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Experimental Study of Freeing Stuck Pipe by Changing in Characterization and Additives of Mud Cake

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ABSTRACT: Differential sticking is one of the most usual and as yet most troublesome problem in drilling. In this paper according to studies on freeing differential sticking by different properties of mud drilling additives, we focused on the impact of water-based mud, bentonite and lignosulfonate. Selecting the appropriate additives are done by mud cake characterization equipment, by measuring the torsional resistance of mud cake with different compositions as the main variable and also measuring secondary variables that consists of mud-weight, mud cake viscosity, Ambient temperature, water loss, mud cake thickness and its physical structure. The results of these tests indicate that in bentonite muds, salt plays role as a destructive factor and PAC as an effective factor in freeing stuck pipe. Lignosulfonate fluid is also effective in freeing differential sticking by its thinner properties. As the main result of this paper, regarding to measurement of torsional resistance in different mud cake, the best method for freeing pipe stuck is low angle rotation of drill string immediately after occurring the pipe stuck.

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1- Introduction

Stuck pipe is a general term used, particularly among drillers, to describe the problem of losing the ability to move the drillstring assembly. The stuck pipe has many reasons and they can be classified into two categories: mechanical and differential sticking. The classification is based on the physical mechanism causing the problem and therefore mechanical sticking refers to the cases where the movement of the drillstring is prevented by mechanical equipment. But differential sticking is different [1].

Differential sticking is one of the most common causes of pipe sticking. It will happen due to a higher pressure in the mud than the formation fluid. Differential sticking happens when the drill collar rests against the borehole wall, sinking into the mudcake. The area of the drill collar that is embedded into the mudcake has a pressure equal to the formation pressure acting on it. The area of the drill collar that is not embedded has a pressure acting on it that is equal to the hydrostatic pressure in the drilling mud. This is shown in the Fig. 1. When the hydrostatic pressure (Ph) in the well bore is higher than the formation pressure (Pf) there will be a net force pushing the collar towards the borehole wall [2].

The differential pressure force is the difference in hydrostatic force and the formation force acting on the drill collar. The hydrostatic force is the hydrostatic pressure times the cross sectional area that is in the borehole and the formation force is the formation pressure times the cross sectional area that the mud cake is in contact with [2].

This dissertation is about differential sticking, an old drilling problem that resurged with more significant consequences due to the expansion of the horizons of hydrocarbon exploration

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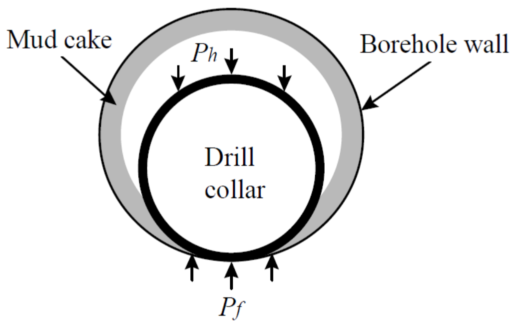


Fig. 1. Differential sticking. P_h is the hydrostatic pressure and Pf is the formation Pressure [2].

from onshore shallow vertical wells to deep offshore wells with complex trajectories. The time to free a stuck pipe can vary from hours to weeks, rapidly becoming a very expensive exercise with disastrous consequences to the cost of drilling campaigns, particularly when drilling offshore. Despite the responding to a significant percentage of overall drilling problems, a theoretical methodology which is able to predict its occurrence with more than a chance probability across different fields and drilling conditions remains to be developed and recognized by the industry [1].

Research about drilling mud is always one of the most important issues in drilling oil wells. Compositions and properties of drilling mud can be used as a determining factor in removing the differential sticking which is occurred in drilling wells. In this context, researches about pipe sticking has been began from 1950. These researches were conducted in two wellhead and laboratory method [3]. Efforts in this area has been continued until, in 2003 by funding from Australian company Csiro manufacturing of Mud Cake Characterization Equipment (MCCE) started, and then an standard for measuring the compressive strength, tensile strength, and torsional resistance of drilling mud cake by using a load cell with triple performance was introduced [4].

2- Methodology

This research experimentally studies the properties of drilling mud associated with differential pipe sticking issue. The main reason of differential sticking is stuck of some parts of drill string into the mud cake of well because of the difference between the hydrostatic pressure of the drilling mud and formation pressure. In the laboratory the maximum torsional resistance of mud cake, mud loss, and thickness of mud cake is measured according to testing standards.

