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Enhanced Rocker Tool to Restore the Permeability of Formations: Case Studies

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Abstract

The Northeastern region is the largest onshore oil producer in Brazil. However, regional oil production is still much smaller than offshore production in other Brazilian basins. Therefore, customized low-cost technologies are routinely employed locally, for example to deal with issues such as perforation plugging, scaling and sediments production. Heavy oil produced in this area builds up paraffin and asphalten deposits over time, further decreasing the productivity of the fields. In this work, we applied a true fluidic oscillator (TFO), an enhanced rocker tool that synergetically combines fluidic, acoustic and chemical effects in order to potentiate the action of a fluid treatment on the formation. Usually, this tool is used in conjunction with coiled tubing (CT) equipment. Since the operator considered a CT operation expensive for the needs of this region, the tool was run into the well with a regular work string, as a lower cost alternative. Three similar wells in the Potiguar basin were selected and treated with diesel and butyl glycol through the TFO, with significant improvement in estimated permeability and oil production (20% to 240% increase) after treatment. Overall, the tool enhanced the treatment effectiveness by amplifying the contact area between fluids and formation. This demonstrates the applicability of this cost-effective solution in the stimulation of low productivity wells.

Introduction

Currently, Brazil´s oil and gas production is unevenly split between onshore and offshore fields. Onshore production is 11.3% of the total (218000 bpd), of which 67.6% (147000 bpd) are developed in the Northeastern region, while the remaining 88.7% (1705000 bpd) are produced offshore, mainly in the Campos basin in the Southeastern region (ANP, 2009). In general terms, the NE region has a much larger number of onshore wells, but a much lower production per individual well than the SE region.

Consequently, one of the main challenges of onshore oil production in the NE region is to reduce production costs in order to keep the fields economically viable, while the operator focuses its main investiments on its most productive fields. This has required creativity and ingenuity, leading to a continuous search for low-cost alternatives to commonly performed operations, including stimulation of marginal wells.

Common stimulation techniques currently applied in the region include treatments such as solvent injection and matrix acidizing, as well as hydraulic fracturing. These operations have significant positive impact in productivity, but they also bring medium-to-long term negative impacts, such as perforation plugging, scaling formation, sediments and fines production and consequent problems such as tubing erosion and pump plugging.

Besides those issues, the oil produced in the region is heavy (about 20°API) and prone to asphalten and paraffin deposition, plugging the formation and reducing productivity over time.

Near-wellbore skin damage has been successfully treated in the field using a true fluidic oscillator (TFO), which is an enhanced rocker tool based on the Coanda effect (McCulloch, 2003). The TFO delivers treatment fluid to the formation and combines the cleaning effect of cyclic loading by pressure waves, acoustic streaming for pinpoint placement of the fluid and the synergistic effect of chemical treatment enhanced by increased fluid mixing and larger area of contact. McCulloch *et al.* (2003) compared the TFO with two conventional jetting tools at the surface, observing that only the TFO was capable of transferring energy through an extended area of screen. In the field evaluation, filtercake solvent was pumped, using the TFO and CT equipment, into horizontal wells in a field located at the UK section of the North Sea, yielding a 62% production increase.

Gunarto *et al.* (2004) reported a significant increase in productivity after applying the TFO in horizontal wells in . For one field, a two-stage treatment was applied, first pumping oxidizers to remove mud debris and after that, pumping acid to remove scale and increase formation permeability. Only when the TFO was used, an oil production increase of 80% was observed. Wells where chemicals were pumped alone did not respond positively. In a second field, only acid was delivered using the TFO and CT equipment, with excellent results (700% fluid production increase).

Harthy *et al.* (2004) compared the TFO (using the term pulse-jetting tool) with two alternatives, a rotational cavity tool and a piezoelectric sonic tool, concluding that the TFO was very successful and economic in wellbore cleanout, while the other tools had short term effects, with production losses as early as one month after treatment. Six oil wells in sustained increases in production for about one year, after treatment with brine, mud acid or mutual solvent, according to well requirements. The operations were performed using CT, but the authors refer to a possible use of work strings, if required.

Hegazy *et al.* (2007) reported increases in gas production from 40% to 325% in two wells located in after treatment with acid followed by brine, through a TFO run with CT equipment.

