FEBRUARY 2007 / VOLUME 59 / NUMBER 2

➤ BY DAVID C. GRAHAM, HIGGINS GRINDING TECHNOLOGY CENTER, AND KEN SAUCIER, SAINT-GOBAIN ABRASIVES INC.

Break on Through

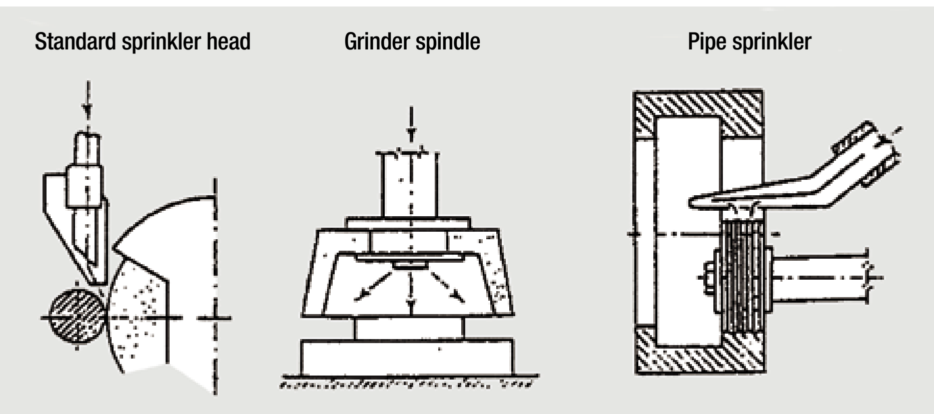
How effective coolant application—including the use of jet-type nozzles—can help optimize the grinding process.

Coolant application plays a significant role in the optimization of grinding processes. This article explores effective coolant utilization, with a focus on how jet-type nozzles can more effectively deliver coolant to the grinding process.

Compared to turning and milling, grinding requires significantly more power to remove a given amount of material. This higher process energy places a greater demand on coolant application and, therefore, coolant application is more critical when optimizing a grinding process. In addition, the cutting speed when turning and milling ranges from about 200 sfm to 2,000 sfm, whereas in grinding it ranges from 3,000 sfm to as high as 20,000 sfm.

When a grinding wheel rotates at such high speed, a boundary layer of air forms around the wheel. This makes it difficult to get coolant into the pores of the wheel for carrying it into the grinding zone. Also, a wheel generally contacts a longer length of the workpiece than a milling or turning tool. These differences require a different approach to coolant system design.

As a new process changes during development on a new machine, coolant application will need to change as well. Additionally, with many production shops



J. Borkowski and A. Szymanski, *Uses of Abrasives and Abrasive Tools*

Figure 1: Conventional ways of supplying fluid to the grinding zone.

New nozzles produce better results

Implementing the principles presented in the main article can significantly improve grinding.

For example, an automotive parts manufacturer was having air quality problems because of oil mist generated while grinding power train components with plated CBN wheels. The mist collection system was unable to remove the very fine particles produced in the grinding zone. Measured at the back of the machine, the central coolant system supplied 180 gpm at 60 psi, but the calculated pressure at the nozzle apertures was only 5 psi.

From this information and the power measurements taken, coherent jet nozzles were designed to provide the correct amount of coolant at 60 psi. After the new nozzles were installed, wheel life increased significantly, the mist in the grinding zone was eliminated and air quality improved substantially.

Another example was at a cutting tool manufacturer having problems with burn when it tried to reduce cycle times for fluting M-2 tool steel. The existing crimped copper tubing nozzles produced a divergent jet that was difficult to accurately target. By replacing the existing nozzles with a coherent jet nozzle that could be better targeted at the grinding zone, the burn was eliminated and tools per dress increased by 150 percent.

In addition, when the toolmaker was gashing 1.0" tungsten-carbide endmills, a wheel running at 2,700 sfm generated excessive heat and broke several tools. Two coolant lines were added for additional cooling, and wheel speed increased to 3,000 sfm. Heat was minimized and, as a result, the feed rate was doubled.

