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INFLUENCE OF IONIC HYDRATION INHIBITORS ON DUAL INHIBITOR SYSTEM MUD PROPERTIES – TECHNOLOGICAL PARAMETERS***

1. INTRODUCTION

The hydration of drilled clay rocks and the related to it risk of complications, due to borehole wall instability, can be reduced by applying inhibited mud [1, 2].

There are numerous mud systems intended for clay rock drilling. Most popular are muds with an ionic-polymeric inhibitive function. This type of mud contains ionic inhibitors in combination with polymeric inhibitors. Nowadays, this system is often completed with polyglycols or amino agents, consequently creating mud with a triple inhibitor system [1].

Various organic and inorganic compounds can be used as hydration inhibitors. Those deliver, as a result of electrolytic dissociation, free ions capable of reaction of ion exchange with clay minerals, causing changes in physico-chemical properties. Useful electrolytes are the ones exhibiting good hydration capacity and not significantly affecting technological parameters of the drilling mud [1].

The functions of a ionic hydration inhibitor are to reduce hydration of clay rock, counteract osmotic pressure generation and binding elementary platelets composing of clay minerals [1].

Surface hydration reduction is the result of interlayer clay ions substitution with ions with the lower hydration number. Osmotic hydration adjustment can be achieved by maintaining a greater concentration of ions in the mud/filtrate than in the formation. One of the important mechanisms of electrolyte's inhibitive function is hydrophobization of the clay surface, that causes a decrease in formation wetting due to drilling mud filtrate [1].

The earliest applied hydration inhibitors were calcium components ($Ca(OH)_2$, $CaSO_4 \cdot 2H_2O$, $CaCl_2$), which were a foundation of calcium mud development (calcium,

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gypsum and chloride-calcium). The main mechanism of hydration inhibition is based on ion exchange. In relation to this, calcium muds were effective in the case of drilling the formation containing great quantity of sodium montmorillonite. Considering drilling the formation containing calcium montmorillonite ion exchange does not occur, however, calcium ion presence in the mud/filtrate prevents both the conversion of calcium montmorillonite into sodium montmorillonite (under the influence of the sodium ions presence in the mud/filtrate) and sensitisation of the formation to the water [1].

Currently, as ionic inhibitors are used potassium components (most commonly potassium chloride).The mechanism of this inhibitor is based on an ion exchange. Potassium ions expel both calcium and sodium ions from the rock. The small size of the potassium ion, characterised by low the hydration number, enables easy placement in interlayer spaces strongly bonding them. There is also possible the placement of potassium ion in the crystal lattice of a mineral. Simultaneously, substitution in tetragonal layers is limited due to a number of isomorphic substitutions, those bonds are very strong [1–3].

Ionic inhibitor concentration selection is based on drilled formation type and minerals occurring in it. The standard concentration of potassium chloride application is 3–7% by weight of the mud, but experience earned at the North Sea shows that for plastic clay drilling increase of KCl concentration, even up to 20%, is essential [1, 3–6].

In the project five different ionic inhibitors of clay rock hydration were examined. The studies include tests of inhibitor influence on both technological parameters of drilling muds and the swelling of the Miocene shale sample.

2. FORMULA OF THE TEST MUD

In order to conduct the studies of ionic inhibitors hydration influence on clay rock swelling, test mud was prepared. Further different ionic inhibitors were added to the mud. The generic formula of the mud developed for the studies is presented in Table 1.

Table 1

Formula of the test mud

Reagent	Concentration [%]
PAC LV	1
Rotomag	2
XCD polymer	0.01
PHPA PT-123/33	0.3
Ionic inhibitor	0–7
Carbonate bridging agent 30 μm	7

In the studies following ionic hydration inhibitors were applied Mud-0 comparative mud without ionic inhibitor:

– Mud-1: KCl,
– Mud-2: K_2CO_3,
– Mud-3: HCOOK,
– Mud-4: NH_4Cl,
– Mud-5: $CaCl_2$.

