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Research paper

One stage process removal of filter cake using micro emulsion

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Abstract

Well productivity could depend greatly on a typical drilling fluid formulation for a particular formation, and to meet specification at the moment. The data used in this study includes experimental data and materials that emphasize the influence of mud formulation and the application on the formation. This study analyzed the effect of drilling fluid filter cake on the productivity of the well. It gives details of the drilling process in relation to mud activity and formulation of remedial chemicals for production enhancement. From the filtration result, it was observed that the 11.9ppg mud cake sample began to respond to the soak solution faster than the 12.3ppg mud sample. Thus using the same soak solution as a standard for comparison, the mud cake with less mud weight was able to show less resistance to the flow of the soak solution through the pores of the discs. The result emphasized the need to optimize mechanical field control equipment to reduce the size (thickness) of filter cake formed.

Keywords: *Filter Cake; Well-Productivity; Impairment; Oil-Wet; Instability; Micro Emulsion.*

1. Introduction

Mud, as called generally in drilling process, has provided the medium for the removal and transportation of drilled cuttings from the hole to the surface. The cuttings are separated from the mud at the surface (using solid control equipment) to be re-circulated downhole. The mud should have the ability to suspend the cuttings according to its gel strength in the event of no circulation [1]. This ability cannot be displayed using air, foam, mist or ordinary water during a drilling operation especially for horizontal wells.

Drilling fluids (mud) are considered a major determinant of the ultimate success of a drilling process and production returns of a particular well. This is because a poorly designed mud could bring about hazardous and stressful drilling practice, formation damage, loss of drilling equipment, blowout and poor production with consequences that may affect the return on investment [2, 3]. Despite the advantage of using premium drilling fluids, it has been discovered that the mud cake formed on the wall of the well and the plugging of the near wellbore pores by the mud filtrate affect the productivity of the well (Fig. 1). As a result of this, there is a quest for drilling techniques that optimize production. Oil and gas wells are usually drilled to form a filter cake on the walls of the wells to significantly reduce large losses of drilling mud to the surrounding formation. Unfortunately, formation conditions that can lead to unacceptable loss of drilling fluid in the surrounding formation often arise, despite the type of mud used and the filter cake created. It is extremely important to optimize the thickness of the filter cake because a very thick filter cake can cause clogging of the drilling pipes and other instability problems with drilling operation [2].

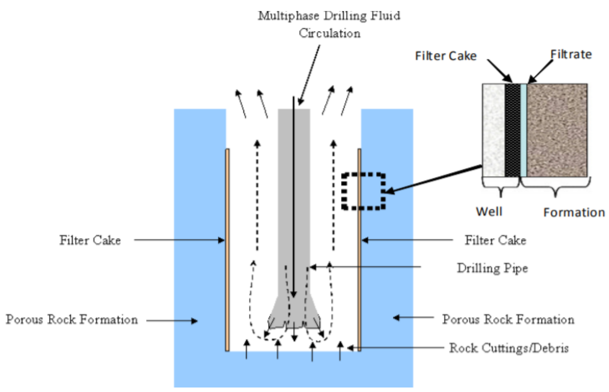

Fig. 1: Drilling Mud Circulation Schematic Diagram [2].

During this study, analysis was based on the assumption that well performance is a function of the flow efficiency (FE); and that the flow efficiency in turn has a direct bearing on the mud formulation employed. This study will show the effect of damage caused by drilling fluids by simulating the flow efficiency in the laboratory.

2. Literature review

The common experience in the oil and gas industry is that oil or gas wells are drilled by circulating drilling fluids. The success of any drilling operation depends on many factors; one of the most important is the effect of drilling fluid. These fluids perform a variety of functions that affect rate of drilling, efficiency and operational safety [4]. Filter cake is the residue precipitated from a drilling mud and deposited on a permeable medium (rock formations in this case). The filtrate is a liquid passing through the medium, leaving a precipitate on the medium [5, 6]. There is a certain degree of cake accumulation that is ideal to isolate the formation from the muds [7], [8].

Arthur and Peden [9] studied and reported the effect of mud composition, temperature and pressure on the properties of filtration cake formed in static filtration using an experimental program. Their results clearly showed the highly compressible nature of the cake formed by drilling fluid. It also showed the deep influence of barite and temperature on the cake properties and fluid loss. They illustrated that the behavior of the cake is compressible under pressure.

