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Removal of formation damage induced by drilling and completion fluids with combination of ultrasonic and chemical technology

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ABSTRACT

Drilling fluids and completion fluids usually contains solids, high amounts of molecular and long-chain polymers, which may result in severe permeability damage. The application of ultrasonic waves has been widely used for formation remedy but the effectiveness on polymer-induced damage is limited by downhole acoustic intensity. Thus, the combination of ultrasonic and chemical (acid and chlorine dioxide) technology has been experimentally investigated in this paper. The effect of core initial permeability and the ultrasonic irradiation characteristics, including frequency and time interval, on the cleaning results were then investigated by an ultrasonic technique such that the optimal ultrasonic parameters could be selected. Experimental results demonstrate that the ultrasonic energy and frequency have positive relationships with cleaning effectiveness, and treatment time duration was measured to extend beyond 60 min to ensure a sufficient physicochemical reaction. A comparison with the plugging removal effect with independent chlorine dioxide (ClO_2), acidizing, ultrasonic remedial treatments, and a combination of ultrasonic and chemical techniques indicates that the combination technique can produce better cleaning results because of the good coordination among the acid, oxidant and ultrasonic wave. The integration of acid, oxidant and ultrasonic technology is beneficial for long-chain polymer degradation and the removal of iron ion precipitation and solids, whereas ultrasonic energy can extend the chemical activation time3, increase the reaction rate and enhance the byproduct removal.

1. Introduction

Drilling and completion fluids, which are non-native fluids for contact with formation rocks, have the potential to invade the formation and react with formation minerals to cause formation damage. Both drilling fluids and completion fluids are composed of liquids, particles, and chemicals, so solid and polymer plugging of pores is the main formation damage mechanism. Damage induced by drilling and completion fluids exists in the majority of oil and gas wells and generally occurs at the first stage of well production, resulting in great reduction of the production rate (Longeron et al., 1995; Hands et al., 1998). Moreover, the usage volume of drilling and completion fluid is generally huge and is readily lost into the formation at overbalance drilling conditions, thus formation damage problems during drilling and completion stages are more serious than other types of formation damage such as organic depositions, including paraffin and wax. Therefore, it is meaningful to remove and mitigate the impact of formation damage due to drilling and completion fluids.

Remedial treatments for conventional formation damage include hydraulic fracturing and acidizing, but these technologies have some issues in fluid compatibility and HSE (health, safety and environmental). Therefore, the removal the formation damage or clean wellbore by ultrasonic technology was presented and has been widely developed in petroleum industry. Some literatures have already been reported on formation and wellbore stimulation by ultrasonic technologies. Some authors carried out experiments on the removal of asphaltene depositions, paraffin precipitation and wax about formation damage remediation with ultrasonic technology (Gollapudi et al., 1994; Zekri et al., 2007;

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Shedid, 2004; Brian et al., 2007). Recently, the laboratory study concerning the application of ultrasound to enhance well stimulation were discussed by some researchers (Bjorndalen and Islam, 2004; Amro et al., 2007; Tunio et al., 2011). The theory behind this was that when such a wave passes through porous media it will be dispersed into higher harmonics producing a series of effects that include: the disruption of the surface film, the coalescence of oil drops together with oscillation, and the excitation of oil drops trapped in capillaries (Mullakaevn et al., 2015). In addition, because fluid and rock interaction and high pressure at the wellhead can be avoided during ultrasonic stimulation treatment, thus it is regarded as one of the most promising techniques among wave methods for increasing well production rates. Comparing to the organic deposits, the main damage mechanism of drilling and complex fluids is more complex. Reed once summarized possible nine mechanisms of formation damage by drilling and completion fluids (Reed, 1989). Robert et al. presented the results of a wide-ranging investigation into the application of high-power sound waves to remove polymer induced damage from the wellbore and near-wellbore regions. But the removal effects were limited from their results (Roberts et al., 1993; Venkitaraman et al., 1995). Bahador performed a series of experiments about mud cake and mud filtration treatment with ultrasonic technology and there is an optimum ultrasonic radiation time for different ultrasonic wave intensities (Bahador, 2012). From the discussion above, tackling the formation damage issues by ultrasonic technology from both the drilling and completion fluids point of view was lacking. On the one hand, the damage mechanisms by drilling and completion fluids come from solids transport, local buildup of polymer concentration and filtrate invasion, ultrasonic technology alone was probably not effective at restoring permeability for this serious damage because ultrasonic effectiveness is limited by its power energy. On the other hand, the removal treatments of drilling and completion fluids by ultrasonic technology are generally performed repeatedly if removal effectiveness is limited, which means more cost and operation time. Thus, it's necessary to improve traditional ultrasonic technology in serious formation damage remedy.

