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# Better Finishing Through Chemistry

Microsurfacing is an alternative finishing process with benefits that extend beyond parts with supersmooth surfaces.

Better part performance and greater wear resistance are two of the benefits that manufacturers can achieve by applying microsurfacing to impart supersmooth finishes. Used more and more to finish parts, microsurfacing—with its vibratory equipment, media and chemical formulation—is also an improved process, offering reduced cycle times, chemical usage and manufacturing costs.

As examples, microsurfacing increased the life of one company's bearings by 500 percent and saved a major hand-tool manufacturer more than $10 million in 1 year after it switched from grinding to this finishing technique.

To perform microsurfacing well, though, manufacturers need to consider the media, chemicals, workpiece alloy and amount of material to be removed in order to achieve the best surface finish for wear performance and load-bearing properties.

Microsurfacing—also called superfinishing, engineered surfacing and isotropic finishing—is a chemically assisted finishing method that can eliminate directional lines on metal surfaces caused by abrasive grit in the grinding wheel or lapping compound. The technique complements or replaces conventional grinding, honing and lapping processes.

Earlier superfinishing processes required costly equipment, like specialized grinding and sanding machines. However, microsurfacing can take place inside a common vibratory bowl. The technique combines various acids with mechanical forces so surface imperfections are removed layer by layer—each layer is of atomic thickness—to impart a supersmooth finish.

The modern concept of microsurfacing was invented and patented by William D. Cheesman in 1963. Prior to this invention, chemically assisted surface finishing typically utilized strong acids, which etched deeper into the existing pits and scratches on the processed metal parts. To overcome this problem, Cheesman introduced conversion agents into chemically assisted mechanical finishing. He stated that "with use of surface conversion agents, which form a friable layer on a metal surface, the metal removal on the parts surface is not only accelerated but is selective, avoiding the phenomenon of pits and scratches deepening."

The surface conversion agents included various phosphoric acids and their salts, nitro compounds and organic acids, such as citric and oxalic acids. The inventor practiced the

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Before and after photos of cementite exhaust system components for racecars, which are polished inside and out with the microsurfacing process.

technique in a so-called barrel finisher using abrasive media.

To help understand the process further, imagine a vibrating bowl filled with metal parts and selected media where a chemical solution is continuously fed. The feed rate varies with bowl size and workload needs. The chemicals in the solution react with the metal surface to form a soft film capable of preventing the layer of metal underneath from further reacting with the solution. The media in the vibratory bowl then wipes off the film through churning and tumbling motions, exposing a fresh metal surface, which in turn reacts with the chemical solution to reform the soft film. This process eventually renders parts with supersmooth surfaces. The amount of material removed depends on part tolerances and on the depth of the directional lines if grinding or lapping was performed prior to superfinishing.

An expansion beyond vibratory processes' use of conversion agents was carried out by Whirlpool Corp. in 1980. The patented process virtually covers all surface finishing processes utilizing conversion coatings. It does so by applying a compound solution capable of forming a friable, relatively impervious conversion coating on the surface and rubbing the conversion coating with a conforming surface while retaining the solution between the surfaces to remove the conversion coating by abrasion.

Although not new, microsurfacing and its related chemistry have advanced in recent years. For example, a criterion for measuring progress in the field is the average surface roughness ($R_a$) of processed parts. A few years ago, a typical vibratory microsurfacing process produced surface finishes from 10 to 15 microns $R_a$. Since then, the technique has benefited from the development of heavier media and variable- and higher-speed vibratory bowls with programmable controls for better process control and more consistent results. Also, the chemicals have been adjusted to take advantage of those changes. Now, the process imparts finishes from 2 to 3 microns $R_a$—practically as smooth as glass.

**This series of mild steel plungers (used in the bottling industry) shows how microsurfacing progressively removes carbon deposits, enabling the parts to function significantly longer before requiring cleaning and maintenance.**

### Why Microsurfacing?

Microsurfacing can dramatically improve the performance of processed parts. The technique has been increasingly adopted as a final finishing process over the last 2 decades, so more and more manufacturers are finding that the process not only improves the appearance of a part, but also exponentially increases its strength and durability—or "wearability." This increase is mainly attributed to three factors.

Foremost, microsurfacing makes surfaces smoother, and generally speaking, the smoother the finish, the better the part's performance. This was the case for the previously mentioned bearing application. The other two factors are, however, less obvious, one being the ambient temperature associated with the process and the other being the isotropic surface finishing of the processed parts.

