Melioration Of Zonal Isolation In Horizontal Wells Drilled With Non-Aqueous Drilling Fluid (NADF) By The Application Of Newly Pondered Polymeric Interactive Cement System (ICS)

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Abstract: The proper placement of cement in the annular space around the wellbore enables the closing off wells drilled with non-aqueous drilling fluid (NADF) by its effective replacement with cement. If this process not occur properly, it results in the residual amount of NADF accumulation inside the wellbore which leads to the lack of stability, fluid influx and constraints in the well stimulation and workover operations particularly in case of horizontal wells. In this paper, a new cementing procedure called Interactive Cementing System (ICS) is formulated along with special physical properties of cement which will be highly effective in the NADF environment.

IndexTerms : Cementing, Conductivity, Drilling fluid, Horizontal wells, Production casing, Well stimulation, Zonal isolation

1. INTRODUCTION

1.1 Cementing

It is the process of circulating a cement slurry through the inner side of the casing and taken out into the annular space through the casing shoe at the bottom of the casing string [1]. The first well was cemented in 1903 at Perkins oil well cementing company, California. The main functions of cementing are:

- It provides zonal isolation
- It supports axial load of casing strings
- It provides protection of casing against corrosive fluids
- It supports the wellbore

The cementing procedure is same for both horizontal & vertical wells.

1.2 Horizontal wells

A horizontal well is an oil or gas well drilled at a minimum angle of 8° to a conventional well [2]. The well is drilled vertically at initial stage and at the kick-off point, the angle of the drill bit changes and is done by two components attached to the drill string assembly and the operating procedure is as follows:

1. The downhole steerable mud motor, at the kick-off point only the mud motor is operating which
2. h allows the drilling fluid to rotate the drill bit to achieve the angle of deviation, during this the drill string assembly is inoperative. Once the angle of interest is achieved, the entire drill string setup is rotated which ensures the drilling of well in horizontal axis.
3. The MWD (Measurement While Drilling) tool, facilitates the real-time data of downhole conditions and allows us to reach the Payzone.

The casing & cementing policy is same as that of conventional well [5].

1.2.1 Advantages

1. Increase in rate of production due to extended borehole length of Payzone
2. Drainage area is high
3. Recovery rate is high in comparison with conventional wells

1.2.2 Applications

1. Side-tracking of well in case of lost drill string
2. Relief well drilling when there is uncontrollable kick
3. Drilling a well in inaccessible locations such as rivers, people's community and so on.

1.3 Non-Aqueous Drilling Fluid (NADF)

Non-Aqueous Drilling Fluids are nothing but the oil based drilling fluids. The common NADF systems are diesel based, mineral oil based or synthetic fluid based [3]. In general, all drilling fluids are NADF except water based mud & Pneumatic muds. NADF are used in high temperature wells, horizontal oil wells and wells with pipe sticking. It was introduced in 1970, to prevent the reactive action with the subsurface formation.

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1.3.1 Advantages

1. Excellent wellbore stability
2. Good lubrication
3. Temperature stability
4. Reduced risk of differential sticking
5. Low formation damage

1.3.2 Disadvantages

1. Highly expensive
2. More attention needed while handling
3. Hazardous to environment & drilling crew
4. Direct discharge to environment leads to pollution

1.4 Stimulation

Once the production casing is lowered, the well has to be activated to get the oil/gas to the surface. Well stimulation is the process of increasing the flow of hydrocarbons from the reservoir to the wellbore. It is generally done by hydraulic fracturing and acidisation treatments. Well stimulation process cleans the debris accumulated in the pore spaces of the formation & increase the fractures and its pore geometry [4].

