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Novel Couplings That Mitigate Friction Boost Rod Lift Efficiency

By Bo Brooks And Anthony Mason

More than 150 years after its first implementation to extract oil, rod lift has withstood the test of time by continuously evolving to meet the needs of a changing industry. Today, rod lift systems must accommodate sandy, corrosive and highly deviated wellbores that accelerate wear, require more frequent workovers and increase downtime.

To address mechanical wear and abrasion in its sucker rod pump wells, a major South Texas producer deployed boron-carbide (B_4C)-treated steel couplings at key points in many of its sucker rod strings. The primary goal was to reduce rod-on-tubing wear. While it is too early to conclude that the couplings achieved that goal, they have demonstrated three secondary benefits: increased lifting efficiency, improved production and decreased peak polished rod loads. These benefits likely result from the treated couplings' reduced friction coefficient.

The producer, Chesapeake Energy Corp., confirmed these effects by evaluating a sample of 20 sucker rod pump wells in conjunction with Endurance Lift Solutions, the treated couplings' provider. The evaluation focused on wells that had more than 50 B_4C couplings installed within the rod string and involved comparing peak polished rod load, net load, gross stroke change, fluid production and other data before and after the couplings' installation.

Figure 1 shows a typical treated coupling. Of the 20 wells evaluated, 70% demonstrated a reduction in peak polished rod load. More than 60% had a gain in downhole stroke, which translated into an improvement in daily production that averaged 41% among those wells and 19% across the sample.

FIGURE 1

B_4C Coupling

Evaluation Details

Chesapeake uses B_4C couplings in rod string sections that have greater than 200 pounds of side load modeled before rod string installation. These higher side load areas tend to show greater coupling and tubing wear resulting from higher friction and abrasive wear over time. The company also puts B_4C couplings in the string in areas where it sees abnormal coupling wear when pulling rod strings out of hole during workovers.

Total well depths in this study averaged 8,792 feet and ranged from 6,975 feet to 10,450 feet. All these wells historically had mechanical wear and abrasion issues from sand, side load and friction within the rod string. Pump outer diameters ranged from 1.25 inches to 2.00 inches, which remained constant for the before and after assessment (i.e., no pump sizes were changed). To reduce the noise from varying wellbore conditions, only days that had oil production greater than 60% of the well's forecast were considered in the analysis. Well data was pulled, and various metrics were compared before and after the B_4C couplings' installation.

As Table 1 indicates, the wells' performance varied. However, all wells showed some level of improvement following the couplings' installation. Because each well has its own characteristics, it is difficult to pinpoint why some wells demonstrated better lifting efficiency than others. The data does indicate that the couplings' ability to reduce friction contributes in general to better lifting efficiency. The more B_4C couplings installed within the rod string, the greater lifting efficiency tended to be.

To further assess the lower friction of B_4C couplings, an experiment was conducted to compare the coefficient of friction (CoF) of B_4C couplings against spray metal (SM) and class T couplings on

