The Effect of Thixotropic Additive on the Properties of the G Class Cement

(Pengaruh Aditif Thikositropik terhadap Sifat-sifat Semen Kelas G)

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Abstract

In oil, gas, and geothermal drilling activities, the casing cementing process is always carried out in order to fulfill its function properly and safely. Therefore, everything that supports these activities must be carefully thought out. Before the actual cementing process is applied in the oil, gas, and geothermal field, laboratory-scale simulation must first be carried out by conducting experiments and testing several formulations of cement, water mixture, and additives to be used. The author chooses thixotropic additives, besides functioning as an accelerator, thixotropic can also strengthen the cement itself. With a number of experiments, an optimal cement slurry composition formulation will be obtained, in the sense that by using as few additives as possible, the requirements of the physical characteristics will meet the required standards for conditions (temperature and pressure) of the formation in the well to be cemented. All cementing activities are expected to run well, smoothly, and on time.

Keywords: Thixotropic, Compressive Strength, Thickening Time, Free Water Content, Drilling Cement

Sari

Dalam kegiatan pemboran minyak, gas, dan panas bumi proses penyemenan casing selalu dilakukan agar dapat memenuhi fungsinya dengan baik dan aman. Oleh karena itu, segala sesuatu yang mendukung dalam kegiatan tersebut harus dipikirkan dengan cermat. Sebelum proses penyemenan yang sebenarnya diterapkan di lapangan minyak, gas, dan panas bumi, terlebih dahulu harus dilakukan simulasi skala laboratorium dengan cara melakukan percobaan dan pengujian beberapa formulasi campuran semen, air, dan aditif yang akan digunakan. Penulis memilih aditif thixotropic, selain berfungsi sebagai accelerator, thixotropic juga dapat memperkuat semen itu sendiri. Dengan mengadakan beberapa eksperimen, komposisi slurry cement terbaik akan diperoleh, yaitu dengan menggunakan aditif thixotropic sebanyak mungkin, persyaratan karakteristik fisik akan memenuhi standar yang dipertimbangkan untuk kondisi (suhu dan tekanan) dari formasi di sumur yang akan disemen. Semua kegiatan proses penyemenan diharapkan bisa berjalan dengan baik, lancar, dan tepat waktu.

Kata-kata kunci: Thixotropic, Kuat Tekan, Waktu Pengerasan, Kadar Air Bebas, Semen Pemboran

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I. INTRODUCTION

The use of cement in drilling is very important to support the success of the next drilling. Initially, the use of cement was only used to cover water formations, but with the current conditions and needs that are growing, the use is increasingly varied in drilling well [1]. The set cement has to withstand stresses caused by changes in temperature and pressure in the wellbore trough out the well’s life [2]. Changes in temperatures resulting from production of high temperature fluids or injection of hot fluids, such as steam, can expand the casing and create great stresses in the cement sheath. These changes can result in tensile stresses that crack the cement [3].

In general, the cement used in the drilling operations of oil and gas wells is a type of Portland, where Portland cement is the cement which has not received the addition of other chemicals as additives [4].

The properties of cement slurry included zero free water, low fluid loss, high compressive strength, along with appropriate thickening time to allow for correct placement [5]. Over time and the application of additive technology began to be used. Because the use of this additive can control nature and the cementing time that we want.

In this study the effect of thixotropic on compressive strength, thickening time and the free water content in the g class drilling cement was analyzed with variations in the concentration of 0, 2, 4, 6, 8, and 10 (%) at temperatures of 100 °F and 140 °F, curing times of 8, 16, and 24 hours.

II. DRILLING CEMENTING

Cementing can be divided into two, namely primary cementing and primary cementing and secondary cementing [6].

2.1 Primary Cementing

The main or initial cementing is cementing which is carried out immediately after the casing is
installed in the borehole, where one of its functions is to bind the casing with the borehole wall. The main objectives of this cementing include:

a. The Conductor Casing aims to seal-off water zones and shallow gas flows, to provide a circulation system for drilling fluid.

b. Pada Surface Casing aims to protect fresh water aquifers, it is the first string on which BOP (Blow Out Preventer) can be set to provide primary pressure control.

c. The Intermediate Casing aims to proximity to a potential reservoir, good cementation is required to ensure isolation of the lower hydrocarbons zones from the upper water zones. Prevent hole problems i.e., lost circulation, salt section, differential sticking, caving, and over-pressure zones.

d. The Production Casing aims to isolate and to separate productive zones from other reservoir formations and to prevent the corrosive occurrence in the casing.

