

## AN EXPERIMENTAL STUDY OF THE EFFECT OF CONTAMINANTS ON THE FLOW PROPERTIES OF OIL BASED DRILLING MUD

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### Abstract

This work presents an investigation of the Effect of Drill Cuttings on laboratory prepared oil base mud recommended to be used in drilling formation. The properties measured are plastic viscosity, yield point, apparent viscosity, mud weight, fluid loss, gel strength and electrical (emulsion) stability. The results show that cuttings increase drilling fluid viscosity, fluid loss and density as the adverse effects of it can lead to increase in thickness of filter cake, loss circulation, stuck pipe, increase in operational cost etc. It also shows the mud condition at which percentage of cuttings become catastrophic and the extent at which cuttings should be allowed in the mud.

**Keywords:** drilling fluid, drill cutting, viscosity, filter cake, fluid loss.

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### 1. Introduction

In geotechnical engineering, drilling fluid is a fluid used to drill boreholes into the earth. Often used while drilling oil and natural gas wells and on exploration drilling rigs. Drilling fluids are also used for much simpler boreholes, such as water wells. The three main categories of drilling fluids are Water-Base Muds (which can be dispersed and non-dispersed), Non-Aqueous muds, usually called oil-based mud, and gaseous drilling fluid, in which a wide range of gases can be used. The Non-Aqueous fluids itself is Synthetic (water emulsified in oil), not a hundred percent oil.

The main functions of drilling fluids include providing hydrostatic pressure to prevent formation fluids from entering into the well bore (controlling formation pressure), remove cuttings from the well, suspend and release cuttings, seal permeable formation, maintain wellbore stability, minimize reservoir damage, cool, lubricate and support the bit and drilling assembly, transmit hydraulic energy to tools and bit, ensure adequate formation evaluation, corrosion control, facilitate cementing and completion and minimize impact on the environment. Mud composition is affected by geographic location, well depth and rock type and is altered as rock depth formulations and other condition change. Drilling fluid maintenance costs can decrease greatly when proper solids control techniques are utilized. Adverse effects caused by drilled cuttings account for a major portion of drilling fluid maintenance expenditures. Considering that a 12 1/4 in gauge hole drilled to 10,000ft would result in 1,327,000lb or more of drilled cutting [1]. Drill cuttings contain, in addition to formation solids, small amounts of liquid and solid drilling mud components. The amounts of drilling fluid solids that remain attached to cutting vary, depending on the grain size of the crushed rock from the strata being drilled [2]. Hole cleaning is the ability of a drilling fluid to suspend and transport drilled cuttings from down hole to the surface. Inadequate / poor hole cleaning is a major problem in drilling operations; it leads to a number of drilling problems e.g. high rotary torque, stuck pipe, formation break down, slow rate of penetration and loss circulation [3]. Drilling fluids have three main functions: (i) to transport drill cuttings out of the hole and to allow for separation of cuttings from the drilling fluids at the surface. (ii) to form a thin filter cake on the walls of the wellbore to prevent inflow of drilling fluids into the formations (iii) to prevent inflow of formation fluids into the wellbore [4]. Combs and Whitemire [5] showed that the change in viscosity of the continuous phase is the main factor in control the change in the viscosity of the mud with pressure. De Wolfe et al [6] reported a close

correlation of the results from their study of less toxic oils to the Herschel-Bulkley model. It was also observed that the magnitude of viscosity difference between oils tend to decrease with temperature in spite of pressure indicating that temperature was the more dominant factor".

This study presents an investigation of the effect of drilled cuttings on four laboratory prepared muds types recommended to be used in drilling formation. The drilling mud is oil based mud and the results obtained show the different behavior of rheological properties of oil based mud and its adverse effect on mud additives.

## 2. Experimental procedures

The mud was prepared to an oil-water ratio of 75/25. The base fluid (continuous phase) used is EDC-99, water was added as discontinuous phase, other mud additives are Calcium chloride ( $\text{CaCl}_2$ ), this forms brine with water and act as the internal phase of the emulsion(the emulsified phase) , which is used for osmotic dehydration of water wet formation, Versagel plus (amine-treated, pure hectorite clay is used as the primary viscosifier in invert emulsion drilling fluid systems), Lime (Calcium hydroxide), Versamul and Versacoat (organic surfactant is a multi-functional additive which serves as an emulsifier and wetting agent, primary and secondary emulsifiers), Versatrol (gilsonite is a naturally occurring asphalt used for high-temperature, high-pressure filtration control).Four samples of mud are prepared using all the materials in the above formulation and afterward adding different percentages of cuttings.

