully recorded. These results were put in a table showing the different temperatures against measured fluid properties (Filtrated, ρ and speed) for each type of Gum Arabic. Calculated fluid properties (the apparent viscosity (μ_a), the plastic viscosity (μ_p), the yield point (YP), gel strength (Gels) and YP/ μ_p) were also included in Table I.

The Calculation of the properties of the fluid is necessary in order to measure the ability of the drilling fluid to form a complex gel structure by measuring the strong attraction or lack of stability in different circumstances. Yield point (YP) determines the lifting capacity of the drilling fluid, because it is a measure of the strong attraction in the drilling fluid, a factor that determines the raising of the crumbs to the earth's surface; and percentage YP/ μ_p was calculated to determine the viscosity of the liquid inside the drill column which should be low, and at the same time has a high viscosity in the remaining portion of the annular space. Additionally, Bingham Plastic Model and Power Law Model were used to calculate the shear stress and the shear rate by using the previous results for all the samples.

Table 1: Laboratory Apparatus's used in this research work

No	Device	Unit	Function
1	Electrical Scale	g	Weight of Material
2	Mud Balance	g/cm ³ , lb/gal	Measurement of Density
3	HPHT Dynamic	MPA, °C, rpm	Put the sample under a condition (temperature, pressure and rotation) similar to the well condition
4	Hydration Dispenser Paper	-	Measurement of pH (Colour visualization on graded paper)
5	pH Meter	-	Measure pH
6	Six Speed Viscometer	rpm	Measurement of fluid rheological properties
7	Four-cups mud Water loss	MPA-time	Measurement of fluid filtration
8	Viscosity factor meter	min/round, angle	Viscosity Factor of the mud cake
9	Lost Circulation Test	MPA-Time	Measurement of lost fluid quantity

Table II: Resulted Fluid properties at different temperature between (30-100°C)

Properties	(Weight %)	Wt% 0.76 (30-100°C)	Wt % 9.4 (30-100°C)	Wt% 13.44 (30-100°C)	Wt% 17.1 (30- 100°C)	Wt% 21.44 (30-100°C)
	Gum Arabic					
Apparent Viscosity (μa) Dimension	AL-Taleh	47.5 - 70	37- 62.5	31.5 – 60	26 - 62.5	22- 49
	AL-Damazeen	50 - 72	49 - 66.5	35.5 – 67	26.5 - 48	24 - 57.5
	Abu Jibiahe	22 - 70.5	14 - 67.5	12.5 – 74	10 - 62	30 – 66
Plastic Viscosity (μp) Dimension	AL-Taleh	26 - 59	15 - 53	10 – 45	9 - 39	9 – 40
	AL-Damazeen	11 – 50	8 - 48	10 – 62	7 - 46	9 – 55
	Abu Jibiahe	9 – 25	5 - 45	12 – 48	8 - 46	20 – 48
Yield Point (Yp) Dimension	AL-Taleh	22 - 52	17 - 34	21 – 49	16 - 34	18 - 34
	AL-Damazeen	36 - s 90	37 - 84	10 – 65	22 - 71	5 - 29
	Abu Jibiahe	14 – 67	8 - 66	2 – 67	7 - 50	16 - 36
Gel Strength (Gels) Dimension	AL-Taleh	0.04 - 0.44	0.25 - 0.5	0.33 - 0.6	0.31 - 0.67	0.3 - 0.5
	AL-Damazeen	0.25 - 0.4	0.18 - 0.6	0.2 - .6	0.4 - 0.67	0.5 - 0.67
	Abu Jibiahe	0.2 - 0.75	0.13 - 0.6	0.15 - 0.27	0.2 - 0.67	0.3 - 0.5
Filtration (F) Dimension	AL-Taleh	31 - 37.5	32 - 37	30 - 35.5	21 - 39.5	25 – 31
	AL-Damazeen	32 - 37	30 - 35	24 – 33	29 - 36	30 - 37.5
	Abu Jibiahe	36 – 42	31 - 43	23 – 36	31 - 41	25 – 31
ratio of YP/μp Dimension	AL-Taleh	0.37- 2	0.32-2.93	0.35-2.77	0.4 – 3.78	0.45 – 3.2
	AL-Damazeen	0.82 - 5	0.77–10.5	0.16 – 6.5	0.48-10,2	0.09 – 1
	Abu Jibiahe	0.8 – 1.6	1 – 2.6	0.55 - 2	0.78 – 2.8	0.73 – 1.5
Friction Coefficient Dimension	AL-Taleh	0.13 - 0.19	0.16 - 0.28	0.16 - 0.26	0.16 - 0.25	0.18 - 0.27
	AL-Damazeen	0.19 - 0.26	0.17 - 0.31	0.19 - 0.34	0.18 - 0.24	0.15 - 0.25
	Abu Jibiahe	0.17 - 0.34	0.18 - 0.27	0.2 - 0.27	0.17 - 0.24	0.18 - 0.27

