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Consistent Rheological Behavior of Formate Based Fluid for Drilling and Workover Operations

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Formate based fluids are environmentally friendly and biodegradable drilling fluids that are compatible and solid free, contributing to eliminate formation damage. In this regard, they find their application in drilling fluids, as well as in completion fluids. In this work, three potassium formate based fluids of different concentrations such as 40, 50, 60 % w/w and water-based fluid (WBF) are prepared with help of additives namely, calcium carbonate, xanthan gum and ethylene glycol. The consistent performance of a drilling, completion or workover fluid is very much necessary for successful and economical drilling, completion or workover operation. Hence the synthesized fluid samples with various concentrations of potassium based fluids are analyzed for their rheological behavior at various temperatures and a function of time.

Keywords: Drilling fluid, Workover fluids, Formation, Rheology, Chemical additives.

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1. INTRODUCTION

Drilling and completion fluids are used while drilling and completing the workover operations to mitigate the well blowout and decrease the formation damage. The fluids need very high densities, and the formate salts of alkali metals can be used for such purposes. Many additives have been reported in literature [1, 2] to impart the required properties to the drilling fluids. The formats of potassium (KCOOH), sodium (NaCOOH), and caesium formate monohydrate ($CsCOOH-H_20$) are the commonly used as drilling and completion fluids owing to their very high solubility in water and their ability to result in high density fluids. The low viscous biodegradable formate-based alkaline brines are however less toxic to aquatic life offshore and have a wide range of properties. These fluids also act as a fluid loss agent for higher temperatures, have a low rate of hydrolytic, oxidative degradation and cause minimal corrosion to ferrous metals used in tubes. These fluids are used in slim and deep hole drilling to minimize frictional pressure losses and in formations with high temperatures and shales for formation stabilization. They also act as gas hydrate inhibitors and scale dissolvers. Techniques available for cost effective clean-up and recycling of formate-based drilling fluids have been reported in literature [3-6].

Gaurina et al. reported based on their laboratory study that at higher temperatures potassium formate-based fluid (DIF-3) has better rheological and filtration characteristics than water-based fluid (WBF). Potassium formate is reported to stabilize viscosifiers and fluid loss polymers, there by aid in enhancing the rheological properties at higher temperatures. At a temperature higher than 125 °C, inadequate rheological properties are reported for WBF and especially for potassium formate based fluids in the absence of PAC (DIF-1). The addition of 10 g/l PAC to the formate based fluid (DIF-2) gave satisfactory results. Further, an increase in the concentration of PAC (DIF-3) has not shown significant results [4]. Wang et al. reported that the formate based fluid is used in the deep well of the Lungu area in Tari during drilling and well completion. From the field experiments, the formate drilling fluid acts as a good shale stabilizer. The capability of bringing cuttings to the surface along with the shear thinning characteristics of the low viscous formate drilling fluid is suitable for meeting the drilling criteria in cutting carrying capacity characteristics. In case of formations with solid particles that can block the pores of the formation, the formate drilling fluid having low density with no solid phase can alarm and detect problems in the formation within less time and helps in reducing formation damage. Further, they exhibit excellent compatibility characteristcs with common treating agents of the oil field [5]. The objective of this work is to conduct preliminary experiments on different concentrations of potassium based formate fluids that are consistent in their rheological behavior with respect to time and temperature. Further in this study, other fluids properties required for both drilling and production operations of an oil and gas well are measured.

2. MATERIALS AND METHODS

2.1 Materials

In this work, three different concentrations of potassium formate and a WBF are prepared. The concentration of potassium formate in the first potassium formate based fluid (PFBF-1) is 40 % w/w. The concentration of potassium formate in the second potassium formate based fluid (PFBF-2) is 50 % w/w, and the concentration of potassium formate in the third potassium formate based fluid (PFBF-3) is 60 % w/w. The additives added to the three fluids are calcium carbonate, xanthan gum,

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ethylene glycol, as shown in Table 1. The samples used in this work are shown in Fig. 1.