In contrast to other finishing processes, such as grinding, microsurfacing does not produce sufficient heat to cause the surface layers to plasticize. This precludes surface contamination by abrasives and preserves the structural integrity of the metal's surface.

Traditional grinding uses abrasives that leave lines in the surface of the metal or, worse, possibly embed grinding media in the workpiece's surface.

Abrasives cut away burrs, remove scale and oxides and remove surface material for dimensional sizing, forming the shape and imparting the desired surface roughness. Abrasives, however, can become embedded in a component's surface and decrease the part's wear performance and fatigue life. In critical wear surface applications, the contaminants must be removed by chemical or electrochemical means. In noncritical wear surface applications, the contaminants usually don't need to be removed, but the parts do not perform optimally or last as long.

In contrast, microsurfacing reduces the need to use abrasives to remove burrs, scale and oxides and refine wear surfaces. This reduction gives an advantage to manufacturers for producing wear surfaces that are metallurgically clean of embedded abrasives. Some grinding with abrasives may be needed, though, before microsurfacing when the surfaces are not equal to one another with respect to their final dimensions.

Also, the motion pattern of the media during microsurfacing renders processed parts with isotropic surface finishes, where the finish is the same when measured along axes in all directions. The combination of these three factors—smoothness, processing at ambient temperature and isotropic finish—is the key to the enhanced performance of microsurfaced metal parts.

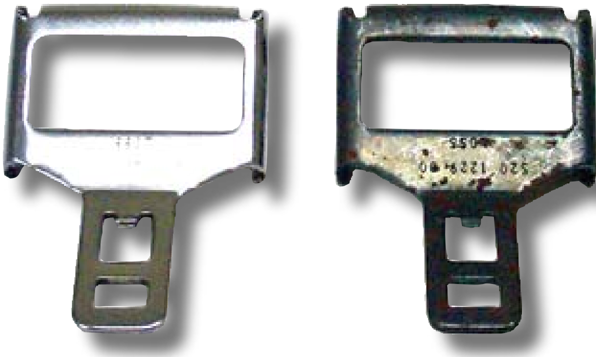
Microsurfacing, which was originally developed for mass-finishing environments, has proven to be a cost-effective alternative to mechanical manufacturing operations like surface grinding, lapping and shot blasting.

In addition to superfinishing, the microsurfacing technology can be extended to regular finishing operations, such as deburring and general cleaning.

The microsurfacing technique has been used by the U.S. military for decades and was first implemented commercially as a final finishing technique for cylinder bores in the early 1970s. A decade later, the diesel industry began incorporating this technique to extend engine life.

Microsurfacing metal parts like gears and bearings, for example, delivers levels of wearability not possible with conventional finishing. The mirrorlike smoothness from superfinishing dramatically reduces asperities that can cause friction or scuffing of the metal, which could cause the parts to lock up while in use. In addition, a smoother part has fewer pits where dirt and other debris can collect and cause corrosion. By reducing the number of these pits, superfinishing improves the longevity of the part while reducing heat caused by friction, and reducing friction improves a part's mechanical mobility for a smoother motion.

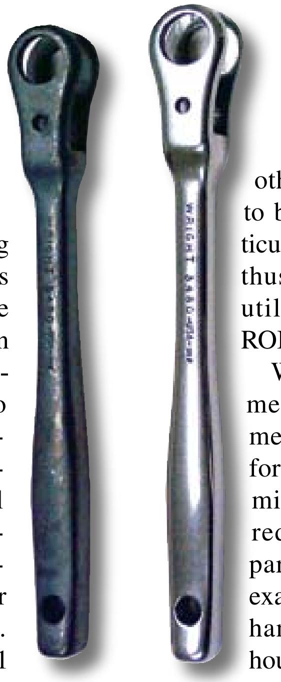
Microsurfacing can reduce scrap and consequently can enhance manufacturing efficiency. The performance of microsurfaced parts are also more attractive to customers, especially in the highly competitive automotive world, where longer warranties require longer-lasting parts.


**Before and after shots of a seat belt component that was microsurfaced.**

Microsurfacing will soon be a main way for Tier 1 and 2 automotive suppliers to secure large contracts with automotive manufacturers. The finishing process is already being applied in the U.S. to gears and bearings and in Europe for other moving parts. Even though existing superfinishing equipment will need to be upgraded to meet increasingly stringent finish standards, microsurfacing still provides a cost-effective alternative to investing in specialized grinding, lapping or other finishing equipment. The savings could be up to $1 million in equipment alone, depending on the company's finishing requirements. Vibratory bowls typically cost from $1,000 to $500,000, depending on part size and annual part volume.