The filtration properties can be described as one of the most important characteristics of all drilling muds. Invasion of the formation filtrate can lead to a substantially low permeability region near the wellbore through a group of mechanisms: swelling of clay, clogging of the particles pores, particle migration and water blocking [10, 11]. In addition, the characteristic and thickness of the filter cake deposited on the wellbore wall will affect the adhesion potential of the differential pressure [12]. Also. According to Blkoor and Fattah [12], monitoring of drilling mud filtration is considered part of the best drilling practice. Improper management of the properties of the drilling mud is associated with instability in wellbore and damage to the formation. This mud filtration control involves not only monitoring the volume of filtrate, but also the quality of the resulting filter cake that is formed on the well wall.

Kabir and Gamwo [2] numerically simulated filter cake formation by using computational fluid dynamics technique. The study was on vertical wellbore wall at HPHT conditions. The drilling muds used were treated as a two-phase system of solids suspended in a non-Newtonian fluid. Their results for the axisymmetric and planar wellbore confirmed that cake formed at extreme drilling processes is thicker when compared with those formed for shallow drilling processes. Thus, the filter cake formed in the vertical wall of the well is not uniform for both extreme and shallow drilling processes.

Akinsete and Isehunwa [13] developed a mathematical model that can analyze drilling fluid filtration in wells that are deviated. The model determined the pressure distribution in the cake, its thickness, the volume of the accumulated filtrate and the degree of invasion under different conditions. The results showed isotropic assumptions from previous studies that overestimate the extent of the damage. It also confirmed that mud filtration tends to increase in deviated wells than in vertical wells.

Cerasi and Soga [14] studied the failure modes for drilling mud filter cakes and examined external filter cake failure for water-based muds. They emphasized on the need to break the filter cakes formed on the borehole walls during drilling operations before starting production operations. The examination was on two failures classification, which are "Pinholing" of the cake and "lift-off" with the failure mode dependent on the pressure drop. At low-pressure drop, the cake is locally deformed and separated from the substrate. Thus, making the pinholes to appear on the detached zones. They proposed a simple model based on a classic analysis of the expansion of the elastic cavity. The model predicts the behavior of the two failure modes under considerations depending on the state of stress and degree of fingering in the "two-phase" formation.

3. Methodology

In carrying out this study, the analysis was because flow efficiency has a very direct bearing on the mud formulation employed in drilling the production zone; and as a result can dictates well productivity and performance. This study employed the MESOPHASE TECHNOLOGY to simulate and evaluate the near wellbore damage and productivity impairment because of drilling fluid activity at the production zone. Experiment were carried out using exert mud samples and mesophase chemicals as used in the field to evaluate the behavior of formation of filter cake and the removal of the filter cake by the mesophase chemicals using laboratory equipment.

This study intends to achieve an increased production index by ensuring that the filter cake is removed, rendering it water wet.

When circulating drilling fluids within the wellbore, fluid filtrate invasion occurs, leaving the mud solid particles on the formation surface [15-17]. During this invasion, the wettability of the formation is altered because the filtrate fluid often mixes and displace the in-situ fluids. This process results to induced formation damage; this damage often leads to drastic drop in permeability. These effects can contribute to reduction in oil producibility [17]. The extent of this damage can be attributed to the characteristics of the drilling fluids used in drilling operation, the properties of the formation and pressure conditions [19].

3.1 Drilling mud formulation

Two mud systems were formulated in this study, which enabled us to determine the effect of drilling fluid filter cake on formation pore space. These mud systems properties were tabulated in table 1.

Table 1: Mud Properties

Density	Mud Weight	ppg	11.9	12.3
Rheology	600	rpm	110	130
	300	rpm	68	90
	200	rpm	50	68
	100	rpm	32	45
	6	rpm	9	11
	3	rpm	7	10
	Plastic Viscosity	Centipoise	50	49
	Yield Point	$lbs/100ft^2$	30	41
	10 Second Gel		8	10
	10 Minute Gel		19	21
E.S	Electrical Stability	volt	258	234
Filtration	HTHP	mls	3.8	4
	Temperature	^oF	250	250
	Pressure	psi	500	500
Alkalinity	H_2SO_4	cc/cc	0.5	0.7
	Lime	ppb	0.65	0.91

The drilling mud contains different chemical compounds and are inverse emulsions of water in oil. A viscometer was used to perform the rheological characterizations summarized in table 1. The yield point (YP) and plastic viscosity (PV) were calculated from the viscometer dial readings using API recommended practice of standard procedure for field testing drilling fluids [20,21]. The phenomenon of filtrate invasion of the reservoir rock is significantly influenced by the rheological properties. Thus, we also characterized the mud according to their rheological properties and electrical stability (ES) as described in the API RP 13B-2 [21].

