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The adsorption behavior of hydroxypropyl guar gum onto quartz sand

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ABSTRACT

Hydroxypropyl guar gum (HPG) is an important guar gum derivative commonly used as thickener for fracturing fluids in the field of petroleum industry. This paper presents an investigation of the adsorption properties of HPG on quartz sand using a modified measurement method. The effects of pH, temperature, inorganic salt, alcohols and polymers on the adsorption density of HPG were also studied. The results showed that the effect of pH and temperature from 20 °C to 60 °C on the adsorption capacity could be negligible. Sodium chloride (NaCl) has little effect on HPG adsorption; however, potassium chloride (KCl), calcium chloride ($CaCl_2$) and magnesium chloride ($MgCl_2$) increased the adsorption capacity while sodium sulfate (Na_2SO_4) and trisodium phosphate (Na_3PO_4) resulted in the decrease of the adsorption density. In addition, monobasic alcohol has no significant effect on HPG adsorption while the addition of polybasic alcohol increased the adsorption. The addition of partially hydrolyzed polyacrylamide (HPAM) decreased the adsorption capacity. The X-ray diffraction (XRD) and scanning electron microscopy (SEM) test demonstrated that HPG was only adsorbed on the surface of quartz sand and not absorbed into the quartz. The Fourier infrared spectroscopy showed that the HPG adsorption mechanism on quartz sand was caused by a hydrogen bond and Van der Waals' forces.

1. Introduction

Hydroxypropyl guar gum (HPG) is a water-soluble polymer. Its unique molecular structure and natural characteristics make it an environmentally-friendly material. HPG has been widely used in food, fracturing fluid, oil field and biomedicine [1,2]. HPG is a naturally macromolecule hydrocolloid and thickener. When HPG is dissolved in cold or hot water, a high viscous solution can be formed even at low concentrations.

Hydraulic fracturing is an important technique used to increase oil and gas production. The fracturing fluids play a crucial role in the hydraulic fracturing process, and production improvement in the reservoir is closely related to the performance of fracturing fluids [3,4]. However, the adsorption of fracturing fluids is one of the important factors resulting in formation damage [5–7]. The fracturing fluids should have minimized damage on formation to maximize oil production [8]; therefore, it is of vital importance to consider decreasing the adsorption of fracturing fluids and reducing the damage to the formation [9,10]. Currently, the commonly used fracturing fluids in oilfields are based on modified guar gum, emulsion polymer [11,12] and viscoelastic surfactant (VES) [13,14]. The concentration of VES and emulsion polymer could be measured with the colorimetric method using the Reinecke salt and the starch cadmium iodide method, respectively [15–17]. However, the adsorption of HPG (the most commonly used thickener in fracturing fluids) on the reservoir rocks has not been fully studied. HPG is a kind of nonionic polysaccharide, and its molecular chain is a mannose backbone with linear chain of β-D-(1–4) linked mannopyranose units with α-D-galactopyranose units by (1–6) glycosidic linkages. The molar ratio of mannose and galactose is 2:1. Previous literature has reported that the molecular weight of HPG was about 2.2×10^5 [18]. HPG had similar molecular structure with cellulose as shown in Figs. 1 and 2 [19]. Therefore, we referred the cellulose determination method to determine HPG concentration. The adsorption behavior and adsorption mechanism of HPG on quartz sands were systematically studied.

2. Materials and methods

2.1. Materials

Hydroxypropyl guar gum (HPG) was provided by the Shengli Oilfield Branch Company. Quartz sand (25–50 mesh sieve) was purchased from Sinopharm Chemical Reagent Co. Ltd. (Shanghai, China). Partially hydrolysis polyacrylamide (molecular weight: 1×10^7 and 2×10^7, hydrolytic degree: 23.8%) was provided by Hebei Tianshi Chemicals Co. Ltd. Concentrated sulfuric acid, anthrone, ethyl acetate, hydrochloric acid, sodium hydroxide, sodium chloride, potassium chloride, magnesium chloride, calcium chloride, sodium sulfate, sal perlatum, methanol, ethanol, isopropanol, ethylene glycol, propanetriol and other reagents were purchased from Shanghai Aladdin Bio-Chem Technology Co., Ltd.

