Why Select Gear Grinding with cBN?

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The global economy is driving demand for precision gears in a wide range of applications and industries. Along with increased demand, pricing pressure has caused manufacturers to seek out lower cost solutions for reducing overhead and manufacturing costs, while still producing high quality gears. However, there are several challenges which must be addressed to achieve these savings.

For example, the consumption of material needed for the manufacturing of drive trains alone has a direct impact on producing more waste, thus increasing manufacturing cost and detrimentally effecting the environment.

A Conventional Approach

Eighty to ninety percent of all gears used in aerospace, automotive and land based applications are finish ground with conventional abrasives.

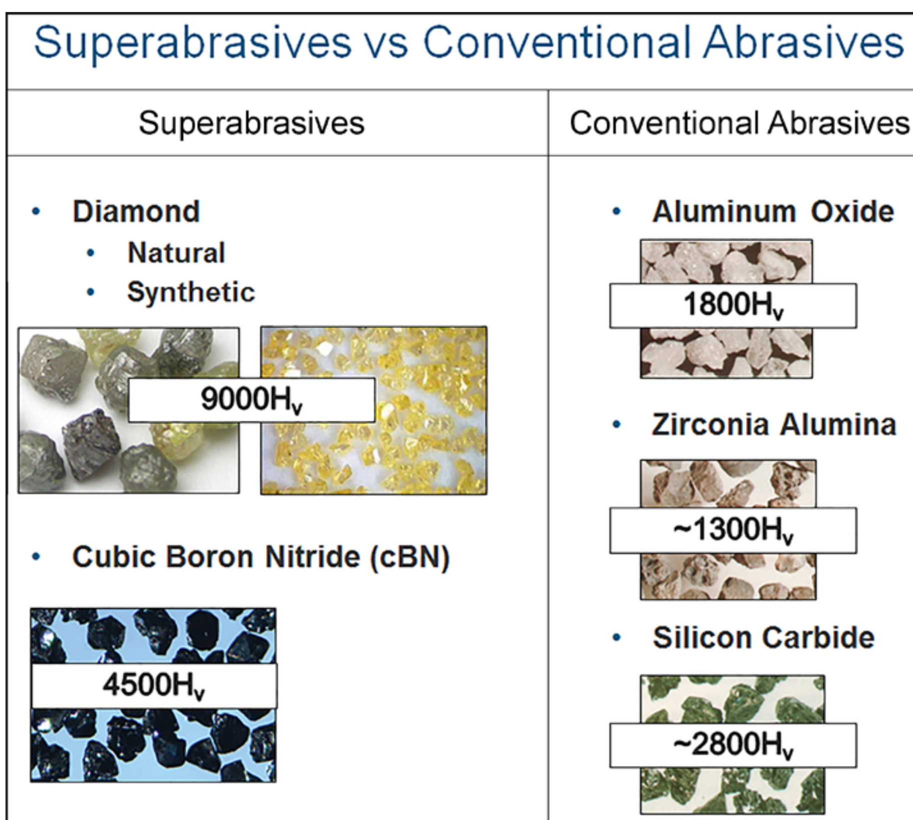
Grinding sludge (abrasive swarf which includes spent abrasive grains) is a byproduct of grinding wheels. The typical large U.S. manufacture of automotive transmissions can go through 25,000 gallons of oil and create 32,000 pounds of used abrasive waste annually. A significant portion of this coolant soaked abrasive swarf is disposed of in landfills.

In high production gear manufacturing (such as automotive), a continuous generation grinding process is used. This efficient grinding process typically yields 40–80 parts per dress. With conventional abrasives, the average consumption of grinding wheels would typically be one to two wheels per week, per machine.

The Case for cBN

Cubic Boron Nitride (cBN) abrasive wheels, which are a specially engineered abrasive grain referred to as a superabrasive, typically yield 2,200–2,500 parts per dress with one wheel lasting as long as four to six months. In addition to the longer wheel life, the physical construction of cBN wheels is also very different. Whereas conventional wheels are made entirely of abrasives, cBN wheels have an aluminum core with only the outer rim containing the layer of abrasives - typically ⅜"–½". When the abrasives on the wheel are used up, the core can either be reused or recycled, while a conventional abrasive wheel stub would end up in a land fill.