3. METHODOLOGY OF THE RESEARCH

In each case the influence of the non-ionic hydration inhibitor on rheological properties, filtration, lubricity coefficient and density of test mud was examined. Furthermore, influence of prepared muds on QSE Pellets swelling were conducted and Miocene shale linear swelling (LST) tests were undertaken (results are presented in [7]).

Tests of mud technological parameters were conducted according to Polish and international standards (API Spec.) [8]. LST tests have been achieved with GRACE Instrument M4600 HPHT Linear Swell Meter. QSE The pellet swelling test involves volume measurement of initial pellet afterwards conditioned in the mud for 24 h. After this time period a second measurement was undertaken and the percentage increase of the volume was calculated.

4. MUD-1 WITH KCl ADDITION

The first the tested non-ionic hydration inhibitors was potassium chloride. The test results are presented in Figures 1–4.

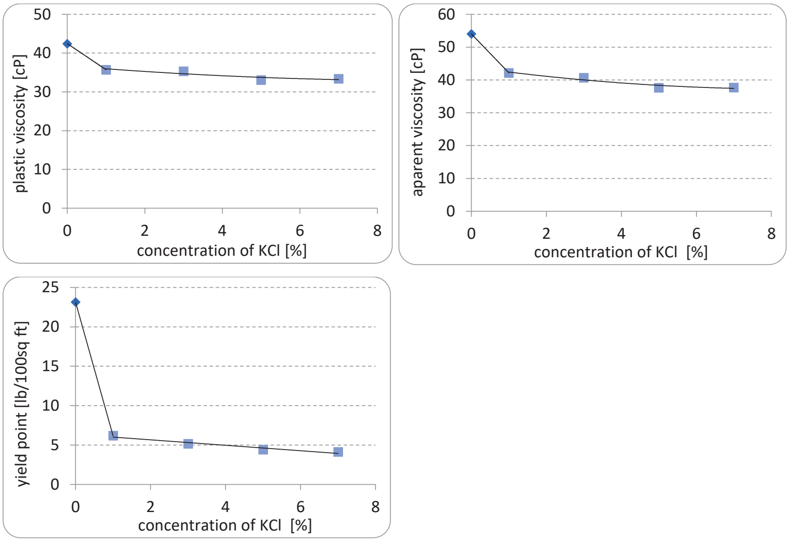

Fig. 1. The change of test mud rheological properties under the influence of KCl

The results of the undertaken tests show that the addition of 1% of potassium chloride causes a considerable decrease of test mud rheological properties. Further potassium chloride concentration increase does not result in significant change of rheological properties.

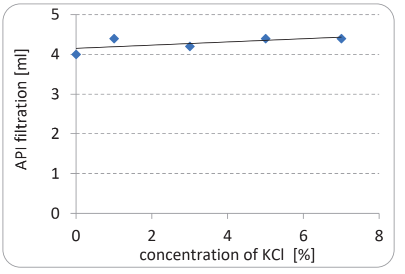

Fig. 2. Change of test mud filtration under the influence of KCl

Mud filtration does not change with the increasing concentration of potassium chloride in the mud and maintain at low level.

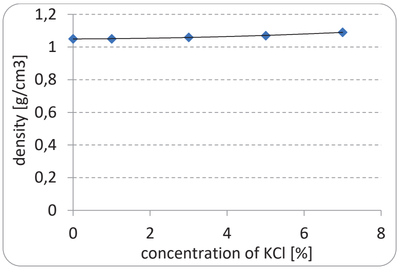

Fig. 3. Change of test mud density under the influence of KCl

Density of the mud slightly increase with potassium chloride concentration growth and reaches value of 1.09 g/cm^3 at 7% of KCl addition.

The lubricity coefficient of the mud increase after 1% of potassium chloride addition, then insignificantly diminish with KCl concentration growth.

