

Acid-Tunneling Technique Shows Success in Carbonates

Rising oil prices and increased efforts to maximize oil production have created global interest in technologies that economically can extend well lifetime. As fields mature, stimulation technology costs become marginally economic as production improvements decline.

For wells completed openhole in carbonate reservoirs around the world, an acid-tunneling technology developed by BJ Services has been shown to provide an economic and efficient stimulation alternative.

The patented process, called StimTunnel, uses coiled tubing (CT) to convey a jointed nozzle that jets acid at the formation rock, dissolving it to create numerous mechanically stable, stimulated tunnels into the formation (**Fig. 1**). These tunnels, and the multitude of wormholes and expanded pores, increase reservoir contact and improve productivity by distributing inflow across more surface area (Rae and di Lullo, 2001).



Fig. 1—The robust, acid-tunneling tool, patent pending, comprises two kickoff joints that simplify tunnel initiation and extension.

Applicable in openhole completions in limestone or dolomite formations, the technology does not require a drilling rig and has no fluid returns, resulting in very low environmental impact.

Economically, the acid-tunneling compares favorably with alternative stimulation options in both cost and time savings. This is especially true when considering resulting production improvements.

The use of these treatments began in Venezuela, Spain, and Indonesia, and recently has spread to Kuwait, Romania, the US, and Libya.

Early Results

The initial field trials of the technology were in the massive Mara carbonate field near Lake Maracaibo, Venezuela, during 2005, where typical permeability is in the range of 1 to 5 millidarcies (md).

In operation, the jointed tool is run on CT to the desired tunneling kickoff depth. Acid is pumped, and the internal CT pressure activates the kickoff tool to make contact with the formation face. Acid is jetted from the nozzle, dissolving the formation face and forming a tunnel entry area in the rock matrix. After tunnel initiation, the CT run into the well will push the tool into the reservoir so that the acid can dissolve more of the formation ahead. When the desired tunnel length is attained, pumping ceases and the CT is pulled out of the tunnel. This process is repeated higher uphole as many times as required, at different elevations.

Typical tunnel lengths vary from 3 to 60 ft, although tunnels longer than 100 ft have been created. Because it is intended for relatively short tunnels, the bottomhole assembly (BHA) does not incorporate a steering tool or telemetry systems to relay inclination or azimuth information back to surface.

In the first five wells treated, 38 tunnels were constructed for a total length of more than 1,000 ft, at half the cost of standard acid treatments in the area and with at least twofold increases in production index. One of the five wells became the first in the field to produce without artificial lift (Moss et al., 2006). The technique was later used in several more wells in the area, achieving long-term production increases and attracting interest from operators in other large carbonate fields.

The first operation outside of Venezuela occurred off the Tarragona coast of Spain (Perex et al., 2008). Production had dropped in an openhole well, and an obstruction was tagged in the openhole section about 130 ft higher than expected. A conventional CT BHA was unable to pass the obstruction, which was attributed to hole rugosity or formation collapse.

Economics precluded the use of a rig to regain access to the hole. Instead, the operator chose to use the acid-tunneling technology. The tunneling tool was run into the well, and acid was pumped at low rate to avoid activating the kickoff tool. As a result, the process reopened the 130-ft section of the main wellbore, using 60 bbl of acid. The tool was then pulled uphole 3 ft and the pump rate was increased to activate the kickoff tool and initiate a tunnel off the main bore. Using 94 bbl of acid, the process created a new 19-ft tunnel off the main wellbore.

Thinner Reservoir

The next series of operations was in Indonesia, where prototype testing of the acid-tunneling technology had taken place in 2001.

The Sumatran field chosen for the work historically had been difficult to stimulate, responding poorly to HCl