2. NECESSITY OF CEMENTING IN DEVIATED WELLS

Nowadays, the wells drilled in US are mostly horizontal wells with multistage stimulation treatments and with 95% artificial lift system installed at the initial stage of production [6]. The multistage stimulation and artificial lift are installed because to increase the rate of production and percentage of recovery respectively. In a horizontal well, the drainage area is more, it results in higher production in a shorter time span. It will be directly beneficial to the operator in terms of rate of return, breakeven point and other fiscal terms [6]. In order to achieve a good simulation job, shutting-off both inside and outside the production casing between each stage is necessary. For external isolation, the cement is squeezed along the sides of the production casing, it gives external isolation and wiper plug is used to provide isolation inside the casing [12]. Secondary cementing job is planned accordingly, if there is any such need arises out but is difficult to figure out the plan because of volatility of the subsurface formation & mud present in it. Currently, all the operators started logging the horizontal wells to understand the cementing quality after cement job, out of which mud channels are identified as the primary reason for poor quality of cementing. It have drastically affect the efficiency of stimulation process and in turn it impacts the profitability of the well because completion effectiveness and productivity of the well rely on good zonal isolation. Over the years, zonal isolation was subjected to complete mud removal, which was influenced by various parameters.

3. REDACTING OF CEMENTING JOB

Mud removal is reliant on sufficient centralization of casing, even after well preparation is executed. Most drilling engineers gave their consent that well-centralized casing ensues the improved cement job, the compromise comes out with the exclusion of bringing forth the casing to bottom on long-lateral and extended-reach wells. Rotating and reciprocating casing can meliorate mud removal and cementing quality by orbitual motion, but it increases the operational cost and sloughing of formation and wear & tear to the rotating equipment. Spacers are used to prevent the communication of drilling mud and it forms an immiscible interlayer between them but the type of spacer and its quantity determine the mud removal. After the finalization of the cementing parameters such as class of cement, volume of cement, additives, type of plug and pumping capacity, the proper placement of cement can be optimized by victimization of computer simulation cementing software models such as CEMENTICS, CEMPRO^{+} [7], OpticemRT^{TM}, CemFACTS^{TM} and so on to assert sufficient rheological properties and to carry out mud removal. The probability of formation of mud channel is very much larger if these design are not optimized.

3.1 Need of advanced cement for mud removal

Mud removal continues to be a rudimentary component of the cementing operation. A newer cement is needed to mend zonal isolation in the upshot of poor mud removal. The mud removal is a major problem in the NADF environment. The water based mud is completely replaced by cement slurry because water easily mixes with cement slurry, it tends to increase the settling time but the cement strength and permeability is within the desired range whereas the NADF mud is not entirely replaced by cement slurry as it cannot mixes with cement slurry and forms an interfacial layer where the mud remains in the cementing zones thus makes the mud removal too difficult in NADF environment. For several years, researchers were trying to formulate a cement which will be highly efficient in the process of mud removal in NADF environment. The cement has to be designed in such a way that it can be reactive with the oil present in the NADF, which reduces the permeability of cement and mobility of NADF in cement slurry thereby resulting in the sealing-off subsurface formation pressure and it's fluid encroachment. It is achieved by the conversion of residual NADF into a substance which has similar properties of cement. The newly developed system improves zonal isolation in the segments of the borehole where NADF remains in place even after the cementing process with the conventional cement. The new cement system which we formulates by addition of newer material has to react with the residual NADF without altering the rheological and mechanical properties of cement. It also has to quash the subsurface hydraulic conductivity of microannuli and minimize the fluid passage upto 1/10th of inch.

3.1.1 Excogitation of Interactive Cement System - ICS

Interactive cement system is an induced-antiphonal cementing operation schema with dewy-eyed design regulations projected to wipe out poor zonal isolation in cemented boreholes exploited with NADF. The ICS is a normal cement type from class A-J [8] (except I) mixed with a polymeric material which is in the form of dry powder. Now the ICS is mixed with water and other

additives to make ICS cement slurry, once the slurry is pumped into the subsurface annular hole, it starts reacting with the hydrocarbons present in the residual NADF which alters the rheology of the mud and heighten the yield point of the mud upto 20 times in the mud window and defying a differential pressure of 1000psi/ft, based on pore geometry. Yield point is the ability of the drilling mud to lift cuttings out of the wellbore and if it is increased by 20 times after the addition of ICS, a polymeric material, it removes the fragments of the leftover NADF binds in the drill cuttings and sides of the wellbore. Before the cement reaches the desired location, the slurry occupies the NADF mud channel where the rheological transformation takes place which will be highly useful during perforation operations. The polymeric material powder can be added with the cement slurry as the normal additive material and it doesn't change the flow and rheology properties of the slurry and we can pump the slurry with a usual power as that for conventional cement slurry.

