CNC Controlled CBN Form Grinding

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Introduction to CBN

Borazon is a superabrasive material originally developed by General Electric in 1969, (Figure 1). It is a high performance material for machining of high alloy ferrous and super alloy materials. Borazon CBN — Cubic Born Nitride — is manufactured with a high temperature, high pressure process similar to that utilized with man-made diamond. Borazon is, next to diamond, the hardest abrasive known; it is more than twice as hard as aluminum oxide. It has an extremely high thermal strength compared to diamond, (Figures 2 & 3). It is also much less chemically reactive with iron, cobalt or nickel alloys.

Traditionally, aluminum oxide wheels have been utilized in production grinding operations. In practice, CBN wheels have advantages due to their hardness and thermal stability. In general, CBN wheels are 3000 to 4000 more wear resistant than aluminum oxide. Since aluminum oxide wheels wear much more rapidly, this wheel must be dressed and/or sized frequently. Further, aluminum oxide wheels must be changed more often with higher machine tool downtime.

In April of 1981, newer CBN materials were introduced by General Electric with their 550, 560 and 570 series. These CBN crystals are micro-crystalline in structure versus conventional CBN which has a single crystal structure. What does the micro-crystalline structure provide? This newer CBN material is composed of micron size (1 um, .000040") crystals. Thus, as the CBN cutting edges becomes dull, any fracturing that occurs to the crystal is microscopic in nature versus large scale fracturing as in the traditional CBN. The 550, 560 & 570 type CBN is self sharpening and will remain sharp throughout its life. A new range of workpiece material applications is now possible: medium hardness steels, forgings, casting and the concept of abrasive machining from the rough or solid part can be effectively and economically done. Another advantage of the newer microcrystalline CBN is its higher thermal stability; approximately 200°C higher than the single crystal CBN.

