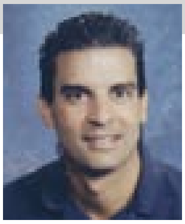
BY MIKE PRINCIPATO



Oracle of the ordinary

I'm not exactly sure when, but sometime during the last few years it was decreed that political campaigning should be a year-round sport for our elected officials and the candidates who aspire to join their noble ranks. Consequently, here in the hotly contested, great state of Pennsylvania, we're subjected to electioneering 24/7. Self-serving press conferences, taxpayer-financed campaign mailings masquerading as helpful newsletters and television commercials that invariably depict the sponsor's opponent as someone with less character than Al Capone are as common as, well, corrupt politicians.

As surely as my mailbox fills with politicians' earnest pleas for money to support their campaigns, they spout platitudes about the importance of protecting U.S. manufacturers. From rising health-care costs. From frivolous litigation. From China.

If I actually listened to them long enough, they would probably get around to promising to reanimate Frank Sinatra. Now that I'd pay for.

A successful entrepreneur can have a far greater impact on his own local constituency of employees, customers and suppliers than any politician.

The reality is that control of most national and global events is out of the hands of politicians. Barring an event that ignites a lasting unification of the minds and hearts of Americans—the likes of which hasn't been seen since World War II—your fate, and the fate of manufacturing, is pretty much in your own hands. That ain't necessarily a bad thing. A successful entrepreneur can have a far greater impact on his own local constituency of employees, customers and suppliers than any politician.

You are where you are because you are a pragmatist. You know people will always need stuff and somebody has to make that stuff. You know how to do it and make money at it. So let's engage that practical brain of yours for a moment and prophesize about the future of U.S. manufacturing, free of the distractions and misinformation of those who don't live in our world.

Not-so-bold prediction No. 1: Manufacturing jobs will continue to move offshore. Products that can be made by low-skilled workers have and always will migrate to countries where overhead costs (taxes, energy and regulatory compliance costs) and internal costs (wages, benefits and more) are lower. For a long time, thanks to Yankee ingenuity and surging, technology-driven productivity gains, that country was often the U.S. It isn't anymore.

Contract shops—those that machine, fabricate or mold other companies' products or components—are getting creamed by global competitors, particularly if what they produce doesn't require advanced technology and isn't freight-cost sensitive. Proprietary product manufacturers aren't immune, either. If you're not the best and don't have the lowest cost in your business, you're vulnerable—unless what you produce is unique.

Not-so-bold prediction No. 2: Energy costs will continue to rise. I'm amazed at how many Americans continue to delude themselves about this inescapable reality, carping loudly that "the government must do something" to lower prices on everything from gasoline to heating oil. News flash: For the first time in industrial history, America is in worldwide competition for a finite supply of crude oil, often with the same countries (China and India, for starters) that we're slugging it out on trade with. Therefore, prices for fossil-fuel-based energy will continue to rise. From what you decide to drive to work to how you heat your plant, plan accordingly.

Not-so-bold prediction No. 3: The pool of skilled manufacturing labor will continue to shrink. Seen any vocational-technical schools under construction lately? Met any young people aspiring to become CNC programmers? I didn't think so. Nothing on the national horizon will reverse that tide, and given that our international competitors have at their disposal literally millions of potential low-cost laborers willing to learn trade skills, it's a fool's errand to worry about it. Instead, invest in technology and train and retain the best workers you can find.

Successful manufacturers deal with what is and don't waste time pining for what was. Worried about Chinese competition? Outsource to China yourself while you work on launching your own offshore-proof product. Stung by high energy costs? Sell to oil exploration and distribution companies—they're booming. Can't find skilled workers? Don't hire anybody. Instead, buy a small vertical machining center and train your best machinist to produce more and better parts on it.

The real foundation of American economic strength has always been based on our rugged individualism and creative thought. So put them to work and stop your whining!

About the Author

Mike Principato is a metalworking industry consultant and former owner of a mid-sized CNC and EDM shop in Pennsylvania. He can be e-mailed at ctemag1@netzero.net.