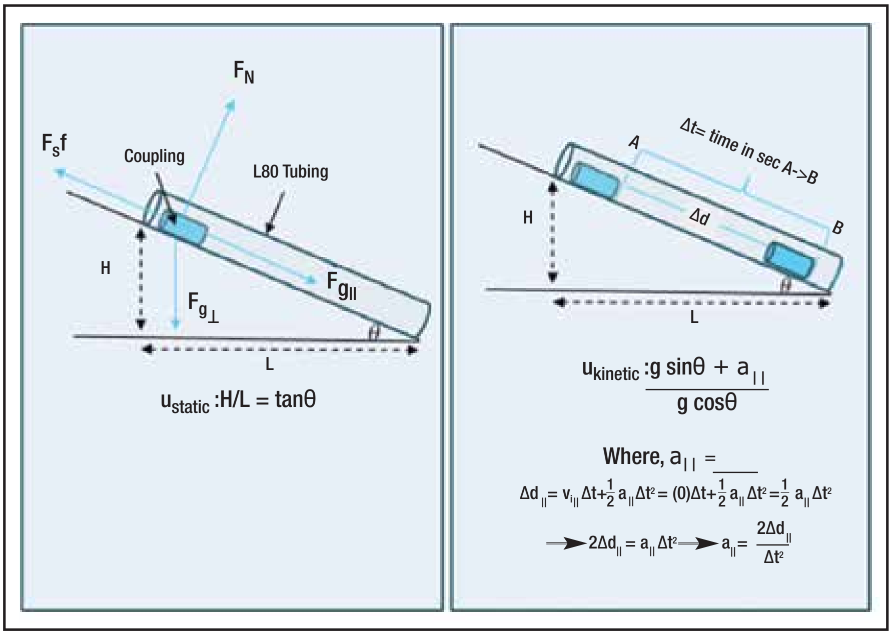
TABLE 1

Well Data Summary

Well	# CPLGS	Well Depth (ft)	Pump Size	Peak Load Change	Adj. PPRL Change	Gross Stroke Change	Net Load Change	Oil Prod. % Gain / Loss	Average Side Load–B_4C Section	Max Side Load–B_4C Section
A	100	6,975	1.50	(1,541)	(2,395)	1	1,749	170%	–	–
B	64	7,250	1.75	1480	768	1	147	56%	44.9	71.4
C	120	9,525	1.50	(139)	(122)	3	(246)	-10%	120.3	140.4
D	73	10,450	1.50	(1,440)	(888)	21	275	15%	59.7	64.4
E	149	10,175	1.50	(980)	(184)	2	(1,176)	93%	146.8	186.6
F	58	6,950	1.75	774	752	7	(53)	22%	21.7	27.9
G	68	10,150	1.25	1,204	(1,514)	(22)	(1,708)	23%	99.8	99.8
H	111	7,625	1.75	(2,618)	484	11	(229)	18%	75.0	223.6
I	74	7,075	1.50	(331)	1,494	(5)	287	38%	41.2	114.2
J	107	8,200	1.50	929	9	(6)	(240)	13%	46.8	72.0
K	68	9,750	1.50	(788)	510	11	352	2%	106.9	119.5
L	71	9,700	1.50	(39)	94	(2)	1,514	-8%	70.7	135.7
M	66	7,200	1.75	(1,966)	(1,382)	(17)	(10,162)	33%	106.9	193.9
N	80	9,983	2.00	(3,751)	(459)	8	(217)	-21%	57.7	72.3
O	71	8,425	1.50	(820)	52	2	(288)	-12%	87.8	167.7
P	75	8,200	1.75	(1,174)	(423)	(4)	(1,150)	15%	122.6	144.2
Q	96	8,850	2.00	(1,592)	1,012	2	268	-4%	16.7	16.7
R	124	9,975	1.50	(1,958)	(2,205)	14	(1,523)	-51%	–	–
S	92	9,675	1.50	491	1,185	4	638	-11%	105.8	145.6
T	57	9,700	1.50	2,455	(941)	(25)	25	-5%	70.0	95.8
Average–All Wells	86	8,792	1.60	(590)	(208)	0	(587)	19%	77.9	116.2

FIGURE 2

Static (left) and Kinetic (right) Coefficient of Friction



L80 tubing. This experiment involved two phases (Figure 2).

In the first phase, single couplings were used to calculate the CoF of each coupling. Ten observations of each coupling were recorded and averaged to determine the CoF for each coupling type.

The second phase aimed to determine if additional couplings could influence the overall CoF. In this phase, two couplings of each type were connected together, the experiment was repeated, and observations were recorded and averaged to determine the CoF. Table 2 lists the results and comparison.

In both experiments, the B_4C couplings showed lower CoF than the SM and class T couplings. Given the small sample size, it is difficult to conclude that additional couplings lead to lower friction overall; however, the data does suggest it is plausible.

TABLE 2

Coefficient of Friction Experiment Results

CoF Results

Single Coupling	CoF-u_{static}	CoF-$u_{kinetic}$
	Single	Single
B_4C	0.1816	0.1568
T	0.3073	0.2714
SM	0.1964	0.1678

Double Coupling	CoF-u_{static}	CoF-$u_{kinetic}$
	Double	Double
B_4C	0.1679	0.1542
T	0.2728	0.2311
SM	0.1781	0.1660

Double v. Single	CoF-u_{static}	CoF-$u_{kinetic}$
B_4C	-8%	-2%
T	-11%	-15%
SM	-9%	-1%

Comparative Assessment

	CoF-u_{static}	B_4C	T	SM
B_4C	0.1816	■	-41%	-8%
T	0.3073	69%	■	56%
SM	0.1964	8%	-36%	■

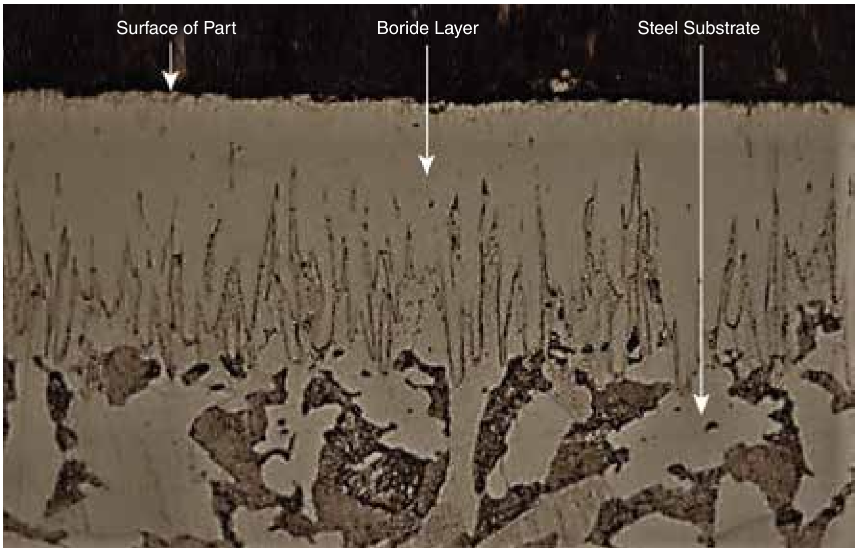
	CoF-$u_{kinetic}$	$B4_4C$	T	SM
B_4C	0.1568	■	-42%	-7%
T	0.2174	73%	■	62%
SM	0.1678	7%	-38%	■

