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Research article

A new type of cementation flushing fluid for efficiently removing wellbore filter cake☆

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Abstract

For effectively removing the water-based drilling fluid filter cake and improving interfacial cementing strength and cementing quality, a new type of cementation flushing fluid (WD-C) was developed based on the strong flushing principle of water soluble fiber and the oxygenolysis principle of filter cake. It is composed of 0.5% WF-H fiber, 2.2% WF-O oxidant, 0.35% $FeSO_4$, 1.8% KCl, 3.0% swollen powder perlite and water with its density of 1.03 g/cm^3. This cementation flushing fluid was systematically tested and evaluated in terms of its washing efficiency on the filter cake of water-based drilling fluid and its capacity to improve the bonding strength of cementation interface. In addition, an analysis was performed of its effect on the physical-chemical characteristics and the micro-structures of interfacial cements by means of infrared spectrum (IR), scanning electron microscope (SEM) and energy dispersive X-ray detector (EDS). It is shown that the new cementation flushing fluid presents excellent washing effect on water-based drilling fluid filter cake (with washing time within 10 min). The cement particles at the cemented interface can be hydrated normally, and hydrated calcium silicate gel, $Ca(OH)_2$ and rod-shaped ettringite (AFt) crystal are generated and interwoven with each other. In this way, dense network structures are formed, so the bonding strength of the second cementing interface rises significantly, and then cementing quality is improved. Based on the research results, one more technology is set up for removing the water-based drilling fluid filter cake efficiently and improving the bonding strength of the second cementing interface.

Keywords: Flushing fluid; Water-based drilling fluid; Washing efficiency; Filter cake; Well cementing; Interfacial cementation; Cementing quality

Drilling operation would encounter a variety of complexities. During cementation, residual drilling fluid and filter cake may block the direct contact between slurry and borehole wall, and slurry would be dehydrated, dried out or pulverized, giving rise to micro-annulus in the interface between cement sheath and casing, lowering the interfacial cementing strength, undermining cementation quality significantly, and even causing oil, gas and water channeling [1−3]. Over the years, how to remove mud cake effectively has been a tricky issue in cementation [4]. In this study, a cementation flushing fluid based on the strong flushing and highly efficient oxygenolysis of water soluble fiber was developed. Its flushing efficiency to water-based drilling mud cake was tested, and its performance and mechanisms in enhancing interfacial cementing strength were evaluated. This fluid system provides a new means to remove water-based drilling mud cake and enhance interfacial cementing strength.

1. Design principle of a new type of cementation flushing fluid

1.1. Strong flushing principle of water soluble fiber

The special water soluble fiber WF-H with −OH, C═O, N−H, −COOH and other hydrophilic groups in its molecules

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added into the water-based mud cake flushing fluid can highly disperse in the water solution, and form 3D spatial network structure with water molecules and polymer molecules due to the electrostatic interaction. In this way, its flushing and cleaning and suspension capacity is improved, which is conducive to the removal of the drilling fluid and mud cake [5,6].

1.2. Oxygenolysis principle of mud cake

A compound highly active oxidant WF-O is added to the flushing fluid. It can generate highly active free radicals (OH•) and free oxygen radicals to oxidize and break big polymer molecules into small molecules, thus lowering the viscosity and eliminating the bridging and adhesion effect of the polymers in the drilling fluid. Then the tough and tensile mud cake turns to be loose and fragmental, and the bentonite, fine calcium carbonate and other inorganic fillings wrapped up and adhered by high polymers are exposed, making the mud cake and solid particles easy to be flushed away. Finally, the flushing efficiency of the flushing fluid is improved [7–9].

