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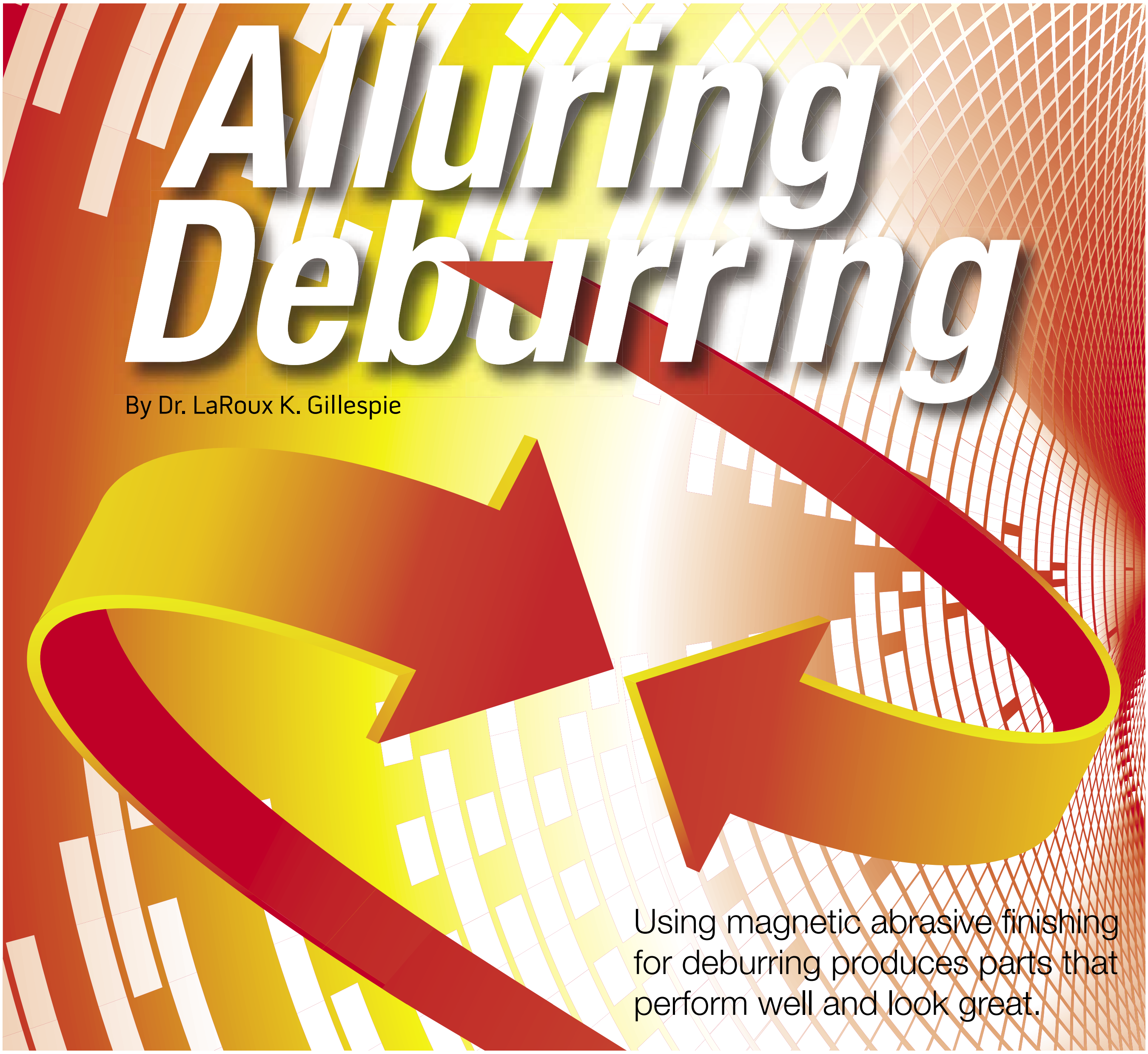
Alluring Deburring

By Dr. LaRoux K. Gillespie



Using magnetic abrasive finishing for deburring produces parts that perform well and look great.