Sample A consists of 0% cutting, Sample B consists of 5% cuttings, Sample C consists of 7.5% cuttings and Sample D consists of 10% cuttings. The muds are mixed according to the procedures recommended by API and other related mud service companies. Mud mixer was used to mix the four types of mud. A rotational V.G viscometer was used to measure the rheological properties of mud samples. This viscometer has 6 speeds (600rpm, 300rpm, 200rpm, 100rpm, 6rpm and 3rpm) as recommended by API to measure the rheological properties of drilling mud samples. The properties were measured at 120°F. The rotational viscometer was also used to measure the gel strength which is classified into 10 seconds gel strength and 10 minutes gel strength. The 10 seconds gel strength reading was taken at 3rpm after 10 seconds while the 10 minutes gel strength reading was taken at 3rpm after 10 minutes and the maximum deflection of the indicator was recorded.HT-HP Filter Press was used for measuring the fluid loss of the mud samples. The drilling fluids were heated to a temperature of 200°F at a pressure of 500psi and the filtrate test was run for 30 minutes upon which the volume of filtrate was recorded and the filter cake thickness was measured and reported. It was made air tight by applying a HT-HP grease to the oil ring.

In all these experiments, conditions were kept constant for mixing and testing to have a representative comparison for the four different types of muds.

## 3. Results and discussion

In Fig 1, increase in contaminants introduced to the mud resulted in significant increase in the plastic viscosity. A critical look at the result shows that, the plastic viscosity increases gradually up to 5% and took a sharp increase from 6%.As a result, it can be concluded that plastic viscosity is primarily affected by the amount and shape of the solids. The sharp increase can also be due to increase in surface area of the particles when they are broken down into smaller particles while drilling. Any increase in total surface area of solids exposed will reflect an increase in plastic viscosity. As a result, the maximum allowable low gravity solids of less than 5% should be allowed when oil base mud is in use, although the lower the better.

The increase in Yield Point in Fig 2 and apparent viscosity in Fig 3 due to cuttings can result from drilling hydratable shale or clay. Perhaps it may also result due to the emulsifying and wetting agents found in the mud which emulsify the water in oil and wet the cuttings with the oil. This emulsification results in the increase in both plastic viscosity, yield value and apparent viscosity. This indicates that the solution to the problem resulting from increase in the cuttings cannot be taking care of completely with increase in the concentration of that versamul and versacoat but removal of the contaminant (cuttings).

