Improve oil well cements performance by commercial nano additive

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Abstract

Cementing operation is one of the most crucial and costly activities performed in the oil wells. The main aim of cementing has always been to separate different fluids in the behind of casing in the oil well. Consequently in this study, a new nano additive was added to a typical kind of oil well cement at different concentrations (5 to 30 wt.%) and then different cylindrical molds were prepared and liquid contact angles were calculated by sessile drop technique .It was observed this additive improved water repellency of cement, in order, in the best case this additive increased water contact angle from 0 to 80.56^0. After that, the optimum additive concentration (lowest concentration, 5 wt.%) was chosen for rheological tests and modeling studies. It was observed this additive doesn't have a significant effect on rheological characteristics of cement. On the other hand, this additive promoted water repellency of cement while kept the rheological characteristics of the original oil well cement.

Keywords - Oil well cement, Water repellency, Rheology, Bingham and Herschel- Bulkley model.

1. Introduction

Cementing operations is one of the most crucial and costly activities performed in the oil and gas wells [1] which depends directly on the cement composition. To enlarge oil well life, the cement shell must be chemically and mechanically stable [2]. In cementing operations, cement is usually employed to fill the annular area between the casing and formation, translocate the drilling fluid and protect the casing from corrosion [3], but the main aim of cementing operation is to provide zonal isolation in oil, gas wells, to barring fluids (water and gas) in one zone from oil in another zone in the well. Improving the properties of the oil well cement slurry which is used in the process of cementing oil wells concerning flow properties (rheological), simplicity pumping, high-temperature high-pressure resistance, and maintain adequate mechanical strength to support and protect the casing to make isolation for a long time. As stated by the American Petroleum Institute Recommended Practice (API RP) 10B, additives are substances attached to cement slurry to change or improve desired characteristics [4]. In cementing operations in oil industry several types of additive added to cement slurry, such as; accelerators to rise of interaction speed between water and cements [5], Retarders for decrease the speed of cement hydration [6], Extenders for reduce weight of cement slurry for low pressure formations [7], heavy weight additives in high pressure wells [8], fluid loss additives to diminish the cement loss in the oil field [9], anti-foam agents to reduce foaming and mitigate air entrancement to cement slurries [10], and etc.

The aim of this study is to introduce an additive for oil well cement that has water repellent property to prevent casing corrosion caused by water invasion. To be sure that other crucial rheological properties of new cement slurry is proper for cementing operation, a comparison between rheological properties of general and introduced cement slurry is also performed. To reach this goal, type G cement with a 0.44 water-to-cement ratio (as a common cement slurry in oil well) was modified with a new water repellent nano additive in different additive concentrations (5 to 30 wt.%).

2. Experimental

2.1. Materials

Portland cement type G was utilized in the construction of the slurries. This class of cement has a density equal to 3.15 gr/cm^3 (196 pcf). Fresh water and Nano Basil (purchased from an Iranian company, Table 1) was used as a dispersing agent and water repellent additive, respectively. Light crude oil (32 API, 0.8639 gr/cm^3) was supplied from one of the oil reservoirs in the southwest of Iran and brine (1 wt.%

NaCl in fresh water) was used in liquid contact angle measurements. Brine was used instead of fresh water because the produced water in the oil reservoir is always salty.

2.2. Methods

In this study, type G cement with a 0.44 water-to-cement ratio was modified with nano Basil in different additive concentrations (5 to 30 wt.%). Then the each prepared slurries (based on API RP 10 B standard) was poured in cylindrical molds and was given time (96 h) them to dry completely (Fig. 1). After that, a common method (the sessile drop) was utilized for determining liquid contact angles [11]. To measure the contact angle of salt water/light oil drops on different samples, a drop of 4 microliters of brine and oil was dropped on each sample. The images of each drop were taken by a camera (Samsung), then the images of contact angles were calculated by ImageJ software. Next, the optimum case in contact angle measurement for again its slurry was produced and then its rheological characteristics were tested by a rotational rheometer (RST-CC, Brookfield, USA).

Table 1: The components of nano Basil

component	concentration
Effective materials	> 99 % according to standard: ASTM D57
Fe_2O_3	0.15 % according to standard: ISO 787/9
$MgCo_3$	1.00 % according to standard: ISO 787/5
HCL Isolated Content	0.1 % according to standard: ISO 787/11

Figure 1: Cylindrical molds of cement slurry with different concentration of additives.