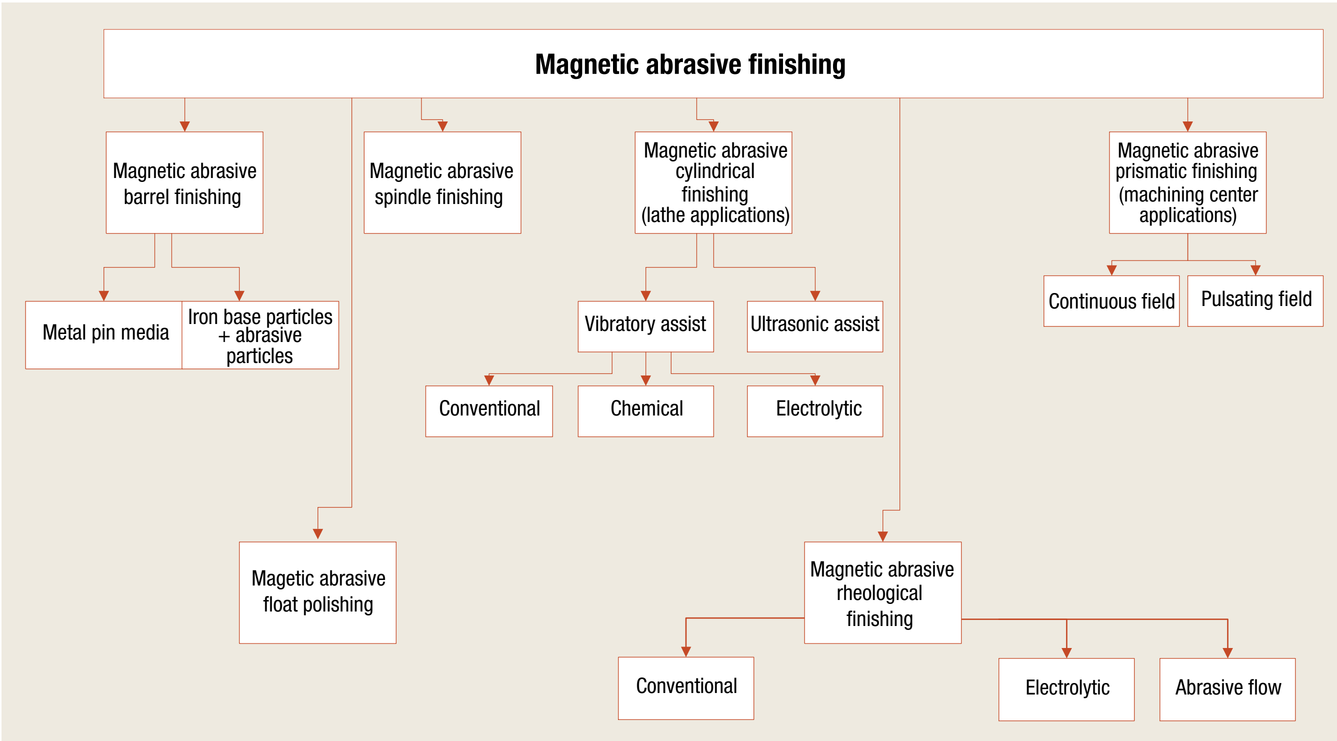
Customers won't accept precision parts with rough surfaces, microcracks, recast metal, burrs, metallurgical phase changes, visible scratches or damaging residual stresses. Yet grinding, EDMing, laser machining, conventional cutting and even polishing can produce these unwanted side effects. However, magnetic abrasive finishing or polishing (MAF or MAP) processes can remove these defects and provide highly polished surfaces (Figure 1).

EDMed surfaces typically exhibit recast metal subsurface damage. This can cause parts to be rejected. Subsequent processes such as reaming, honing, lapping and grinding must be used, but they too can create problems to a lesser degree. MAF, however, does not create additional quality problems and is one of the least complicated processes for removing material to provide a true base-metal surface.

Equipment is Part Dependent

The equipment needed for deburring with MAF depends on part geometry. For example, a small lathe can typically be used for MAF of cylindrical surfaces, while a milling machine performs MAF on flat surfaces, recessed pockets, rectangular parts and parts with both flat and cylindrical surfaces.

