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WARP: An Advance Drilling Fluid

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Abstract: ***In mature fields the difference between the pore pressure and fracture pressure, expressed as the pressure window, is reduced. Industry is currently facing this challenge of narrow pressure window, which inhibits various drilling and completion activities. Underbalanced drilling, managed pressure drilling and the use of low-viscosity drilling fluids are primary solution of this problem but a few of the many approaches that have addressed this challenge. When we use low-viscosity fluids, it severely reduces frictional pressure loss in comparison to conventional more viscous fluids. But there is a limit to how much viscosity can be reduced before conventional weight material begins to settle. This paper describes the development and application of novel technology of advance drilling fluid that has resulted in a ten-fold reduction in the particle size of the weighting agent (1/50th of original size). With this evolution, invert emulsion drilling fluids can be designed which contains high density, low viscosity with minimal settling potential of the weight material. The paper will explain in detail the first field applications of this polymer- coated, micron-sized weighting agent in an oil-based drilling fluid. How it helps in different conditions particularly in HTHP.***

Keywords: Basics of WARP, HPHT condition, Sag Potential, Effective Solid Control, Successful Application

1. Introduction

Drilling high-temperature, a high-pressure (HTHP) well is technically very challenging. Along with a number of other factors, the drilling fluid used will be of utmost importance for the progress and success of the drilling and completion operations. The narrow operational window between pore pressure and fracture pressure when operating in these environments requires drilling fluids that deliver minimal frictional pressure loss during pumping and displacement to minimize ECD (Equivalent Circulating Density) and surge/swab effects during tripping with drilling assembly or running completions.

Development of this field has required drilling of long and complex wells, often in reservoir compartments with high pressure depletion. Good hole cleaning and ECD have been and still are main focus areas for achieving a successful drilling operation. Introducing annular pressure- while-drilling tools in the mid 90's highly increased the understanding of hydraulic behaviour in the drilling process.[2] However, introduction of Through-Tubing-Reservoir-Drilling (TTRD), possible future ERD wells, and several lost circulation events in the later years, have pinpointed the need for a highly inhibitive drilling fluid system exhibiting a low ECD, low friction and low sag system exhibiting a low ECD, low friction and low sag potential. A drilling fluid with these combined properties will also be of key importance if the planned pressure blowdown of the reservoirs in the field is being carried out, as this will narrow the hydraulic window further. In case of pressure blowdown, there will also be a need for openhole sand screens, and the drilling fluid must preferably be "screen friendly".Here barite is grinded to 1/50th of its original particle size as shown in figure.

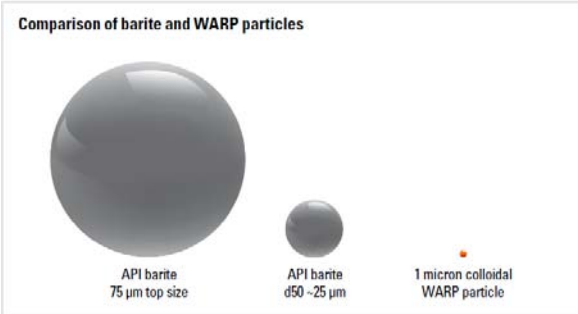


Figure 1: Comparison of particle size between barite and warp particles (Source :-Drilling fluid catalog, MI SWACO)

Generally, oil-based drilling fluids exhibit better temperature stability when drilling at high temperatures compared to water-based fluids. Oil-based drilling fluids also in general provide better drilling performance by producing a lower coefficient of friction than water-based systems as well as improved hole stability. Traditional oil-based drilling fluids are weighted with barite. The heightened tendency for sag in non- aqueous fluids is believed to be a function of the differences in structural build-up or the gelling mechanisms of the two systems. Consequently, employing conventional weight materials in the development of oil-based drilling fluids for HTHP drilling that possess acceptable rheology to minimize ECD while also maintaining satisfactory sag stability has been very difficult. As a consequence, the use of heavy brine-based systems has been introduced as drilling and completion fluids for HTHP fields.

2. Basics of warp

As a solution of above problem solution was to develop a sag- resistant oil-based fluid. This weighting agent research project (WARP) led to the development of a unique highly sag- resistant weighting material.). Conceptually, the foundation of the program was to employ ultra-fine particles of a weighting agent that have been polymer coated to provide a number of technical benefits in drilling fluids. The weighting agent, in this case barite, is milled in an enhanced mineral oil using high-performance milling technology. In this manufacturing process as the barite particles are milled, the new surfaces that are continuously exposed are coated with the special polymer additive. This coating provides effective oil-wetting of the barite weighting agent to produce stable high-solids, high-density and less viscous slurries.