Aluminum oxide ($Al0_2$) has been used in manufacturing for over 100 years to effectively finish grind parts. In the mid 1980's Norton|Saint-Gobain introduced a new abrasive grain, which is a sintered ceramic grain that micro fractures as it grinds, leading to better performance and longer wheel life than the A/O wheels. cBN was invented by GE in 1957 and is considered a superabrasive. Like conventional abrasives, over time it has been improved by GE and other superabrasive producers.



Transferring Heat

Being much harder than conventional abrasives, cBN resists dulling–stays sharper longer during the grinding process, which results in a significant improvement in wheel life. It features excellent thermal conductivity characteristics for grinding applications, allowing the heat generated during the grinding process to transfer out and away from the grind zone. cBN has approximately 40 times higher heat transfer rate than that of aluminum oxide (Ref. 1).

Additionally, the thermal diffusivity of cBN is almost two orders of magnitude greater than that of aluminum oxide (Ref. 2).

Further work by GE suggests that in grinding with aluminum oxide, about 63% of the heat generated goes into the work piece, while with cBN grinding only 4% goes into the work piece. The study at GE suggests cBN grinding of carburized parts and hardened parts can impact additional residual compressive stress to the part surface. These stresses may be as little as 30% greater to as much as 250% greater than the heat treated surface stresses (Ref. 3).

Less tensile stress and more compressive stress equals stronger gear teeth. Therefore, cBN provides excellent wear resistant and thermal transfer qualities which result in a very robust grind, beneficial to the surface integrity of the gear tooth and gear.

Baseline Specification:	A80H8V0058
Test #1 Specification:	CBN
MACHINE:	Rieshauer

Technical Summary				
	Compare Baseline	to Test Spec 1	BENEFIT	
Grind Contact time per part	78.61	78.61		Seconds
Percent Scrap				%
Parts per Wheel	6526	233301	**226,775**	Parts per Wheel
Contact Time per Year	90166	90166		Hours
Annual wheel usage	633	18	**615**	Wheels per year
Abrasive Change Time Per Year (All Steps)	949.5	27.0	**923**	Hours

Economic Summary				
	Baseline	**Test Spec 1**	**BENEFIT**	
Abrasive Cost per Year	$344,043	$195,398	$148,645	Total Abrasive $/Yr
Machine time cost per year	$1,843,557	$1,217,167	$626,390	Machine time $/Yr
Cost of Scrap				Scrap $/Yr
Finishing Cost per Year	$2,073,824	$2,073,824		Machine $/Yr
Abrasive Change Costs per Year	$21,839	$621	$21,218	Abrasive Change $/Yr
Total cost per year	$2,209,439	$1,413,186	**$796,252**	Total Costs $/Yr
Total cost per part	**$0.5351**	**$0.3422**	**$0.1928**	Dollars Per Unit
Cost Savings per part			**36.0%**	Savings per Unit %
Total Benefit/Cost Down, All Categories			**$796,252**	**Savings $**

Impact to the Bottom Line & More

Recent field tests show that cBN wheels can produce as much as 2,200–2,500 parts per dress.

This increase in productivity can offer a significant reduction in manufacturing costs. The field case study (see chart above) shows bottom line impact to a large gear manufacturer.

In addition to the cost advantages, the generation of grinding sludge by using cBN wheels is significantly reduced, lessening the impact to the environment. Also, by nearly eliminating spent abrasive grit from the machine, maintenance costs are reduced and machine life is extended. The reduction in the generation of grinding sludge on a yearly basis can result in significant cost savings and reduce material going to landfills. As waste disposal costs continue to rise, reducing the waste going to the landfill will become even more important.