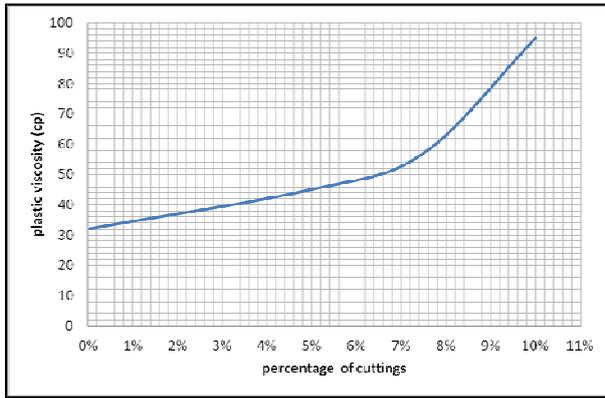


Figure 1. A graph of plastic viscosity against percentage of cuttings

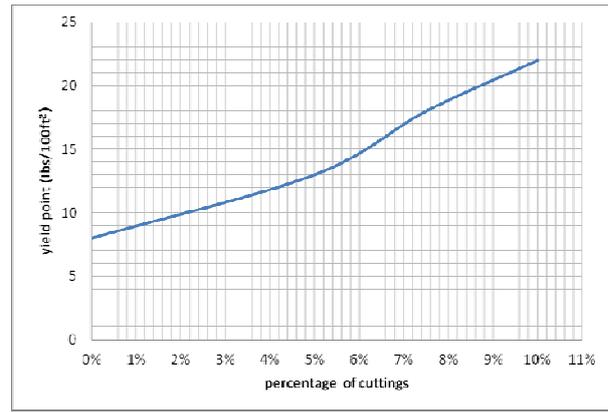


Figure 2. The graph of yield point against percentage of cuttings

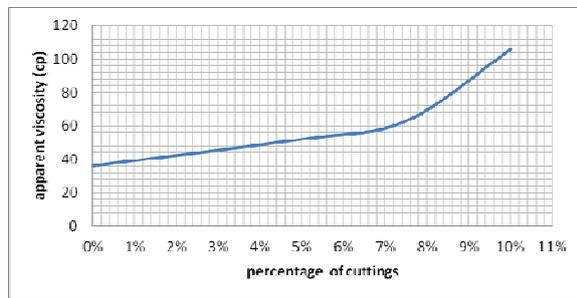


Figure 3. The graph of apparent viscosity against percentage of cuttings

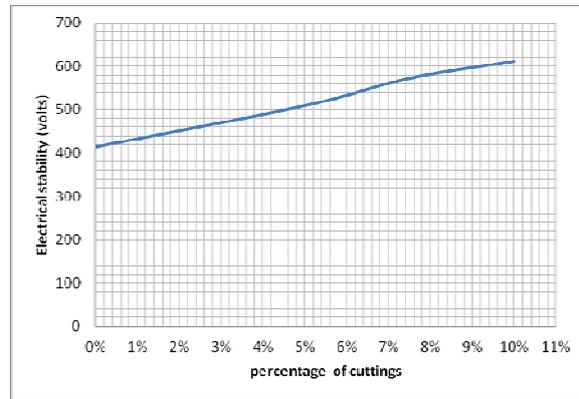


Figure 4. A graph of electronic stability against percentage of cuttings.

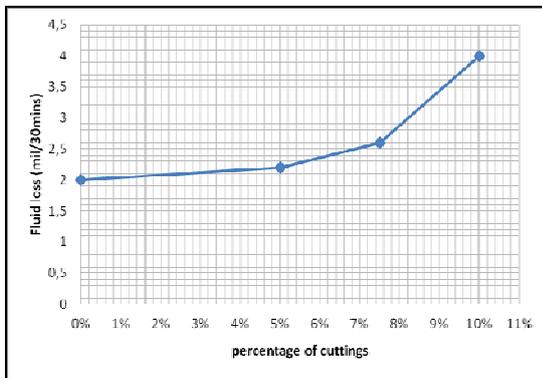


Figure 5. A graph of fluid loss against the percentage of cuttings

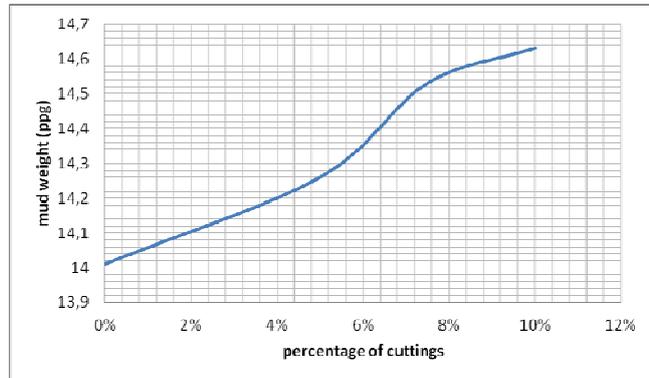


Figure 6. The graph of mud weight against percentage of cuttings

Fig 4 shows increase in electrical stability as percentage of cuttings increase. The increase in the emulsion stability of the mud indicates the amount of voltage required to break down the emulsion and allow the emulsified water droplet to connect, allowing electrical current to flow. It is observed that increase in the percentage of cuttings in the mud did not show reduction in the electrical stability values but water wet solids reduces electrical stability value.

Fig 5 shows the effect of cuttings on fluid loss. From the fig above, it is deduced that 5% cuttings increase the fluid loss which signifies appreciable amount of fluid entering the formation and increase the thickness of filter cake in the wellbore which may cause differential sticking and excessive drag in extremely permeable formation. However 0% as well as 4% cuttings have little or no effect in comparison to 5% cuttings. Solids (clays, drill cuttings) must "wetted" by the base liquid or else they will settle, increasing both viscosity and fluid loss as shown in the experiment.