In the oil-based WARP project, the barite is milled to a particle size specification, where typically 60% of the particles are less than 2 micron. The particle size distribution is measured by a particle size analysis on a Malvern Mastersizer 2000 using optical model Rl1.7, Absorption 0.05 and Rl1.46. The high-density slurries produced are then used to formulate the oil-based WARP drilling fluids through the addition of additives, including the emulsifier and brine phase similar to conventional drilling fluid formulations. Normally, use of such ultra-fine particles in conventional drilling fluids would create high viscosities and gel strengths, particularly in high-density and high-solids fluids. The WARP technology uses polymer-coated ultra-fine particles to allow drilling fluids to be formulated with low viscosities, low gel strengths and low sag potential.

These performance characteristics make such a fluid a viable candidate for drilling high-angle and other critical wells where a low-viscosity profile will deliver reduced ECD, as well as providing the sag performance required in drilling these types of wells. The difference in particle-size distribution (PSD) between the ground barite resulting from this research project and normal API-ground barite is illustrated in the PSD curves shown in **Fig. 2**.

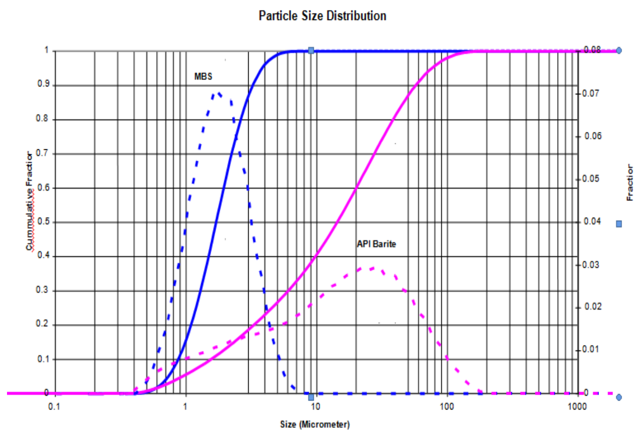


Figure 2: Comparison of particle-size distribution of warp agent and API(Source:- Warp manual)

It has been well documented in the literature that the potential for sag is considerably higher in oil-based drilling fluids (OBM) when compared to their water -based counter-parts. The heightened tendency for sag in non-aqueous fluids is believed to be a function of the differences in structural build-up or the gelling mechanisms of the two systems. Thus, field trials of an oil-based drilling fluid system employing the new weighting agents were seen as critical to learning more about the behavior of the system under actual field conditions. Of particular interest was evaluating the contribution of the new fluid in reducing or eliminating sag, while simultaneously applying a system that is thinner than conventional water-based and oil-based drilling fluids, thus reducing the equivalent circulating density (ECD).

The micronized barite slurries (MBS) that arose from the project was first used in the Statfjord field. This pilot test of the oil-based MBS fluid validated its beneficial performance for drilling wells in a field with ECD limitations. The average temperature in the Statfjord field is approximately 120°C and the fluid density 1.58 sg.(publish data of statfjord well) Furthermore a number of evaluation criteria were established to monitor the performance of the WARP system as compared to conventional OBM. These evaluation criteria were based on comparing several parameters like , ROP, ECD, pump rates, pump pressures, torque, drilling fluid con-sumption, durability of the system and screen configuration.

3. Features of WARP

- WARP Fluids Technology particles are 10 times smaller than drilling-grade barite
- Low-viscosity fluids with low plastic viscosities and yield point and low- shear-rate viscosity, a drilling fluids reduced risk of barite sag
- Lower friction factors: up to 10% in cased hole and 25% in openhole
- WARP micron-sized weighting agents pass more efficiently through shaker screens and openhole-completion screens
- Lower dynamic and static fluid-loss with thinner filter cakes and lower breakthrough pressures
- Non-damaging to producing formation and completion hardware

4. Different parameters

Barite Sag:- In order to check the stability against settling of weight material, the oil-based MBS fluid was tested in a large scale flow loop following the test design described by Bern, *et al*. The oil-based MBS fluid was compared to a conventional HTHP oil-based fluid. In this test the influence of flow velocity and pipe rotation on dynamic barite sag is monitored. The test results are given in **Fig. 3**. For a conventional oil- based fluid, barite will start settling out when the flow rate and rotation of the pipe is reduced. This is seen as a drop in fluid density. For the oil-based MBS fluid, no weight variations were seen during the test period indicating considerable improvement in the fluid stability towards barite sag.

