For Superfinishing Excellence, Start With The Right Finish

Superfinishing is a process in which an abrasive stone is made to oscillate rapidly across a workpiece surface. Systems for superfinishing may consist of a stand-alone machine as shown here, or as an attachment for a lathe or grinder. Photo courtesy of Supfina Machine Co. (North Kingston, Rhode Island).

The key to excellence in superfinishing operations is the incoming grinding finish on the workpieces. With the right start, superfinishing is a very effective and economical process for achieving mirror-like finishes.

By JEFF SCHWARZ

Darmann Abrasive Products

Most manufacturers see grinding and superfinishing as separate operations. Unfortunately, the most meticulous superfinishing setup, using the best equipment and the latest abrasives technology, cannot correct all the problems (many of them subtle) which can be introduced in the previous manufacturing step. Conversely, achieving desired geometry and finish at the highest rate of productivity with super finishing can only be accomplished by taking the incoming operation into consideration.

One of the conditions for producing uniformly good parts from a superfinisher is a consistent level of finish from the grinding operation. The rough finish for the incoming part should be approximately 10 or 15 Ra (micro inches). This level of finish makes it possible for the superfinishing stone to aggressively cut the surface profile and bring the finish down to 5, 2, l Ra, or whatever the specification requires. The more consistent the incoming finish, the more consistent the output will be from the superfinishing operation.

Here are some grinding occurrences that will thwart superfinishing consistency:

Too Smooth A Finish

Ironically, one of the most common of all grinding problems in relation to superfinishing is too smooth a finish. It is still not widely understood that too smooth a finish from the grinding operation is a negative factor. When the superfinishing stone rides on too smooth a surface it begins to glaze, causing it to ride on a film of oil and remove very little material from the part. A coarser finish tends to keep the stone open, so it can cut more freely.

Engineers and grinding machinery operators typically take a great deal of pride in their work. Wanting to do their best, they try to get the finish as low as possible. When this happens, the hone stone is unable to bear into the part and remove the amount of stock required to reach the specified result.

Another reason why incoming finish is often reduced from optimum to a low limit is a byproduct of wanting to in- crease grinding throughput. Extending dress cycles to a bare minimum maximizes throughput but it also results in a dull wheel which does not cut freely. When the wheel is dull, it produces a smoother finish and increases the likelihood of thermal damage, lobing and chatter.

The grinding operations need both upper and lower limits on the finish specification. Avoiding over finishing will result in a better superfinished part and improved grinding productivity. Here's an example.

The throughfeed superfinishing operation for an automotive engine component was set up based on an incoming part finish of 6 to 8 Ra, removing 30 to 50 millionths of stock to product a 1 Ra finish. The finish from the grinding operation was allowed to deteriorate to 3 or 4 Ra. Because the stones could no longer efficiently penetrate the part, superfinishing stock removal fell to about 10 millionths—insufficient to clean up the part. Although Ra was good, many of the parts were visually unappealing and rejected. When the grinding operation was directed to dress more frequently and grind more aggressively (to 6-8Ra), the cosmetic issues were eliminated.

Thermal Damage

Trying to do too much finish work in the grinding operation can generate excess heat and cause thermal damage to the subsurface of the part. If the part is burned in grinding, it may still be possible to reach the desired level of superfinish, but visual imperfections and metallurgical damage will likely necessitate scrapping the part. Superfinishing is not a fix for burned parts.

Burnishing

A problem frequently associated with thermal damage is burnishing. When the wheel is not cutting freely because it is dull, it generates excessive heat. Instead of removing meta l, it pushes it around on the surface of the part, smearing it into the microscopic valleys. This may result in a smooth surface, but one that is not acceptably prepared for the superfinishing process. It is not as stable under load. Because this type of burnishing leaves softer metal on the surface of the part, it ma y become less wear resistant. Burnishing can create a situation in which the part looks good and meets specifications yet is in fact an inferior part.

High Amplitude Lobing

A certain amount of lobing is associated with all internal and external diameter grinding operations. Lobing is generally caused by deflections in the system between the wheel, the work and the tooling when grinding forces are applied. As a result of these fluctuating forces, no workpiece is ever perfectly round. In- stead, the workpiece will have a number of rounded projections call lobes.

