PUSHING BEYOND PROPPING

TERRY PALISCH, CARBO, USA, PRESENTS AN OVERVIEW OF PROPPANT TECHNOLOGY CAPABILITIES IN A RANGE OF GLOBAL OIL AND GAS APPLICATIONS.

Proppant has evolved to the point that the name itself is an imperfect description of the technology's ever-increasing breadth of capabilities. Indeed, while propping open fractures to enhance hydrocarbon flow remains their fundamental reason for being, new generation proppants, supported by associated engineering and analytical tools, have become an integral component of many asset development strategies.

Recent advancements, for instance, have transformed proppant into chemical delivery platforms for preventing scale and other flow assurance problems that lead to costly intervention and can jeopardise production. Proppant technology is also continuing to evolve as a core mechanism for visualising propped reservoir volume, extending to early investigations into far-field imaging.

Vital in any proppant development programme, however, is balancing the multi-functional capabilities with the primary function of sustaining propped fracture integrity to optimise reservoir drainage. The engineering of exceptionally conductive ceramic proppant is gaining wider traction with the drilling of deeper wells with higher pressure profiles and downhole stresses. In the US alone, it is estimated that more than 50% of new wells drilled will have closure stresses greater than 6000 psi – a level that will crush even the most robust white sand proppant, compromising maximum production and ultimate recoveries.

Advancing conductivity

The KRYPTOSPHERE ultra-conductive ceramic proppant represents an advancement in technology designed to provide the required

conductivity, contact and durability to enhance production across the full range of low to ultra-high closure stress conditions. Engineered as either a high or low-density ceramic proppant, the proppant portfolio provides high crush-resistance and withstands stress-cycling to ensure fracture conductivity, integrity and connectivity to optimise production.

A multi-pronged engineering programme that focused on improving both the raw material selection and the manufacturing process resulted in a ceramic proppant with a distinctive microstructure and unprecedented shape, uniform sizing and strength (Figure 4). The shape provides maximum porosity for hydrocarbon flow, while nearly eliminating the internal porosity that restricts maximum conductivity. Specifically, every proppant grain of both the high-density and low-density versions is designed with high roundness to increase conductivity and improve the flow profile through the propped fracture, thereby helping increase hydrocarbon flow.

A highly smooth proppant surface reduces erosivity and protects downhole equipment, while lowering flow-path tortuosity. The technology has a low beta factor and with minimising non-Darcy flow effects, reduces the pressure drop in the fracture.

For applications on the upper scale of downhole stresses, the ceramic proppant is designed with over twice the baseline conductivity of the highest-strength bauxite proppant. The high-density version is reserved for the most challenging environments, such as the Gulf of Mexico's deepwater Lower Tertiary play, where reservoir pressures can exceed 20 000 psi and high flow rates can aggravate cyclic loading, as well as harsh geothermal and steam-flood applications.

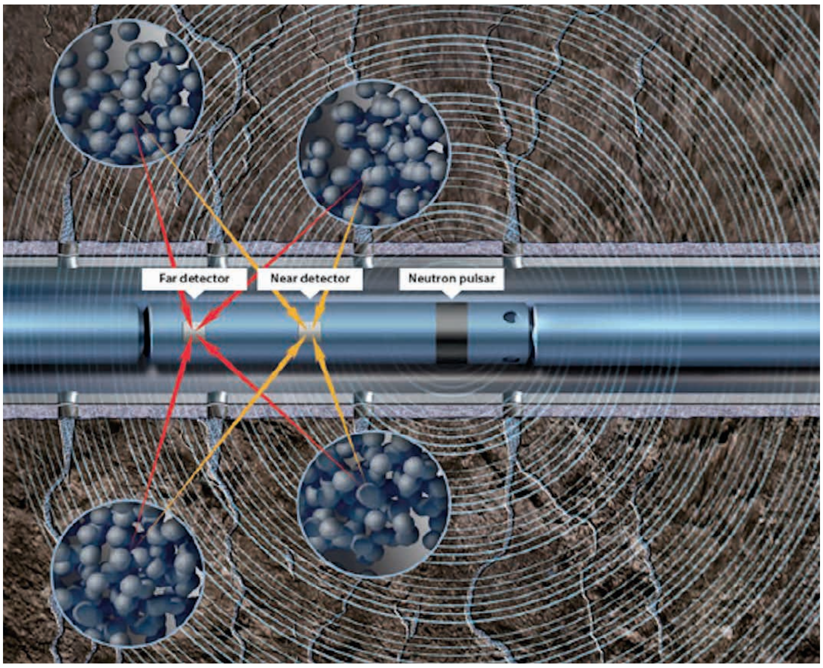

Figure 1. *The first generation CARBONRT non-radioactive traceable proppant is manufactured with a high thermal neutron capture compound (HTNCC) added uniformly throughout every grain of the host proppant. A standard neutron log run before and after the fracture treatment can then detect the presence of the proppant to accurately measure proppant coverage and fracture height near the wellbore.*