In this work, we report recent applications of the tool in Brazil, including the successful removal of scaling in an offshore horizontal well in the Campos basin (SE region), using a conventional approach, and the successful removal of asphaltens and paraffins from three onshore vertical wells in the Potiguar basin (NE region), using a low-cost approach.

Enhanced Rocker Tool

The Enhanced Rocker Tool (ERT) is based on a patented true fluidic oscillator (TFO), designed to be run into the well in a coiled tubing (CT) or jointed string (McCulloch, 2003). The tool creates pulsating pressure waves within the wellbore and formation fluids. These pressure waves help to break up near-wellbore damage and to restore the permeability of the formation, by carrying a treatment fluid into the formation.

The tool is run into the well on coiled tubing or on a regular work string. While both approaches were tested in this work, running on a work string provided a lower cost solution for the low productivity onshore wells. The tool does not require a packer, and it does not contain elastomer sealing elements, reducing the number of elements to fail. However, a packer may be used to isolate zones from the treatment fluids, when necessary. The treatment fluid is then pumped through the tool, into the borehole and the formation.

As fluid flows inside the tool, oscillating pressure waves are created by the Coanda effect, discovered in 1930 by Henry Coanda. He observed that a fluid that emerges from a nozzle tends to flow near a curved surface, provided that the curvature is not too accentuated. Inside the tool, a fluid stream is repeatedly switched from one passageway to another by means of this effect, rapidly oscillating between two different paths. This allows the tool to create pressure waves without moving parts and without relying on cavitation. These waves are not affected by standoff as with conventional jetting or velocity tools. The kinetic energy travels through the fluid with little energy loss.

When the wave reaches the formation, the energy is dumped and damage removal is initiated. As the damage is removed, the pressure waves are now able to penetrate deeper into the formation, removing perforation tunnel damage, scales, formation fines, mud and cement damage, drilling damage, water and gas blocks and asphalten/paraffin deposits.

The acoustic streaming induced by the oscillator focuses the treatment on the immediate area of the tool. The action of chemicals is enhanced by the increased contact area with the formation.

The high performance and success rate of the TFO in case studies (McCulloch, 2003; Gunarto, 2004; Harthy, 2004; Hegazy, 2007) can be attributed to a synergy between the chemical effect of the fluid treatment being pumped, the mechanical action of the pressure waves and the focusing effect of acoustic streaming.

Comercially available ERTs have an outside diameter (OD) ranging from 1.75” to 2.88”, designed for optimal flow rates from 0.5 to 3 bpm at a nozzle pressure of 2000 psi, oscillating at 300 to 700 Hz.

Case Studies

Well A. Offshore well at Campos basin

This horizontal well (10815 ft MD, 8697 ft TVD and final inclination 94º), developed barium sulfate and strontium sulfate scales on the production string (8727 ft to 9641 ft) and on the screen (9693 ft to 10814 ft), requiring treatment with scaling inhibitor.

First, the well was mechanically conditioned using a 2 ½” conical bit driven by a 2 1/8” downhole motor, run into the well with coiled tubing (CT) equipment. A viscous Xanthan gum-based fluid was used to carry scaling debris.

In a subsequent operation, treatment fluid containing scaling inhibitor was pumped through the TFO, which was assembled and run into the well with CT equipment. The performance was assessed by running caliper logs before and after treatment. The result was a significant improvement in measured internal diameter for the production column, as well as for the screen, demonstrating that there was scaling removal. These logs are shown in Figure 1.

Well B. Onshore well at Potiguar basin

The successful experience above suggested the use of the tool in the NE region. Three wells (Wells B, C and D) on the same field at the Potiguar basin were selected for this trial. However, the cost of a coiled tubing operation was considered too high for the local needs; therefore the tool was run using a regular work string, avoiding the additional costs of CT equipment.

Well B is a vertical well 2559 ft deep, with two production zones at 1721 ft (primary) and 1499 ft (secondary). It had been producing a total of 3.71 bpd of oil, with 54% water cut. The well has a 5 ½" production casing.