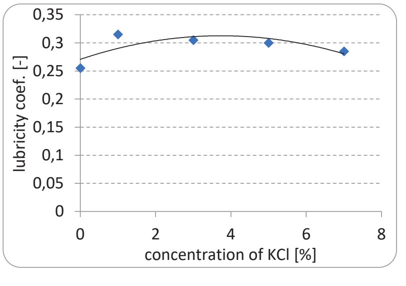

Fig. 4. Change of test mud lubricity coefficient under the influence of KCl

5. MUD-2 WITH K_2CO_3 ADDITION

Graphs (Fig. 5–8) show the test outcomes of the test mud with the addition of potassium carbonate (K_2CO_3) as an ionic inhibitor of hydration.

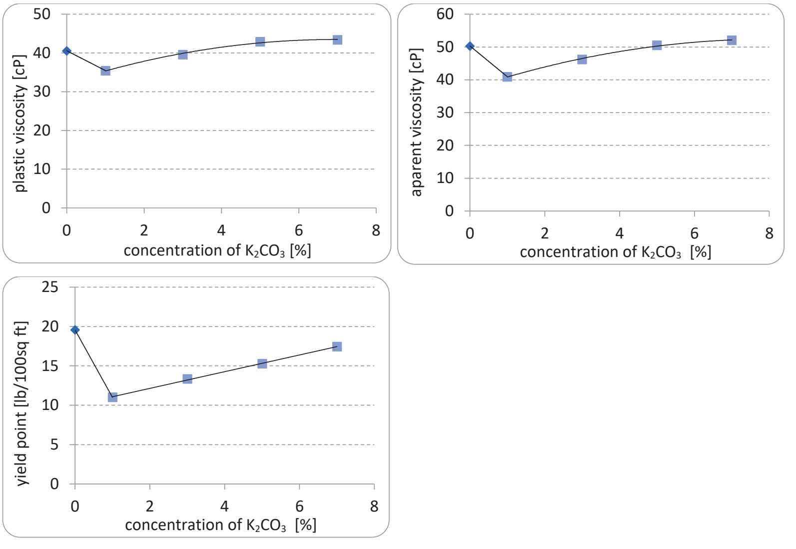

Fig. 5. Change of test mud rheological properties under the influence of potassium carbonate

Tests findings show that test mud rheological properties diminish under the influence of 1% of potassium carbonate addition, subsequently increasing with K_2CO_3 concentration growth.

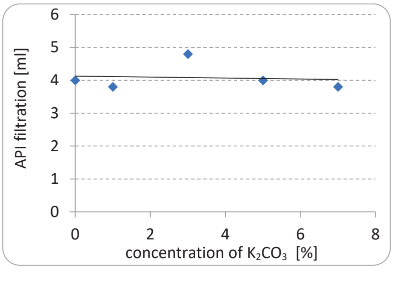

Fig. 6. Change of test mud filtration under the influence of potassium carbonate

Filtration of the studied drilling muds does not considerably change under the influence of potassium carbonate concentration increase.

Under influence of the increasing concentration, mud density slightly increases up to 1.083 g/cm^3 value at 7% of the potassium carbonate addition.

Addition of potassium carbonate does not impact lubricity coefficient of the studied muds regardless of its concentration.

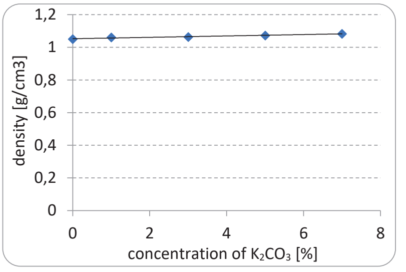

Fig. 7. Change of test mud density under the influence of potassium carbonate

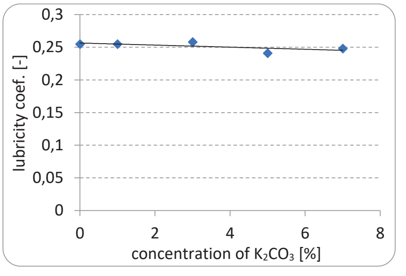

Fig. 8. Change of test mud lubricity coefficient under influence of potassium carbonate

6. MUD-3 WITH HCOOK ADDITION

The test findings of the test mud with an addition of HCOOK as an ionic hydration inhibitor are presented in Figures 9–12.