Xanthan gum is a viscosifying biopolymer that provides thixotropic properties and solid carrying capacity. Calcium carbonate is used as a bridging agent between solid particulates. Ethylene glycol is used as a foam breaker to control the foam generated during the preparation of formate based drilling fluid.

Table 1 – Composition of the drilling fluid samples used in the experiments

Component (units)	WBF	PFBF-1	PFBF-2	PFBF-3
Water (ml)	1000	500	500	500
k-formate (ml) (w/w)	0	500 (40 %)	500 (50 %)	500 (60 %)
Xanthan gum (g/l)	4	4	4	4
Calcium carbonate (g/l)	30	30	30	30
Ethylene glycol (ml)	As required			

2.2 Rheological Study

In this experimental work, the consistentency parameters of the formate based fluids when subjected to different reservoir conditions (50 and 60 °C) at different times are measured. In time studies, shear stress values are measured from the dial deflections of the viscometer at 600, 300, 200, 100, 6, and 3 rpm at various time periods of zero hours, 24, 48 and 72 h after the preparation of different formate based fluids (40, 50, and 60 % w/w) and WBFs. Further, during temperature studies, a shift is created, the dial deflections of the viscometer are measured at room temperature, 50 and 60 °C.

The measured dial deflections at different rates of revolution of the outer cylinder are converted into shear rate versus shear stress values.