Making easy work of hard turning

BY LAROUX K. GILLESPIE

Turning hardened workpieces (45 to 65 HRC) on a lathe is standard practice for a variety of parts, ranging from high-production automotive components to low-volume molds and dies. With a rigid machine—one having tight gibs, no backlash and strong spindles—stiff toolholders having a short overhang and high-performance inserts, a shop can effectively turn hardened parts instead of having to grind them.

Hard turning can compete with grinding because the process imparts surface finishes as fine as 16 R_a, allows the user to achieve a ±0.0005" tolerance and eliminates grinding-generated lobes. In addition, parts can be machined faster on a lathe than a grinding machine, even when both roughing and finishing passes are required. These parts can be machined in a single chucking on multipurpose lathes, while grinding may require multiple part fixturings and wheel changes. Also, because hard turning is normally performed dry, metalworking fluid costs are eliminated.

The main practitioners of hard turning are manufacturers of bearings and other automotive components. The reason is that in the production machining of hardened bearing steels, such as 52100, they can slash processing time by 60 percent if they don't have to finish-grind the hardened part.

Hard turning is also common at tool and die shops. Because these shops only make a few of the same items, being able to produce them in a lathe saves considerable time compared to grinding. In addition, multiple turning tools can be applied to machine several features in a single operation on a lathe, whereas only one wheel can be used when grinding.

The three basic tool material choices for hard turning are whisker-reinforced ceramic, polycrystalline CBN and, for nonferrous materials, PCD. (Carbide isn't an option for turning hard metals.)

Whisker-reinforced ceramic is the low-cost option and can be applied to turn many hardened materials. Whisker-reinforced ceramic is not as durable as the other two tool materials, but it is a good starting point for many shops. A ceramic insert costs about $20, a PCBN insert costs about $50 and a PCD insert costs $200 to $300.

All three of these tool materials can be used for heavy, interrupted-cut turning of hardened, sand-encrusted castings as well as bar stock. However, success with PCD is highly dependent on the tool material's structure because PCD quality varies.

Regarding tool geometry, inserts with a 5° negative rake and a 20° chamfer are the norm for hard turning. In addition, insert wipers cut surface roughness by half at the same feed rate, or allow faster feed if a fine surface finish is not needed.

Table 1 provides some parameters for turning hardened materials. For example, forged and heat-treated differential gears made from 5046 steel (58 HRC) and other carburized or induction-hardened materials are turned with a ceramic insert at a cutting speed of 385 sfm. A finish feed rate of 0.003 ipr (roughed at 0.005 ipr) on a rigid machine achieves a diameter tolerance of ±0.0015". Solid-ceramic inserts can take a deep cut, but the CBN and PCD inserts are typically limited to less than 0.020" DOC under these conditions. A low feed rate and small DOC are the rule for hard turning. Also, 8615 hardened-steel parts (60 HRC) can be semifinish-turned at 450 sfm and 0.010 ipr and finished at the same speed and a 0.008-ipr feed. A DOC of 0.010" for semifinishing and 0.0015" for finishing should be used.

Hard turning requires some experimentation to find the best tool and machining parameters for a specific application. Tool selection is based on insert chemistry, heat buildup and cycle time.

Tool material	Speeds (sfm)	Feeds (ipr)	DOC
Whisker-reinforced ceramic	200 to 800	0.001 to 0.010	0.060" to 0.125"
PCBN	150 to 850	0.006 to 0.025	0.020" to 0.180"*
PCD	130 to 660	0.004 to 0.040	0.002" to 0.020"

Table 1: Recommended parameters for turning hardened steels (45 to 65 HRC).
**May be limited by small bonded insert dimension. Solid insert can handle larger DOC.*

Different tool manufacturers and different grades should be tried, based on (when applicable) grain size, binder material, cutting edge geometry, i nsert coating, workpiece details and cutting conditions. Reduction in total part costs is the measure of success, not increased insert life and lower tool cost.

About the Author

LaRoux K. Gillespie is a retired manufacturing engineer and quality-control manager. He is the author of 10 books on deburring and almost 200 technical reports and articles on precision machining. Special thanks to Craig Carr at Wm. F. Hurst Co. Inc., Olathe, Kan., and Bob Patterson at Representative Sales and Service, Overland Park, Kan.