This manufacturer can now grind five times the number of tools between dressings and has decreased cycle time by 50 percent. As a result, cost per tool decreased, resulting in a savings of 51.5 percent.

—D. Graham and K. Saucier

using central coolant systems, the demands of a new process or machine in the production line and its effect on the total system are not always fully understood. Once a machine is installed, operators or floor supervisors generally don't have the authority to change the coolant system; they do the best they can with the existing system. All of these limitations can be overcome through a better knowledge of coolant application and its role in the optimization of grinding processes.

Coolant use when grinding provides six main benefits:

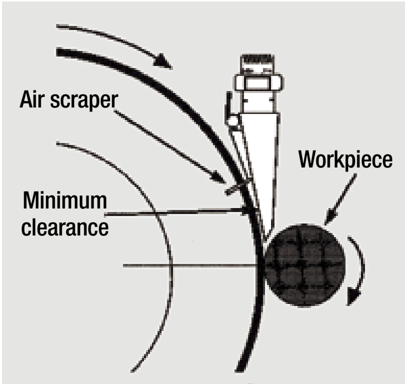
- Bulk cooling of the workpiece in and around the grinding zone;
- Chip flushing from the grinding zone;
- Lubrication, which reduces energy consumed by the many microscopic sliding interactions occurring in the grinding zone;
- Temperature reduction, thereby extending wheel life;
- Wheel cleaning, which prevents loading; and
- Temporary corrosion resistance.

System Approach

When designing a coolant delivery system, each system element—including nozzles, pump, pipes, filtration and overall system capacity—must be evaluated.

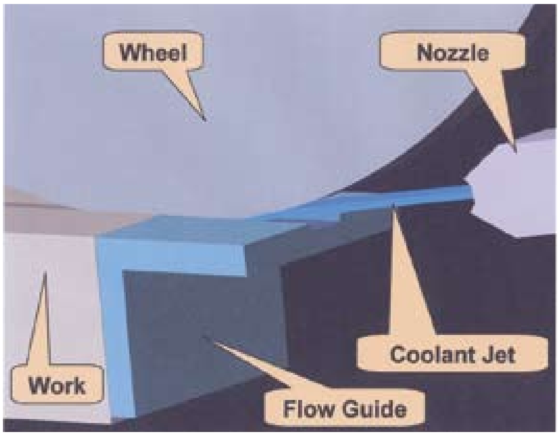
The type of coolant is also key. Types of coolants include oils, water-soluble oils, semisynthetic coolants and synthetic coolants. Oils, in general, provide better lubrication to reduce grinding power, while water-soluble oils, semisynthetic coolants and synthetic coolants are more effective at removing heat from the grinding zone because of their water content. When using oil, a fire suppression system should be installed on the machine in case the coolant supply is interrupted.

There have been many types of nozzles designed for various grinding processes. On older, open machines where applying large quantities of coolant is impractical, dribble-type nozzles have been used at low pressures and



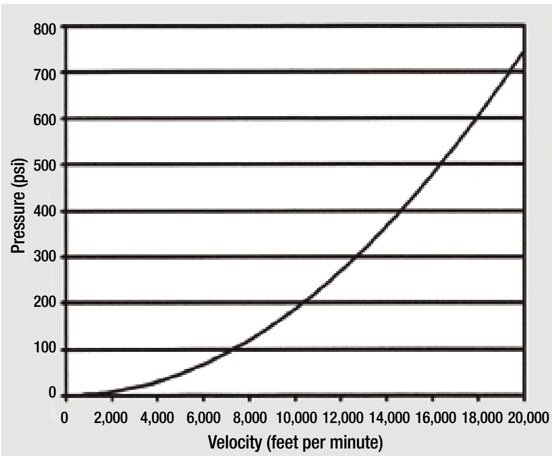
Jerry P. Byers, Metalworking Fluids

Figure 2: A fire hose-type nozzle supplies large volumes of coolant at low pressures.



