International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 10 | Oct 2018 www.irjet.net p-ISSN: 2395-0072

# EFFECT OF SHALE ON THE BASIS OF ITS PARTICLE SIZE, ON THE RHEOLOGY OF SODIUM FORMATE DRILLING FLUID

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**Abstract -** *Drilling formations rich in shale have always led to widespread complications due to which expenses involving the drilling operation of shale formations have been high. However, shale though is known to be a fine grain sedimentary rock and occurs in extensive sheets, segregates into unalike particle sizes due to the action of drill bit on the formation. Along with the concentration of shale in water based mud (WBM), the influence of shale on the rheology of WBM was also found to be dependent on the particle size of shale grains. Sodium formate drilling fluid, a polymer WBM having considerable inhibitive properties was contaminated with different particle size of shale from Upper Assam basin in India in varying concentrations ranging from 1% to 5%. It was inferred from the study that at the same concentration, with increase in the particle size of shale grains from 325 ASTM to 80 ASTM, the effect of shale on the rheology of the WBM increased. To counter complications arising from drilling shale formations, proper formulations of drilling fluid is obligatory for efficient drilling job*

***Key Words*: Shale, Sodium Formate, OBM, WBM, Rheology**

## 1. INTRODUCTION

Drilling a well for producing hydrocarbon involves a lot of challenges obstructing the effectiveness of the operation and raises the costs of the drilling work. The primary task prior to drilling a well is the proper selection of a drilling fluid. The performance of drilling fluid is evaluated in terms of providing good wellbore stability and faster drilling rates through various sedimentary layers like clay, shale, limestone etc.

Water based mud (WBM) are widely being used due to the cost and environmental factors. However it is pertinent to mention that by overall performance, WBM are not as efficacious as oil based mud (OBM) or synthetic oil based mud (SOBM). Hence, there is a necessity to formulate WBM with excellent parameters in par with OBM/SOBM. To counter the change in properties due to contamination by shale, polymer WBM is being used.

Sodium formate drilling fluid, a polymer WBM having considerable inhibitive properties was contaminated by typical shale sample from the upper Assam basin in India. The detailed problems involving drilling shale formations and the composition of the drilling fluid used are being analyzed below.

### 1.1 PROBLEMS ATTRIBUTABLE TO SHALE FORMATIONS

Shales are fine grain sedimentary rocks having low permeability and medium porosity. They are composed of clay, silt and may also contain traces of fine sand. Since more than 75% of formations drilled are shale formations, hence a large amount of cost is attributed to shale instability problems. Shale is highly sensitive to water, hence it hydrates and swells; shale cuttings in the well become tenacious and thus form a cluster, or can stick to the drill string down hole.

The annulus can thus be blocked leading to stuck pipe or swabbing. Swelling occurs due to an increase in size of the silicate minerals increasing the clay structure leading to hole destabilization. On the surface, sticky hydrated shales can plug up the shale shaker screens, causing loss of mud over the shakers. The solutions include getting WBM chemistry correct to prevent shale hydration

### 1.2 DRILLING FLUID USED IN THE STUDY

Oil based muds (OBM) are noted for their effectiveness to encounter the wellbore problems which arises as a result of drilling shale formations. Nonetheless, uses of OBM have led to problems involving costs, mud disposal difficulties and environmental restrictions. Thus, WBM having ability to reduce shale instability problems have come into limelight in the recent years. Formates based fluids for example, are biodegradable, have reduced rate of degradation at high temperatures and are much less influenced by problems in shale formations.

A similar formate based WBM; sodium formate drilling fluid has been used in the study. Sodium formate fluids are non-corrosive organic monovalent fluids and offer a number of performance benefits over traditional divalent brines. The study showed us how shale can affect rheology of such WBM even after having good inhibitive properties.

**PROPERTIES OF SODIUM FORMATE DRILLING FLUID**

| | |
|---|---|
| Higher density | Sodium formate fluids can reach 10.8 ppg at saturation. Sodium formate is 49% w/w soluble in water. |
| Environmentally friendly | Sodium formate fluids are comparatively very less harmful to the environment with respect to other drilling fluids. |
| Non damaging | Sodium formate fluids are monovalent and do not react with reservoir water to form precipitates. |
| Thermally stable | Sodium formate fluids are stable at higher temperatures. |
| Lubricious | Sodium formate fluids exhibit lubricity characteristics equal or exceeding those of OBM. |

**COMPOSITION OF SODIUM FORMATE DRILLING FLUID**

| |
|---|
| Sodium formate (42 % w/w) |
| Xanthan gum (0.3%) (To thicken the drilling mud) |
| Polyanionic cellulose (PAC-R) {0.5%} [Filtration control additive] |
| Polyanionic cellulose (PAC-SL) {0.4%} [Filtration control additive] |
| Polyol ( Shale and gas hydrates inhibitor) |
| Calcium carbonate (Weighting agent) |
| EP lube (For lubrication) |

**Density of the drilling fluid used: - 10.29ppg**

## 2. MATERIALS AND PROCEDURES

Shale samples that were obtained were crushed with agate mortar and then separated into three different samples on the basis of their particle size. Three sizes were being considered, 80 ASTM (180 micron), 170 ASTM (90 micron) and 325 ASTM (45 micron). Fresh sample of Sodium Formate drilling fluid was taken. In each step, we measured 200 ml of the drilling fluid sample and mixed shale in increasing concentrations from 1% to 5%, for different particle sized samples.

