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Investigating the Effects of Dispersant as Cementing Additives on the Thickening Time of Cement Slurry

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Abstract

This experiment was done following American Petroleum Institute (API) recommended practice 13B-2, with the aim of investigating the effect of solid dispersant known as lomar'D on the thickening time at a constant temperature of 110°F and downhole pressure of 3153 Psi and dispersant concentrations of 0.3 %BWOC, 0.5 %BWOC, 0.6 %BWOC and 0.7 %BWOC. The significance of the thickening time test is to determine the duration of cementing operation to ensure successful zonal isolation without cementing the drilling pipes and damaging the wellbore. The results obtained at the different dispersant concentration are 4hrs:47mins, 7hrs:20mins, and 7hrs:58mins respectively. The results obtained showed a positive relationship between the concentration of dispersant and the thickening time. The data was modelled and polynomial model of $y = 0.9864x^2 - 0.5803x + 0.266$ *with* R^2 *0.8937 fitted the data at given bottom hole temperature and pressure with little variation, Hence The results have shown that the dispersant concentration does not only thin the slurry viscosity but it also has a secondary effect on the cement slurry thickening time at constant temperature and pressure, therefore it must be considered during the cement slurry design so as to save time and materials.*

Keywords: *Dispersant, Thickening time, Cementing additive, Cement slurry, Concentration of dispersant*

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1. Introduction

Oil well-cementing operation involves amongst other things, the introduction of cement slurry down the Oil well annulus i.e the space between the casing and the formation to ensure complete zonal separation of the different formations. The target is to completely hinder fluids in the well from interacting between the borehole and the producing zone, shield the casing from corrosion, provide a base for the casing, during drilling hinder shock load, for well abandonment, seal off unconsolidated zones, and ensure there are no blowouts (Otaraku and Anaele, 2020). Cementing operation is the most important aspect of oil wellbore construction (Lootens et al., 2004). How long the oil well construction last or serve lies, to some extent on the type and quality of the slurry formulation (Ridha et al., 2010), and the essence is to ensure the durability of the well as well as the safety of the well (Pourafshary et al., 2009; Ebadi et al., 2011). Studies have shown that partial zonal isolation as a result of the inefficient cementing operation can cause low production capacity of the well as well as efficiency (Calvert, 2006). Poorly designed cement slurry with poor cementing operations are the major factors that greatly reduce the efficiency and the performance of the well. and most of the times it leads to environmental degradation as a result of oil spillage. Oil spills causes low agricultural produce, death of aquatic lives, pollution of land. When Oil is spilled on the land it makes it unsafe for living for animals, and plants, it can cause respiratory diseases in animals (Lootens et al., 2004). Down-hole Temperatures are the major concern when designing cement slurry. When cement slurry is poured downhole it usually encounters different pressure ranges from both low and high pressures of about 1360 kPa in wells that is more than 10000 ft (Joel, 2009). Despite the downhole pressure and temperature that is often been considered when formulating cement slurry, it is also important that well formation conditions such as weak or unconsolidated formation, and reactive fluid downhole are also taken care of. Many breakthroughs attained in slurry design have been attributed to discoveries, research, and observation from additives used to different well conditions encountered during cementing operations. Additives are added to the cement slurry to manipulate its properties in order to achieve the desired objective of cementation.

