Petroleum xxx (2017) 1–8

Contents lists available at ScienceDirect

Petroleum

journal homepage: www.keaipublishing.com/en/journals/petlm

Shale hydration inhibition characteristics and mechanism of a new amin-based additive in water-based drilling fluids

Pezhman Barati [a, *], Khalil Shahbazi [a], Mosayyeb Kamari [b], Amin Aghajafari [a]

[a] Department of Petroleum Engineering, Ahwaz Faculty of Petroleum Engineering, Petroleum University of Technology, Ahwaz, 63431, Iran
[b] Reservoir Evaluation Department, National Iranian South Oil Company, Ahwaz, Iran

ARTICLE INFO

Article history:
Received 25 September 2016
Accepted 15 May 2017

Keywords:
Drilling fluids
Dynamic linear swelling
Hydrogen bond
Mechanism
Shale stabilizer
Tallow amine ethoxylate
Wettability
Zeta potential
Amine-based additive

ABSTRACT

In this work, shale hydration Inhibition performance of tallow amine ethoxylate as a shale stabilizer in water based drilling fluid, was investigated through these tests: bentonite hydration inhibition test, bentonite sedimentation test, drill cutting recovery test, dynamic linear swelling test, wettability test, isothermal water adsorption test, and zeta potential test. The results showed that bentonite particles are not capable of being hydrated or dispersed in the mediums containing tallow amine ethoxylate; tallow amine ethoxylate had shown a comparable and competitive inhibition performance with potassium chloride as a common shale stabilizer in drilling industry. Some amine functional groups exist in tallow amine ethoxylate structure which are capable of forming hydrogen bonding with surfaces of bentonite particles. This phenomenon decreased the water adsorption on bentonite particles' surfaces which results in reduction of swelling. Tallow amine ethoxylate is also compatible with other common drilling fluid additives.

1. Introduction

A large part of underground formations consists of shaly rocks which face with swelling and disintegration when meeting the aqueous phase of drilling fluids. This event causes the wellbore washouts and drill string sticking in the borehole, wasting 1 billion USD per year worldwide during the drilling operations [1–3]. Drilling fluid designers are always seeking for high performance drilling fluids which are resistant to shale hydration and disintegration, so they are more willing to use oil-based drilling fluids. But this sort of drilling fluids also has severe degenerative effects on the environment in addition to its high operation and disposal costs. This makes them less desirable to the drilling fluid designers in recent years [4,5]. In most recent researches, amines and their derivatives are of high interest to the researchers because of their sufficiency in controlling the shale hydration and capability to extend their specification to almost any drilling operation conditions [6,7]. Qu et al. (2009) synthesized polyoxyalkyleneamine (POAM) and investigated its inhibitive properties to Na-montmorillonite. Based on their results, POAM is completely water soluble, low toxic and compatible with other common drilling fluid additives. The reaction between POAM molecules and clay minerals can involve several mechanisms including hydrogen bonding and compete with water molecules for reactive sites [1]. A new modified polyethylene glycol (M-PEG) was introduced by Souza et al. (2010) as a new shale inhibitor additive which could adsorbed via hydrogen bonding on the clay particles' surfaces. It had much greater effect on reducing the water uptake by the clays and increasing their stabilities than those of polyethylene glycol [8]. The ability of poly(oxypropylene)diamine in suppressing the montmorillonite hydration was investigated by Wang et al. (2011). They showed that poly(oxypropylene)diamine adsorbed on particle surfaces via hydrogen boning and could form a hydrophobic shell around them, and in some cases intercalate into the montmorillonite interlayers which results in clay swelling

* Corresponding author. Department of Petroleum Engineering, Ahwaz Faculty of Petroleum Engineering, Petroleum University of Technology, P. O. Box 63431, Ahwaz, Iran.
E-mail address: pezhman.barati1987@gmail.com (P. Barati).
Peer review under responsibility of Southwest Petroleum University.

Production and Hosting by Elsevier on behalf of KeAi

http://dx.doi.org/10.1016/j.petlm.2017.05.003
2405-6561/

reduction [9]. The inhibition performance of polyether diamine (PEDA) was studied by Zhong el al. (2011). Their research showed that PEDA stabilized shales by exchanging protonated diammonium ion to native sodium ions and expelled the water molecules out of the clay galleries which could bind the plates together and improve their hydrophobicity against the water molecules [4]. Poly(oxyprolylene)-amidoamine (POAA), a new counteractive agent, was examined by Zhong (2012) in order to neutralize the negatively charged sites of clay minerals which make them more hydrophobic and stable against hydration [2]. Other new introduced amine-based additives could be referred to bis(hexamethylen)triamine (BHMT) and dopamine (DA) [6,7]. Recently, Nano additives were used to improve the sealing ability of muds during drilling through shaly formations by plugging of pore throats and micro fractures [10,11]. Some researchers have turned to investigate the performances of plant-based additives such as horse tail in inhibiting the shaly formations against hydration and disintegration [12].

