Novel Proppant Surface Treatment for Enhanced Performance and Improved Cleanup

This paper describes the development and testing of a new proppant designed to exhibit a neutrally wet surface. The modified surface does not have a preferential affinity for oil, gas, or water and therefore will not promote the preferential entrapment of any phase within the proppant pack. This proppant technology and the results described in this paper should be useful for completions, production, and the work of reservoir engineers dealing with hydraulically fractured wells, particularly in oil- and condensate-rich reservoirs that are particularly challenged by multiphase flow.

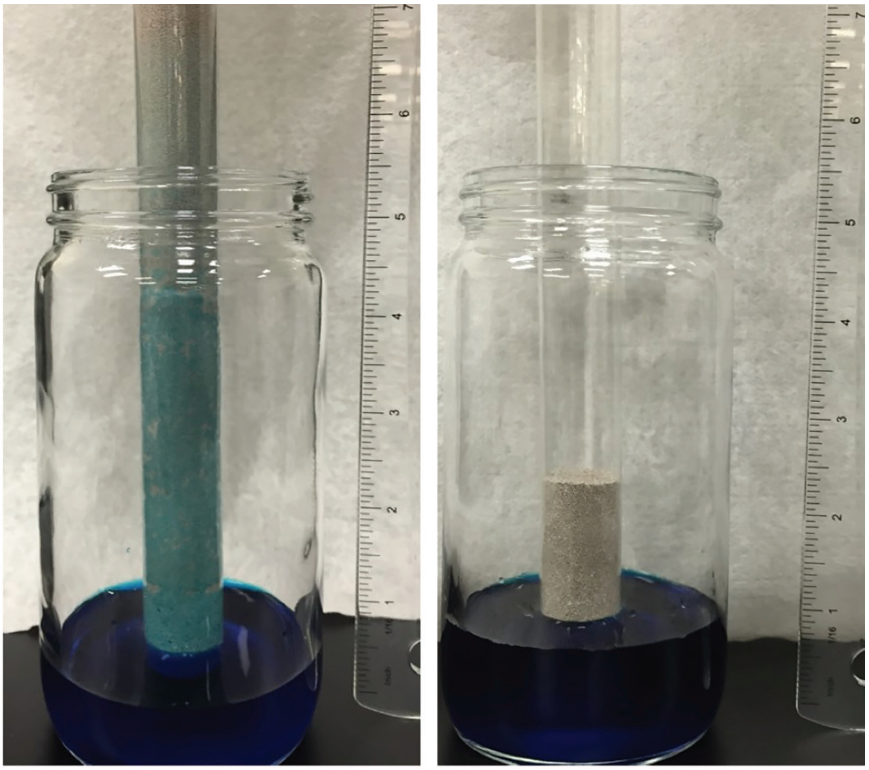

Fig. 1—Visual capillary demonstration test. When a tube of standard 40/80 LDC proppant is submerged in blue-dyed water (left), water is drawn into the tube by capillary forces. When the same proppant, with the neutral-wettability coating, is submerged, no water is drawn into the tube (right).

Introduction

A new proppant technology has been developed whereby a thin chemical coating is permanently applied to the ceramic proppant surface. The coating is very thin, approximately 0.13 µm, or less than 1% of the thickness of the resin on a standard resin-coated proppant grain. The coating is applied to every grain, after the manufacture of the base substrate. It can be applied to any size and type of ceramic proppant, including low-, intermediate-, and high-density ceramic proppant.

The key attribute of the coating is its ability to modify the surface wettability of the proppant grain to a neutral state. Because the coating is applied to every proppant grain, the entire proppant pack exhibits a neutral-wettability surface. When a surface is neutrally wet, the contact angle of the wetting fluid is 90°. For this contact angle, the capillary pressure in the proppant pack is eliminated. A visual test was performed to illustrate the impact of eliminating capillary forces in the presence of the new coating (**Fig. 1**). Tubes of the 40/80 low-density ceramic (LDC) proppant were assembled with screens at the bottom that would allow water to enter while keeping the proppant in place. When the tube containing uncoated standard proppant was placed in the water, the capillary forces in the proppant pack caused the water to be drawn up into the tube. However, when the same process was repeated with surface-modified proppant, the water level was not drawn up inside the tube.

The coating also has been tested and exhibits several additional attributes. The coating itself has been qualified at up to 400°F. In addition, testing has been performed to ensure that the coating is both durable and permanent. Surface-modified LDC proppant was placed in a roller oven at 65, 100, and 200°F along with various fluids, including fresh water, 2% potassium chloride

This article, written by JPT *Technology Editor Chris Carpenter, contains highlights of paper SPE 175537, "Novel Proppant Surface Treatment Yields Enhanced Multiphase-Flow Performance and Improved Hydraulic-Fracture Cleanup," by* ***Terry Palisch, Mark Chapman,*** *and* ***Joshua Leasure,*** *SPE, Carbo Ceramics, prepared for the 2015 SPE Liquids-Rich Basins Conference—North America, Midland, Texas, USA, 2–3 September. The paper has not been peer reviewed.*

(KCl), 10% hydrochloric acid (HCl), and 10% sodium hydroxide (NaOH). The roller oven was allowed to tumble, and the coating effectiveness for each temperature and in the presence of each of the fluids was observed after 24 hours, 72 hours, and 1 week. No loss of coating was observed for any fluid or any length of time at 65 or 100°F. At 200°F, no coating loss was observed, except in the case of the NaOH and HCl, where less than 15% coating loss was observed at 1 week. No coating loss was detected for these fluids at 24 or 72 hours, however. Finally, fluid-compatibility testing was performed in a standard 40-lbm/1,000 gal guar borate-crosslinked system at various shear rates, and no impact on the fluid performance was observed. To date, the coated proppant has been used in the field on many stimulation treatments with various pumping companies and fluid systems, with no noticeable impact on the fluid properties.

