Experimental Investigation Different Factors on Performance of Cement during Well Completion

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Abstract: One of the biggest challenges in petroleum upstream is well completion during well drilling operation due to cement thickening time, compressive strength and cement slurry rheology behavior. To tackle the addressed issue in well completion specifically in well cementing, rheology behavior and thickening time cement before injection into well annulus should be determined to design high performance well completion and production operation. To defeat this referred obstacle, current research implemented various experiments on one of northern Persian gulf oil field wells cement slurry. These experiments are condensed to ultrasonic cement analyzer, High Pressure – High Temperature consistometer, rheology and thickening test.

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1. Introduction

Oil well cementing is necessary in disconnecting between various layers with various pressures. Origin problem in cementing operation of oil and gas wells is existence of capillary channels while strengthening the cement. These channels making cement network isolation weak, as a consequence avoid disconnection between various areas by the cement. As summary, existence of capillary channels in cement, typically obstacle to accessing to cementing aims, sometimes this is impossible.

Since various situations of temperature, pressure, permeability, wall texture, and etc. in oil wells are act as various conditions, it is necessary to use some chemical materials in water or cement or both of them to reinforcement the physical properties of the fluid, so that the fluid has suffered these situations to find the ability of cementing throughout the well. The additives are classified into two category based on type of affecting in to cement: Chemical, Physical, so they are adding to the cement followed by one of these reasons:

For increasing or decreasing the slurry density, increasing or decreasing the thickening time of slurry, increasing the strength specially strength of first cement rock, for avoid circulation lost in the formation has been drilled, for increasing or strengthening the cement, for decreasing water loss of slurry and waiting time for consolidation.

The main goal of this paper is to use superabsorbent as cement additive, so it has been analyzed laboratorial. The superabsorbent with various concentrations are add to the drilling cement and all of the cement properties such as: density, rheological properties, free water, circulation loss, compressive strength, thickening time before and after adding superabsorbent are measured.

2. Materials and procedure

2.1. Materials

Superabsorbent polymer (SAP) materials are hydrophilic networks that can absorb and retain huge amounts of water or aqueous solutions. They can uptake water as high as 1,000-100,000% (10-1000 g/g) whereas the absorption capacity of common hydrogels is not more than 100% (1 g/g). Common SAPs are generally white sugar-like hygroscopic materials, which are mainly used in disposable diapers and other applications including agricultural use. Visual and schematic illustrations of an acrylic-based anionic superabsorbent hydrogel in the dry and water-swollen states are given in Figure 1 [1-2].

The synthesis of the first water-absorbent polymer goes back to 1938 when acrylic acid (AA) and divinylbenzene were thermally polymerized in an aqueous medium [3]. In the late 1950s, the first generation of hydrogels was appeared. These hydrogels were mainly based on hydroxyalkyl methacrylate and related monomers with swelling capacity up to 40-50%. They were used in developing contact lenses which have make a revolution in ophthalmology [5].

The first commercial SAP was produced through alkaline hydrolysis of starch-graft polyacrylonitrile

(SPAN). The hydrolyzed product (HSPAN) was developed in the 1970s at the Northern Regional Research Laboratory of the US Department of Agriculture [4]. Expenses and inherent structural disadvantage (lack of sufficient gel strength) of this product are taken as the major factors of its early market defeat. In the Middle East, SAP production was started around 2004 by Rahab Resin Co., an Iranian private sector company, under the license of Iran Polymer and Petrochemical Institute (IPPI) [6-7].

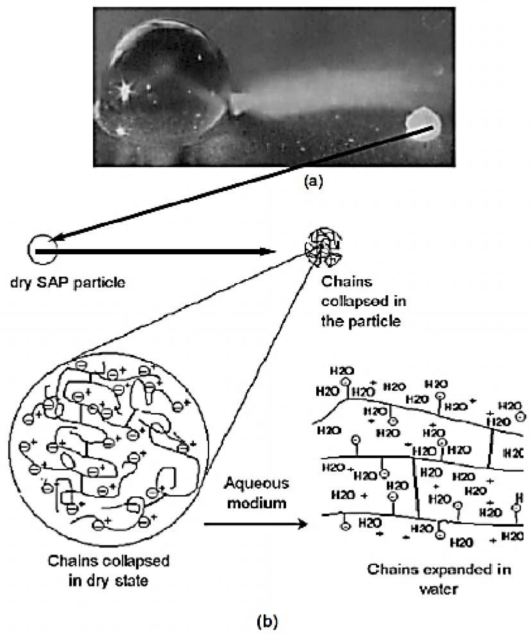

Figure 1: Illustration of a typical acrylic-based anionic SAP material: (a) A visual comparison of the SAP single particle in dry (right) and swollen state (left). The sample is a bead prepared from the inverse-suspension polymerization technique. (b) A schematic presentation of the SAP swelling.