The concentrations of shale added were in regard to weight of shale/ volume of mud. These tests were conducted for two temperatures. First the drilling fluid was heated to 86°F and then to a higher temperature of 122°F. Fresh sample of drilling fluid was taken for each step throughout the tests and no sample of the drilling fluid was reused. After shale sample of particle sized 80 ASTM was mixed with the drilling fluid for two temperatures with gradual increase in concentrations (1%,2%,3%,4%,5%), the plastic viscosity, yield point, gel 0 and gel 10 values were evaluated and the trend in its changing values was observed. The same procedure was then carried out for 170 ASTM and 325 ASTM particle sized shale samples.

## 3. RESULTS AND CONCLUSION

After addition of shale, changes in rheological properties were observed as expected. However it is pertinent to mention that larger particle sized shale samples were more effective in changing the rheological properties of the drilling fluid.

As can be seen in Figure 1, plastic viscosity of drilling fluid increased with increase in concentration of the shale. Plastic viscosity is an indication of solid particles like clays which hydrate as their volume increases with hydration. From figure 1, for 80 ASTM particle sized shale addition, it can be inferred that increase in plastic viscosity of drilling fluid is 58.9% from 0% to 1% (17.8 cp at 0% to 28.3cp at 1%), 6.007% from 1% to 2%, 5.3% from 2% to 3%, 2.2% from 3% to 4% and 7.4% from 4% to 5%.

For 170 ASTM particle sized shale addition, increase in plastic viscosity is 15.16% from 0% to 1%. For 325 ASTM particle sized shale addition, increase in plastic viscosity is 11.79% from 0% to 1%. Hence, it is evident that 80 ASTM sized shale samples are the most effective and 325 ASTM sized shale samples are least effective in changing the plastic viscosity of drilling fluid.

As shale is initially mixed at 1% concentration, there is a sudden spurt in plastic viscosity and the rate of increase decreases with increasing concentration, however value of plastic viscosity increases.

As can be inferred from the subsequent figures, despite the fact that Sodium Formate drilling fluid has adequate inhibitive properties, larger particle sized shale can nonetheless influence the plastic viscosity of the drilling fluid to a large extent. Furthermore at 86°F, smaller particle sized shale decreases the yield point of the drilling fluid whereas larger particle sized shale sample is not as effective as smaller particle sized sample in decreasing the yield point. Alternatively, 80 ASTM shale samples increases the yield point of the drilling fluid from 2% concentration.

GEL values can also be seen increasing with increase in shale concentration and particle size of shale sample. The effects in rheology of the drilling fluid upon addition of shale can be analyzed even more effectively from the subsequent figures.

