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Vegetable oil-based preflush fluid in well cementing

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ABSTRACT

Efficient cement bonding in wellbores provides better zonal insulation, containment of gas migration, prevention of excessive water production, besides affecting their economical performances. Carrying out a properly sized and formulated cleanup process (or pre-flush) is one of the most costly tasks in wellbore preparation. Different chemicals are commonly used both to remove filter cakes and enhance surface water-wetting, such as solvents and surfactants. The search for environmentally-friendly cleanup fluids, in particular, with acceptable wetting properties, has been challenging. This paper describes an experimental study to characterize and prepare a vegetable oil-based microemulsion to work as pre-flush fluid in wellbores. Results obtained from cleaning assays (removal test), wettability testings and fluid compatibility analyses have exhibited excellent performances in filter cake removal. Enhanced water-wetting and suitable rheological compatibility of cement/cleanup fluid/mud systems and good compressive strength were also achieved.

1. Introduction

Well drilling has been reaching locations increasingly deeper in petroleum exploration activities (Goel et al., 2014). During this process, the drilling fluid is pumped down inside the drilling column and carried back to the surface through the annular space between the drilling column and the borehole. Among other functions, this fluid is responsible for cooling and lubricating the drill bit, as well as for carrying the drilling cuttings and other debris (Gordon et al., 2008).

The drilling fluid (or mud) creates a film of low permeability on the borehole's wall, called filter cake. Removing all of the filter cake out the formation and drilling column is required to avoid a poorly-efficient case cementing (Quintero et al., 2008; Ren et al., 2015; Ba Geri et al., 2017).

According to Mcdonald et al. (2014), the efficient bonding between cement-coating and formation is attained when pumping fluids into the well (pre-flush). The fluids are injected after the drilling, but before the application of the cement slurry, so that the remaining mud along the annular space is thoroughly wiped. Consequently, the inner structural stability is ensured during the well cementing operation (Li et al., 2016; Pernites et al., 2015). The pre-flush is required to achieve: high efficiency of drilling mud cleaning; avoidance of emulsion or sludge formation; chemical compatibility with both drilling fluid and cement slurry; and, in a few cases, to correct the wettability of the rock formation (Quintero et al., 2008). Fig. 1 shows typical well cementing apparatuses adapted from Curbelo et al., 2017.

Aiming to increase the efficiency of well cementing, the oil industry has stimulated the development of new technologies based on microemulsified systems. For instance, Quintero et al., 2007 (a,b) and Ren et al., 2015 have studied microemulsions to invert the wettability and remove oil-based and synthetic-based (S/OBM) drilling fluids from the borehole's wall. These systems are potentially suitable for the drilling activities due to their high chemical affinity with both drilling fluid and cement slurry.

According to Pietrangeli and Quintero (2013), low interfacial tensions occur between the microemulsion and the oil-based mud (OBM) filtrate, thus increasing the tendency of the surface become water-wet. In turn, microemulsions with these properties provide suitable cleaning/removal of the organic material using low mechanical energy and enhance the water-wet condition.

By following the objectives aforementioned, this paper is intended to develop a pre-flush fluid with high efficiency, capability of wettability inversion and chemical properties compatible with the drilling fluid and cement slurry. Likewise, vegetable oil was preferred as the microemulsion oil phase to minimize environmental hazards.

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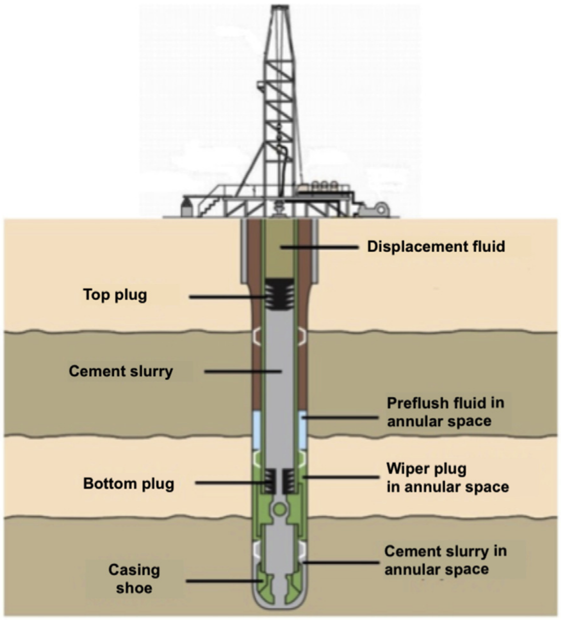

Fig. 1. Scheme of pre-flush fluid pumping inside the well.

2. Experiments

2.1. Phase diagram

Fig. 2 shows a schematic ternary phase diagram to determine the microemulsion region. To build the ternary diagram, we have used a mixture of two constituents (mass fraction given), which was titrated with the third one to be observed possible phase changes.