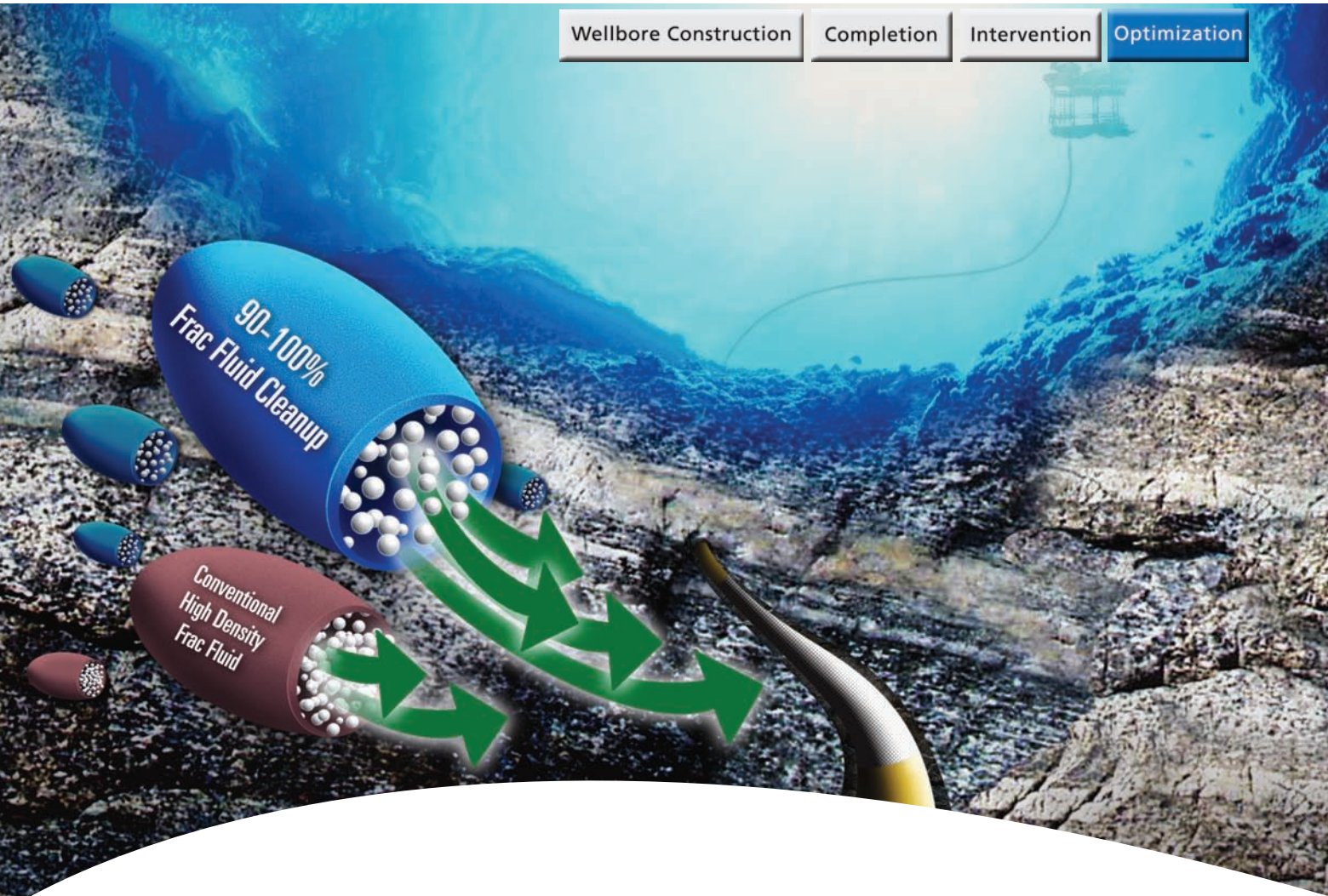
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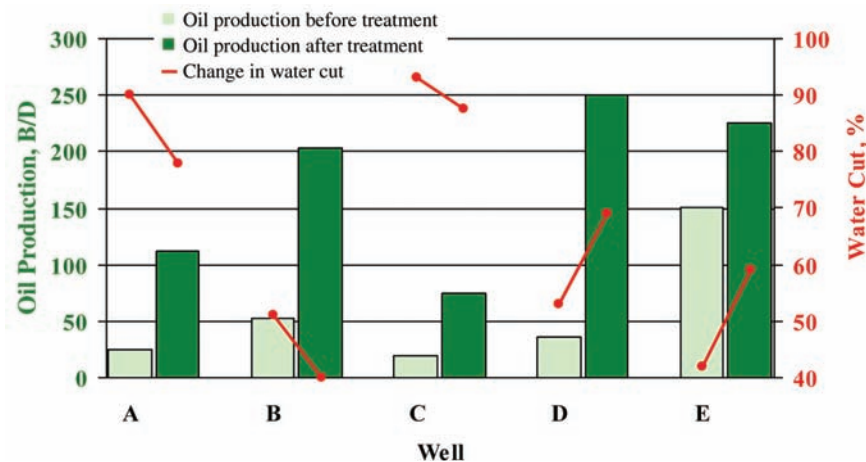


Fig. 2—Production results after several acid-tunneling operations in Indonesia showed increased oil production and reduced water cut (from Soper et al. 2008).

matrix acidizing or HCl fracture stimulation in the past—despite its relatively clean carbonate reservoir and high matrix permeability (220–4,150 md). For acid tunneling, a reservoir thickness of just 16–20 ft (with water contacts immediately below) also added new challenges.

In the first set of operations, the engineering design called for two tunnels in Well A and four in Well B, with the use of the same tool design as had been used in Venezuela and Spain. In operation, the tool jetted 765 bbl of HCl to create six tunnels from 8.5 to 26 ft in length (Soper et al., 2008).

The results were dramatic. Ignoring initial flush production, the sustainable production rate rose from 50 to 128 B/D, a 160% increase, in Well A; and from 50 to 228 B/D, a 360% increase, in Well B. Both also saw reductions in water cut. This demonstrates that even short tunnels in a thin reservoir can provide significant production benefits.