Table II shows calculated properties of the drilling fluid at different temperatures 30°C, 40, 50, 60,70,80,90 and 100°C (30°C room temperature was control temperature) when percentages by weight of the three gum Arabic samples in the drilling fluid is varied. The first value in the range of each property is its value at a temperature of 30°C, and the last value corresponds to its value at 100°C .Intermediate values corresponding to 40, 50, 60,70,80,90 100 typically fall between the ranges shown.

SHEAR STRESS and SHEAR RATE

Using data obtained from the effect of different temperatures on the properties of the drilling fluid, the Flow Behavior index (n) and Consistency index (k) are calculated by equations (5) and (6):

$$n = 3.32 \text{Log} (\Theta 600/\Theta 300) \tag{5}$$

$$k = \Theta 300/(511)^n \tag{6}$$

Furthermore, these indices together with the plastic viscosity and yield point, the Shear stress for all temperature ranges for different gum percentages are calculated using the Bingham plastic And Power Law Model. With Shear rate

arbitrarily taken from 0, 1, 2, 3 up to 10, by equations (7) and (8):

Bingham plastic Model

$$\tau = PV (\gamma) + YP \tag{7}$$

Where: τ is the measured shear stress in Lb/100ft² Shear Stress, γ is the Shear Rate in sec⁻¹, PV is the Plastic Viscosity in cp and YP is the Yield Point in lb/100ft².

Power Law Model

$$\tau = K (\gamma)^n \tag{8}$$

Where: τ is the shear stress sec⁻¹, γ is the shear rate sec⁻¹. Graphs of the above data are drawn by excel program and then analyzed to study the behavior of the fluid flow.

RESULTS and DISCUSSION

Using the above table, Table II a deep analysis of the properties of drilling fluid with changes in temperature for all the sample percentages (0.76, 9.4, 13.44, 17.15 and 21.44) was made. A discussion of this analysis for the three types of Gum Arabic (AL-Talih, Hashab AL-Damazeen and Hashab Abu Jibaihe) is presented below:

I- TEMPERATURE RANGE (30° TO 50° C):

The following is clear from table (2): For the **GUM AL-TALIH** that the apparent/plastic viscosity, yield point, the gel strength, the filtration and the ratio of Y_p/μ_p properties all increased for the different Gum percentages except filtrations 17.15% and Y_p/μ_p for 13.44% and 17.15% that were unstable. There was a general decrease of the coefficient of friction for the percentages except 13.44% which only showed an initial decrease.

For **GUM HASHAB DAMAZEEN**, Generally, apparent/plastic viscosity, Gel strength and coefficient of friction 9.4% and 17.15% showed a decrease.

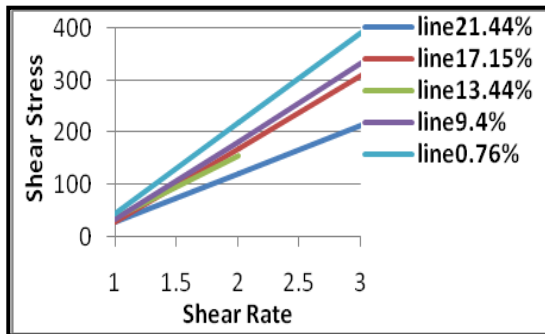


Figure 1: AL-TALIH GUM Bingham Plastic model fluid Behavior.

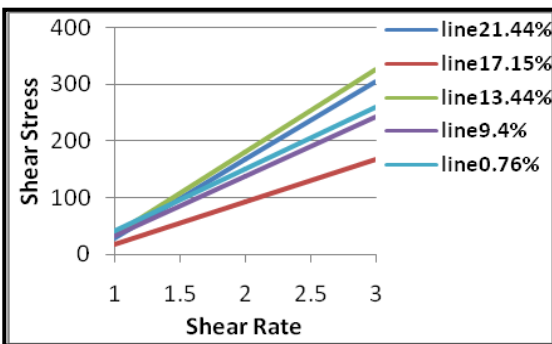


Figure 2: ABU JIBIAHE GUM Bingham Plastic model fluid Behavior.

