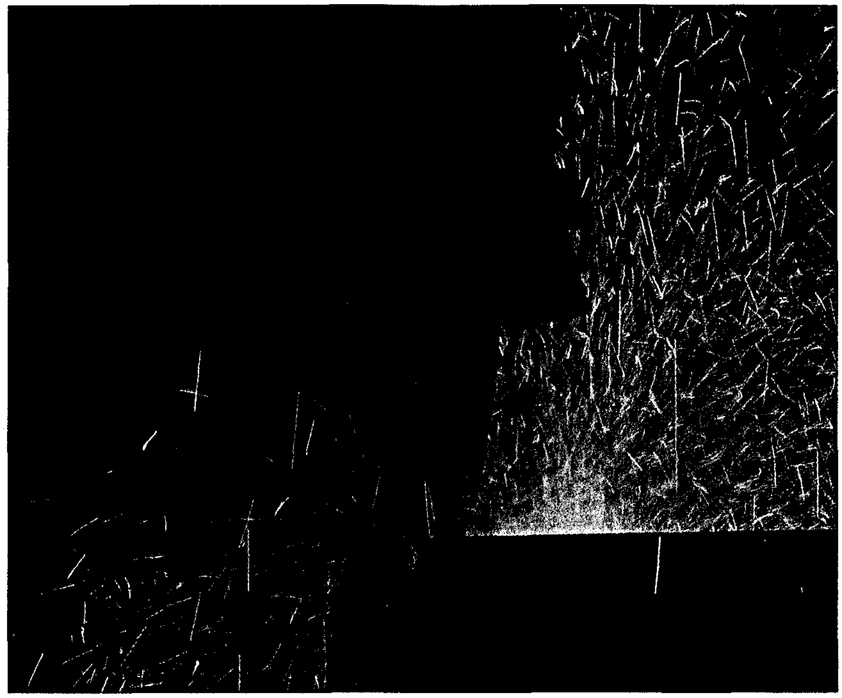
COST-CONSCIOUS GRINDING

If it's hard to justify a grinding investment, try some new approaches



In cost-justifying grinding equipment, manufacturing engineers and managers do well to focus less on payback periods, cost per part, and other conventional accounting approaches and more on rethinking this traditionally slow and expensive process to make it more productive.

Flexibility is king because fast turnaround has a major impact on the bottom line. In plants all over the world, says Pat Harrington, vice president of engineering, Bryant Grinder Corp. (Springfield, VT), "manufacturers want to order material for a part, make the part, invoice the customer, and ship the order before the invoice for the material comes in."

"Even aerospace manufacturers are learning that dedicated multimillion-dollar machines that must grind thousands of parts to pay their way are no longer the best choice," says Dr. Mike Hitchiner, CBN grinding systems manager at Universal Superabrasives Precision Grinding Systems Div. (Romulus, MI). "Flexible grinding centers that can grind a lot of 100 here and 100 there allows them to get rid of their inventory."

To eliminate processing steps, some manufacturers are experimenting with approaches like near-net-shape and simple-shape. Juergen Richter, president of United Grinding Technologies (Miamisburg, OH), says customers often want a part shipped the next morning. "There's no time to process orders like that on several machines."

"Imagine a cell with a few machines in which you green-turn raw stock to close tolerances, induction-harden, and finish-grind a few critical features," says Dr. Joe Kovach, department manager, Enabling Process Development, Manufacturing Technologies Center, Eaton Corp. (Willoughby Hills, OH). "If your company designs and develops its own processes, eliminating a process like rough broaching or milling by grinding a slot from a solid should be easy to justify. Take the idea further: at the design stage, combining certain part features into one will reduce size, complexity, and number of parts to be assembled later. That speeds up the manufacturing process even more."

In many high-production plants where dedicated equipment was once the norm, standard machines are doing the job. Automating load-unload, inspection, and machine and wheel monitoring gets around shop-floor skills shortages and makes round-the-clock operation an option for many companies. In working with Big Three automakers on gaging systems, Jack Dunda, president of gage builder Marposs Corp. (Auburn Hills, MI), says that "instead of custom systems dedicated to a particular application, automakers are extending reliable and maintainable systems to more applications. Standardization lowers equipment costs, and CNC allows users to reconfigure gaging systems easily for other parts. Downsizing is a fact of life in engineering departments and on shop floors, so systems that don't rely on one person's knowledge or extensive training are what those big companies are looking for."