Cementation activities are done mostly at high temperatures and pressures in oil wells and this causes a lot of issues that need designing cement slurry that is good technically to address these issues (Anaele and Otaraku, 2020). The thickening time or setting time test determines the duration of cementing operation to ensure successful zonal isolation; it indicates the period the slurry will remain pumpable before it hardens (Anaele et al., 2019). According to Anaele et al 2019, There are several cement additives in the industry up to 100, and they are grouped into eight classes such as weighting Agent, Retarder, and Dispersant, special Additives such Antifoams, Lost circulation material, Extender, accelerator, and Fluid loss. The dispersant function is to reduce the viscosity of cement slurry and increase the mixability of other additives and ensure good mud removal during placement. It prevents the tendency of the cement slurries from gelling up (Anaele et al, 2019). A dispersant is known as a friction-reducing additive and this is due to its ability to improve the rheology of the cement slurry when added (Adams et al, 1985). In an appropriate concentration, it reduces slurry permeability and enhances the slurry homogeneity. But when the concentration of the dispersant is much more than needed for the slurry design, it can cause phase separation of the slurry leading to settling at the bottom and excess free fluid, based on this phase separation tendency, The optimum concentration of these additives is based on the slurry density, for 15.8ppg cement the optimum concentration is 1%BWOC, and above this concentration, the cement slurry tend to be unstable and the solid parts of the slurry tend to settle at the bottom (John, 2013). The popular dispersant used in the industry is the sodium salt of Polynapthalene Sulphonate (PNS), the reason for the use of PNS is the fact that it can be used to formulate slurries with higher solids-to-water ratio with enhanced properties. PNS are made from polymeric materials whose molecular weights are in the range of 3,000 to 20,000 (Cowan and Eoff, 1993).

2. Materials and methods

2.1 Cement slurry composition

Table 1 shows the additive concentration and the slurry composition. The water used was fresh water obtained from the laboratory tap, the chloride content was measured to be 200ppm, and the fluid loss additive, deformer, and the cement concentration were kept constant while the varying additive was solely the dispersant which was varied from 0.3%BWOC in the first run, 0.5%BWOC in the second run, 0.6%BWOC in the third run and finally 0.7%BWOC and their thickening time results were recorded.

Table 1: Additive Concentration and slurry composition

Additive	1	2	3	4
Dyckerhoff- G Cement (%BWOC)	100	100	100	100
Deformer (Gal/SK)	0.014	0.014	0.014	0.014
Solid dispersant (%BWOC)	0.3	0.5	0.6	0.7
Fluid loss (Gal/SK)	0.35	0.35	0.35	0.35
Water requirement (Gal/SK	4.78	4.694	4.649	4.604
Slurry Density (PPG)	15.8	15.8	15.8	15.8
Type of Water	Fresh	fresh	Fresh	fresh
Chloride content (PPM)	200	200	200	200

2.2 Thickening time testing

Several tests were carried out at different dispersant concentrations and at a constant temperature of 110^{o}F and pressure of 3153 Psi in line with API specifications for materials and testing for well cement (Anon, 1997). All the slurries were formulated in line with the API specification 10A standard (1995) and the slurry composition is as shown in Table 2. The Thickening Time test was carried out by the use of a High-Temperature- High Pressure (HTHP) Consistometer which was rated as follows: pressure up to 206.8 MPa (30 000 psi) and temperatures up to 204^{o}C (400^{o}F). The time it took the cement slurries to reach 40Bc, 70Bc and 100Bc consistency were recorded. Fig. 1 shows the picture of High Temperature and high Pressure consistometer.

Fig. 1: Ofite HTHP Consistometer for thickening time test

Table 2: Additive Concentration and slurry composition

Additive	1	2	3	4
Dyckerhoff- G Cement (%BWOC)	100	100	100	100
Deformer (Gal/SK)	0.014	0.014	0.014	0.014
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Type of Water	fresh	fresh	fresh	fresh
Chloride content (PPM)	200	200	200	200

2.3 Data analysis

The data obtained from the experiment was analysed using regression analysis tools, different models were tested and the one with best fit was selected.

2.4 Model development

simple linear regression models, we want to establish the relationship between the dependent variable Y which could be yield, consumption rate, etc. but for this case Y is the thickening time, and the independent variable x could be concentration, temperature, feed quality, etc.

Let's say $Y = a + bx + e$ (1)

The above equation represents the simple linear model, where b and a are constant and e is the error.

2.4.1 Methods of parameter estimation

The value of a and b was estimated using the least square method.

