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Primary Evaluation of the Sudanese Guar Gum with respect to the Hydraulic Fracturing Fluid

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Abstract— Hydraulic fracturing has been used as stimulation technique to improve the productivity of hard, brittle formations and soft formations for more than 60 years. The technique involves pumping of a viscous fluid to create a fracture; the major consideration for the fluid selection is usually viscosity, which can be achieved by thickening agent. The common thickening agents on the market are mainly guar, the -modified hydroxypropyl guar gum and xantha gum. The good properties of the guar made its demand raised considerably. This paper presented evaluation of the local Sudanese guar gum with respect to fracturing fluid. A series of standard laboratory tests were performed for the first time to address the performance of the guar gum itself and the fluid prepared with different concentrations of guar and different additives at different temperature and share rates. The fluid exhibit a good stability with time at 65 oC; also high returned permeability was obtained when the fluid was used to saturate core samples obtained from different wells in Fulla North Oilfield in Sudan..

Index Terms— Fracturing Fluid; Thickening Agents; Additives; Viscosity Stability

1 Introduction

Since its inception in 1947 hydraulic fracturing has proven to be an effective and widely accepted stimulation technique to increase or restore the rate which fluids can be produced from the formation. This technique has been used to simulate hard, brittle formations; nonetheless, an increasingly important segment of the industry is currently stimulating very soft and poorly consolidated formations. The physical process of the treatment involves pumping of a viscous fluid to create a fracture and injecting proppant slurry to hold the fracture opening after the hydraulic pressure is removed. The major consideration for fluid selection in Fracturing treatment is usually viscosity, that the fluid must have sufficient viscosity to create fracture wide enough to place high proppant concentration necessary for highly conductive fracture. Also the fluid viscosity must be enough to suspend proppant under the high shear stress. Another important issue is the pressure drop in the pipe and suitable surface pump pressure during fracturing. Other considerations that may be major for particular cases include the compatibility with reservoir fluids and rock.

The fracturing fluid is mainly categorized to Gelled fluids, Foamed gels, or Acids one. On any one fracturing job, different fluids may be used in combination or alone; based on formation characteristics, the engineers will devise the most effective fracturing scheme. Proper selection of the optimum fluid for a particular situation requires the judicious use of fracture and reservoir simulators. The gelled fluids can be Linear Gels, Cross-linked Gels or Foamed Gels. For low permeability formation Wine et al [11] presented that forecasted cumulative production of wells fractured with guar and HPG are similar; the selection of the best fluid will be depend on the Net Present Value .

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A substantial number of fracturing treatments are completed using thickened, water-based linear gels. The gelling agents used in these fracturing fluids are typically guar gum, guar derivatives such as (HPG) and (CMHPG), or cellulose derivatives such as (HEC). Another type of polymer is xanthan gum which can suspend sand better than HPG; however it is more expensive than guar or cellulose derivatives. Currently, more than 65% of all fracturing fluids are water-base gels viscosified with guar or hydroxypropylguar. Guar and its derivatives is have low formation damage as it have low residue; while the powder guar has less than 2% residue, the derivatives guar has less than 0.5 % residue. (Economides -2007)

The good properties of the guar made the demand for guar gum raised considerably not only in the oil industry but also in the food and textile industry. The world leaders for exportation of guar are India and Pakistan; however, some other countries (Sudan, South Africa, U.S.A. and Brazil) have also good conditions for the cultivation of guar.

Due to the variation of the cultivation conditions of the guar, the guar properties is varying for one product to other; therefore, it is worthwhile to evaluate the properties of the gum itself before formulating cross-linking fluid systems.

Guar gum is used as a gelling agent with different pH range depending on the type of the cross-linkers. Borate ion can perform an extremely viscous gel in a matter of seconds for pH above 8. The optimum stability of the cross-linked gel can be achieved with a pH of 10 to 12 [1]. Several fluid additives have been developed to enhance the efficiency and increase the success of fracturing fluid treatments such as Biocides, Breakers, Friction Reducers, Fluid-Loss Additives and Corrosion Inhibitors. The type and amounts of these additives must be balanced to achieve such properties as high viscosity, formation compatibility, appropriate breaker times, and complete return of the spent fluid.