2. Experimental materials and methods

2.1. Experimental materials

The new cementation flushing fluid system WD-C is composed of 0.5% WF-H fiber, 2.2% WF-O oxidant, 0.35% $FeSO_4$, 1.8% KCl, 3.0% swollen powder perlite and water with a density of 1.03 g/cm^3. The cementation flushing fluid commonly used in field is composed of penetrating agent, dispersive agent, suspension agent and weighing agent in the formula of 10% flushing agent and water with a density of 1.01 g/cm^3. The water-based drilling fluid with a density of 1.30 g/cm^3 is a polymer anti-collapse drilling fluid system provided by Sinopec Shengli Oil Engineering Co. Ltd., in a detailed formula of water + 0.2% Na_2CO_3 + 3% bentonite + 0.4% sulphonate copolymer + 1.6% natural polymer loss controller + 3% sulfonated phenolic resin SMP-II + 0.7% organic amine +1.0% polymer inhibitor JBY + 1.2% al-based polymer + 3.5% latex asphalt + 2% lubricant +0.5% surfactant span-80 + 3% superfine calcium carbonate + 15% weighing agent. The G grade cement used in Linqu wells was provided by Shengli Huanghe Cementing Company, and the ethyl alcohol absolute was provided by Sinopharm Chemical Reagent Co. Ltd.

2.2. Evaluation method for flushing efficiency

With drilling fluid or mud cake stuck to the inner and outer walls, the rotary drum of rotating viscometer was washed at a rotating speed of 100 r/min, and weighed at regular interval to work out the percentage of drilling fluid washed from the rotating drum to the total drilling fluid stuck to the rotary drum, that is flushing efficiency [10–13].

2.3. Test of interfacial cementing strength

The man-made sandstone core was soaked in water-based drilling fluid and set aside for 30 min at 75 °C, allowing drilling fluid to adsorb and stick to the core surface fully. Then the core was soaked in the flushing fluid at 75 °C for 30 min, and observation was made of the cleaning situation of the drilling fluid on the core surface. The sandstone core was put in the middle of a bond strength mold, and conventional slurry (with a density of 1.90 g/cm^3) was poured around the core, the mold was put into a water bath of 75 °C to cure after being sealed. Then, the cement sheath and sandstone core were displaced respectively with displacement mold on a compressive strength testing machine to test the interfacial bonding strength after 24 h and 72 h of curing, which was divided by interfacial bonding area, and the interfacial bonding intensity was obtained and compared with the interfacial bonding strength of sandstone core not soaked with drilling fluid [14–16].

2.4. Characterization and analysis of interfacial cement

A representative interfacial cement sample was taken and ground into powder of 75 μm for infrared spectrum analysis. Then the cement sample piece was pasted to a copper sample stage with conductive adhesive, and plated gold in vacuum, then observed under S4800 FSEM made by Hitachi at an accelerating voltage of 5.0 kV, and analyzed to find out its element composition.

3. Cleaning efficiency test of the cementation flushing fluid

According to GB/T 16783.1-2012 – On-site Drilling Fluid Test (Section 1), the filtration test of water-based drilling fluid was conducted at 75 °C and 3.5 MPa for 30 min. The mud cake formed in the drilling fluid was then taken and bound to the outer drum of the rotating viscometer with glue tape. The outer drum and the mud cake were weighed. The cleaning efficiency of conventional cementation fluid and the new cementation flushing fluid to the mud cake at 75 °C and the viscometer rotating speed of 100 r/min were evaluated. The test results (Table 1) show that: ① the conventional cementation flushing fluid had poor flushing effect, after 10 min or even 20 min of flushing, there was still substantial mud cake stuck on the filter paper, and after 30 min of flushing, there was still a layer of mud cake on the filter paper unable to be removed; the cleaning efficiency at this time was 76.92%; ② the new cementation flushing fluid worked much better in removing the mud cake, with a cleaning efficiency of 93.41% after 10 min of flushing, meeting the requirements of on-site cementation. In one word, the new cementation flushing fluid can clean the mud cake of water-based drilling fluid around wellbore effectively in a short time, which is good for enhancing the interfacial bonding strength and cementing quality.