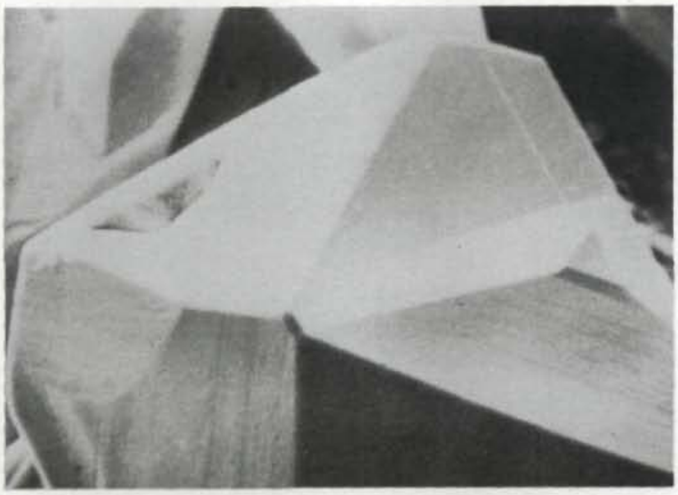

Figure 1 — Cubic Boron Nitride crystals

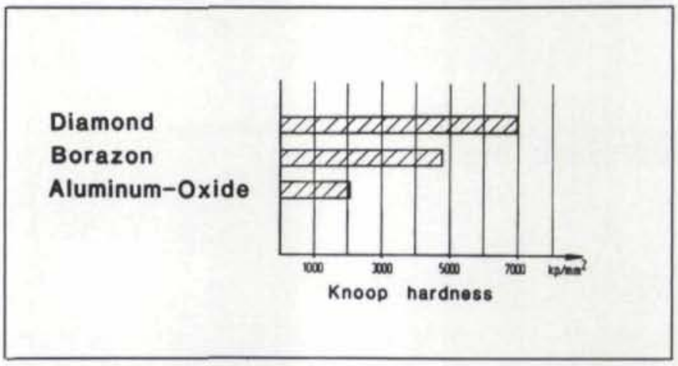

Figure 2 — Knoop hardness scale

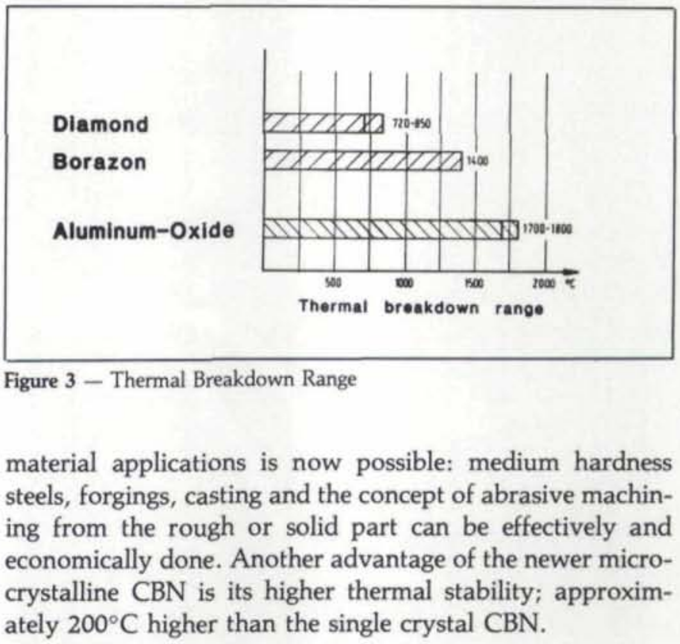

Figure 3 — Thermal Breakdown Range

CBN Machining

To understand how CBN "grinds", or more correctly machines, it is useful to think of it as a milling process rather than as a grinding process. Each exposed CBN crystal is, in effect, like the tooth of a milling cutter. Consider then, the thousands of consistently sharp cutting edges which are exposed to the workpiece and making chips, (Figure 4). Creep feed, (without stickslip effect), and heavy infeed are applied to give the CBN time to cut much in the same way as a milling cutter is fed through its cut, based upon chip load per cutting tooth. Swarf collected from CBN machines consists of tiny chips similar to those from a milling operation. The chip making action also reduces heat generation which is a

Figure 4 — Micro Photograph of CBN plated form wheel

constant problem with dull aluminum oxide wheels. Aluminum oxide also tends to burnish rather than cut a material, which increases heat and reduces metal removal rates.

The effective application of coolant to the workpiece and CBN wheel is critical. Coolant is utilized for two purposes; as a lubricant for the cutting process and to dissipate heat. When CBN is properly utilized, the workpiece will remain cool and show no thermal damage. Any heat that is generated during the process is transferred to the chip and coolant medium. Lubricity is important to prevent workpiece chips from adhering to the wheel and reducing the CBN machine efficiency. Many different coolants have been utilized from straight mineral oil to a 10% soluble oil. The Kapp Company recommends Texaco Transultex Type A cutting oil which has a sulfur chlorinated base. In high metal removal conditions, flow rates of 150 1/min (40 gal./min) are recommended.

A stiff rigid machine tool is required to successfully apply CBN techniques. The machine should be equipped with such modern items as ball-screw drives for feed slides, way materials with low coefficients of friction and high dampening qualities and intensive coolant flooding of the grinding zone. The grinding spindle must be both a precision running spindle and of a rigid design. Although horsepower required is not high due to the efficient CBN chip making process, it is normally greater than on traditional grinding machines. Lower horsepower will not allow full advantage of CBN capabilities. The General Electric Company recommends a minimum of 2 to 3 spindle horsepower for each inch of CBN wheel width on a 6 to 10 inch diameter wheel. Another good machine feature is an electric load meter. As the CBN wears down, the cutting efficiency decreases which results in a higher spindle power load. With a load meter, it is possible to monitor this cutting efficiency and to replace (and replate) the CBN wheel at the desired point.

CBN Electroplated Wheels

Until recently, Borazon has been primarily utilized in resin or metal bond wheels. This bonded wheel was dressed and/or conditioned to expose the grain. Further, the bonded wheel required periodic redressing to maintain correct form due to the bond failing. Worth repeating, is the fact that this redressing was required since the CBN crystal simply was no longer supported by the bonding material. If the form had a complex or highly accurate geometry, costly dressing rolls or equipment were needed. In some traditional aluminum oxide form grinding applications, 25% of the total grinding time is spent on dressing. In small diameter form wheel applications, the problems of traditional dressing and truing becomes even greater.