This research is based on Amanullah's articles, the inventor of mud cake characterization equipment. First to confirm data from Amanullah's article and equipment calibration, properties of muds in this research has been measured. Then according to subject, selected sawdust additive in lignosulfonate water based mud, changes in torsional resistance comparatively studied. This research was done in the drilling and geomechanic labs of department of petroleum engineering of Amirkabir University of technology. In this research variables of mud weight, mud viscosity, test temperature, fluid loss volume, thickness, physical structure of mud cake, and mud cake torsional resistance has been measured, among them the maximum torsional resistance of mud cake, and thickness of mud cake as the major variables discussed. Measured variables with the units and their measuring tools have been shown In the Table 1 .

One of the additives used in this research is lignosulfonate. It is used as a thinner in prehydrated water based muds. It reduces the viscosity of muds which has few solids and high PH, and high yield point, and its color is dark brown [5].

In order to verify and compare data, first tests were ran on muds from article [4] which are named with prefix A.

Mud cake characterization equipment as shown in Fig. 2 schematically, measure the mechanical properties of mud cake such as penetration rate, tensile strength, and torsional resistance by using 2 load cells and 1 torque cell sensor.

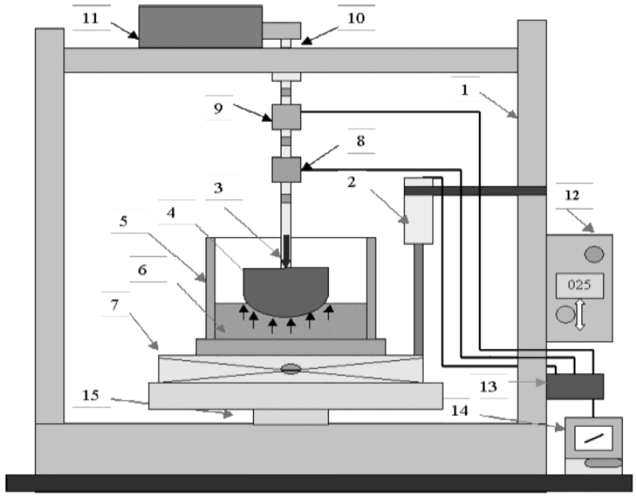
3- Discussion and Results

In each test the secondary variables such as temperature, compressor pressure, mud weight, and mud viscosity are reported, and also diagrams related to changes in the torsional resistance and its maximum amount, mud cake thickness, and time for 100ml fluid loss are reported.

Then three main variables mud cake thickness, time for 100ml fluid loss, and maximum torsional resistance are analyzed separately.

In lignosulfonate muds as seen in Fig. 3, $lingo_0$ mud comparing to $lingo_1$ and $lingo_2$ muds which has mica and saw dust additives respectively, has lower mud cake thickness, shows that additives specially saw dust can make a thicker mud cake which also has more porosity due to its foam-like mud. This porosity causes thicker mud cake and then more active contact surface with the pipe, which can lead to increase the probability of differential pressure sticking.

For lignosulfonate muds according to the type of calibration for these muds, comparing to Bentonite muds, different numbers are shown, but generally because of their lubricant property they are placed in mud groups with low torsional



1-Wykenham Farrarance Stepless Compression Machine
2 – Potentiometer 3 - Foot Stem 4 - Spherical Foot
5 - API Cell 6 – Mudcake 7 - Lab Jack 8 - Torque Cell
9 - Load Cell 10 - Gear Box 11- DC Motor 12 - Control Panel
13 - Data Logger 14 - PC Computer 15 - Movable Base

Fig. 2. Schematic layout of Mud Cake Characterization Equipment (MCCE) [12].

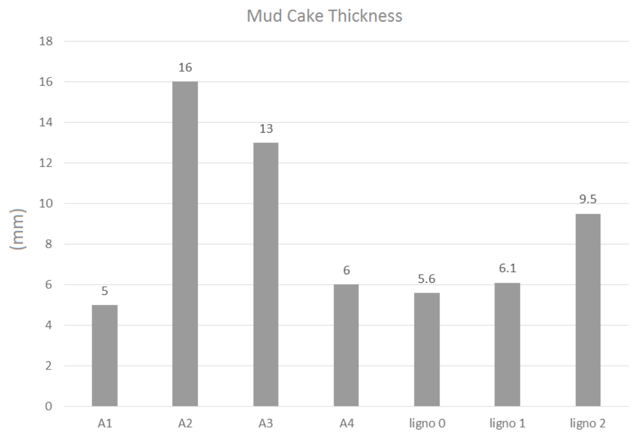


Fig. 3. Measured thickness of mud cakes

resistance which are very prone to remove differential sticking. As seen in Fig. 4 saw dust additive in $lingo_2$ mud, despite the negative score in last two factors thickness, and fluid loss, here shows less resistance that is more appropriate than other two muds. The results indicate that despite the definition of the main variables to select the right muds, there are other effective factors too.