Jean V. Owen
Senior Editor

Eddie McClymont, director of engineering, Toyoda Grinding Div. (Wixom, MI), says efforts to raise productivity through round-the-clock operation make manufacturers look to the controls on their grinders to make up for shortages of skilled tradespeople. "In fact," he says, "the main function of the CNC in future may be making machines automatic and self-diagnosing through user-friendly diagrams, instructions, and checklists."

As superabrasives and CBN become cheaper and better understood, thanks to better wheels and truing and dressing equipment, more companies are choosing them to achieve speed and precision.

Improving Grinding's Predictability

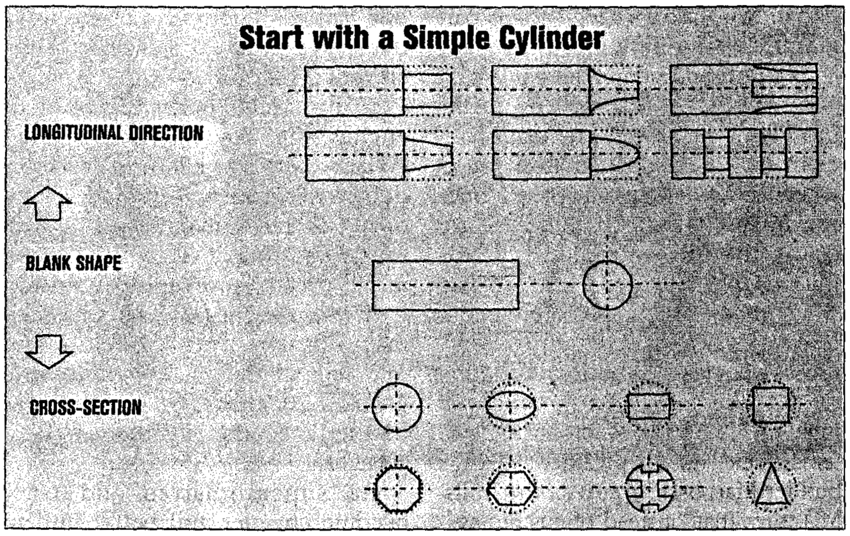
A software package called Cimform Predict-a-Grind 130 uses wheel speed, machine static stiffness, horsepower, size tolerance and surface finish required, material used, amount of stock to be removed, work diameter, and grindability to determine cycles and production rates. Abrasive type and bond system can also be plugged into cycle design.

Cornelis A. Smits, manager of advanced grinding system engineering at Cincinnati Milacron (Cincinnati), developed the package to make grinding less of a black art and more of a science. Still, he says, the approach continues to depend on real-world experience.

Frank J. Savel, grinding system engineer at TRW valve div. (Cleveland), was able to predict the form grind cycle of radius, chamfers, and flats on an automotive valve three months before runoff of a rebuilt machine. Savel says that when predicted grind parameters for the valve head and tip end were installed in the machine, cycle time rose 20% and target tolerance rose 60% over the previous best cycle, with all parts within the statistical target.

These improvements held good on TRW's tests on grinders from different builders, materials ranging from low-carbon, tool, and stainless steels to Inconel, titanium, and stellite, various grinding wheel types, and 20 part geometries. Savel cautions that using the program takes practice: "When grinding cycles change, wheel grades and sometimes fluids or truing practices must be adjusted." The software predicts production possibilities, not the tools you need to reach those rates, says Smits, who promises that the next version will specify these variables.

"Higher volumes have lowered superabrasive costs," says Universal Superabrasives' Hitchiner. "The bond structure is more efficient, we understand better how to true and dress, and machine accuracy is higher. People used to buy rotary diamond dressers to achieve form accuracy, part consistency, and tight tolerances. Now CBN grinding wheels can get the same job done with a much simpler truing and dressing device and wheel changes every six or nine weeks—even annually."



If lots are small, lead times are short, and part geometry is flexible within an envelope, consider simple solid shapes, says Norton's Tricard. Per-part cost drops because of low tooling and in-process inventory, lower setup and inspection times, minimal capital and labor, and less part distortion and differential shrinkage.

It's easy to get dazzled by new approaches and the explosion of grinding technology. Kovach urges manufacturing engineers to remember that there is no "right" manufacturing investment. "Step back, and look at your manufacturing environment. Define your part geometry and features, volume mix, tolerances, and any other factors that affect your plant like local environmental laws. See what process fits best. Then you're ready to do a pretty good job of capitalizing the plant correctly."