In MAF, a magnetic field is created by rotating the part opposite a fixed magnet or rotating the magnet around a fixed part. These magnets attract abrasive grains of different sizes and materials, such as silicon carbide, which come into contact with and finish the part's surface. The abrasive grains are mixed with small amounts of metalworking fluid, such as distilled water, SAE30 motor oil or kerosene. The fluid helps retain the abrasive, adds lubricity and cools the parts. It also reduces abrasive impregnation and improves finishes. Some abrasives have metal cores that respond to the magnetic field. If abrasives without this core are used, loose magnetic grit (such as iron filings) is added to create a medium that responds to the magnetic field. The magnetized grit



L. Gillespie

Figure 1: There are several types of magnetic abrasive finishing (MAF), which can be divided into groups and subgroups. MAF float polishing and rheological finishing are primarily processes for semiconductor and ceramic parts. Other processes can accommodate metal, glass and ceramics.

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and coolant medium carries the abrasive particles along with it.

An MAF setup for deburring does not need to be precise or rigid to produce mirror finishes because the magnetic field directs the loose abrasive grains. These grains act as self-sharpening tools because different edges rotate to make tiny cuts in the workpiece. The magnetic field orients the abrasive/magnetic grit mixture into long strings, producing a brush-like tool. Since the field constantly exerts a force attracting the abrasive medium, this "brush" does not need compensation. Real brushes wear and their length must constantly be adjusted in CNC machines. Grinding and honing require dressing of their tools, but MAF does not.

Figures 2a and 2b show two typical MAF setups. In a milling machine (2a), the magnetic tool is chucked in the spindle and rotated. Cylindrical parts are typically chucked in a small lathe (2b). In the latter example, magnets are placed a few millimeters from the part. While it is possible to use conventional production machines for MAF, many shops use special dedicated MAF machines for deburring.

Figure 2a shows a simple flat plate workpiece. More complex workpieces can be finished using spheroid, cycloid, cylindroid or free-curved tools that are inserted into the spindle and then into the magnetized abrasive. The abrasives form a layer on the tools, which can then be used to impart a finish on the sides of dies and molds as well as under the ledges of irregularly shaped parts or the bottom sides of through-holes.

MAF Research

Biing-Hwa and colleagues at Taiwan's National Central University demonstrated that EDM recast layers from 0.0005" to 0.0015" thick can be removed from 55 HRC tool steel cylinders in 30 minutes using MAF. Grinding, lapping and honing may also remove the recast, but they impart surface damage not allowable in critical applications. MAF does not impart surface damage because the forces and energy involved are low. In their study, the authors found that the 0.0004"-thick recast surface had a starting finish of 80μin. R_a. Using lathe-based MAF, the recast was totally removed in 30 minutes while finish improved to 1.6μin R_a. The surface then had the same hardness and grain structure as the parent material. The process works on any curved or flat surface.

V.A. Litvinenko and other researchers at Omsk (Russia) State Technical University, used MAF to polish drill flutes. They found that when using appropriate setups, cutting edges are unaffected by the treatment. The researchers recommended helical polishing rather than cylindrical, prismatic or flat surface finishing because it allows the media to go up the helical flutes and polish along the chip flow path. Litvinenko's research showed that the retained austenite in the drills' surface was reduced by 36 to 49 percent. The researchers believe the magnetic field helps reduce the retained austenite in HSS tools, i.e. improvement is not just from polishing affected areas; it is a combination of the magnetic field and the polishing action that reduces the austenite.

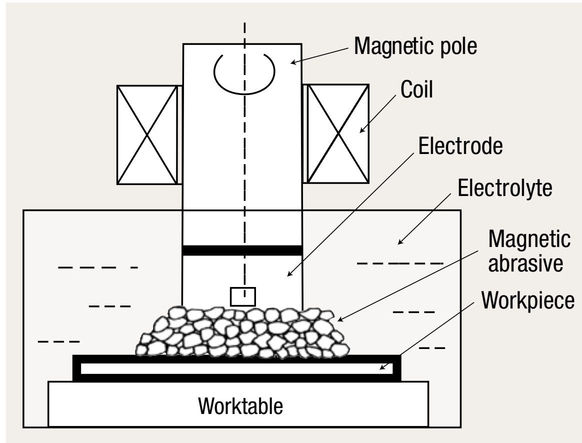
Litvinenko pointed out that the grinding of drills produces residual subsurface tensile stresses. With MAF, these stresses were transformed into compressive stresses, which should increase tool life. He cited tool life improvements of 300 to 350 percent with MAF.