When a stone can bridge two or more lobes at a time, it can then work to reduce their amplitude. See Figure 1. Superfinishing can remove a certain amount of lobing perhaps as much as 50 percent depending on amplitude, frequency and the application. Figures 2 and 3 show the relationship between incoming workpiece lobing and roundness improvement in super finishing.

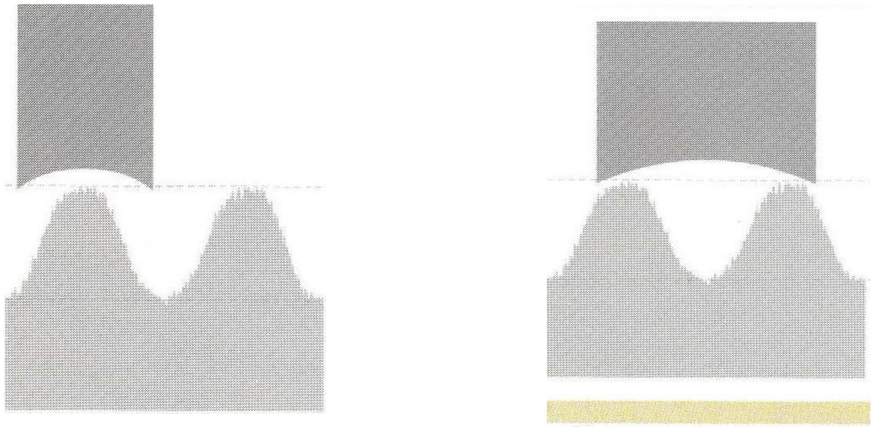


Fig. 1-While superfinishing can put a mirror finish on the port, it may also be used to improve roundness, depending on the incoming roundness of the workpieces and the width of the stones. Narrow stones (above) ride up and down on the lobes to improve surface finish only. Wider stones (below) con bridge the lobes to reduce their depth (that is, to improve roundness) and import a high degree of surface finish at the same time.

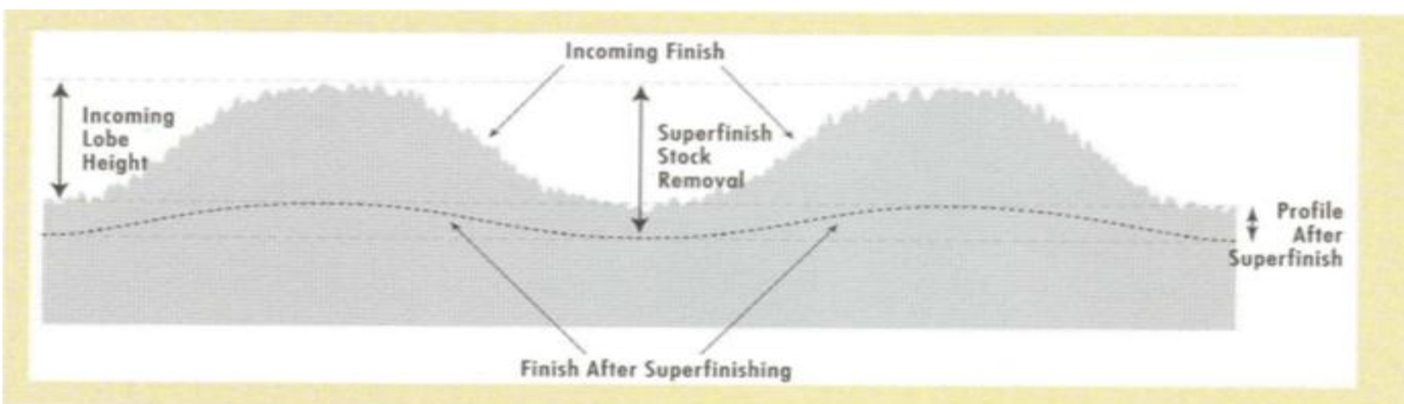
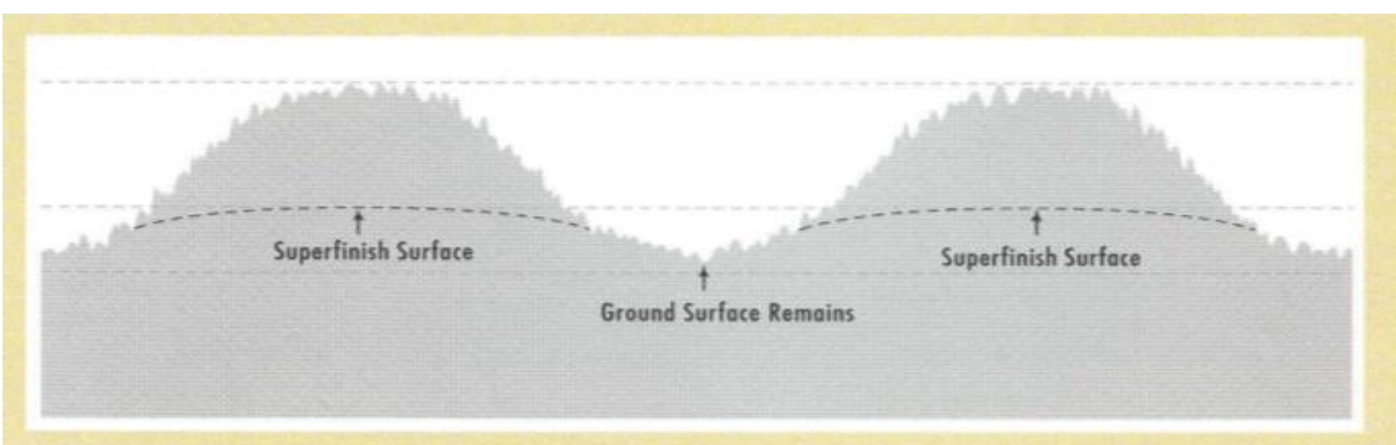