Initially, the maximum solubility of the surfactant in the aqueous phase (point P) was obtained. Thereafter, to determine the lateral boundary of the microemulsion region, three points (A, B, and C) on the surfactant/oil phase binary (S/O) were prepared and titrated with the aqueous phase (W) until the turbid emulsion became clear. The lower bound was determined by preparing other three points (D, E and F) on the aqueous/oil phase binary (WO) and titrated with the surfactant (S) until the system changed its turbid aspect to a clearer, when the microemulsion was obtained (M). The amounts of the WOS phases at each point were obtained by material balances. Points inside the microemulsion region were tested to characterize the cleaner pre-flush fluid.

To build a ternary phase diagram and delimit microemulsion regions, the following constituents were used: aqueous solution of glycerin (mass ratio 1:1) as aqueous phase; vegetable oil (pine oil) as oil phase; Tween 80 (T80), polyoxyethylene (20) sorbitan monooleate, by Dinâmica (manufacturer), and Ultranex NP 150 (NP150), nonylphenol etoxilated by Oxiteno - Brazil, as non-ionic surfactants. The diagrams were constructed experimentally at room temperature by a conventional titration technique. Glycerin was used to increase the microemulsion's viscosity. The rheology of the microemulsions was measured with a Fann 35 viscometer, according to the API testing recommendations.

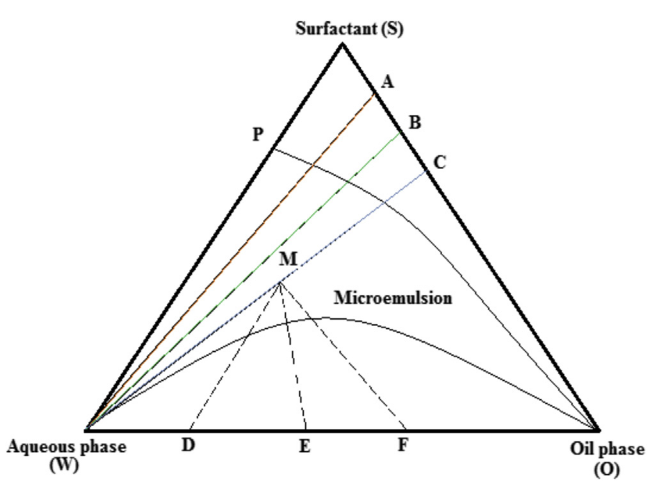

Fig. 2. Schematic ternary phase diagram to determine the microemulsion region.

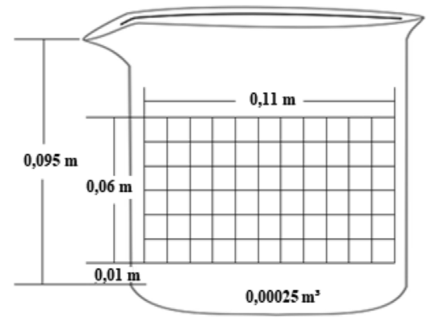

Fig. 3. Schematic representation of the visualizing frame.

2.2. Removal test

This test aims to simulate the removal operation of the drilling fluid from the borehole's wall using a microemulsion-based cleaner fluid. Initially, it was prepared $2.0 \times 10^{-4}\,m^3$ of the microemulsion, heated under agitation up to 361.15 K. Simultaneously, the non-aqueous drilling fluid was homogenized with a Hamilton-Beach agitator for 900 s. After agitating, about 2.0×10^{-6} to $4.0 \times 10^{-6}\,m^3$ of the drilling fluid were poured into a beaker to completely cover the visualizing frame (Fig. 3) so as to form a uniform filter cake layer. Subsequently, the microemulsion was carefully poured into the beaker in the opposite side of the visualizing frame to maintain it intact. This procedure was done in according to Procelab (Campos, 2009).

The beaker was placed on the Fann 35 viscometer and, simultaneously, the chronometer was started. The removal test lasted a maximum time of 600 s, being the chronometer stopped before the end time whether the visualizing frame was completely clean. Finally, the percentage of clean area in relation to the total area of the visualizing frame was calculated, obtaining, therefore, the efficiency of the cleanup fluid, according to equations (1) and (2), namely the cleaning efficiency of the pre-flush fluid.

$$\text{Removed area} = \text{number of squares removed x } 0.0001\,m^2 \tag{1}$$

$$\text{Removal efficiency} = (\text{removed area} / 0.0066\,m^2) \text{ x } 100\% \tag{2}$$

2.3. Wettability inversion test

Synthetic oil-based drilling fluids can be altered by the continuous addition of water-based fluids containing surfactants (cleaner fluids) under dynamic conditions. The magnitude of these changes can be observed by using specific techniques, such as microscopy or electrical conductivity measurements (Quintero et al., 2015). The brine-in-oil (W/O) emulsion has near-zero conductivity, whereas oil-in-brine (O/W) emulsion has high conductivity, like the aqueous phase.

Phase inversion may occur gradually or suddenly with change of composition depending on the correct formulation of the surfactant mixture used in cleanup fluids. At the phase inversion point, the fluid system undergoes its lowest interfacial tension. Under these conditions, spontaneous microemulsification occurs between the oil and water phases of the system.