2.2 Secondary Cementing

Secondary cementing is cementing the second stage where the cementing is carried out to repair cementing if there is damage to the initial cementing or cementing of certain parts of a hole. Secondary cementing is divided into:

a. Squeeze Cementing aims at:
   - Closing non-producing formations.
   - Improving the cementing of the casing because the bond is ugly.
   - Stop lost circulation during drilling.

b. Plug Back Cementing; the goals are:
   - to plug back a zone or plug back a well.
   - to solve a lost-circulation problem during drilling phase.
   - to provide an anchor for open-hole tests.
   - to side track above a fish or to initiate directional drilling.

2.3 Cement Drilling Function

The main function of cement drilling is to seal the annular holes between the rock walls and the casing so supporting the casing and isolate the intervals of interest:

1. Attach the casing to the formation wall, so it is sturdy and strong so that the casing can function perfectly.
2. Protect the casing from the influence of the surrounding environment that can damage the casing, such as temperature, high pressure from the formation, and corrosiveness from formation fluid.
3. Closing the lost circulation zone.
4. Isolate the zone behind the casing to prevent communication between zones.
5. Prevent the penetration of high-pressure gas or fluid formations into the space between the casing and the borehole.
6. Closing the gap between the gas-oil ratio and the water-oil ratio.
7. Closing the unnecessary zones.
8. Fix perforation error.
9. Correct the perforation misplacement.

2.4 Physical Properties of Drilling Cement

The cement slurry must be adjusted to the properties of the formation to be cemented. Therefore, there are several types of physical properties of cement that need to be discussed, namely density, rheology, thickening time, compressive strength, and free water content.

2.4.1 Thickening Time

Thickening time is the time required by cement to reach a consistency price of 100 BC (Bearden Unit of Consistency). The price of 100 BC is considered as the maximum limit where ordinary cement can still be pumped because the cement in its hydration with water causes better consistency. The amount of thickening time needed depends on the depth of well, the volume of cement slurry pumped, and the type of cementing. Generally, the thickening time is 3 - 3.5 hours, for cementing with a depth of 6000-18000 ft, this time includes the time of making the cement slurry to place the cement behind the casing plus the price of the safety-factor, whereas in deeper cementing where the pressure and temperature will be increasingly high additives are needed to slow hardening or thickening time.

If the cement hardens inside the casing is a fatal problem for further drilling operations. The maximum pumping time is generally equated with thickening time by considering the safety factor. The pumping time required is affected by the column height and volume of the cement suspension that must be pumped, the speed of the pumping rate, and the operating temperature of the well.

2.4.2 Compressive Strength

Strength in the cement is divided into two, namely compressive strength and shear strength. Compressive strength is defined as the strength of the cement in holding pressures from the side while the shear strength is defined as the strength of the cement in holding the load/pressure from the vertical direction.

At high temperatures (above 100 °C) there will be a disturbance in the strength of the cement known as "strength retrogradation". This is due to the emergence of alpha dicalcium silicate hydrate which changes the composition of cement components and causes decreased strength and even loss. In measuring cement strength, what is measured is compressive strength rather than shear strength.
Generally, compressive strength has a price of 8-10 times greater than the price of shear strength. Compressive strength testing in the laboratory is carried out using a hydraulic mortar curing device.

2.4.3 Free Water Content

The cement slurry used in oil and gas drilling is a suspension consisting of cement powder with a large amount of water, so that it reaches a low suspension, generally between 0.4 to 0.6 to make conventional cement suspensions. Striebel and Czernin (1967) in their research showed that the WCR (Water Cement Ratio) of 0.25 - 0.26 is the minimum requirement of a cement slurry to fully hydrate the Portland Cement. It was given the term "Chemical Bound Water" (water that is chemically bound). In fact, WCR is always used greater than 0.4 so that the viscosity of the suspension of cement is low enough, so it can be pumped. But of course, it will have higher porosity and permeability, and smaller compressive strength.

WCR is a comparison between the amount of water and cement mixed to get the desired properties of the cement slurry. The amount of water mixed should not be more or less, because it will affect the merits of the cement bond. WCR is influenced by the surface area of the cement, ie the surface area of all the grains in [cm] \(^2\) / g of cement, where the smaller the grain of cement, the greater the surface area so that the greater the surface strength, while the thickening time will be increasingly short.

2.4 Implementation of the Experiment of Compressive Strength

The cementing process is made based on the compressive strength of the cement so that in the drilling hole the compressive strength is an absolute force calculated. In laboratory experiments, this is important so that we can find out to what extent the strength of the G class cement holds pressure or vertical and horizontal direction forces. The tool used in conducting compressive strength experiments is by using hydraulic pressure.

2.5 Implementation of the Experiment of Thickening Time

Thickening time is a measure of time that shows the length of time required by cement slurry in certain experimental conditions calculated from the time of manufacture until the cement begins to harden and cannot be pumped again ie at a value of consistency greater than 100 BC because the consistency value of 100 BC is the limit maximum where cement can be pumped.