Fig. 2-Superfinishing can improve roundness in cases of moderate lobing.

In Figure 2, a workpiece with an in- coming surface finish of 10 Ra and lobing depth of 50µ (micro inches) enters superfinishing. The original lobes). The result is a workpiece with a 3 Ra surface finish and a 45µ of roundness improvement. The remaining 5µ lobes were left by the superfinisher itself.



Fi g. 3-Excessive lobing cannot be totally corrected with superfinishing. In fact, superfinishing may create unacceptable chatter lines, causing the piece to be rejected.

In Figure 3, a workpiece with an in- coming surface of 10 Ra and lobing depth of 75µ enters superfinishing. The superfinisher removes 60µ of stock (above the depth of the original lobes). In this example, superfinishing only removes the tops of the lobes and

gives them a shining mirror-like 3

Ra finish. However, the 15µ valleys are untouched and continue to have a relatively dull 10 Ra finish. This roundness improvement may, or may not, be acceptable depending on the specification. The workpiece now has chatter marks- zebra-like lines of contrasting surface finish causing the workpiece to be rejected for cosmetic reasons. The problem is not the superfinishing operation but excessive lobing of the workpiece.

Honing In On The Right Abrasive Product For Superfinishing

Over the years, the demands of the market have required product manufactures to broaden product offerings to the extent that there are currently thousands of combinations of abrasive type, grit size, hardness, bond type and treatment to meet nearly every superfinishing requirement. Selecting the right product for the application is not only critical to success in many cases, but the selection process itself reveals how versatile but exacting the application of superfinishing can be. Darrell Wickman, president of Darmann Abrasive Products, describes the methodology his company has developed to help customers hone in on the right abrasive product. The chart shown here, which uses his company's nomenclature, is generally indicative of the range of product choices available to superfinishers today.

This three-step selection process involves sending customers a series of customized product samples, then adjusting the compositions of the samples after obtaining results from their trial runs. Usually, after two or three trial runs, it is clear which stone is best for the application. Sometimes, especially for advanced applications, the process may take longer, but in these cases, the effort is motivated by big paybacks, which include step increases in productivity or eliminating a move to more costly custom – engineered superfinishing systems.

