Determination of Rheology of Drilling Fluid for HPHT Wells

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Abstract: During drilling operation, many challenges are faced in context of drilling mud performance. With the increase in depth temperature and pressure unwanted impacts on drilling fluid. In addition, usually at higher temperature and high pressure the additives and polymers are not too effective. Keeping in view that problem, we have conducted experimental study on HIPOLY based drilling mud for high temperature conditions. In this research rheological properties of HIPOLY polymer base fluid are determined at wellbore conditions in order to check sustainability and performance of drilling fluid at elevated temperature and pressure. Rheological parameters of HIPOLY based drilling fluid samples at eight different concentrations were measured at laboratory. The usage of Hipoly in drilling fluid will ameliorate its working as viscosifier agent in HTHP conditions that improves the API property of drilling fluid up to 180 ºC.

Keywords: *Drilling fluid, rheology, polymer, plastic viscosity, HPHT*

1. Introduction

Drilling is the most complicated and difficult operation in petroleum industry, challenges increase with the increase of depth and changed lithology. In order to make drilling operation successful drilling mud must be designed in such a way that it may work smoothly and should not degrade at HPHT conditions. Since beginning various additives have been used which alter the properties of drilling fluid. The increasing number of additives increases the operational cost as well as decreases the overall properties of drilling fluid.[1] To curb this problem industry is using different type of polymers as additives which not only reduces the cost but also enhance the performance of drilling fluid. for instance, HEC, CMC, HPMC, Guar Gum, xentham gum and surfactants are used as polymers.

However, it is seen that numerous n polymer-based drilling fluids degrades with increase of temperature and pressure of wellbore with respect to depth. Such deterioration of polymer base fluid poses a difficulty in drilling operation. Therefore, to cop this difficulty this research was conducted and HIPOLY polymer was used in drilling fluid. It serves dual functions-being thermal resistive and as well as fluid loss agent[2]. In order to evaluate its performance and compatibility its rheological properties are determined with eight different concentration at elevated temperature. Tests were carried out to observe changes not only in rheological parameters like viscometer readings, but also in mud weight, pH, fluid loss and filtration cake.

This study will help to use HIPOLY polymer as additive in drilling fluid as various tests were conducted at different concentration and temperature. it implies that HIPOLY polymer not only saves the cost but also maintains its originality and working performance at High temperature and pressure

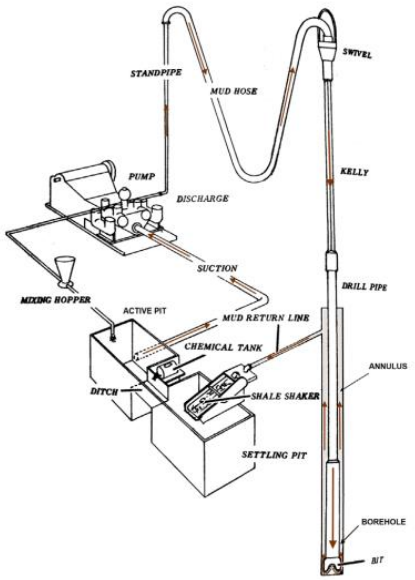

Fig. 1.1 Drilling Fluid System

2. Literature Review

In various studies are carried out in order to mitigate the challenge of thermal degradation of drilling fluid at elevated temperature.Biopolymer like Strach and Guargam does not work properly at elevated temperatures.[3,4]Thermal decomposition of biopolymers results in a loss in filtration control, suspension and viscosity.Unfortunately, all biopolymers lose viscosity at

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temperatures higher than 300ºF due to thermal decomposition.[5]

A multitude of very similar definitions for a HTHP drilling project exist in the literature. According to Proehl and Sabins (2006), a typical HTHP project is one wherethe bottom hole static temperature (BHST) is expected to reach more than 350oFand the bottom hole static pressure (BHSP) is in excess of 24500 PSI. Buchan (1993),provides a more conservative threshold based on the original Department of TradeIndustry de_nition for the United Kingdom Continental Shelf (UKCS) and states thata HTHP well \is any well where the undisturbed bottom hole temperature at totaldepth or prospective reservoir section is greater than 300oF and the anticipated porepressure exceeds a hydrostatic gradient of 0.8 psi/ft. or pressure control equipmentwith a working pressure of greater than 10000 psi is required.[5]

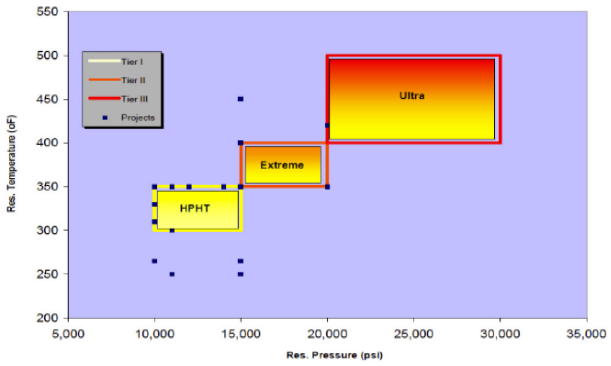

Fig 1.2 Classification of HPHT Wells.

