The effect of drilling mud on hole cleaning in oil and gas industry

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Abstract. The primary function of drilling mud is to lift the drill cut and to avoid problems in drilling hole. The purpose and objective of this study are to determine the ability to lift cutting in oil drilling wells. The method in the cutting process can use in three ways, first is Cutting Transport Ratio (Ft), Cutting Concentration (Ca), and the last is Cutting Carrying Index. The three methods have a standard that must be considered. Drilling mud affects the penetration rate during drilling activities. In drilling operations, a high penetration rate is always desirable. Mud pump as a tool for flowing mud into the wellbore affects the speed of the fluid flow of the mud in the annulus, the flow pattern in the mud circulation, and the ability to lift the cutting in the well while the mud pump specification determines the significant flow rate to circulated in the drilling process. The value of rheology of mud such as plastic viscosity and yield value of mud density also affect the performance of the slurry to become a medium for lifting drill cut. The three methods have a standard that must be considered. Cutting Transport Ratio (Ft) must have a value of > 90%, for the cutting concentration (Ca) method must have a value < 5%, and cutting carrying index (CCI) has a value of 1.

1. Introduction

Drilling mud is one of the considerations in optimizing drilling operations; therefore it is necessary to maintain and control the physical properties to confirm the desired specifications. The primary function of drilling mud is to lift the drill cut and to avoid problems in drilling hole. Optimization of hole cleaning during drilling operations is critical to enhancing the drilling rate. To ensure optimum hole cleaning in drilled hole section that remains a significant challenge, hole cleaning it must engineer. It is often the deciding factor between success and failure during drilling. Insufficient hole cleaning can cause decrement in drilling rate, lost circulation, wellbore instability, erratic trends in ECD, more wiper trips, back reaming, lousy quality of cement jobs bit balling and increment in the increasing cost of drilling operations and extension of the operations time. If no attention paid to hole cleaning, such problems can finally be a root cause of losing the well [1,2].

Cutting Concentration in the annulus (CCA) and Carrying Capacity Index (CCI) is the essential tools to be considered to ensure optimum hole cleaning, optimized ROP performance, and useful mud properties. CCA It is an effective tool that can indicate how the number of cuttings that general while drilling loaded in the annulus. The cutting concentration in annulus or cuttings volume has a limit that is not supposed to exceed [1,2].

The minimum speed needed to cut the pieces needs to calculate according to the size of the annulus. Because mud drilling will be circulated through the drill string volume, then exiting at high speed
through the hole in the tool which then flows to the annulus with the cutting carried from the bottom hole to the flow line. The rotation of the bits and drill string and the speed of the mooring of the formation mountain layer will also influence the drilling mud hydraulics and the form of cutting obtained on drilling. While the evaluation and optimization of the calculation of drilling hydraulics on the tool are to produce the optimal circulation rate, the total energy is need on the surface which is a pressure layer on the fluid circulation system [1-5].

The purpose of this study are to determine the ability to lift cutting in oil drilling wells.

2. Methods
The design of this study is analytical and description research which is both to find out the causal relationship between 2 operational variables, differences, relationships, and researcher intervention in it. The researcher will conduct interferences on data sources such as drilling parameters and mud rheology at these two depths which will be carried out by analyzing the cutting of the sample. Thus the researchers can use the relationship to the data to get the optimal cutting appointment results. [1,3],

![Flowchart of pressure losses.](image)

Figure 1. Flowchart of pressure losses.
In the first phase, the relationship between the rheology of mud and drilling parameters will be evaluated to determine how strong they are. The data will be screened and filtered to capture the critical drilling parameters and mud rheological properties. The data includes Pumping Rate, String rotation speed, Torque, weight on bit, Footage, Hours spent to drill hole section, Flow area of nozzles, stand Pipe pressure, Mud Weight, Mud Funnel Viscosity, Plastic Viscosity, gel strength, Yield Point [1,3,6,-11].

In the second phase (figure 1), study the effect of mud properties and drilling hydraulics such as ratio of plastic viscosity over yield point, rate of yield point over plastic viscosity, flow behaviour Index, consistency Index, annular velocity, critical velocity, slip velocity, bit pressure loss, jet velocity of nozzles, annular pressure loss, equivalent circulating density, drilling rate, transport ratio, cutting concentration in annulus, cutting concentration Index, consistency index and flow behaviour index. [1, 6,7,9,10-12].

In the third phase, analyze the data that has obtained before. In (Figure 2), 3 methods in the cutting process can use in three ways, first is Cutting Transport Ratio (Ft), Cutting Concentration (Ca), and the last is Cutting Carrying Index. The three methods have a standard that must be considered. Cutting Transport Ratio (Ft) must have a value of > 90%, for the Cutting Concentration (Ca) method must have a value of <5%, and Cutting Carrying Index (CCI) has a value of 1 [1,2,13].
3. Results and discussion
The circulation system will significantly affect the smoothness of drilling with one of the functions needed to cut from the bottom of the hole to the surface. Unsuccessful appointments cut this can cause drilling problems. Besides, the efficiency of drilling hydraulic power is increased by pressure loss; having minimal pressure loss can increase the efficiency of hydraulic power. Related to improvements in drilling operations it is essential to consider that studying the large power pumps on the surface needed for mud circulation needs optimal assistance.

To reduce the pressure in the pipe depends on the inner diameter of the drill string and the mud pump discharge. After that, the results of calculating the average flow velocity in the drill string exceed the critical speed so that the flow pattern formed turbulently. While to reduce the pressure in annulus depending on the size of the borehole with the drill string outside diameter and mud pump discharge, the flow pattern formed will vary.