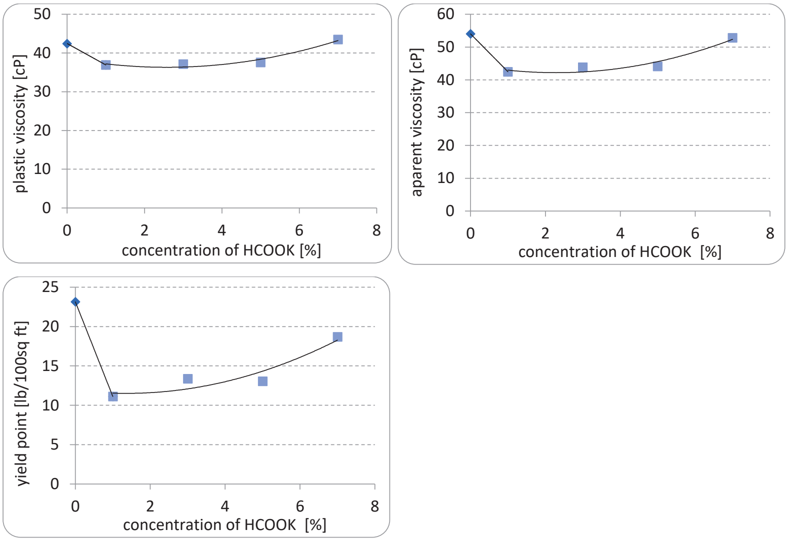

Fig. 9. Change of test mud rheological properties under influence of HCOOK

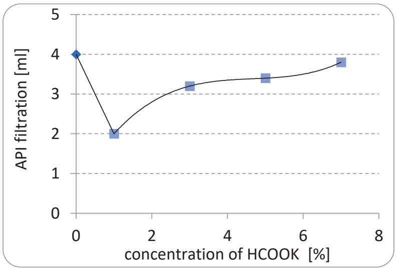

Fig. 10. Change of test mud filtration under the influence of HCOOK

The rheological properties of the test mud diminish after 1% of potassium formate implementation, subsequently with HCOOK concentration growth an increase of those properties can be observed. At 7% of salt concentration results reach values comparable to the results of mud without an inhibitor addition.

The filtration of studied muds decreases to the value of 2 ml for 1% of potassium formate addition, afterwards increases with HCOOK concentration growth.

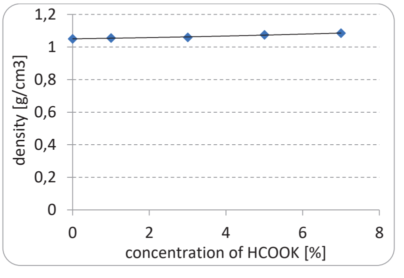

Fig. 11. Change of test mud density under influence of HCOOK

The density of mud insignificantly increases with potassium formate concentration growth and reaches the value of 1.085 g/cm^3 for 7% of salt concentration.

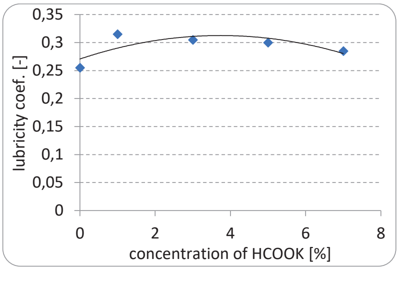

Fig. 12. Change of test mud lubricity coefficient under the influence of HCOOK

The lubricity coefficient of the test mud increases after an addition of 1% of potassium formate, next decreases with salt concentration growth.

