BORON-CARBIDE TREATED ROD PUMP PARTS INCREASE RUN TIMES IN CHALLENGING CONDITIONS

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ABSTRACT

This paper explores the application of boron-carbide (B_4C) treated rod pump parts in sucker rod pump (SRP) wells as a solution to the challenges posed by modern-day drilling and completions practices. These practices often result in sandy, corrosive, and highly deviated wellbores, leading to increased wear, frequent interventions, and downtime in rod lift systems. The paper highlights the improved run times a large producer in the Permian Basin was able to achieve by utilizing boron-carbide treated components in their sucker rod pumped wells. The evaluation assesses the run time performance of a sample of 60 wells, with a focus on 30 wells with prior run-time and failure mode history established. The results showed improved run times in many of the wells evaluated and highlights the components and configurations used. The paper further discusses the B_4C treatment technology and the potential in enhancing the performance and longevity of various artificial lift equipment.

INTRODUCTION

Rod Lift, or sucker rod pumping, is one of the most prevalent forms of artificial lift used for oil extraction. Throughout the Permian Basin, this form of lift is easily recognizable by the pumping units dotting the landscape. These units, energized by a prime mover, drive the vertical reciprocating action that lifts and lowers the rod string connected to a downhole pump located below the surface. Relatively simple in concept, rod lift systems have evolved to meet the challenges of a changing production environment. New equipment designs, materials, and other solutions have been introduced to extend equipment longevity and reliability, even in the sandy, corrosive, and highly deviated wellbores associated with today’s drilling and completions practices. These downhole conditions pose significant challenges to operators using rod lift, which can include excessive wear, more frequent wellbore interventions, and increased downtime.

A large producer in the Permian Basin was facing similar challenges with their sucker rod pump wells and, in 2018, began utilizing boron-carbide (B_4C)- treated components in their downhole pumps as a potential solution. The producer’s goal was to address premature wear and short run-time performance as they pursued fluid levels deeper downhole. Previously, as the producer placed pumps deeper in the wellbores, they would be set at increasingly higher deviations. The angle of the pumps in these deviated areas would naturally increase stress on pump components, most notably components located at the top of a pump. The added stress would result in excessive mechanical wear of these pump components, causing pumps to fail.

To assess the benefits of utilizing B_4C-treated components, an evaluation of sixty wells was conducted.

EVALUATION

For this evaluation, sixty (60) wells were analyzed to assess the performance achieved by incorporating B_4C-treated components into the downhole pump design. The wells reviewed had pump systems installed between the years 2018 and 2022. Historical failure modes were primarily attributed to wear and tear, sand or solids, corrosion, or a combination of these factors [Figure 1].

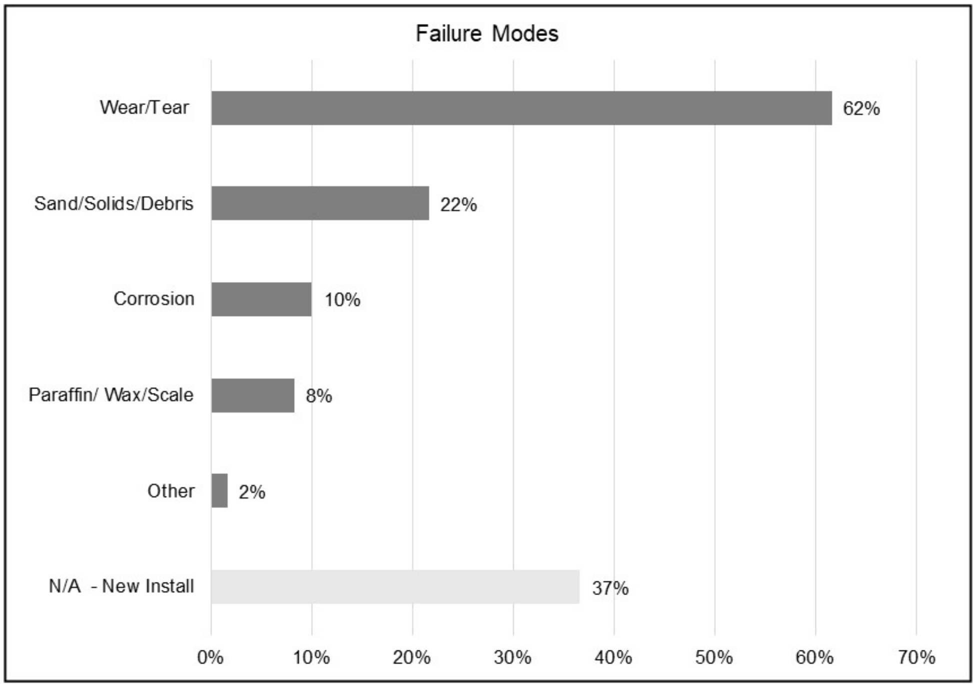

Figure 1 – Historical failure modes of initial 60 well sample
(Note: Percentages total more than 100% due to some wells having multiple failure modes.)