Saint-Gobain Abrasives

Figure 3: A flow guide is positioned at the end of a part to trap coolant and force it into the wheel structure and the grinding zone.



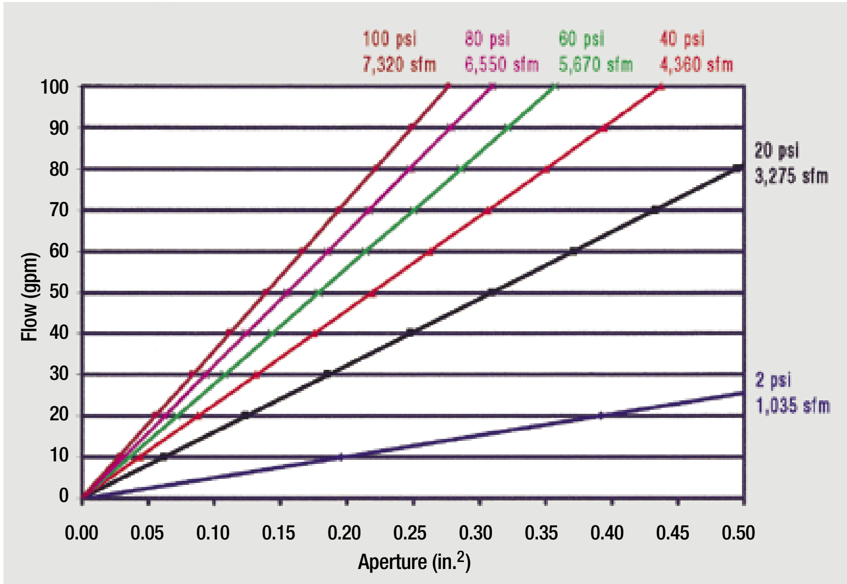
Saint-Gobain Abrasives

Figure 4: The relationship between coolant pressure and jet velocity.

flow rates (Figure 1). These provide some cooling of the workpiece but are inadequate for today's highly productive machines.

The fire hose-type nozzle supplies large volumes of coolant at low pressures (Figure 2). They may employ a piece of metal to help break the air barrier surrounding the wheel.

Flow guides are also employed, particularly in cases where burn occurs only at the end of the part (Figure 3). The flow guide is usually positioned at the end of the part and traps the coolant, thereby forcing coolant into the wheel structure and the grinding zone. Without the flow guide, the coolant is reflected off the face of the part and away from the grinding zone.



Saint-Gobain Abrasives

Figure 5: The relationship between aperture size and flow rate at given pressures.

Jet Set

The jet-type nozzle is more effective when properly designed because it provides the right amount of coolant—no more, no less—at the appropriate velocity to penetrate the air barrier and target an exact location using a coherent coolant jet.

When roughing, more heat is generated and more coolant is required to cool the process. But how much is enough, and what's the best way to get the coolant to the grinding zone where it will do the most good?

At the Higgins Grinding Technology Center, Worcester, Mass., engineers have conducted creep-feed grinding tests with metal workpieces and determined the optimal amount of coolant to be 2 gpm per horsepower of grinding energy. Numerous field applications have confirmed these results. Therefore, the first step in designing a coolant system is to measure or estimate the grinding power and the corresponding width of grind through the entire grinding cycle. This can be done using a measurement and analytical tool.

Maximum grinding power is the highest power consumed during grinding, minus the power draw when the wheel and coolant are on but not grinding. Once the maximum grinding power is determined, the amount of coolant required can be easily calculated.