3.1.2 Anterior substantive of conventional cementing

By considering the intriguing conditions of the process of cementation in the deviated well, the ICS is found to be a good palliation step for wells with residual mud. Still, ICS found not to be the alternative for removal of mud. Hence, it is invoked to comply with the standard mud-removal procedure even when this advanced ICS is employed.

4. Versatile testing of ICS

Tests such as API testing, NADF yield strength change, Scaled pressure testing were conducted to check the integrity and stability of the ICS.

4.1.1 American Petroleum Institute Testing

In API testing, a set of tests were conducted, one without ICS & one with ICS to ensure that the addition of polymeric material powder doesn't affect the rheological & set cement properties such as mixability, stability, thickening time and compressive strength [9]. We use rotational rheometer and HPHT consistometer to found out the properties of cement as per API RP 10B-2 standards [10].

4.1.2 NADF yield strength change

Two cement slurry mixtures say ICS & normal cement slurry were prepared with veritable constituent such as cement, water, thickener, fluid loss material, viscosifying agent and dispersant & for ICS a polymeric material powder is added as a special additive and is used to demonstrate the mud removal in NADF occupied zones. When ICS is used, the yield point increases, then it completely replaces the mud in the invaded zones. The density is maintained at 14.5 ppg and the rheometer with parallel plate configuration is used for the measurement of yield strength.

4.1.3 Scaled Pressure Testing

In this the laboratory set up of ICS cemented region after settling is taken and placed in a permeameter and cement cylinder to show in evidence the quantity of NADF mud removed and the reduction in permeability of the cemented zone, thereby minimizing the flowpath in the annular space.

5. SONIC CEMENT BOND LOG

It is a wireline tool which has transmitter and receiver for sending and receiving the acoustic (sound) waves towards the formation. It passes through the casing and cemented zone [11]. The perfectly cemented zone will have lower amplitude than that of the loosely packed cemented region. The data obtained is qualitative and easily detect the presence of microannulus in the cemented zone. Normally, the amplitude is <10mV and for heavier casing it falls between 12mV – 13mV. A field test has to be conducted with the similar geological well pattern drilled using NADF and cemented with conventional cement and with ICS, the amplitude is to be noted. That will show the difference in the bonding between the outerside of casing and the cement. When we go for CBL in the horizontal wells having high pressure high temperature (HPHT) phenomena, it is suggested to go for ultrasonic CBL but precautions & calibrations has to be mend for the CBL tool to prevent the external physical parameters acting on it. So, this CBL will be good in the determination of bonding between the exterior of the casing with the cement.

6. ICS Operating window

The study reveals the operating range of the ICS and is tabulated as follows:

S.No	Parameter	Unit	Operational Range
1	Density	ppg	12 – 18
2	Temperature	°C	24 – 170
3	NADF types		All muds except water & air based mud used globally
4	Width of the Channel	mm	<5

RESULTS AND DISCUSSION

The ICS can be good in the regions with residual NADF but the polymeric material cost is high. A new material has to be designed as the replacement for polymeric material which is cost-effective. Apart from this, the ICS have the following advantages:

1. Effective mud removal by inter-reaction with NADF
2. Increases the bonding between the cement & casing
3. Improves the hydraulic isolation of well from formation

4. ICS cemented zone will have less degradation during the stimulation operation

More advancements and research & development effort is needed in the application of ICS by reducing the time needed for the settling of cement and increase in the rheological properties of cement without affecting the subsurface environment.

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