Given $Y = a + bx$ generating the system of the equation to estimate a and b the following step was taken.

i. Take the summation of Y, multiply a by the number of data n, and sum x to generate Equation (2)

ii multiply the generated Equation (2) by x and take their sum as shown below.

$$\sum Y = na + b\sum x \quad (2)$$

$$\sum Yx = a\sum x + b\sum x^2 \quad (3)$$

Given the two equations above it can be solved simultaneously to obtain a and b values as follows**:**

$$b = \frac{n\sum Yx - \sum Y \sum x}{n\sum x^2 - (\sum x)^2} \quad (4)$$

$$a = \frac{\sum Y - b\sum x}{n} \quad (5)$$

For polynomial

Given equation of the form:

$$Y = a + bx + cx^2 \quad (6)$$

Where a, b, and c are constant

Applying similar procedure, the following equations were obtained:

$$\sum Y = na + b\sum x + c\sum x^2 \quad (7)$$

$$\sum Yx = a\sum x + b\sum x^2 + c\sum x^3 \quad (8)$$

$$\sum Yx^2 = a\sum x^2 + b\sum x^3 + c\sum x^4 \quad (9)$$

For Exponential Model

Given equation $Y = ae^{bx}$ (10)

Linearizing the equation 10 and solving as in linear model

Microsoft excel was applied to generating the constants and the equations.

3. Results and discussion

3.1 Physical parameter

The physical parameter was calculated using API recommended practices 13B-2, the values obtained are shown in Table 3. The obtained results were inputted into the Consistometer, The BHCT stands for bottomhole circulating temperature which was 110oF, the downhole pressure was 3153psi and the ramp time was 29mins, while the ramp rate was 1.03oF/min.

Table 3: Physical parameter

TVD = 5422ft	**1**	**2**	**3**	**4**
T.G(oF/100ft)	1.2	1.2	1.2	1.2
BHCT (oF)	110	110	110	110
BHST (oF)	147	147	147	147
Initial Pressure (Psi)	421	421	421	421
Final Pressure (psi)	3153	3153	3153	3153
Ramp time (mins)	30.68	30.68	30.68	30.68
Ramp rate(^{oF}/mins)	1.4	1.4	1.4	1.4
API Schedule	9.40M	9.40M	9.40M	9.40M

3.2 Thickening time test

The thickening time of the different dispersant concentration of 0.3%BWOC, 0.5 %BWOC, 0.6 %BWOC and 0.7 % BWOC were obtained at 100BC as follows, 4hrs:47mins,7hrs:20mins, and 7hrs:58mins respectively. The obtained results were plotted as shown in Fig. 2 and Table 4. From the Fig. 2, it has clearly shown that there is a relationship between the concentration of the dispersant and the thickening time of the cement slurry, and that an increase in the concentration of the dispersant does not only reduce the viscosity of the cement slurry but it also acts to an extent as a retarder since it tends to delay the setting time of the cement slurry this is an agreement with the finding of Joel, 2009 and Anaele et al., 2019.