A solution to the problem of maintaining a true form is the electroplated CBN wheel, (Figure 5). The high form accuracy is achieved by the use of a precision machined form wheel with a single layer of galvanically bonded CBN. This electroplated bonding is nickel with sufficient plating to capture approximately 50% of the crystal. Since the form wheel is precisely controlled, the need for wheel dressing is completely eliminated. Further, after the CBN form wheel has worn, it can be stripped of the remaining CBN crystals and recoated. A prime example of successful plated CBN wheel application is the grinding of internal ball tracks of constant velocity joints. In one case, an electroplated wheel was able to grind 200 parts. Previous aluminum oxide wheels ground less than 3 parts before dressing was required.

Future developments with electroplated CBN wheels look promising. Present wheel surface speeds are limited, to an extent, by present machine and grinding spindle design. With higher wheel speeds of up to 100 m/second (20,000 sfpm), wheel life and material removal rates can both be increased. Work is presently underway with magnetic bearing designs to allow higher wheel speeds with small diameter wheels. Another problem to be solved with increased wheel speeds is the critical requirement of proper coolant application. As wheel speeds increase, the phenomenon of high-speed air barrier occurs. This phenomenon makes the application of coolant at the wheel and workpiece more difficult. Wheel manufacturers are now experimenting with slotted wheel designs and direct coolant application through integrated coolant holes in the wheel itself.

Figure 5 — CBN plated form wheel

Conclusion

The use of Borazon CBN form grinding represents one of the most significant process developments for soft and hard machining in the last 50 years. With multi-axis CNC machine tools, the process is repeatable and precise with setups a simple matter of recalling axis and feed data from memory as a coded parts program. CBN is no longer an "expensive" method done only when no other way is possible. It now competes with milling, shaping and other finishing processes by metal cutting and, in some instances, even against rough cutting. Any form machinable by a disc or pencil type milling cutter or grinding wheel can be ground by CBN form grinding. On tough materials such as stainless, inconel and the high nickel content types, CBN may be the only "practical" method of finishing.

Advantages of Electroplated CBN Form Wheels

1) Accurate control of form
2) Maintain modified profile due to form incorporation in wheel
3) Possible to grind finer forms from the solid where heat treatment allows
4) Non-standard forms can be ground, i.e. gerotors or compressor screw rotor
5) Can grind full form, including root
6) No dressing is required
7) CBN wheels can be stripped and recoated hence, low cost per workpiece
8) Free cutting without heat checking
9) More economical than vitrified wheels on a production basis
10) Long life. CBN wheel life has an average of 10,000 times the diameter of the wheel equal to linear units of form length ground
11) Reduced grinding time
12) Low machine wear due to creep feeds and absence of grinding dust
13) High precision

Disadvantages of Electroplated CBN Form Wheels

1) Requires CBN form wheel for each distinct form
2) Lead time required to design and manufacture form wheel

Production Examples

Hob Sharpening

Wheel Data
15 degree CBN electroplated wheel
200 mm, (7.87") diameter

Hob Data
5 Pitch
145 mm, (5.75") face width
14 gashes
Material M3
.80 mm, (.032") wear

Machine Data
Kapp Model AS204GT Hob Sharpener

Grinding Wheel
1370 surface meters (4500 surface feet)
2030 mm, (80") stroke per minute
.20 mm, (.008") stock removal per pass

Total Grinding Time
12.5 minutes

Quality
MCTI Class AA

Internal Gear Grinding

Wheel Data
CBN Electroplated Wheel
65 mm (2.56") Diameter

Part Data
20/40 Pitch
114 Teeth
30 mm (1.18") Face
1.37 mm (.054") Whole Depth
Material — High Heat Resistant

