METALLURGY

Boron hardening makes combine parts last longer

Modern combines have more power, which exerts greater pressure on the processing unit and creates new "weakest links." Rasp bars, concaves, rotors and chopper blades wear faster. An Alberta company may have a solution — boron. ~ Ron Lyseng

WP photos / Michael Raine

Boron hardening may hold the secret to longevity for combine parts, according to Gerald Foster of Sunnybrook Welding.

A CHAIN IS ONLY as strong as the weakest link. You strengthen that link, only to find that a different component is the new weakest link. So it is with the modern combine, according to Gerald Foster, president of Sunnybrook Welding in Sunnybrook AB.

"The high throughput of the modern combine is very demanding on wear parts," says Foster. "The power and capacity of the modern combine has grown to meet producers' demands. There's no doubt of that. But all that new capacity is going through a processor about the same size as it was in the 1970s.

"This puts a tremendous demand on the wear parts. The volume of after-market chrome-plated combine parts increased 10-fold from 1993 to 1997. Think of this. A big combine used to be 150 horsepower, of which 60 horsepower was required to move the machine around your field. Today it's 300 horsepower, yet it takes about the same 60 horsepower to move the combine. All that extra power is available to the farmer for processing grain.

"A class six conventional combine has a 60-inch to 65-inch cylinder width. A class seven is 65 inches to 70 inches. We can push a lot more product through the combine today, but the bulk of that grain still is concentrated at the centre of the cylinder, regardless of how wide you make it."

Ray Steukle revisited

Farmers are back in the spot they were 25 years ago, when Ray Steukle told them what was wrong with combines. But the reasons are different. Manufacturing technology is better today, so cylinders and concaves are better. But surface-hardening technology has become the new weak link in the chain.

Foster says a modern cylinder and concave might each have a one-eighth-inch flex in the centre, creating a quarter-inch gap. But the problem is more difficult to identify today, because manufacturers use higher-grade steel that springs back to its original shape when the combine stops.

"High quality material like 1040 and 1045 is now being used. You set up the combine with no product on the concave and it looks great. But when you're running, it sags in the middle. When you stop, it bounces back and your settings look good again," says Foster.

"Now compound this flex problem with metal loss you're experiencing in those high wear areas because of the higher capacity, and you can be throwing a lot of grain out the back."

Chrome plate chips

"When you use chrome to harden those high wear surfaces, the wear problem occurs very rapidly once the chrome layer begins to chip off. Chrome treatment doesn't actually harden your metal surface at all. It merely adds a layer that's anywhere from 10 thousandths to 14 thousandths of an inch thick. The metal actually grows in size. You compensate for this when you make your cylinder adjustments," he says.

According to Foster, chrome usually doesn't wear thinner. It's so hard that it maintains its thickness until it chips off in pieces called agglomerates. When the chips start to come off, there is bare metal in those spots. With no protection, the metal wears quickly.

"An operator will notice two problems simultaneously when the chrome surface starts to go. You get cracked grain and you get unthreshed heads. The gap in the middle suddenly starts to open up, so you adjust to bring things closer. That pinches the outer ends, giving you cracked grain. Even with the adjustment, the gap in the middle quickly becomes larger as the metal wears, giving you unthreshed grain," Foster says.

"The basic problem is that chrome adds an extra layer to the original surface of the steel. And just like the chrome on a car bumper, it's temporary."

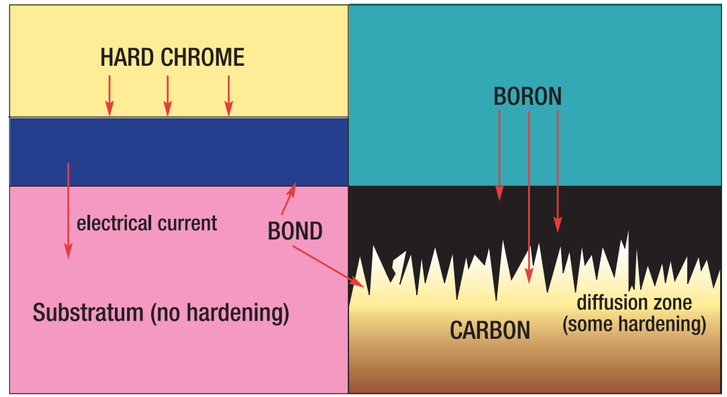
Tiger II tanks

Foster said he first thought about researching the boron process in his welding business after reading a history book about military armor. German engineers built their famous, battle-durable Tiger II tanks using boron treatment for the armor plating and the cannon barrel bore.