RUN-TIME COMPARISON

Table 1 reflects the initial run-time assessments for the 60 wells sampled. It's important to note that of the 60 wells evaluated, fifty percent (50%) had no comparison data as they were either new installs or had no prior run-time history recorded. Nonetheless, the improved run-time performance of the pumps with B_4C-treated components was noteworthy.

Table 1. Average run-time performance of untreated vs B4C-treated components as of April 2024

Total Wells Evaluated	60		
Wells with Comparison Data:	30	Run-Time (days)	
		Untreated	B4C-treated
	Max	1268	1316
	Min	36	283
	Average	531	789
Wells without Comparison Data*:	30	Run-Time (days)	
		Untreated	B4C-treated
	Max	n/a	1960
	Min	n/a	476
	Average	n/a	948
*New installs (ESP to Rod Pump conversion) or no prior run-time history available.			

Since half of the wells had no comparison data, they were omitted from further evaluation; however, it is worth noting that only one well in this sample set had been pulled - the remaining 29 installs were still running and had an average run-time of 948 days.

The remaining 30 wells with comparison data were further evaluated to assess the performance achieved by utilizing B_4C-treated components vs untreated components. Table 2 highlights the run-time comparison of B_4C-treated components vs untreated components for the same wells. Of these 30 comparison wells, 23 were still in operation during the evaluation in April 2024.

As Table 2 reflects, since using B_4C-treated components, the wells have an average run-time of over 26 months - approximately nine months longer than prior run times when untreated components were used for the same wells.

Table 2. Run-time comparison of untreated vs B_4C-treated components – Same Wells as of April 2024

				(Days)		(Months)	
WELL NAME	TVD	WELL TYPE	FORMATION	Untreated	B4C-treated	Untreated	B4C-treated
WELL 1	7,656	HORIZONTAL	WOLFCAMP A	482	1007	16.1	33.6
WELL 2	9,955	HORIZONTAL	WOLFCAMP B UPPER	307	1008	10.2	33.6
WELL 3	11,245	VERTICAL	MIDLAND VERTICAL	858	618	28.6	20.6
WELL 4	10,951	HORIZONTAL	WOLFCAMP A UPPER	420	616	14.0	20.5
WELL 5*	10,398	VERTICAL	MIDLAND VERTICAL	124	524	4.1	17.5
WELL 6	9,314	HORIZONTAL	LOWER SPRABERRY	251	1115	8.4	37.2
WELL 7*	9,325	HORIZONTAL	LOWER SPRABERRY	1154	426	38.5	14.2
WELL 8*	9,240	HORIZONTAL	LOWER SPRABERRY	594	520	19.8	17.3
WELL 9*	9,109	HORIZONTAL	LOWER SPRABERRY	117	322	3.9	10.7
WELL 10	9,256	HORIZONTAL	LOWER SPRABERRY	738	1072	24.6	35.7
WELL 11	9,178	HORIZONTAL	LOWER SPRABERRY	109	1220	3.6	40.7
WELL 12	9,608	VERTICAL	MIDLAND VERTICAL	1175	812	39.2	27.1
WELL 13	10,853	VERTICAL	MIDLAND VERTICAL	964	846	32.1	28.2
WELL 14	9,931	HORIZONTAL	WOLFCAMP B LOWER	455	1186	15.2	39.5
WELL 15	9,992	HORIZONTAL	WOLFCAMP B LOWER	1016	1085	33.9	36.2
WELL 16	9,909	HORIZONTAL	WOLFCAMP B LOWER	694	1316	23.1	43.9
WELL 17	9,904	HORIZONTAL	WOLFCAMP B UPPER	1268	882	42.3	29.4
WELL 18	9,327	HORIZONTAL	LOWER SPRABERRY	112	801	3.7	26.7
WELL 19*	11,009	HORIZONTAL	3RD BONE SPRING SAND	36	590	1.2	19.7
WELL 20*	11,069	HORIZONTAL	3RD BONE SPRING SAND	342	283	11.4	9.4
WELL 21	11,062	HORIZONTAL	3RD BONE SPRING SAND	537	1177	17.9	39.2
WELL 22	10,497	HORIZONTAL	3RD BONE SPRING SAND	291	555	9.7	18.5
WELL 23	10,782	HORIZONTAL	WOLFCAMP B LOWER	122	521	4.1	17.4
WELL 24*	11,021	HORIZONTAL	3RD BONE SPRING SAND	511	547	17.0	18.2
WELL 25	10,453	HORIZONTAL	3RD BONE SPRING SAND	134	532	4.5	17.7
WELL 26	11,603	HORIZONTAL	WOLFCAMP C	156	563	5.2	18.8
WELL 27	8,131	HORIZONTAL	WOLFCAMP A	355	928	11.8	30.9
WELL 28	7,923	HORIZONTAL	LOWER SPRABERRY	897	934	29.9	31.1
WELL 29	8,226	HORIZONTAL	WOLFCAMP A	727	916	24.2	30.5
WELL 30	8,261	HORIZONTAL	WOLFCAMP A	979	757	32.6	25.2
			AVERAGE	531	789	17.7	26.3
					Days		Months
Average Incremental Run-Time, B4C-treated vs Untreated Materials - Same Wells				>>>	258	>>>	8.6
*Pump pulled. All others still active.							