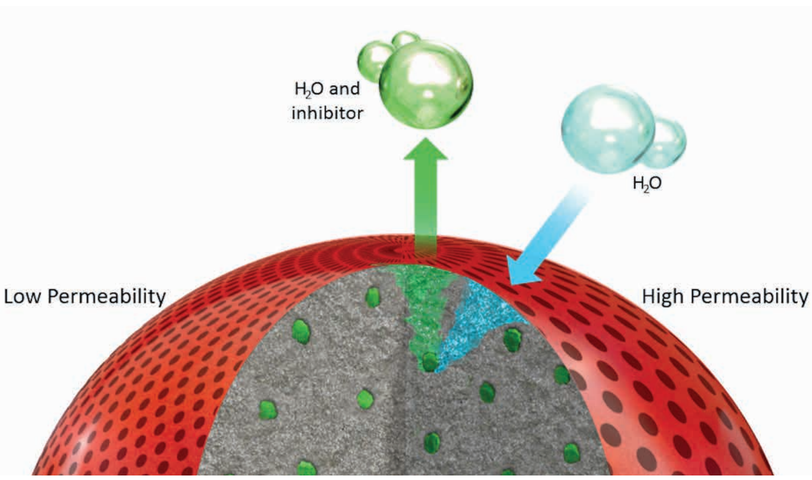

Figure 2. *GUARD technology features a controlled release technology that ensures a predictable release of the infused chemical in the well only on contact with water. The controlled release technology significantly lengthens treatment life and reduces initial inhibitor washout.*

Notably, the dual-functionality of a new generation ceramic proppant was reflected in the inaugural application of the KRYPTOSHERE HD in a deepwater Lower Tertiary well. There, the proppant also served as the delivery platform for SCALEGUARD proppant-delivered scale-inhibiting technology. The application met the operator's dual requirements for maximum conductivity and sustainable scale prevention and reinforced proppant technology as a key component of an integrated production-enhancement strategy.

KRYPTOSPHERE LD is designed with the same engineering principals as its high-density counterpart. Compared to intermediate and low-density conventional ceramic proppant, the newest generation ceramic proppant has exhibited considerably higher conductivity across the entire range of low to high-stress well conditions and yields the same uniform size, superior shape and high strength microstructure as the high density version.

Case study: Pennsylvania

The proppant's high conductivity capacity was demonstrated in its debut application in a well targeting the Utica deep gas horizon in Pennsylvania, which was programmed with a total vertical depth (TVD) of 13 500 ft (4115 m) with a 6150 ft (1875 m) lateral. At that depth, the excessive downhole stresses called for a proppant with enhanced and sustainable conductivity (such as a bauxite based ceramic). This prompted the independent operator to select the new ceramic proppant.

The well, which was completed in 30 stages, flowed at an initial production (IP) rate of more than 60 million ft^3/d in a 24 hour period, which at the time made it one of the Utica's highest producing gas wells. Furthermore, by using the proppant, the operator eliminated the need for costly gel and cross-linked fluids typically required to place the higher density bauxite-based proppant.

Non-radioactive tracers

Maintaining maximum conductivity, while critical, is only one component of an optimal field development strategy. An essential component is ensuring the stimulation programme delivers uniform coverage of all the productive zones, which requires ascertaining the fracture height and/or the precise proppant placement. The capacity to identify a specific zone as not producing or under-producing is an imperative step in determining root cause, be it a poor reservoir or inadequate stimulation.

Historically, the primary methodology for detecting the proppant entry points or propped fracture height was pumping radioactive tracers with the fracturing fluid or proppant, typically measured by a gamma ray log to search for high levels of radioactivity to identify the fluid entry point. Obviously, pumping radioactive material under high pressure poses severe HSE implications and requires stringent regulatory oversight.