WP photo / Sunnybrook

This photo of boronized metal, magnified 100 times, shows a 0.006" layer plus sawtooth penetration deeper into the metal.

ELECTROPLATING VS. DIFFUSION ALLOYING



The sawtooth morphology of the boronized surface provides a well anchored layer, including a diffusion zone enriched with boron and displaced carbon.

Field tests

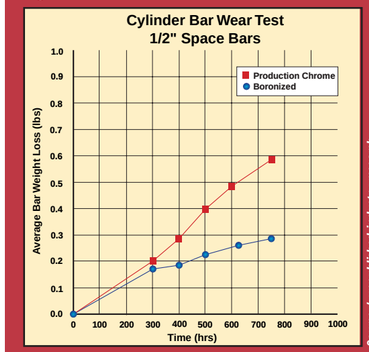
The boron treatment should make combine wear parts last three to five times longer than chrome plated wear parts, according to field tests conducted by Sunnybrook and by a major North American combine manufacturer.

Wear in combine components is measured by loss of weight in the steel. Parts are weighed before testing and again after testing. Cylinder bars in the test that have lost six-tenths of a pound are considered to have failed. They no longer function in the combine at the performance level specified by the manufacturer. As the cylinder bars approach the six-tenths of a pound loss, their effectiveness drops dramatically.

Tests conducted by the combine manufacturer documented wear in terms of hours on the machine along the bottom of the chart in Figure 1. The 750-hour test is roughly equivalent to 7,000 acres.

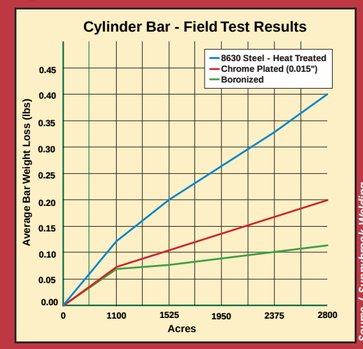
Losses in cylinder bar weight are on the left side of the chart. The company compared only chrome and boron. At the 300-hour mark, there was little difference between the two processes. But when the test stopped at 750 hours, the chrome bars had lost an average of six-tenths of a pound per bar. At this point, the bars were no longer doing their job. The boron treated bars experienced half the weight loss at this point.

Figure 1



Source / unpublished industry research

Figure 2



Source / Sunnybrook Welding

Foster says he can't disclose the name of the combine manufacturer because of negotiations to supply boron technology to the industry.

The independent Sunnybrook tests were based on acres rather than hours, as shown in Figure 2. They also used the weight loss method to measure component wear. They compared heat-treated 8630 steel, chrome plating at 0.015" and boron. This test was conducted on the abrasive volcanic soils in Oregon.

When they stopped the combines at 2,800 acres, the heat-treated steel bars had lost four-tenths of a pound, the chrome bars had lost two-tenths of a pound and the boron bars had lost one-tenth of a pound.

Foster says wear resistance is the main benefit of boron, but lower friction is tied into that overall package. The friction coefficient for boronized steel is 0.8, with chrome plating at 1.2.

He points out that lower friction reduces metal wear and also lets grain feed easily through the combine processor. There is less horsepower demand and less wear and tear on shafts, bearings and other components.

Boronizing allowed the Tiger IIs to be more effective because of the increased muzzle velocity and virtually impenetrable armor. They were strong enough to take a beating and continue functioning. Foster figured this combination was the criteria farmers needed in combine wear components.

Harvest in volcanic ash

The Alberta manufacturer says his first experimental work with boron treatment for combine parts was with farmers in the northwestern states of Idaho, Oregon and Washington. The volcanic ash in these soils is considered more abrasive than any other soil in North America. It's hard on all implements, not just combines.