7. MUD-4 WITH NH_4Cl ADDITION

The subsequent studied ionic inhibitor of hydration was ammonium chloride. Test outcomes are presented in Figures 13–16.

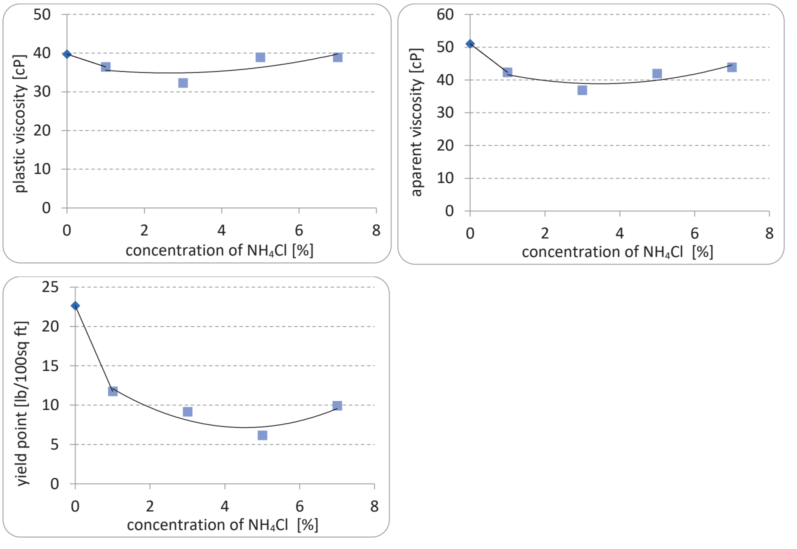

Fig. 13. Change of test mud rheological properties under the influence of NH_4Cl

An addition of ammonium chloride does not cause meaningful changes of test mud plastic viscosity. However, a noteworthy decline of yield point value can be observed.

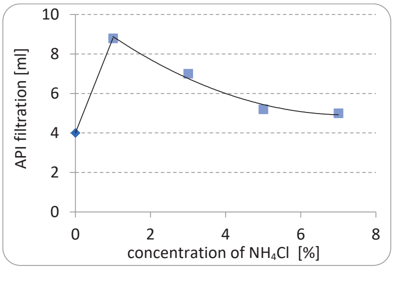

Fig. 14. Change of test mud filtration under influence of NH_4Cl

Test mud filtration grows after addition of 1% of ammonium chloride. A further increase of NH_4Cl concentration results in diminishing filtration.

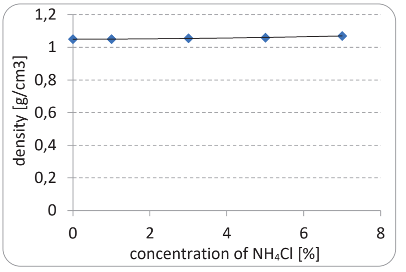

Fig. 15. Change of test mud density under the influence of NH_4Cl

Mud density slightly increases with ammonium chloride concentration growth and reaches the value of 1.07 g/cm^3 at 7% of the salt addition.

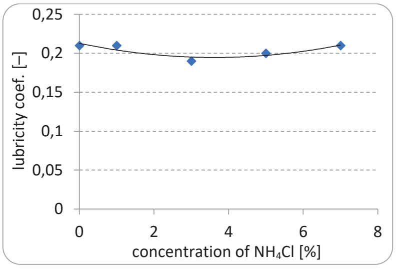

Fig. 16. Change of test mud lubricity coefficient under influence of NH_4Cl

Lubricity coefficient of studied muds does not significantly change with ammonium chloride concentration increase.

8. MUD-5 WITH $CaCl_2$ ADDITION

Last studied non-ionic inhibitors of hydration was calcium chloride. Test results are presented in Figures 17–20.