3. Result and Discussion:

3.1. Contact angle measurement

The main aim of cementing has always been to provide zonal isolation in oil wells to separate the water from oil and prevention from casing corrosion. Thus cement must don't let to water to arrive at the oil zone and to the casing. The contact angle of brine and oil is shown in Fig 2. It was observed from Fig. 2 that the contact angles of brine and oil on the net cement (without any additive) are 0^0 and 22.17^o, respectively. Also was deduced that with increasing water repellent additive concentration the brine (salty water) contact angle at the same time increases, but it does not have a significant effect on the oil contact angle. Consequently, with concern to the economic aspect, the lowest additive concentration was chosen as an optimum case and then rheological tests were performed on it.

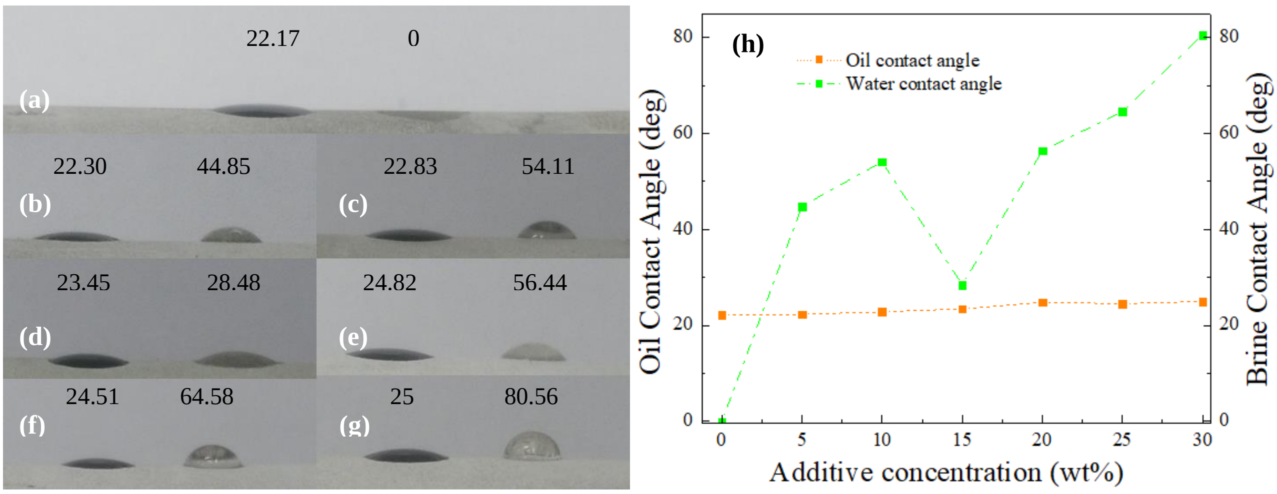

Figure 2: Brine and oil contact angles at different additive concentration; (a):0 wt%, (b):5 wt%, (c):10 wt%, (d):15 wt%, (e): 20 wt%, (f): 25 wt%, (g): 30 wt%,. (h): plot of brine and oil contact angles.

3.2. Rheological test

One of the most concern about using an additive in oil well cement is about changes in rheological properties, in the other hand, although sometimes additives are used to enhance the rheological properties but about the other additives, it is so important that they do not have inverse effects on rheological properties. Here, the main aim is to propose an additive to prevent from casing corrosion and isolate water and oil zone, therefore, the rheological properties of the slurry containing proposed additive were compared with the case of without additive to show that it does not have inverse rheological effects. As previously mentioned, the case of include 5 wt.% additive was chosen for rheological tests. To investigate the rheological characteristics of two cement slurries (net class G cement and containing 5 wt.% additive), a common shear rate sweep test was conducted from 10 to 1000 S^{-1}. Fig.3 represents the viscosity and shear stress versus the shear rate for both of the samples. It was concluded that there is no significant difference between the two samples, in other hands the sample that containing 5 wt.% water repellent additive has almost the same rheological trend with net cement sample while according to Fig.2 has better water repellency in comparison the net sample.