Beautiful beast

BY BILL KENNEDY, CONTRIBUTING EDITOR

More noise, more style, more power. If there's one group that personifies the belief that "more is better," it's riders of Harley-Davidson and custom motorcycles. That's especially true when it come to engine size.

A 96-cu.-in. motorcycle engine was once considered big. Today, big motors are 113 cu. in., and the more-is-better types push 150 cu. in. Big motors mean more horsepower and more gear-wrenching torque.

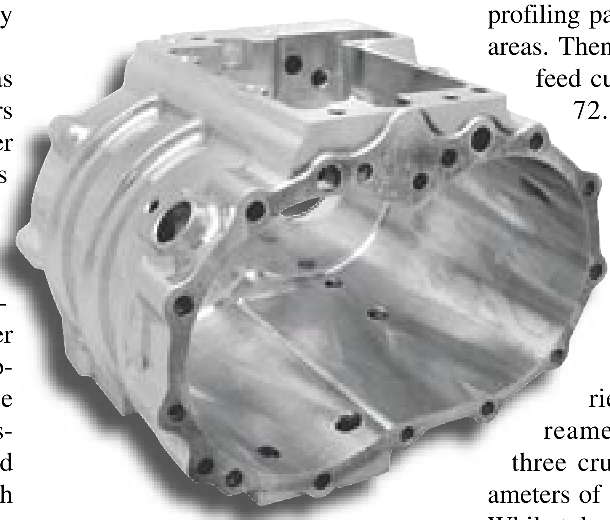
Baker Drivetrain, Haslett, Mich., makes performance parts for Harleys and custom motorcycles. Founder Bert Baker feels today's monster motors are putting out too much torque for the traditional Harley-based transmission. Accordingly, he designed the Torquebox transmission, which has wider gears with bigger center distances "to handle the torque of the 150-cu.-in.-plus crazies out there." The Torquebox increases continuous-duty torque capacity to, conservatively, 250 ft.-lbs. or better. It also provides "more style," with a beautifully contoured case machined from a solid aluminum billet.

Head machinist Tom Peek made the prototype Torquebox case from a 6"×8 5⁄16"×7" billet of 6061 T6 aluminum. CAD designer Scott Lerg created 3-D models in SolidWorks CAD software, and Peek programmed the part in FeatureCAM. "It took only a day to program the whole thing," Peek said.

After clamping the block in a vise on a Haas VF2 vertical machining center, Peek squared all six sides in 15 minutes using a 6"-dia. Valenite shell cutter run at 5,200 rpm and 80 ipm and tooled with two carbide inserts. The flycutting method produced a 16μin. R_a finish.

Then, he cored the case out using a 2"-dia., 3-flute A&B Tool hog mill featuring three uncoated, 0.125"-radius inserts. The cutter ran at 5,500 rpm and 100 ipm, ramping in 0.100" per pass, completing the 4.399"-wide × 7.132"-long × 5.7"-deep cavity in 35 minutes.

Next, Peek made holes for the fork rod, dowels and bolts. A 0.238"-dia. drill, run at 4,012 rpm and 14.3 ipm to a depth of 0.375", made two dowel holes, which were reamed to 0.2495" at 1,910 rpm and 43 ipm. Peek generally applies Precision Twist cobalt-HSS drills and National reamers.



Baker Drivetrain

Baker Drivetrain machined this high-torque-application motorcycle transmission case from a 6"×8 5⁄16"×7" billet of 6061 T6 aluminum.

Two through-holes to guide the fork rod were drilled with a 0.358"-dia. drill run at 2,667 rpm and 14.3 ipm and then reamed to 0.375" at 1,273 rpm and 43 ipm. Next, 13 1"-deep, 5⁄16-18 threaded holes were made with a 0.257"-dia. drill run at 716 rpm and 14.3 ipm and a Morse tap. Operations performed in this setup took 1 hour and 15 minutes.

In the next setup, the case was rotated 180˚. It was bolted to a 1½"-thick aluminum fixture featuring 0.100"-high mirror images of the dowel holes made previously. "The two dowel holes were the key to the location," Peek said. "Everything had to line up right on the money."