Minimizing Machine Investments

Because of rapid turnarounds, the big, flexible, complex, expensive machines preferred in the '80s are no longer the best choice for every manufacturer, says Richter of United Grinding Technologies. "When retooling a machine for two or three days' work takes a day, the relationship between productive and nonproductive machine time becomes highly unfavorable. Many users would do just fine with the simple no-frills machine of the '70s, with '90s ballscrews and CNC technology added."

Richter argues that a million-dollar machine must run all the time, but a company can afford to buy several small grinders for $100,000 apiece, tool each of them up for one of three or four frequently made parts, store programs, and install clamping fixtures on each machine table. When the next order for one of those parts comes in, everything is ready, and the job is done faster and cheaper.

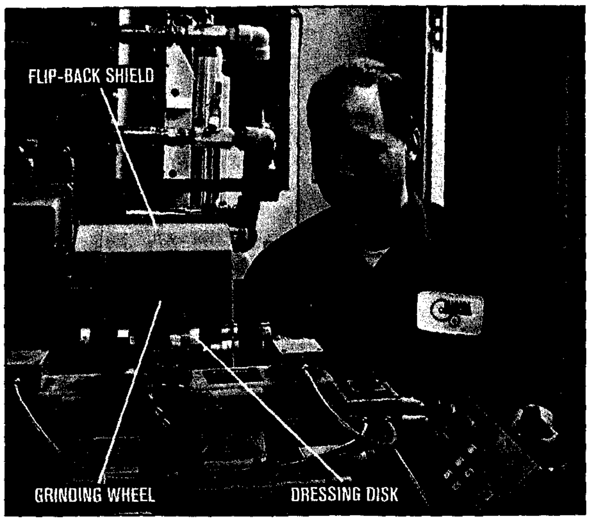
A big company with a skilled workforce making a lot of parts should think twice about this strategy, says Eaton's Kovach. Its best bet might be to buy a new CNC grinder and run it in a cell. But in a small shop with high setup times and few or no maintenance operators, he thinks Richter's approach makes sense, "The technology of the '70s is bullet-proof. Variability is minimal."

Be warned: that '70s grinder does need '90s technology. McClymont says the grinders Toyoda remanufactures must work to a tenth of the tolerance they were built for, and they need '90s feedback and monitoring systems. "That old machine has to join the gaging revolution," he says.

"Sophisticated computer feedback gives you sizes and positions that make the grinder do just what you want." Such monitoring keeps dressing of expensive material to a minimum, prevents crashes of expensive wheels, and eliminates rough dressing.

Blanking Out a Step

Grinding the geometry a customer orders directly from near-net shapes, rather than milling, hardening, and then grinding, is what Richter of United Grinding Technologies favors. Little stock is removed to get the surface finish and tolerances required. Software that lets you grind triangular shapes on a cylindrical grinder and round forms on a surface-type grinder makes it possible. Combining the rotary with the in-feed motion of the grinding wheel on cylindrical and creepfeed grinders allows forming triangular or oval or square shapes without clamping the part a second time. Once the operator enters the length of the sides or the angles of the shape wanted, a form-generating macro does the rest.



Once the operator sets the new grinding wheel and dressing disk in place on Gleason's TAG 400 CNC grinder, automatic grinding and dressing cycles take over. The shield flips back to expose the wheel to the gear on the other side of the grinder. Though state-of-the-art CNC machines like this cost 35% more than non-CNC grinders and about 25% more than the latest electronic machines, Niagara Gear found output doubling, tripling, even quadrupling.

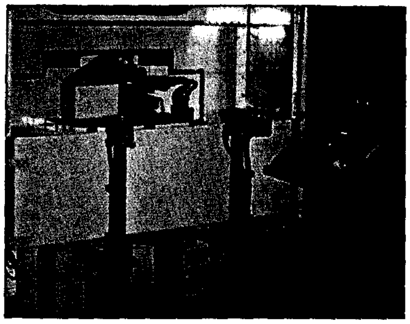
Users like near net shapes because they minimize material cost, says Marc Tricard, project development manager at Norton Co. (Worcester, MA), but there is a down side. "Though you use the minimal amount of raw material, you significantly increase tooling cost. Instead of pressing a simple cylinder, you must press an entire component. A slight variation in a part may mean changing dedicated tooling."