During an increase of calcium chloride concentration in the test mud, it can be noticed viscosity properties decrease and meaningful yield point decline in the beginning. Calcium chloride concentration growth up to 7% causes considerable increase of mud parameters. In view of the viscosity – above the values of the output parameters.

Filtration of the mud diminishes with calcium chloride concentration growth and at 7% of salt concentration reaches the value of 1.6 ml.

The density of the mud slightly increases with calcium chloride concentration growth and for 7% of salt addition reaches value of 1.07 g/cm^3.

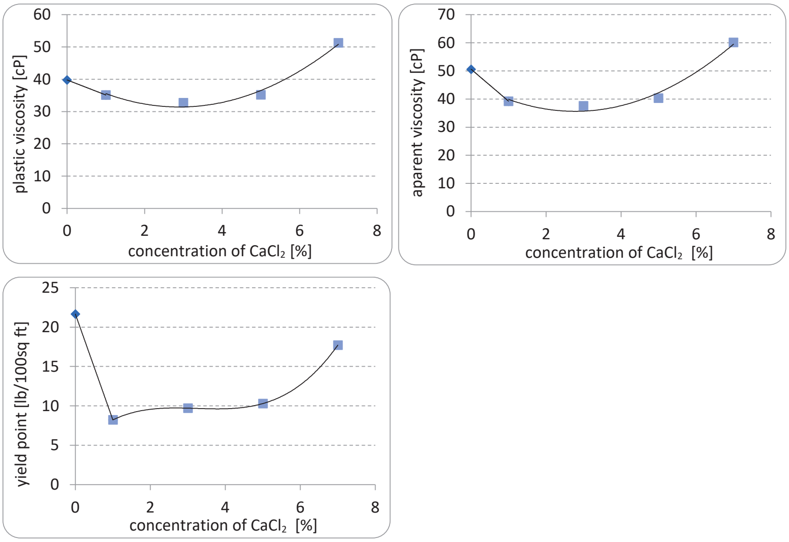

Fig. 17. Change of test mud rheological properties under the influence of $CaCl_2$

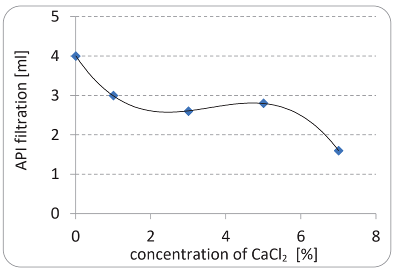

Fig. 18. Change of test mud filtration under the influence of $CaCl_2$

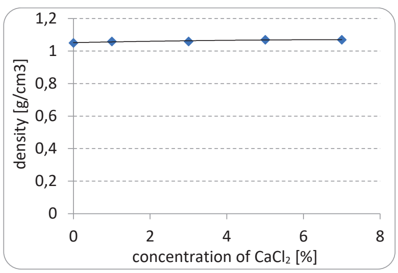

Fig. 19. Change of test mud density under the influence of $CaCl_2$

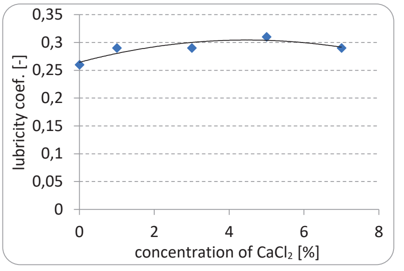

Fig. 20. Change of test mud lubricity coefficient under the influence of $CaCl_2$

Base on the results, it can be observed an increase of lubricity coefficient value after 1% of calcium chloride addition. Further $CaCl_2$ concentration growth does not significantly affect this coefficient.

9. CONCLUSIONS

The undertaken tests do not undeniably define which one of the studied inhibitors is the most effective addition to the mud with dual inhibitor system. It was observed a decrease of rheological properties after 1% of salt addition by weight for each studied inhibitor – especially noticeable considering the yield point value. Rest of the technological parameters do not significantly change with ionic hydration inhibitor concentration.

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