Unconventional Reservoirs

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The world's energy demand is steadily increasing where it has now become not easy for conventional hydrocarbon reservoirs to meet levels of demand. Therefore, oil and gas companies are seeking novel ways to exploit and unlock the potential of unconventional resources. Drilling of high-pressure high-temperature (HPHT) wells and shale reservoirs has become more widespread in the global petroleum and natural gas industry. There is a current need to extend robust techniques beyond costly drilling and completion jobs, with the potential for exponential expansion. This paper explains a better understanding of the selection of drilling fluids and additives for unconventional hydrocarbon reservoirs.

Unconventional reservoirs shale inhibition drilling technology

1. Definition

The world's energy demand is steadily increasing where it has now become difficult for conventional hydrocarbon reservoirs to meet levels of demand. Therefore, oil and gas companies are seeking novel ways to exploit and unlock the potential of unconventional resources. These resources include tight gas reservoirs, tight sandstone oil, oil and gas shales reservoirs, and high-pressure high-temperature (HPHT) wells. Drilling of HPHT wells and shale reservoirs has become more widespread in the global petroleum and natural gas industry. There is a current need to extend robust techniques beyond costly drilling and completion jobs, with the potential for exponential expansion. Drilling fluids and their additives are being customized in order to cater for HPHT well drilling issues. Certain conventional additives, e.g., filtrate loss additives, viscosifier additives, shale inhibitor, and shale stabilizer additives are not suitable in the HPHT environment, where they are consequently inappropriate for shale drilling. A better understanding of the selection of drilling fluids and additives for hydrocarbon water-sensitive reservoirs within HPHT environments can be achieved by identifying the challenges in conventional drilling fluids technology and their replacement with eco-friendly, cheaper, and multi-functional valuable products. In this regard, several laboratory-scale literatures have reported that nanomaterial has improved the properties of drilling fluids in the HPHT environment.

2. Introduction

Drilling fluids are essential consumables for drilling and exploration activities. Every drilling activity requires an appropriate drilling fluids program, where they are used extensively across the globe. Different types of drilling fluids are available within the market with differing performances designed to fit selective purposes, in addition to varied costs of fluid and environmental impacts [1][2]. The consumption of drilling fluids and additives depends directly on drilling fluid activities that are carried out globally. The increasing demand for energy has encouraged oil and gas companies to drill unconventional reservoirs in order to fulfill energy supply. Energy demand can be compensated through unconventional resources include heavy oil [3][4], gas hydrates [5], coal bed methane [6][7][8][9][10][11], tight gas [12][13][14][15][16], gas and oil shale [16][17][18], and high pressure high temperature (HPHT) wells [19][20][21]. New explorations in HPHT environments has led to a rise in drilling activities globally. The HPHT environment (i.e., 422–589 K and pressure of 138 MPa to 276 MPa) requires suitable techniques and selection of particular technologies in order to conduct drilling into extreme environments [22]. Likewise, formulations of drilling fluids play an important role in drilling within HPHT environments. Therefore, oil-based drilling fluids (OBDF) have been repeatedly used in HPHT drilling fluid systems, where they have been shown to be effective in shale drilling in HPHT downhole environments [23]. However, OBDF is toxic for marine species [24] and involves a high cost [25] because it is mostly made up of diesel oil [26]. Therefore, investigators have been consistently working to improve the characteristics of the water-based drilling fluid system (WBDF) for unconventional reservoirs and drilling operations, where WBDF is inexpensive [27] and environmentally friendly [28]. Eighty percent of oil and gas wellbore drilling operation uses WBDF [29]; however, WBDF possesses several problems related to drag and torque, pipe sticking, formation damage, lost circulation, and wellbore instability within HPHT downhole environments. However, researchers are currently working on improvements to WBDF systems using polymers to enhance rheology, reduce filtrate loss and shale inhibition, and to increase salt resistance [30][31][32].