Step One. Depending on the material being finished, Darmann generally recommends starting with either a standard white aluminum oxide (WA) or green silicon carbide (GC) product. Aluminum oxide is preferred for roughing and silicon carbide for finishing applications. The customer's requirements for stock removal and finish will determine the initial selection of grit size hardness and treatment on a case-by-case basis.

Step Two. The next step to fine- tuning the grit size/hardness combination is to optimize the surface finish versus stock removal results. Finer finishes require either harder products (a smaller number is harder) or finer grit sizes (a larger number is finer). Higher stock removal requires either softer products or coarser grit sizes.

The cut rate and finish are also affected by the initial treatment selection. Stones can be supplied in either no-treat, wax-treat or sulfur-treat. Treatment fills the natural pores in the abrasive products and protects the stone from loading with swarf while providing some lubrication within the cutting zone. Treating a stone also effectively makes the stone act harder, improving its useful life.

Step Three. Should no optimum

combination emerge, then Darmann looks at other abrasive types. If greater stock removal is required, then fused aluminum oxide (FA) in a free-cutting bond system (VS) is the direction in which to move. A free-cutting bond breaks down more readily to shed dull abrasive and present sharp, unused abrasive particles on the surface of the stone. Ceramic abrasive (SA) in this free-cutting bond is also available. It is even sharper and harder for more aggressive cutting and longer stone life but is also more expensive. How- ever, it is a fraction of the cost of superabrasives.

Some abrasive types provide higher stock removal, others lower Ra finishes. A recently developed blended abrasive has been found to improve both in some applications, including plunge and through-feed applications.

When conventional abrasive products have not been successful either because the material being finished is so hard it cannot be cut, or the conventional product is so short lived that there is tremendous downtime in the operation, then superabrasives (diamond and cubic boron nitride) may be a reasonable and perhaps the only alternative. Some of the materials where superabrasives have been applied include M50, ceramics, glass, nitrated products or other materials with a hard shell.

Because of this iterative approach to product selection, the abrasive product manufacturer's knowledge of superfinishing applications and its product offerings are continually expanding. For this reason, Mr. Wickman cautions customers with a difficult superfinishing problem not to assume that there is no solution. Seeking the advice of a competent superfinishing abrasive products manufacturer is the best bet. Innovations are constantly appearing.

High Frequency Chatter

Excessive lobing is not the only reason for chatter. It may also appear on incoming parts. A series of lines, generally a result of induced vibration caused by improper setup, worn equipment or poor wheel performance, is termed chatter. Some of the conditions that create chatter may also cause thermal damage to the part.

Chatter is a high frequency surface aberration superimpose d on top of the lobing. It is like ripples on ocean waves. Superfinishing is far more effective in correcting chatter than lobing. Reducing chatter is important because it allows assembled components to operate quietly and with less vibration. It is a major factor in eliminating premature failure.

Ironically, superfinishing can sometimes make excessive chatter generated in the grinding operation look worse. When insufficient stock is

removed by the super-finisher, the problem of chatter is actually highlighted. Superfinishing polishes the peaks of the chatter, but the valleys remain dull in contrast. Previously invisible to the naked eye, chatter now becomes clearly visible and disturbing. Although it becomes obvious in superfinishing, chatter is a problem that is passed on from grinding.

Highlighted chatter due to insufficient tock removal in superfinishing takes u back full circle to the problem of too smooth an incoming finish. Of course, the superfinishing operation could use a softer stone which breaks down readily and cuts more aggressively. Another way to improve the efficiency of chatter removal is by selecting a stone geometry which presents more surface area to the part. The degree to which stone geometry may be altered depends on part geometry and the superfinishing equipment's capacity.

But changing the stone to compensate for grinding-related problems means less efficient superfinishing. Softer stones also wear out more often. The best solution is maintenance of quality output from the grinding operation.