	CoF-u_{static}	B_4C	T	SM
B_4C	0.1679	■	-38%	-6%
T	0.2728	63%	■	53%
SM	0.1781	6%	-35%	■

	CoF-$u_{kinetic}$	B_4C	T	SM
B_4C	0.1542	■	-33%	-7%
T	0.2311	50%	■	39%
SM	0.1660	8%	-28%	■

FIGURE 3

Microscopic View of a B_4C-Treated Surface



Why Friction Matters

A sucker rod pump system consists of a prime mover, a surface pump, sucker rod string and downhole pump. The prime mover provides energy to the surface pumping unit to drive the vertical reciprocating action that lifts and lowers the rod string connected to the downhole pump. This reciprocating action operates the downhole pump and allows it to displace wellbore fluid up the tubing, where it exits through the flowline at surface.

Many prime movers are electrical and consume a significant amount of energy. The monthly electrical bill typically is a large contributor to lease operating expenses, so system and lifting efficiency are of utmost importance to the production engineer. Friction substantially reduces the system's lifting efficiency and drives up operating costs.

At the same time, the friction from the downhole drag of components against the tubing causes mechanical wear. Therefore, lessening friction throughout the system can improve equipment reliability and run times while reducing the energy required to operate the system.

Chesapeake uses B_4C couplings to address mechanical wear and abrasion issues in SRP systems and considers the increase in lifting efficiency and extra production ancillary benefits. Since the initial evaluation, Chesapeake has deployed several thousand more couplings across the asset base and now has the couplings installed in more than 170 wells. Of all the installations thus far, there have been zero coupling or tubing failures associated with the B_4C couplings.

The B_4C treatment creates a slick, hard, intermetallic boride layer that (unlike coatings or plating) does not alter the dimensions of the part. The slickness, hardness and corrosion resistance the treatment provides slows wear by protecting the couplings from abrasion and corrosion. The slick surface exhibits a lower coefficient of friction than the base metal or current industry coatings, which translates into a permanent characteristic of lubricity regardless of load, a key factor highlighted in the evaluation.

In both lab tests and field trials, the surface hardness created by thermal boron-diffusion has outperformed chrome, nickel carbides and standard hardness coatings. The surface hardness of treated parts acts to reduce abrasion and mechanical wear, leading to longer product life. With near-zero porosity, the treated surface exhibits excellent corrosion resistance. In lab tests, the couplings had no signs of surface loss after spending 48 hours submerged in acid.

Treatment Process

B_4C treatment is a form of surface hardening in which boron is diffused into the steel substrate. The process results in a diffused layer of boron at the surface of the substrate (Figure 3). While the treatment is not appropriate for some materials, such as copper, aluminum and resulfurized steel, it works on many ferrous and nonferrous materials used in the oil and gas industry.

Endurance Lift Solutions' B_4C treatment technology, which the company markets under the trade name BLAZE®, combines proprietary chemistry with heat to enhance a steel parts' surface. Boron atoms migrate into the treated material during the treatment process, converting the surface to a condition such as iron, nickel, cobalt or chrome boride, depending on the substrate alloy.

As Chesapeake's evaluation shows, the engineered surface reduces friction. In conjunction with extreme hardness and abrasion resistance, as well as excellent corrosion resistance, this feature enables treated parts to outlast untreated parts in challenging conditions.

It's worth emphasizing that the treatment is not a coating or plating that is applied to the surface. Instead, it is a thermal diffusion treatment that creates an intermetallic boride layer within the metal surface. This intermetallic layer cannot crack or peel.

Unlike coating or plating methods, the diffusion process does not change parts' dimensions. This eliminates the cost, time and potential for mistakes associated with under-machining parts to accommodate a new coating or plating layer.

The treatment can be applied not only to couplings but to trim kits, plungers, pump components and related equipment. ❒

BO BROOKS

Bo Brooks is a production engineer with INEOS Energy Corp., which he joined from Chesapeake Energy Corp. in mid-2023, when INEOS acquired the wells discussed in this article alongside other Eagle Ford assets. Brooks' artificial lift experience includes overseeing wells on rod pump, gas lift, gas-assisted plunger lift and plunger lift. Since he began his oil field career as a roustabout intern at Southwestern Energy, he has worked in Appalachia, Texas and Oklahoma. Brooks holds a B.S. in petroleum engineering from the Missouri University of Science and Technology.

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Editor's Note: This article is based on "Boron-Carbide Treated Couplings Improve Rod Lift Efficiency in South Texas Wells," a presentation given at the Artificial Lift Research & Development Council's 2023 Sucker Rod Pumping Workshop, which took place Aug. 28-31 in Midland. The full presentation includes more details on four of the 20 sample wells.

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