2.2. Experimental Procedure

2.2.1. Slurry Design

Each well has certain basic characteristics that dictate the required cement slurry properties and performance. Careful and thorough review of these well characteristics is essential for designing effective slurry [8]. In this research CEMCADE software used for slurry design.

2.2.2. Constant Speed Mixers

The Chandler Model 3060 Constant Speed Mixer provide all the necessary functions to mix cement slurries according to API Spec 10, Section 5. The mixers can also be used to thoroughly mix other shear-sensitive dry or fluid materials. Recent detailed testing within the API has shown that the methods of mixing cement slurries will significantly effect the thickening time. The Model 3060 Mixer are designed in accordance to API Spec 10 and have constant speed operation independent of the line voltage and rate that cement is added to the mix water. Good practice indicates that the cement be added slowly over a fifteen second period as specified by API Spec 10, Section 5. Specification of the Chandler Model 3060 Constant Speed Mixer [9]:

Container Material: Stainless steel

Maximum Speed: 18,000 rpm *

Speed Selection Switch: Three push button switches to quickly select the desired speed

Constant Speeds: Two independently adjustable speeds over a wide range of rpm, adjusted by Chandler to 4,000 and 12,000 rpm (per API Spec 10)

Adjustable Speeds: From 1000 to 18,000 rpm

Display: Speed is displayed directly in rpm

Container Volume: 1 quart (1 liter)

Dimensions: 26” (66 cm) high x 16” (41 cm) deep x 11” (28 cm) wide

Net Weight: 45 lbs. (20 Kg)

Shipping Weight: 80 lbs. (36 Kg)

2.2.3. Pressurized Mud Balance

The Pressurized Mud Balance is a self-contained measuring device used to accurately determine the densities of drilling fluids, cement slurries and similar materials under pressure [10].

2.2.4. Ultrasonic Cement Analyzer (UCA)

The *CHANDLER* Ultrasonic Cement Analyzer (UCA), Model 4265, provides a determination of the strength development of a cement sample while it is being cured under downhole temperature and pressure conditions. Cement strength is inferred by measuring the change in velocity of an ultrasonic signal transmitted through the cement specimen as it hardens [11].

2.2.5. Atmospheric Consistometer

The CHANDLER Model 1250 Atmospheric Consistometer is specifically designed to prepare cement slurries for the testing of various parameters in strict compliance with API Spec 10 A/B.

The testing of cement slurries requires the measurement of rheological properties, fluid loss, free water and various other properties. The Model 1250 provides a simple and accurate method for conditioning the cement slurries in preparation for making these tests. API Spec 10 A, Section 7 outlines the requirements and provides the basis for the design and operation of Atmospheric Consistometers [12].

Cement slurries are initially mixed with a Chandler Model 3060 or 3070 Constant Speed Mixer in compliance with API Spec 10 A/B. The slurry is then placed into the Model 1250 for any or all of the following tests:

a) **Determination of Rheological Properties-**

Measured as specified in Section 12, API Spec 10B.

b) **Determination of Fluid Loss at Temperatures less than 194°F-**

Measured as specified in Section 10, API Spec 10B.

c) **Water Content of Slurry-**

Measured as specified in Section 7, API Spec 10A.

2.2.6. HP-HT Consistometer

The CHANDLER Pressurized Consistometer has revolutionized cement thickening time tests. The Consistometer has a wide pressure and temperature operating range- up to 50,000 psi. (350 Mpa) and 600°F (315°C). With high temperatures and pressures applied to the cement, it is possible to simulate virtually all down-hole well cementing conditions [13].

Cement slurries are prepared with a Chandler Model 3060 Constant Speed Mixer in compliance with Section 5 of API Spec 10A and API RP-10B. The slurry is then poured into the slurry container and placed in the consistometer. Next, the pressure and temperature in the consistometer are brought up to the desired levels- according to either API cementing recommendations or the conditions of a specific well. The slurry container is rotated at a constant speed of 150 rpm to impart circulation to the cement in the slurry container.