PUMP COMPONENTS USED

The most commonly used components contributing to the run-time improvements include the rod guide, collet and nut, and top valve cage [Image 1]. Each of these components is found at the top of the pump and serves a critical role in the operation of the downhole pump. In addition, these parts are subject to extreme mechanical wear when pumps are set in deviated areas.

Image 1 – Commonly used components

Table 3 highlights the most commonly used components and the average run-time days of B_4C-treated components vs untreated components.

Table 3. Most commonly used B_4C-treated components and average run-time comparison

		Average Run-Time (days)		
Component	Description	Untreated	B4C-treated	Run-time Multiple
Cage	CGE 1-7/8" 2WG W/3/4"PIN	509	889	1.75x
Bushing Nut	BSG B75N20-113 NUT HT OTC	495	872	1.76x
Rod Guide	GDE G63-20 HPT RW CLT	473	877	1.85x
Collet	BSG B75C20-113 COL HT OTC	558	895	1.6x
Bushing Nut	BSG B21N25 NUT VR TO SR	558	748	1.34x
Collet	BSG B21C25 COL VR TO SR	598	750	1.26x
Rod Guide	GDE G12-25-125 VR BX VRT P	627	1004	1.6x
Spiral Guide	GDE G72-206 SPIRAL BxP	915	872	.95x
Collet	BSG B75C25 COL HT OTC	654	761	1.16x
Bushing Nut	BSG B75N25 NUT HT OTC	654	761	1.16x
Cage	CAGE, 3W 3/4P TOP PLGR	654	761	1.16x
Rod Guide	GDE G63-25 HPT RW CLT	729	736	1.01x
Rod Guide	GDE G63-20-125 HPT RW CLT	592	1145	1.93x
Collet	BSG B75C20-094 COL HT OTC	395	730	1.85x
Bushing Nut	BSG B75N20-094 NUT HT OTC	395	705	1.78x
Rod Guide	GDE G12-25 VR BX VRT PRT	274	741	2.71x
Barrel Connector	CON, C21- BBL UPPER 2-1/2	537	1177	2.19x

Table 4 highlights the most frequently used combination of components and the average run-time comparison of B_4C-treated components vs untreated components.

Table 4. Most frequently used combination of B_4C-treated components and average run-time comparison

			Average Run-Time (days)		
Combination	Component	Description	Untreated	B4C-treated	Run-time Multiple
Combo A - HVR Pump	Cage Bushing Nut Collet Rod Guide	CGE 1-7/8" 2WG W/3/4"PIN BSG B75N20-113 NUT HT OTC BSG B75C20-113 COL HT OTC GDE G63-20 HPT RW CLT	509	883	1.74x
Combo B - API Pump	Bushing Nut Collet Rod Guide	BSG B21N25 NUT VR TO SR BSG B21C25 COL VR TO SR GDE G12-25-125 BLZ VR BX VRT P	594	834	1.4x

Based on the initial evaluation, it was evident that B_4C-treated components contributed to improved run-time performance. Given the success achieved, the producer has standardized on B4C-treated pump components to address wear-related issues and extend run times for over 300 wells in the Permian Basin.