The ramifications of radioactive tracers were resolved with development of an inert tracer for ceramic, and more recently, sand proppant. The first generation CARBONRT non-radioactive traceable proppant is manufactured with a high thermal neutron capture compound (HTNCC) added uniformly throughout every grain of the host proppant. Since the inert HTNCC is integrated in sufficiently low concentration, it has no impact on mechanical strength, conductivity, durability or particle density. A standard neutron log run before and after the fracture treatment can detect the presence of the proppant. The consistent distribution of the traceable marker throughout the proppant pack enables a more accurate measurement of proppant coverage and fracture height, allowing for the development of more accurately calibrated models to optimise fracture designs.

Since the inert tracer material has no half-life deterioration of its detectable properties, the proppant is permanently identifiable, enabling operators to conduct logging runs months or years after the initial stimulation.

The original technology was designed solely for ceramic proppant, but has evolved for use in sand-completed wells. The second generation of the inert tracer technology comprises the same inert traceable material, but engineered to enable effective detection within otherwise non-traceable sand and cement, or through casing, by replacing a portion of the proppant treatment with the inert tracer material.

The non-radioactive tracers are compatible for use with compensated neutron logging tools (CNT), pulse neutron capture logging tools (PCN) or when using only a post-fracturing CNT log. The inert tracer also is the enabling technology for the FRACTUREVISION proppant-delivered fracture evaluation service, which provides high-definition measurements of propped fracture height and near-wellbore connectivity in both ceramic and sand-completed wells.

As illustrated recently in Saudi Arabia's Jafurah Basin, the safe identification and modelling of fracture geometry, proppant placement and, ultimately, the overall effectiveness of the stimulation is especially valuable in formulating a development strategy for emerging plays.

Case study: Saudi Arabia

The Jafurah Basin's thick and organic-rich marine carbonate shale sequence has emerged as a highly prospective multi-stage unconventional target. To effectively stimulate the carbonate reservoirs, the operator relies on diversion techniques to temporarily plug off perforations with the highest fluid flow in favour of diverting treatment to less permeable zones. Verifying the success of the diversion operation, particularly with respect to individual perforation and stage efficiency, requires precise knowledge of near-wellbore proppant placement. However, with local regulations barring radioactive tracers, the operator selected the inert CARBONRT within a high-strength sintered bauxite ceramic proppant.

The non-radioactive tracer was run in tandem with a PNC tool deployed in both the pre- and post-fracture logs to determine proppant location. In addition, the FRACTUREVISION service was used to develop a near-wellbore connectivity index to provide a qualitative measurement of contact between the wellbore and formation.

During the operation, signals were clearly observed in all stages, with the overall success of the diversion technique in stimulating the targeted perforations reflected in close alignment of the perforation and proppant flags (signals). Moreover, the connectivity index was proportional to the volume of proppant detected within the near-wellbore formation.

The resulting data will prove invaluable in evaluating perforation and cluster efficiencies to optimise future completion designs in this emerging unconventional play.

Preventing flow barriers

Proppant also offers an ideal platform for delivering treatment chemicals to inhibit the formation of inorganic scale, halite salt (NaCl), paraffin and equally restrictive flow barriers at their point of origin. The first in a developing series of production assurance treatment platforms, the aforementioned SCALEGUARD proppant-delivered scale-inhibiting technology merges interconnected and uniformly dispersed porosity with the high conductivity of a ceramic proppant. Specifically, the proppant is infused with water-activated scale inhibiting chemicals to prevent – in a single treatment – the development of scale deposition.

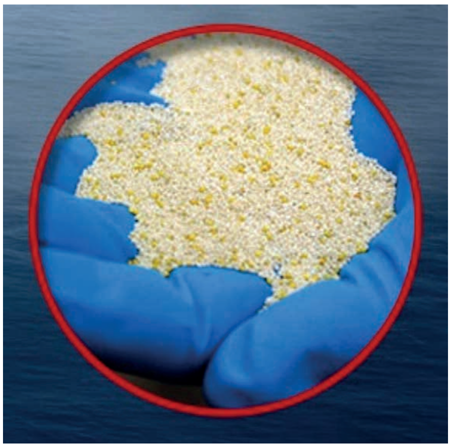

Figure 3. *The dual-functionality of proppant technology was reflected in a deepwater Lower Tertiary well. KRYPTOSPHERE HD ceramic proppant also served as the delivery platform for SCALEGUARD proppant-delivered scale-inhibiting technology. The application met the operator's dual requirements for enhanced conductivity and sustainable scale prevention.*