### Not Your Father's Superfinishing

Thanks to innovations in technology, superfinishing has become much more affordable. Until recently, existing superfinishing technologies required investment in an expensive piece of specialized equipment that made the technique cost prohibitive to many manufacturers. Even worse, these expensive machines may often have a single function, such as processing a special shaft, for example. Because of this specialization, the machine could sit idle for long periods of time, producing no return on investment (ROI).


**Before and after shots of a ratchet wrench that was microsurfaced.**

Microsurfacing, on the other hand, does not need to be designated to one particular part or family of parts, thus increasing equipment utilization and improving ROI.

With today's improvements in vibratory equipment, media and chemical formulation, cycle times of microsurfacing have been reduced 50 percent compared to 5 years ago. For example, microsurfacing of hand tools used to take 7 hours. The cycle time is 3 to 4 hours today.

The reduced cycle times have led to proportionate reductions in chemical use. In addition, new techniques and chemistries allow manufacturers to use common vibratory bowls with minimal processing steps, further reducing the operating cost.

Another benefit of microsurfacing is the reduction in manufacturing operations. According to a major hand-tool manufacturer, it saved more than $10 million in 1 year by eliminating more than half of the steps it used to require to get the same finish after switching its finishing technology to microsurfacing. The manufacturer was able to cut out a minimum of eight belting operations—sometimes 16—on every tool in the production line, plus achieve a brighter finish than it had with the previous technique. The belting operations were all manually performed by skilled craftsmen, costing the company money and time.

Also, microsurfacing reduced hand-tool breakage in the field and made the tools more attractive to buyers due to their bright, mirrorlike finishes. Also, if the manufacturer needed to plate a tool, it would be able to do so with less plating material, like chrome, titanium, nickel and gold.

## Getting it Right

The physical process of superfinishing may be less complicated than before, but achieving the desired result requires sophisticated knowledge and careful monitoring. Engineers must understand the topology parameters of the wear surface and how this topology affects the tribological, or friction, performance of the wear surface. They must then evaluate ways to achieve the desired topology.

There are many design engineers who still believe that low surface roughness ($R_a$) is the primary surface parameter that controls friction (heat production) on wear surfaces. However, several surfaces can have the same $R_a$ and yet have different topologies and wear very differently. Though $R_a$ is important, it must be accompanied by other surface parameters in the correct state to produce the desired tribological performance.

Design engineers must understand which profiles yield the best surface finish for wear performance and load-bearing properties. The following are some profile parameters and value ranges that indicate whether a particular wear surface would have good load-bearing properties:

$R_a$–Roughness average: 1.5 to 5.0 µin. (0.038 to 0.127 microns).

$R_{sk}$–Skewness: negative skew of –0.25 to –3.0 µin. (–0.006 to –0.076 microns).

$R_t$–Maximum height of the profile: less than 20 µin. (0.508 microns).

$R_z$–Average maximum height of the profile: maintained close to $R_t$ results.

$R_{pk}$–Reduced peak height: 1.0 to 3.0 µin. (0.025 to 0.076 microns).

$R_{vk}$–Reduced valley depth: 2.0 to 12.0 µin. (0.051 to 0.305 microns).

A precision wear surface performs best when its $R_{vk}$ to $R_{pk}$ ratio is at least 2:1. When parameters are maintained in these ranges, the resulting wear surface has its microasperities (peaks) removed while maintaining valley depths for lubricant retention. Microsurfacing technology produces surface ratios that have a negative skew ($R_{sk}$) as well as the optimum ratio of $R_{vk}$ to $R_{pk}$.

Each ingredient that goes into the vibratory bowl must be carefully selected and controlled. The media, chemicals, workpiece alloy and amount of material that needs to be removed from a part's surface are all complicating factors that must be analyzed. For these reasons, manufacturers are advised to look for a superfinishing partner that is willing to work closely with the people involved in the process, is experienced in superfinishing, and an expert in chemistry.

Initially marketed to the gear and bearing industries, microsurfacing has since found applications in manufacturing a variety of other industrial components, including conveyor chains, precision washers, forging dies, piston sleeves, camshafts, crankshafts, engine valves, hydraulic pumps, hydraulic and pneumatic shafts, injection mold dies and springs.

With its lower costs and improved cycle times, microsurfacing has now also found applications in manufacturing of consumer products where durability and flexibility are important, such as medical prostheses. △

## About the Authors

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