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Grinding fundamentals: understanding wheel preparation and grinding fluids.

Abrasive Lessons

PART 2

BY DR. STUART SALMON

This is the second installment of a two-part article on grinding fundamentals. The first portion, which appeared in the March issue, looked at the types of available abrasives and bonding systems. The information presented here covers wheel preparation and grinding fluid application.

Preparing the Wheel

Wheel preparation includes mounting, balancing, truing and dressing. It is also where many grinding problems occur.

First, mount the grinding wheel according to the manufacturer's guidelines to ensure good initial balance and minimal runout prior to dressing. Second, take care when mounting a grinding wheel so as not to damage the wheel bore. The bore of a rotating wheel undergoes the highest stress; "wheel-bursts" that occur on startup can often be attributed to poor handling and mounting practices. Third, be sure to use the paper blotter/washers provided when mounting vitrified wheels, and, fourth, tighten the flanges with an even torque and tightness.

After mounting, the grinding wheel should be rough-balanced, dressed and fine-balanced prior to grinding. An additional dressing and rebalancing operation may be required if the wheel was initially and significantly out of round or out of balance.

Proper wheel balance will yield consistently good surface finishes and long wheel life. In addition, proper dressing will produce both a consistent grinding wheel surface and grinding action.

The dressing procedure determines the level of wheel sharpness and the accuracy of the form on the grinding wheel. Therefore, it's important to keep

Glossary of Grinding Terms

Arc of Cut: The arc of contact between the workpiece and the grinding wheel.

Concentration: The amount of superabrasive material contained in a unit volume of the grinding wheel. The measurement is based on the number of carats per unit volume.

Dressing: The removal of material from the periphery of a grinding wheel using a diamond tool.

Hard Turning: Turning hardened metal on a special lathe with special tooling to eliminate grinding.

Mesh: The mesh number refers to the size of an abrasive grain based on the number of holes per linear inch of a gauze or wire grid.

Overlays: The number of passes a diamond dressing point makes across the periphery of a grinding wheel.

pH level: Describes the acidity or alkalinity of a chemical solution on a scale of zero (acidic) to 14 (more alkaline).

Porosity: The air pockets within a grinding wheel that make it appear sponge-like.

Swarf: The mass of chips and debris remaining after grinding.

Truing: Application of a diamond tool to a grinding wheel to ensure roundness and concentricity.

the dressing equipment, whether it's a single-point diamond in a holder or a diamond roll dresser in a motorized unit, in precise working order.

Single-point dressing is the most common way to dress vitrified grinding wheels. It is also the most common cause of erratic grinding behavior, creating a need to constantly adjust and readjust the process.

When grinding a workpiece surface, the wheel typically rough-grinds an initial amount of stock and then, after a change in dressing parameters, finishes the surface. The rule of thumb is to rapidly traverse the diamond across the grinding wheel periphery for the initial roughing pass. For fine finishing, the dresser is traversed at a much slower speed to achieve a smoother grinding wheel and, accordingly, a smoother workpiece finish.

A system of "overlays," or "overlaps," should be used to ensure a correct, consistent dress (Figure 1). An example is a 16"-dia. grinding wheel, running at 6,000 sfm, being dressed with a 0.010"-radius, single-point diamond for a rough-grinding operation. The amount to be dressed, per pass, is 0.001".

It is typical for the dresser feed to be too fast, causing the diamond to miss a large area of the wheel periphery. Multiple passes, on the other hand, often result in the entire wheel being dressed, but leave the surface uneven. That can lead to an aggressive wheel, but one that wears unevenly and too quickly.

Dressing should always be performed at the operational grinding speed. The only exception is when crush dressing, which is done at a low speed of about 300 sfm. A calculation needs to be made with respect to the dresser diamond size and the condition required on the grinding wheel periphery (Figure 2). Generally, roughing requires two to three overlays and finishing requires four to six overlays.

