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Feasibility of Proppant Flowback Control by Use of Resin-coated Proppant

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Abstract:

Proppant flowback is a problem in Xinjiang oilfield. It decreases production rate of a fractured oil well, corrodes surface and downhole facilities and increases production costs. Curable resin-coated sand is a common technique to control proppant flowback. This article presents an experimental investigation whether it is feasible to control proppant flowback by use of resin-coated sand and whether resin-coated sand has a negative effect on proppant pack conductivity. It included two kinds of experiments, Proppant flowback experiment measured critical flow rate while the Proppant pack conductivity one measured proppant conductivity. The experimental results of proppant flowback show that the critical flow rate of resin-coated sand is far greater than that of common sand which means proppant flowback would not happen by resin-coated sand tail-in. Compared to Xinjiang sand conductivity, resin-coated sand conductivity is far smaller though it declines slightly which means use of resin-coated sand would lead to conductivity loss and sequentially results in production impairment. Experimental results show that it is feasible to control proppant flowback by use of resin-coated sand and resin-coated sand would affect fracture conductivity of a fractured oil well. Based on the experimental results, resin-coated proppant conductivity can be improved by use of resin-coated ceramic or liquid-resin-coated proppant. The achievements can give a direction towards how to select a resin-coated proppant and how to improve resin-coated proppant.

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1. INTRODUCTION

Proppant flowback is an issue after an oil well is hydraulically stimulated in Xinjiang oilfield. It generally refers to proppant production phenomenon after a fractured well is put in production [1]. It leads to many negative effects including production loss, corrosion of surface and downhole equipments and increase of production costs etc., so some techniques must be applied to control proppant flowback during production of a fractured well [2, 3]. One kind of such techniques is to consolidate proppant grains together and prevent them entering the wellbore. Resin-coated proppant is one of them. It chemically bonds proppant grains together to form a consolidated proppant pack which locks uncoated proppant grains in fracture and stops them entering the production system [4-7]. When use of resin-coated proppant to control proppant flowback is planned, two questions emerge. Can resin-coated proppant effectively control proppant flowback? Has it no effect on postfracture performance of an oil well? The goal of this article is to answer these questions [8].

Resin-coated proppant is produced by coating common proppant with epoxy resin or phenolic resin. It is divided into precured resin-coated proppant and curable resin-coated ones [9-11]. The former is used to increase proppant resistance to fracture closure stress and improve proppant pack conductivity. It is added in slurry like common proppant at hydraulic fracturing treatment sites. The latter is mainly used to control proppant flowback in oilfield. The resin coating chemically bonds resin-coated proppant grains at contact points under the underground conditions after resin-coated proppant is tailed in into fracture. Researches about resin-coated proppant have mainly focused on the compatibility between resin coating and fracturing fluid, its effects on fracturing fluid, applicable problems encountered in low- and high- temperature reservoirs, effects of formation conditions on resin-coated proppant, and evaluation methods of resin-coated proppant [12, 13]. An economic evaluation showed that it was economically feasible to use resin-coated proppant to control proppant flowback by proppant tail-in [14]. Some researchers investigated effect of resin-coated proppant on the components of fracturing fluid and effect of fracturing fluid and reservoir fluid on resin-coated proppant. It was found that resin consumed oxidizing breaker and some components of fracturing fluid intervened consolidation of resin-coated proppant. Compatible experiment showed that the pH of fracturing fluid had a negative effect on proppant pack strength of resin-coated proppant. As for low temperature wells, the combination of resin-coated proppant and inert fibers was proved to be successful in controlling proppant flowback effectively [15]. Under such circumstances the curable proppant needed a chemical activator to enhance its consolidation strength. Simulated experiments showed that maximum resin-coated proppant pack strength occurred at the closure stress of 500 psi. Moreover, fluid shear, stress cycling and formation temperature were proved to affect performance of resin-coated proppant. Most importantly, L.R. Norman found that compressive strengths of about 150 psi were adequate to control proppant flowback at high production rates [16]. Some experimental results implied that resin-coated proppant could effectively control proppant flowback [17-19]. Is this true for resin-coated proppant used in Xinjiang oilfield? It leads to this experimental research in order to confirm feasibility of proppant flowback control by use of resin-coated proppant and show effect of resin-coated proppant on performance of a fractured well.

2. EXPERIMENTAL DETAILS

2.1. Experimental Principle

When an experimental research is conducted to confirm whether it is feasible to control proppant flowback by use of resin-coated proppant, critical flow rate is a parameter that can be used to indicate the possibility of proppant flowback. It is defined as fluid flow rate over which proppant flowback will occur. A small value means that proppant flowback probably happens. If the critical flow rate of resin-coated proppant is greater than that of uncoated proppant under same conditions, it means that resin-coated proppant can successfully control proppant flowback. Therefore, one task of this paper is to measure critical flow rates of both resin-coated sand and uncoated sand, and then compare one to another.