In this harsh environment, farmers typically replace or rechrome the primary wear parts on their combines every year. The list of parts that see regular rechroming includes concaves, cylinder bars, straw choppers, augers and clean grain elevators. Farmers in this area who have tried the Sunnybrook boron hardening treatment report triple the life of their wear parts.

Foster finds that many western Canadian farmers recondition their combines every three or four years, depending on harvest conditions. In areas of the prairies with more abrasive soil, he says cylinder bars sometimes last only 500 hours before they need replacement.

Costs like chrome

There was some concern that boron would be too expensive. Sunnybrook engineers developed a process that brings the cost equal to chrome plating. Foster says he expects to have a boronizing facility up to full capacity in early 2001, with the goal of meeting all requests for boronized combine parts for the 2001 harvest. ■

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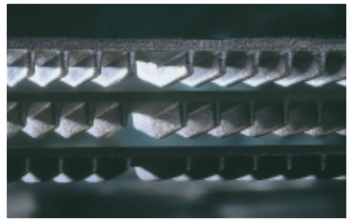
A welder at the company works on cylinder shims (below). Sunnybrook had to design its own polishing equipment to remove the boron crust from the finished parts. The machine allows the company to recover nearly all of the unused boron for recycling.

WP photos / Michael Raine



Top: Chrome plated rub-bar.
Middle: Boron treated rub-bar.
Bottom: Untreated rub-bar.

Figure 3

Wear Resistance Hardness Comparison

Hardness Procedure	Hardness Scale (Vickers)
Annealed	200 - 300
Carburized	750 - 900
Sand (quartz)	850 - 1050
Nitrided	800 - 1100
Chrome Plate	920 - 1000
Boronizing	1400 - 1900

Boron is a treatment, not a layer

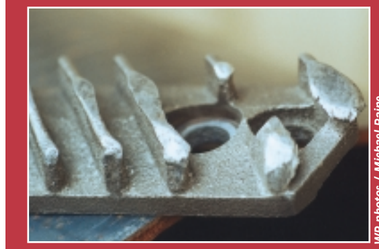
Boron is a non-metallic solid element that can penetrate and form an alloy with steel under high temperatures. It forms a molecular bond with the metal. Unlike chrome, boron does not add a layer to the original surface.

Chrome coating shows wear and surface chipping.

Traditional hardening treatments depend on high temperature to add carbon to steel. Boron treatment does the opposite. It removes carbon and other impurities from the steel, leaving a pure iron boride layer with boron as deep as 40 thousandths of an inch.

Rocks through the combine will damage boron-treated surfaces, but they are more likely to pound small dents onto the surface than chip pieces of metal away.

Foster explains: "Rocks will still impact a boronized surface, but they usually make a dent and push the boron deeper into the part without chipping it off, so there's no loss of steel. That's the advantage of a hardening process that becomes part of the existing surface, compared to something like chrome that adds new material on top of the original surface. The deeper the boron is pounded into the surface, the less chance for chipping and loss of material. The sub-strata retains some resistance to abrasion."



WP photos / Michael Raine

Boron-treated steel rub-bar after a rock impact.

The Vickers Scale is the internationally recognized system for rating the hardness of metal compounds. Figure 3 uses the Vickers Scale to compare steel hardened by annealing, carburizing, sand/quartz, nitriding, chrome plating and boronizing. The chart shows that boron hardening produces a surface at least six times harder than annealed steel.

Farmers' first impressions of boron

~ Ron Lyseng

EIGHT PRAIRIE FARMERS tested various types of boronized wear parts on a variety of different combine makes and models in fall 2000. Not all testers had finished harvest when this story was written, but the response was generally positive.

John Wright, Swift Current SK

John Wright has replaced the concave on his five-year-old R-62 Gleaner once and repositioned the separating bars once to get more acres out of them. He says the separating bars are ready for replacement.

Before harvest this year, Wright also replaced the rotor. He bought a new high-inertia rotor with boronized cylinder bars from Sunnybrook Welding. In September, he blew a gearbox, so he had the new rotor out while making repairs.