Applying Fluid

The proper application of grinding fluid is essential to successful grinding. The action of the fluid is to cool and lubricate the arc of cut.

Water-based fluids mostly cool, while providing some lubrication, whereas straight oils provide mostly lubrication and some cooling. Fully synthetic, water-based fluids are ideal for sharp and aggressive grinding wheels when the arc of cut is moderately long and a good flushing action is required.

Semisynthetics work best when the wheel is creating an intricate form and extra lubricity is necessary to avoid grinding burn. Straight oils perform best when the form is intricate, the arc of cut is short and a high degree of surface finish is required. Glycol-based fluids are ideal when cubic boron nitride is the abrasive and straight oils need to be avoided.

Choosing a grinding fluid can be a formidable task. The initial cost of the fluid needs to be considered, of course, but so does the cost of managing and disposing of it. Environmentally friendly, or "green," fluids are a hoax. The virgin fluid, in its drum, may be drinkable, but

Understanding Superabrasive Concentration

An important detail about the specification of a superabrasive wheel is its grain concentration. The industry seems to have a misconception that a 100 concentration means 100 percent. The number 100 refers to there being 72 carats of grain per cubic inch of wheel.

So, a 50 concentration means there are 36 carats of grain per cubic inch of wheel.

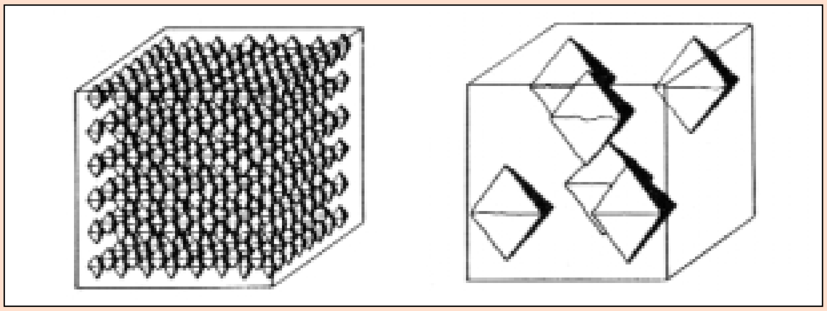
Grains are available in many different sizes. Yet wheels with different sized grains can have the same concentration.

Consider a 75-concentration, 60-U.S.-mesh wheel vs. a 75-concentration, 200-U.S.-mesh wheel. Each wheel has 54 carats by weight of abrasive per cubic inch of wheel. For the 60-mesh grain, 6,900 grains weigh 1 carat, whereas 262,000 200-mesh grains weigh 1 carat. Therefore, the 60-mesh-grain wheel has 372,600 grains per cubic inch and the 200-mesh-grain wheel has 14,148,000 grains per cubic inch.

If we assume that the grains are distributed evenly throughout the grinding wheel, then by taking the cube root of the number of grains per cubic inch, the average number of grains per linear inch can be found. For the 60-mesh grain, the average number is around 72, and for the 200-mesh grain, the average is about 242.

The reciprocal of those numbers gives the average grain spacing. The grain spacing is 0.014" for the 60-mesh-grain wheel and 0.004" for the 200-mesh-grain wheel. If the length of the arc of cut is 0.013", then each grain in the 60-mesh wheel is spaced farther apart than the arc length is long. On the other hand, the grain spacing of the 200-mesh wheel is 0.004", so there would be at least three grains in the arc of cut, along any linear line, at all times. However, the rule of thumb is to ensure that between four and 10 grains are in contact along an average line around the arc of cut.

—S. Salmon



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The variety of abrasive grains means there are more smaller grains (left) than larger grains when the concentration is the same.

once grinding swarf has contaminated the fluid, it generally becomes an environmentally “unfriendly” waste.

Whichever grinding fluid is chosen, it should be filtered and maintained, not only with respect to cleanliness, but also to control the concentration, electrical conductivity and pH level.