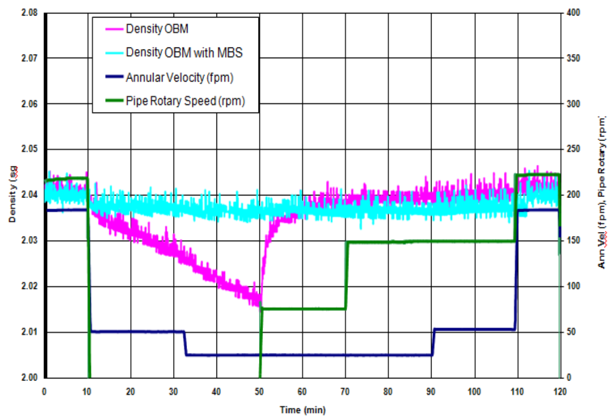


Figure 3: Sag flow loop measurement (T.H. Omland et. al)

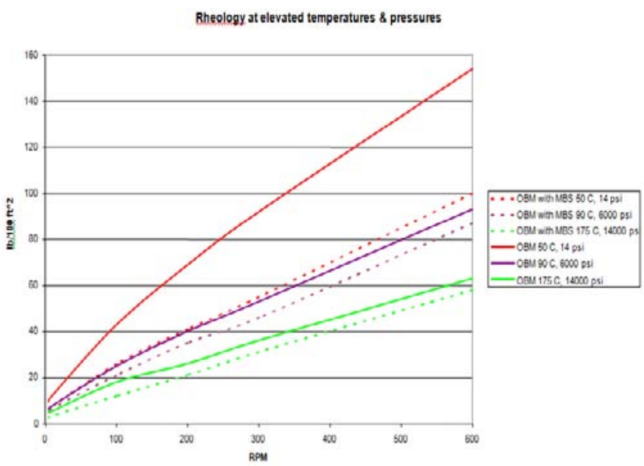
Hole Cleaning:- The frictional part of the ECD is the major contributor to hole cleaning as it epresents the shear force applied on the borehole wall and a cuttings bed surface. If the fluids are thin and without a pronounced gel formation or if a formed gel is relatively fragile, minimal force is necessary to remove the cuttings. In this case there are no drilling fluid properties that try to onsolidate the bed and the different cuttings can easily be removed as single units.

The low-shear-rate viscosity is significantly less in the WARP system than in the conventional OBMs. Likewise, the gel formation values of the WARP system are less than the similar values of the OBMs. Therefore, based in the theory above, it was anticipated that the WARP system should give good hole cleaning. Good hole cleaning was observed in both field trials, validating the hole-cleaning aspects of the WARP system.

Solids Control and Drilling Fluid Consumption:- For the 8½-in. section of the first test well, the four Gann shakers were fitted with 110E/150S AGR screens. Upon completion of the displacement with flow-line temperatures increasing, all four shakers were dressed with 190E-200S screens. After drilling through the Dunlin formation, three shakers were dressed with 190E/250S screens for the rest of the well without any significant losses.

In the TTRD section of the second test well, only two shakers were used. In this case a screen configuration of 210E/250S was applied. Furthermore, operating with finer screens and employing thinner base oil combined to reduce overall drilling fluid consumption. Compared to offset wells, the consumption of the WARP fluid was lower, particularly over the solids control equipment

Rheology as a Function of Temperature and Pressure:- The Fann 70 instrument has been used to measure the rheological properties at elevated temperatures and pressures. These measurements are crucial in order to be able to perform correct hydraulics calculations. Results from these measurements are given in **Fig 4**. For comparison, results from tests of a standard HTHP oil-based drilling fluid are also included showing the beneficial reduction in viscosity with the oil-based MBS fluid.



Source: Drilling fluid manual

Rate of penetration:- In one pilot test the initial rate of penetration (ROP) was up to 90 m/hr, sending a significant volume of cuttings over the shakers. Regardless, the shakers had no problems handling the cuttings. The high rates of penetration were maintained until entering the top of the reservoir and drilling into the Mime chalk where it was reduced and maintained at 20 to 25 m/hr.

Screen-Flow-Back Testing:- Fluid left in the open hole around the production screens is of concern because this fluid will be left for a long period. Tests have been performed in order to check the flow-back behavior of the oil-based WARP fluids as well as for standard oil-based drilling fluid. The samples were aged in specially designed aging cells with a screen in the bottom. After aging, the fluid is produced through the screens, then displaced by mineral oil at a constant rate. During this operation the pressure over the screen is monitored in order to measure the plugging tendencies. This simulates the back production of mud when a well is being produced and determines how easily the mud is cleaned out without damaging the flow capacity for the reservoir fluid. **Fig. 5** shows the comparative results of oil-based WARP fluids and standard oil-based drilling fluids. The maximum pressure seen during the back production of standard oil-based fluids as well as oil-based WARP fluids are presented above. The flow back properties are better for the weighted fluids that use the WARP technology. A more detailed description of the test design is given in SPE 94558.