Tricard believes the emphasis on fast throughput, small-batch production, and little in-process inventory is working in favor of the simple-solid-shape approach. "An inventory of simple shapes costs a company little and speeds throughput," he says. The grinder must be a three to five-axis CNC machine with creepfeed, cylindrical creep feed, and high-speed out-of-round capability with a stiff wheel, fixture, and workpiece. When a part is needed, sophisticated grinding techniques put the required geometry in rapidly. Lead time amounts to preparation for the grinding operation.

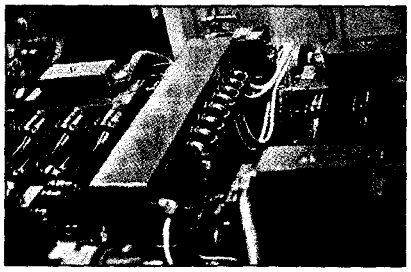
Because the block or cylinder or other form is slightly bigger than most of the parts carved out of it, Tricard says, many components with only slight variations in shape can be made from the blank: "No special tooling is needed for forging or centering operations, just the equipment to make a cylinder."

An end-mill supplier who keeps two-flute, three-flute, and five-flute styles in inventory, ready to heat-treat and final-grind when ordered, can prepare and heat-treat the simple cylindrical rods on which they are all based, so that when the order comes in, the operator simply carves out the right number of flutes.

Bill Phleger, vice president, Landis Tool Co. (Waynesboro, PA), says users have been intrigued by the idea of simple solid shapes for many years, and many camshaft and crankshaft manufacturers who can use similar blanks for different cams do mill from solid blanks. The idea never became widespread, he says, because so much waste material goes into the coolant where it's hard to dispose of. As for near-net shapes, "everyone likes that idea, but only when running larger part quantities."



Automation speeds up the grinding process at a Big Three automaker. Loading proceeds on one side of the Magerle machine, with the operator protected by splash guarding, while slot grinding proceeds on the other side. The machine indexes around to bring the next part under the wheel. Because the loading side of the machine is stationary, it's easy to add a robotic loading mechanism.



Double the Productivity

When Bob Barden, vice president of Niagara Gear (Buffalo, NY), bought a TAG 400 CNC gear grinder from Gleason Works (Rochester, NY), he had to justify spending twice the price of a nonelectronic grinder and 25–30% more than a non-CNC electronic grinder.

Barden's argument was productivity, not labor savings. "One operator on the TAG doesn't do the work of two," he says. "One machine does the work of two, so our 40-employee shop gets the productivity of 80 people without adding one square foot or one employee."

Instead of enticing people with high skills to the plant, says Barden, "we can use present employees with

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lower skill levels effectively because the environment created by CNC isn't intimidating." The TAG 400's "nonintimidating" atmosphere includes a real-time grinding-mode monitor that fine-tunes the grinding process; sensors to monitor and report coolant temperature and purity, pressure, and lubricants; and computerized timed and dated preventive maintenance programs.

Using Cost Savings, Not Capacity

High-production operations traditionally justify large capital investments on the basis of cycle time reductions that increase capacity. Bill Schutt, a manufacturing engineer at Dana Corp.'s Spicer Driveshaft Div. (Pottstown, PA), used extra capacity as the reason to buy eight grinders from Bryant Grinder. After the line was installed, Schutt changed his argument for buying the next group of ten grinders to one of cost savings.

Spicer grinds 70–90 million U-joint cups every year on a line that runs around the clock, so a small improvement in cycle time represents a major saving. When Bryant's Ultraline high-speed bore grinders and CBN wheels replaced some of Dana's cam-operated Bryant machines 16 months ago, cycle time for grinding the ID diameter of the U-joint cup dropped 33%. "Producing in five days what used to take seven saves those wages and fringe benefits," says Schutt. "When we began to plan for a second group of machines, I worked out the money saved throughout the process. At that point, I changed my cost-justification argument."

On the cam-operated machines at Dana, one operator oversees five machines, but one of them is always down for maintenance, usually slide repair/rebuild. Operators change wheels every 39 min, removing 0.001″ (9.03 mm) from the wheel, and then spending time regaining size. "On the new grinders we dress every 200 pieces and take off 0.0001″ [0.003 mm]," says Schutt. "We change wheels every two weeks, and the CBN wheel returns to size on the first piece after dressing, bringing scrap levels close to zero."