Recent fluid-performance tests showed that fluid concentration does not affect the grinding process in a linear fashion. It has long been believed that by increasing the concentration of a water-based fluid, the grinding process will improve proportionally. This is not true. Grinding fluids with a known performance at a 5 percent concentration were not as effective as the concentration approached 7.5 to 8 percent, but improved again as the concentration approached 10 to 12 percent (Figure 3).

Of the more than 50 water-based fluids tested, every one followed the same pattern. In some cases, the trend was hardly noticeable. In others, the fluid literally stalled the machine at 7.5 percent while working quite well at 5 and 10 percent.

Having selected a suitable fluid and fluid management system, it is of para-

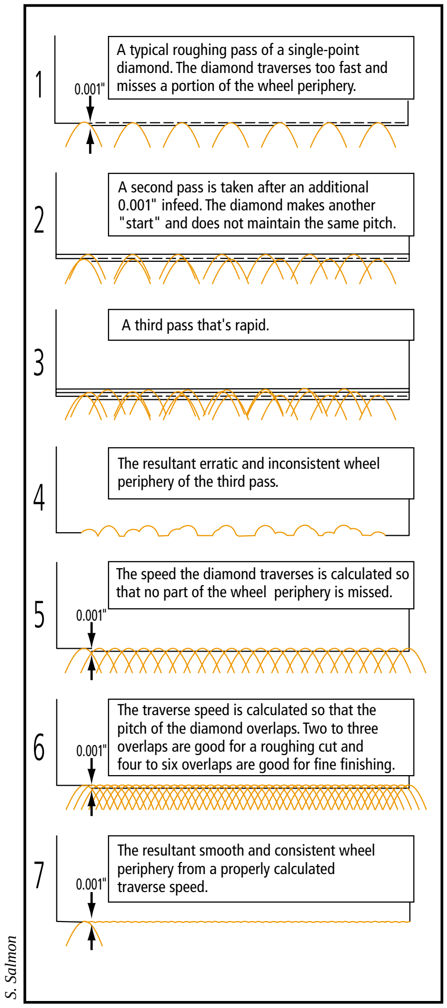

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Figure 1: The use of overlaps, or overlays, ensures a correct and consistent wheel dressing. Two to three overlays are generally incorporated for roughing and four to six for finishing.

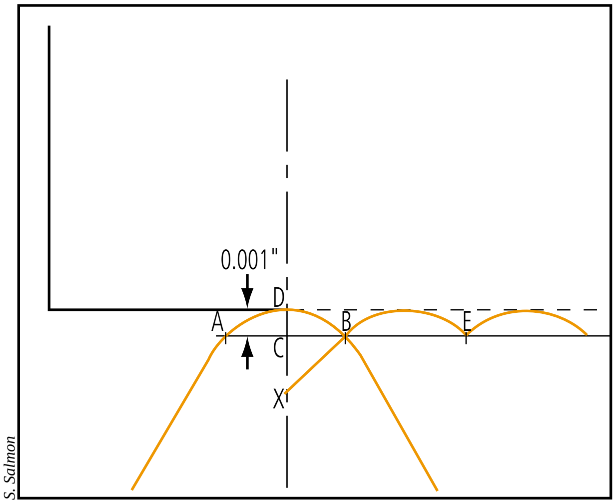

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Figure 2: The dresser traverse speed is calculated by knowing the diamond’s radius (XB = 0.015"), the diamond infeed (0.001") and the wheel rpm (1,400). The distance CB can be calculated, where XB = 0.015" and CX = 0.015" - 0.001" = 0.014", as: $\sqrt{(XB^2 - CX^2)}$ = $\sqrt{(0.00025 - 0.000196)}$ = 0.00735. Therefore, AB = 2 x CB = 0.0147". The diamond has to pitch the distance AB every wheel revolution, so as not to leave a gap. That speed is AB x 1,400 rpm = 20.58 ipm, which is the speed where the diamond covers the wheel once. If the diamond needs to overlay twice, the traverse speed would be halved, to 10.29 ipm, an ideal roughing feed. For finishing, the overlay is four to six times, so the traverse speed would drop to 5.14 ipm for four overlays.