Measuring the thickening time of cement slurries is a fundamental procedure that must be done prior to primary or secondary oil well cementing. The proper technique and procedures are outlined in detail in Section 8 of API Specifications 10A and API RP-10B.

2.2.7. Pressurized Curing Chamber

The *Chandler* Pressurized Curing Chamber is specifically designed to prepare cement samples for compressive strength testing in strict accordance with API Specification 10, Section 7.

These Pressurized Curing Chambers contain pressure vessels with controlled heating rates, and are used to cure standard two-inch cement cube samples [14].

Cement slurries for testing are initially mixed with a Chandler Model 30-60 Constant Speed Mixer in compliance with Section 5 of API Spec 10. The slurry is then poured into slurry molds and the molds are lowered into the pressure vessel. The pressure vessel is brought up to temperature and pressure to meet the conditions of the specific well being studied. (Typical values for the increase of temperature and pressure on the samples in the molds are detailed in API Spec 10.) Testing to determine the compressive strength of samples is usually done after the samples have been in the pressure vessels for periods of 8,12, and 24 hours, and seven days [14].

3. Results and Discussion

3.1. Slurry Design

Implemented cement slurry through this research was selected from one of the northern Persian oil field wells located in Khuzestan state. Carried out cement slurry contained Norwell 100% and CD-1B by 0.2 weight percent. To determine weight of these ingredients in gram, CEMCADE software was implemented. Obtained results from CEMCADE software as follow:

Cement G Norwell 737 gr, Dispersant CD-1B 1/47 gr, D- water 367 gr.

3.2. Mix

To assess high quality cement slurry, mixer which contains distilled water was run in 4000 rpm and after that dispersant was added gradually. It should be noted that here, mixing time of cement is around 30 second.

3.3. Compressive Strength Test

Provided cement slurry was carried out to figure compressive strength out by implementing ultrasonic cement analyzer. Obtained results from compressive strength demonstrated in Figure 2.

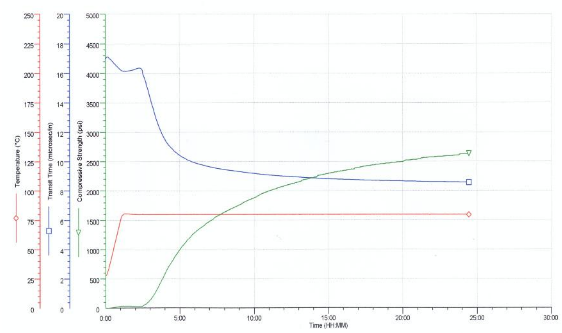

Figure 2: Compressive strength test results

3.4. Atmospheric Consistometer

3.4.1. Free water test

Free water content of reference cement slurry after 2 hour is 9 cc.

3.4.2. Rheology test

Rheology behavior of cement slurry is illustrated in Table 1.

Table 1: shear stress of reference cement slurry in different shear rate

Shear Rate (rpm)	**Shear Stress** $(\frac{lbf}{100\ ft^2})$
300	**42**
200	**37**
100	**30**
6	**14**
3	**11**

By plotting shear stress versus shear rate of cement slurry, rheology behavior of cement slurry can be determined. As shown in Figure 3, cement slurry followed Herschel model.

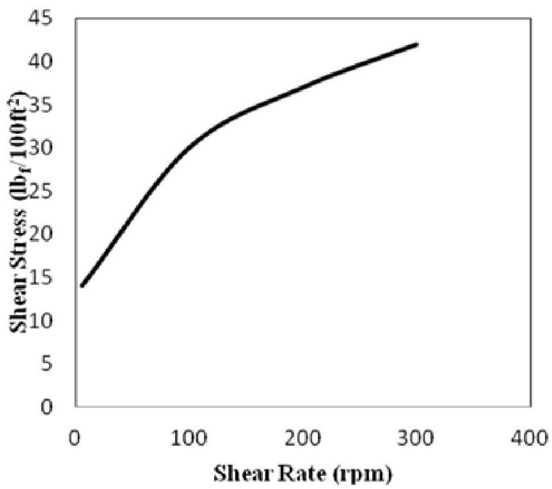

Figure 3: Rheology behavior of reference cement slurry

3.4.3. HP-HT Consistometer

Thickening experiment on reference cement slurry is demonstrated in Figure 4 due to 3 and 4 Volts in 88 and 116 minutes, correspondingly.