New-Proppant Performance

Before first placement in the field, laboratory testing was performed to demonstrate the benefits of placing a neutral-wettability surface on ceramic proppant.

The first test consisted of a multiphase-flow test performed at a third-party laboratory. In this test, both coated and uncoated 20/40 LDC proppant were loaded in a Cooke conductivity cell between Ohio-sandstone cores at 2 lbm/ft². In this test, a 2% KCl, silica-saturated solution was circulated at 50 mL/min while nitrogen was pumped at various rates. Testing was performed at 2,000-psi stress and at 180°F, and 300-psi backpressure was held on the system. The pressure drop was measured across the conductivity cell at each nitrogen rate tested. The proppant with the neutral-wettability coating exhibited a 20 to 50% reduction in pressure drop depending on nitrogen rate when compared with standard uncoated ceramic proppant.

Another test was conducted at the same laboratory in which "wet" nitrogen gas was circulated at various rates. In this test, a conductivity cell was loaded that was similar to the previous one: 2 lbm/ft², 180°F, and 300-psi backpressure, while 2,000-psi stress was placed on the cell. A constant gas/liquid ratio was maintained throughout the test. In this test, the neutral-wettability ceramic proppant exhibited a 35–55% increase in system permeability over the standard uncoated ceramic proppant.

Finally, a standard permeability test was performed to measure the permeability difference to oil. In this test, a 30/50 uncoated LDC proppant and a 30/50 LDC proppant with the neutral-wettability coating were loaded into a Cooke conductivity cell at 2 lbm/ft². The stress was increased to 2,000 psi, and the proppant pack was saturated with silica-saturated 2% KCl. The cells were then circulated with mineral oil, and after 24 hours, a standard conductivity/permeability measurement was performed. At 2,000 psi, the coated LDC proppant exhibited a 25% increase in oil permeability. The stress was increased to 8,000 psi, and another test was performed with the mineral oil. At this higher stress, the oil-permeability benefit of the coated LDC proppant increased to 45% over standard uncoated ceramic proppant, confirming that, as the pore throats decrease (and capillary pressure increases), the benefit of this technology increases. It also suggests minimal breakage of the ceramic proppant, indicating that the application of this technology to lesser-strength particles may be problematic.

Field Results

This new proppant technology has been used in several locations, including north Louisiana, south Texas, and the Permian Basin.

One of the first trials was implemented in two wells located in DeSoto Parish, Louisiana. These wells were part of a recompletion program in which existing wells were being reperforated in an uphole zone and then hydraulically fractured to access additional reserves. The two wells were chosen because they were in close proximity to each other, had similar depth and net pay in the recompleted zones, and had similar producing characteristics before the recompletion.

Additionally, both wells were recompleted at similar times and were planned for similar recompletions. The control well was planned for four stages vs. three stages for the coated proppant test well; however, both wells were scheduled to receive a similar mass of proppant. Upon implementation, the control well screened out early on the second stage, leading to the control well receiving 20% less proppant placed compared with the test well. Both wells exhibited similar fracture gradients, further suggesting that the recompleted zones were similar.

Both wells were flowed back at the same time and in a similar flowback/choke program and were monitored daily. After more than a year, several positive observations were made from the well production. First gas was produced from the well containing treated proppant after just 38 hours, as compared to the well containing untreated proppant, which took 60 hours—an 80% improvement. This is likely because of the higher permeability relative to hydrocarbons caused by the neutral-wettability surface.

After 6 days, the treated well had produced 5.6 MMcf, 80% more than the untreated well (3.1 MMcf). After 13 months, the treated well has produced more than 40 MMcf of incremental gas (+13%) and nearly 1,000 bbl of incremental oil (+45%) compared with the untreated well, generating nearly USD 200,000 in incremental revenue. In addition, results indicate that the condensate yield of the treated well is nearly 30% higher, suggesting that the neutral-wettability surface is affecting the relative permeability to hydrocarbons positively.

Conclusions

Laboratory testing at various stresses and flowing conditions in a standard Cooke conductivity cell has shown the coated proppant to

- Reduce the multiphase-flow pressure losses in the proppant pack by 20 to 50%
- Increase the wet-gas permeability of the proppant pack by 35 to 55%
- Increase the permeability to oil in the proppant pack by 25 to 45%

The critical benefit, however, will be realized in the long-term increase in recovery. Increasing load recovery as well as decreasing the flowing-pressure losses in the proppant pack will increase the effective drainage area of the fracture. This is expected to lead to an effective increase in hydrocarbon recovery. **JPT**