Machine Data
Kapp VIG335CNC Internal Gear Grinder

Grinding Data

Pieces Per Load	1
Stock Removal	Roughing 1.0 mm (.039") Finishing .3 mm (.012")
Number of Passes	2
Feed Rate	Roughing 300 mm (11.81") Finishing 300 mm (11.81")

Total Grinding Time
90 Minutes Per Piece

External Gear Grinding

Wheel Data
CBN electroplated wheel
250 mm, (9.84") diameter

Part Data
6.35 Pitch
30 Teeth
40 mm, (1.61") face
8.9 mm, (.350") whole depth
AISI E52100 material
Rc 62 hardness

Machine Data
Kapp Model VAS481CNC External Gear Grinder

Grinding Data
Pieces per load — 2
Stock removal per flank .1mm (.004")
Number of passes — 1
1370 surface meters (4500 surface feet) per minute
600 mm (23.6") per minute feed rate
6000 mm (236.0") per minute rapid return

Total Grinding Time
6.0 minutes per load
3.0 minutes per piece

(Continued on page 46)

VIEWPOINT

The staff of GEAR TECHNOLOGY would like to thank you for the warm and enthusiastic response we have received, both by phone and letter, regarding our new publication. Excerpts from some of the letters received have been included in our first column. For future editions, we welcome your thoughts and comments as a regular part of our magazine. Let us here from you.

Dear Editor:

We share your interest in promoting the existence of a periodical dealing with the subject of gear manufacture. It seems that the scope of the new magazine fits our objectives for process and product exposure.

Lew Wallace
Gleason Machine Division

Your new magazine GEAR TECHNOLOGY certainly does sound exciting. All I can say is: "It's about time!" Best of luck in your adventure.

Joseph W. Coniglio
Vice President — Engineering
Gould & Eberhardt Gear Machinery Corp.

Letters for this column should be addressed to Letters to the Editor, GEAR TECHNOLOGY, P.O. Box 1426, Elk Grove Village, IL 60007. Letters submitted to this column become the property of GEAR TECHNOLOGY. Names will be withheld upon request; however, no anonymous letters will be published.

CNC CONTROLLED CBN . . .
(Continued from page 28)

Accuracy

Profile Tolerance	.010 mm (.0004")
Lead Tolerance	.008 mm (.0003")
Pitch Variation +/−	.007 mm (+/− .0003")
Surface Finish	.0005 mm, 20 CLA

External Gear Grinding

Wheel Data
CBN electroplated wheel
250 mm (9.84") diameter

Part Data
2.25 Pitch
62 Teeth
127 mm (5.00") face
24.4 mm (.960") whole depth
SAE 5046 material
Rc 55-60 hardness

Machine Data
Pfauter P1000 FSNC External Gear Grinder

Grinding Data
Pieces per load — 1
Stock removal .15 mm, (.006")
Number of passes — 1
650 mm (25.6") per minute feed rate

Total Grinding Time
38.8 minutes per piece

AUTHOR:

DENNIS GIMPERT is one of American Pfauter's two Sales Managers. Mr. Gimpert was educated at Michigan Technological University and Rockford College. He worked for Clark Equipment Corp. from 1971-1974, and for Barber-Colman Co. from 1974-1976 as an application engineer for gear hobbing and shaping equipment. In 1976, he joined American Pfauter. Mr. Gimpert has served on the Vehicular Gear Committee of American Gear Manufacturers Association and is active in various activities of the Society of Manufacturing Engineers.

...AND FROM THE INDUSTRY

What's new . . . as a service to our readers, GEAR TECHNOLOGY will offer space to announce personnel and corporate changes that would be of interest to the Gear Industry. If you have an announcement you wold like to make, please send it to **GEAR TECHNOLOGY,** P. O. Box 1426, Elk Grove, IL 60007.

BOURN & KOCH
William (Bill) Beal has joined **Bourn & Koch Machine Tool Co.,** Rockford, Illinois as manager of Hobber Remanufacture. Beal brings 36 years of gear manufacturing experience to Bourn and Kock, a rebuilder and retrofitter. Beal was formerly responsible for rebuilding at the Barber-Colman Co.