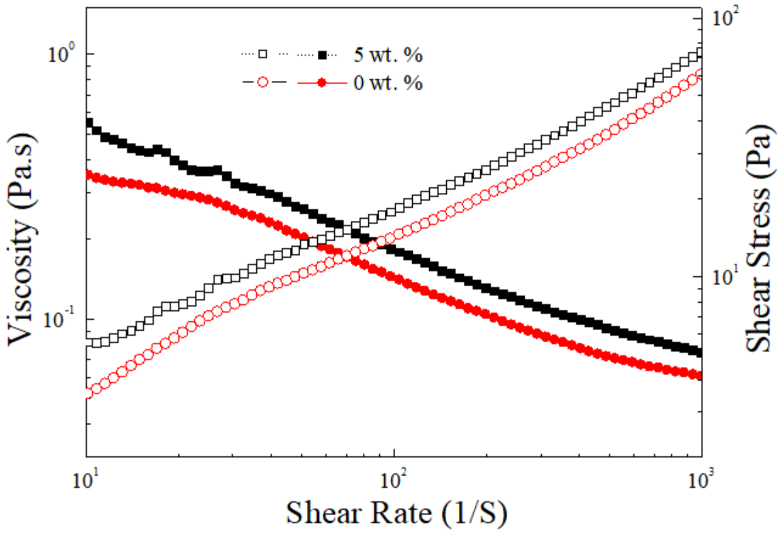

Figure 3: Shear stress (open) and viscosity (closed) of the samples.

To have more evidences about the rheological characteristics, two of the most popular rheological models, which they called Bingham and Herschel-Bulkley models, were utilized as represented in the following equations:

Bingham plastic [12]:

$$\tau = \tau_y + \eta_0\gamma \qquad (1)$$

where τ and τ_y show shear stress and yield stress, respectively and η_0 demonstrate the shear viscosity.

Herschel- Bulkley models [13]:

$$\tau = \tau_y + k\gamma^n \qquad (2)$$

where τ and τ_y are as the aforementioned, and k demonstrate the consistency coefficient and n is the flow behavior index. Tables 2 and 3 list the optimal fitting parameters of the Bingham and the Herschel-Bulkley model, respectively. The results show that after adding nano Basil, the yield stress increases slightly but overall there is no significant changes.

Table 2: Parameters values of samples using Bingham model

Additive Concentration	**τ_0**	**η_0**	**Adj. R-Square**
0 wt.%	5.3	0.057	0.97
5 wt.%	7.6	0.07	0.97

Table 3: Parameters values of samples using Herschel- Bulkley model

Additive Concentration	**τ_0**	**k**	**n**	**Adj. R-Square**
0 wt.%	1.64	0.448	0.706	0.99
5 wt.%	2.49	0.656	0.679	0.99

Although the Adj. R-square is a validate parameter to present the accuracy of a model, but for more a comprehensive investigation about the ability of the proposed models for predicting the rheological characteristic appropriately, figure 4 was

plotted based on experimental data and data had been predicted by models. Fig. 4 represents the shear stress that has been taken from empirical data and predicted by model versus shear rate for Bingham and Herschel- Bulkley models.
Based on the Fig. 4, there is a well match between the actual and predicted area for samples for both of Bingham and Herschel-Bulkley models. It was concluded from Adj. R-squares of two models, that Herschel-Bulkley has better fitting in comparison to the Bingham model, which besides Fig.4 confirms these results.

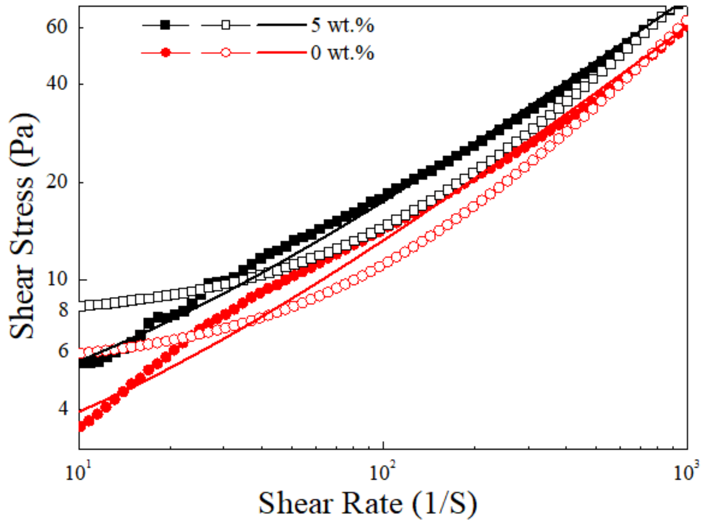

Figure 4: Shear stress versus shear rate of two samples, predicted values by Bingham model (open), Herschel- Bulkley model (line) and data from experiment (close).

