Investigating the effect of different salts on rheological properties of oil well cements

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***Ab*stract**

Hydrocarbons production quantity, strongly affected by quality of cementing operation which can be considered as the one of the most important operations performed in the petroleum industry operations. Using sweet water as a dispersing agent is rarely in drilling operations for preparation mud drilling and cement slurries. Consequently, accurate understanding the effect of salts on the rheological properties of cement slurries which is a key factor to have a sufficient job, is crucial. So in this study the effect of monovalent and divalent salts on the rheological characteristics of two types of oil well cements slurries (class G cement and class G cement modified with a water repellent nano additive) was investigated through shear rate sweep test, thixotropic test, fixed shear rate test and modeling with two common models in this field. Results showed that both salts affect on the rheological properties of oil well cements but divalent salt ($CaCl_2$) has more vigorous effect than monovalent salt (NaCl).

Keywords- Oil well cement, Modeling, Viscosity, Shear stress, Thixotropic**.**

1. INTRODUCTION

Petroleum has a vast influence on the whole world economy. Hydrocarbons production quantity, strongly affected by quality of cementing operation. Among all activities being done during oil well drilling, the cementing operation can be considered as the most important activities [1]. Cementing job is the procedure to placing a cement slurry in the annulus area between the casing and well-rock. The rheological characteristics of the oil well cement slurries must be upgraded to achieve an effectual well cementing job. In the past few decades, different types of additives such as accelerators [2], retarders [3], anti-foam agents [4], extender additives [5], fluid loss control additives [6], and etc. were utilized to creating desired rheological properties in the oil well cements. The main goal of cementing job in oil wells, is to create zonal isolation in the reservoir and separate different fluids in the well. In some oil reservoirs, it is required to drill and cement the different salt rocks, the interactions of cement with the salt rock during the cementing job can cause the dissolution of the rock and salt can migrate to the cement slurry [7] as well as oil and gas well cementing operations in offshore face more challenges in comparison to cementing in onshore; for example in the sea operations there is little access to sweet water. Consequently, in offshore drilling and cementing the sea water used to prepared the cement slurries. Here, the goal is to study the effect of salinity on rheological properties of cement slurries.

2. EXPERIMENTAL

2.1 Materials

Class G cement and Nano Basil (purchased from an Iranian company, Table 1) were utilized as the dispersing agent and water repellent additive, respectively. Two type of salts, NaCl and $CaCl_2$ (Merck, Germany) as the monovalent and divalent salts, respectively were used to produce salty water.

2.2 Method

The water/cement ratio: 0.44, was used to produce all of slurries in according to American Petroleum Institute Recommended Practice (API RP) 10B. Based on our previous study, the optimum concentration for Basil nano particles is 5 wt.% [8] therefore the effect of salinity was investigated in two steps, 0 wt.% and 5 wt.% of nano Basil. Different types of water were used as the dispersing fluid, such as fresh water (distillated water), tap water, salty water (Medium salinity; 42000 ppm NaCl and High salinity; 42000 ppm NaCl and 18000 ppm $CaCl_2$) to simulation of Persian Gulf seawater [9]. After that rheological characteristics of each sample was measured by rotational rheometer (RST-CC, Brookfield, USA). Table 2 represents the samples' specification.

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

Table 2 : Samples' specification.

Code	Composition	Slurry weight (pcf)
CS 1	Cement + Fresh water	117.48
CS 2	Cement + Tap water	117.64
CS 3	Cement +42000 ppm NaCl	117.83
CS 4	Cement +42000 ppm NaCl+18000 ppm $CaCl_2$	120.21
CS 5	5 wt% Add.+ Cement + Fresh water	109.37
CS 6	5 wt% Add.+ Cement + Tap water	111.37
CS 7	5 wt% Add.+ Cement +42000 ppm NaCl	101.25
CS 8	5 wt% Add.+ Cement +42000 ppm NaCl+18000 ppm $CaCl_2$	101.88

3. RESULT AND DISCUSSION

3.1 Effect of monovalent and divalent salts:

As previously mentioned drilling and cementing operations in offshore face more challenges in comparison to cementing in onshore; for example in the sea operations there is little access or even lack of access to sweet water. Consequently, in offshore drilling and cementing, the sea water used to prepare the cement slurries. Therefore the interactions between the different salts and oil well cement must studied to check the feasibility of using sea water as a dispersing agent for cement slurries. It was concluded from Table 2, when both salts added to cement slurries, the weight of cement increases slightly, which this phenomenon more tangible in case of divalent salts ($CaCl_2$) in comparison to the monovalent salts.