"There's absolutely no chips on these bars. We're at about 3,000 acres so far this year. Just looking, I know I would have already seen chips in the past on new chrome-plated bars. There are no chips. It's almost a gunmetal gray in color. They're not even polished up yet," said Wright.

"We don't have a lot of rocks here, but doing lentils, you can't help but pick up some rocks in the combine. With the chrome bars, they start chipping and when that happens, you can feel the rough chrome surface. Once you've lost that hard surface, it starts to wear down into the bar itself. But I haven't seen even a trace of that on these boron bars. There's no chipping at all so far. It's just the bar and the bar isn't showing us any wear yet.

"My experience has been that if there was going to be chipping, we would have seen it by now."

Wright says this is his first year with a high-inertia rotor and his first experience with the new boron-treated surface, so it may be difficult to determine which of the two factors has the biggest impact on his combine performance.

"It's a different bar configuration than I have ever used before, so we're really comparing two separate factors here. The combine performs totally differently. It feels very smooth, even in tough crops like green lentils. The crop just goes right through like you've always wanted. Now, whether this is because of the rotor design or the reduced friction due to the boron, I can't really say for sure.

"The one thing that is for sure is that our bar wear is greatly improved and the combine works better. When this combine gets traded in, that cylinder is coming out and I'm keeping it. I'd say that if the price of boron-treated parts is really going to be competitive with chrome, I would not have to think twice. I'll buy the boron parts."

Roger Welsh, Vegreville AB

Roger Welsh has two identical MF8680 combines, both extensively revamped with parts from Sunnybrook. In addition to replacing the cylinders, Welsh has upgraded to more aggressive beaters just behind the cylinders on each combine. Each unit does about 2,000 acres per year, working a bit more than 200 hours a year. Crops include peas, wheat, barley and canola.

Welsh says the problem isn't that parts wear out. That's to be expected. But the timing and speed of wear causes problems on the farm.

"Once the wear parts start to go, they really go. And that's always going to happen near the

WP photos / Michael Raine

Roger Welsh says the problem with combine wear parts is that they always deteriorate quickly right near the end of harvest when nobody wants to take the downtime to rebuild them.

"We have the highest implement wear anyplace on the continent."

end of the harvest when you don't want to stop and take the time to re-build the combine. So the tendency is to let it go and keep running until harvest is finished," he says.

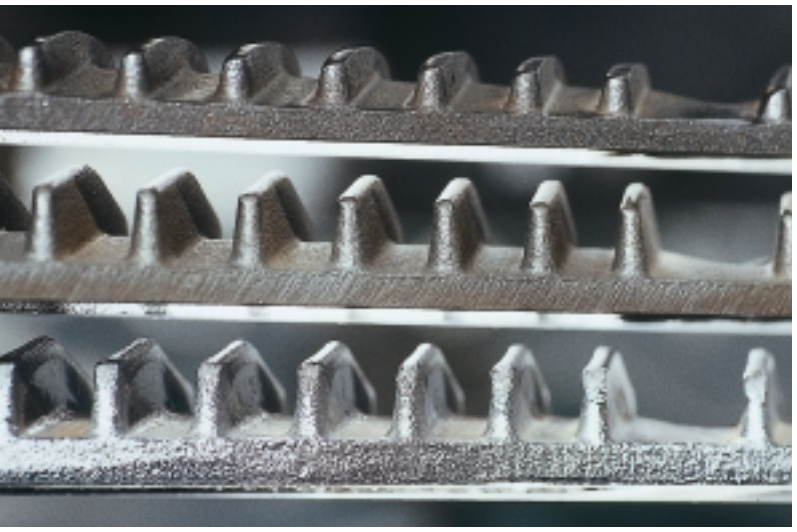
"Nobody minds doing this work in the off-season. But when you should be combining, the time and labor is a big factor. The hammers and knives on straw choppers aren't so hard to get to. But to pull a cylinder to change rub bars, when you should be out combining, is a bit of a job. It's never a good situation to be in."

