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The effect of the TiO_2/polyacrylamide nanocomposite on water-based drilling fluid properties

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ABSTRACT

Drilling fluids tend to be used for the drilling of deep wells to clean and transport the rock cuttings, maintain the hole integrity, lubricate and cool the drill bit, and control the formation pressures. The present work aims at improving the water-based drilling fluid properties by using the TiO_2/polyacrylamide (PAM) nanocomposite additive. This additive was obtained through the polymerization of acrylamide monomer in the presence of TiO_2 nanoparticles using the solution polymerization method. The TiO_2/PAM nanocomposite was characterized by X-ray diffraction (XRD), Fourier transform infrared (FTIR) spectroscopy, Ultraviolet–visible (UV–Vis) spectroscopy, scanning electron microscopy (SEM), and dynamic light scattering (DLS). The rheological and filtration properties of the nano-enhanced water-based drilling fluid (NWBF) were investigated using the rotational viscometer and low temperature and pressure filter press apparatus. The results indicated that the additive contributes to an increase in the viscosity and a decrease in the fluid loss and filter cake thickness.

1. Introduction

The first stage to have access to a reservoir is the drilling operation. The proper development of this operation plays a major role in increasing productivity. It must be pointed out that the drilling fluid – mud – is pivotal in achieving this objective. Different drilling fluids such as water-based fluids, oil- or synthetic-based fluids and pneumatic or air fluids are commonly used in various drilling circumstances. Among these fluids, water-based fluids are the most common ones, which have been utilized to drill approximately 80% of all wells and are more economical compared with oil- or synthetic-based fluids. The main functions of these fluids are to clean the bottom of the deep wells and transport the rock cuttings to the surface, to cool and lubricate the drill bit, to line up the walls of the well to maintain the stability of borehole, to control the formation pressure, to prevent the inflow of reservoir fluids, oil, gas, or water from the permeable drilled rocks, and to form a thin and low permeable filter cake in order to close the pores and holes in drilling formation [1–5].

The water-based drilling fluid contains bentonite and other additives to control the rheological and filtration properties. Various water-soluble polymer additives with the condensing properties that influence the viscosity of the fluid include natural polymers like xanthan gum [6] and guar gum [7], or modified natural polymers like polyanionic cellulose (PAC) [8] and sodium carboxymethyl cellulose (NaCMC) [9,10]. In fact, these compounds are not stable at high temperatures and salty environments. Therefore, to solve these problems, the water-soluble synthetic polymers additives were used. Dairanieh and Lahalih [11] used methyl cellulose and poly(vinyl alcohol) to study the drilling mud properties and their results showed improvement in the yield point and the stability against the shear force. Also, they [12] used sulphonated amino-formaldehyde polycondensates as drilling mud dispersants, leading to improving the thermal stability. Wan et al. [13] used the inverse microemulsion polymerization method for the synthesized copolymer of different hydrophilic monomers, such as acrylamide (AM), acrylic acid (AA) and sodium 4-styrenesulfonate (SSS). They [14] used this copolymer as an additive in the drilling fluid, thereby improving drilling fluid properties, thermal stability and salty resistance.

Nanoparticles have also been reported to be used in drilling fluids. Nanoparticles can be described as solid particles or particulate dispersion in the size range of 1 to 100 nm. Amanullah and Al-Tahini [15] defined nanofluid as the fluid which is used in oil and gas drilling and exploitation and contains at least one nanoscale additive. As the shale formations have small pores, the prevention of the fluid from penetrating into the formation is the main application of the nanoparticles in the drilling fluids. The presence of nanoparticles contributes to the sealing of the micro cracks in the shale and hence filter cake becomes dense, thinner and impermeable. Forming such a filter cake will reduce the fluid loss and stabilize the well [16–19]. Salem Ragab and Noah [20] used the nano-sized silica drilling fluids for the reduction of formation damage and fluid loss, thereby providing a smooth drilling operation. William et al. [21] investigated the effect of CuO and ZnO nanofluids in the xanthan gum on the thermal, electrical and rheological properties

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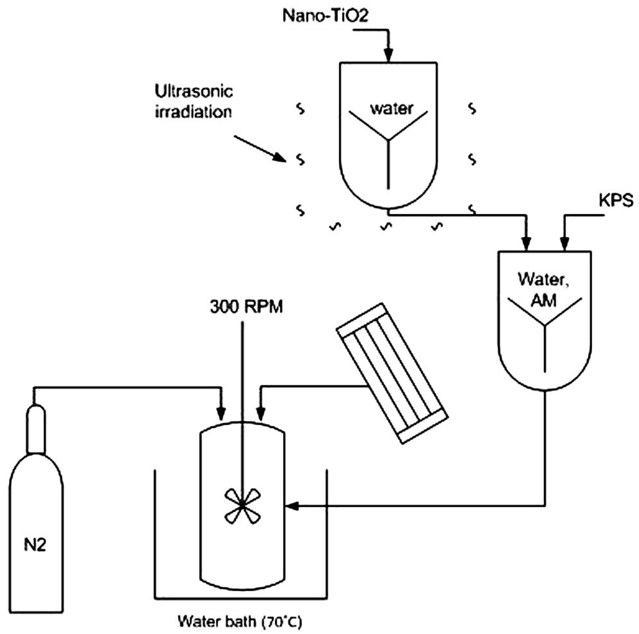

Fig. 1. Schematic of the solution polymerization process.

of the water-based drilling fluids. Results showed that the increased concentration of nanoparticles enhances electrical and thermal properties and improves rheological stability using the nanofluid-enhanced water-based drilling mud. Moreover, these results are the same as those of such additives as carbon black [22], palygorskite [23] nanoparticles and multiwall carbon nanotube [24]. In addition, natural polymer nanoparticles like polyanionic cellulose polymer [25] and carboxymethyl cellulose (CMC) nanoparticle [26] have been reported to reduce the amount of fluid loss and mud cake thickness. Therefore, the created mud cake is more uniform and rheological properties are improved when the nanoparticles are used.