Fig 6 shows an increase in mud weight with increase in drill cuttings which signifies that there is recirculation of excessive cuttings that results in increased density of drilling mud. High concentration of solids or cuttings in the mud is detrimental to almost all aspect of drilling operation, reduction in penetration rate, increase mud weight and viscosity which in turn increases maintenance cost and need for dilution. It will also require and increase in the horsepower required for circulation which is a potential for hydraulic fracturing, an increase of the thickness of the filter cake which is more easily eroded and contributes to a less stable hole as compared to a thin filter cake, and excessive abrasive cuttings in the drilling mud which cause significant wear to the mud pump and drilling tools.

Fig 7 measures the ability of the drilling fluid to hold cuttings in suspension after flow ceases. It means that the longer the stagnation time, the harder the internal structures and more pressure will be required to initiate the flow of the fluid. Another important thing is that the percentage of cuttings in the mud increase the level of the gel strength.

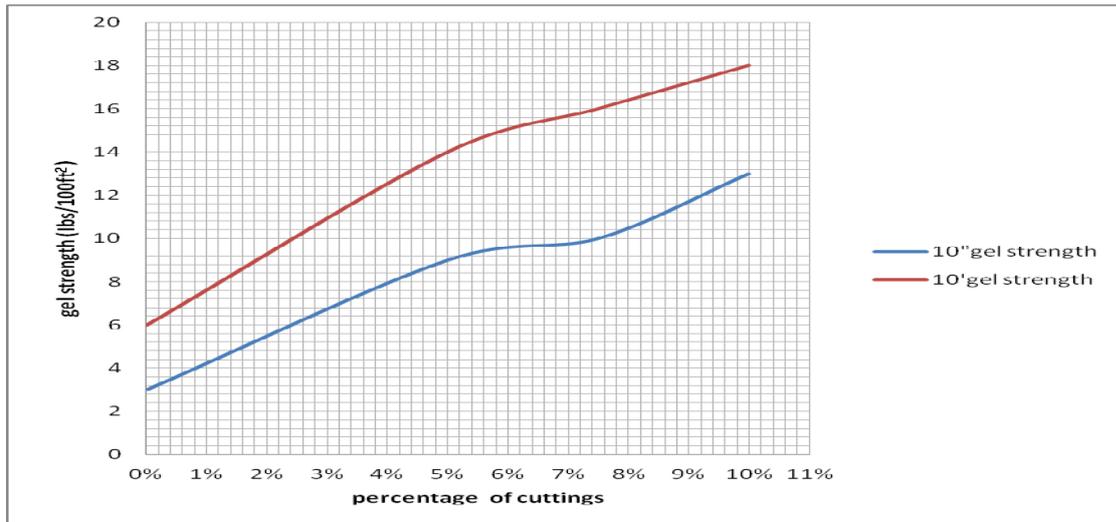


Figure 7. The graph of gel strength against percentage of cuttings

## Conclusion

The following conclusions were drawn from the results of this study:

- (1) Maintaining a low mud density minimizes viscosity, reduces pressure within the borehole annulus caused by the circulating fluid and minimizes the filter cake thickness.
- (2) As the drill cuttings are removed, the plastic viscosity decreases. Decrease in plastic viscosity will increase the low shear rate viscosity which will bring larger, more easily removable cuttings to the surface. It also works the other way; failure to bring cuttings to the surface while they are large enough to be removed by the equipment will increase the plastic viscosity. Increase in plastic viscosity will decrease the ability to bring cuttings to the surface and allow them to grind into smaller, more numerous particles.
- (3) With a thick filter cake sealing or restricting the flow, the pressure beneath bit increases and can cause lost circulation. A thin filter cake is acceptable.
- (4) A 0% drill cutting is allowed in the mud to maintain its viscosity and yield value while 5% drill cuttings are allowed to maintain its fluid loss properties.
- (5) As the drill cuttings in the mud are removed the Equivalent Circulating Density (ECD) is kept in the safe range.
- (6) Summarily, solids control (cuttings removal) influences mud and well costs. A proper solids control (i.e drill cuttings removal) plan / implementation is a thing that should be looked into and given preference for successful drilling since it has a direct bearing on drilling efficiency.

## Nomenclature

API = American Institute of Petroleum  
 HT-HP = High Temperature High Pressure  
 YP = Yield Point

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