SPE 92866

Abrasive Cutting Technology Deployed Via Coiled Tubing

S.W. Loving, SPE, and A. Ferguson, SPE, Thru Tubing Solutions, and R. Hart, SPE, GMX Resources

This paper was prepared for presentation at the 2005 SPE/ICoTA Coiled Tubing Conference and Exhibition held in The Woodlands, Texas, U.S.A., 12 – 13 April 2005.

Proposal

This paper will discuss the development of abrasive cutting technology deployed via coiled tubing for cutting production tubing, drill pipe, drill collars, exotic stainless steel completion components, single strings of casing and multiple strings of casing. This technology is performed utilizing a sealed bearing, positive displacement motor and a cutting head along with conventional coiled tubing tools and conventional coiled tubing. This technology gives operators an additional tool when severing of the drill string or production tubing is required.

Additionally the paper will discuss perforating tubing and casing using abrasives, particularly in horizontal wells where conventional wire-line operations are not possible.

The paper will discuss:

1. Utilizing a positive displacement motor to perform abrasive cuts via coiled tubing,
2. Design and testing phases of the abrasive cutting system,
3. Initial field runs to prove the viability of this technology,
4. Total jobs completed to date,
5. Lessons learned throughout the process,
6. Where this technology leads from here.

The paper will also discuss future applications for this technology which include cutting casing for plug and abandonment programs, permanent packer retrieval, and abrasive perforating all deployed via coiled tubing.

Introduction

A reliable cutting system deployed via coiled tubing has been required in the industry for several years for cutting tubulars. The mechanical and hydraulic cutters that are available on the market for coiled tubing conveyed applications have their limitations. There is the risk of the cutter blades not fully retracting preventing the cutter from being pulled through the restrictions in the completion. Most of these types of cutters require some type of anchoring devise that adds additional risks and costs to this operation.

The Abrasive Cutting System

The design criteria for the Abrasive Cutting System were to use existing Thru Tubing equipment that was industry accepted and to keep it simple. The key component in this system is the sealed bearing pack positive displacement motor. A reliable sealed bearing pack motor is needed because once the abrasive sand is introduced to the system, sand in the bearing pack would damage the motor and cause the operation to be unsuccessful.

Proper nozzle selection in the abrasive cutting head is critical to performing a successful cut. When the flow rate through the coiled tubing is determined, hydraulic calculations are run to determine the orifice size and the number of orifices that will generate optimum performance.

Figure 1 shows the Abrasive Cutting System BHA drawing.

Below is a brief description of the BHA components;

<u>Coiled Tubing Connector</u> – Connects the BHA to the coiled tubing that will hold both tension and torsion loads.

<u>Dual Back Pressure Valve</u> – Prevents flow back up the coiled tubing.

<u>Dual Acting Hydraulic Fishing Jar</u> – Provides impact to free the BHA in the event the BHA becomes stuck.

<u>Hydraulic Disconnect</u> – A ball activated device that will release the BHA if unable to jar the BHA free.

<u>Sealed Bearing Positive Displacement Motor</u> – Provides rotation by pumping sand laden fluid through the motor.

<u>Abrasive Cutting Head</u> – Orifices placed in the cutting generate the velocity required to cut the tubulars.

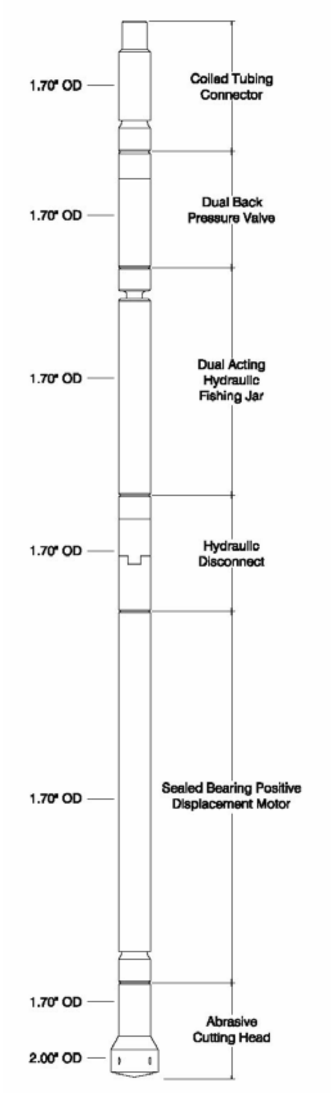


Figure 1

The abrasive slurry can be mixed on location in a batch mixer and pumped with conventional high pressure pumping equipment. Normally, a gel is mixed on location in the batch mixer and continually stirred with the paddles while sand is slowly blended into the fluid. Once the cutting BHA has reached the required cutting depth, the slurry is pumped at a pre-determined rate for a pre-determined time to make the cut.