3.2. Data collection

For successful execution of this study, the laboratory experiment was carried out using the HTHP cell to simulate the down hole conditions (impaired production zone). A cleaning operation to remove the impairment was done to simulate the wettability of the formation rock for increased production. A comprehensive mud check was considered on the two mud samples and the mud properties were tabulated for comparison. Mud cakes were formed with the two mud samples, on two Aloxite discs using the HTHP double-ended filter cell at 500 psi deferential pressure and constant temperature (250 ^oF) (Fig. 2). The filtrate was collected and recorded for analysis.

Fig. 2: Mud Cake before Addition of Micro Emulsion Fluid.

The mud cake was collected in the static filtration test under conditions of high temperature and pressure. The objective was to simulate the probable condition of the fluid downhole during the period that circulation is stopped in the well. These tests were conducted using an OFI Testing Equipment HTHP filter press.

The mud cake was also subjected to a micro emulsion soak solution (Table 2) to destroy the cake and render it water wet. The time taken to destroy the mud cake was recorded for both mud cake of different mud properties and will be computed for analysis. Relevant data relating to well production parameters for varying mud system and mesophase chemicals were soughed from relevant concerns.

Table 2: Micro Emulsion (Soak Solution) Formulation

Product	Concentration (%)	Volume (m^3)	Density (SG)
Surfactant	20.0	6	1.114
$CaCl_2$ Brine	59.2	17.76	1.3926
Organic Acid	15.6	4.5	1.0491
Water	5.6	1.68	1
OHRAC	0.2	0.06	0.892
	100	30	1.26

The micro emulsion (MICROWASH) chemical were applied in the HTHP double ended cell to measure the intensity of damage and simulated production zone of a production well and to render the associated solids water wet for production enhancement. The parameters calculated was breakthrough time and filtrate volume. In addition, the characteristics of the filter cake formed before and after treatment, and the extent of water wettability for the treated solids, using two different mud samples, with the same composition but different properties were determined.

The experiment carried out on both mud samples have shown that:

1) The soak solution was able to break through the filter cake.
2) The filter cake showed some resistance to the penetration of the soak solution as seen in the delayed time to break through.
3) The filter cake properties were destroyed and rendered water wet.

4. Results and discussion

Table 1 show the rheological properties and electrical stability of the mud systems, and the concentrations of the additives used in the formulation were selected based on the values found in the literature and calculated with mud calculator [22, 23]. Most studies emphasize on how to reduce the volume of filtrate, consequently many additives have been proposed to optimize most mud systems [24-26]. The electrical stability value recommended by the American Petroleum Institute (API) for non-aqueous fluids is approximately 200 V. ES values greater than 200 V indicate stable emulsions; thus from table 1 we can state that both mud systems with ES values greater than 200 V are stable.

Mud systems with YP > PV exhibit partial flocculation of solids, this often results in clogging of drill string. The YP values of the mud systems investigated were lower than the PV. Thus, flocculation will not occur when these mud systems are used for drilling operations.

In this study our emphasis was on how to remove, and optimally clean these solid particles (filter cakes) deposited on the formation during dynamic or static conditions.

Typically, well drill-in and servicing fluids include fluid loss control fluids. These fluids may comprise a comparatively small portion capable of forming a filter cake to plug off thief zones. In general, well drill-in and servicing fluids are formulated to form a fast and efficient filter cake on the walls of a well bore within a producing formation in order to minimize leak-off and damage. The filter cake often contains an inorganic portion and an organic portion. The methods of filter cake removal consist of contacting and washing the filter cake with suitable fluids. In addition, the filter cake can be removed by special formulations of the drilling fluid, as it contains an acid-soluble particulate solid bridging agent.

Oily filter cakes, especially cakes that are formed in the formation are often resistant to chemical interaction and their surface areas are small, which further limits the chemical removal of mechanical impurities. Oil intrusion transports various oil-wet surfactant into formulations. However, these surfactants are necessary for the stabilization of water-in-oil emulsions but can change or alter the natural wetting state of the reservoir from water-wet to oil-wet when it passes through the reservoir pore throats; this process prevents the flow of hydrocarbons through the rock matrix during production. Test have shown that oil moist state within the pore throat will not only limit the flow of hydrocarbons, but can also increase the mobility of fine particulates, clays or other fine rock particles. After mobilization, these particles can block the pore throats, which further reduces permeability. The micro emulsion fluid possesses the characteristics of low interfacial tension [27].