By knowing the value of thickening time (hardening time) of cement slurry, we will be able to estimate the grace period needed so that we can mix and pump cement slurry safely, meaning that the cement will not start to harden before it reaches the cemented area target. Because if this happens then in addition to hampering work will also damage the equipment used in cementing operations.

2.6 Implementation of the Experiment of the Free Water Content

The free water content of cement slurry is very important to know the quality of cement permeability produced in the cementing process. The smaller the permeability, the better the cement produced. If the free water content exceeds 3.5 ml of 250 ml of cement slurry, it will result in a large cement permeability, due to the presence of water bags in the cement slurry, so that the quality of the resulting cement becomes unfavorable.

In the cementing operation, it is expected that the permeability of the resulting cement is as small as possible so that good cement quality will be obtained and can seal the borehole wall with the casing so that communication between zones can be prevented.

III. METHOD

Experiments carried out in this study include the manufacture of cement slurry, the immersion of cement slurry with various time and temperature, testing the compressive strength of cement and time testing. Figure 1 shows a flowchart regarding the experimental procedure in the laboratory.

IV. RESULTS AND DISCUSSION

Following testing of class G cement in the laboratory is carried out to obtain compressive strength, thickening time, and free water content at temperatures of 100°F and 140°F with variations of time 8 hours, 16 hours, and 24 hours by using Thixotropic additives.

4.1 Free Water Content Test Results

Table 1 shows water content test results using thixotropic at the temperature of 100°F and 140°F. It can be seen that there is a decrease in water for addition of 2% and 4% Thixotropic. However increases in water content were noted when 6%, 8%, and 10% Thixotropic additive were added. The value of free water content by not adding and when adding additives at each temperature and time variation of the cement slurry does not exceed the maximum limit of 3.5 ml.

The greatest value of free water content at each variation of the conditioning time of the slurry occurs when adding 10% thixotropic additives that are 3.5 ml at 100°F and 3.3 ml at 140°F.

4.2 Compressive Strength Test Results

Normally, the preparation of the cement slurry is carried out in accordance with API procedures. After that, the cement slurry is poured into a mold
that already has a certain shape and its geometry is easily measured, which is then put into a pressurized curing chamber whose temperature is set for a certain time interval. After that, the specimen is then removed from the device and allowed to cool. Compressive strength testing is done by pressing the specimen until it breaks with a hydraulic tester. Table 2 shows Compressive Strength Test Results Using Thixotropic at the Temperatur of 100°F and 140°F. The value of compressive strength by conditioning the cement slurry at 100°F for 8 hours, 16 hours, and 24 hours does not meet the class G cement classification because the results obtained are below 1500 Psi.

The value of compressive strength by conditioning the slurry at a temperature of 100°F for 8 hours, 16 hours and 24 hours that meet the class G cement classification is by adding an additive of 4% at a time of conditioning for 16 hours that is equal to 1576 psi and at the addition of additives amounting to 2%, 4% and 6% at the 24 hour conditioning time that is equal to 1876 psi, 2364 psi, and 1830 psi.

4.3 Thickening Time Test Results

Table 3 shows thickening time test results using thixotropic at the temperature of 100°F and 140°F. It can be seen that there is a decrease in water for each additive of 2% and 4%, but when adding additives 6%, 8%, and 10% increase in water content in each addition of additives at each temperature and time variation.

The value of thickening time by conditioning the cement slurry at a temperature of 100°F for 8 hours, 16 hours, and 24 hours when adding 2% and 6% additives meets the class G cement classification, namely 118 minutes and 110 minutes.

Thickening time value by conditioning the slurry at 140°F for 8 hours, 16 hours and 24 hours when no additives were added and when adding additives 10% met the class G cement classification of 93 minutes and 90 minutes.

IV. CONCLUSIONS

From the results of the analysis from 4 wells to improve performance by strategy from KPI target as the objective to achieve performance.

1. The value of free water content by not adding and when adding additives at each temperature and time variation of the cement slurry it is found that all the results obtained do not exceed the maximum limit of 3.5 ml.

2. The greatest value of free water content at each variation of the conditioning time of the slurry is when adding 10% thixotropic additives that are 3.5 ml at 100°F, and 3.3 ml at 140°F.

3. The value of compressive strength by conditioning the slurry at a temperature of 100°F for 8 hours, 16 hours and 24 hours that meet the class G cement classification is by adding an additive of 4% at a time of conditioning for 16 hours that is equal to 1576 psi and at the addition of additives amounting to 2%, 4% and 6% at the 24 hour conditioning time that is equal to 1876 psi, 2364 psi, and 1830 psi.