Table 1. Total pressure losses.

| Depth (ft) | Surface Equipment Pressure Loss (psi) | Pressure Losses Drill Pipe (psi) | Pressure Losses Annulus (psi) | Pressure Losses Bit (psi) | Total Pressure Losses (psi) |
|------------|--------------------------------------|----------------------------------|-------------------------------|--------------------------|---------------------------|
| 6704.04    | 283.03                               | 289.4                            | 2.65                          | 491                      | 1066.08                   |
| 986.58     | 289.32                               | 404.99                           | 7                             | 501                      | 1202.31                   |

In table 1, it can be that the two samples have a significant pressure value which affects the big bit hydraulic horsepower (BHHP). High-pressure loss is affected by a high viscosity due to a lot of friction that occurs, but if the viscosity is too low, then the cutting lif is not right. The ability of the pump to put pressure on the circulation system will be exhausted to overcome the pressure loss in the entire circulation system, even though the loss of bit pressure is the decisive parameter in the optimization calculation [14].

To pump drilling fluid from mud pit back to the surface, the pump pressure needed is the sum of the pressure losses of all drilling equipment. Too much surface pressure that is applied can cause fractures in the formation to be weak under the casing shoe, which later can cause drilling fluid losses. Besides, the loss of pressure on the bit helps the hydraulic performance of the formation drilled as well as cleaning the cutting from the area. It expected that the pressure on the rig could channel to the bit and the remaining pressure will lose due to friction on the drill string. The main parameter that considered in the drilling hydraulics optimization is to know for sure the maximum flow discharge capacity owned by the mud pump. Besides, the maximum power of the mud pump will show the pump's ability to circulate mud [1].

After developing the hole cleaning model, the optimization of drilling mud parameters and drilling parameters was performed to achieve effective hole cleaning and optimum drilling performance. Using CCI, CA and FT together empowered us to have effective hole cleaning and clear chance about the limit to improve the rate of penetration. Using CCI alone gives an idea about how the whole section is clean, but, does not tell about drilling rate performance. On the other hand, CA has a limit of the maximum drilling rate that can reach without causing any hole problems or cuttings accumulation. The maximum limit of CA is 5%.
Table 2. Hole cleaning @ 674.04 ft.

| Equipment         | Flow Pattern @ Annulus | Ft (%) | Ca (%) | CCI  |
|-------------------|------------------------|--------|--------|------|
| A800M4536SP       | Laminar                | 95.13  | 2.62   | 1.59 |
| Float Sub         | Laminar                | 94.97  | 2.62   | 1.51 |
| ABHO Sub          | Laminar                | 94.97  | 2.62   | 1.51 |
| MWD               | Laminar                | 95.13  | 2.62   | 1.59 |
| Flow Sub          | Laminar                | 94.97  | 2.62   | 1.51 |
| NMDC              | Laminar                | 94.97  | 2.62   | 1.51 |
| Crossover         | Laminar                | 94.97  | 2.62   | 1.51 |
| HWDP              | Laminar                | 93.63  | 2.66   | 1.04 |
| JAR               | Laminar                | 94.18  | 2.65   | 1.21 |
| (Conductor) HWDP  | Laminar                | 93.63  | 2.66   | 1.04 |

Table 3. Hole cleaning @ 986.58 ft.

| Equipment         | Flow Pattern @ Annulus | Ft (%) | Ca (%) | CCI  |
|-------------------|------------------------|--------|--------|------|
| A800M4536SP       | Laminar                | 95.48  | 3.65   | 1.82 |
| Float Sub         | Laminar                | 95.33  | 3.66   | 1.74 |
| ABHO Sub          | Laminar                | 95.33  | 3.66   | 1.74 |
| MWD               | Laminar                | 95.48  | 3.65   | 1.82 |
| Flow Sub          | Laminar                | 95.33  | 3.66   | 1.74 |
| NMDC              | Laminar                | 95.33  | 3.66   | 1.74 |
| Crossover         | Laminar                | 95.33  | 3.66   | 1.74 |
| HWDP              | Laminar                | 94.08  | 3.71   | 1.2  |
| JAR               | Laminar                | 94.6   | 3.69   | 1.39 |
| HWDP              | Laminar                | 94.08  | 3.71   | 1.2  |
| DP                | Laminar                | 94.08  | 3.71   | 1.2  |
| (Conductor) DP    | Laminar                | 94.08  | 3.71   | 1.2  |

The calculation results show the right parameters at each drilling depth can produce a proper cutting sequence in the table. This result is due to the selection of suitable types of mud and excellent grass rheology characteristics so that the slurry can bring the cutting to the surface well. In addition to mud, the flow pattern also has a role in influencing the removal of cutting. The results obtained from the cutting flow pattern of the cutting in the annulus section of the two samples provide laminar results so as not to cause caving or wash out on the wall of the borehole formed. The pattern of laminar flow, Cutting Transport Ratio (Ft) can reach more than 90%, Cutting Concentration (Ca) is below 5%, Cutting Carrying Index (CCI) shows a reasonable limit and tends to be right above 1.

4. Conclusion
The specification of mud and pumps in the well is correct. The result of cutting at 674.04 ft depth with CCI method was 1.04 - 1.59, Cutting Transport Ratio method were 93.63% - 95.13%, and Cutting Concentration (Ca) were 2.62% - 2.66%. In Depth 986.56 ft, the result of cutting using the CCI method were 1.2 - 1.82, with Cutting Transport Ratio method were 94.08% - 95.48% and the Cutting
Concentration (Ca) method were 1.2 % - 1.82%. Based on the results above, the drill cuttings process is a good result.

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