Historically, the operator observed alphalten and paraffin deposition in similar wells, which responded well to treatment with diesel containing 10% butyl glycol, working respectively as solvent and mutual solvent for the deposits (Holm, 1971; Newberry, 1985; Broaddus, 1988). Before treatment, the well is mechanically conditioned using a scraper.

The work string was composed of 1716 ft of 2 3/8" tubing and a packer, with a reduction and a 2 1/8" ERT installed at the end of the string. The packer was intended to isolate the two production zones, concentrating the action of the tool on the primary zone. A volume of 2000 gal of diesel/10% butyl glycol fluid was pumped into the primary zone through the TFO at 1.5 bpm, with 2600 psi of wellhead pressure (estimated pressure drop of 2000 psi at the tool), with a total contact time of about 25 min.

During a 4-month follow-up, average production increased to 12.6 bpd with 94% water cut, a 240% increase in oil production. The increase in water cut was very severe, suggesting the need for a water control treatment. Both production zones benefited from the treatment and displayed very similar increases in oil and water production. Table 1 and Figure 2 summarize these results.

Well C. Onshore well at Potiguar basin

This well is a vertical well 1591 ft deep, located at the same field as Well B, with two production zones at 1396 ft (primary) and 1314 ft (secondary). Historical production was 2.52 bpd of oil, with 75% water cut. The well has a 5 ½" production casing, which was conditioned using a scraper, prior to this treatment.

The work string was composed of 1391 ft of 2 3/8" tubing and a packer, with a reduction and a 2 1/8" ERT installed at the end of the string. The packer was intended to isolate the two production zones. A volume of 2000 gal of diesel/10% butyl glycol fluid was pumped into the primary zone through the TFO at 1.2 bpm, with 2800 psi of wellhead pressure (estimated pressure drop of 1200 psi at the tool), with a total contact time of about 30 min.

During the next 4 months, average production increased to 2.96 bpd with 90% water cut, an 18% increase in oil production. The increase in water cut was significant, demonstrating that the tool was able to restore permeability. Although the secondary zone was affected by the treatment, its oil production did not increase, only the water production. These results can be found in Table 1 and Figure 2.

Well D. Onshore well at Potiguar basin

The final trial was performed at a vertical well 2280 ft deep, located at the same field as Wells B and C, with two production zones at 1462 ft (primary) and 1375 ft (secondary). Historical production was 3.96 bpd of oil, with 83% water cut. The well has a 7" production casing. This casing was conditioned using a scraper before running the work string.

The work string was composed of 1424 ft of 2 7/8" tubing, a packer and 33 ft of 2 3/8" tubing, with a reduction and a 2 1/8" ERT installed at the end of the string. The packer was intended to isolate the two production zones. A volume of 2000 gal of diesel/butyl glycol fluid was pumped into the primary zone through the TFO at 1.5 bpm, with 1800 psi of wellhead pressure (estimated pressure drop of 2000 psi at the tool), with a total contact time of about 45 min due to operational issues.

In the 4-month follow-up, average production increased to 11.51 bpd with 73% water cut, a 190% increase in oil production with a reduction in water cut. Again, both production zones were equally affected by the treatment, as seen in Table 1 and Figure 2.

Conclusions

The Enhanced Rocker Tool ERT) based on the True Fluidic Oscillator (TFO) has reliable results reported, when used to deliver stimulation treatments, successfully removing several kinds of formation damage, such as drill-in fluidcake, scaling, asphaltens and parafins deposits, among many other applications, such as gravel pack or frac pack clean outs. The synergistic effects of the multiple cleaning mechanisms of this tool result in increased well productivity.

The operation sucess depends essentially on the treatment selection and design, since the TFO acts as a mechanic catalyst when applying well stimulation treatments. However, it is important to highlight that the tool plays an important rule on this type of application because it amplifies the action of the treatments, by increasing the contact area. Furthermore, the well response will be directly affected by the correct damage mechanism identification and the proper stimulation treatment selection.

The TFO conected to a work string showed a very satisfactory performance when compared to the standard method (via CT). This low-cost configuration appears to be the best option to treat formation damage in low productivity onshore wells, taking into account the high costs associated to the CT equipment.