According to Nasser et al during the drilling operation in deep reservoirs, to minimize the cost of drilling fluid and to ensure a well-organized drilling program, the rheological properties must be maintained continuously.[6,7] Following are the major functions of drilling fluid in drilling operations:

1. Control subsurface pressures, maintaining well control
2. Remove drilling cuttings from beneath the bit and circulate them to the surface
3. Maintain wellbore stability, mechanically and chemically
4. Cool and lubricate the drill string and bit
5. Allow adequate formation evaluation

To study the rheology at HPHT conditions, HUI Zohav mixed the two polymer that rare stable at 140 C. But it was observed that high viscosity of polymers shows rheology problem and creates problem at the time of pumpability. [1,7,8]

Therefore, in petroleum industry there is no such type of polymer that single works as viscosifying agent. Amani et al investigated the influence of HTHP on the viscosity of oil-based muds and water-based muds.[9,10] The aforementioned studies showed that the rheological properties of the selected drilling fluids subjected to these conditions and these changes might have an undesirable influence on the drilling fluid's functions.[11,12]

3. Methodology

In this research HIPOLY polymer was tested at laboratory with various equipment. all tests were conducted at laboratory.

3.1 Material selection:

Drilling mud cannot be prepared without use of additives such as viscosifying agents, inhibitor for this research an additive named HIPOLY was used for preparation of drilling fluid. That was water base mud and its components are given below.[14]

Additive name	**Function**
Water	Base fluid
Sodium hydroxide or caustic soda (NaOH)	It is used for controlling the alkanity (PH) of water base mud
SODA ASH(Na2CO3)	Source of carbonate ions through which PH can be increase in drilling mud
Defoamer	Antifoaming agent
Potassium chloride (KCL)	Shale inhibitor (protect from swelling)
Calcium carbonate (CaCO3)	Weighting agent (build mud cake)
Barite (BaSO4)	Weight material
Hipoly polymer	HIPOLY is used as High-temperature viscosifying agent in a drilling mud.

Table 1.1 Additives of drilling fluid

3.2 DETERMINATION OF RHEOLOGICAL PARAMETERS OF HIPOLY BASED DRILLING FLUID

The following parameters were determined at various temperature in order to analyse the effect of HIPOLY as viscosifying agent. So, all parameters of polymer are

evaluated in accordance with API standards to achieve the best results.[7,15]

1. Mud density with mud balance.
2. Viscosity with HTHP Viscometer
3. For roller functionality & heat, roller oven is used
4. Aging test with fann aging cell
5. Drilling fluid evaluation and filter loss with HTHP filter press
6. Power of hydrogen with help of pH meter

Fig 3.1 HPHT Viscometer used to measure Viscosity

Fig 3.2 Mud balance

There are many weighting agents available that server serval purposes during drilling operation as shown in below given table: [17,18]

Material	Sp.gravity
Galena	7.4-7.7
Haematite	4.9-5.3
Magnetite	5.0-5.2
Barite	4.2-4.6

Table 2.1 Common weighting agents

The main object of this work is:

- To find out the effect of high pressure and high temperature on the rheological properties of polymer-based drilling fluid.

4. Results and Discussion

4.1 RHEOLOGY OF DRILLING FLUID:

The Rheology of drilling fluid was measured in terms of plastic viscosity, gel strength and yield point. Following equations were used to determine plastic viscosity and yield point:

1. PV (cps) = θ 600 -θ 300 [5,9,18]
2. YP(lb / 100sqft) = θ 600 – PV [5,9,18]

The PV and YP can be quickly calculated from the shear stress values measure at rates of 600 and 300 rpm. The PV in centipoise (cps) is calculated from the 600-rpm dial reading (θ600) minus the 300-rpm dial reading (θ300). The PV depends mainly on the concentration of solids and the viscosity of the base liquid. The YP in (lb/100ft2) is then calculated from the 300-rpm dial reading minus the PV.[19,20]

Gel strength measured by observing the maximum shear stress value while slowly turning the 3-rpm setting after being static for some period of time. Standard values for gel strength are taken after 10 seconds, 10 minutes.[21,22]

I. Plastic Viscosity:

With increasing temperature, plastic viscosity also changes but due to thermal resistance properties of polymer, the plastic viscosity of the solution increased with increasing concentration. The plastic viscosity changed from 5 cp to 20 cp with higher polymer concentration. This change depicts that polymer is effective in retaining plastic viscosity of drilling fluid at elevated temperatures.[23,24]

In the given figure 4.1, it is visible that temperature has significance impact over the plastic viscosity of drilling fluid. However, addition of viscosifying agent has help reduced the thermal degradation of drilling fluid. Hence,

its plastic viscosity is still quite effective at high temperature of 180 Celsius.

