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Research Note

The Use of Nanoaccelerator in Cement Slurries in Low Temperature Well Conditions

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ABSTRACT

It has long been known that temperature during circulation and after cement placement is one of the most important parameters for slurry design and the success in cement production. Conventional cements and low density cement slurries usually take a long time to set and cannot provide significant compressive strength. Therefore, it is important to design appropriate low density cement slurries for low temperature conditions during surface casing cementation. In well cementing procedures, the slurry must be fluid for a sufficient time to allow the task to be completed. One of the problems that frequently happens in cementing a low temperature formation is a long setting time, in which the cement is influenced by low temperatures and the thickening time increases. To solve this problem, a unique cement system, which contains nanosilica, hollow spherical material, and class-G oil well cement, was developed for the first time. For this purpose, some additives such as; dispersants and fluid loss control agents were used in the cement system. The laboratory tests show that this slurry has a low density, excellent fluid loss control, no free fluid, right-angle-set, and a short thickening time (47 minutes) at low temperatures. The experimental results presented herein can help resolving problems in surface casing cementing.

Keywords: Nanoaccelerator, Cement, Compressive Strength

INTRODUCTION

The main purpose of cementing operation is providing good zonal isolation between formations, while maintaining the integrity of the well. For this reason, cement mixed with additives is pumped into the wellbore. The drilling mud must be displaced from the annulus and the cement should set as soon as possible. The success in such an operation depends on some physical parameters. Temperature is the most critical factor, which strongly affects the setting time of the cement slurry. To achieve the sufficient setting time, accelerators or retarders are used in the slurry composition [1, 2].

Cement slurry design using conventional additives for primary casing cementation at a low temperature is an industrial challenge. Cement slurries for field implementation have to possess an adequate placement time, minimum fluid loss, good rheological properties, minimum free water separation, good stability, and early strength development capability in operational conditions. However, with all empirical developments in cementing technology, achieving all of the above requirements is extremely difficult with conventional cement additives [3, 4]. Thickening time of cement

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slurry plays a critical role in cementing operations. Several problems are the result of ineffective setting time control. Accelerators such as calcium chloride are often used to reduce the slurry thickening time and enhance early compressive strength development; they are employed to minimize waiting on cement (WOC) time. The use of a standard cement-setting accelerator $CaCl_2$ was not sufficient for shortening the curing time of lightweight cement slurries, since this accelerator became active, only when the slurry density exceeded 1.6 g/cm^3. If used in slurries with lower densities, intensive slurry sedimentation may happen [5]. This paper recommends a low cost high performance alternative by using nanosilica and hollow sphere materials.

Surface Casing Cementing

Surface casing is used in well construction in order to isolate unconsolidated formations and fresh water aquifers found at shallow depths. The surface casing prevents the contamination of groundwater with drilling fluids used in the well and the produced fluids such as oil, gas, or brine. Additionally, the surface casing is the structural foundation of the well, and it is often the first casing string, which connects to the blowout preventers. However, surface casing cementing is encountered with such new problems as low temperature, rig cost, compressive strength, and so on. These problems can seriously affect the quality and cost of surface casing cementing [6].

Low Temperatures

For cementing the temperature is around 30 °C. Lower temperatures during cementing decrease the rate of hydration process of cement significantly, compromising static gel and compressive strength development, which are essential to prevent fluid migration and provide structural support for the well [7]. Figure 1 shows the effect of temperature on the thickening time of cement class G with 2% $CaCl_2$.

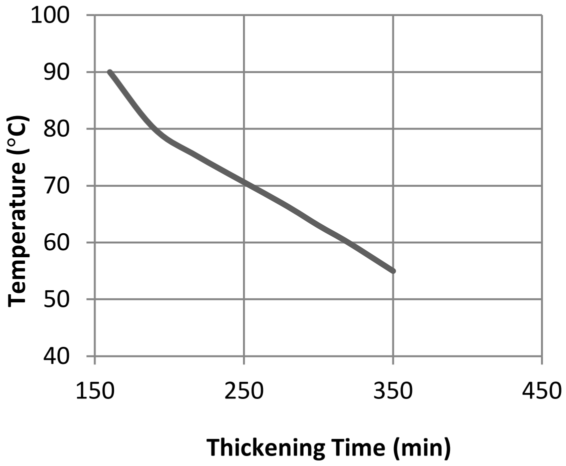

Figure 1: Effect of temperature on thickening time of cement class G with 2% $CaCl_2$ [1, 2].

