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Weldon Solutions has developed a work drive adapter that allows mounting a diamond roll onto the workhead for wheel truing. Here, a Beck (Universal) sintered diamond roll is truing a Universal vitrified CBN wheel on a Weldon Solutions peel grinder.

All images: Saint-Gobain

Well-dressed PLAN

New online dressing technology eliminates inefficient offline dressing and advances CNC production of round cutting tools.

Advances in online truing and dressing of grinding wheels—coupled with better monitoring and control—are helping to increase production and improve the quality of round tools, such as drills and endmills.

New superabrasive wheels, lap-free bonded profile dressing rolls and high-speed DC dressing spindles are eliminating the need for time-consuming and problematic offline dressing. Lap-free refers to the elimination of the need for regrinding or relapping of the diamond to restore tip geometry. Lap-free, bonded profile dressing rollers have 0.250" of usable dense diamond particles, which are uniform and do not require relapping.

The benefits of online truing and dressing include:

- Improved workpiece quality due to decreased wheel runout, increased wheel geometry accuracy, and more frequent truing and dressing.
- Increased production throughput due to decreased machine downtime, increased unmanned production hours, increased wheel life and shorter grinding cycle times due to the grinding wheel remaining conditioned.
- Improved operator safety since truing is completed inside the CNC machine, dressing and conditioning needs are significantly

decreased and manual "sticking" is eliminated by having it performed automatically inside the machine.

Truing and Dressing

Truing, or form regeneration, makes a wheel round to its axis of rotation and restores the wheel profile, which breaks down with use. Cutting tool manufacturers typically perform truing on an offline dressing machine.

Dressing, or conditioning, involves removing or sharpening dull grains and removing loaded material and small amounts of the wheel's bond to expose new abrasive grains, which allow the wheel to cut freely.

Offline truing and dressing present major challenges. First, when an operator removes a grinding wheel from the machine for truing and dressing, runout accuracy—how round and true the wheel is to the spindle on which it is grinding—can be compromised.

This is because when the operator mounts the wheel to the truing spindle of an offline dressing machine, the wheel becomes round and perpendicular to the truing spindle. Then, when he remounts the trued wheel on the grinding spindle, there could be 0.001" to 0.002" (best case) or 0.005" to 0.006" (worst case) of runout. In the latter case, the grinding wheel will not cut equally along its entire circumference. This creates chatter, increases wheel wear and leads to an inferior surface finish.

Offline dressing also causes production delays. When retruing a wheel, a shop loses an hour of manufacturing time for removal, truing, re-installation and dressing. In addition, the price of an offline dressing machine ranges from $45,000 to $90,000. It doesn't make parts, so it remains idle much of the time.

ANCA has a system with a conventional truing wheel or diamond roll mounted onto its high-speed work drive. Here, a silicon-carbide wheel is mounted to the workhead of an ANCA machine.