Litvinenko said MAF also improved the subsurface properties of titanium and non-heat-treated aluminum. It improved the fine crystal structure of these materials because the process removes saturated atoms of oxygen, nitrogen and hydrogen to return the crystal structure to its normal state. Returning to normal is an improvement because the saturated atoms typically increase stresses in the crystal structure. Wear in the titanium alloys studied was reduced by 50 percent compared to parts finished with traditional polishing methods. The use of MAF increased titanium's hardness by 10 percent and aluminum's hardness by 15 percent.

MAF's media can impregnate the workpiece surface. SiC can be seen in the surface when electron probe micro-analysis, energy dispersive X-ray analysis or related Auger laboratory analyses are used. When SiC is the abrasive, MAF can impart a mirror finish but it will be a darker color than when SiC is not used. Magnification of 1,800× or greater will be needed to find any impregnated particles, according to Geeng-Wei Chang of Taiwan's National Central University. His research indicated that the minute amounts of impregnated SiC can distort the grain structure enough to add a small amount of beneficial residual compression stress. Chang's hardness values, however, indicated no change in surface hardness. Residual stresses would normally be indicated by hardness changes. This added stress may, however, be responsible for a 16 percent increase in the steel's corrosion rate.

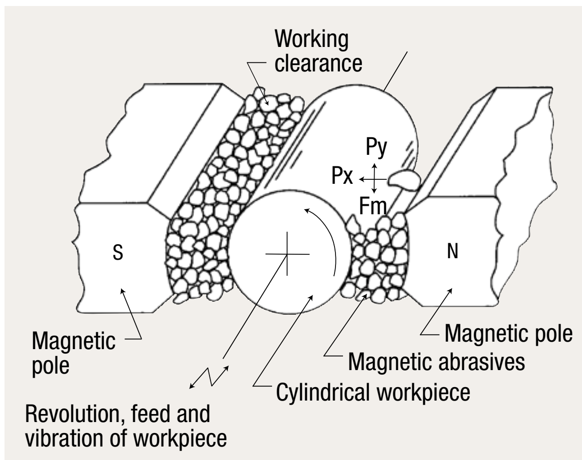
The choice of MAF media can minimize impregnation. Research by Yuri Baron, Ph.D., of St. Petersburg (Russia) State Polytechnic University demonstrated that using an iron powder alone or a mixture of iron powder and Al_2O_3 produces a surface that is chemically the same as the base surface.

For many applications, MAF provides major surface finish improvements in less than 5 minutes. Surface finish can be further improved by using a multistage process—large grain sizes in the first, smaller ones in the second and very small ones in the third stage. Researchers using a three-step MAF



"Advances in Abrasive Technology"

Figure 2a: Milling machine-based MAF (conventional MAF uses coolant rather than the electrolyte shown here).



Shinmura, Takazawa and Hatano

Figure 2b: Lathe-based magnetic abrasive finishing for cylindrical workpieces.

process demonstrated surface finish improvements in 1045 steel from 32µin. R_a to 1.8µin. R_a in 12 minutes (94 percent improvement), according to S.R. Zhang, Ph.D., Changchun (China) University of Science and Technology. Using four steps, Y. Zou of Utsunomiya University in Japan reduced surface roughness in 304 stainless steel from 270µin. R_a to 1.2 µin. R_a in 2 hours (Figure 3). Few applications will begin with a surface of that roughness, nor run that long. Also, as Figure 3 shows, surface finish improvement tapers off over time. The finest finish on metals reported in research studies appeared to be 0.4µin. R_a.

MAF equipment is generally inexpensive because most shops have the required machine tools (mills and lathes). However, with the exception of an MAF process using small barrels with metal pins, equipment for MAF is custom.