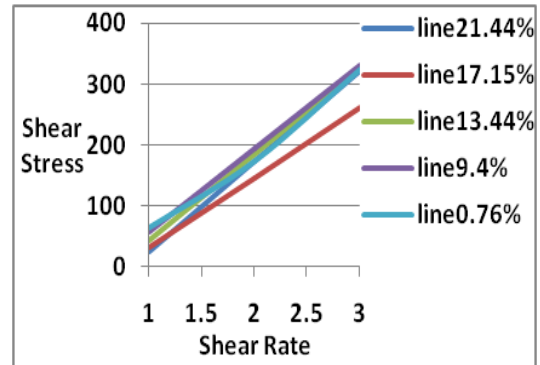


Figure 3: AL DAMAZEEN GUM Bingham Plastic model fluid Behavior.

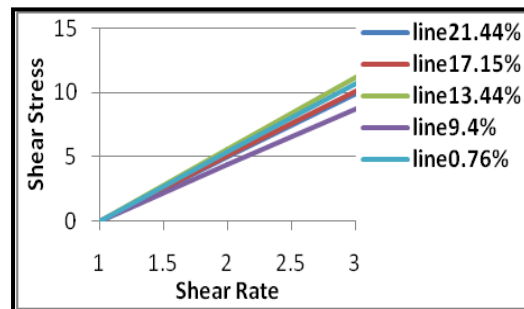


Figure 4: AL-TALIH GUM Power Law model fluid Behavior.

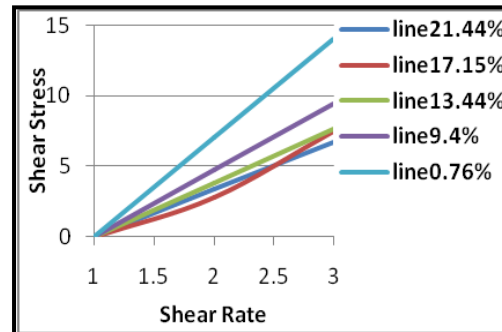


Figure 5: ABU JIBIAHE GUM Power Law model fluid Behavior.

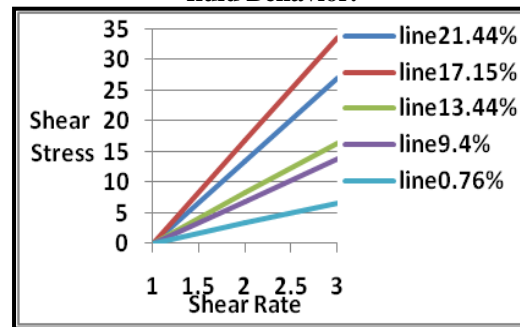


Figure 6: ALDAMAZEENGUM Power Law model Fluid Behavior.

Furthermore, the yield point, filtration and the other percentages of the coefficient of friction showed an increase although there was instability for Gel strength 13.44% and 21.44% and yield point 17.15%. There was stability for the ratio of Y_p/μ_p and notably for filtration 9.4%. For **GUM ABU JIBIAHE** was founded that the apparent and plastic viscosity decreased except percentage 13.44% that increased.

The Yield point, gel strength and filtration were increased beside Yield point for 9.4% and 13.44%, gel strength 0.76%, 21.44% and filtration 13.44% and 21.44% were decreased. The ratio Y_p/μ_p for the gum percentages was generally stable; the coefficient of friction showed that there was general stability with intention to increase around 40° C.

II- TEMPERATURE RANGE (50° TO 80°C): Medium temperature range of Table II was subjected to a detailed analysis; for **GUM AL-TALEH**, the following was noted: Generally, Apparent/plastic viscosity and Filtration 17.15% decreased. However, there was instability of apparent/plastic viscosity 0.76% and 9.4% as well as Gel strength 9.4%, 13.44% and 17.15%. The Yield point and The Y_p/μ_p ratio were similarly unstable. Other percentages of Gel strength, filtration and the Y_p/μ_p ratio 21.44% were semi-stable. Co efficient of friction showed significant stability. **GUM HASHAB DAMAZEEN:** Notably, Apparent/plastic viscosity and Filtration 9.4% decreased. However, there was instability for the Yield point, Gel strength 9.4%, 17.15% and 21.44%, Apparent/plastic viscosity 9.4%, 17.15% and 21.44% and Filtration 17.15%. Conversely, the other percentages of the gel strength, the Filtration and percentage 0.76% of Yield point increased. Co efficient of Friction was stable, though with fluctuations. **GUM ABU JIBAHASHOWED:** Apparent and plastic viscosity of all the percentages decreases then increases but conversely sample 0.76% increases then decreases. The yield point, gel strength and filtration were totally unstable but notably, percentage 0.76% was stable and percentage 13.44% showed a dramatically decrease.