But there was more to learn.

FURTHER EVALUATION

Approximately seven months after the initial evaluation concluded, a follow-up review was conducted to further assess run-life performance of the remaining wells in service along with a deeper dive related to the part level performance of B_4C-treated vs untreated materials for the entire 30 well sample. For clarity, this secondary review only focused on the original 30 wells with comparison data and had two primary objectives. The first objective was to review the run-time performance of the 23 wells that remained in operation and secondly, review the product and material level performance of all 30 wells.

Recall, table 2 highlighted that the average run times of wells with B_4C-treated components ran approximately 9 months longer than the untreated components in the same wells, and, at the time of the evaluation, only 7 wells had pumps with B_4C-treated components pulled. Since the original evaluation, five additional wells have been pulled bringing the count of wells pulled to twelve or 40% of the total sample set.

Table 5 is a refresh of the original table 2 and reflects the updated runtime comparisons across the 30 wells. The updated runtimes reveal that the B_4C-treated components achieved nearly a 14-month runtime improvement over the untreated components.

Table 5. Updated run-time comparison of untreated vs B_4C-treated components – Same Wells as of November 2024

				(Days)			(Months)		
WELL NAME	TVD	WELL TYPE	FORMATION	Untreated	Original Eval B4C-treated	Updated B4C-treated	Untreated	Original Eval B4C-treated	Updated B4C-treated
WELL 1	7,656	HORIZONTAL	WOLFCAMP A	482	1007	1224	16.1	33.6	40.8
WELL 2**	9,955	HORIZONTAL	WOLFCAMP B UPPER	307	1008	1096	10.2	33.6	36.5
WELL 3	11,245	VERTICAL	MIDLAND VERTICAL	858	618	835	28.6	20.6	27.8
WELL 4	10,951	HORIZONTAL	WOLFCAMP A UPPER	420	616	833	14.0	20.5	27.8
WELL 5*	10,398	VERTICAL	MIDLAND VERTICAL	124	524	524	4.1	17.5	17.5
WELL 6	9,314	HORIZONTAL	LOWER SPRABERRY	251	1115	1331	8.4	37.2	44.4
WELL 7*	9,325	HORIZONTAL	LOWER SPRABERRY	1154	426	426	38.5	14.2	14.2
WELL 8*	9,240	HORIZONTAL	LOWER SPRABERRY	594	520	520	19.8	17.3	17.3
WELL 9*	9,109	HORIZONTAL	LOWER SPRABERRY	117	322	322	3.9	10.7	10.7
WELL 10	9,256	HORIZONTAL	LOWER SPRABERRY	738	1072	1289	24.6	35.7	43.0
WELL 11**	9,178	HORIZONTAL	LOWER SPRABERRY	109	1220	1387	3.6	40.7	46.2
WELL 12	9,608	VERTICAL	MIDLAND VERTICAL	1175	812	1029	39.2	27.1	34.3
WELL 13	10,853	VERTICAL	MIDLAND VERTICAL	964	846	1063	32.1	28.2	35.4
WELL 14	9,931	HORIZONTAL	WOLFCAMP B LOWER	455	1186	1403	15.2	39.5	46.8
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WELL 16	9,909	HORIZONTAL	WOLFCAMP B LOWER	694	1316	1532	23.1	43.9	51.1
WELL 17	9,904	HORIZONTAL	WOLFCAMP B UPPER	1268	882	1099	42.3	29.4	36.6
WELL 18	9,327	HORIZONTAL	LOWER SPRABERRY	112	801	1018	3.7	26.7	33.9
WELL 19*	11,009	HORIZONTAL	3RD BONE SPRING SAND	36	590	590	1.2	19.7	19.7
WELL 20*	11,069	HORIZONTAL	3RD BONE SPRING SAND	342	283	283	11.4	9.4	9.4
WELL 21	11,062	HORIZONTAL	3RD BONE SPRING SAND	537	1177	1394	17.9	39.2	46.5
WELL 22	10,497	HORIZONTAL	3RD BONE SPRING SAND	291	555	772	9.7	18.5	25.7
WELL 23	10,782	HORIZONTAL	WOLFCAMP B LOWER	122	521	738	4.1	17.4	24.6
WELL 24*	11,021	HORIZONTAL	3RD BONE SPRING SAND	511	547	547	17.0	18.2	18.2
WELL 25	10,453	HORIZONTAL	3RD BONE SPRING SAND	134	532	749	4.5	17.7	25.0
WELL 26**	11,603	HORIZONTAL	WOLFCAMP C	156	563	750	5.2	18.8	25.0
WELL 27**	8,131	HORIZONTAL	WOLFCAMP A	355	928	1008	11.8	30.9	33.6
WELL 28	7,923	HORIZONTAL	LOWER SPRABERRY	897	934	1151	29.9	31.1	38.4
WELL 29	8,226	HORIZONTAL	WOLFCAMP A	727	916	1133	24.2	30.5	37.8
WELL 30**	8,261	HORIZONTAL	WOLFCAMP A	979	757	918	32.6	25.2	30.6
			AVERAGE	531	789	942	17.7	26.3	31.4
					Days	Days		Months	Months
Average Incremental Run-Time, B4C-treated vs Untreated Materials - Same Wells				>>>	258	>>> 411	>>>	8.6	>>> 13.7
*Pump pulled (initial eval.).**Pump pulled (updated eval). All others still active.									