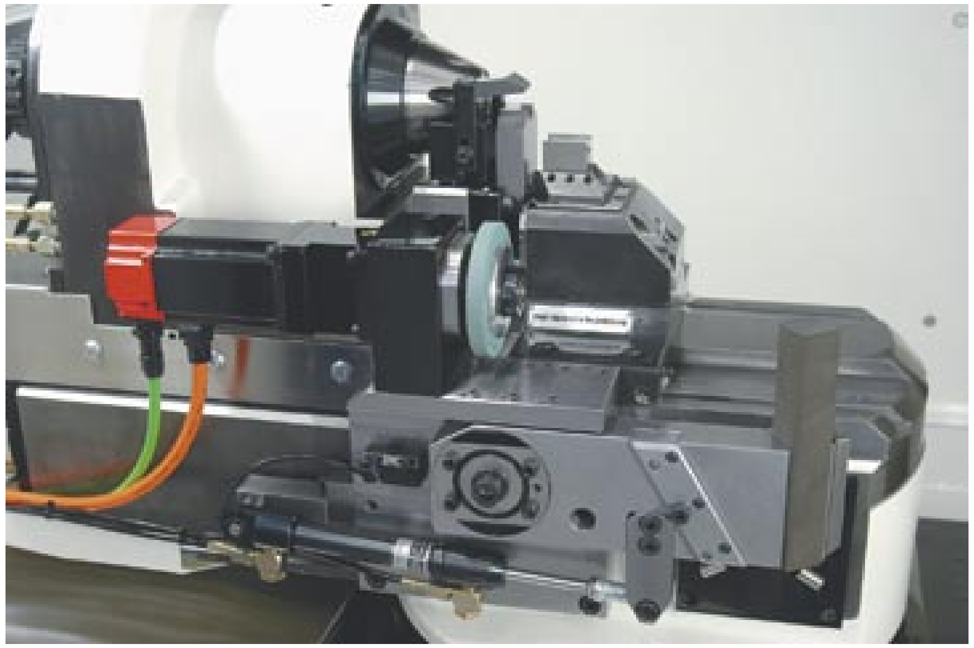
Saving Time, Money

Long recognized as a timesaver when grinding metal parts, online dressing was first performed with superabrasive wheels on machines used to produce bearings. Today, manufacturers always perform online truing and dressing when grinding camshafts and crankshafts, and the practice is also prevalent in the aerospace industry.

Machines for grinding cutting tools have become so sophisticated that with the right wheel, dressing roll and dressing spindle, truing and dressing can be done online. Nonetheless, over 95 percent of cutting tool manufacturers running superabrasives still apply resin-bond, metal-bond or direct-plated wheels. And, in the case of direct-plated wheels, they dress offline or not at all.

Cutting tool manufacturers considering upgrading to online dressing will need the following to ensure success:

- superabrasive wheels that can be dressed online;
- lap-free, bonded profile dressing rollers;
- variable-speed DC spindle assemblies; and
- sound applications engineering.



A new system from Rollomatic combines an online dressing spindle with an automated stick dresser, allowing for automated truing and conditioning. This lends itself to increased reliability for extended production.

Superabrasive grinding wheels are specifically designed for grinding hard metals. Vitrified superabrasive wheels are the easiest type to true. The bond post, which is made of glass, is actually crushed.

Historically, resin- and metal-bond superabrasive wheels were so difficult to true that the process was never attempted on the grinding machine. Today, hybrid polyimide wheels have self-dressing, wear-resistant bonds that, in many cases, require little or no stick dressing. Compared to resin and polyimide, vitrified and hybrid polyimide superabrasive wheels decrease downtime in applications that involve offline dressing and extend wheel life when dressing online.

Regardless of the type of truing and dressing system used, when compared to competitive products for producing micro- to large-diameter round tools, hybrid polyimide superabrasive wheels:

- consistently remove more stock per pass at a given spindle power;
- achieve a higher grinding ratio and longer life;
- produce finer tool finish and edge quality; and
- yield a lower overall cost per tool.

Relapping Sent Packing

Lap-free, bonded profile dressing rollers offer several advantages over traditional rollers made with polycrystalline-diamond particles or chemical-vapor-deposition diamonds and conventional sintered rolls with natural diamond particles. These traditional rollers require relapping as many as four times during their lives—at 30 to 50 percent of the initial cost for each relapping. Even in online truing and dressing operations, relapping or replacing a dressing roll produces machine downtime.

Brazed profile rolls (BPRs) support truing and dressing applications that require a tip radius as small as 0.005" and a tip angle as small as 0°. (Most other profile rolls have larger starting radii and require a tip angle to support the diamond tip.) BPRs are, however, currently limited to obtaining work piece finishes of greater than 20μin R_a.

Diamond dressing rolls other than BPRs, such as reverse-plated construction (RPC) rolls, can be used effectively for online dressing. RPC rotary diamond dressers are manufactured by electroplating nickel to the diamonds, inside a precision mold. During online dressing, RPC dressing tools have consistently outperformed direct-plated diamond dressers.

A Varied Approach

Variable-speed spindle assemblies

Success stories

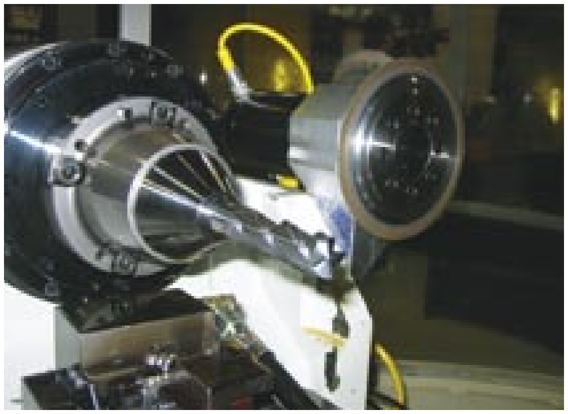
The combination of factors described in the main article—superabrasive wheels, lap-free dressing rollers, DC dressing spindles and good applications engineering—have produced superior results in round cutting tool production runs.