Next was profiling the end of the case using a ⅜"-dia., 4-flute Imco Powerfeed endmill run at 6,621 rpm and 99.3 ipm. A second rough-profiling pass cleared out a few small areas. Then a ¼"-dia., 4-flute Powerfeed cutter, run at 7,500 rpm and 72.1 ipm, finished the profiled contours. Peek noted that the flutes on the Powerfeed tools are unequally spaced to prevent generation of harmonics at high speeds.

After making a variety of drilled, tapped and reamed holes, Peek machined three crucial bearing bores, in diameters of 3.364", 1.260" and 1.264". While tolerances on the case generally were within ±0.002", the bearing bores required +0.0005"/-0.0."

Additionally, the 1.264"-dia. bore had four steps. The 1.264"-dia. step reached a depth of 0.525", a second diameter of 1.102" extended 0.400" deeper, the third step had a 0.900" diameter and was 0.267" deep and the last 0.850"-dia. step extended 2.959" to the bore's full depth of 4.151". Peek roughed the four diameters with a ¾"-dia., 3-flute, high-helix Imco Streaker endmill, interpolating to within 0.020". He finished the first three diameters to ±0.001" using Criterion boring heads. The 0.850"-dia. was not finish-bored because it exists simply to provide clearance for installation of the shifter mechanism from inside the case.

Peek ran the boring heads with carbide boring bars tooled with 0.031"-radius carbide inserts. "I ran them at 400 rpm and 1.2 ipm and got a mirror finish," he said.

Next, the ¾"-dia. endmill interpolated the 1.260" bore at 3,310 rpm and 50 ipm. "The reason I ran the endmill so slow was that I had 4" of it hanging out in the breeze," Peek said. A Criterion head machined the bore to size. The 3.364"-dia. bore was finish-bored with the same interpolation technique. Machining time during this setup took 32 minutes.

For the next setup, the case was returned to the vise. The first operation created a two-tiered, 4.490"-wide, 4.9"-long pocket to accommodate the shifter drum, shifter pawl and forks. The pocket's first level was 0.486" deep, cut with a ½"-dia., 1"-flute-length Streaker endmill run at 4,966 rpm and 99.3 ipm.

The second tier extended 1.1" deeper, penetrating the case's main cavity. Peek machined it with a 3-flute, ½"-dia., 2"-flute-length endmill run at 4,966 rpm and 49.7 ipm. "For the first [tier], the endmill with the short flute length removed the material really fast, while with the longer endmill I had to cut the feed in half because I was getting a lot of vibration," Peek said.

Following more holemaking, Peek began 3-D contouring of the case exterior. The shapes were complex. "I had ridges, peaks and lobes," he explained. "I was cutting out areas around bolt holes, enveloping around it. There's maybe only one straight surface on the case."

First, a ¾"-dia., 3-flute, solid-carbide Streaker endmill, with 2" of flute length and no corner radius, performed a Z-level roughing operation. That means the endmill stepped down into the case to a specific depth (0.375") each pass and removed any material that should be taken off at that level, until the depth reached 2". Peek said the method, "basically is really, really fast." Roughing down 2" at 5,000 rpm and 150 ipm took 16 minutes.

Then a ½"-dia., 2-flute carbide ballnose endmill made a semifinish pass at 7,500 rpm and 90 ipm, consuming 17 minutes. The contours were finished in 28 minutes with a ⅜"-dia., 2-flute ballnose endmill run at 7,500 rpm and 90 ipm.

Peek noted that he machined the case in multiple setups in a vise because his VMC wasn't large enough to contain both the case and a 4th-axis table that would eliminate a number of setups.

For the fourth setup, the case was rotated 90˚ and contoured. The machining took 27 minutes. After being rotated another 90˚, the case received more drilled and tapped holes and more 3-D contouring was performed. This setup took 1 hour and 5 minutes to complete.