The dress compensator resolution on the old machines was too coarse for CBN, but very fine compensators on the Ultraline grinders are designed for truing CBN wheels, and the machines themselves are stiff enough to handle fast movements, thanks to hydrostatic slides. The hydrostatics drastically reduce maintenance time, and a pressure filtration system from Flo-Con Industries (Plainfield, NJ) keeps the wheel clean, producing a dry cake that can be sent to a landfill (or burned).

The 100%-inspection operation at the end of the line on each shift was replaced by a postprocess gaging system from Airtronics (Elgin, IL). Gaging of each part ID now takes place outside the grinding area while the next part is ground. The Ultraline operators spend most of their time on new duties like making sure part hoppers are filled. Schutt expects two operators working as a team to run all 10 machines on the proposed new line. Apart from eliminating three inspection-machine operators, Schutt expects the overall reliability of the

Circle 55

system to decrease maintenance labor on the new line by 1.5 operators.

Learning Superabrasive Economics

Though the savings at Spicer were clear, manufacturing engineers often find selling a superabrasive application difficult. "In the late '80s CBN got a bad reputation because people didn't yet understand the process and applied it on every machine they could think of," says Universal Superabrasives' Hitchiner. "Meanwhile, the wheel they were using cost fifty times the conventional wheel."

Because a big factor in the cost of CBN isn't how much abrasive gets used during grinding but how much gets dressed off in truing, machine tool builders are working with suppliers of abrasives and dressing devices to optimize their approach. Users are taking different tacks as well. One auto company is subcontracting all its abrasive purchases to a supplier specializing in just that, to see whether costs go down.

"CBN's accuracy and guaranteed uptimes give you more cycle time, so capital costs are lower," Hitchiner argues. "If you can use 22 or 25 grinders in a line instead of 30, at $750,000 each, you've just saved $10 million. That will buy you enough CBN wheels to run that line for 10 or 20 years."

This is not the kind of economics most manufacturers favor, however, as suppliers know well. Hitchiner: "Abrasive producers know they are judged both on the cost of the abrasive and the cost per part. Budget line items like $100,000 for grinding wheels get close scrutiny."

At GE Aircraft Engines (Evendale, IL), GE Superabrasives' (Worthington, OH) William R. English and manufacturing engineer Jerry Geverdt compared grinding a 34" (864-mm)-diam high-pressure turbine nozzle shroud assembly made of a superalloy with vitrified-bond CBN and aluminum oxide. The CBN wheel itself cost 140% of the conventional wheel, and wheel cost per part was almost triple. What English calls the "hidden costs" of the conventional method reverse the equation, however.

English and Geverdt tracked per-part costs of storing, uncrating, and delivering wheels; machine maintenance; coolant replacement; swarf disposal; the postgrinding processes that superabrasives eliminate; inspection/quality procedures; and scrap and rework. They calculated time saved in assembly because of greater dimensional control and the increase in sales generated by higher product performance.

Total cost dropped 36%, or $569.40/part, partly because CBN produced 380 pts/yr compared with aluminum oxide's 336. Annual cost savings in the total production system were $191,318.40/yr (336 × $569.40). Wheel change cost/part for aluminum oxide, for example, was $30, $0.62 for CBN. Per-part labor cost was $1012 vs. $888.15. Maintenance labor cost was $62.81 vs. $36.75. Inspection cost was $22.50 vs. $14.40. Scrap cost, always a major concern for aerospace manufacturers, was $440.48 vs. $48.68, an 89% reduction.