Testing of Abrasive Cutting System

The first field application for the Abrasive Cutting System was to cut 2.875", 8.7#/ft, P-110 production tubing. A test was set up to prove the viability of the abrasive cutting system.

A joint of 2.875", 8.7#/ft, P-110 production tubing was mounted in a test fixture. The abrasive cutting BHA consisting of the following was made up to the coiled tubing and lowered into the production tubing:

~1.70" OD Coiled Tubing Connector for 1.25" coiled tubing
~1.70" OD Dual Back Pressure Valve
~1.70" OD Hydraulic Disconnect
~1.70" OD Sealed Bearing Positive Displacement Motor
~2.00" OD Abrasive Cutting Head

A gelled slurry sand was pumped at a maximum rate of 1.0 BPM. After 75 seconds of pump time, initial penetration through the production tubing was observed. Pumping was continued at 1.0 BPM to complete the cut. After 4 minutes the production tubing was completely severed. Both ends of the production tubing were inspected and shown to be clean cuts with no flaring of the tubing ends, easing possible fishing operations.

Initial Field Run

Figure 2 shows the well schematic where the Abrasive Cutting System was required. This is a deep gas well in western Oklahoma. The goal of the workover was to pull the 2.875" production tubing from inside the 5" casing. There was dehydrated drilling mud in the 5" casing annulus making it impossible to pull the tubing and the 5" casing was slightly collapsed at approximately 16,000' so conventional overshots and washpipe could not latch the 2.875" tubing couplings.

After numerous failed chemical cuts and failed jet cutters the abrasive cutting system was ran on 1.50" coiled tubing to a cutting depth of 16,697'. The tubing had previously been cut at 16,540' using a chemical cutter. A sand slurry was mixed and pumped through a 1.70" OD positive displacement motor and the tubing was cut in approximately 4 minutes. With the clean ends from the cut, a 157' section of the tubing was readily retrieved from the well. An additional abrasive cut was required to cut the tubing near the production packer at 17,250' so the production packer could be washed over and pulled from the well. The second abrasive cut was ran to 17,202' and cut in the same manner as previous in approximately 4 minutes. A 505' section of tubing was pulled from the well and the production packer was washed over and retrieved. The well was recompleted and is currently producing.