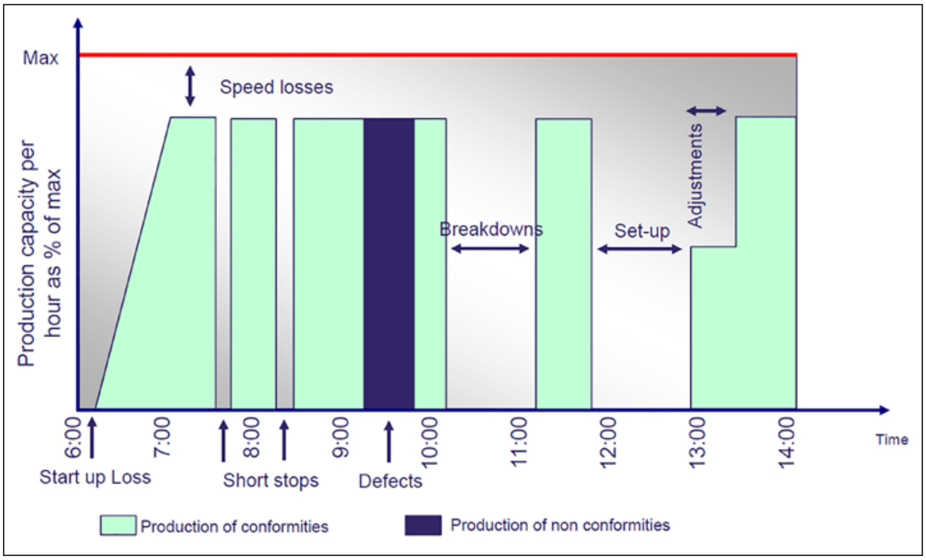
There are other economic savings to be realized. When using cBN grinding wheels, less time is spent dressing the wheel, allowing increased machine uptime for grinding gears.

Gear quality is improved by the inherent benefits of grinding with cBN adding to the compressive residual stress of the gear tooth. Additionally, cBN helps to transmit heat much the way copper transmits electricity, by pulling the heat out of the grinding zone.

Extended dress frequency means more time in the grind cycle. In a conventional grinding process and grind cycle, a wheel has a break-in period after dress. The efficiency of the grind cycle and part quality drops when the wheel requires dressing or reconditioning.

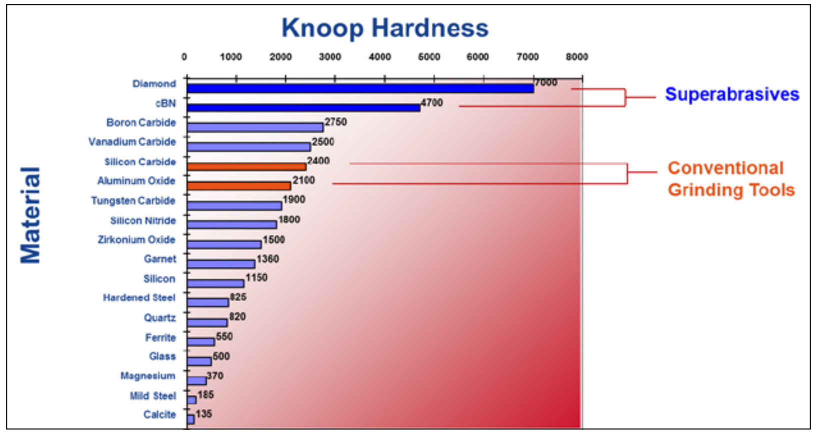
cBN excels at providing long periods of peak cutting performance and high part quality. This has a direct impact on CPK, which is the measure of quality and the ability to hold the process within a certain tolerance bandwidth, and OEE (Overall Equipment Effectiveness) which is the measurement of efficiency and quality in a manufacturing environment.

As shown in the chart (to the left), OEE provides a simple way to look at process improvement in a production environment. More quality parts are produced when grinding without interruptions for longer periods of time.



Compared to the conventional abrasives like Aluminum Oxide and Ceramic Seeded Gel/Norton Quantum, cBN is significantly harder. Dressing and conditioning the cBN wheel requires a different approach than with conventional abrasives.

For example, when dressing threaded vitrified cBN grinding wheels, the dress compensation amount (which is the radial in-feed of the diamond roll into the cBN wheel face) are greatly reduced as compared to conventional wheel dress amounts to re-establish the form of the grinding wheel.