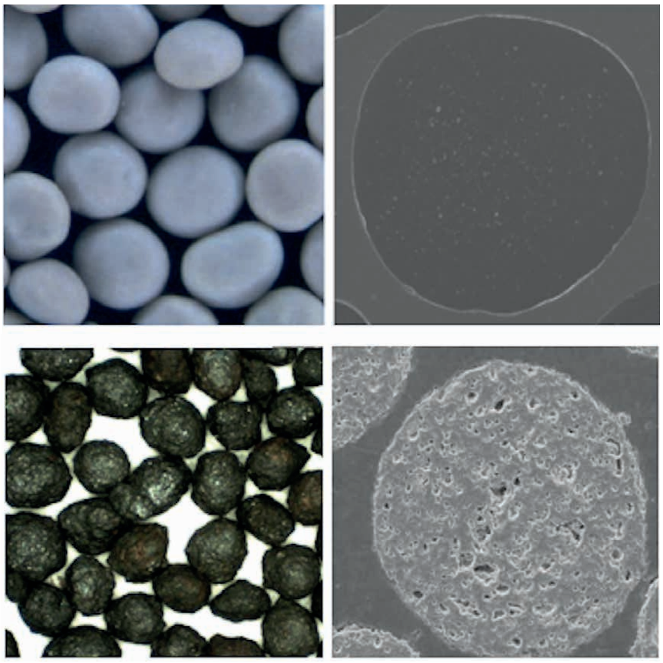

Figure 4. *KRYTPOSPHERE ceramic proppant technology exhibits exceptionally low internal porosity levels. This results in a proppant with increased compressive strength, high durability and improved crush-resistance.*

The porous proppant substrate engineered during manufacture provides maximum pore space to infuse the chemical inhibitor, without compromising the strength of the proppant pack. Unlike a simple coating process, infusion allows for the sustained incorporation of more inhibition chemicals, while also clearing the way for unrestricted hydrocarbon flow within the fracture.

The controlled release technology significantly lengthens treatment life and reduces initial inhibitor washout compared to liquid scale inhibitors and other conventional treatments. Importantly, the controlled release of the inhibiting chemical into the fracture only occurs upon contact with produced water, which serves as the breeding source for most oilfield scales. Accordingly, the technology has gained wide acceptance in the South Rockies, the Permian Basin of West Texas and southeast New Mexico, which are notorious for excessive produced water levels.

The technology has been used extensively in most of the unconventional plays in the US, with some operators reporting nearly 700 days of continuous production without requiring any intervention to treat scale build-up.

Case study: Canada

More recently, an operator targeting the Bakken/Spearfish formation in Manitoba, Canada was producing from a 22 stage horizontal well, comprising of natural sand proppant. The well had been online for approximately one year when production declined sharply, which was quickly attributed to severe scale deposition. The operator faced the prospect of pulling the pumps and drilling out the well to remove the scale deposits.

Following an evaluation of specific well characteristics and the produced water chemistry, the operator modified the stimulation strategy to replace a portion of the sand in the proppant pack with SCALEGUARD infused low-density ceramic proppant to reduce the near-wellbore pressure drop. Initial results suggest incorporating the proppant-delivered scale inhibiting technology has the potential to double the productive life of the targeted well.

Far-field imaging

While in its infancy, another promising initiative is exploring the combination of a novel ceramic proppant and electromagnetic (EM) testing to provide the location of the proppant at distances far-field from the wellbore. Accurate detection of far-field proppant placement has wide-ranging implications, from determining well and stage spacing, to stage design and refracture candidate selection. Prior to this technology, proppant location techniques had been limited to the depth of investigation of standard neutron or gamma ray logs.

Case study: Delaware Basin

A recent field test in the Delaware Basin (a subset of the Permian) took the first step toward filling that void. The protocol included the injection of a ceramic proppant with an electrically conductive coating to make the location clearly visible when stimulated by electromagnetic energy from the well casing. Along with the electrically conductive coating, the pre-trial developments included a transmission method capable of creating a strong EM field in the steel casing, and novel algorithms for processing.

Following the injection of 180 000 lb (81 647 kg) of white sand in the 8000 ft (2438 m) TVD well, 230 000 lb (104 326 kg) of the specially coated ceramic proppant was injected through four perforation clusters in the last stage fractured. While researchers continue to sift through the large body of data collected to reduce the noise and enhance the recorded images, initial views of the proppant location were extremely encouraging. Additional tests are planned for this year with the aim of imaging larger areas and increasing the ability to observe smaller details.