In general, proppant transportation can be done by one of two ways: either Increasing the fluid viscosity or high flow rate which performs turbulent flow. Viscous fracturing fluid, gelling agent is dissolve in a carrier fluid such as water or diesel fuel. Concentrations of guar gelling agents within fractur-

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ing fluids have decreased over the past several years. It was determined that reduced concentrations provide better and more complete breaks in the fractures [3].

This paper evaluates the local Sudanese guar gum to be used as fracturing fluid in a Sudanese oilfield have a maximum temperature of 65 ^{o}C.; although the gum has good markets in and out of Sudan; however it was not evaluated yet for hydraulic fracturing purposes.

2 Instruments and Experiments

2.1 Preparation of the Material

All the sample of the Guar Gum used her is produced by the Guar Gum Company, Sudan. Guar gum was obtained as dry powders, and then dissolved in the water with diffrentconcentrations. Borax ions were used as a cross-linker due to its extensive application in low temperature wells and its diverse cross-linking characteristics in low temperature reservoirs.

2.2 Moisture Content in Powder

Before starting the preparation of the gum solutions, Moisture Content was measured according to SY/T 5764 [7] using Moisture Content Detectors; for more accurate result the test was repeated 4 times and the result was recorded to obtain the average.

2.3 Insoluble Components Measurement

Different concentrations solutions were tested to estimate the insoluble components according to and SY/T 6296 [8] and SY/T 6376 [9]. First the solutions was placed in a centrifuge tube then centrifuged; then upper clean solution in tube was dumped out and distilled water was added to the sold residual in the tube and stirred with a glass rod; the mixture was centrifuged again and the top solution in tube was also dumped out; the tube was kept at high temeartautre to totally dry the residual. Finally the sold residual was weighted, and then the insoluble components were calculated as percentage of the total weight.

2.4 Viscosity Measurements

RT 20 HAAKE rotational viscometer was used to estimate the fluid viscosity and fluid rheology in accordance with SY/T 5107 [6]. To study the stability of the fluid, the fluid was heated to reservoir temperature; then fluid-viscosity was recorded for 120 minutes at constant shear rate. Other tests were performed to optimize the effect of Bactericides on fluid viscosity.

2.5 Static Proppant Settling Measurement

Static proppant settling was first tested at room temperature; the fluid was prepared at the different concentration then cross-linked with the recommended amount of cross-linker; and then packed into cup; a single particle sand was placed into fluid to observe the single particles' settling velocity. Then to simulate the reservoir condition, the sample was placed into a heated water bath to achieve the required temperature, after stringing, the mixture kept under static condition at reservoir temperature and the settling velocity was then observed [4].

2.6 Fluid Broken Characteristics

Breaker is used to degrade the fracturing fluid viscosity, which helps to enhance post-fracturing fluid recovery. Ammonium Per-Sulfate (NH4)2S2O8 (APS), was used to break a liquid with a viscosity of 370 mPa.s was mixed with APS by different ratios at room temperature and stirred then heated to reservoir temperature according to SY/T 5764; during the heating the viscosity of the mixtures were recorded with time.

2.7 Clay Stabilizer Test

Clays are generally not dispersed as long as their chemical environment is not changed. For this reason, brines are not nearly as damaging to sandstone as is fresh water. Ammonium chloride, potassium chloride or sodium chloride will stabilize clays and prevent swelling. According to SY/T 5971-94 tests were conducted using centrifuge; different KCl concentration was mixed with fluid , then the mixtures were kept under static condition at room temperature; the mixtures then centrifuged and the Bentonite volume (V1) was recorded; The procedures was repeated using fresh water and kerosene to obtain the volume of the Bentonite in the water (V2) and in the kerosene (V0); the clay stabilizer efficiency was calculated as follows:

$$B1 = (V_2 - V)/(V_2 - V_0) \times 100\% \qquad (1)$$

2.8 Core Damage Test

According to SY/T 5107(1995), formation damage measurements were performed on a multipart high temperature and High pressure flow cells. The sample length was measured, and then the core permeability of the samples before damage was first measured using refined kerosene at several rates ranging from 0.5 to 1 cm3/s. Then permeability of core sample K1was calculated with Darcy equation. The direction of flow was opposite, and the broken liquid was pumped into the core. Following fluid loss, the cells were shut-in for one hr to allow the liquid to fully penetrate to the core. The permeability after damage, K2 were then measured using also refined kerosene and Darcy equation, The core damage rate was determined as follows:

$$\text{Damage Rate} = (K_1 - K_2)/K_1 \times 100\% \qquad (2)$$

3 Results and Discussion

3.1 Basic Properties of the Dry Gum

The result of testing the basic properties indicates that the Moisture Content is 9.0% and the Insoluble Components is varying from 18.8 to 21.7 % for the different gum concentrations; the initial pH of the fluid without additives is 7.0. When comparing this result with the standard stated by to SY/T 5764 [7] it was founded that the basic properties of the gum with in acceptable rang and the gum can be categorized as good thinking agent. The following section presented the result of evaluating the properties of the fluid performed using this gum.

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3.2 Effect of Different Components Concentrations

Fig (1) is the result of the experiments performed to address the effect of the different gum concentrations on fluid viscosity; the figure shows that, to achieve a viscosity of up to 200 mPa.s at 65 oC, the optimum concentration of the gum need to be above 0.30%. The test result of optimizing Bactericides concentration indicates that concentration of 0.1% Bactericides is required; below this value, the fluid viscosity decreases due to the Bacteria effect; on the other hand for value more than 0.1% the effect of the Bacteria can be neglected.

The result of optimizing the Sodium Borate concentration shows increasing in fluid viscosity with the increases of the cross-linker concentration; however, 0.06% concentration is required to obtain a viscosity of up to 200. mPa.s at 65 o. Likewise, tests were run to optimize KCl concentration as previously discussed; the result was presented in Table (1), from the result it is clearly shown that with increasing the agent concentration, the efficiency is in rise increase. The experiences showed that the best efficiency needs to be above 80% to obtain a good fracture job.

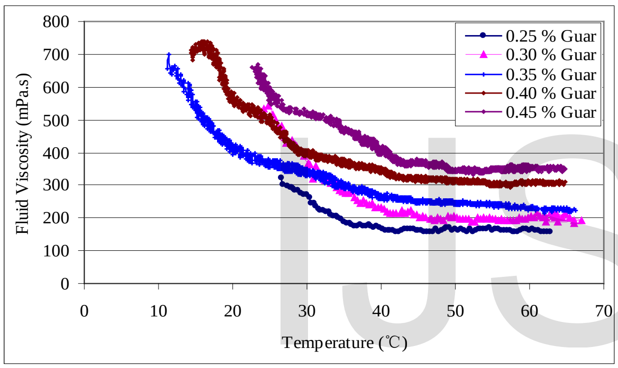

Fig.1. The effect of Temperature on Fluid Viscosity

3.3 Effect of Temperature on Fluid Viscosity

Viscosity was measured at different temperature as presented in Fig (1). The figure shows that at 15 ºC to 65 ºC, as the temperature increased, the viscosity of fluid decreased; and the lowest viscosity remains more than 200 mPa.s for concentration above 0.3%. Fig (2) presented the fluid-stability test under constant shear rate; from the figure the maintained fluid viscosity is 210mPa.s with a good stability.

3.4 Evaluation of the Fluid under Different Shear Rate

Rheological characterization of a non-Newtonian fluid requires that the apparent viscosity can be calculated under the different shear rate in the fracture. Fluid without breaker was tested to address its response for shear rate. Fig (3) presented that the fluid is following the typical non-Newtonian behavior; behavior index (n/) was found between 0.4498 to 0.61 for the different concentrations, while consistency index (K/) is 6.133 to 15; hence, the fluid can be categorized in shear thinning fluid of the power law model which is the most widely used to represent fracturing fluid behavior in fracture design simulators

TABLE 1
EFFECT OF KCL CONCENTRATION ON CLAY VOLUME

Fluid	Kerosene	Water	0.00 KCL	0.05KCL	0.10 KCL	0.15 KCL	0.20 KCL
Clay Volume	0.5	3.37	1.8	1.3	1.2	1.0	0.87
Efficiency	---	----	54.70383	72.12544	75.60976	82.5784	87.10801