Fig. 1 – Drilling fluid samples

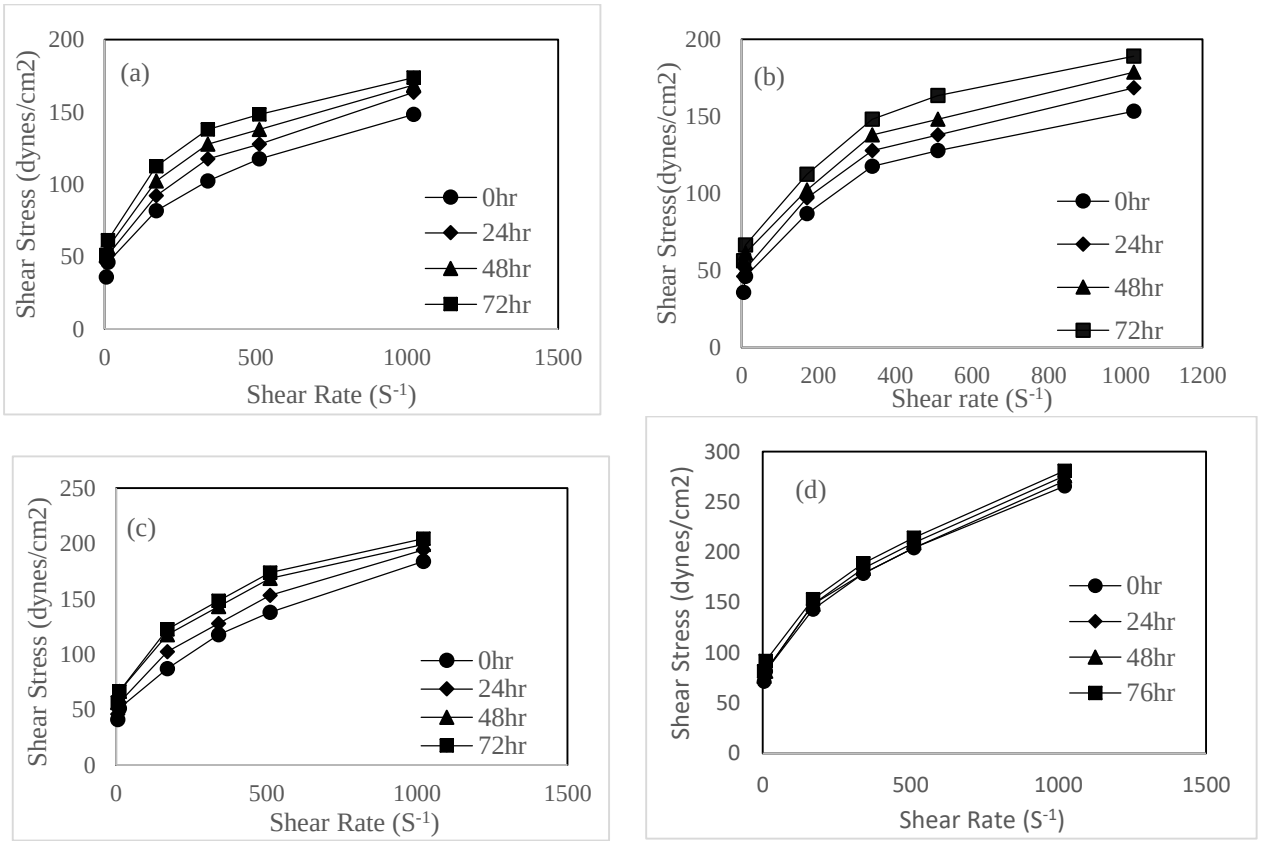

Fig. 2 – Influence of time on rheological behavior of different well fluids: (a) WBF, (b) 40 % w/w k-formate, (c) 50 % w/w k-formate, (d) 60 % w/w k-formate