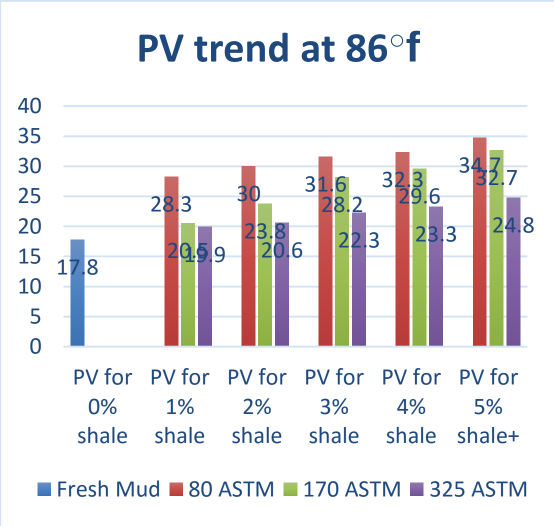



**FIGURE 1**

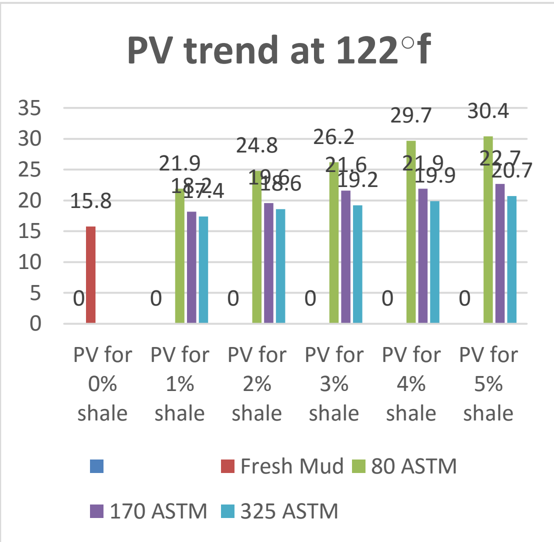
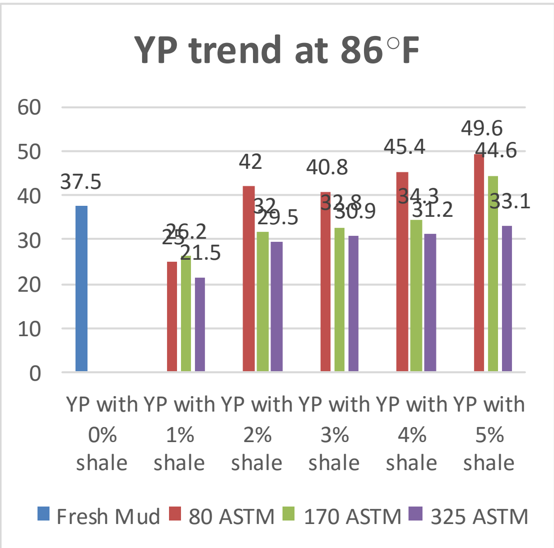



**FIGURE 2**

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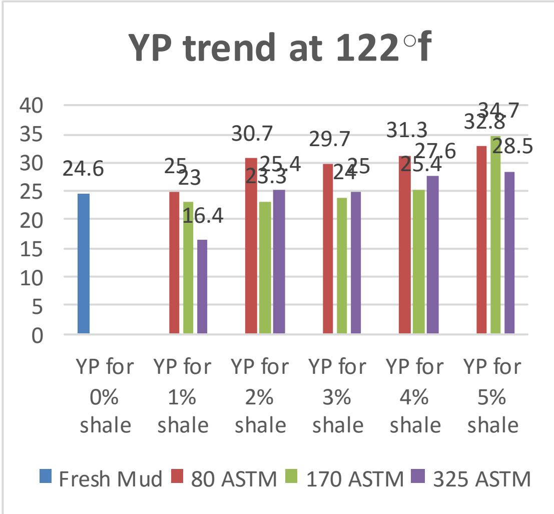


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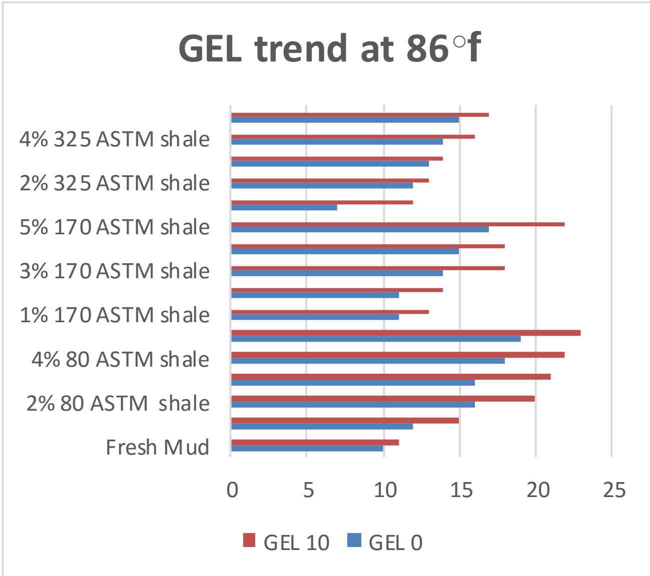


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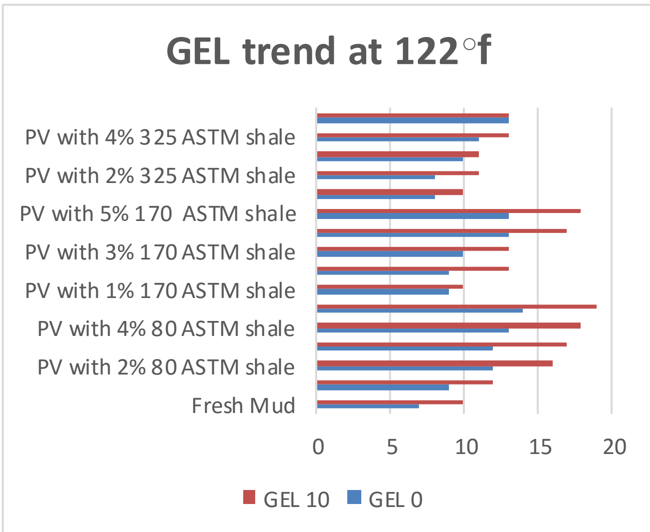


**FIGURE 6**

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