For the final setup, the case was rotated 90˚ but was bolted to a fixture and aligned on ¼" dowel holes on the case top. "There were no straight planes left on the case to clamp on firmly," Peek said, so "I took a little bit lighter cuts because I didn't want to take a chance of moving the part." He machined at 5,000 rpm and 90 ipm with the ¾" endmill, 5,200 rpm and 90 ipm with the ½" ballnose endmill, and 5,700 rpm and 90 ipm with the ⅜" endmill. Machining time for the final setup was 32 minutes.

Counting setup time, Peek invested 9 hours in machining each case. "We made a couple for Biketoberfest last fall, four more for Bike Week in March, then made 28 preproduction cases." Having perfected the manufacturing process, Baker Drivetrain, plans to subcontract volume production to a premium machine shop in its home region.

For more information about Baker Drivetrain, call (877) 640-2004 or visit www.bakerdrivetrain.com.

Mathcad 13: software you can count on

BY BILL FANE

Before we get started, let's set the record straight: Mathcad from Mathsoft (www.mathsoft.com) is not drafting software, in spite of the "cad" in its name. It is actually an amazingly powerful and versatile calculation program. Think of it as a combination scientific graphing calculator, spreadsheet program and word processor.

The real beauty of it is that equations, formulas and calculations appear in the same format as if they had been written by hand. Notes and comments can also be included to explain what the variables mean and to give background information about the calculation.

Let's start with a simple example. A spreadsheet would show a calculation like this:

	A	B
1	x	3
2	y	2
3	z	4
4	result	51

where we would have to enter the equation: $= B1+[3\times(B2^{B3})]$ into cell B4.

Mathcad lets us enter and display the same calculation this way:

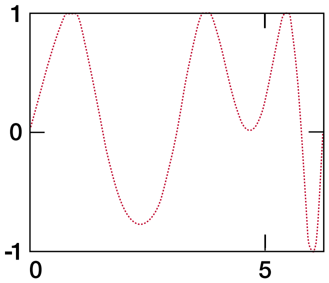
if $x: = 3$
and $y: = 2$
and $z: = 4$
then $x+3y^{z} = 51$

Isn't that version much easier to understand?

Better yet, you can change values and even the definitions of variables within the display and everything updates automatically. For example, you can click on the 4 and change it to x/5. This redefines the variable z, so the result changes to display 7.547.

You can also graphically display a curve and calculate the arc length between two points on the curve defined by the expression:

$f(x): = \sin[x+x\times\sin(x)]$
$a: = 0$
$b: = 2\times\pi$



Arc length:

$$\int_a^b \sqrt{1+\left(\frac{d}{dx}f(x)\right)^2}\,dx = 12.056$$

There are two important points about this example. First, everything from $f(x): = \sin[x+x\times\sin(x)]$ through the arc-length equation was simply cut or copied from Mathcad and pasted into a Word document as opposed to a cryptic spreadsheet macro. Second, any changes to the a and b values or to the format of the original equation will almost instantly be reflected in the graphical representation of the function and in the calculated arc-length value.

Mathcad also lets you "save as" in HTML format so that anyone with a Web browser can open, display and print your worksheets. They cannot revise and update the worksheets, though.

Mathcad is not limited to simple algebraic equations. Its math functions include basic arithmetic, differential and integral calculus, Boolean operations, Fourier and Laplace transforms, graphing, curve fitting, Bessel functions, financial calculations, probabilities, random numbers, sorting, vector and matrix operations and text-string functions. Mathcad can also read and write files, including reading and writing external data files or a matrix of the red, green and blue components of common graphic files.

It also predefines a huge list of units and mathematical and physical constants, as well as checks for consistency of units within calculations.

Now that we have seen the basic principles, let's take a look at what's new in the latest version.

Mathcad 13 includes an automatic, timed backup feature, but I am not sure why the Mathsoft programmers bothered. Computers never crash, do they?

It also includes enhanced unit conversion capabilities. For example, Mathcad provides nonmultiplicative scaling functions, including Fahrenheit to Celsius conversions. On the other hand, if you regularly need to convert between furlongs per fortnight and light years per a 31-day month, then you can create your own custom conversion factors.