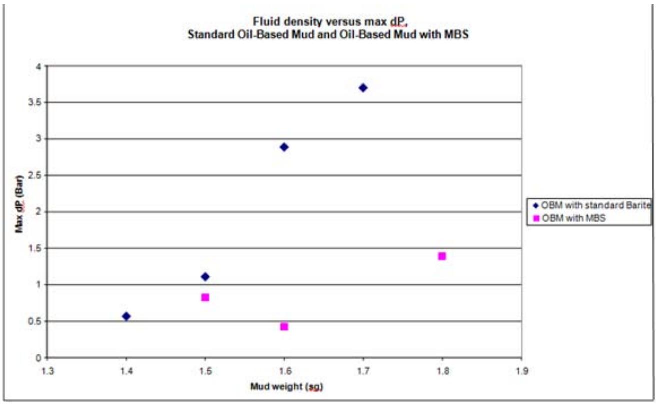


Figure 5: Screen-Flow-Back Testing (pressure)(source:- SPE 94558)

HSE:- No HSE incidents were reported, relating to the oil-based WARP system. The only disadvantage seen was an increase in the workload relating to the introduction of a new system. Because it employs a liquid weighting agent as opposed to dry barite, the WARP system requires closer monitoring to maintain the desired constant density.

5. Benefits

- Reduces risk of static and dynamic sag
- Lower ECD values
- Lower swab and surge pressures
- Lower pump pressures
- Improved cement quality
- Faster pipe-running and tripping speeds
- Improves MWD/LWD data quality
- Lowers rotary torque and friction factors

- Increases solids-removal efficiency and lower dilution/aintenance
- Reduces risk of completion- screen plugging
- Lower downhole fluid-losses can be used

6. Applications

These and other advantages make WARP Fluids Technology the ultimate choice for reducing drilling risk and well costs for a wide array of critical drilling applications, including:

- Horizontal and extended-reach wells
- Coiled-tubing and through-tubing rotary drilling
- Managed-pressure drilling reservoir drill – in fluids
- Wells with narrow operating windows
- HPHT wells Casing drilling
- Wells with risk of barite sag
- Inhibitive Fluids
- Drilling waste management
- Critical cementing operations

WARP Fluids Technology: Success stories from around the world
WARP Fluids Technology has been applied successfully in a wide variety of critical drilling, kill/barrier-fluid, extended-reach and horizontal drilling and HTHP applications.

- Onshore Europe, a 17.5-lb/gal (2.1-kg/L), water-base WARP Fluids Technology kill pill was spotted across a perforated zone through a 27⁄8-in. (73-mm) tubing, where it was to remain prior to pulling the tubing for a plug and abandonment operation. After two months static under downhole conditions in an H2S environment, no sag or settlement was observed. The fluid was subsequently reused on subsequent wells and remained stable for more than nine months.

In the Caspian Sea, a 15.8-lb/gal (1.9-kg/L), water-base logging and testing fluid was formulated using WARP Fluids Technology. Ease of handling, no environmental or personnel safety concerns and the ability to use and reuse the fluid were all accomplished for this client.

- Onshore Mexico, a 12-lb/gal (1.4-kg/L), dispersed bentonite system formulated with water-base WARP Fluids Technology was used to drill a deviated 12Π-in. (311.5-mm) section. Dilution factors were reduced 33% by using 270-mesh screens handling 500 gal/min (1,893 L/min) full flow, and the sectionwas completed four days ahead of schedule.
- Offshore Norway a 3,189-ft (972-m),57⁄8-in. (149.2-mm) through-tubing rotary-drilling section was directionally drilled at 78° from the 7-in. (177.8-mm) liner using a VERSAVERT oil-base system that incorporated WARP Fluids Technology to 16,630 ft (5,069 m). The low-shear-rate rheology (3 RPM Fann reading of <3 units) ensured that sufficient flow rate was delivered to the bit without exceeding the fracture pressure.ROP was 10% higher than expected, and dilution factors were reduced by half, resulting in the fluid costs being 18% under budget.

Source: MI SWACO manual

7. Conclusions

A new advance drilling fluid has been formulated using specially treated ultrafine weight material. The fluid was qualified through an extensive laboratory test program. The fluid was field tested during drilling a near 3000-m long, 12¼- in. section showing very good performance. The following results were obtained using this new fluid:

- Low ECD, high pump rates, good hole cleaning and low surge-swab pressures.
- Sag was shown to be insignificant, with much lower potential than observed with conventional oil-based drilling fluid.
- The average rates of penetration do not appear to be affected by the properties of the WARP system.
- Efficient solids separation at the shakers and an ability to use finer screens with reduced fluid dilution and fluid consumption.
- Low torque and friction, clearing the way for the possibility of drilling longer and smaller-diameter wellbores.
- Drilling fluid properties remained stable in both sections.
- Both ECD and pump pressures can be predicted accurately by software models.
- From a logistical perspective, the system requires more planning with respect to fluid transfer.
- Controlling density with the new system requires closer follow-up than those incorporating regular barite.

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