Before harvest started this year, Welsh installed new boron-treated rub bars on one combine and new straw chopper knives on the other. Some of the new knives were boron-treated. Others were factory original equipment.

"Everything started fresh at zero hours. All the knives are brand new this year. At 40 hours, you can already see a substantial difference in the knives. The steel in the untreated straw chopper hammers is starting to polish off and they're starting to warp. The boron-treated hammers have a bit of a gloss to them, but that's all. There's no rounding off of any of the factory forging markings on the raw metal. Once we get a full season, we'll be in a better position to make a better judgment of the difference," he says.

"These 8680 straw choppers are made by Redekop. They're high-speed choppers and they force the material out quite a distance behind the combine. So these knives are very fast-wearing items. I don't know if this wear is common for all straw choppers, but I know I was concerned when I removed the original knives from last year. They only had 220 threshing hours and it looks like the steel is maybe good for only one more season.

"On the cylinder, we left the old rub bars from last year in place on the outside half and put the boron-treated rub bars on the middle, where they get more abuse. I looked in on these new rub bars, but I don't have enough hours yet to say anything for sure."



WP photos / Michael Raine

Top: Untreated worn steel.
Middle: Boronized, little wear.
Bottom: Chrome plated. Chrome chipped, cupping on vertical faces.

Top: Untreated worn face, thinned to bent over, with some rock dents.
Bottom: Boron treated, slight wear and some denting from rocks.

Welsh doubts the boron-hardened bars will help combine performance while everything is new. He doesn't think the reduced friction will make much difference.

"But when things start to wear down and you're trying to work with something that's half worn out and not pulling the material through, that's when I think we'll really see the difference compared to the original factory parts," he says.

"From what I've seen so far, the boron material has a very slow-wearing characteristic, so it will be like working with new equipment all the time, or at least for a longer time. I think it might be up around the 500-hour mark where we really see the advantage. And when it does start to wear, it's not going to go off all of a sudden. That's the important thing.

"It's sort of like a shaver when the heads get dull. Finally one day you take the time to put in new heads and your shaver is like brand new again. Same with a combine, only it's a major time factor to install new parts. Slow, predictable wear on these parts is a good thing. That's why boron looks promising."

Brian Jones, Pendleton, Oregon

Brian Jones was the first farmer to test the Sunnybrook prototype boron-treated parts. He harvests 5,000 to 6,500 acres a year using two Gleaner R-72 combines. They grow a lot of soft white dwarf wheat, which is hard on combines because they cut low and the crop often yields 120 bushels per acre or more. The soil makes matters more challenging.

Brian Jones reconditions his combines once a year.

"Volcanic ash dust is always blowing around. There's no real topsoil here. Everything we have has been blown in from the volcanoes over time. It's very abrasive, like sandblasting material. It never really becomes what you could call topsoil. It seems to remain a gritty dust forever," says Jones.

"We have the highest implement wear anyplace on the continent. That's why everyone around here switched over to chrome surfacing years ago. A few years ago, we were in a pinch because we couldn't get our hands on any chrome cylinder bars for an N-7 we were running. So we just put in the black hardened-steel OEM bars. They lasted 60 hours and they were shot, finished."

Jones says industrial hard chrome isn't the answer. Once it chips, the soft metal below eats away quickly. And chrome chipping causes hooking problems and adds to friction within the combine. The wear was so bad that when he took the chrome bars out, they were scraped and couldn't be re-built.

"The worst part of it all is finishing your harvest with bad equipment," says Jones. "If you have bars that are half worn out, they're really only 40 percent efficient. The first half of the wear with chrome parts isn't so bad, but then it drops off very quickly."

It was the perfect situation for Foster to test his prototype boronized parts. He fitted one of the R-72 combines with boron-treated cylinder bars in 1998.

Says Jones: "We put 300 hours on the combine that season. There was virtually no sign of wear that we could see. We can get 300 to 500 hours on chrome bars if we're lucky. I'd say that in our conditions, we will at least double the life of our wear parts if we use the boron treatment. It seems to penetrate the surface and push the hardness down into the steel." ■

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