Examples	Results
1. Fluting 1"-dia., 4-flute, HSS endmills. These workpieces had a 0.650" core and 2.00" flute length. Grinding was done on a Walter Vision 44-hp machine, using a 7", 150-grit, vitrified CBN wheel running at a peripheral speed of 10,000 sfm. Reconditioning was performed online, unidirectionally, after every five parts using a BPR diamond roll, one traverse dress at a depth of 0.0002", +75 percent speed ratio and a dress lead of 0.004" per wheel revolution. The vitrified CBN wheel ground each flute to final depth at a feed rate of over 8 ipm.	The cycle time to complete the ball-nose endmill was under 8 minutes (including robot load and unload) for fluting, OD relief, the center cut and all end features. The initial lights-out run produced more than 500 parts with no scrap. This represents more than a 100 percent improvement in cycle time per part. The finished endmills exhibited excellent cutting edge quality and very good rake face finish when viewed at 150× magnification.
2. Knuckle grinding ½"-dia., 4-flute carbide roughing endmills. The specifications called for roughing the endmill knuckles to have a 1mm pitch and a 1.5" flute width. Grinding was done on a Rollomatic 600X machine with a 6-hp spindle, using a 6" 320-grit vitrified diamond wheel running at a peripheral speed of 7,400 sfm. Reconditioning was performed online, unidirectionally, using an RPC plunge diamond roll with two forms, a plunge dress at a 0.0008" depth and a +67 percent speed ratio.	Operators increased the knuckling feed rate by 50 percent over the previous direct-plated diamond wheel. Three hundred parts per dress were obtained before the form grew out of tolerance with the vitrified wheel. Cycle time dropped significantly and, more importantly, this operation produced improved cutting edges over the direct-plated wheels, when viewed at 150× magnification.
3. Flute grinding 6mm, 2-flute, high-performance carbide drills. Grinding was done on an ANCA MGX 11-hp machine using a 6" hybrid polyimide wheel running at a peripheral speed of 6,000 sfm. Reconditioning was performed online, counter-directionally, after every 40 parts using a BPR diamond roll, a traverse dress at a depth of 0.0005", a -1,467 percent speed ratio and a 0.626 overlap ratio. The feed rate was 12 ipm vs. 8 ipm for the previous wheel, a 50 percent increase.	The hybrid polyimide wheel offered four times the life of the wheel it replaced and twice as many parts per dress (40 vs. 20). It could be dressed online; the metal-bond wheel could not. Also, the hybrid polyimide wheel did not require stick dressing. Cycle time was reduced by one-third, and the cost per part was reduced by 31 percent.

Sidebar compiled by Timothy M. Finn

with DC brushless motors allow online dressing that takes full advantage of the CNC capabilities of high-speed grinding machines. These DC spindle assemblies provide three times the power, 10 times the torque and have three times faster spindle speeds than the AC spindles typically used in offline dressing.

Since they are one-quarter the size of AC spindles, the DC units are compact enough to fit on grinding machines not typically designed for online truing and dressing. The DC spindles' maximum runout accuracy is 0.000080" or, more typically, 0.000040".



Walter Helitronic Power grinding machine with a BPR diamond profiling roll mounted onto a DC brushless dressing spindle. The workpiece is a ¾" 4-flute carbide endmill.