In this work, a new type of water-soluble additive has been used by combining the polymer and mineral nanoparticles. To achieve this purpose the solution polymerization method was used for the synthesis of TiO_2/polyacrylamide (PAM) nanocomposite. This is the simplest method of AM polymerization and is widely used in the industrial processes [27,28]. Abdollahi et al. [29] obtained the high molecular weight homopolymers of acrylamide, (2-methacryloyloxyethyl) trimethyl ammonium chloride (DMC) and copolymer of DMC with acrylamide (P(AM-co-DMC)), synthesized by using the solution polymerization technique. Besides, Tang et al. [30] used the aqueous solution polymerization method to synthesize the TiO_2/PAM composite to study the photocatalytic degradability.

Different amounts of TiO_2/PAM nanocomposite obtained by the solution polymerization method were added to the distilled water and bentonite (the conventional drilling mud) to study the filtration and rheological properties using the rotational viscometer and low temperature and pressure filter press apparatus, respectively. The synthesized nanocomposite was characterized by XRD, FTIR, UV–Vis, SEM, and DLS.

2. Experimental detail

2.1. Materials

Acrylamide monomer and potassium peroxydisulfate were purchased from Merck Chemical Co. TiO_2 nanoparticles with an average particle size of 10–15 nm, and a specific surface area of 100–150 m^2g^{-1} was purchased from TECNAN Ltd. Natural bentonite was supplied by National Iranian Drilling Co.

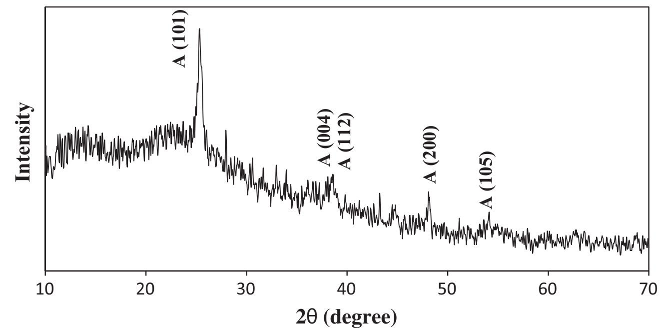

Fig. 2. XRD pattern of the TiO_2/PAM nanocomposite (A: anatase).

2.2. Preparation of TiO_2/PAM nanocomposite

The TiO_2/PAM nanocomposite was synthesized by solution polymerization. A certain amount of acrylamide monomer (30 g) was dissolved in 60 mL of distilled water at room temperature, and the nanoparticles were dispersed by ultra-sonication (output power 120 W, work time 1 s, pause time 1 s) in the distilled water to have a homogenous dispersion separately, and then the resulting nanofluids were added to the water-soluble monomer. The polymerization was poured into a glass reactor equipped with a condenser and a mechanical stirrer in a water bath under nitrogen atmosphere. The reaction was started by adding potassium peroxydisulfate as an initiator and performed at 70 °C for 15 min at the stirring rate of 300 RPM in the whole process. Fig. 1 shows the schematic of this process. After the completion of polymerization, the obtained nanocomposite was sliced into small pieces and dried at room temperature for one day. Then it was completely dried in an oven at 80 °C for about 4 h to obtain the constant weight and was milled to obtain powdered nanocomposite.

2.3. The preparation of the fluid samples

The 1–10 and 14 g of TiO_2/PAM nanocomposite were added in 350 mL of the distilled water while being stirred at 11000 RPM by a commercial Hamilton Beach stirrer to obtain the nanofluids of the TiO_2/PAM nanocomposite in an aqueous solution as base fluids. Then 10 g of natural bentonite was added while being stirred for 20 min to prepare the nano-enhanced water-based drilling fluid (NWBF).

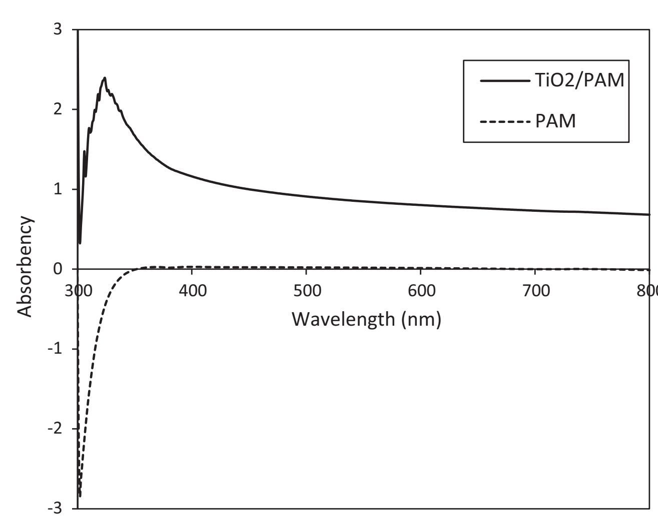

Fig. 3. UV–Vis spectra of the PAM and TiO_2/PAM nanocomposite.