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Experimental study on modified polyacrylamide coated self-suspending proppant

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HIGHLIGHTS

- Evaluation standards and methods for self-suspending proppant are put forward.
- Influence of different factors on proppant suspension is evaluated by experiments.
- The scope of polyacrylamide coated self-suspending proppant application is clearly identified.

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ABSTRACT

In recent years, different types of self-suspending proppants have come up. Among these proppants, "fracturing fluid coated" self-suspending proppant, which can adopt different types of proppants, is evaluated experimentally in this research. Evaluation standards and methods for this "fracturing fluid coated" proppant are discussed firstly. Suspension parameters are essential indicators of performance evaluation, the final proppant settlement volume and deposition time consumed from uniform mixture to the final volume under relative sensitive experiment conditions are selected as evaluation indexes. Influence of different factors on proppant suspension is evaluated by experiments, and corresponding results make the application scope of self-suspending proppant clear.

1. Introduction to proppant and fracturing fluid

When high-viscosity liquid is injected into a well by surface high pressure pump unit at a speed that greatly exceeds the absorptive capacity of the formation, the well bottom pressure will surpass the field stress and rock tensile strength, thereby generating fractures. Then, with the injection of fracturing fluid carrying proppant, fracture supported by the proppant will be generated. The fracture may change the flow type from radial flow to bilinear flow, break through near-wellbore blockage, expand and communicate the original micro fractures, thus increasing the production remarkably [9–13].

Nowadays, costly massive hydraulic fracturing is essential for coalbed methane, shale/tight and other unconventional reservoirs, in which thousands of tons of proppant and tens of thousands of cubic fracturing fluid is consumed. The preparation (equipment, material, redundancy, staff and transportation) of these 'tens of thousands of cubic fracturing fluid' accounts for a large part of the cost [2,5,6]. Given the fact of low oil price globally, self-suspending proppant, which can save the preparation cost largely, has caught more and more attention from researchers. There are different types of proppants, such as hollow, super-low density proppant. Among these proppants, "fracturing fluid coated" self-suspending proppant, which can adopt the conventional high strength ceramic proppant [7,8], is relatively mature and hence analysed in this research.

2.1. Mechanism of self-suspending proppant

With the increasing wide application of self-suspending proppant, more than 10% of the fracturing cost has been saved. One point needs to be put forward that this self-suspending proppant is in initial period, and many technologies are confidential, some self-suspending proppants have characteristics of high suspension

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and low damage [1,3,4]. There are mainly two self-suspending mechanisms for this "fracturing fluid coated" proppant.

(1) Proppant's surface coating swells after hydration, the effective relative density can be reduced greatly, Therefore improving the ability of suspension and reducing the proppant settlement, as can be seen in Fig. 1.
(2) Surface coating material will crosslink and form a viscous liquid after dissolution, which generates the sand- suspending effect as normal fracturing fluid.

It needs to be stressed that (1) is the main mechanism under low sand ratio conditions, (2) plays a vital role when massive coating modified polyacrylamide is fully dissolved under high sand ratio condition.

2.2. Polyacrylamide introduction

Polyacrylamide is a kind of linear high-molecular and water-soluble polymer. Polyacrylamide and its modifications can be used as effective flocculating agent, thickening agent and fluid drag reduction agent, etc. Hence it is widely used in enhance oil recovery (EOR) process, drilling, water plugging, fracturing, well clean and completion, drag reduction, etc.

With the effect of flocculating, thickening and drag reduction, Polyacrylamide has great potential to be the ideal surface coating material for proppants. Moreover, cross-linking will further enhance its performance.

In this research, a new developed modified-polyacrylamide coated self-suspending proppant is evaluated by experiment. Evaluation standards and methods for this type of "fracturing fluid coated" proppant are discussed firstly. Then meaningful and important performance parameters are evaluated experimentally, which clarifies its advantages, disadvantages and applicable scopes.

2.3. Necessity analysis of evaluation items

Firstly, evaluation standards and methods for this 'fracturing fluid coated' proppant are discussed.

Since self-suspending proppant integrates fracturing fluid and proppant, the evaluation items and methods are controversial. The conventional fracturing fluid and proppant evaluation methods are not suitable. All self-suspending proppants is in pursuit of better suspension performance, more evenly distribution in the fracture, more thorough breaking and no gel clogging between proppants, therefore making less damage to reservoir and improving productivity.

The routine proppant and fracturing fluid measurement items are shown in Table 1:

Viscous fracturing fluid, generated from the coated material, will break finally, leaving proppant only in the reservoir. Hence, it is meaningless to measure coated proppant's sphericity, density, broken rate, acid solubility, conductivity, etc. But the following characters need intensified evaluation:

(1) Suspended performance
Coating quality on proppant and sand ratio will both affect the suspension performance
(2) Shear resistance
Proppant's surface coating swells after hydration, the shear resistance of this coating material greatly influences the suspension performance
(3) Broken performance
Incomplete breaking of coating will block the pore space between proppants and then reduce fracture conductivity
(4) Sensitive influence factor
Mineralization, temperature will also affect the suspension performance.

2.4. The basic performance of ceramic proppant

20–40 mesh ceramic proppant is utilized in this research, an interfacial bond layer exists between proppant and polyacrylamide, the coating amount of polyacrylamide is 1.2% of proppant weight. Related test methods and standards are: 《SY/T 5108-2014 Hydraulic fracturing and gravel packing proppant performance test methods》, 《SY/T 5107-2005 Water-based fracturing fluid performance evaluation method》, 《SY/T 6376-2008 General technical conditions of fracturing fluid》, 《SY/T 6380-2008 Fracturing gel breaker performance test methods》.

Basic performance parameters of ceramic proppant are shown in Table 2:

2.5. Swelling and suspension performance

It can be seen from the suspension mechanism of proppant and the character of Polyacrylamide,

Only when the sand coating amount is large enough, can the viscosity of fracturing fluid become sufficient and hence satisfy suspension effect.

Normally the sand ratio, volume percentage of proppant, steps up form a very low initial sand ratio (5%) to a high sand ratio (up to 50%) during fracturing process. A sand ratio of more than 10% will form a relatively stable suspension system under relatively static laboratory conditions, and therefore increasing the initial

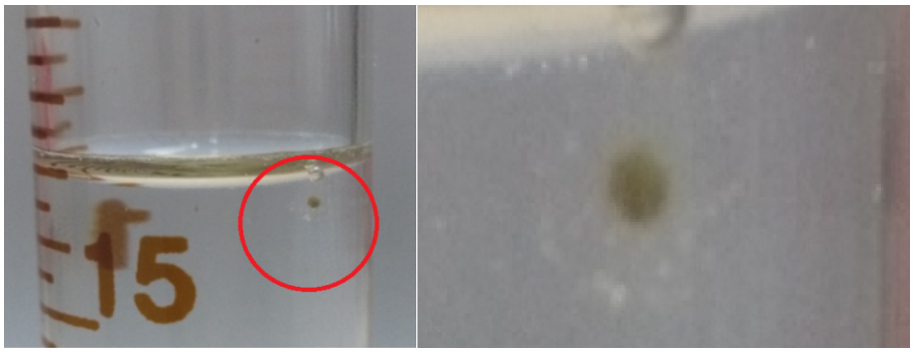

Fig. 1. Surface swelling proppant, marked in red cycly-left, enlarged view of the proppant-right. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)