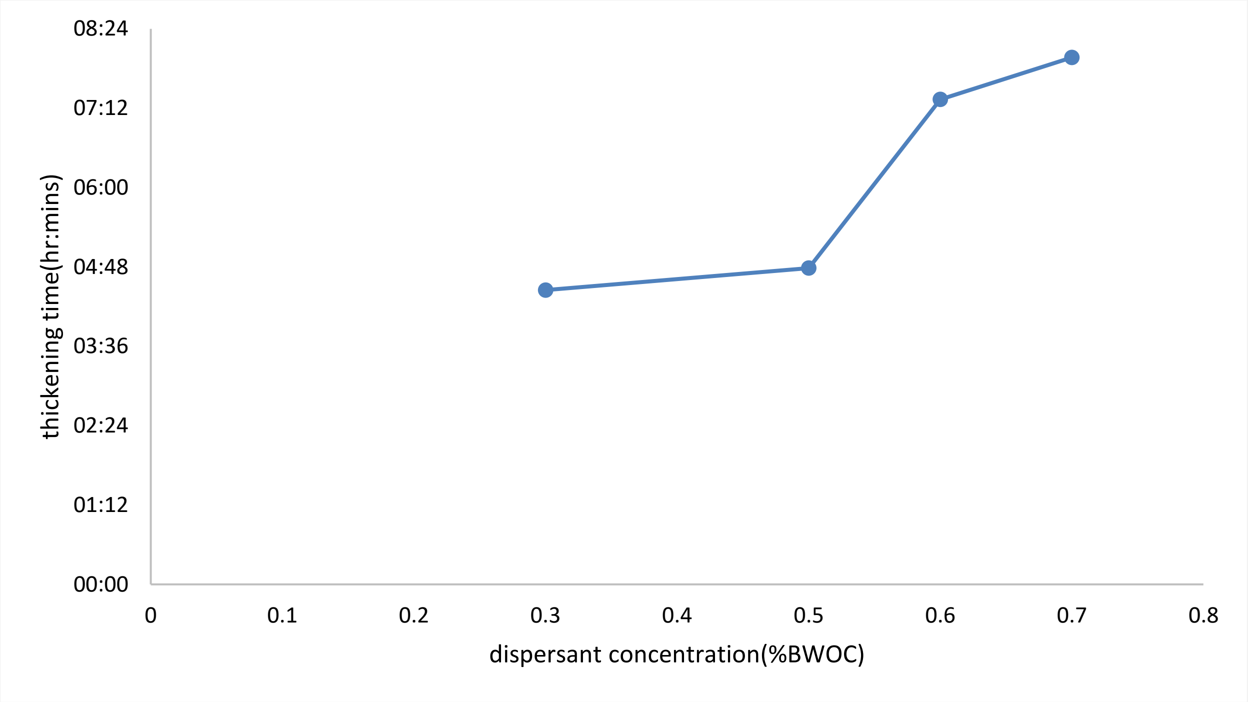

Fig. 2: Thickening time test result at 100BC

Table 4: Thickening Test Results at different dispersant concentration

Consistency	Concentration (%BWOC)	Thickening time (Hr:min)
100Bc	0.3	4:27
	0.5	4:47
	0.6	7:20
	0.7	7:58

3.3 Modelling the relationship between dispersant concentration and thickening time

The obtained data was modelled with different model and the result is presented in Table 5. The results show the model relationship between the dispersant concentration and the thickening time from the Table the models' coefficient of correlation R^2 for linear, polynomial and exponential are as follows 0.8192, 0.8937, and 0.8574. from the values of the R^2 it can be deduce that the polynomial model fits the data better with model equation given as $y = 0.9864x^2 - 0.5803x + 0.2667$ with R^2 of 0.8937, then followed by the exponential model with the model equation given as $y = 0.1084\,e^{1.5723x}$ with R^2 of 0.8574 and the least is a linear model with the model equation given as $y = 0.3921x + 0.0497$ with R^2 of 0.8192. where y represents the thickening time in hours and x represents the dispersant concentration in %BWOC.

Table 5: Modelled equation showing the relationship between dispersant concentration and the thickening time

Model	Equation	R squared
Linear	$y = 0.3921x + 0.0497$	0.8192
Polynomial	$y = 0.9864x^2 - 0.5803x + 0.2667$	0.8937
Exponential	$y = 0.1084e^{1.5723x}$	0.8574

4. Conclusion

A study on the relationship between solid dispersant (lomar'D) on the thickening time of cement slurry has been carried out at a constant temperature of 110°F and downhole pressure of 3153 Psi. Different dispersant concentrations were used and the thinking time was observed. The test results show that:

a. There is a positive relationship between the concentration of dispersant and the thickening time of cement slurry.
b. Adequate consideration should be taken when designing cement slurry with dispersant and retarder as both have a similar function of delaying the thickening time of the cement slurry.
c. Polynomial model of $y = 0.9864x^2 - 0.5803x + 0.266$ can adequately predict the thickening time values at a given dispersant concentration at a given bottom hole temperature and pressure with little variation.

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