Well B had been subjected to several conventional acid jobs before the tunneling work. The most recent (2003) had not significantly changed the well's production.

For a second campaign in Sumatra, a new, patent-pending tool was developed. The most significant change was to include two kickoff joints rather than one, which increased the tool's lateral reach from 6.1 to 26.3 in. This simplified tunnel initiation and extension. Also, the dual-kickoff tool reduced the theoretical build radius from 75 to 41 ft (76–140°/100 ft). A shorter build

radius allows tunnels to be extended further into the formation for a given tunnel length.

In the three wells of this campaign, 11 tunnels ranging in length from 6.5 to 23 ft were created to avoid breaching a nearby water zone. Each of the three wells saw significant, sustained increases in oil production.

For the entire Indonesia campaign, the average prestimulation production was 280 B/D. The sustained average rate after tunneling was 860 B/D, a threefold increase. In addition, across the five wells, water cut decreased from 71 to 69% (Fig. 2). Average payout for all jobs was one month.

Fourteen Tunnels in Kuwait

After the Indonesia successes and additional modifications to the dual-kickoff tool, two operators in Kuwait recently became the first in the Middle East to use the acid-tunneling technique.

In the first well, which was vertical, one 13-ft tunnel and one 50-ft tunnel were created, with average penetration rates of 0.8 ft/min.

In the second well, which was horizontal, a caliper log was run before the operation. Although the well had originally been drilled with a 4¹/₈-in. bit, two previous acid-stimulation treatments had expanded the wellbore diameter to as much as 6¹/₄ in.

For this treatment, 15% HCl was used to initiate tunnels and 10% HCl to continue the tunnel to the desired depth. The operation ultimately created 12 10-ft tunnels, spaced about 100 ft apart.

Only one operator shared production data, indicating a 75% production improvement after the tunneling treatment. Five more candidate wells are being evaluated in the area.

Ten wells in Romania

In Romania, an operator was studying ways to improve production from a number of mature oil wells that had been drilled as openhole completions in various fields around the country.

Romania's oilfields include large areas of carbonate formations, which are traditionally stimulated by simply bullheading acid. In an effort to boost production above the normal levels, the operator proposed to evaluate the acid-tunneling process by using it in six horizontal and four vertical wells in four fields.

Total vertical depth for the wells averaged about 3,050 ft for the vertical wells and 5,730 ft for the horizontal wells. Vertical openhole sections averaged 108 ft long. Horizontal openhole sections were about 1,640 ft long, with key zones of about 650 ft. Permeability was estimated at 14 md for the horizontal wells and 5 md for three of the vertical wells, with the fourth being unknown. Bottomhole temperature was expected to be 142°F for the vertical wells and 171°F for the horizontals.

In the May and June 2008 operations, each tunnel was initiated by kicking off the jetting tool to a predetermined angle and then jetting 20 bbl of 15% HCl to create an "entrance pocket" off the main wellbore. The BHA was then pushed into the pocket to continue the tunnel with 47 bbl of acid.

In all, the operations created 43 tunnels, with a combined length of approximately 1300 ft. After the first 21 days, combined average daily production of the 10 wells added about a 30% initial oil increment to their prejob production. Compared with conventional acid treatments, the initial data indicated that the horizontal wells were seeing more production improvement than the vertical wells.

Most Recent Work

In July, an acid-tunneling operation created three tunnels off the main wellbore of an Oklahoma well that originally had been drilled in 1924 (Fig. 3).

The operation used 1,000 gal of 15% HCl and 24,000 gal of 10% HCl to create tunnels reaching 28, 36, and 44 ft out from the main wellbore into likely oil-production zones in the limestone formation. After several weeks, the operator reported a sustained, 110% increase in oil production.

A few weeks after the Oklahoma operation, another acid-tunneling operation was performed in Libya. The well was one of the most challenging for this technology to date because of the available wellbore length. Originally, the zone of interest was in excess of 100 ft, but when a lower section showed signs of water contact and a middle zone was found to be nonproductive, a cement plug was placed to isolate these from the top section, leaving only 30 ft of openhole for tunneling.

During the operation, five tunnels were created with a total length of 176 ft at approximately 1.5 ft/min. After testing the well, the operator confirmed that production increased by a factor of six following the tunneling operation.

Candidate Selection

BJ Services is working with operators to plan additional tunneling efforts in Libya, Saudi Arabia, Thailand, and Indonesia.

All wells with openhole completions in carbonate formations are candidates for the technique, but design considerations include

- Vertical distance of oil/gas/water contacts to the tunnel elevation because of the natural tendency of tunnels to dip downward
- Formation acid solubility (>80% HCl solubility is best)
- Potential benefit with respect to remaining oil relative to original oil in place

Information provided by Lance Portman, Abrar Bouarki, Manuel Navarro, Joseph Strasburg, and Alfredo Mendez, BJ Services Company.

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Fig. 3—The acid-tunneling tool was run on CT during a July 2008 operation that increased production from a well in Oklahoma.

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