Compressive Strength Development

It is important to notice that in cementing the surface casings, compressive strength at low temperatures will significantly be developed. Figure 2 shows the effect of temperature on compressive strength.

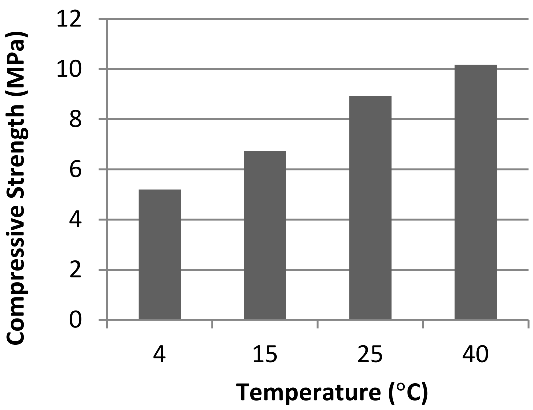

Figure 2: Effect of temperature on compressive strength [1].

Rig Cost

Total operating cost influenced by waiting on cement (WOC) is an important parameter in drilling cost. The time needed to achieve enough compressive strength in order to resume drilling, is determined by the cement formulation and the well conditions. Reductions in the WOC time decrease drilling costs and lead to an improvement in the rig cost [8].

The Solution

Hollow Sphere Material (HSM)

Thickening time is reduced by increasing solid to liquid ratio of slurry. Therefore, some water should be eliminated from system; however, it increases the weight of cement. For solving these problems, we add HSM and dispersant to cement slurry for reducing the weight of cement and friction respectively. A cement slurry design using G grade cement was previously developed for cementing a surface casing string. Hollow microspheres are low-density agent in lightweight cement slurries. Its composition includes 30% By weight on cement (BWOC) of hollow microspheres.

Accelerator

Accelerators can speed up the hydration and enhance the early compressive strength of the set cement. They are usually added to cement slurries to reduce the setting time, especially in low temperature environments. [1, 3] Although calcium chloride is the most common accelerator for Portland cement, it has some secondary effects on the heat of hydration, rheology, compressive strength, and permeability. The selected additive should provide high pozzolanic reactivity to participate in the chemical reactions towards the reduction of the thickening time at low bottom hole temperatures [11]. The selected material also should be compatible with the other conventional cement additives and should be inexpensive, unhazardous, and also eco-friendly. Nanosilica is an accelerator which can enhance cement early strength at low temperatures; it has no secondary effects and is environmentally friendly [9, 10].

Nanosilica has been one of the most widely used products for concrete for over eighty years. Their properties provide a high compressive strength and also water- and chemical-resistant set cement, and they are utilized in a large number of buildings we see nowadays. Using Nanosilica in cement composition leads to [10]:

- Improving compressive strength by at least 25-30%;
- Water proofing due to nanosized particles filling up all the pores;
- Excellent crack resistance;
- Reducing the thickening time of cement [8].

Due to chemical reactions, the kinetics of cement hydration severely depends on the degree of contact between the primary reactants, i.e. cement particles and water, in this case. Generally, for a specific chemical composition of cement, a greater surface area leads to a faster reaction between cement and water, and, consequently, the setting time decreases and the cement strength rises faster. The accelerating effect of nanosilica in cement is well reported in the literature. The faster hydration of cement in the presence of nanosilica is due to its chemical reactivity upon dissolution (pozzolanic activity) and to their sufficient surface activity. Nanosilica accelerates the dissolution of the C_3S phase and renders a more rapid formation of the calcium–silicate–hydrate (C–S–H) binding phase.

Nanospherical silica has been used in concrete, but its use for slurry designing for low bottom hole circulation temprature (BHCT) wells is not an established practice. With considering the advantages of the high reactivity of nanospherical silica and its fine particle size, it was realized that using this material in slurry designing for low BHCT wells might provide an effective solution to this problem [11, 12].