Mathcad 12 added several metadata options. These have been enhanced and expanded in Version 13. For example, if you cut and paste equations from one worksheet to another, you can right-click on the copy and determine the worksheet's provenance. This is helpful when conducting forensic studies on a worksheet. For example, you may have a nonfunctioning worksheet developed by someone else. This feature lets you check the author's sources.

Another fascinating new capability in Version 13 is the Explicit function. This returns the expression with variables replaced by their current values but without the actual calculations taking place.

For example, if a=2 and b=3 then a/b explicit, a,b $\rightarrow \frac{2}{3} = 0.666667$. You do not need to substitute all variables, but can specify exactly which ones to show. This can be a great teaching tool and a valuable debugging weapon, because it shows the calculations step-by-step—just as if you were doing them with paper and pencil.

Two-dimensional graphs include new options that give the user much more control over the traces in a graph. The color, line type, line weight and symbol shape and size for each trace are controlled from a new dialog box.

New algorithms yield faster, more flexible and more accurate solutions for linear algebra and parametric fitting functions.

Error messages are now much more meaningful. For example, instead of just saying "Units in this expression do not match," Mathcad highlights the problem part of the expression. When you click on this error, the program produces a message along the lines of "This value has units: Time must have units: Length." Note that Mathcad evaluates from left to right, assuming everything is correct until something doesn't match. The actual error may be in an earlier part of the expression, but at least you know what you are looking for.

If you use Mathcad's programming capabilities, you will be happy to hear it now includes a trace window and related commands for use when debugging Mathcad's internal programming language. This window displays the current value of selected variables as the program runs, and programs can be paused as they are running.

Version 13 introduces many changes, some of which may be incompatible with worksheets produced by earlier versions. To overcome this problem, the new version includes a compatibility switch. This lets older sheets continue to work the old way until you update them. All in all, Mathcad 13 is a powerful tool for performing and documenting many mathematical calculations and analyses.

About the Author

Bill Fane is a former product engineering manager, a current instructor of mechanical design at the British Columbia Institute of Technology and an active member of the Vancouver AutoCAD Users Society. He can be e-mailed at Bill_Fane@bcit.ca.

Bursting speeds and loaded wheels

Dear Doc,

My vitrified-bonded aluminum-oxide wheels work best at high speeds, so I always run them at the maximum-rated rpm specified on the wheel. However, when a wheel wears to a smaller diameter, it's running at a slower surface speed. At a smaller diameter, can I crank up the rpm beyond the maximum rating, maintain the same surface speed and still prevent the wheel from bursting?

The Doc Replies:

The stresses that cause a wheel to burst are proportional to the surface velocity squared. Surface velocity = 3.14 × wheel diameter × wheel rpm. So, theoretically, you're right. As the diameter gets smaller, you should be able to increase the wheel rpm accordingly to maintain the same surface speed and still be on the safe side.

But I'd never recommend running higher than the maximum rating. Here's what you can do: Ask your wheel supplier if he'll rate the wheel based on surface speed (sfm or m/s) instead of wheel rpm. Many wheel producers already do this. That way, you can run a wheel at a higher rpm as the diameter decreases and still know you're safe.