Overall, the diesel treatment containing 10% of buthyl glycol pumped through the TFO on 3 onshore wells located in the Potiguar basin (Wells B, C and D) increased considerably the productivity of the wells, tripling the oil production for Wells B and D and increasing in 20% the productivity of Well C, 4 months after treatment. Beasides, the treatments effects were also sensed by the secondary zones that were isolated by a packer during the job.

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Tables

Table 1. Well productivity before and after treatment using the TFO

Well	Oil production before treatment (bpd) / water cut			Oil production after treatment (bpd) / water cut			Increase
	Primary Zone	Secondary Zone	Total	Primary Zone	Secondary Zone	Total	
B	2.26	1.45	3.71	7.55	5.03	12.58	239%
	53%	54%	54%	94%	94%	94%	
C	1.89	0.63	2.52	2.33	0.63	2.96	18%
	68%	85%	75%	87%	95%	90%	
D	2.20	1.76	3.96	6.16	5.35	11.51	190%
	83%	83%	83%	73%	73%	73%	

Figures

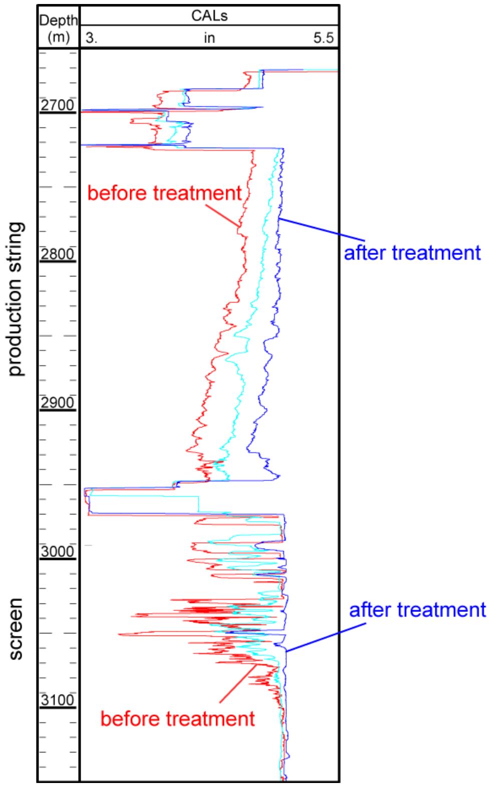

Figure 1. Caliper logs in Well A, before and after treatment with scaling inhibitor through the TFO.

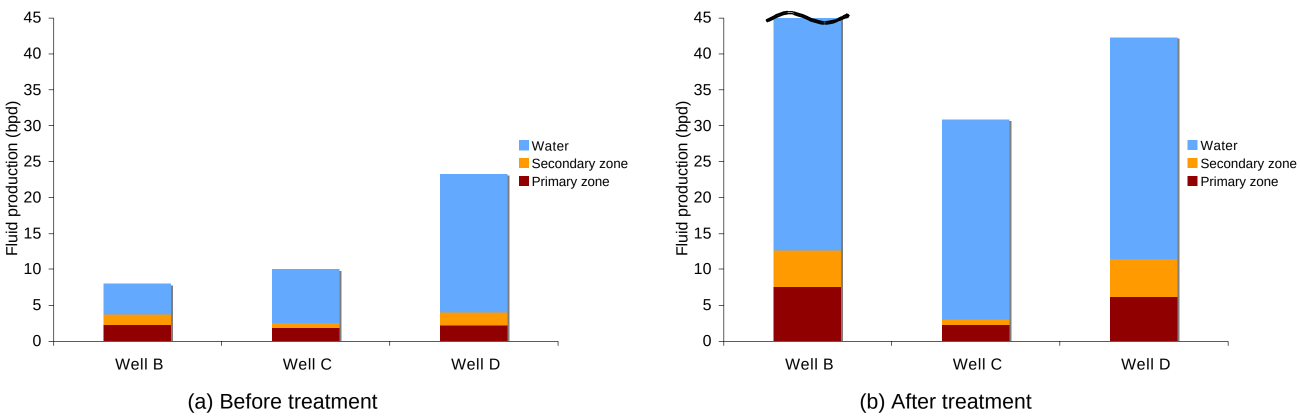

Figure 2. Well productivity of Wells B, C and D, before and after treatment with the TFO.