Comparing proppant pack conductivity of resin-coated proppant to proppant pack conductivity of common one shows whether resin-coated proppant has a negative effect on post fracture performance of an oil well. If conductivity of resin-coated proppant is not smaller than that of common proppant, there is no effect, otherwise resin-coated proppant would cause conductivity impairment and consequently leads to production loss. Therefore, another task of this paper is to measure conductivities of both resin-coated sand and uncoated sand, and then compare their values.

2.2. Materials and Apparatus

Resin-coated proppant tested was called fusheng sand which was manufactured in Beijing, capital of China. It was produced by coating natural sand with epoxy resin. Its curing temperature is 70 ˚C. The average grain size for 20/40 fusheng sand is 0.594 mm and the bulk density is 1.58 g/cm^3. This resin-coated sand contains 4.7 wt % resin. The experiment still used Lanzhou sand and Xinjiang sand. They are all 20/40 meshes [20, 21].

Fluids used in experiment included 2 % KCl solution, distilled water and simulated oil. The first one was used as curing fluid, distilled water was used as both curing fluids and testing fluids and the last one was used as testing fluid. Base on oil properties produced in Shixi oilfield, the viscosity of simulated oil is 66 mPa•s and the density is 0.881 g/cm^3 at 25 ˚C.

This research used two key apparatuses. One was modified fracture conductivity evaluator manufactured by STIM Lab. It equips three cells. The cells and fluid system can be heated to 150 ˚C and the range of flow rate is from 1 to 600 cm^3/min. It served proppant flowback experiments. Another one was long-term proppant pack conductivity instrument which was manufactured by Shandong Shiyi Science and Technology Co. Ltd. It can exert maximum closure stress of 300 MPa on the cell and can heat the cell up to 200 ˚C. This apparatus can also keep closure stress constant for 300 hrs. It is capable of conducting proppant pack conductivity experiments.

2.3. Experimental Procedure

As for common proppant flowback testing, proppant sample and experimental apparatus were firstly prepared. Proppant was then poured into the cell and the testing system was assembled. After the cell was stabilized for some time at certain closure stress and temperature, simulated oil flew thorough the proppant pack. Flow rate increased till that proppant flowback happened or till the maximum capacity of pump. The flow rate at which proppant flowback happens is the critical flow rate. This was experimental procedure for single-stress proppant flowback.

The difference between single-stress flowback and multi-stress flowback was that closure stress increased with increment of 10 MPa to next testing point and testing process was repeated after testing finished at a lower closure stress [22].

For proppant flowback with resin-coated proppant, proppant pack was cured for 4 hours under the closure stress of 20 MPa and 50 ˚C temperature before flowback experiment started.

Common proppant pack conductivity employed experimental procedure recommended by SY/T 6302-2009 [23].

As for resin-coated sand pack conductivity, the procedure at the initial closure pressure differed from that of common proppant. After linear variable displacement transducer (LVDT) was calibrated, closure stress increased to the initial closure stress (usually 10 MPa). And then curing fluid was pumped into the cell and the cell was heated to 70 ˚C. After that the sand pack was cured for 14 hrs before testing started. From then on, the following procedure was similar to that of common proppant.

3. RESULTS AND DISCUSSION

3.1. Comparison of Effect between Resin-Coated Sand and Lanzhou Sand

The investigation firstly conducted proppant flowback experiments using Lanzhou sand and resin-coated sand. The results are shown in Table **1**. They show that the critical flow rate of resin-coated sand is more greater than that of Lanzhou sand. The critical flow rate for 20/40 Lanzhou sand is 12 ml/min whereas it is greater than 522 ml/min for 20/40 resin-coated sand under the same conditions. Moreover, the critical flow rates for resin-coated sand in multi-stress flowback experiments are all greater than that of Lanzhou sand. The critical flow rate at 30 MPa is greater than 525 ml/min and it is greater than 514 ml/min at 40 MPa. The experimental results imply that resin-coated proppant can effectively control proppant flowback in a fractured oil well.