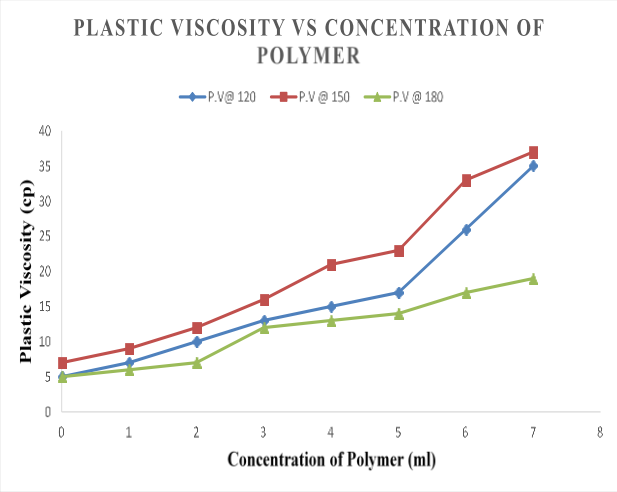

Figure 4.1 P.V of Drilling fluid sample by changing polymer concentration at different temperatures

II. Yield point: -

YP is dependent upon the surface properties of the mud solids also the volume concentration of the solids. As HIPOLY's concentration increased in the drilling mud solution, number of solid particles also increased.[25]

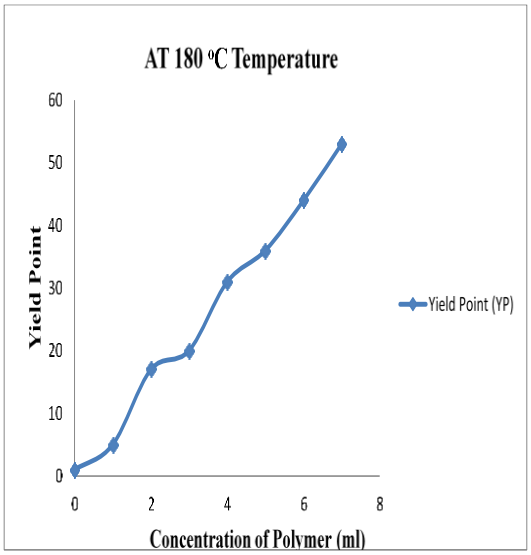

Figure 4.2 YP of Drilling fluid sample by changing polymer concentration at 180 °C

According to test result when polymer was introduced in the solution at 180 ^{0}C. With ascending polymer concentration yield point increased up to 50 lb/100 ft2.

III. Gelstrength:

This is essential property of any drilling fluid which help to sustain cutting to carry upto surface [26,27].

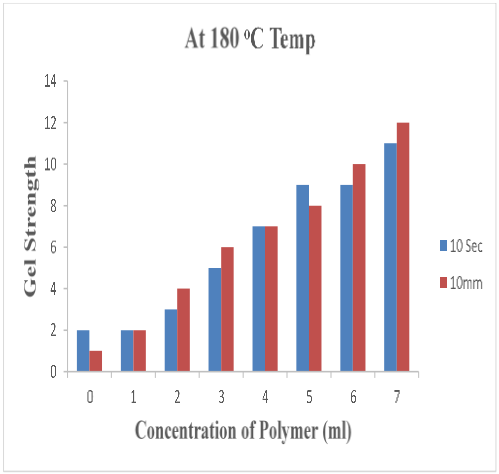

Figure 4.3 Gel strength Drilling fluid sample by changing polymer concentration at 180 °C

As figure show, at highest temperature of 180 °C gel strength was effective. Thus, it is evident that HIPOLY worked as effective viscosifying agent

III. Mud density:

During study it was found that mud density was about 13 to 14 ppg.it means that drilling fluid can provide hydrostatic head to control the formation pressure work. Mud weight use to control the trapped fluids or gas in the formations by adding a hydro static pressure on them, increasing the mud weight = increasing the hydro static pressure. If the hydro static pressure increased over the formations pressure that will make a fracture in the formation leading to lose the mud to the formation, so adding loss circulation material like gel-flake or wood chips that can refill the gap and stop the mud loss. If the mud loss continues, then the hydro static pressure will decrease and flammable fluids and gas trapped under pressure will start leaking to the surface.[28] This can lead to a potential blowout.

5. Conclusion

HIPOLY is a viscosifying agent that may help to reduce to the problem of drilling fluid degradation at high temperatures. If the rheology of drilling fluid is not maintained it may cause face several problems like pipe sticking, low cutting carrying capacity, ineffective rate of penetration during drilling operation. [3,29] Hence, introduction of HIPOLY as additive in drilling fluid can help mitigate this problem. After experimental study it was found that HIPOLY is showing promising result as a viscosifying agent in drilling mud.

Hence, there was improvement seen in rheology of drilling mud with respect to yield point, plastic viscosity and gel strength. Furthermore, its density was also sufficient enough to control the formation pressure. This drastic impact on rheology of drilling fluid was due to structure of HIPOLY polymer as it did not break due to carbon-carbon bond that made it difficult to disintegrate at high temperature. The research is carried out on water-based mud. The same research must be carried out on oil base mud by using HIPOLY as additive. Furthermore, mud cake formation and mud filtrate must be studied by using HIPOLY as fluid loss additive in both oil and water base mud.

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