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Surface modified proppants used for porppant flowback control in hydraulic fracturing

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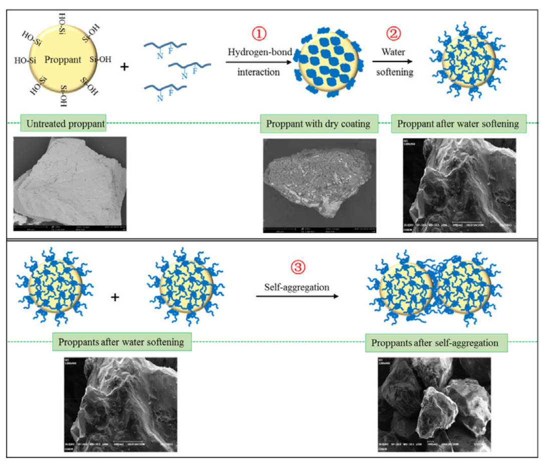
HIGHLIGHTS

- Poly (2-fluorine-4-vinylpyridine) modified proppant is prepared.
- The modified proppant exhibits self-aggregating property in water.
- The proppant flowback rate is significantly reduced.
- The fracture conductivity is increased by 3 times.

GRAPHICAL ABSTRACT



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ABSTRACT

In order to solve the problem of proppant flowback in postfrac fracturing fluid flowback treatments and hydrocarbon productions, new heterocyclic polymer modified proppants were introduced. The most important characteristic of the modified proppants is self-aggregation in the water environment. Due to this special character, an evaluation method based on ultrasonic oscillation effect is developed to measure the aggregating strength of the proppants congeries, with which the optimal formula and the recommended dosage are determined. By virtue of the reaggregating property of the modified proppants, which is different from the one-time bonding effect of resin coated proppants, the fracture conductivity and the proppant flowback control ability are improved greatly. Experimental results show that with the dosage of 1.0% of the PFVP, the strength of the reaggregating column decreases by 54.6% after ten times of collapse and reaggregation, which is even big enough for proppant flowback control. The larger the dosage of PFVP is, the higher the strength of the reaggregating proppant column regains. Compared with untreated proppants and resin coated proppants, the maximum sand free flow rate of the modified proppants increases by 80.6% and 39.8%. The higher the closure stress is, the more obvious the proppants flowback control ability is. In addition, the formation fines adsorption property of the PFVP modified proppants endows the self-cleaning

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property of the flow channels in the fracture. The results provide a new alternative for proppant flowback control, especially in unconsolidated sandstone formation with high closure stress.

1. Introduction

Hydraulic fracturing technology is the most effective stimulation treatment in hydrocarbon productions, especially for the tight oil, shale gas and other unconventional oil and gas resources [1–3]. Proppants are the hard solid particles, such as quartz sand or ceramic particles, that props the fracture when the pumping pressure is released [4,5]. The main function of the proppants is to hold the fracture open and form numerous flow channels for the hydrocarbon to flow into the wellbore [6]. Therefore, the quality of the proppant, as well as the pattern of their placement, directly determines the stimulation effect of the hydraulic fracturing treatment [7].

Proppant flowback is the most common problem after hydraulic fracturing treatment [8]. Copper pointed that many reasons account for proppant flowback, such as high drag forces of the fluid with high velocity, low fracture closure stress, mechanical properties of the treated formation, high viscous of the produced fluid, and improper size or density of proppants [9]. Proppant flowback has a lot of adverse effects, such as narrowing down the width of the fracture, reducing the conductivity of the fracture, and decreasing the effectiveness of the treatment [10]. In addition, downhole remedial operations, such as sand washing, are needed for wells with high backflow rate, which will inevitably affect the normal hydrocarbon production [11]. Moreover, the discharged proppants can erode downhole equipments, as well as surface pipelines and equipments, shortening their service lives [12].