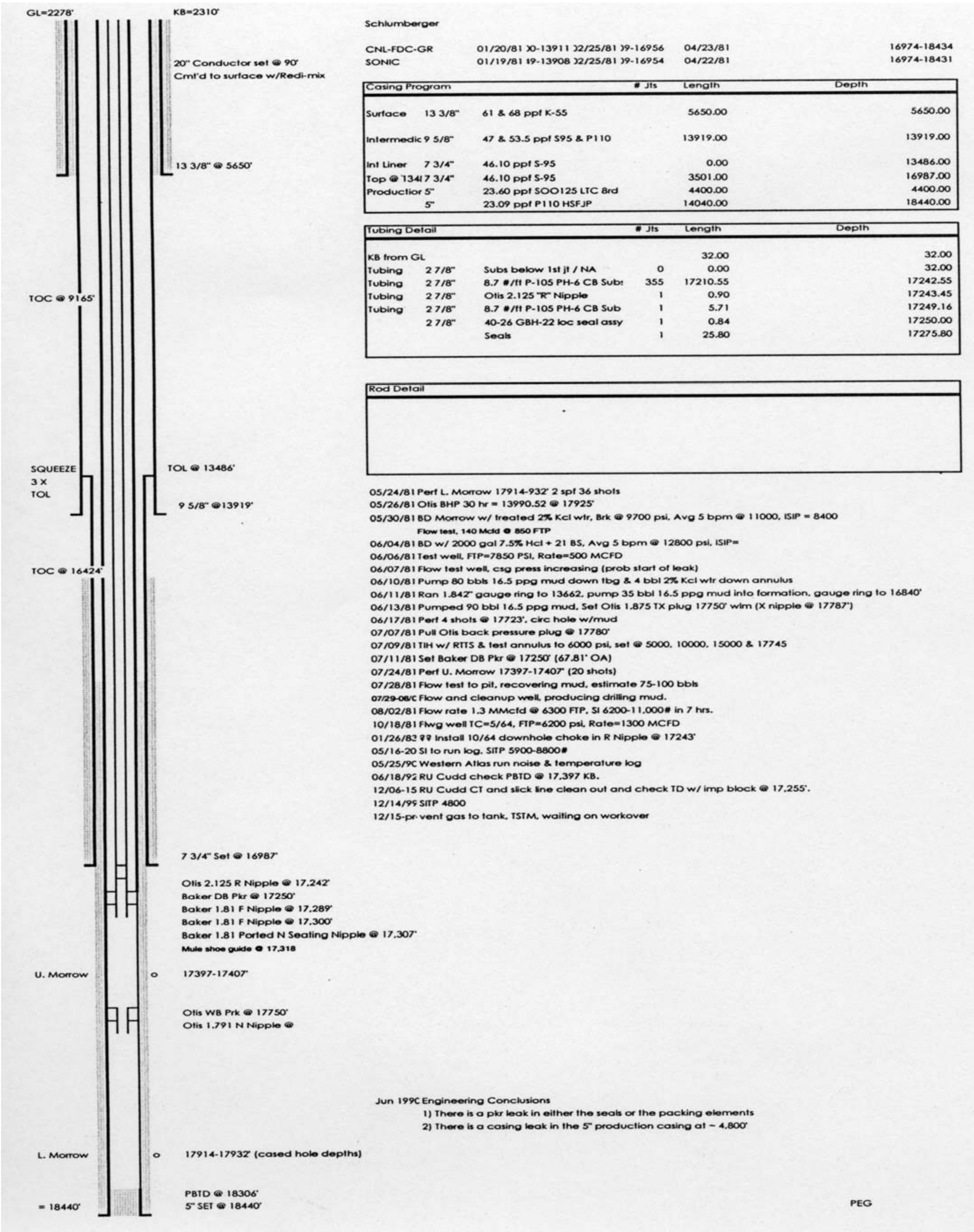
Total Field Runs

To date over 30 successful field runs have been made utilizing the abrasive cutting system on coiled tubing.

~ 25 operations cutting tubulars up to 3.50" OD
~ 10 operations cutting drill pipe or drill collars up to 6.25" OD
~ 4 operations cutting casing up to 13.375" OD
~ 6 operations cutting inconel or chrome completion components

In plug and abandonment applications we have successfully, and reliably, cut single and multiple casing strings. Successful multiple casing applications include cutting both 9-5/8" and 13-3/8" casing at the same time

All of these operations were completed on coiled tubing sizes ranging from 1.25" OD to 1.75" OD.



Schlumberger

CNL-FDC-GR	01/20/81)0-13911)2/25/81)9-16956	04/23/81	16974-18434
SONIC	01/19/81 19-13908)2/25/81)9-16954	04/22/81	16974-18431

Casing Program			# Jts	Length	Depth
Surface	13 3/8"	61 & 68 ppf K-55		5650.00	5650.00
Intermedic	9 5/8"	47 & 53.5 ppf S95 & P110		13919.00	13919.00
Int Liner	7 3/4"	46.10 ppf S-95		0.00	13486.00
Top @ 134	7 3/4"	46.10 ppf S-95		3501.00	16987.00
Productior	5"	23.60 ppf SOO125 LTC 8rd		4400.00	4400.00
	5"	23.09 ppf P110 HSFJP		14040.00	18440.00