Calculating the length of the arc of cut

The length of the arc of cut is calculated by knowing the radius of the grinding wheel (the distance OC or OB) and the wheel depth of cut (the distance AB.)

For example, if the wheel radius is 10" and the wheel depth of cut is 0.100", then the angle subtended by the arc of cut is the COS^{-1} of angle T, which is OA/OC = 9.900/10 = 0.9900. Angle T is 8.1°. Angle T in radians is (8.1 x 2π)/360 = 0.14154 radians. The length of the arc of cut is the wheel radius multiplied by angle T in radians, or 1.4154" (10 x 0.14154).

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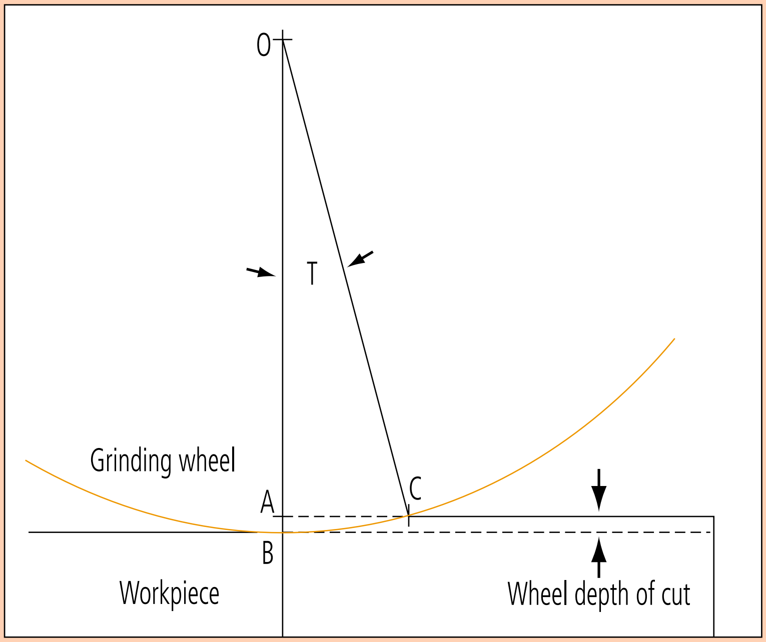

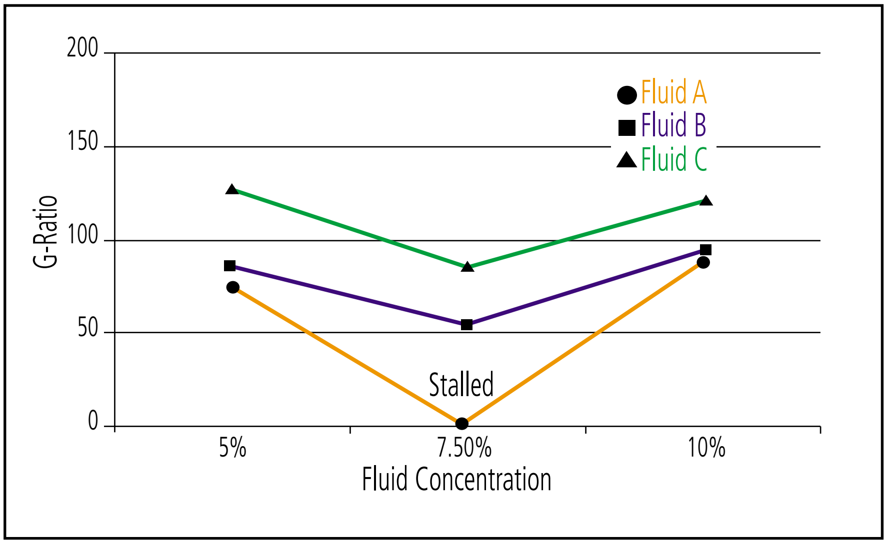

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Figure 3: Grinding fluids with a known performance at 5 percent concentration (95 percent water) are not as effective at 7.5 percent concentration, but improve at 10 percent concentration. G-Ratio is the amount of workpiece material removed vs. the amount of grinding wheel used.