Fig. 1 shows the shear stress and viscosity of slurries without nano Basil versus shear rate. It is obvious that monovalent salt (NaCl) almost has the similar shear stress and viscosity values whit base case (slurry containing fresh water and type G cement), but divalent salt ($CaCl_2$) has a devastating effect on both rheological characteristics; shear stress and viscosity. About the slurries containing nano additive (Fig. 2), both of monovalent and divalent salts (NaCl and $CaCl_2$), improved viscosity and shear stress which implies the positive interaction between nano additive and salts. Tap water in comparison to fresh water, causes to a reduction in viscosity of slurries regardless to the adding of nano additive.

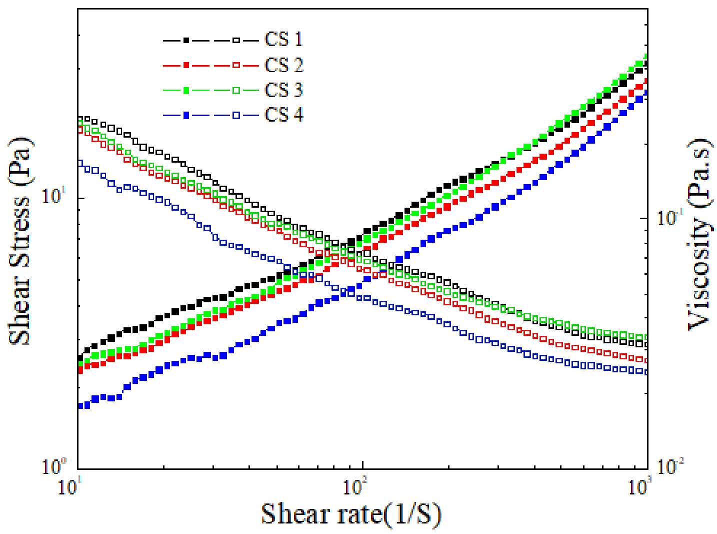

Figure 1: Shear stress (close) and viscosity (open) versus shear rate for slurries without nano additive.

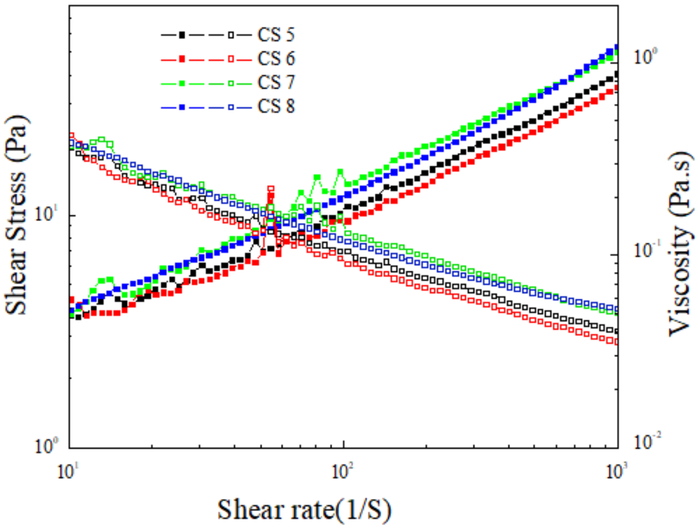

Figure 2: Shear stress (close) and viscosity (open) versus shear rate for slurries containing nano additive.

One of the main rheological properties of cement slurries is thixotropic which is a gradual reduce of the viscosity under shear rate and then by a gradual increase of viscosity when the force is removed. Thixotropic fluids represents both a shear thinning and time-dependent status [10]. Fig. 3 shows a clear hysteresis for all slurries that is a good confirmation for thixotropic behavior and in accordance to previous figures, it is obvious that monovalent salt (NaCl) almost has the similar thixotropic properties whit base case (slurries containing fresh water and type G cement), but divalent salt ($CaCl_2$) has a devastating effect on both thixotropic characteristics.