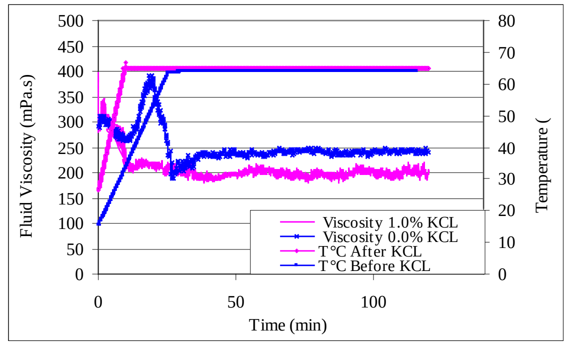

Fig.2. Stability of the Fluid with Time (0.35% Guar

3.5 Sand Carrying Properties

Following the procedures described through section 2.5, the settling velocity of single sand is 4.86×10^{-2}mm/s. The particles settling velocity of the 2 gram sand is approximately 1.46×10^{-1}mm/s. According to Huang experiences [2], which presented that the pest fracturing fluid should have settling velocity of 0.08~0.18mm/s, this results indicate that the fracturing fluid has a good sand carrying ability.

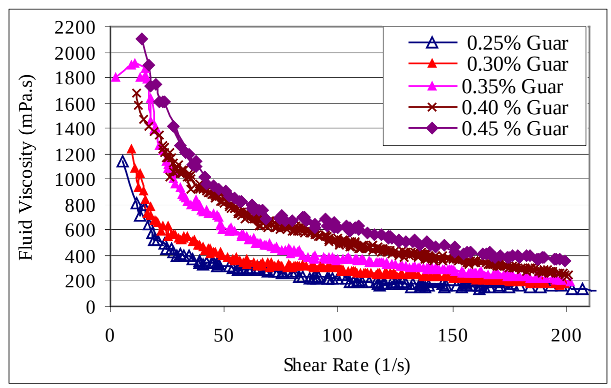

Fig. 3 The of Shear Rate on the Fluid Viscosity

3.6 Breaker Concentration

Test result showed that, a good gel-breaking was obtained by the APS Breakers; the lowest viscosity was achieved at the higher breaker concentrations. Fig (4) the broken time achieved by higher concentration is less than 30 min, and a good gel-breaking was obtained. Schlumberger [5] presented that five times the expected pumping time is a good starting place for fluid broken time hence the optimization of the concentration will be done according to the time need to create the fracture.

3.7 Core Damage and Returned Permeability Test

A very important consideration in fracturing job is the returned permeability which insures the effect of the fluid in the formation permeability. Using the procedure described in section 2.8; the global permeability, the returned permeability and core damage of the core samples was measured at room conditions; result shows that, the permeability of the sample before damage is 588 um², after damage the retuned permeability is 462 um², with core damage of 21.57%. As stated by Willberg et al. [10], only 30 - 45 % of the guar-based polymer fracturing fluid can returned back from the well during flow back period. These unbroken residues from polymer-base fluids can indeed plug the pores of the proppant pack. For low permeability formation; the above result presented shows that the fluid can result in high returned permeability due to low formation damage.

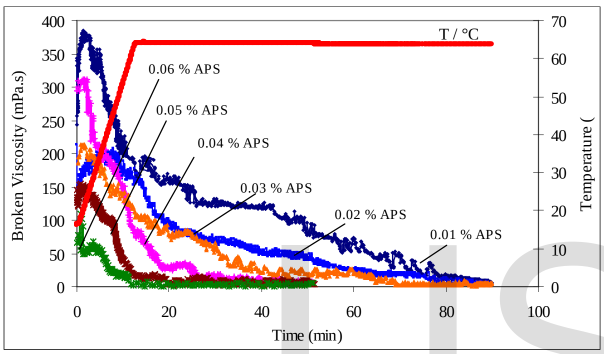

Fig.4.. Effect of APS on the Fluid Viscosity

4 Conclusions

Based on this work it can concluded that Sudanese guar gum has the ability to perform a good fracturing fluid with acceptable damage and acceptable retained permeability and it can be used to obtain a good fracturing job.

The gum is sensitive to temperature; however a fluid with a good stability and viscosity up to 200 mPa.s with can be obtained at 65 oC

Since this study is first developed to evaluate Sudanese guar gum, additional research including the fracture fluid losses and leak-off and conductivity damage tests may yield healthy profits and improve the economic returns.

Acknowledgment

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