mount importance to apply the fluid to the grinding zone properly. The fluid needs to be applied so that it's present in the arc of cut and not simply splashed or sprayed in the direction of the wheel/workpiece interface. Generally, little fluid enters the arc of cut under flood conditions. The rotating wheel, like a spin dryer, tries to throw the fluid out and away from its periphery.

The porosity of the wheel allows for chip clearance and the transportation of the grinding fluid, but it is the wheel itself that takes the fluid through the arc of cut. The fluid needs to be applied to the wheel periphery at wheel speed for this to happen.

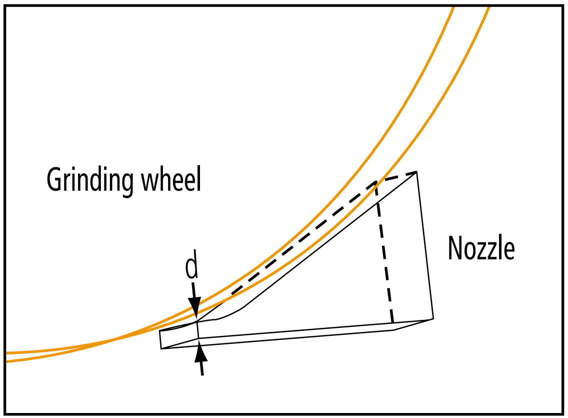

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Figure 4: The height of the nozzle opening (d) can be calculated to determine the proper nozzle dimensions.

Furthermore, the nozzle needs to be designed specifically to apply the fluid to the right impingement point and at the correct velocity. The nozzle will need to cover the grinding wheel's width, which is known. Therefore, the height of the nozzle opening (d) needs to be calculated (Figure 4). If the nozzle width is 1.5", then the exit area of the nozzle is 1.5d in.^{2}. The grinding speed might be 5,500 sfm, which, when multiplied by 12, equals 66,000 in./min. Therefore, the velocity of the fluid exiting the nozzle is:

(1.5d in.^{2}) × 66,000 in./min. =
99,000d in.^{3}/min.

Let's say the pump delivers the fluid at 58 gpm, at a maximum pressure of 110 psi. There are 231 cu. in. in a gallon. Therefore, the pump delivers 231 cu. in. × 58 gpm = 13,398 in.^{3}/min.

Obviously, what goes in one end of the pipe must come out of the other, so since 13,398 equals 99,000d, the height of the nozzle (d) should be:

0.135" (13,398/99,000).

It is better to make the height of the nozzle opening slightly smaller than the calculated value, as the fluid velocity will drop off slightly after exiting the nozzle. This is particularly important if the nozzle is not right up against the grinding wheel. A nozzle measuring 0.125"×1.5" would be ideal.

The pressure drives the fluid through the system. The resistance to flow might exceed the pump's 110-psi capacity if the nozzle is made incorrectly, or if the path of pipes, joints and elbows through which the fluid flow is contorted. If any of these flow inhibitors exists, the fluid velocity will probably be reduced. Therefore, the flow rate should always be checked using a flow meter. It is insufficient to monitor the flow with only a pressure gage.

About the Author

Dr. Stuart Salmon is president of Advanced Manufacturing Science and Technology, Rossford, Ohio. He will present his SME-sponsored Modern Grinding Technology course Oct. 23-24 at the Cleveland APEX.