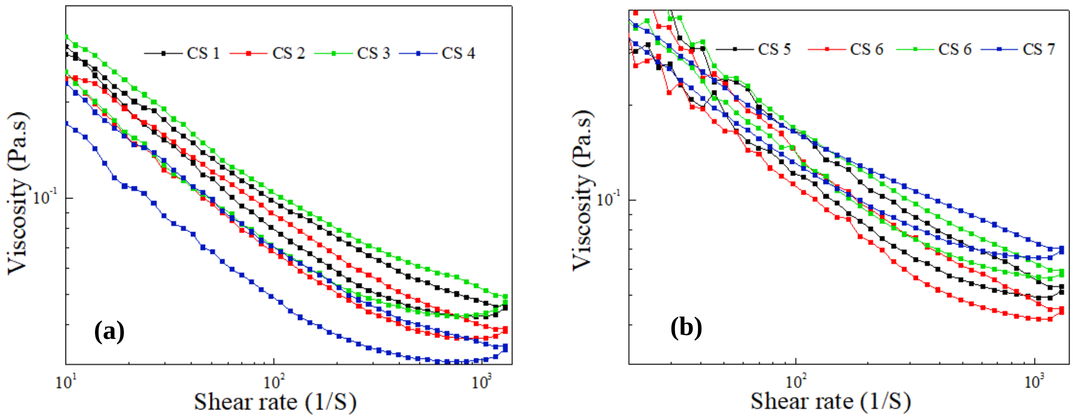

Figure 3: Thixotropic behavior of cement slurries a) without and B) with nano additives in different salinity.

To show the effect of salts and nano additive more clearly, a constant shear rate test was performed in 3 fixed shear rate (3, 100 and 600 S^{-1}) as shown in Fig. 4. It can be inferred from Fig. 4 that tap water in both cases (whit and without nano additives) has the lowest viscosity and shear stress values, and all samples that contain nano additive, have larger values of viscosity and shear stress. Furthermore, $CaCl_2$ as a divalent salt has more significant effect on rheological properties of oil well cement slurries in comparison to NaCl even in higher concentration.
To shed light rheological characteristics, two of the most common rheological models, which they called Bingham and Herschel-Bulkley models, were used as shown in the following equations:

Bingham plastic [9]:

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

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

Herschel- Bulkley models [9]:

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

where τ and τ_y are as the aforementioned, and k demonstrate the consistency coefficient and n is the flow behavior index. Table 3 shows the optimal fitting parameters of the Bingham and the Herschel-Bulkley model. The results show that after adding both salts the value of τ_0, decreases but after adding nano additive the value of τ_0, increases. Also it was concluded based on Adj. R-Square that the Herschel- Bulkley has better performance than Bingham model to fitting actual data.

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

Code	Bingham model			Herschel- Bulkley model			
	τ_0	η_0	Adj. R-Square	τ_0	k	n	Adj. R-Square
CS 1	3.15	0.029	0.98	1.75	0.154	0.76	0.99
CS 2	3.15	0.029	0.98	1.53	0.129	0.76	0.99
CS 3	2.72	0.031	0.99	1.77	0.101	0.83	0.99
CS 4	1.89	0.023	0.99	1.37	0.057	0.86	0.99
CS 5	5.01	0.037	0.97	2.49	0.307	0.69	0.99
CS 6	5.07	0.032	0.96	3.20	0.216	0.72	0.98
CS 7	6.24	0.047	0.96	2.35	0.523	0.65	0.99
CS 8	4.94	0.05	0.98	2.38	0.286	0.75	0.99

