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Treatment efficiency gets a boost

Sometimes the very permeability operators are trying to improve contributes to ineffective distribution of stimulation fluids.

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Fluids injected into a downhole formation follow the path of least resistance as they permeate into treatment zones. But this may not achieve the desired treatment results. Pumping service companies know this and have developed menus of different diversion agents they can pump to enhance the distribution patterns of treatments to improve reservoir contact.

The search for hydrocarbons has turned to reservoirs that are characterized by heterogeneity or viscous fluid content. These require aggressive treatments to access the producing zones and provide the hydraulic conductivity needed to deliver commercial volumes of oil and gas at commercial rates. But the formation heterogeneity or nature of the well fluids often impair the ability of the treatment to fully permeate the reservoir. Differences in relative permeability to the various fluids present in the reservoir or in the treatment also contribute to poor treatment distribution.

Heterogeneity can result from the basic sedimentary process that created the reservoir or from subsequent tectonic activity that creates natural fractures. Contrary to conventional wisdom, fractures are not always the producers' friend. During treatments, they can provide the path of least resistance that funnels valuable treatment or injection fluid away from the reservoir zones they are intended to treat. Conversely, on production they can provide channels for premature water or gas breakthrough.

Near-wellbore drilling damage can impair production or injection. In fact, many treatments performed during the completion process are designed to mitigate wellbore damage. But if the treatment doesn't reach all of the target zone, it may do more harm than good by opening up preferential paths for subsequent coning of undesirable water or gas later in the life of the reservoir.

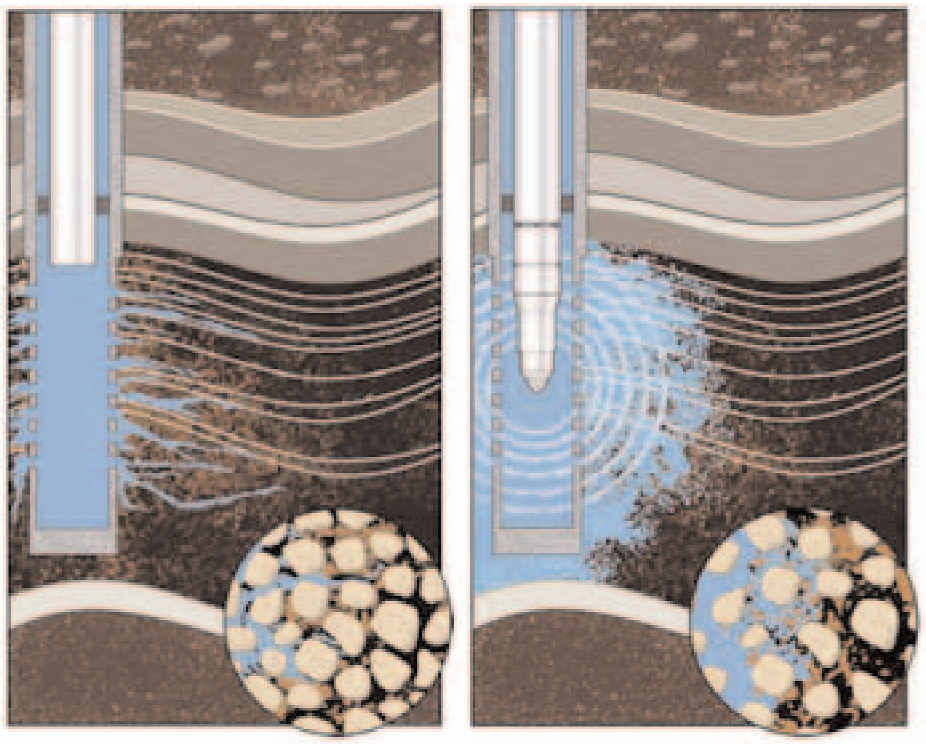
So the basic objective of most stimulation jobs is to target poor permeability or damaged zones to deliver more uniform formation drainage or injection patterns.

Conventional solutions only go so far

Up till now, the solutions for treatment distribution involved mechanical or chemical means. Zones can be treated in stages by setting plugs or inflatable packers to help divert the treatment to different reservoir volumes. Chemical diverters such as viscoelastic surfactants work well but may have some limitations. Most chemical diverters either alter the formation fluid viscosity or temporarily plug off high-conductivity zones to create a mechanical diversion of treatment fluids to unswept zones. Later, the temporary plugs dissolve and restore conductivity to all zones.