Tubing Detail			# Jts	Length	Depth
KB from GL				32.00	32.00
Tubing	2 7/8"	Subs below 1st jt / NA	0	0.00	32.00
Tubing	2 7/8"	8.7 #/ft P-105 PH-6 CB Sub:	355	17210.55	17242.55
Tubing	2 7/8"	Otis 2.125 "R" Nipple	1	0.90	17243.45
Tubing	2 7/8"	8.7 #/ft P-105 PH-6 CB Sub	1	5.71	17249.16
	2 7/8"	40-26 GBH-22 loc seal assy	1	0.84	17250.00
		Seals	1	25.80	17275.80

Rod Detail

05/24/81 Perf L. Morrow 17914-932' 2 spf 36 shots
05/26/81 Otis BHP 30 hr = 13990.52 @ 17925'
05/30/81 BD Morrow w/ treated 2% Kcl wtr, Brk @ 9700 psi, Avg 5 bpm @ 11000, ISIP = 8400
Flow test, 140 Mcfd @ 850 FTP
06/04/81 BD w/ 2000 gal 7.5% Hcl + 21 BS, Avg 5 bpm @ 12800 psi, ISIP=
06/06/81 Test well, FTP=7850 PSI, Rate=500 MCFD
06/07/81 Flow test well, csg press increasing (prob start of leak)
06/10/81 Pump 80 bbls 16.5 ppg mud down tbg & 4 bbl 2% Kcl wtr down annulus
06/11/81 Ran 1.842" gauge ring to 13662, pump 35 bbl 16.5 ppg mud into formation, gauge ring to 16840'
06/13/81 Pumped 90 bbl 16.5 ppg mud, Set Otis 1.875 TX plug 17750' wlm (X nipple @ 17787')
06/17/81 Perf 4 shots @ 17723', circ hole w/mud
07/07/81 Pull Otis back pressure plug @ 17780'
07/09/81 TIH w/ RTTS & test annulus to 6000 psi, set @ 5000, 10000, 15000 & 17745
07/11/81 Set Baker DB Pkr @ 17250' (67.81' OA)
07/24/81 Perf U. Morrow 17397-17407' (20 shots)
07/28/81 Flow test to pit, recovering mud, estimate 75-100 bbls
07/29-08/C Flow and cleanup well, producing drilling mud.
08/02/81 Flow rate 1.3 MMcfd @ 6300 FTP, SI 6200-11,000# in 7 hrs.
10/18/81 Flwg well TC=5/64, FTP=6200 psi, Rate=1300 MCFD
01/26/83 ?? Install 10/64 downhole choke in R Nipple @ 17243'
05/16-20 SI to run log. SITP 5900-8800#
05/25/9C Western Atlas run noise & temperature log
06/18/92 RU Cudd check PBTD @ 17,397 KB.
12/06-15 RU Cudd CT and slick line clean out and check TD w/ imp block @ 17,255'.
12/14/99 SITP 4800
12/15-pr vent gas to tank, TSTM, waiting on workover

Jun 199C Engineering Conclusions
1) There is a pkr leak in either the seals or the packing elements
2) There is a casing leak in the 5" production casing at ~ 4,800'

PEG

Figure 2

Abrasive Cutting Stainless Steel Components

Further testing on both chrome and inconel completion components has been successfully completed.

The inconel component with a 0.80” wall tickness was successfully cut with the abrasive cutting system in 4 minutes 35 seconds. This test was completed in the horizontal position to simulate the actual completion.

The 13 chrome component with a 0.80” wall thickness was successfully cut with the abrasive cutting system in 7 minutes 50 seconds. This test was completed in the horizontal position to simulate the actual completion.

Both of these tests were completed with the following BHA:

~2.88” OD No-Go Sub
~2.88” OD Spacer Subs
~2.88” OD Sealed Bearing Positive Displacement Motor
~5.25” and 4.25” OD Abrasive Cutting Heads

Both of the cuts were successfully made with no flaring of the component ends.

Abrasive Perforating

After the successful abrasive cutting operations, we began to abrasive perforate using similar technology. The Abrasive Perforator System is basically the same BHA without the sealed bearing positive displacement motor that creates the rotation for cutting. *Figure 3* shows an abrasive perforating BHA. The sand slurry is pumped through the orifices to create a hole in the casing.

Numerous abrasive perforating jobs have been performed using this technology. Typically conventional explosive perforating could not be used, or abrasive perforating was more economical than TCP perforating.