Recently, researchers have widely studied polymeric material in conjunction with bentonite to prepare drilling fluids for harsh conditions, in particular HPHT [33][34]. Molecules of polymer have long carbon chains and yield viscosity in the solution form [32][35]; thus, influencing rheology filtrate loss and lubricity of drilling fluid systems [31][36]. Some natural polymers, in particular guar gum, starch, and cellulose, have been successfully used alongside bentonite to achieve adequate drilling fluid properties [37]. Naturally available polymers have been widely used due to their low cost [38], and environmentally friendly nature [39]. Nonetheless, natural polymers have low-temperature stability [40][41][42]. High temperatures render the superior and thixotropic properties of polymers inactive, adversely affecting rheological characteristics and resulting in a loss of drilling fluid [43], inappropriate cutting, lifting barite sag problems [44][45], and increasing the cost of drilling. Recently, Jain et al. [46] found that grafted polymer showed better rheological properties and filtration performance compared to carboxymethyl cellulose (CMC) when considered as a drilling fluid additive for shale drilling. Ternary copolymer reduced the fluid loss in the presence of high salt content of drilling fluid additives and resulted in better salt tolerance. Moreover, the copolymer produced better thermal stability within the drilling fluid system [29]. Nonetheless, some cellulose polymers have been shown to degrade at 483 to 533 K [47], where polyacrylamide was substantially lost at around 378 K in the presence of oxygen. However, another study has reported this degradation between 388 to 723 K [48]. Drilling engineers currently require thermally stable, multifunctional, environmental, and inexpensive durable drilling fluid additives for the drilling of unconventional HPHT reservoirs [49].

Nanosize additives with enhanced characteristics are actively being investigated in regards to drilling of HPHT wells [33][50]. Several nanomaterial have been investigated such as nano silica [51], graphene oxide [52], graphene nanoplatelets [43][53], multi-walled carbon nanotube [51][54][55], single walled carbon nanotube [54][56], nano ZnO [57]

[58], TiO_2 [59], CuO [60], and Fe_2O_3, nano-cellulose, nano-silica polymer grafted polymer [61], ZnO polymer nanocomposite [43], TiO_2/polymer nanocomposite [62], TiO_2/clay nanocomposite [63], and several others [64].

Nanomaterials are widely used for different purposes, including enhanced oil recovery [65][66][67][68], wettability alteration [69][70][71][72], IFT reduction [73][74][75], surface adsorption [76], and CO_2 storage applications [77][78][79][80][81]. They have the potential to augment rheological properties and shale inhibition of unconventional HPHT wells, but this has not been reported in a review work to date. This paper is devised to present a review on unconventional resources, HPHT wells, and drilling fluids additives used to drill HPHT and the superior role of nanomaterial additives in the drilling of HPHT wells.

3. Data, Model, Influences and Applications

3.1. Designing Drilling Fluid for HPHT Environment

High-pressure and high-temperature well drilling process is challenging and required robust drilling fluid program. Conventional drilling fluids additives in particular cellulosic polymer, and high concentration of KCl, may rise instable rheological properties. Bern et al. 2006 stated that there are many interdependencies within the rheological and hydraulic area of the drilling bit. However, they note the important criteria in selecting base drilling fluid for HPHT operations as being: (1) environmental impacts, (2) the stability at high pressure and temperature, and (3) minimum rheology to minimize ECD and reduce the frictional pressure loss [4].

Followings are several points-to-ponder when selecting a drilling fluid system for the HPHT environment, which include:

1) Narrow drilling operating window vs. high density of HPHT drilling fluid. The importance of balancing the need for thin, low incremental pressure fluid without creating the problem of poor solids support (settling of conventional weighting materials). Moreover, high-density drilling fluids may plug nano-pores in unconventional reservoirs in particular shale.

2) Thermal stability of fluid products and systems. Destabilization of products and aggressive and rapid reactions towards any contaminants in the system will occur when products reach their operating condition limits.

3) The technical performance of the fluid for the HPHT environment should be placed as the main priority, not cost, as the margin for error in the HPHT environment is very small, causing the whole operation to fail with the under performance of drilling fluid.

4) The fluid and additives should not only be stable at high temperatures but must also withstand the maximum expected time under the most extreme conditions anticipated.

5) For HPHT operations, rigorous planning thorough laboratory work, detailed drilling, and well and drilling fluid programs becomes more critical, where it is important to prepare backup plans.

6) Every HPHT well is unique; thus, a specific drilling fluid design may only work for a particular well. More importantly, the drilling fluid weight window becomes more critical when drilling with a managed pressure drilling plan. The hydrostatic pressure of the drilling fluid is controlled with the density of the drilling fluid. Thus, hydrostatic pressure could be lower compared to pore pressure according to the availability of equivalent circulation density.

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