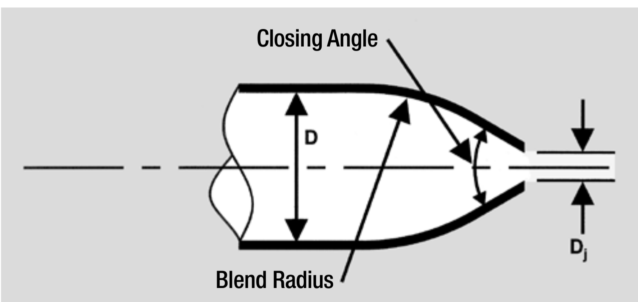
By using a jet-type nozzle and matching the coolant jet velocity to the wheel speed, the coolant will penetrate the air barrier and be carried into the grinding zone. Because coolant jet velocity is a function of the pressure at the nozzle, use Bernoulli's equation to calculate the required pressure. Once the pressure and velocity requirements have been determined, the nozzle aperture size can be calculated using the formula:

$$V_j = \frac{19.25 \times Q}{A_j}$$

Where V_j is feet per minute, Q is the flow rate in gpm and A_j is the nozzle's exit area in sq. in.

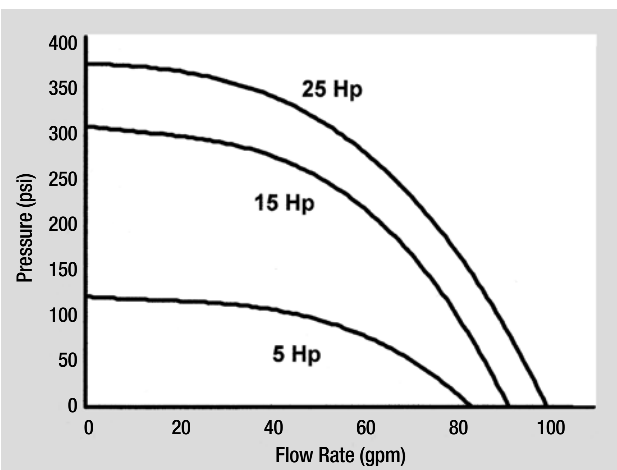
Figure 4 shows the relationship between pressure and jet velocity, while Figure 5 shows the relationship between aperture size and flow rate at given pressures.

To produce a coherent jet, the nozzle should have smooth transitions, converging geometry, a fine surface finish and no burrs at the exit. Sharp bends in the supply line produce turbulence and cause poor jet quality. Figure 6 depicts a recommended jet-type nozzle configuration.



Saint-Gobain Abrasives

Figure 6: A recommended jet-type nozzle configuration to produce a coherent coolant jet.



Saint-Gobain Abrasives

Figure 7: Typical performance curves for centrifugal pumps.

Pipe ID	0.5"	0.75"	1"	1.25"	1.5"	2"
Flow rate (gpm)	10	20	40	70	140	260

Figure 8: Recommended pipe diameters for various flow rates.

Pumps and Pipes

It's also critical to consider the coolant delivery system's pump and the piping. Centrifugal-type pumps are typically used for coolant systems, and they each have a unique performance curve for pressure and flow rate. The lower the flow rate, the higher the pressure, up to the pump's maximum capability. Figure 7 shows typical performance curves for centrifugal-type pumps.

Note that as coolant volume increases, pressure decreases, reducing the jet's velocity. If the jet velocity is too low, coolant doesn't penetrate the air barrier; more volume is not always better.

Additionally, if the pipe diameter is too small, a pressure drop occurs across the length of pipe, requiring a higher pump pressure or a reduction of pressure at the nozzle. Figure 8 shows the recommended pipe diameters for various flow rates.

Because coolant systems are an already integrated part of grinding machines, operators and their supervisors often give little thought to coolant and how it is delivered to the grinding zone. In this scenario, they fail to recognize that optimizing coolant supply or coolant quality can produce remarkable benefits. Optimizing the use of cutting fluids and the coolant system itself helps manufacturers optimize the overall grinding process, resulting in significant cost savings. △

About the Authors

David C. Graham is a research engineer at Worcester, Mass.-based Saint-Gobain Abrasives Inc.'s Higgins Grinding Technology Center in the Grinding Systems Services group. Ken Saucier is an application engineer for Saint-Gobain Abrasives as a part of the Corporate Applications Engineering function. For more information about Saint-Gobain Abrasives' grinding wheels and other grinding products, call (508) 759-5000, or visit www.nortonabrasives.com.