When common sand is pumped into a fracture, the force holding sand grains together is relatively weak. The proppant pack is relatively loose and a small pressure drawdown will lead to collapse of proppant pack which eventually results in a smaller critical flow rate. After resin-coated sand is pumped in by tail-in, it stays at the entrance of the fracture. Under formation conditions the coating of resin-coated sand bonds proppant grains together at contacting point by chemical reaction to form a consolidated proppant pack. This pack has higher strength and has a higher resistance to pressure drop. Injecting formation fluid

Table 1: Proppant Flowback Experiments

Proppant	Proppant concentration (kg/m²)	Curing fluid	Testing fluid	Closure stress (MPa)	Critical flow rate (ml/min)
20/40 Lanzhou sand	15	/	Simulated oil	20	12
20/40 resin-coated sand	15	2% KCl	Simulated oil	20	>522
20/40 resin-coated sand*	15	2% KCl	Simulated oil	20	>522
				30	>525
				40	>514
				50	>415

*multi-stress flowback experiment.

will not result in proppant backflow before the consolidation proppant filling fails. This can explain why the critical flow rate of resin-coated sand is greater than that of common sand.

3.2. Comparison of Effect between Resin Coated Sand and Xinjiang Sand

In Xinjiang oilfield, sand proppant usually chosen is Xinjiang sand because of it low costs relating to manufacture and transportation. Therefore, this experiment compared conductivity of resin-coated sand to that of Xinjiang sand. The result is shown in Figure **1**. On the whole, the conductivity of resin-coated sand is lower than that of Xinjiang sand. At 10 MPa closure stress the conductivity value of Xinjiang sand is 150.0 μm•cm² while it is just 45.0 μm•cm² for resin-coated sand. At the closure stress of 30 MPa the conductivity value of Xinjiang sand is about 50.0 μm•cm² while the value is just 28.8 μm•cm² for resin-coated sand. When closure stress is higher than 40 MPa, resin-coated sand conductivity is very close to that of xinjiang sand. Comparing the curve of Xinjiang sand conductivity to that of resin-coated sand, it is found that xinjiang sand conductivity declines sharply while resin-coated conductivity declines slightly.

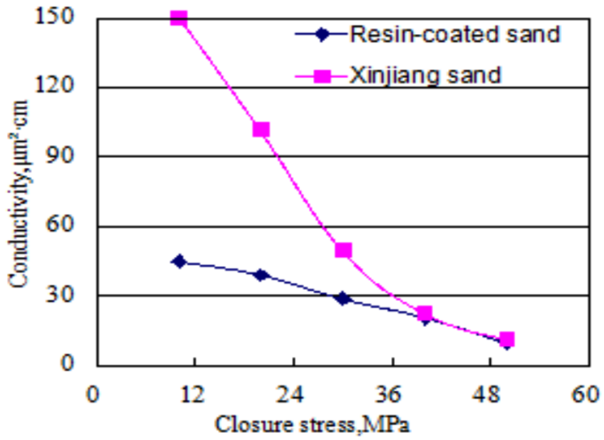

Figure 1: Proppant pack conductivity.

Resin-coated sand is manufactured by coating common sand with resin. The resin coating is elastic. When resin-coated sand stays in a closed fracture, it deforms under the formation closure stress. This will decrease the porosity of proppant pack. After the resin coating chemically bonds proppant grain together to form a consolidated proppant pack, the porosity of proppant pack will decrease further. It is known that the porosity of proppant pack relates to the permeability of proppant pack and small porosity would lead to low permeability. This certainly results in lower conductivity base on the definition of fracture conductivity. For common sand,e.g. Xinjiang sand, proppant will crush and produces many fines as closure stress increases which also leads to a bit smaller fracture width. The fines can damage proppant pack and lead to the decrease of proppant pack permeability. These all contribute the rapid decline of common sand conductivity. As for resin-coated sand, the resin coating not only increases resistance of sand proppant to closure stress but also traps the fines and prevents them from moving after resin-coated sand crushes which eliminates the damage to proppant pack and increases the retarded proppant pack permeability. This is the reason why conductivity value of resin-coated sand declines slowly compared to the value of Xinjiang sand.

Proppant flowback experiments show that the critical flow rate of common sand proppant is far smaller than that of resin-coated sand on the whole. At the range of low and medium closure stresses resin-coated sand conductivity is far lower than that of common sand. Proppant pack conductivity of resin-coated is close to that of common sand at the range of high closure stress though ceramic proppant is always preferred at this stress level.

4. CONCLUSIONS

1) It is feasible to control proppant flowback by use of resin-coated sand in Xinjiang Oilfield.

2) The resin-coated sand evaluated can cause impairment to fracture conductivity which will negatively affect production performance of fractured wells.

3) Meanwhile, using resin-coated ceramic or liquid resin system would improve fracture conductivity of resin-coated sand and eliminate negative effects of resin-coated sand on performance of fractured wells.

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DATA AVAILABILITY STATEMENTS

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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