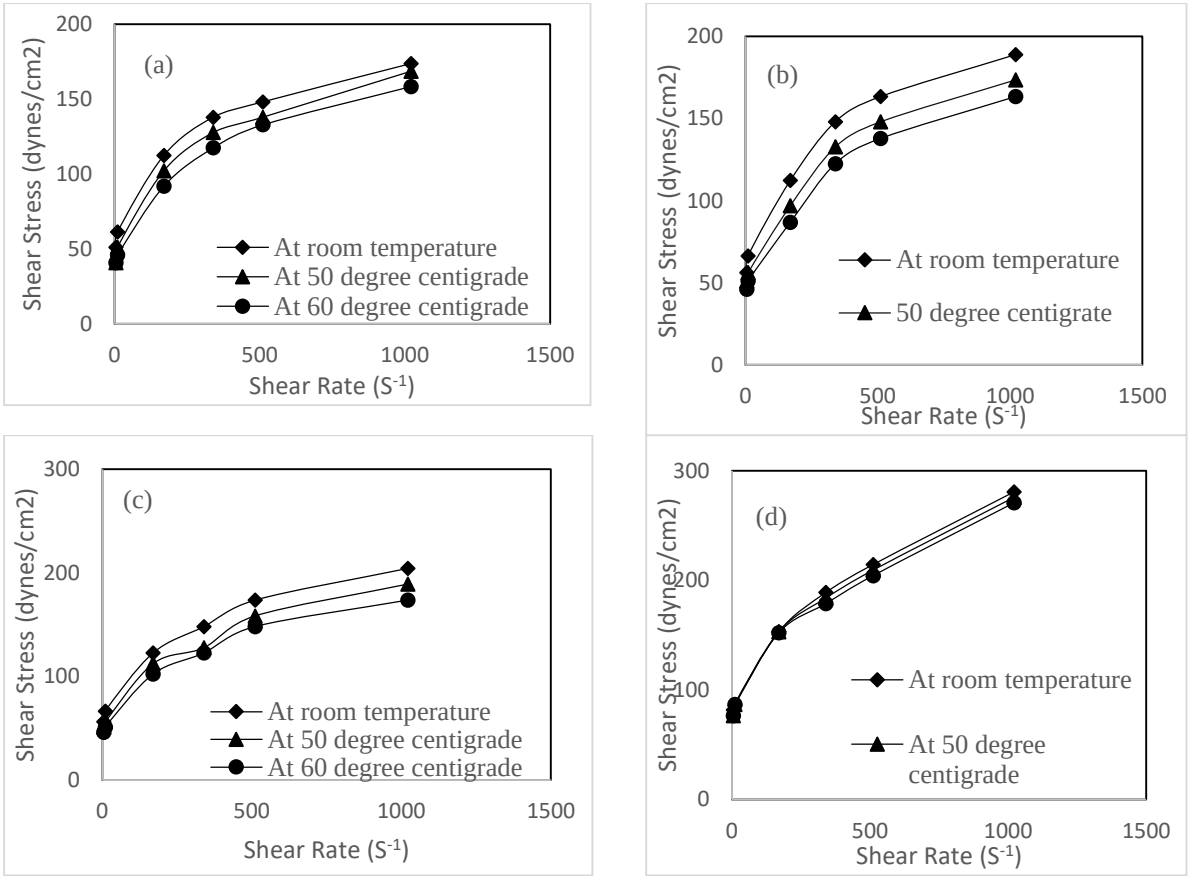

Fig. 3 – Temperature effect on rheological behavior of well fluids: (a) WBF, (b) 40 % w/w k-formate, (c) 50 % w/w k-formate, (d) 60 % w/w k-formate

3. RESULTS AND DISCUSSION

3.1 Rheological Analysis of Nanofluds

Fig. 2 shows the influence of time on rheological behavior of water based, 40, 50 and 60 % w/w k-formate. Any point on the shear stress versus shear rate curve is viscosity in poise. Shear stress versus shear rate curves of different fluids show great variations relative to each other. Viscosity of the potassium formate based fluid increases with the concentration of potassium formate in the fluid and decreases with temperature. In time studies, it is observed that viscosities of the fluids increase with time. Both 40 and 50 % w/w potassium formate based fluids show great variations in viscosities throughout the time period where the changes observed in the viscosity of 60 % w/w potassium formate are minimal. The performance of 60 % w/w potassium formate based fluid is more consistent throughout the time period, as shown in Fig 2.

Fig. 3 shows the effect of temperature on rheological behavior of water based, 40, 50 and 60 % w/w k-formate. In temperature studies, it is observed that the viscosities of the fluids decrease with increasing temperature. Both 40 and 50 % w/w potassium formate based fluids show great variations in the viscosities with increasing temperature, whereas changes in the viscosity of 60 % w/w potassium formate based fluid are minimal. There is a rapid decrease in the viscosities of 40 and 50 % w/w potassium formate based fluids, whereas the performance of 60 % w/w potassium formate based fluid is less consistent, as shown in Fig. 3.

4. CONCLUSIONS

In this work, the consistent rheological behavior of three formate based fluids (40, 50 and 60 % w/w k-formate) are measured, based on which it can be concluded that the 60 % w/w potassium formate based fluid may be used as a drilling, completion or workover fluid owing to its optimum characteristics.

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Послідовна реологічна поведінка рідини на основі форміату при бурінні та капітальному ремонті свердловин

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Рідини на основі форміату – це екологічно чисті та біологічно розкладані бурові розчини, які сумісні та не містять твердих речовин, сприяючи усуненню пошкодження пласта. У зв'язку з цим вони знаходять своє застосування як бурові розчини, а також як розчини для завершення свердловин. У цій роботі три рідини на основі форміату калію різних концентрацій, таких як 40, 50 та 60 мас. %, і рідину на водній основі (WBF) готують за допомогою добавок, а саме карбонату кальцію, ксантанової камеді та етиленгліколю. Послідовна продуктивність рідини для буріння, для завершення або капітального ремонту є дуже необхідною. Таким чином, зразки синтезованих рідин з різними концентраціями рідин на основі калію аналізуються на їх реологічну поведінку при різних температурах і в залежності від часу.

Ключові слова: Рідина для буріння, Рідина для капітального ремонту, Формування, Реологія, Хімічні добавки.