Dear Doc,

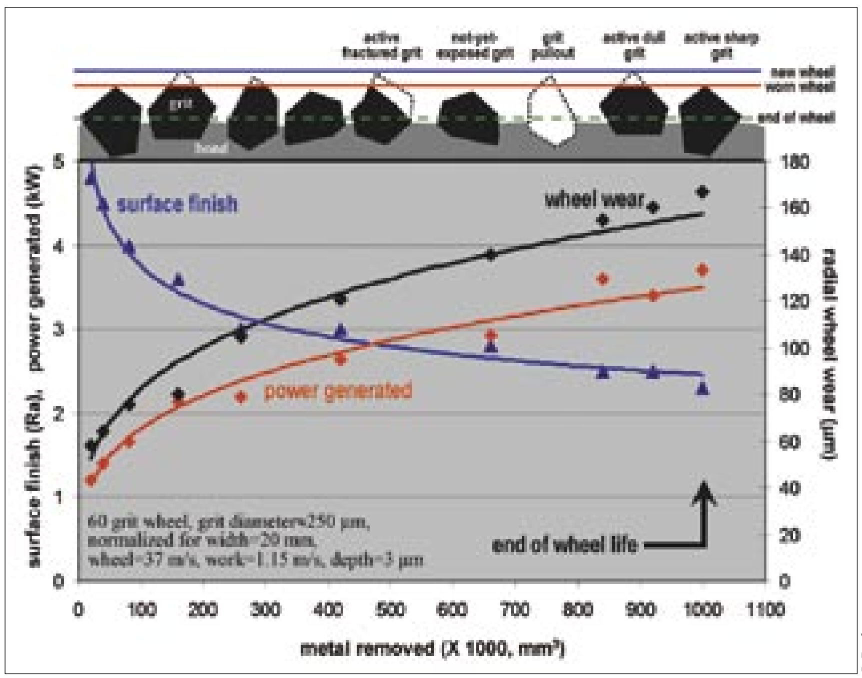
I grind nickel-based alloys and stainless steel and recently switched from Al_2O_3 wheels to CBN wheels. I now get a lot more wheel loading. Why the change, and what can I do about it?

The Doc Replies:

Both of those materials are "gummy," making the wheel prone to loading. You probably had about the same amount of loading with the Al_2O_3 wheel, but you dressed and wore away the wheel before it became severely loaded. The CBN wheel, on the other hand, wears less and is dressed much less frequently, so loaded material accumulates.

First, make sure the main arc-of-cut cooling is adequate, meaning coolant velocity matches wheel velocity. Second, put a high-pressure cleaning nozzle on the machine to blast away loaded material. This requires a separate, high-pressure (1,000 to 1,500 psi), low-flow pump along with a high-pressure nozzle.

The nozzle should be situated at the top of the wheel. There's some debate on how to orient the nozzle: either radially into the wheel or tangentially, with the coolant going in the opposite direction of the wheel. Try both and see which one works better.



J. Badger

Figure 1: Wheel wear, surface finish and power generated vs. the amount of material removed when grinding with electroplated wheels. Reference: Shi and Malkin. Wear of Electroplated CBN Wheels. Trans. *ASME Journal of Manufacturing Science & Engineering*, February 2006, Vol. 128, p. 110.

Dear Doc,

I use electroplated CBN wheels and get erratic results—poor surface finish but no burn when the wheel is new and a gradually finer surface finish but more burn as the wheel wears. What am I doing wrong?

The Doc Replies:

You're not doing anything wrong—that's just the nature of electroplated wheels. When EP wheels are produced, some grits protrude higher than others. Consequently, with a new wheel, only the high grits are doing the grinding. This results in a rough surface finish. As the wheel wears, the higher grits become dull and the lower grits get into the grinding action (Figure 1). Now that the chip thickness is reduced, the surface finish is finer, but more power—and, thereby, heat—is generated.

Archives MNATP, Collection Meillassoux

If the surface finish is unacceptable, you'll probably have to switch to a smaller grit size. But first, when the wheel is new and imparting a poor surface finish, increase the wheel speed and take finer and finer finishing passes (a smaller DOC at a slower table speed) with several spark-out passes. This will impart a finer surface finish and you might be able to get away with it without having to use a smaller grit.

Finally, ask your wheel supplier what type of CBN grit is in the wheel. Angular grits and friable grits impart a rougher surface finish. If you're using one of these, ask about switching to a tough, blocky grit, such as Diamond Innovation's Borazon 500 or Element Six's ABN600.

Dear Doc,

I've been trying to find some literature on carbide grinding but haven't had any luck. Can you recommend a good book?

The Doc Replies:

The reason you haven't been able to find a good book on carbide grinding is that none exists. They're either too theoretical or too commercial.

The best thing out there is a booklet titled "Grinding of Carbides." It's simply a collection of technical articles, but it is somewhat useful. You can get a copy for $35 from Ted Giese at www.abrasivemall.com. △

About the Author

Dr. Jeffrey Badger is an independent grinding consultant. His Web site is www.TheGrindingDoc.com. E-mail grinding questions to him at badgerjeffrey@hotmail.com.