III: HIGH TEMPERATURE RANGE (80° TO 100°C)

High temperature range of table (2) was subjected to a detailed analysis. **GUM AL-TALIH:** Generally, The Apparent/plastic viscosity, filtration, the Y_p/μ_p ratios and Yield point 21.44% decreased. But, Apparent/plastic viscosity 0.76% and 9.4%, the Y_p/μ_p ratio 0.76% and the other percentages of Yield point increased. Although, Y_p/μ_p ratio 9.4% and 13.44% showed an initial increase. The Gel strength and Co efficient of Friction showed that there was a degree of stability in behavior though with slight increase or decrease. **GUM DAMAZEEN HASHAB:**

Apparent/plastic viscosity, Gel strength and The Y_p/μ_p of the fluid increased with increasing temperature, but 0.76% and 13.44% of The Y_p/μ_p ratio initially decreased and later increased. Generally, Yield point and filtration were stable although percentages 9.4%, 13.44% and 17.15% of Yield point were unstable and percentages 0.76% and 13.44% of filtration initially decreased. **GUM ABU JIBIAHE:** The Apparent/plastic viscosity, Yield point, Co efficient of Friction and the Y_p/μ_p ratio 13.44% and 21.44% decreased. The apparent/plastic viscosity 9.4%, Gel strength, the other percentages of the Y_p/μ_p ratio and the Filtration increased. Although, Filtration 21.44% was stable. Yield point 21.44% was however, unstable.

Additionally, from the above Bingham plastic and Power law models; Figures 1 to 6 the following points were noticed about the behavior of drilling fluids:

- i. Bingham plastic figures show that it is stable Non-Newtonian type of fluid used throughout all the tested samples.
- ii. Power Law figures show the change of fluid behavior as stable Pseudo plastic fluids throughout all the tested samples.
- iii. The two models show the behavior of flow as “stability”. The best stability was when 0.76% and 21.44% of AL-Taleh and Abu Jibaihe were used .AL- Damazeen however had its best stability when 0.76% and 9.4% were used.

CONCLUSION

The use of gum Arabic in Drilling fluids for water-based fluid which consists of Bentonite as a basic material has shown an impact on the properties of the fluids. This is applicable for the three types of Gum (Al-Taleh, Al-Damazeen and Abu Jibiahe), their use as an additive could improve the properties of the drilling fluid as explained below:

1. Apparent and plastic viscosity were increased all throughout the low temperature range, which means an increase in the wellbore stability by reducing the risk of swabbing but with a major decreasing of flow rate and high pump pressure. Between 50° to 80°C (mid range) these AV/PV properties were stable with high percentage of hole cleaning and the best functioning of the fluids. Apparent and plastic viscosity however decreased all throughout the high temperature range.

2. Yield point showed an increased behavior between 30° to 50°C. This means: a tendency to decrease the pressure inside the drill string i.e. (increase hydraulics in the bit). Such a tendency is stipulate to cause Laminar flow and increase cutting transport percentage. The Yield point, though was unstable within the mid temperature range. Nonetheless it decreased all throughout the high temperature range. This decrease could lead to inadequate suspension of cuttings.

3. Gel Strength increased between temperatures of 30° to 50°C. This increase could lead to inadequate suspension of pumping operation and also causes swabbing when the pipe is pulled out. But between points 50°C to 80°C, the Gel strength was unstable. Between 80°C to 100°C the Gel strength was stable which leads to high efficiency of fluid performance.

4. The Filtration loss increased between 30° to 50°C tending to cause problems such as formation damage, hole collapse, caving, fracturing, dispersion of clays and may lead to pipe sticking. The Filtration loss was semi stable though 50°C to 80°C with a decrease between points 80°C to 100°C. A decreased in Filtration loss through the high temperature range showed the best behavior to minimizing shale hydration

and dispersion and also for the successful running and retrieval of logs.

5. The ratio of YP/μ_p generally increased between 30° to 100°C. This means that the fluid in drill pipe would have low viscosity and bottom hole. At the same time it would have high viscosity in another place away from the wall. This condition corresponds to the best fluid properties.

6. The coefficient of friction (ϵ) was decreased for Al -Taleh Gum, slightly increased when using Al-Damazeen Gum and was stable when using Abu Jibiahe Gum. This means that reducing problems caused by pipe sticking meanwhile, improving behavior and efficiency of fluid.

7. Bingham Plastic and Power Law Models Figures (1 to 6) showed the extent of pseudo plastic stability fluids behavior.

Finally, it was clear that the Gum Hashab Damazeen is the best of the three kinds of gums for overall temperature ranges analyzed. Therefore, this Gum (Hashab Damazeen) could be recommended to be used as an additive for water based fluid.

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