New technique is less-invasive

An innovative technique has recently been introduced



Real-time DTS logs confirm that the Powerwave Odyssey tool distributed its acid uniformly across the completion as indicated by the blue rectangle. As the tool was moved across the pay zone, the area treated corresponded to the tool position.

that is less invasive than chemical or mechanical diversion. The Powerwave process from Wavefront Technology Solutions Inc. uses a downhole system that provides pulsing energy to the stimulation fluid in the form of fluid displacement waves that help move the treatment fluid through the reservoir to uniformly penetrate the productive zone. By creating low-frequency waves in the form of fluid pressure pulses, treatment fluid is effectively displaced into the farthest reaches of the reservoir. The fluid pressure pulses generate localized elastic flexure of the pore structure. This creates a momentary path of least resistance that encourages fluid to move in and out of a large number of alternate pore volumes, thus providing uniformity to the treatment fluid distribution. Perhaps a reasonable analogy is the macro mechanism that ultimately results in a delta development. The river's main channel cannot handle the "pulses" of fluid that occur due to seasonal upstream flooding, dam openings, or localized rain deluges, and the river's automatic defense mechanism is to create a broad delta consisting of alternate paths to the sea.

In the Powerwave process, the amplitudes of the pressure pulses range from 300 psi to 1,000 psi, so the local pressure gradients associated with the natural paths of least resistance in the formation are relatively insignificant. Pressure waves have been characterized as "mini-tsunamis" and permeate the reservoir at speeds of more than 300 ft/sec (100 m/sec).

Surging the treatment fluid with low-frequency fluid pressure pulses helps it work its way through tight or partially plugged pore throats into reservoir volumes that might be bypassed by conventional treatment techniques. Whether it involves matrix alteration such as acidization, or if it performs fluid deviscosification, the treatment must get to the problem area to be effective. By improving the distribution uniformity and increasing the volume treated, higher reservoir productivity will result.

The Powerwave technology works on any process where disruptive pressure technology can be applied, such as CO2 floods and water or polymer treatments to improve production, injection, or conformance. Oil producers have experienced several benefits from the technique, including:

- More ultimate recovery with prolonged field lives;
- Additional secondary recovery from oil fields that have been largely depleted or even abandoned;
- Higher flow rates; and

- Fewer wells delivering the same or better oil production.

Field results prove efficacy

A comparison test was run in a California oil shale well between the Powerwave process and an ultrasonic stimulation device from another provider. A downhole fiber-optic distributed temperature survey (DTS) was run to evaluate the placement of the stimulation fluids. Figure 1 shows the completion details. Beneath the packer, approximately 2,000 ft (610 m) of 4½-in. slotted liner spanned the naturally fractured shale pay zone. The permanent DTS fiber-optic sensor was installed across the entire completion. In previous conventional stimulation attempts using acid frac treatments, the acid had followed the paths of least resistance and had permeated only the fracture network, leaving large volumes of the reservoir untreated.

In the comparison test, the same result was observed by the DTS survey when the ultrasonic device was used in conjunction with the acid frac treatment. The ultrasonic tool was run on 1½-in coiled tubing, and several passes were made across the stimulation interval where the pump rate and pulse parameters were varied according to the standard practices of the service provider. Regardless of tool placement or technique used, the acid only entered the zone of existing fractures, according to the DTS logs.

A horizontal 4½-in slotted liner completion in a California oil shale well was chosen for a technology comparison. The presence of a naturally fractured zone is indicated by an orange rectangle. The ultrasonic tool deposited all of its acid into the existing fracture zone. (Images courtesy of Wavefront Technology Solutions)

The 'acid test' proves the concept

When the Powerwave Odyssey tool was run over the same interval, the real-time DTS logs showed that acid was permeating the formation at the spot where the tool was pulsing. Accordingly, full coverage of the pay zone was achieved with acid penetration in all zones, including the naturally fractured zone. As the tool moved up and down the section, the treatment zone indication moved with it.

More recently, the system was run on a commercial well in Southern Alberta, Canada, and delivered an incremental boost of 40,500 bbl of oil production, flattening the operator's decline curve by 75%.

Because the Powerwave pulsed pressure technique enables the treatment fluid, in this case acid, to permeate the entire near wellbore region, it can dissolve interstitial clays and residual wall cake that clog pore throats. Accordingly, permeability is improved in the critical near-wellbore area, and conductivity is achieved with a much larger reservoir volume. Virtually any treatment fluid can be energized using the Powerwave process to achieve better penetration of the reservoir. Chemical enhanced oil recovery technologies, liquid CO2 or water injection, or surfactant placements can be optimized by providing more uniform distribution of the treatments across the target zone. Scale inhibitors can be placed in the near-wellbore region to facilitate flow assurance and reduce the frequency of interventions. Because the technique is deployed by coiled tubing, equipment mobilization is efficient, and disruption of production operations is minimized. ■