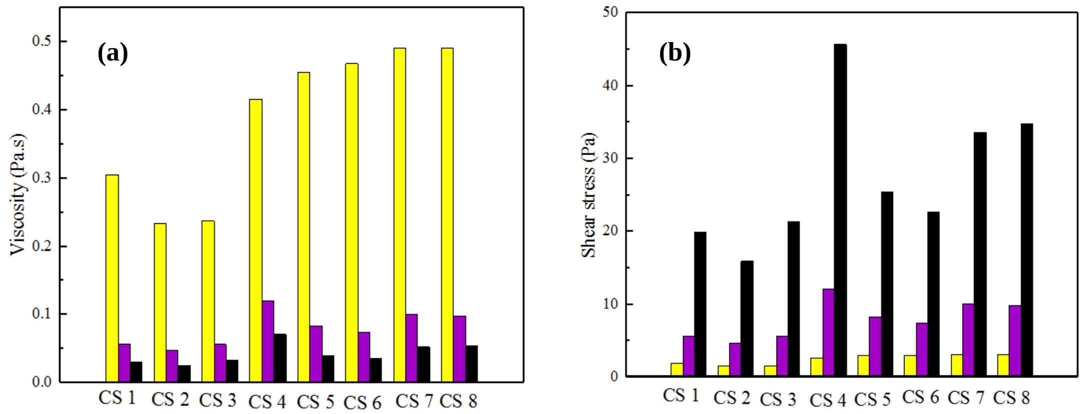

Figure 4: Viscosity (a) and shear stress (b) of constant shear rate test @ 6 s^{-1} (Yellow), 100 s^{-1} (Purple) and 600 s^{-1} (Black)

3.2 Effect of nano additive:

Our previous study showed [8] that nano Basil has the ability to promote contact angle of water in the best case from 0 to 80.56^0. Consequently, here the effect of different salts on rheological properties of oil well cement containing nano Basil (5 wt%) was investigated. It was concluded from Figures 5 and 6 in all cases, the samples that containing nano additive water repellent have more value of viscosity and shear stress. Also deduced that as the same time which salinity increases the variances between two cases (with nano additive and without nano additive).

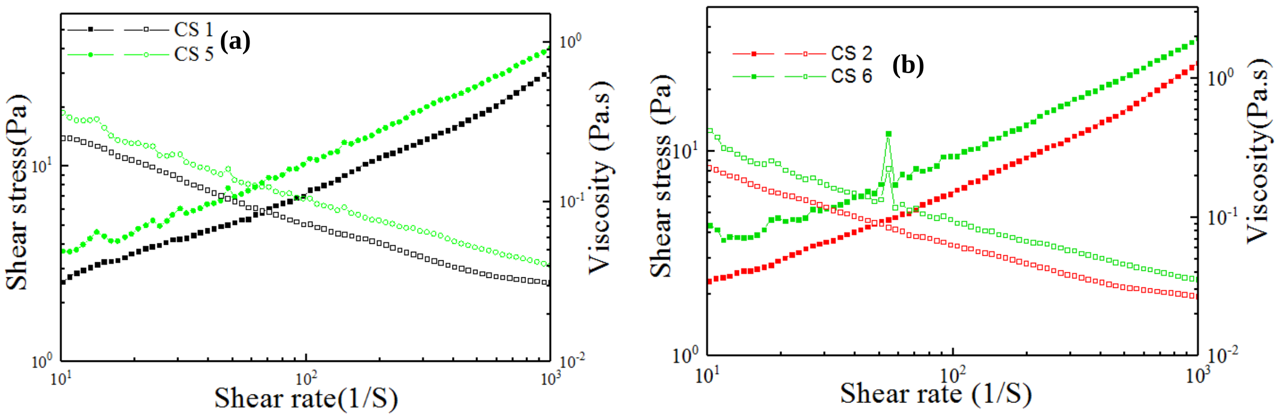

Figure 5: Effect of nano additive on viscosity (open) and shear stress (close) of cement slurry, in different dispersing fluid; (a) Fresh water and (b) Tap water.

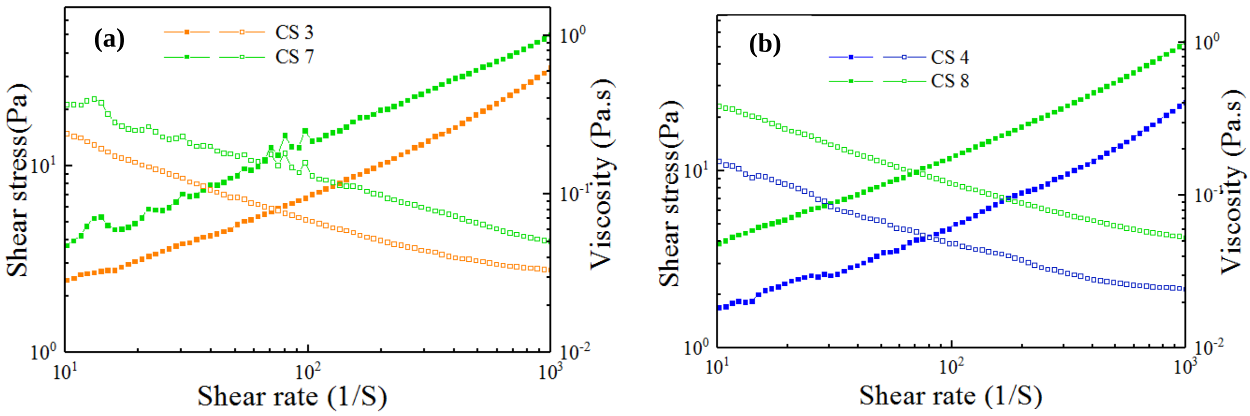

Figure 6: Effect of nano additive on viscosity (open) and shear stress (close) of cement slurry, in different dispersing fluid; (a) Medium salinity brine and (b) High salinity brine.