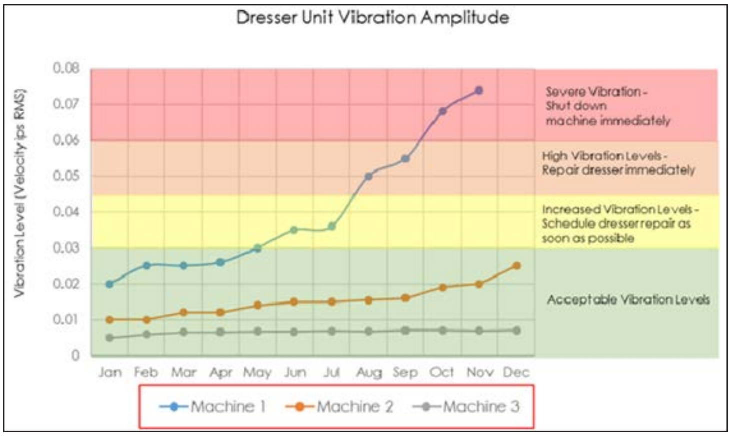
Wheel construction difference

With conventional abrasives, infeed would be .001"–.002" per pass whereas with cBN wheels it would be a fraction of this amount. During the initial dressing period, operators dress a newly installed wheel aggressively, often dressing .020"–.030" of the wheel face. A cBN wheel requires only a fraction of this infeed. The usable abrasive depth of a cBN wheel is typically .250"–.375", so wheel manufacturers need to make certain the wheel face and thread form are close to operating tolerances.

Care needs to be taken when dressing a cBN wheel. Aligning the dresser with the face of the wheel is critical to prevent wheel chipping, and to reduce the total dress amount required for the machine to produce good quality parts.

Continuous gear generation machines use a threaded wheel to generate the involute form on a gear tooth. As continuous generation machines have

Diamond dressing rolls thread gear wheels.



evolved, efficient dressing features have improved. Faster grinding methods have also been developed by introducing multiple starts or multiple wheel threads along the face of the wheel. By introducing diamond rolls with multiple ribs to complement the cBN wheels, dressing times have been significantly reduced.

Often times, the number of "starts" on a wheel dictates the numbers of ribs on a dress roll. These multi-start rib rolls add efficiency to the dressing process, but can also add pressure on the rotary truing device spindle and spindle bearings. To be successful with cBN wheels, a solid, good quality rotary truing device is required. A rotary truing device that is old and worn can cause issues.

During a cBN grind test on a Reischauer RZ400, it was discovered through vibration analysis that the bearings were nearing the end of their life. The vibrations in the spindle bearings had been transmitted into the cBN wheel face, resulting in the vibration showing up in gear tooth inspection of the lead and profile.

This demonstrates the importance of having a rotary dressing unit in good condition when profiling a cBN wheel. In order to lower the dressing pressure, a single rib diamond roll should be considered.

Clear Benefits with cBN

The economic benefits of using cBN wheels in high production environments such as automotive applications are significant. The benefits of using

cBN wheels in continuous generation gear grinding can also be found in shops that grind large internal spur and helical gears using a simple cBN form wheel. Machine builders like Höfler, Gleason, and Kapp sell machines that grind both external and internal spur gears. Grinding an internal spur or helical gear requires an internal attachment which looks like a bicycle fork with a much smaller wheel fitted to the machine.

These smaller conventional wheels typically have a much shorter life (lower G ratio) and require more dress cycles than in external grinding. To extend dress cycles, increasing the wheel life by as much as 100 percent, cBN wheels are the ideal choice. This often means one dress cycle will allow the grinding wheel to complete the gear without any additional dressing, whereas using a conventional grinding wheel in the same application could require more than one wheel to complete the job.

For gear manufacturers, cBN wheels can provide better quality gears with higher compressive residual stress, and allow greater throughput with less dress time and wheel changes. The absence of grinding swarf floating around in the machines promises longer machine life and fewer repairs. Coolant systems run cleaner, requiring less maintenance, filter paper and service. Lower abrasive consumption reduces tooling cost. Less waste going to landfills reduces costs and helps to protect the environment. All of these factors have an impact on the bottom line, helping gear manufacturers remain globally competitive and eco-friendly.

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