As we know in soft and thick muds the possibility of differential sticking is higher [6]. On the other hand the active surface of mud (the contact surface with drill pipe) is seen as an important factor which in writer's opinion as the cake is thicker, the active surface will be more, and possibility of differential sticking phenomena will be high. Fluids with higher fluid loss also increase the possibility of stuck.

The most important variable in these tests is mud cake torsional resistance, whatever it is higher, pipe will rotate harder in well, and its stuck removing will be more difficult.

As seen in Fig. 5, in all three curves, in the rotation of about 5 degrees maximum torsional resistance occurs, this indicates that in differential sticking instead of using jars or pulling out

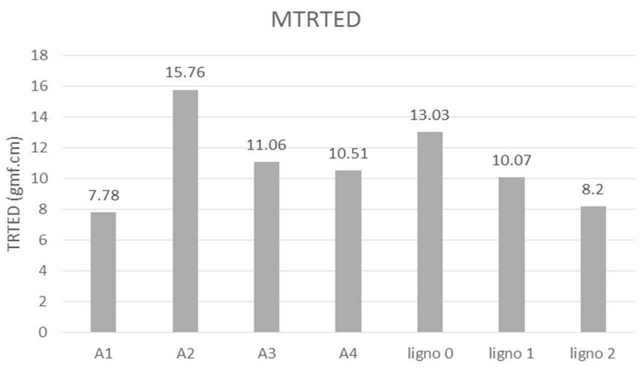


Fig. 4. Maximum Torsional Resistance at Targeted Embedment Depth (MTRTED) of mud cake in the experiments

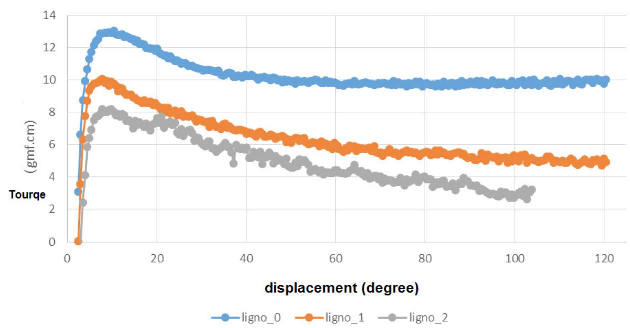


Fig. 5. Torsional Resistance at Targeted Embedment Depth of Lignosulfonate mud cakes

the tubes, chance of removing stuck can be increased by a small rotation. Achieving the maximum torsional resistance indicated that the highest bond strength between mud particles are in response to the applied torque. After the peak failure occurs which in microscopic scale, reflects mud particles slippage on each other or on the pages included them under torsional forces which is affected by physical and chemical properties of mud additives. From 10 to 30 degrees a steady decline with small increasing and decreasing noises is seen which is caused by the interaction of separated particles. From 30 degree to end is related to remained torsional resistance. Variation in the maximum torsional resistance was seen in tests of a sample, which is due to the different surface contacts between tool's hemisphere and different particles in mud and their different orientations. However, this data had acceptable coefficient of variation [6].

Another notable point is that in these tests modeling was done on a small scale, if this model is in real scale well, due to more active surface we will see very different numbers for the torsional resistance of mud cake.

4- Conclusions

In this research, the effect of KCl, NaCl, and PAC on Bentonite muds and also effect of saw dust and mica on lignosulfonate muds, in removing differential sticking has been studied. Main variables, mud cake thickness, time for 100ml fluid loss, and torsional resistance of mud cake with other secondary variables are reported for each mud. The results indicate that the Bentonite muds show poor performance in the presence of salt, also lignosulfonate muds without any additives show better performance in removing differential sticking.

According to the tests and analyzes carried out, the following results has been obtained:

- Salts are as an intensifier factor for differential sticking.
- As the size of cations in salts are bigger and their bonds are stronger, mud cake torsional resistance will be higher and also probability of differential sticking will increase.
- PAC existence as a fluid loss controller, can be effective in removing differential sticking.
- Lignosulfonate fluids due to their high lubrication properties are so useful for removing differential pressure sticking.
- Mica additive is ineffective to facilitate the act of removing stuck by lignosulfonate fluid.
- Small rotation of drill pipe at the beginning of differential sticking is much more effective than other methods.
- In order to achieve the right solution to remove differential sticking the following proposals are presented:
- Improving torsional resistance measurement methods in the MCCE.
- Further researches on the physical and chemical properties of sawdust additive.
- study the effect of salts in lignosulfonate fluids
- Find more variables involved in the differential sticking phenomenon and removing it
- Research on other additives to find a suitable combination of mud to prevent differential sticking
- Adjust statistical methods, and neural networks algorithms based on the results of the variables presented in this study

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