4.1. Presentation of results and analysis

A common approach to remove this filter cake is the application of acids or strong oxidative solutions. However, Kameda et al., [28] considered non-specific and a possible alternative, which lies in enzymatic preparations that are able to hydrolyze such polymers. This is the method adopted in this study and these enzymes catalyze specific substrates are environmentally friendly.

Figures 3 and 4 show graphical representation for the typical filtration time and filtrate volume obtained from the HTHP cells, after applying the treatment fluid on the mud cake. The data for the 11.9ppg mud cake sample shows that, it took about 150 minutes for 1ml filtrate of the soak solution to break through the filter cake, and 180 minutes for the 12.3ppg mud cake sample to have 1ml filtrate break through.

From the filtration result, it was also observed that the 11.9ppg mud cake sample began to respond to the soak solution faster than the 12.3ppg mud sample. It took the 12.3ppg mud sample a longer time than the 11.9ppg mud sample to break through the filter cake. Using the same soak solution as a standard for comparison, the mud cake with less mud weight was able to show less resistance to the flow of the soak solution through the pores of the discs (Fig. 5). The result is similar to the study reported by Wang et al., [29], where they used a Nano emulsion to effectively remove both oil-based drilling mud filter cake. Geri et al., [30] in their study emphasized on the single stage removal of this filter cake. One stage filter cake removal was achieved in this study.

In as much as the both mud show resistance to flow before break through, it is logical, as simulated, that the 12.3ppg mud will pose more resistance to the flow of hydrocarbon into the well bore, causing damage to the near well bore than the 11.9ppg mud if both muds were to be used to drill the same well type.

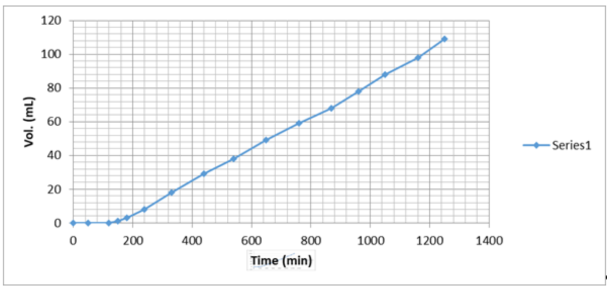

Fig. 3: Filtration Rate Test on an 11.9ppg Mud Cake Sample.

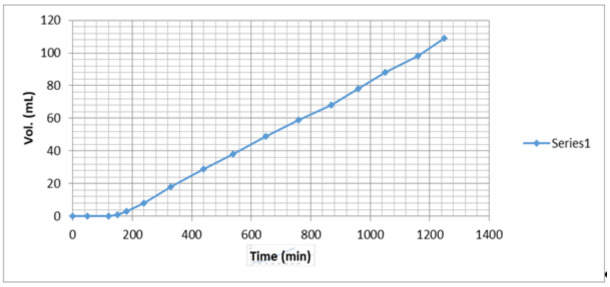

Fig. 4: Filtration Rate Test on a 12.3ppg Mud Cake Sample.

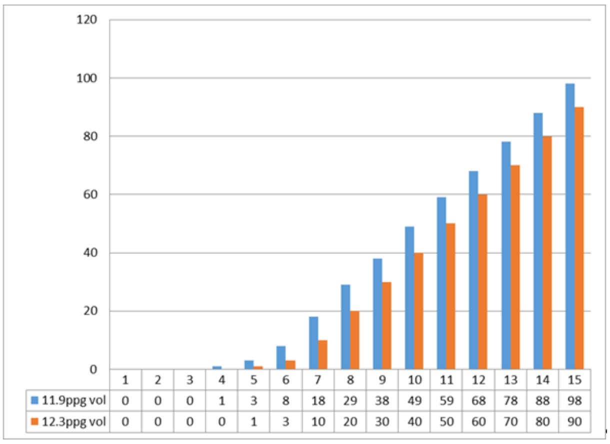

Fig. 5: Comparing of Both Samples Respond to Soak Solution.

5. Conclusion

1) The experiment results, comparing two distinct mud samples with the same composition but different properties have shown the possibility of near well bore damage as the effect of poorly designed mud on the production zone.
2) The OBM cake filter treated with the soak solution caused a loose, porous filter cake that displayed high injection permeability.
3) Cleaning of the OBM filter cake was efficiently achieved using the soak solution in one stage removal process.

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