In this work, shale hydration inhibition performance of tallow amine ethoxylate along with its mechanisms have been investigated through bentonite hydration inhibition, bentonite sedimentation, hot rolling shale particle disintegration, dynamic linear swelling, wettability alteration, isothermal water adsorption, and zeta potential measurement tests. Also the compatibility of tallow amine ethoxylate with other common drilling fluid additives has been checked using drilling fluid making tests.

2. Materials and methods

2.1. Materials

Tallow amine ethoxylate (CAS No. 61791-26-2) with chemical name of tallow amine polyethylene glycol ether has been purchased from Kimyagaran Chemical Industries Company. The theoretical structure of this tertiary amine has been shown in Fig. 1. This polyamine is known as KETALO (trade name) and is a non-ionic surfactant with a certain number of ethylene oxide unites (EO_n). In this study, KETALO with EO_{15} (KETALO15) has been used. This kind of polyamine is cationic in nature because of existence of amine groups in its molecules structure, which can be protonated [13]. KETALO15 properties presented by the company has been summarized in Table 1.

Bentonite with high percentage of sodium montmorillonite has been purchased from Pars Drilling Fluid Company, Tehran, Iran. The drilling cuttings have been obtained from Asmari formation of Maroon oilfield in southwest of Iran, well number 281, and in depth of 4001–4008 m. Bentonite and drilling cuttings' CECs (Cation Exchange Capacities) (CEC) were have been determined to be 18 and 3 mmol/g respectively, by sodium acetate method according to ISRIC soil analysis procedures [14]. Potassium hydroxide and potassium chloride have been supplied by Merck Company, Germany. Other drilling fluid additives (PAC-LV, PAC-R, starch-HV, PHPA, Xanthan gum, anti-foam, biocide, and barite) have been purchased from Pars Drilling Fluids Company, Tehran, Iran. All materials have been used without any further purification treatments.

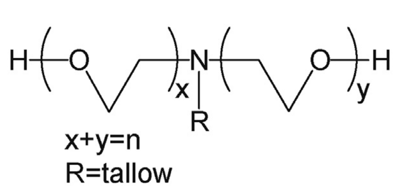

Fig. 1. Theoretical structure of tallow amine ethoxylate [13].

Table 1
KETALO15 properties.

Product	KETALLO15 (Tallow Amine Ethoxylate)
Appearance at 25 °C	Brownish Liquid
pH	9.8
Molecular weight (g/mole)	910.7
Specific gravity at 25 °C	1.023
Freezing/Melting point (°C)	−7
Boiling point (°C)	>260
Total amine value (mg KOH/g)	61.6
Water (wt%)	0.08
Solubility in water	Soluble

2.2. Methods

2.2.1. Bentonite hydration inhibition test

To assess the inhibition performance of KETALO15 against the bentonite hydration in aqueous phases, the bentonite hydration inhibition test has been used. In this test, at first, the aqueous solutions of KETALO15 with concentrations of 0, 0.5, 2 and 3 wt% have been prepared and then 10 wt% bentonite powder has been added, mixed and aged at atmospheric conditions for 24 h. Then their filtration and rheological properties (i.e. yield point, apparent and plastic viscosities) have been obtained using API low pressure–low temperature filter press and 35SA Fann rotational viscometer respectively, according to API recommended practice on the rheology and hydraulic of oil-well drilling fluids [15]. At the last part, inhibition performance of KETALO15 has been compared with potassium chloride as a common shale stabilizer.

2.2.2. Bentonite sedimentation test

Instability of dispersed bentonite particles in aqueous mediums containing KETALO15 has been determined via bentonite sedimentation test. In this test, 3 wt% bentonite powder has been added to KETALO15 aqueous solutions with concentrations of 0, 1, 2 and 3 wt%, mixed thoroughly using magnetic stirrer, poured into the glass test tubes and kept in static-atmospheric conditions for 24 h. Then, by measuring the distance from the clearly formed horizontal interference (between sediment and supernatant) to test tube cap (h) and dividing it by internal length of test tube (H), the ratio h/H can be calculated and plotted for each test tubes containing different KETALO15 concentrations. Finally, the h/H ratios have been compared to those of potassium chloride as a common shale stabilizer.

2.2.3. Compatibility test

In order to investigate the compatibility of KETALO15 with the other common drilling fluid additives, two different formulated drilling fluids have been selected (Table 2). Then the effects of 2 wt% KETALO15 addition on their rheological and filtration

Table 2
Test fluid formulation used in compatibility test.

Drilling fluid	Formulation
Base drilling fluid	Distilled water (450 ml), PAC-LV (2.57 g), Starch-HV (10.28 g), Xanthan gum (1.54 g), Antifoam (0.2 ml), Biocide (0.5 ml), Barite (up to 1.078 g/ml), Potassium hydroxide (up to pH 9).
High performance drilling fluid	Distilled water (450 ml), PAC-LV (2.57 g), PHPA (1.14 g), PAC-R (1.28 g), Starch-HV (10.28 g), Xanthan gum (1.54 g), Potassium chloride (21 g), Antifoam (0.2 ml), Biocide (0.5 ml), Barite (up to 1.078 g/ml), Potassium hydroxide (up to pH 9).