Growing Body of Research

Over 200 recent research reports and 300 global patents and patent applications testify to the emerging technology for MAF devices and methods used for deburring, polishing and edge finishing. The force of a single abrasive grain against a part is very small, which minimizes damaging side effects. Cutting forces can be as low as 0.00036 lbs. on a single part. In contrast, the force on the spindle accumulated by many magnetic elements may be as great as 22.5 lbs. In MAF, cutting forces are smaller than the magnetic forces employed since many particles are not oriented to cut. When finishing large parts with MAF, there will be more cutting force than for small parts since the actual cutting is an accumulation of many particles cutting and large parts have more area to cut. In an MAF milling application, the magnetism is supplied by a magnetic spindle inserted in the chuck or in the machine spindle.

MAF can deburr and treat an entire surface or, with a special tool, can be limited to areas smaller than 0.040 cu.

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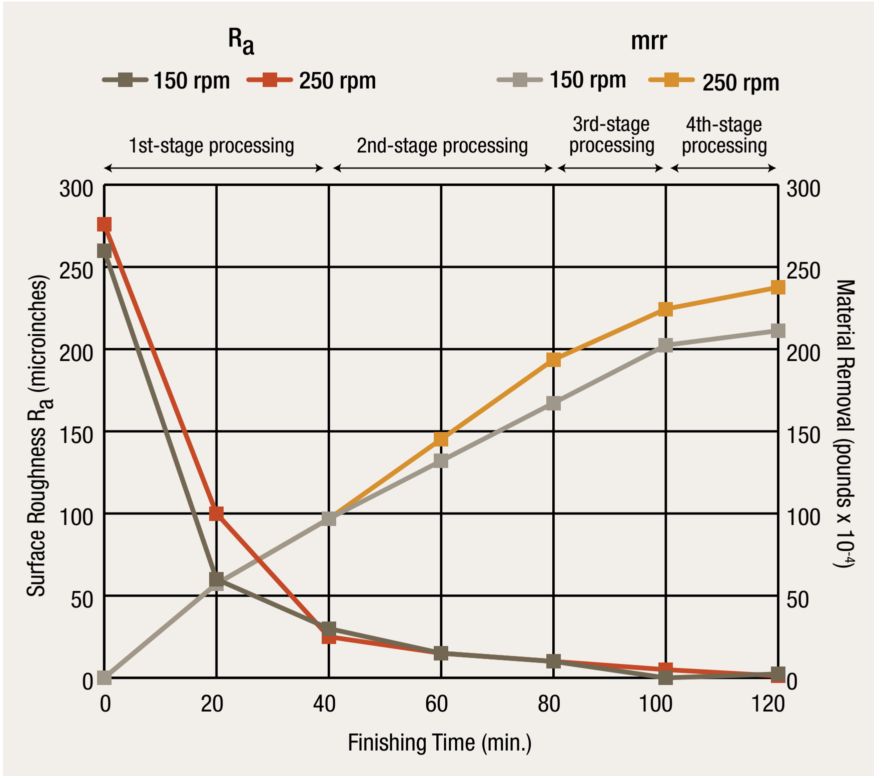
in. MAF can be limited to removing no more than 0.000001" of surface material or it can remove a few thousandths. It can be used to finish parts for pressurized vessels, medical components or the insides of hypodermic needles. It is ideal for finger- and hand-sized parts. MAF also measurably improves part roundness while it deburrs and polishes. CTE

About the Author: *Dr. LaRoux K. Gillespie has a 40-year history with precision part production as an engineer and manager. He is the author of 10 books on deburring and 200 technical reports and articles on precision machining. He can be e-mailed at laroux1@myvine.com. Contact him for a list of research works, contacts or further details of MAF technology. Chapter 20 of Gillespie's textbook, "Mass Finishing Handbook," published by Industrial Press, discusses magnetic abrasive finishing in more detail.*



"Key Engineering Materials"

Figure 3: Comparison of surface roughness and material removal using MAF on 304 stainless steel on a lathe operating at 150 rpm and 250 rpm. Using four finishing stages imparts a mirror finish.