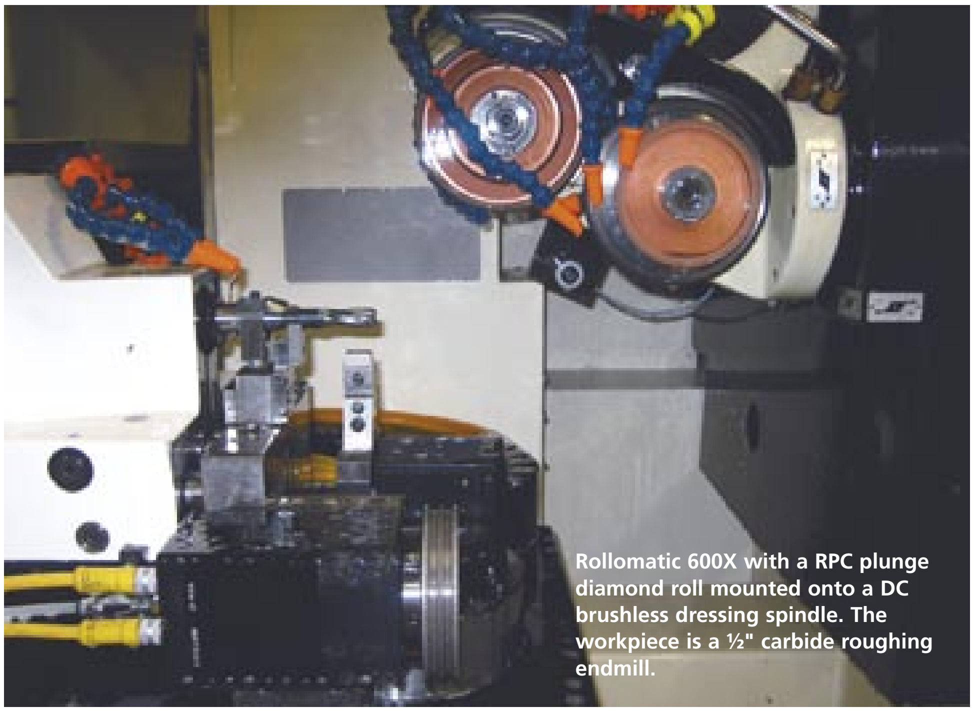
Engineering a Solution

Effective online truing and dressing for vitrified and hybrid polyimide wheels require sound applications engineering. Critical parameters include the speed ratio (between the dressing spindle and the grinding wheel), the proper direction of dress (counter- vs. unidirectional) and the proper overlap ratio (determined by the diamond width of the dressing roll, wheel speed and the diamond's traverse rate across the width of the wheel).

For a given application, the user determines optimal settings for these parameters according to the finish and tolerance requirements, as well as the type of grinding wheel used and how best to condition it to make a specific tool.

Applications engineers have developed truing procedures for different workpieces and grinding wheels. For example, unidirectional truing, also called crushing—in which the grinding wheel and the dressing roll actually turn in the same direction at the point of contact—is generally the best technique for conditioning vitrified CBN and diamond wheels. Unidirectional dressing takes higher dressing forces, which lead to a sharper wheel. This sharper wheel allows for lower grinding forces and imparts a rougher surface finish.

Unidirectional dressing is shown in the speed ratio with a plus (+) sign. Therefore, a +75 percent speed ratio is an excellent starting point for vitrified wheels where bond posts are being broken. That means the dressing roll must rotate at about 75 percent of the grinding wheel's speed (in sfm).



Rollomatic 600X with a RPC plunge diamond roll mounted onto a DC brushless dressing spindle. The workpiece is a ½" carbide roughing endmill.

Counter-directional truing, or shearing, is generally used when lower truing forces are required, such as with hybrid polyimide grinding wheels. Counter-directional truing at a high speed ratio allows the diamond dressing roll to grind the wheel. The diamond roll is rotating 10 to 15 times faster (in sfm) than the grinding wheel. Counter-directional dressing is shown in the speed ratio with a minus (-) sign. The result is a speed ratio of approximately -10 to -15 (-1,000 percent to -1,500 percent).

Proof is in the Sensors

The applications engineering and associated grinding processes used to produce cutting tools (see sidebar) can be measured and analyzed with sensor-based systems using Hall-effect current probes and linear variable-differential transducers. These systems measure and monitor various performance indicators, such as power consumption, cycle time and workpiece behavior.

Software converts the transducer signals into quantitative process data that can be used for various calculations and comparisons. Options include comparisons of different cycles or the same cycle on different days, with different machines or abrasives. Or, one might wish to compare power trends over several cycles. Other factors that can be calculated from data captured by the system include grind times, feed rates and material-removal rates. Data can even be gathered about microscopic interactions occurring in the grinding zone.

For fluting round cutting tools such as drills, stepdrills and endmills, one option is an operation that combines online wheel conditioning with hybrid polyimide grinding wheels, which have been tested on all makes of round tool machines in North America against nearly all competing wheels from multiple suppliers. The increased wheel velocity achievable with hybrid polyimide wheels produce improved rake face surface finish and outstanding edge quality. See example 3 in sidebar (page 70) for more information.

These process-monitoring capabilities point to a bigger issue: grinding optimization using sophisticated monitoring systems. Using data from the sensor-based measurement and analysis system, engineers can determine the impact any factor that influences grinding might have on grinding results.

At the same time, engineers can also consider all of the process monitoring input groups: machine tool, workpiece material, abrasive product and operational factors—including wheel balancing, truing, dressing and conditioning parameters.

The systems approach to improving round tool production has led to many of the advances described in this article and promises to lead to more in the future. △