Dispersant

Dispersants are often used in oil and gas well cementing. Dispersants can reduce the apparent viscosities of the cement slurry. They are utilized to allow the cement slurry to be pumped at a low friction pressure and horsepower. In addition, the lower viscosity often allows the cement slurry to be pumped in a turbulent flow [1]. CFR-2 is a dispersant, which is used for designing the cement slurry.

Slurry Design

Formulation 1 ($CaCl_2$)

It was tried to show that $CaCl_2$ could not decrease the thickening time of cement slurry for low temperature wells. The slurry compositions, used for cement slurry designed using $CaCl_2$ as an accelerator, are shown in Table 1. The rheology test showed a plastic viscosity of 18 cp and a yield point of 12 lb/100ft^2. A pressurized Consistometer was used to measure the thickening time of the cement slurry. The result of the consistency test showed that the slurry was not set after 700 minutes.

Table 1: Slurry components of the $CaCl_2$ experiment.

Sample No.	Water (cc)	Cement (g)	Bentonite (g)	Low loss161 (g)	Microsilica (g)	$CaCl_2$ (g)
1	1200	1000	30	10	100	40
2	1200	1000	40	10	100	40

Formulation 2 (Nanosilica)

The former experiment showed that $CaCl_2$ cannot be used as an accelerator for cementing wells in low temperature conditions. The components used to design cement slurry by utilizing nanosilica as an accelerator are shown in Table 2. These slurries showed better rheological properties with respect to the previous experiments, but none of these slurries set after 700 minutes.

Table 2: Slurry components of nanosilica experiment.

Sample No.	Water (cc)	Cement G (g)	Bentonite (g)	Low loss161 (g)	Microsilica (g)	Nanosilica (g)
3	1200	1000	30	10	100	40
4	1200	1000	30	10	100	40

Formulation 3 (Nanosilica+D124)

Reducing the water content of slurry leads to the reduction of the thickening time. Also, the cement slurry density will be increased. To prevent this problem, D124 is used; D124 is a hollow sphere material with a very low density. By reducing water, the solid to liquid volumetric ratio will be increased, which causes a higher friction loss during pumping operation. Therefore, CFR-2 is used as a friction reducer additive. Table 3 illustrates the components used in the cement slurry design. By comparing the results of various tests, class G cement consisting of D124 (30% BWOC), Microblock (10% BWOC), nanosilica (3% BWOC), and friction reducer (1% BWOC) with a density of 1.45 gr/cm³ was chosen due to its better rheological properties, especially its thickening time. Thickening time was measured about 47 minutes for this cement slurry. Table 4 shows the rheological properties of sample No. 6.

Table 3: Slurry component of nanosilica and D124 experiment.

Sample No.	Water (cc)	Cement G (g)	D124 (g)	Microblock (g)	CFR-2 (g)	Nanosilica (g)
5	600	1000	300	100	10	30
6	600	1000	300	100	5	20
7	600	1000	300	100	10	20
8	600	1000	300	100	10	15

Table 4: Rheology of sample No. 6 at 30 °C.

YP	PV	θ3	θ6	θ100	θ200	θ300	θ600
7.5	82.5	7	9	35	65	90	110

CONCLUSIONS

- Conventional cement slurry is not ideal for surface casing cementation of wells at low temperatures. For cementing these types of wells, accelerator is used for the reduction of thickening time. Calcium chloride is a common additive as an accelerator in petroleum. However, calcium chloride did not have any effects on the thickening time of the slurry for these well conditions.

- Cement slurry design for low temperature environments may be carried out with an alternate approach to incorporating a suitable material in the slurry design, which should have a high pozzolanic reactivity and a small particle size to fill up the void spaces between the solid cement particles for achieving better mixing properties.
- Nanospherical silica has been used for designing cement slurry for low temperature wells. This additive negligibly decreases the thickening time of the slurry.
- Hollow sphere material has a very low density; therefore, by using hollow sphere material, one can reduce the water content of cement slurry. It is obvious that water content reduction will decrease the thickening time.
- Use of nanosilica and hollow sphere material in cement slurry simultaneously causes an early compressive strength development and results in the reduction of its thickening time.

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