Table 6 provides a summary of the runtime comparison of pulled and active wells. As table 6 highlights, the wells pulled with B_4C-treated components achieved a 10-month run-time improvement. Whereas the active wells have achieved greater than 16 months of run-time improvement.

Table 6. Summary run-time comparison pulled and active wells – untreated vs B_4C-treated components

		(Days)				(Months)		
		Untreated	B4C-treated	Delta	Perf. Multiple	Untreated	B4C-treated	Delta
Total Pulled	12	399	698	299	1.75x	13.3	23.3	10.0
Total Active	18	619	1105	486	1.79x	20.6	36.8	16.2
All Wells	30	531	942	411	1.77x	17.7	31.4	13.7

To further assess the performance of B_4C-treated vs untreated materials, a component level analysis was conducted for each well using actual pump teardown reports to determine the frequency of usage, failure modes, and material types used in the pumps. It is important to note that not all pumps utilize every component in the pump design, therefore, the total component count may be less than the total well count of 30.

Table 7 is a breakout of the failure modes, usage and material types of the untreated vs B_4C-treated components (i.e., top valve cage, bushing, collet, and guide) for the 30 well sample.

Table 7. Component Detail – Failure modes, usage and material type – untreated vs B_4C-treated

	Components Used							
	TV Cage		Bushing		Collet		Guide	
	Untreated	B4C-treated	Untreated	B4C-treated	Untreated	B4C-treated	Untreated	B4C-treated
Well Count with Component Type Installed	20	24	29	29	23	28	30	30
% of Wells Using Component	67%	80%	97%	97%	77%	93%	100%	100%
Failure Modes: Wear	3	1	8	3	9	2	8	3
Wear/Corrosion	2		2		2		2	
Wear/Corrosion/Solids	1		2		2		1	
Wear/Sand/Solids	4	4	8	4	6	4	7	5
Wear/Scale	1		1				1	1
Failure Total	**11**	**5**	**21**	**7**	**19**	**6**	**19**	**9**
Other - Assembly Change Out Total	5		4		3	1	5	
Good Total	**4**	**19**	**4**	**22**	**1**	**21**	**6**	**21**
% of Components Failed	55%	21%	72%	24%	83%	21%	63%	30%
% of Components Good	20%	79%	14%	76%	4%	75%	20%	70%
Failure Rate Multiple - Untreated vs B4C Treated Components	2.6x		3.x		3.9x		2.1x	
Material Types Used:	Untreated	B4C-treated	Untreated	B4C-treated	Untreated	B4C-treated	Untreated	B4C-treated
Stainless Steel, Untreated	20	0	28	0	22	0	20	0
Steel, Untreated	0	0	1	0	1	0	10	0
Stainless Steel, B4C-treated	0	16	0	4	0	4	0	1
Steel, B4C-treated	0	8	0	25	0	24	0	29

Table 7 offers a few key insights related to the untreated vs B_4C-treated components. First, the most common failure modes of the untreated and B_4C-treated components were very similar with mechanical wear and wear from sand or solids being the most dominant. Secondly, the failure rate of untreated components was much higher overall than B_4C-treated components – 2.6x higher for top valve cages, 3.0x -3.9x for bushings/collets, and 2.1X for guides. Lastly, for some components there was a shift in the types of material types used for the various components. Except for the top valve cage, there was a substantial shift from using untreated stainless steel for many of the bushing, collet and guides to using B_4C-treated steel versions after the initial failures.