Proppant flowback control has always been a challenge in hydraulic fracturing [13]. Curable resin coated proppant (RCP) was first brought into oil industry in 1980s by Pope [14]. During the past years, Peard [15], Browne [16], and Terracina [17] employed different kinds of resin, such as epoxy resin, phenolic resin, furfural resin, and furfuralcohol resin, to coat the propants, and pointed out that choosing the appropriate resin for different conditions can prepare effective RCP to prevent proppant flowback. Although the cured proppant pack of RCP provides chemical bonding beteween grains to provent proppant flowback, the RCP is usually partially cured during the storage and transportation, making RCP cannot provide sufficient consolidation strengths for the proppant pack and weakening the proppant flowback control ability [18]. On-the-fly liquid resin coating technology is to pour liquid resin and untreated proppants into the fracturing fluid. Under the stirring action, liquid resin is absorbed onto the proppants. The liquid resin cures under formation conditions, and proppants pack with high compressive strength is formed [19]. The non-curable resin modified proppants with the tacky surface to bond the proppants together as a cluster was developed by Nguyen to prevent proppant flowback [20]. In general, the resin coated proppants usually perform well in proppant flowback control, but usually cause significant reduction in the permeability of the proppant pack.

Injecting fibers into the fracturing fluid with the propants is another effective method in proppant flowback control [21]. Unlike chemical reactions of resin coated proppants, fibers provide framework and bond the proppants together only by physical bondage effect. So there is no obvious impact to the permeability of the proppant pack. However, fibers are easy to break into smaller fragments, and cause blockage in the injection [22] or lead to a weakened framework in the frature [23].

Both of the resin coated proppants and fibers bonded proppants are helpless if the proppants are out of their original positions. In this study, a new modified proppant is introduced for proppants flowback control. The modified proppandts can aggregate together spontaneously in liquid conditions, and reaggregate together if the proppants congeries is scattered to strewing sands. The mechanism of the surface modification and the aggregating process were illustrated. The maximum sand free flow rate tests were conducted to study their proppant flowback control abilities. The self-cleaning property was evaluated by the fines control tests. The fracture conductivity tests were carried out to study the performance in improving the permeability of the proppant pack.

2. Experimental section

2.1. Materials

Both the quartz sand propppants and ceramic proppants with a size range of 0.425–0.850 mm were taken from Juxing Mining Products Plant. The coal fines with a size range of 0.063–0.075 mm were purchased from Zibo Mining Group C., Ltd. The epoxy resin coated quartz sand proppants were purchased from Yuanyang Science and Technology Co., LTD, China. The dosage of epoxy resin was 4% of the mass of the prppants and the curing agent was polyamide resin. The KCl and methanol were purchased from Sinopharm, China. Without special instructions, the KCl solution in the paper all means 2 wt% KCl solution. The C_7H_6FN was purchased from Shanghai Xietong Co., Ltd, and the heterocyclic polymer of poly (2-fluorine-4-vinylpyridine), or to say PFVP, was synthesized in our laboratory. The surface modifier is a mixture of PFVP and methanol, with the mass ratio of 1:3.

2.2. Preparation of surface modified proppants

The whole preparation process was carried out at the ambient temperature and pressure. Firstly, 20 g of the untreated proppants was poured into the container of the sand mixer. Secondly, 0.8 g of the surface modifier was poured in to the container, and turned on the mixer with a speed of 100 r/min for 2 min. Thirdly, the proppants were put out from the container and placed into the oven for 2 h under the condition of 60 °C.

2.3. Evaluation of the self-aggregating property

2.3.1. Qualitative evaluation

The qualitative evaluation of the self-aggregating property of the modified proppants is observing the status of the particles dispersed in liquid. Firstly, 20 g of the modified proppants or untreated proppants or resin coated proppants, were put into the sample bottle, followed by 80 g of KCl was added. Secondly, 10 min later the bottle was turned upside down to observe if the particles aggregated to form a proppants column.

2.3.2. Quantitative evaluation

Because the self-aggregating property of the modified proppant is different from compressive strength of the common resin coated proppants, there is no uniform evaluation method for such self-aggregating property. Therefore, the following evaluation