Case 1 : An operator had a 9.625” service packer cemented in a vertical well that had a 2.44” ID and needed to perforate 9.625” and 13.375” casing. There was cement behind both the 9.625” and 13.375” casing. A 2.13” OD Abrasive Perforator was designed with 9 orifices that could perforate a 10 foot interval. A 50 BBL sand slurry was pumped through 1.50” coiled tubing to achieve the perforating. This was repeated twice in order to perforate the 30 foot interval on a single trip in the hole.

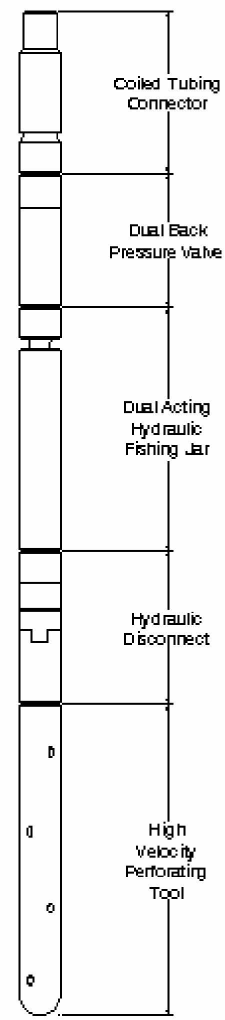


Figure 3

Case 2 : An operator had ran 1,000’ of 2.875” liner into a horizontal section of the Mississippi formation in northern Oklahoma and required it to be perforated over the complete 1,000’. TCP guns were not economical so abrasive perforating was chosen to perforate this section. The well was perforated with 4 shots per foot over a 5 foot interval then repeated every 50 feet over the 1,000’ interval. A 2.13” OD Abrasive Perforator was ran on 1.75” OD coiled tubing to the total depth of the well. A sand slurry was pumped at 2.0 BPM and 2 holes were perforated using 2.0 BBL of slurry. A pressure change across the tool gradually occurred while perforating the first 208 holes. The Abrasive Perforator was pulled and replaced with a new perforator and the perforating was completed by perforating an additional 180 holes. *Figure 4 & 5* are photos the the Abrasive Perforating heads at the completion of the job.

Figure 4

Figure 5

Case 3 : An operator in the Barnett Shale area of north Texas had ran a 3 ½", 9.3 lb/ft production liner from a sidetrack well. The well was perforated with TCP guns at 6 shots per foot across the toe and heel of the horizontal section at 8400-8406 and 8900-8906. The frac job was attempted and only 5 bpm rate was achieved. The zones were reperforated at 12 shots per foot with TCP guns and again only 5 bpm was achieved.

An Abrasive Perforator was ran on a tapered work string. Both zones were perforated with 4 shots per foot. The well was successfully fraced at 55 BPM, 5400 PSI. At the time of writing the well was still flowing back the frac fluids. All indications are that the well will be commercial.

Conclusions

1. The Abrasive Cutting System is a proven and efficient method for cutting all types of tubulars via coiled tubing.
2. The Abrasive Cutting System can cut tubulars without flaring or deformation of the tubulars so no milling run is required to "dress" the cut.
3. The Abrasive Perforating System is a viable alternative to TCP or conventional wireline perforating.
4. The Abrasive Perforating System can perforate wells where TCP and conventional wireline perforating cannot.
5. The Abrasive Perforating System may create deeper penetration into the formation than TCP or conventional wire-line perforating.

Acknowledgments
The authors thank GMX Resources, Sojourner Drilling, Crawley Petroleum, Schlumberger, and Merritt Energy for permission to publish this paper.

References

1. Perry Courville, Michael L. Connell, James C. Tucker, Alton L. Branch, and Robert S. Tyre. "The Development of a Coiled Tubing Deployed Slow Rotating Jet Cleaning Tool that Enhances Cleaning and Allows Jet Cutting of Tubulars", IADC/SPE 62741.
2. Ashley Johnson, David Eslinger, and Henrik Larsen. "An Abrasive Jetting Scale Removal System". SPE 46026.
3. O.M. Vestavil, T.H. Fidtje, and A.M. Faure. "Casing Window Milling With Abrasive Fluid Jet". SPE 30453
4. J.S. Corbett. "Sand Jet Perforating Revisited". SPE 55044.