Table 8 further compares the failure rates of untreated vs B_4C-treated pump components.

Table 8. Comparison of failure rate by component type and materials used

		Pumps with Untreated Components					Pumps with B4C-Treated Components				
Component Type		Usage	ASC	Fails	Good	% Fail	Usage	ASC	Fails	Good	% Fail
Cages	Stainless Steel, Untreated	20	5	11	4	55%	-	-	-	-	-
	Steel, Untreated	-	-	-	-	-	-	-	-	-	-
	Stainless Steel, B4C-treated	-	-	-	-	-	16	-	3	13	19%
	Steel, B4C-treated	-	-	-	-	-	8	-	2	6	25%
	Sub-Total	**20**	**5**	**11**	**4**	**55%**	**24**	**0**	**5**	**19**	**21%**
Bushing	Stainless Steel, Untreated	28	4	21	3	75%	-	-	-	-	-
	Steel, Untreated	1	-	-	1	-	-	-	-	-	-
	Stainless Steel, B4C-treated	-	-	-	-	-	4	-	2	2	50%
	Steel, B4C-treated	-	-	-	-	-	25	-	5	20	20%
	Sub-Total	**29**	**4**	**21**	**4**	**72%**	**29**	**0**	**7**	**22**	**24%**
Collet	Stainless Steel, Untreated	22	3	18	1	82%	-	-	-	-	-
	Steel, Untreated	1	-	1	-	100%	-	-	-	-	-
	Stainless Steel, B4C-treated	-	-	-	-	-	4	-	1	3	25%
	Steel, B4C-treated	-	-	-	-	-	24	1	5	18	21%
	Sub-Total	**23**	**3**	**19**	**1**	**83%**	**28**	**1**	**6**	**21**	**21%**
Guide	Stainless Steel, Untreated	20	4	13	3	65%	-	-	-	-	-
	Steel, Untreated	10	1	6	3	60%	-	-	-	-	-
	Stainless Steel, B4C-treated	-	-	-	-	-	1	-	-	1	-
	Steel, B4C-treated	-	-	-	-	-	29	-	9	20	31%
	Sub-Total	**30**	**5**	**19**	**6**	**63%**	**30**	**0**	**9**	**21**	**30%**

In all cases, untreated components had a higher failure rate than the B_4C-treated components. For instance, stainless steel cages had a 55% failure rate compared to a 19% failure rate for B_4C-treated stainless steel cages. Stainless steel bushings had a 75% failure rate compared to 20% for B_4C-treated steel versions. Similarly stainless steel collets had a failure rate of 82% compared to 21% for B_4C-treated steel versions, whereas stainless steel guides had a 65% failure rate compared to 31% for B_4C-treated steel guides.

B4C SURFACE TREATMENT

B_4C surface 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 [Image 2]. The slickness, hardness, and corrosion resistance of B_4C treatment slows wear by protecting parts from the effects of abrasion, erosion, and corrosion. Combining extreme hardness and abrasion resistance with excellent corrosion resistance, B_4C treatment is proven to enable treated parts to outlast untreated parts in even some of the most challenging conditions.

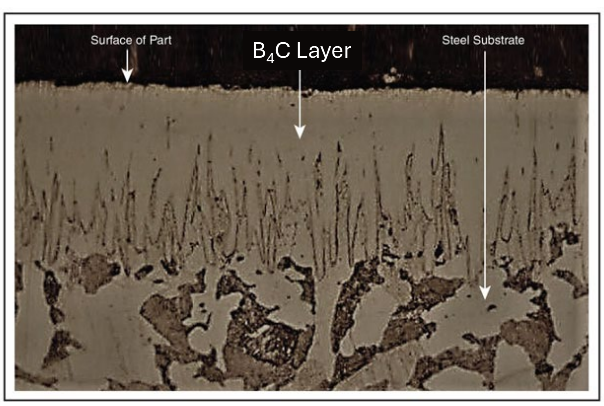

Image 2 – Microscopic view of B_4C diffused layer

CONCLUSION

As the data has shown, B_4C-treated components have had a significant influence on the runtime performance level of the sucker rod pumped wells evaluated. Further, the B_4C-treated materials have shown to have a lower failure rate compared to untreated materials for the product types used. It is thus no surprise that the producer has standardized on B_4C-treated materials when facing challenging downhole conditions. B_4C- treated components are a viable option when considering ways to address mechanical wear, abrasion and corrosion in various artificial lift applications.