4. The value of thickening time by conditioning the cement slurry at a temperature of 100°F for 8 hours, 16 hours, and 24 hours meet classification by adding 6% Thixotropic, while that at 140°F meet classification by adding 10% Thixotropic.
REFERENCES
1. Duckworth, D.A. (2009). Metrics for Evaluating Cementing Success. Society of Petroleum Engineers, SPE 120559MS.
2. Nelson, E. B. (1990). Well Cementing. 2nd Edition. Houston: Schlumberger Educational Service.
3. Branko, L., Vesna, K. M., and Dusan D. (2015) Casing Cementing in Difficult Geological Conditions. Underground Mining Engineering, 27, pp. 65-74
4. American Petroleum Institute (2010) Specification for Cement and Materials for Well Cementing API Spec 10A. Washington: API.
5. Salehi, R. and Paiaman, A.M. (2009). A Novel Cement Slurry Design Applicable to Horizontal Well Conditions. Petroleum & Coal, 51(4), pp. 270-276.
6. Rubiandini, R. (2012). Teknik Operasi Pemboran Volume 1. Bandung: Institut Teknologi Bandung.
7. Rahmanto, A.E. (2011). Study Pengaruh Kuat Tekan Semen Pemboran Class-G Dengan Pemakaian Additive CFR-2 Dan Lignosulfat Terhadap Variasi Waktu Dan Temperatur. Jakarta. Universitas Trisakti.
8. Sulito, A. (2013). Studi Laboratorium Pengaruh Penambahan Thixotropic Terhadap Kuat Teken, Waktu Pengerasan dan Kadar Air Bebas pada Semen Pemboran Kelas G. Jakarta: Universitas Trisakti.
9. Reza, M. (2015). Pengaruh Penambahan Accelerator CaCl2, NaCl, Dan Nano3 Sebagai Additive Semen Kelas-B Terhadap Thickening Time, Compressive Strength, Dan Rheology Bubur Semen Dengan Variasi Temperatur (BHCT). Jakarta. Universitas Trisakti.
Table 1. Water Content Test Results Using Thixotropic at the Temperatur of 100°F and 140°F

| Additive (%) | Water Content (ml) | T = 100°F | T = 140°F |
|--------------|--------------------|-----------|-----------|
|              |                    | 8 hrs     | 16 hrs    | 24 hrs    | 8 hrs     | 16 hrs    | 24 hrs    |
| 0            | 3                   | 3         | 3         | 2.8       | 2.8       | 2.8       |
| 2            | 2.8                 | 2.8       | 2.8       | 2.7       | 2.7       | 2.7       |
| 4            | 2.6                 | 2.6       | 2.6       | 2.5       | 2.5       | 2.5       |
| 6            | 3.2                 | 3.2       | 3.2       | 2.9       | 2.9       | 2.9       |
| 8            | 3.4                 | 3.4       | 3.4       | 3         | 3         | 3         |
| 10           | 3.5                 | 3.5       | 3.5       | 3.3       | 3.3       | 3.3       |

Table 2. Compressive Strength Test Results Using Thixotropic at the Temperatur of 100°F and 140°F

| Additive (%) | Compressive Strength (psi) | T = 100°F | T = 140°F |
|--------------|----------------------------|-----------|-----------|
|              |                            | 8 hrs     | 16 hrs    | 24 hrs    | 8 hrs     | 16 hrs    | 24 hrs    |
| 0            | 217                        | 433       | 650       | 343       | 686       | 1029      |
| 2            | 325                        | 650       | 664       | 513       | 801       | 1371      |
| 4            | 276                        | 254       | 678       | 591       | 1182      | 1773      |
| 6            | 226                        | 225       | 381       | 460       | 922       | 1343      |
| 8            | 117                        | 215       | 271       | 331       | 662       | 973       |
| 10           | 127                        | 206       | 375       | 201       | 402       | 603       |

Table 3. Thickening Time Test Results Using Thixotropic at the Temperature of 100°F and 140°F

| Additive (%) | Thickening Time (min.) | T = 100°F | T = 140°F |
|--------------|------------------------|-----------|-----------|
|              |                        | 8 hrs     | 16 hrs    | 24 hrs    | 8 hrs     | 16 hrs    | 24 hrs    |
| 0            | 147                    | 147       | 147       | 93        | 93        | 93        |
| 2            | 118                    | 118       | 118       | 89        | 89        | 89        |
| 4            | 89                     | 89        | 89        | 84        | 84        | 84        |
| 6            | 110                    | 110       | 110       | 86        | 86        | 86        |
| 8            | 146                    | 146       | 146       | 88        | 88        | 88        |
| 10           | 178                    | 178       | 178       | 90        | 90        | 90        |