In this paper, we follow up on work presented previously, in which the integration of ultrasonic and acidizing treatments was used simultaneously to reduce damage caused by drilling mud infiltration, fines migration and polymer concentration. In the first section, the main formation damage mechanisms due to drilling and completion fluids are discussed. In the next section, we discuss the experimental setups and experimental procedures taken throughout the investigation. Furthermore, to investigate the removal of damage effects by a combination of acoustic and some commonly used chemical treatments, acidizing (niobium hydroxide) and strong oxidants (ClO_2) were used in the experiments to accelerate the breakdown of high-chain polymer. The comparison of the measurement results for independent chemical damage removal, independent ultrasonic damage removal, and the combination of chemical and ultrasonic damage remove are given. Moreover, the influence of many relevant parameters of these new techniques are reported, and the study's conclusions are presented in the final section.

2. Formation damage mechanisms and remedial treatments

2.1. Formation damage mechanisms

A variety of fluids are used for drilling and completion engineering, thus mechanisms of formation damage by fluids are different. In general, two main reasons can be used to characterize the drilling fluids damaging mechanisms.

(1) filtrate invasion

The filtrate invasion of drilling and completion fluids to the formation usually happens when the wellbore pressure is greater than pore pressure. Drilling and completion fluids can induce clay minerals swell and the disintegrated solids results in a local buildup at pore throats, which cause permeability decline. Some authors think the clay expansion only have obvious effect on permeability damage if reservoirs contain as much as 5–10% smectite. In addition, when the expandable clays undergo expansion, this tends to destabilize the associated non-expanding clays and cause them to migrate and plug flow channels. Moreover, flowing non-nature liquids can invade into reservoirs and reduce flow capability of oil and gas or cause water blocking although water blocking can be avoided or alleviated to some degree by use of special drilling techniques, like underbalance drilling or the application of gas-based working fluids (Van der Bas et al., 2004).

(2) solids and polymer plug

Because the performance of drilling and completion fluids are influenced mainly by three main factors; i. e, fluid density, viscosity and pH. Therefore, fluids usually consist many substances in solid phases, like drilled solids, weighting materials, and polymer, which can penetrate into formation and result in pore throats blocking (Poesio and Ooms, 2007). In addition, water-based drilling mud most commonly consists of Bentonite, with some additives such as Barium Sulfate (Barite), Calcium Carbonate (Calcite). Thus, drilling fluids mix underground fluids and rock, so if not compatible, precipitant from bacteria community or polymer can be generated. In particular, drilling fluid with more calcium chloride can cause formation damage when kill well for formation with connate water having bicarbonate. Precipitants due to drilling and completion fluids can block pore throats, which is more serious if mud cake is not created.

In addition to above formation mechanisms, the possible drilling and completion fluids induced formation damage mechanisms are summarized in Table 1.

2.2. Formation damage remedial treatments

Well productivity can be seriously reduced by formation damage formed by drilling and completion operations, thus numerous remedial treatments have been available to recover formation permeability after formation damage.

The conventional techniques to remove formation damage are mechanical treatments, acidizing stimulation and hydraulic fracturing, which get great success in some field applications. Several potential critical issues need to be considered before conventional permeability remedy. One is the compatibility between injected fluids and nature fluids. The second is the fluid placement efficiency, which probably divert and penetrate into unwanted flow channels. Thirdly, the remediation fluids, usually acids, used in matrix stimulation can cause apparatus and tubing corrosion, safety risk of toxic chemicals and environmental pollution. Mechanical methods only can utilize instruments like knives or hook et al. to remove deposits in the wellbore. Hydraulic fracturing is usually time consuming and expensive. Acidizing or is used as a remedial procedure, only if the hydraulic fracturing technologies are not feasible or successful. This technology involves the use of low and high concentration of acid that can redissolve and disperse the deposit, but it must be adapted in response to rock's mineralogy and physical properties. Because the application of some cross-linked polymer such as HPMC (hydroxypropyl methylcellulose) or PAM (polyacrylamide),