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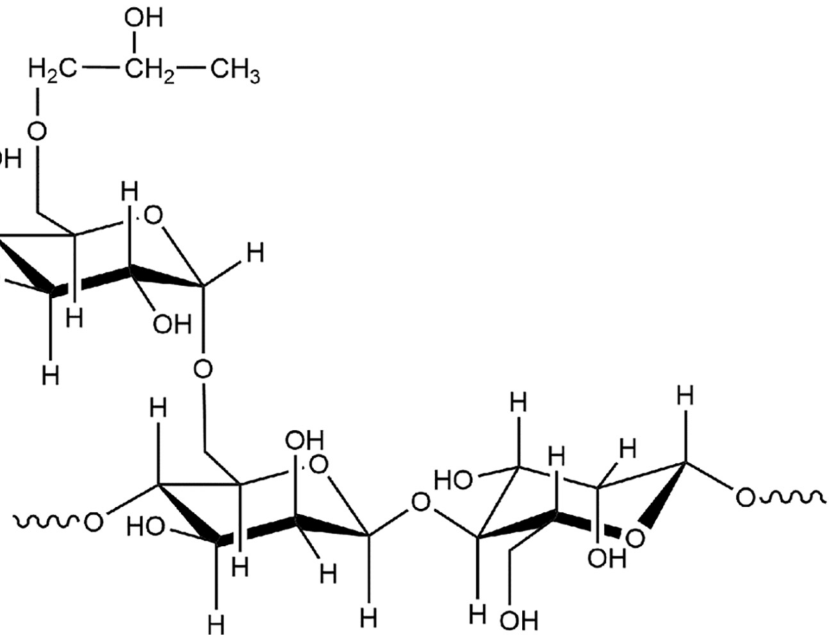

Fig. 1. Structure of hydroxypropyl guar gum.

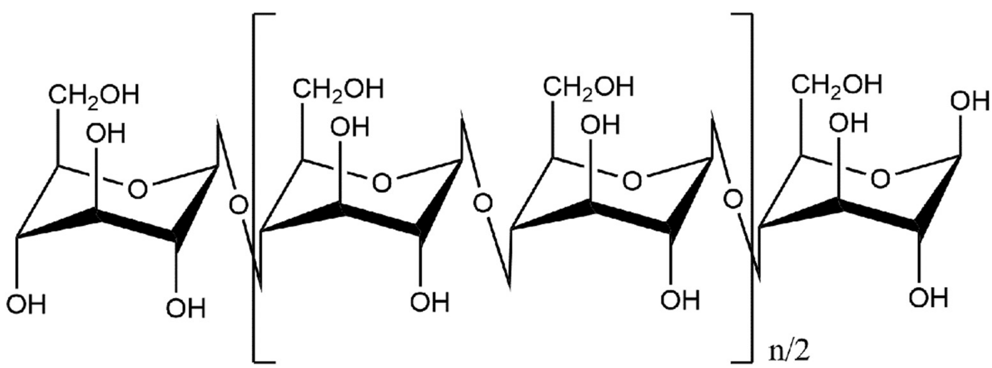

Fig. 2. Structure of cellulose.

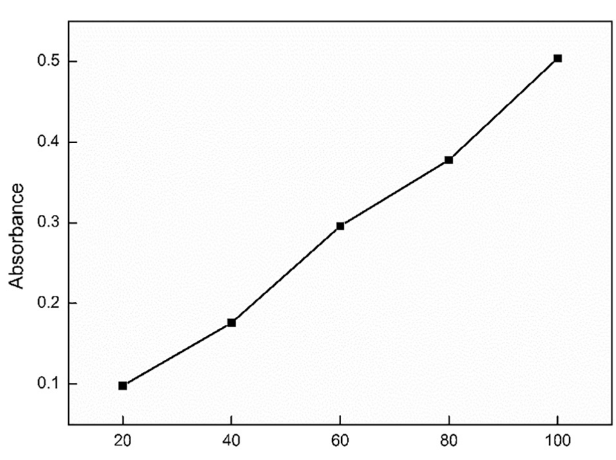

Fig. 3. The relationship of the concentration of HPG and the absorbance.

2.2. Pretreatment of HPG solution for concentration measurement

The HPG solution for concentration measurement was pretreated using a modified method according to [2,19]. The modified treatment process can be described as follows.

10 mg HPG was added dropwise into 10 mL of sulfuric acid (60% wt) at 0 °C. After 1 h wet digestion at 0 °C, the solution was diluted with deionized water up to 100 mL to make a 100 μg/mL standard solution of HPG. The as-prepared solution was diluted with water to obtain a series of HPG solutions with concentrations of 0, 20, 40, 60, 80, and 100 μg/mL, in that order. 0.5 mL 2% anthrone solution (2 g anthrone dissolved in 100 mL ethyl acetate) and then 5 mL concentrated sulfuric acid was added slowly to each of the above six solutions. After anthrone was dissolved absolutely by shaking, solutions were put into thermostat water bath cauldron at 90 °C for 10 min, and then cooled down to room temperature, getting HPG solutions for measurement.

2.3. Establishment of the standard curve

The absorbance value was measured under the wavelength of 620 nm using a spectrophotometer. The standard HPG curve was