What's Ahead

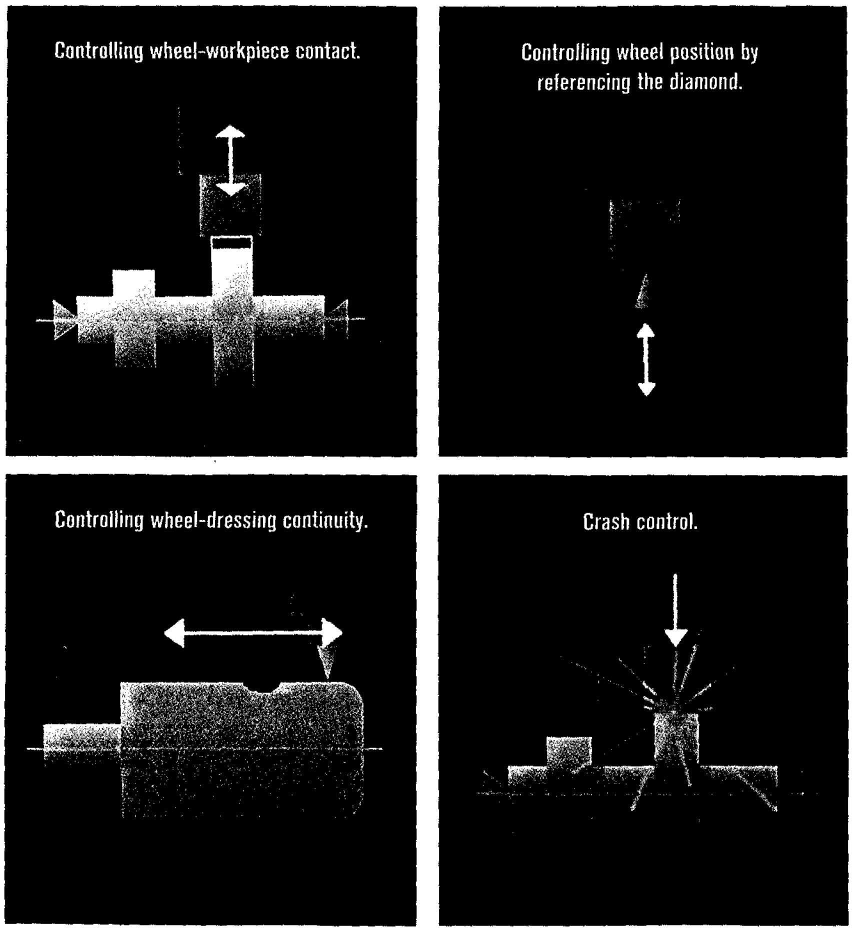
"Because customers buy machine tools to use for decades, not years, machine-tool vendors are ultraconservative," says Kovach. "In an era of mass customization and proliferating niche markets, however, users must tweak their machine tools to get the most out of them." Open-architecture controls on grinders are coming, he says. When they do, plug-and-play tool sensing modules will appear to take advantage of them, while software vendors will quickly develop ID grinding software packages that allow users to do their own customizing.

Ceramic parts, a problem to grind today, may soon get help from laser-assisted grinding, according to Dr. Ioan Marinescu of the Center for Grinding Research & Development, University of Connecticut (Storrs). Preheating the ceramic with a low-power laser makes the ceramic more ductile and increases the depth of cut. As machining represents 50–80% of the cost of a ceramic part, says Marinescu, the laser assist could significantly reduce the cost of manufacturing these parts. As for dressing these difficult parts, a process being tested in Japan called ELID (Electrolytic In-Process Dressing) erodes the bond and cleans the wheel so that the grinder produces mirror surfaces at higher removal rates.

Another strategy for running faster and cheaper from the University of Connecticut is an acoustic emission sensor for cylindrical, internal, and centerless grinders to detect wheel contact in 3 ms. Digital signal processing monitors wheel/work and wheel/truer contact. Operators can greatly increase approach spee without fear of collision.

Hybrid ceramic bearings bei tested allow running at higher spee but the experts say they don't ha the damping and stiffness of oth systems. Hydrostatics and antifricti rolling elements have their adva tages, but the tradeoffs are cost an reliability.

As new cost-effective technologi appear in the next few years, or thing is certain, says Dunda Marposs: "The pressure on supplie for more flexible systems and great involvement will continue to b intense. As more manufacturing con panies shrink, assembling their proc ucts to order from kits of parts the subcontract from job shops, thos shrunken engineering departmen will be demanding total support fro their vendors." ■



Don't be one of those people who won't run the process to the maximum, who change tools prematurely or do other things to minimize the risk of catastrophic failure, says Eaton's Kovach. They take only marginal advantage of the new technology because they can't accept the fact that the sensors and controls make it safe to go just a little faster in their application. Marposs's acoustic sensor, for example, signals contact of the grinding wheel with the workpiece, the wheel dresser, and other unpredictable elements to minimize dressing, avoid crashes, and optimize the grinding cycle.

Want More Information?

SME offers a two-day course, Modern Grinding Technology, at the Charlotte '96 APEX conference and exposition March 12–13, along with a day-long course, Purchasing Your Next Machine Tool, on the 12th. To get employees up to speed, take a look at the newest video, *Basics of Grinding*, in SME's video series, Fundamental Manufacturing Processes.

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