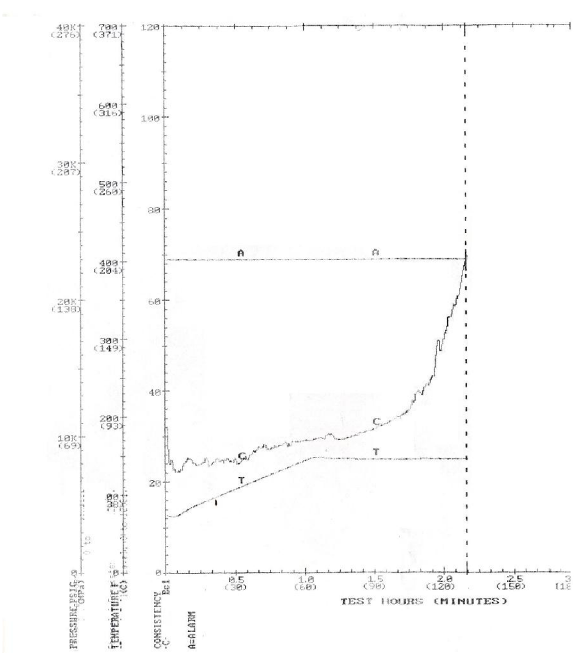

Figure 4: Thickening time of cement slurry

X axis in Figure 4 represent thickening time of cement slurry in unit of hour and minute and each line of plot represent 5 minute. In Y axis pressure reported in MPa, Temperature in ^{o}C and ^{o}F and cement slurry concentration reported in Bc. As shown in Figure 4, plot A represent set value as a stop criteria of experiment, plot T represent temperature and plot C represent concentration degree and thickening degree of cement slurry. It should be noted that here, by plotting straight line on plot C, thickening time of each current determined.

Conclusions

Various parameters were investigated systematically to figure out effect of each parameter onto cement slurry robustness during well completion job. Based on obtained results of this research following conclusion can be drawn:

- Cement slurry followed Herschel rheology model.
- Thickening time of cement slurry for 3 and 4 volts are 88 and 116 minutes, respectively.

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References

1. M. J. Zohuriaan-Mehr, K. Kabiri; Iranian Polymer Journal 17 (6), 2008, 451-477).
2. H. Omidian, M. J. Zohuriaan-Mehr, K. Kabiri, K. Shah, Polymer chemistry attractiveness: Synthesis and swelling studies of gluttonous hydrogels in the advanced academic laboratory, *J Polym Mater*, 21, 281-292, 2004.
3. Buchholz FL, Graham AT, Modern Superabsorbent Polymer Technology, Wiley-VCH, New York, Ch 1-7, 1998.
4. Buchholz FL, Peppas NA, *Superabsorbent Polymers Science and Technology*, *ACS Symposium Series*, 573, American Chemical society, Washington, DC, Ch 2, 7, 8, 9, 1994.
5. Dayal U, Mehta SK, Choudhari MS, Jain R, Synthesis of acrylic superabsorbents, *J Macromol Sci-Rev Macromol Chem Phys*, C39, 507-525,1999.

6. Superabsorbent hydrogels, Website of the leading Iranian manufacturer of superabsorbent polymers; Rahab Resin Co., Ltd.; www.rahabresin.com, available in 10 September 2007.
7. Web Site of iramont Co. (www.iramontinc.com).
8. High- Pressure/ High- Temperature Cementing., Halliburton, chapter 1, April 1996.
9. CONSTANT SPEED MIXERS CHANDLER's catalog, HOUSTON SALES & SERVICE.1997, (www.chandlereng.com).
10. Mud balance CHANDLER's catalog, HOUSTON SALES & SERVICE.1997.
11. The CHANDLER Ultrasonic Cement Analyzer's catalog, HOUSTON SALES & SERVICE.1997.
12. The CHANDLER Model 1250 Atmospheric Consistometer's catalog, HOUSTON SALES & SERVICE.1997.
13. The *CHANDLER* Pressurized Consistometer's catalog, HOUSTON SALES & SERVICE.1997.
14. The Chandler Pressurized Curing Chamber's catalog HOUSTON SALES & SERVICE.1997.

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