EXAMPLE: WA 1000-50 V2 W

ABRASIVE TYPE	GRIT SIZE	HARDNESS		BOND TYPE	TREATMENT
Aluminum Oxide	280	20	HARD		
WA	320	50		V2, V4	
FA		5 pt increments		V5	
Silicon Carbide	400				
GC	500	100		V2	W - WAX
C		150		V2	S - SULFUR
	600	160			
Ceramic Sol-Gel	800	10 pt increments			
SA				V2, V5	
	1000	200			
Blends		220			
WG	1200	240		V2	
FG	1500	260	SOFT	V5	

Stones for superfinishing ore are available in o myriad of offerings. This table shows how one manufacturer, Darmann Abrasive Products, creates a nearly unlimited variety of products by combining different types, grit sizes, hardness levels, bonds, and treatments. Finding the best choice, however, is straightforward and systematic. The company also offers an array of superabrasives (diamond and CBN) stones.

While cost-effective superfinishing can be circumvented by poor incoming part quality and/or inappropriate level of finish from the grinding operation, other problems can arise within the superfinishing operation itself. Darmann Abrasive Products provided this list of some common superfinishing problems and the most likely steps that can be taken to correct them.

Table I
Common Superfinishing Problems And How To Correct Them

Condition	Increase	Decrease	Other
Excessive stone wear	spindle RPM	stone/wheel pressure; reciprocation/oscillation	use harder abrasive product
Insufficient stock removal	abrasive pressure reciprocation/ oscillation rate	spindle RPM	use softer abrasive product; use coarser grit abrasive product
Rough finish	spindle RPM	stone/wheel pressure; reciprocation/ oscillation rate	use finer and/or harder abrasive product
Undesirable smooth finish	reciprocation/ oscillation rate; abrasive pressure	spindle RPM	use coarser and/or softer abrasive product
Excessive heat generated	coolant flow rate	stone/wheel pressure	use softer abrasive product
Out-of-round parts	reciprocation/ oscillation rate	stone/wheel pressure; spindle RPM	use softer abrasive product
Glazing of abrasive surface	reciprocation/ oscillation rate; abrasive pressure	spindle RPM	use finer and/or softer abrasive product
Loading of abrasive surface	reciprocation/ oscillation rate	spindle RPM	use finer and/or softer abrasive product

What To Do?

Ideally, grinding and superfinishing operations should be synchronized to achieve the common goal of producing consistently good parts at the end of their inter- related processes. The grinder needs to take the workpiece to size within a pre- scribed semi-rough finish range and then leave it alone. There is a relatively narrow window in which to operate. Below 1Oμ of surface finish, problems can appear in superfinishing; below 6μ, they are almost certain. (Problems attributable to incoming grinding finishes are not the only one's superfinishing can face. Table I presents some other common problems and suggests the appropriate correction.)

To contribute to much more effective superfinishing, the upstream grinder should use free cutting wheels and process parameters that properly prepare the part for superfinishing, while avoiding additional problems like thermal dam- age, chatter, lobing or burnishing. "We can always catch it later" should not be part of the grinder's thinking.

The grinding operation is the last chance to catch problems that could significantly impact manufacturing yields, even though the rejection may occur downstream and appear to be somebody else's problem. When yields from superfinishing are high and within spec, the grinder deserves much of the credit.

There's no reason why operations leading to superfinishing can't be monitored effectively to assure that proper in-

coming workpiece conditions are met. Find these related articles on the Web:

Measuring Part Geometry On The Shop Floor

Surface Measurement Of Round Parts Helps Minnesota Manufacturer

These two articles show that measuring roundness is practical and economical.

Measuring Roughness With Buttons And Donuts

Finding surface roughness (Ra) values is likewise doable and affordable with the right type of contact gage.

For the link to these articles, visit http://www.mmsonline.com/ articles/129804 .html

The grinding operation is the last chance to catch problems that could significantly impact manufacturing yields, even though the rejection may occur downstream and appear to be somebody else's problem. When yields from superfinishing are high and within spec, the grinder deserves much

of the credit. ■

About the author. Jeff Schwarz is general manager of Darmann Abrasive Products, Clinton, Massachusetts.

For more information about superfinishing stones and other abrasive products from Darmann Abrasive Products, call (978) 365-4544, visit www.darmann.com