4. CONCLUSION

In the oil industry, cementing operation is one of the most crucial activities, thus, different additives are added to cement slurry to preparing cement slurries with desired properties regard to corrosion inhibition and zonal isolation. In this study, a new water repellent additive was introduced and added to class G cement in different concentration (5 to 30 wt.%) and contact angles of water (brine) and oil were measured to investigate the ability of proposed slurry to protect the casing from corrosion by prevention from water invasion. In the high concentration case (30 wt.%) was observed this nano additive can promote water contact angle from 0º to 80.56º which shows the proposed slurry is non-wet regard to water. The optimum sample (5 wt.%) was chosen and its slurry was again produced and its rheological characteristics were tested. It was deduced from the rheological test that the rheological characteristics of both samples are almost as same. The rheological data was modeled by two common models in oil well cementing filed to be sure that proposed slurry does not have inverse effects on rheological properties. Consequently, it was concluded that the sample containing 5 wt.% water repellent additive has the same rheological properties with net cement sample but has better water repellency in comparison to the net sample, therefore the proposed slurry can be a good alternative for cement type G slurries.

REFERENCES

[1] Soares, L.W., Braga, R.M., Freitas, J.C., Ventura, R.A., Pereira, D.S., Melo, D.M. (2015). The effect of rice husk ash as pozzolan in addition to cement Portland class G for oil well cementing, *Journal of Petroleum Science and Engineering*, vol. 131, p. 80-85.

[2] Boukhelifa, L., Moroni, N., James, S., Roy-Delage, L., Thiercelin, M.J., Lemaire, G. (2005). Evaluation of cement systems for oil and gas well zonal isolation in a full-scale annular geometry, *SPE Drilling & Completion*, vol. 20, no. 1, p. 44-53.

[3] Choolaei, M., Rashidi, A.M., Ardjmand, M., Yadegari, A. (2012) Soltanian, H. The effect of nanosilica on the physical properties of oil well cement, *Materials Science and Engineering: A*, vol. 538. p. 288-294.

[4] Broni-Bediako, E., Joel, O., Ofori-Sarpong, G. (2016). Oil well cement additives: a review of the common types, *Oil Gas Res*, vol. 2, no. 1, p. 1-7.

[5] Plank, J., Echt, T. (2019). CSH-PCE Nanofoils: A New Generation of Accelerators for Oil Well Cement, *SPE International Conference on Oilfield Chemistry, Society of Petroleum Engineers*. Texas, April 8.-9.2019.

[6] Crump, D.K., Wilson, D.A. (1984). Set retarding additives for cement from aminomethylenephosphonic acid derivatives, *Google Patents*.

[7] da Silva Araujo Filho, R.G., de Oliveira Freitas, J.C., de Freitas Melo, M.A., Braga, R.M. (2018). Lightweight oil well cement slurry modified with vermiculite and colloidal silicon, *Construction and Building Materials*, vol. 166, p. 908-915.

[8] Al-Yami, A.S., Al-Humaidi, A.S. (2016). High density cement formulation to prevent gas migration problems, *Google Patents*.

[9] Li, M., Xie, D., Guo, Z., Lu, Y., Guo, X. (2017). A novel terpolymer as fluid loss additive for oil well cement, *International Journal of Polymer Science*.

[10] Salam, K., Arinkoola, A., Ajagbe, B., Sanni, O. (2013). Evaluation of thickening time of oil field class G cement slurry at high temperature and pressure using experimental design, *International Journal of Engineering Sciences*, vol. 2, no.8 , p. 361-367.

[11] Munshi, A., Singh, V., Kumar, M., Singh, J. (2008). Effect of nanoparticle size on sessile droplet contact angle, *Journal of Applied Physics*, vol. 103, no. 8, p. 1-5.

[12] Esmaeilnezhad, E., Choi, H.J., Schaffie, M., Gholizadeh, M., Ranjbar, M., Kwon, S.H. (2017). Rheological analysis of magnetite added carbonyl iron based magnetorheological fluid, *Journal of Magnetism and Magnetic Materials*, vol. 444, p. 161-167.

[13] Esmaeilnezhad, E., Choi, H.J., Schaffie, M., Gholizadeh, M., Ranjbar, M. (2018). Polymer coated magnetite-based magnetorheological fluid and its potential clean procedure applications to oil production, *Journal of cleaner production*, vol. 171, p. 45-56.