4. CONCLUSION

In petroleum industry operations (drilling and cementing operations), formation water always contain some anions and cations and is salty. Using sweet water for water flooding or other operation such as cementing and mud drilling preparation is not sufficient and cost effective and sometimes is impossible due to inaccessibility. Therefore salts and their effects on the base fluid for all operation specially for cementing operation has a vital role. In this study the feasibility of using Persian Gulf's water as a dispersing agent for cement slurries was investigated by artificial synthesizing of water. Nano Basil as an additive were added to slurries to have more non-wet water slurries to prevent from corrosion. Results showed that for divalent salt ($CaCl_2$), the condition is more vigorous in comparison with monovalent salt (NaCl). All of samples including tap water, fresh water, medium salinity and high salinity have thixotropic behavior either with and or without nano additive and modeling of slurries by two common rheological models represented that adding nano additive lead to an increment in yield stress. Thus using proposed nano additive can increase the rheological properties even in high salinity media.

REFERENCES

[1] M. Labibzadeh, B. Zahabizadeh, A. Khajehdezfuly, Early-age compressive strength assessment of oil well class G cement due to borehole pressure and temperature changes, Journal of American Science, 6 (2010) 38-45.
[2] J. Zhang, E.A. Weissinger, S. Peethamparan, G.W. Scherer, Early hydration and setting of oil well cement, Cement and Concrete research, 40 (2010) 1023-1033.
[3] K. Kupwade-Patil, P.J. Boul, D.K. Rasner, S.M. Everett, T. Proffen, K. Page, D. Ma, D. Olds, C.J. Thaemlitz, O. Büyüköztürk, Retarder effect on hydrating oil well cements investigated using in situ neutron/X-ray pair distribution function analysis, Cement and Concrete Research, 126 (2019) 105920.
[4] P.D. Meireles, D.S. Pereira, M.A. Melo, R.M. Braga, J.C. Freitas, D.M. Melo, F. Silvestre, Technical evaluation of calcium sulphate α-hemihydrate in oilwell application: An alternative to reduce the environmental impacts of Portland cement, Journal of Cleaner Production, 220 (2019) 1215-1221.
[5] R.G. da Silva Araujo Filho, J.C. de Oliveira Freitas, M.A. de Freitas Melo, R.M. Braga, Lightweight oil well cement slurry modified with vermiculite and colloidal silicon, Construction and Building Materials, 166 (2018) 908-915.
[6] L. Cao, J. Guo, J. Tian, M. Hu, C. Guo, Y. Xu, M. Wang, J. Fan, The ability of sodium metasilicate pentahydrate to adjust the compatibility between synthetic Fluid Loss Additives and Retarders applying in oil well cement, Construction and Building Materials, 158 (2018) 835-846.
[7] C.A. Abelha Rocha, C.A. Simão, G.C. Cordeiro, R.D. Toledo Filho, Effect of the sodium and potassium chloride on the mechanical and plastic properties on the oil well cement slurries, ASME 2012 31st International Conference on Ocean, Offshore and Arctic Engineering, American Society of Mechanical Engineers Digital Collection, 2012, pp. 805-811.
[8] M. Shayan, E. Esmaeilnezhad, Improve oil well cements performance by commercial nano additive, 5th national Conference and 1st International Conference on Cement Industry and Oncoming Horizon, Tehran, (2019).
[9] E. Esmaeilnezhad, H.J. Choi, M. Schaffie, M. Gholizadeh, M. Ranjbar, Polymer coated magnetite-based magnetorheological fluid and its potential clean procedure applications to oil production, Journal of cleaner production, 171 (2018) 45-56.
[10] A. Shahriar, Investigation on rheology of oil well cement slurries, (2011).